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ANALYSIS OF COAL PREPARATION PLANTS FOR APPLICABILITY OF THE NATIONAL ELECTRICAL CODE

Part I: Analysis and Review

Part II: Recommended Guidelines

Prepared for

UNITED STATES DEPARTMENT OF THE INTERIOR

BUREAU OF MINES

by

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16. Abstract

A survey was conducted relating to the current practices for the classification of hazardous locations in coal preparation plants. Several plants processing bituminous, anthracite and lignite coal in Pennsylvania, West Virginia, North Dakota, Colorado, Montana and Wyoming were visited. Coal preparation plant operations and designers as well as MESA inspectors were interviewed. The National Electrical Code was discussed with selected members of the NFPA committee and electrical equipment manufacturers.

Data provided by MESA on fire and explosion accidents in coal preparation plants were examined. The requirements of the pertinent Federal Regulations, National Electrical Code, National Electrical Manufacturers Association and Underwriters' Laboratories were compared and evaluated.

This report consists of two parts. Part I: "Analysis and Review" provides a summary of the findings. Part II: "Recommended Guidelines" consists of recommended uniform guidelines that may be used for interpreting the National Electrical Code as it applies to the classification of hazardous areas in coal preparation plants.

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FOREWORD

This report was prepared by Arthur D. Little, Inc. Cambridge, MA under USBM Contract Number J0166059. The contract was initiated under the Coal Mine Health and Safety Program. It was administered under the technical direction of PM&SRC with Mr. Roger L. King acting as the Technical Project Officer. Mr. F. Naughton was the contract administrator for the Bureau of Mines.

This report is a summary of the work recently completed as part of this contract during the period June 17, 1976 to March 15, 1977. This report was submitted by the authors on October 15, 1977.

Arthur D. Little, Inc. wishes to acknowledge the cooperation of and the information provided by the many coal preparation plant operators who graciously allowed the contractor representatives to visit their plants. In addition, Arthur D. Little, Inc. wishes to thank the designers of coal preparation plants, representatives of insurance companies, manufacturers of electrical equipment and MESA inspectors who freely shared their individual interpretations of the codes with us, and whose names must be kept anonymous by prior agreement.

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PART I

ANALYSIS AND REVIEW

1. INTRODUCTION

1.1 BACKGROUND

Surface installations which handle coal, including coal preparation and cleaning plants, involve many unit operations. Typically, the mined coal is conveyed to the plant, crushed to an appropriate size, screened, concentrated by separating it from impurities, dried and transported or stored in preparation for shipment. Typically, lignite is conveyed immediately after the screening operations while anthracite and bituminous coals are processed further.

The nature of the unit operations involved in coal preparation is such that some are conducted under "wet" conditions while others are carried out with dry or slightly moistened coal. The latter conditions are conducive to coal dust generation. In addition, certain operations (such as storage and crushing) may result in the release and accumulation of methane gas. Under specific conditions, suspended coal dust and methane gas, if ignited, can result in damaging explosions. Furthermore, the accumulation of coal dust on hot surfaces may result in autoignition and fire.

The inescapable presence of coal dust and the potential presence of methane in certain locations of coal preparation plants demand care in the selection and use of electrical equipment. Federal Regulations (30 CFR 77.516) require that all wiring and electrical equipment used in coal preparation plants meet certain National Electrical Code (NEC) requirements. NEC classifies hazardous industrial locations into three major categories depending on the presence or potential for release of flammable concentrations of vapors, gases or dusts under normal and abnormal operating conditions. Unfortunately, neither the National Electrical Code nor the Federal Regulations provide adequate guidance for interpreting the code as it applies to coal preparation plants. The definitions for Class I and II locations and the acceptable methods for downgrading a classification are subject to personal interpretation. This has resulted in conflicting views among MESA inspectors, operators of coal preparation plants and designers of these facilities.

In its concern for the establishment of uniform interpretations of the National Electrical Code in coal preparation plants, the Bureau of Mines issued a contract to Arthur D. Little, Inc. to conduct an analysis of current practices and to recommend guidelines that may be used by all concerned in the selection and use of electrical equipment in coal preparation plants.

1.2 OBJECTIVES

The main purpose of this program was to provide MESA inspectors as well as operators and designers with recommended guidelines for interpreting the National Electrical Code as it relates to the classification of hazardous areas in coal preparation plants. Where possible, it was desired to quantify the guidelines and to recommend alternative solutions for downgrading the classifications of hazardous areas.

1.3 APPROACH

To achieve these objectives, Arthur D. Little, Inc. surveyed selected bituminous, anthracite and lignite coal preparation plants in Pennsylvania, West Virginia, North Dakota, Colorado, Montana, and Wyoming and interviewed representatives of coal preparation plant operators and designers and a number of MESA inspectors. The National Electrical Code was discussed with members of the NFPA committee that prepared the code and who also happened to represent a major insurance agency. Manufacturers of electrical equipment used in coal preparation plants were also contacted.

Data provided by MESA on fire and explosion accidents in coal preparation plants were examined. The requirements of the pertinent Federal Regulations, National Electrical Code, National Electrical Manufacturers Association and Underwriters' Laboratories were compared and evaluated.

This report consists of two parts. Part I: "Analysis and Review" provides a summary of our findings. Part II: "Recommended Guidelines" consists of recommended uniform guidelines that may be used for interpreting the National Electrical Code as it applies to the classification of hazardous areas in coal preparation plants.

2. TECHNICAL DISCUSSION

2.1 COAL PREPARATION OPERATIONS

Coal preparation plants involve several unit operations which utilize electrical components and are thus subject to the provisions of the National Electrical Code. In this section, an attempt is made at categorizing the unit operations generally found at coal preparation plants and identifying the types of electrical equipment associated with these operations.

2.1.1 Storage

The storage of raw or finished coal in preparation for processing or shipment is an important step in coal preparation plants. Raw or finished coal is often stored by piling it in open spaces of land. This is the most common method of building up a supply for high-speed unit train loading. The most popular form of open storage is a conical pile fed by an overhead belt conveyor, situated over an underground reclaim tunnel.

The unventilated tunnels beneath open coal storage have been known to accumulate relatively high methane concentrations as well as coal dust. Electric motors, switches, wiring and electrical lights are used within these tunnels and near their exits. Generally, tunnels are provided with forced ventilation.

As with open storage, silos are usually designed to hold a minimum of one-half the capacity of the unit train. Storage in silos requires less ground space, reduces the effect of wind in blowing coal dust, and protects the coal from rain and snow. In some locations, silos eliminate stream pollution by solids or acid.

During storage, coal releases methane slowly. The rate of release of methane increases if coal begins to self-heat. Under certain conditions, the gas may accumulate to explosive concentrations in silos and conveyor tunnels unless adequate ventilation is supplied. In some silo designs there are electrical motors on top or underneath the silo for driving conveyor belts. Electrical devices are sometimes used within a silo for measuring the level of coal.

To obtain a more uniform raw coal feed rate, a dumping or surge bin is sometimes used. Because raw coal is generally relatively dry, the operation may be dusty and electrical motors and other components required to operate the load-out gates and drive the conveyor belt under these bins may be exposed to high concentrations of coal dust.

2.1.2 Crushing and Breaking

There are two main reasons for crushing coal: to reduce raw coal to a size suitable for the plant cleaning processes, and to get the large lumps of finished coal to marketable sizes (e.g., stoker or pea). The principle of crushing is to apply mechanical energy by impact or compression to a point where the coal will break or shear. Single and double rollers, hammermills, and ring crushers are examples of commonly used crushers.

Rotary breakers are machines that not only reduce the size of the coal, but also separate rock from the coal. Rotary breakers consist of a rotating drum made up of perforated plates. The drum picks up the coal and allows it to drop to the bottom. The gravitational force breaks the coal which passes through the plates. Refuse which does not break from the fall continues through the breaker to a rejects area.

The nature of coal crushing and breaking operations is such that they are conducive to dust generation within and near the equipment. Furthermore, certain coals may produce methane upon breaking. On the other hand, electrical motors and associated controls are usually placed outside the crusher and, thus, are not exposed to methane. Furthermore, many crushing operations are conducted with large quantities of water sprays which minimize the dust problem.

2.1.3 Screening

Sizing operations are conducted to separate raw coal into various sizes for marketing, feed various types of coal washing units, recover the solids used to control the specific gravity in washing operations and to recover fines in the original feed and those produced during the processing operations.

Screening is accomplished using either vibrating or shaking equipment. Coal is passed over a screen which may be in a variety of designs, e.g., circular punched plates, wire rod screens or rubber-clad perforated plates. The screen is either in a horizontal position or inclined. Although there are still many applications where shaker screens are used, they have recently lost ground to vibrating screens. The amount of dust generated can be heavy in dry screening processes and is usually negligible in wet screening operations. Screening units are usually non-enclosed operations and dust that is created by the units can easily reach the drive motors.

2.1.4 Washing

The purpose of washing coal is to separate the waste from the raw input and to obtain desired levels of ash content. Obviously, washing operations are limited to plants where temperatures are not allowed to fall below freezing.

Washing processes include dense-medium separation, hydraulic separation and froth flotation. Dense-medium separation is a process where the run-of-the-mine coal is placed in a fluid having a density which is between that of coal and the waste. Hydraulic concentrating devices depend on the differences among physical characteristics (e.g., size, shape, density) of coal particles and waste material. These devices include jigs, launders, and water tables. Flotation depends on fine coal particles adhering to air bubbles rising to the surface while the waste material settles to the bottom of the tank. The fines would then be skimmed off the top of the liquid surface. Because of the large amounts of water used in washing operations, there is essentially no coal dust generated by these processes. On the other hand, the splashing of the water coal suspension outside washing equipment results in the accumulation of a layer of caked coal dust. When dry, this caked layer may contribute to the overheating of electrical equipment and the propagation of fires.

2.1.5 Dry Concentration

Dry concentration is a process which uses air as a separating medium instead of water. Pneumatic jigs, tables and launders are used to effect the separation. The use of the latter two devices has declined, and today the majority of dry concentration is achieved with air jigs. Because the operation is dry, there is a potential of a very dusty atmosphere near all equipment. Most equipment have air-tight, hooded exhaust systems. Problems with dust can occur either upon failure of the exhaust equipment or from leaks within the system.

2.1.6 Drying

After passing through the washing operations, coal has a high moisture content. This is undesirable because moisture reduces the heating value of coal, and increases shipping costs and the difficulty with which the product is handled.

The method used to dewater coal depends upon the coal size. The types of dewatering processes include screening, centrifuging, vacuum filtration and thermal drying. The amount of dust generated by these operations depends upon the particle size and moisture content of the final product. Thermal drying systems handle dry, fine coal dust and can create hazardous dust levels in the immediate and surrounding areas if leaks develop in the system.

2.2 ELECTRICAL HAZARDS AND CONTROL METHODS

2.2.1 Fire and Explosion Hazards

Methane is released whenever coal is broken or stored, albeit in varying amounts depending on the type of coal, the volume of coal involved, and the length of time it has been exposed to air. Accumulation of methane gas in amounts sufficient to be explosive is most likely to occur where coal is stored for extended periods of time, as in silos or associated conveyor tunnels, or where coal is crushed. The potential for accumulation is heightened if these locations were enclosed without adequate ventilation.

Airborne coal dust, if present at concentrations above the minimum explosible limit (∿ .055 g/liter) may be ignited by open flames, sparks having a minimum ignition energy of 60 millijoules, or hot surfaces having a temperature of 610 °C.*

While the concentration of airborn coal dust is important in evaluating potential explosion hazards, of equal importance is the amount of dust accumulation on surfaces within a building. Dust, if allowed to accumulate, can create fire and/or explosion hazards in a building which normally might be considered "clean" in terms of airborne dust. Layered coal dust becomes a hazard under the following conditions:

1. When in close proximity to arc welding operations where sparks can create fires,
2. When vibration or sudden structural shock can shake dust loose from surfaces in heavy concentrations close to ignition sources,
3. When layers become sufficiently thick to impair heat dissipation in heat-producing equipment to the extent that the dust layer autoignition temperature of ∿ 170 °C* is exceeded, and
4. When coal dust mixed with grease and moisture becomes sufficiently conductive to short out high voltage electrical leads.

It is important to note that layered dust can be the source of a secondary explosion and fire following a primary explosion. The shock of the initial explosion can shake layered dust loose and the result may be a second explosion equal to or greater in magnitude than the initial explosion.

2.2.2 Control Methods

The potential hazards created by methane, airborne coal dust, and layered coal dust can be reduced by employing one or a combination of the following control methods:

- ventilation and purging
- addition of water
- housekeeping

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* NFPA, "Fire Protection Handbook", 14th Edition, National Fire Protection Association, Boston, Mass. (1976).

- maintenance and repair
- removal of electrical equipment from the hazard source
- inerting

Each of these methods can help to reduce the hazards although none can eliminate all of the hazards completely.

2.2.2.1 Ventilation and Purging

Probably the most effective method for reducing potential high methane concentrations is to provide sufficient ventilation to an enclosure at a rate of several air changes per hour. Reliance on natural ventilation to remove methane and respirable coal dust in such areas appears to be a common practice of many coal preparation plants. However, variable weather conditions (wind speed and direction, precipitation) can cause wide variations in the effectiveness of natural ventilation. The introduction of either forced or induced ventilation systems in coal preparation buildings and other key locations (e.g., tunnels, silos) greatly reduces the potential for methane accumulation.

Purging of control rooms and enclosures of electrical power equipment which do not generate heat involves the pressurization of these enclosures with fresh air to prevent the infiltration of dust and methane. NFPA No. 496 "Purged and Pressurized Enclosures for Electrical Equipment in Hazardous Locations" provides guidelines relating to purging and ventilation.

2.2.2.2 Addition of Water

The impact of water addition to coal during processing on the levels of airborne and layer dust is substantial. It may be possible to establish three levels of external moisture according to its apparent effect on airborne dust levels. These levels are:

- Dry: Only inherent moisture is present. No water is added during mining or preparation. Operations involving dry coal are expected to be very dusty.
- Moist: Water is present as inherent moisture plus surface water provided by a spray during mining and/or on the raw coal

conveyor. Dust may be generated during operations handling moist coal depending on the ratio of water to coal and the effectiveness of the water spray system.

- Wet: Large quantities of water are added through deluge sprays to the coal as it enters the plant and during the crushing operation, to form slurries for conveying, washing and flotation separation. Typically, little or no dust is generated during these operations.

It is extremely difficult to assign quantitative values to these moisture levels since the quantity of water added to the coal is not a sufficient indication of the "dustiness" of the process. Observations made during visits conducted as part of this program showed that dustiness was highly dependent on where and how the water was applied. Typically however, it was observed that if less than 10 gallons of water were added for every ton of raw coal at the crusher, the process was relatively dusty. On the other extreme, when a high rate of 75 gallons of water was used per ton of raw coal at the same location, the operations tended to be dust free. Between these two water application rates dustiness was dependent on the effectiveness and location and distribution of the spray nozzles.

A secondary issue encountered in plants using water in the process is the problem of water spillage. The water-coal slurry subsequently dries leaving a residue of coal dust which, as indicated earlier, could cause overheating of electrical equipment and contribute to surface fires.

2.2.2.3 Housekeeping

Housekeeping plays a major role in reducing the hazard potential as it relates to dust. Without exception, among the plants visited, those which shoed leaste accumulations of dust and process residue were those which were cleaned regularly (either once per shift or once per day). In these instances, housekeeping included daily washdown of all levels in the plant and monthly cleaning of all floor and equipment surfaces to remove dust accumulations.

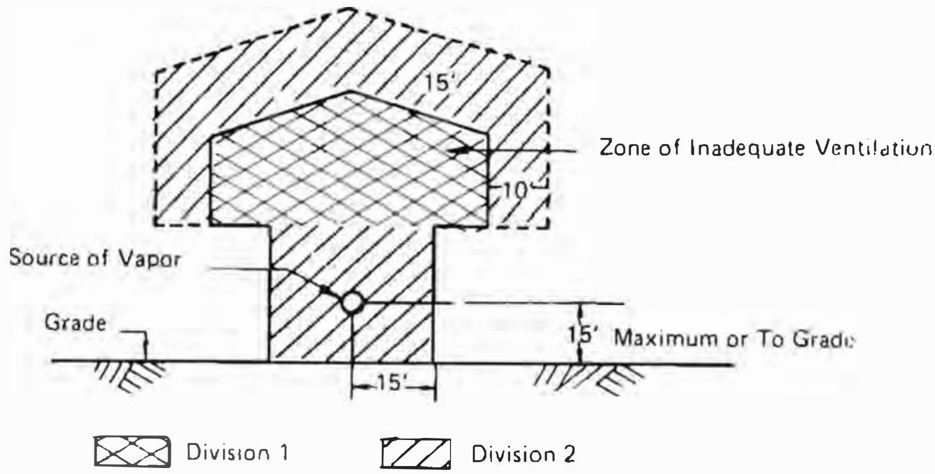
2.2.2.4 Maintenance and Repair

Maintenance and repair of electrical equipment is particularly important within preparation plants to ensure that equipment is in proper working condition. Failure of improperly maintained electrical equipment can occur rapidly causing arcing or sparking which, under the proper conditions, can result in a fire or explosion. Incipient failures can exist for extended periods of time without being recognized. However, if conditions change (as when a switch is called upon to operate, a motor bearing seizes, or a loose light bulb is jarred) the failure may become "active" causing an explosion or fire. While a maintenance program will not prevent all accidents, many potential failures can be detected early and faulty equipment removed from service and repaired before an accident occurs.

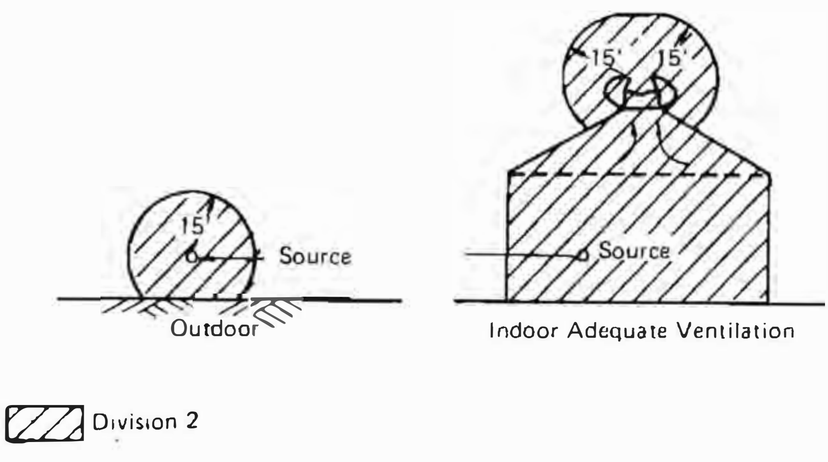
2.2.2.5 Removal of Electrical Equipment from the Hazard Source

An obvious solution for the prevention of methane ignition by electrical equipment is the placement of potential ignition sources at a location which is some distance away from the point expected to attain maximum methane concentrations. However, for economic and human engineering reasons, conveyor belt motor drives, switches and other electrical devices are often placed at a convenient location adjacent to the point where methane and coal dust may be present. A problem arises then in determining when a location adjacent to an area classified by NEC as hazardous Class I, Division 1 becomes classified as Class I, Division 2.

NFPA 497 "Recommended Practice for Classification of Class I Hazard Locations for Electrical Installations in Chemical Plants" provides some guidance in determining safe separation distances from vents on the roofs of buildings handling gaseous hydrogen and from compressors handling lighter-than-air flammable gases within an adequately ventilated building (see Figure 2.1). In both cases, the NFPA Standard recommends that areas within 15 ft from the vent of the building be classified as Class I, Division 2. The Standards do not provide scientific evidence to support this distance neither do they necessarily apply to the methane problem in coal preparation plants, particularly for the tops of silos.



Building Housing a Compressor of Lighter-Than-Air Flammable Gas



Gaseous Hydrogen Source In Buildings And Outdoors

FIGURE 2.1 NFPA CLASSIFICATIONS OF AREAS ADJACENT TO CLASS I LOCATIONS

We have calculated the safe separation distances from the top of a silo where coal is being dumped at a given rate. For details of the the calculation procedure see Appendix D. The calculation was made assuming that the methane concentration in the silo is 5, 10 and 15% (by volume). Dispersion theory was utilized to calculate the distance at which methane concentration drops to 1% under the worst weather condition (moderately stable, wind at 2 meters/sec). The rate at which the methane/air mixture was emitted from the top of the silo was determined from the volumetric rate at which low-density coal was being dumped into the silo. The results of these calculations are summarized in Figure D.2 (see Appendix D) and Table 2.1 below.

The results show that depending on the assumed methane concentration in the silo, the NFPA code may be too conservative or it may underestimate the hazard for high coal rates. It is recommended that Figure D.2 be used for determining safe separation distances between electrical equipment and the nearest edge of the silo opening.

2.2.2.6 Inerting

Another approach to the prevention of explosions and fires from electrical equipment is to inert the potential ignition source with a gaseous inerting agent such as CO_2, N_2 or SF_6. Obviously, such an approach requires either the absence of leaks in the system or the continuous flow of the inerting agent, both of which are costly.

2.3 APPLICABLE STANDARDS FOR ELECTRICAL EQUIPMENT

In this section we review some of the applicable Federal and concensus standards that govern the selection and use of electrical equipment and components in coal preparation plants.

2.3.1 Federal Regulations

Title 30, Chapter I, Part 77 of the Code of Federal Regulations

> ". . . sets forth mandatory safety standards for bituminous, anthracite, and lignite surface coal mines, including open pit

TABLE 2.1

Calculated Safe Separation Distances from Gassy Silos

Coal Flow Rate (tph)	Methane Concentration (volume %) 5%	10%	15%
100	2.4 ft	4.7 ft	6.6 ft
300	5.4	10.0	13.3
1000	10.8	20.3	27.9
3000	21.3	39.4	53.1
10000	43.6	81.3	114.1

NFPA No. 497 recommended value = 15 ft.

and auger mines, and to the surface work areas of underground coal mines, pursuant to section 101 (i) of the Federal Coal Mine Health and Safety Act of 1969."

Part 77 is subdivided into 21 subparts dealing with various aspects of surface coal mines and work areas including custom coal preparation facilities (Subpart C) and electrical equipment (Subpart F). For the purposes of this program, Subparts C and F contain the pertinent Federal Regulations. Within these two subparts, several paragraphs were considered critical to the issues being addressed and deserve recognition. The first reference to methane and coal dust is contained in Subpart C beginning at §77.200.

§77.200 Surface installations; general

All mine structures, enclosures, or other facilities (including custom coal preparation) shall be maintained in good repair to prevent accidents and injuries to employees.

§77.201 Methane content in surface installations

The methane content in the air of any structure, enclosure or other facility shall be less than 1.0 volume per centum.

§77.201-1 Tests for methane; qualified person; use of approved device.

Tests for methane in structures, enclosures, or other facilities, in which coal is handled or stored shall be conducted by a qualified person with a device approved by the Secretary at least once during each operating shift, and immediately prior to any repair work in which welding or an open flame is used, or a spark may be produced.

§77.201-2 Methane accumulations change in ventilation

If, at any time, the air in any structure, enclosure or other facility contains 1.0 volume per centum or more of methane changes or adjustments in the ventilation of such installation shall be made at once so that the air shall contain less tha 1.0 volume per centum of methane.

§77.202 Dust accumulation in surface installations.

Coal dust in the air of, or in, or on the surfaces of, structures, enclosures, or other facilities shall not be allowed to exist or accumulate in dangerous amounts.

§77.211 Draw-off tunnels; stockpiling and reclaiming operations; general.

(a) Tunnels located below stockpiles, surge piles, and coal storage silos shall be ventilated so as to maintain concentrations of methane below 1.0 volume per centum.

(b) In addition to the tests for methane required by §77.201 such tests shall also be made before any electric equipment is energized or reparied, unless equipment with a continuous methane monitoring device installed and operated in accordance with the provisions of §77.211-1. Electric equipment shall not be energized, operated, or repaired until the air contains less than 1.0 volume per centum of methane.

§77.211-1 Continuous methane monitoring device; installation and operation; automatic deenergization of electric equipment.

Continuous methane monitoring devices shall be set to deenergize automatically electric equipment when such monitor is not operating properly and to give a warning automatically when the concentration of methane reaches a maximum percentage determined by an authorized representative of the Secretary which shall not be more than 1.0 volume per centum of methane. An authorized representative of the Secretary shall require such monitor to deenergize automatically electric equipment when the concentration of methane reaches a maximum percentage determined by such representative which shall not be more than 2.0 volume per centum of methane.

§77.212 Draw-off tunnel ventilation fans; installation

When fans are used to ventilate draw-off tunnels, the fans shall be:

(a) Installed on the surface;

(b) Installed in fireproof housings and connected to the tunnel openings with fireproof air ducts; and,

(c) Offset from the tunnel opening.

The provisions of Subpart C are such that only methane content is defined in terms of a measurable quantity; i.e., methane content is to be less than 1.0 volume per centum (1.0%). This defined level is equivalent to about 20 percent of the lower explosive limit (LEL) of methane.

Dust accumulations have no similar explicit maximum level. In this case, the regulations are vague, stating only that dust "shall not be allowed to exist or accumulate in dangerous amounts." The word "dangerous" is not defined.

Electrical equipment regulations are contained in Subpart F beginning at paragraph 77.500. Again, the standards are vague with regard to establishing specific requirements.

From Subpart F - Electrical Equipment, General

§77.502 Electric equipment; examination, testing, and maintenance.

Electric equipment shall be frequently examined, tested, and properly maintained by a qualified person to assure safe operating conditions. When a potentially dangerous condition is found on electric equipment, such equipment shall be removed from service until such condition is corrected. A record of such examinations shall be kept.

§77.502-1 Qualified person.

A qualified person within the meaning of §77.502 is an individual who meets the requirements of §77.103.

§77.502-2 Electric equipment; frequency of examination and testing.

The examinations and tests required under the provision of this §77.502 shall be conducted at least monthly.

§77.503 Electric conductors; capacity and insulation.

Electric conductors shall be sufficient in size and have adequate current carrying capacity and be of such construction that a rise in temperature resulting from normal operation will not damage the insulating materials.

§77.503-1 Electrical conductors.

Electric conductors shall be sufficient in size to meet the minimum current carrying capacity provided for in the National Electrical Code, 1968. All trailing cables shall meet the minimum requirements for ampacity provided in the standards of the Insulated Power Cable Engineers Association-National Electrical Manufacturers Association in effect when such cables are purchased.

§77.506 Electric equipment and circuits; overload and short-circuited protection.

Automatic circuit-breaking devices or fuses of the correct type and capacity shall be installed so as to protect all electric equipment and circuits against short circuit and overloads.

§77.506-1 Electric equipment and circuits; overload and short-circuit protection; minimum requirements.

Devices providing either short circuit protection and protection against overload shall conform to the minimum requirements for protection of electric circuits and equipment of the National Electrical Code, 1968.

§77.516 Electric wiring and equipment; installation and maintenance.

In addition to the requirements of §77.503 and §77.506, all wiring and electrical equipment installed after June 30, 1971, shall meet the requirements of the National Electrical Code in effect at the time of installation.

It is significant to note that 30 CFR 77, Subpart F contains no specific references to electric motors as it does to conductors (§77.503), switches (§77.507), transformers (§77.509) and other electrical equipment. In fact, the requirements of 30 CFR 77 Subpart F are very broad and give little direction to the potential user (operator, MESA inspector, or plant designer) as to the "safety standards" purportedly set forth.

However, as the preceeding excerpts indicate, 30 CFR 77 does establish, by specific inclusion within the regulations, that the requirements of the National Electrical Code (NEC) must be met for all wiring and electrical equipment installations. Specifically, in paragraphs 77.503-1 and 77.506-1, the regulations refer to the 1968 NEC, which was the Code in effect at the time 30 CFR 77 was adopted. Paragraph 77.516 provides the mechanism for updating the Federal requirements as the NEC is revised.

The status of surface facilities which were in operation prior to the adoption of 30 CFR 77 is unclear in cases where no new installations or modifications are being made. However, where work is being performed on electrical equipment or wiring in older (pre-1971) facilities, the regulations clearly require conformity with the NEC in effect at the time of installation.

2.3.2 National Electrical Code (NEC)

As discussed in Section 2.3.1 above, the substance of the mandatory safety standards established in 30 CFR 77 Subpart F is drawn directly from the NEC. Coal handling operations can result in the release of methane gas and creation of coal dust. In Chapter 5 - Special Occupancies, the NEC has established standards for locations which involve hazardous conditions. For the purposes of this program, the classification of hazardous locations according to the presence of specific flammable mixtures (as given in Articles 500-503) is of particular relevance. Two hazardous classifications have been established, each of which is further divided into two divisions. Class I hazardous locations are categorized into four groups (A, B, C, and D). Class II is divided into three groups (E, F, and G). Definitions of each hazardous classification, Division and relevant Group follow.

2.3.2.1 Class I Locations

These are areas in which flammable gases or vapors are or may be present in the air in sufficient quantities to produce explosive or ignitible mixtures.

(a) Class I, Division 1. This is a location in which 1) hazardous concentrations of flammable gases or vapors exist continuously, intermittently, or periodically under normal operating conditions; or 2) hazardous concentrations of such gases or vapors may exist frequently because of repair or maintenance operations or because of leakage; or 3) breakdown or faulty operation of equipment or processes may release hazardous concentrations of flammable gases or vapors, or cause simultaneous failure of electric equipment.

(b) Class I, Division 2. This is a location 1) where volatile flammable liquids or gases are handled, processed or used, but in which the hazardous liquids, vapors or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems, or in case of abnormal operation of equipment; or 2) where hazardous concentrations of gases or vapors are normally prevented by positive mechanical ventilation, but which may become hazardous through failure or abnormal operation of the ventilating equipment; or 3) which is adjacent to a Class I, Division 1 location, and to which hazardous concentrations of gases or vapors may occasionally be communicated unless prevented by adequate positive-pressure ventilation from a source of clean air, and effective safeguards against the failure of the ventilation system are provided.

Crushing and breaking operations within a coal preparation plant mav result in the production of methane and thus fall within the definition of a Class I Division 1 hazardous location. Similarly, the interiors of silos fall within this classification. A major problem arises as to what constitutes "adjacent" locations referred to in Class I Division 2 definition.

Heat producing equipment must be approved for use in the specific gas or vapor atmosphere to be encountered. The surface temperature should not exceed the ignition temperature of that gas or vapor. Formerly, the ignition temperature for each Group was taken as the lowest of any material in the Group (280 °C for Group D which includes methane). As the NEC reads presently, heat producing equipment for use where methane gas may be present should not exceed its ignition temperature of 530 °C.

2.3.2.2 Class II Locations

These are locations which are hazardous due to the presence of a combustible dust. There are three groups of combustible dusts within this classification of which only Group F is relevant. According to the 1968 NEC, Group F is defined as "atmospheres containing carbon black, coke or coal dust . . ."

The current issue of the NEC (1975) defines Group F atmospheres as ". . . atmospheres containing carbon black, charcoal, coal or coke dusts which have more than eight percent total volatile material (carbon black per ASTM D1620, charcoal, coal and coke dusts per ASTM D271) or atmospheres containing these dusts sensitized by other materials so that they present an explosion hazard."

Within Class II there are two divisions which are defined as follows:

(a) Class II, Division 1. This is a location 1) in which combustible dust is or may be in suspension in the air continuously, intermittently, or periodically under normal operating conditions, in quantities sufficient to produce explosive or ignitible mixtures; or 2) where mechanical failure or abnormal operation of machinery or equipment might cause such explosive or ignitible mixtures to be produced, and might also provide a source of ignition through simultaneous failure of electric equipment, operation of protection devices, or from other causes; or 3) in which combustible dusts of an electrically conductive nature may be present.

(b) Class II, Division 2. This is a location in which combustible dust will not normally be in suspension in the air or will not be likely to be thrown into suspension by the normal operation of equipment or apparatus in quantities sufficient to produce explosive or ignitible mixtures, but where deposits or accumulations of such combustible dust may be sufficient to interfere with the safe dissipation of heat from electric equipment or might be ignited by arcs, sparks, or burning material from such equipment.

As applied to coal preparation plants, Class II, Division 1 locations would include rooms containing grinders or pulverizers, graders and scalpers as well as coal pulverizing plants and any other location where combustible dusts may be present under normal conditions in sufficient amounts to produce explosive or ignitible mixtures. According to the NEC-1975, pulverized coal is considered an electrically conductive dust. Recent studies* indicate that coal should be classified as a semi-conductor.

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*See Chiang, S. H., "Measurement of Electrical Conductivity/Resistivity of Dust Samples", report submitted to Bureau of Mines, P.O. No. 364050, September 1976, and Instrument Society of America, "Area Classification in Hazardous Dust Locations", ISA-212.10 (October 1973).

This fact has been reflected in more recent NFPA codes (see NFPA 653 337-371 for 1977).

Class II Division 2 locations are those in which airborne dust is not present but where dust might accumulate on or near electric equipment in sufficient amounts as to interfere with proper and safe heat dissipation, thus creating a potential for exceeding layered dust ignition temperatures.

The maximum surface temperatures for heat-producing equipment under normal operating conditions should not exceed the following in Class II locations:

- Equipment not subject to overload :165 °C
- Equipment subject to overload (e.g., motors, transformers) :120 °C.

2.3.3 National Electrical Manufacturers Association (NEMA)

NEMA has established standards for the manufacture and application of electrical equipment. These standards classify equipment according to types of enclosures, operating temperatures, classes of insulation and various other design parameters. The pertinent standards are listed below.

2.3.3.1 Classification of Enclosures for Industrial Control Equipment

NEMA assigns type-numbers to identify the various non-ventilated enclosures designed for specific conditions. However, these numbers are not presently marked on the enclosures, making field identification of enclosures difficult. Referral to manufacturers' catalogs is necessary to provide type-number information for a particular device or equipment.

Type 1, General purpose-Indoor. An enclosure intended primarily to protect against accidental contact of personnel with the enclosed equipment.

Type 2, Dripproof-Indoor. An enclosure intended to protect the enclosed equipment against falling noncorrosive liquids and falling dirt.

Type 3, Dusttight, Raintight and Sleet Resistant Outdoor. An enclosure intended to protect the enclosed equipment against windblown dust and water.

Type 4, Watertight and Dusttight-Indoor. An enclosure intended to protect the enclosed equipment against splashing water, seepage of water, and falling or hose-directed water.

Type 6, Submersible, Watertight, Dusttight and Sleet Resistant-Indoor Outdoor. An enclosure intended for locations where occasional submersion is encountered.

Type 7, Class I, Group A, B, C, or D-Indoor Hazardous Locations. An enclosure for air-break devices intended for use in Class I, Group A B, C, or D hazardous locations.

Type 8, Class I, Group A, B, C, or D-Indoor Hazardous Locations. An enclosure for oil-immersed devices intended for use in Class I, Group A, B, C, or D hazardous locations.

Type 9, Class II, Group E, F, or G-Indoor Hazardous Locations. An enclosure for air-break devices intended for use in Class II, Group E, F, or G hazardous locations.

Type 10, Bureau of Mines. An enclosure designed to meet the requirements of the U. S. Bureau of Mines which relate to atmospheres containing mixtures of methane and air, with or without coal dust present.

Type 11, Corrosion Resistant and Dripproof-Indoor. An enclosure for oil-immersed equipment intended to protect the enclosed equipment against dripping, seepage, and external condensation of corrosive liquids and the corrosive effects of fumes and gases.

Type 12, Industrial Use Dusttight and Driptight-Indoor. An enclosure intended to protect the enclosed equipment against lint, fibers, flyings, dust, dirt, and light splashing, seepage, dripping and external condensation of noncorrosive liquids. It has an oil-resistant gasket between the case and cover. There are no unused holes through the enclosure and no conduit knockouts or conduit openings.

Type 13, Oiltight and Dusttight-Indoor. An enclosure intended to protect the enclosed equipment against lint and dust, and seepage, external condensation, and spraying of water, oil, or coolant.

2.3.3.2 Classification of Motors

There are several NEMA classifications for motors and generators. Of these, only the classification according to Environmental Protection and Methods of Cooling is relevant to coal preparation plants.

Within this classification, motors are divided into open machines and totally enclosed machines. An open machine is defined as:

> ". . . one having ventilating openings which permit passage of external cooling air over and around windings of the machine."

Open machines are further categorized into eight groups: Drip-proof, splash-proof, semi-guarded, guarded, drip-proof fully guarded, externally ventilated, pipe-ventilated, and weather-protected. Among these, the most common is the drip-proof, which is constructed such that the ventilation openings prevent entry of water at any angle from 0 to 15 degrees downward from the vertical.

According to NEMA, a totally enclosed machine is one which is "...so enclosed as to prevent the free exchange of air between the inside and the outside of the case but not sufficiently enclosed to be termed air-tight."

There are ten categories of totally enclosed machines. Only four of these are pertinent to coal preparation plants:

- Totally-Enclosed Fan-Cooled Machine (TEFC) which is equipped for exterior cooling by means of a fan or fans integral with the machine but external to the enclosing parts.
- Explosion-Proof Machine (XP) which is a totally-enclosed machine designed and constructed to withstand an explosion of a specific gas or vapor which may leak into it and to prevent the ignition of the gas or vapor surrounding the machine by sparks, flashes or explosions of the gas or vapor within the machine casing.

- Dust-Ignition-Proof (DIP) Machine which is a totally-enclosed machine designed and constructed in a manner which will exclude ignitible amounts of dust or which might affect performance or rating. Neither will it permit arcs, sparks, or heat otherwise generated or liberated inside of the enclosure to cause ignition of exterior accumulations or atmospheric suspensions of a specific dust on or in the vicinity of the enclosure.
- Totally-Enclosed Pipe-Ventilated Machine (TEPV) which is a totally enclosed machine except for openings so arranged that inlet and outlet ducts or pipes may be connected to them for the admission and discharge of the ventilating air. This air may be circulated by means integral with the machine or by means external to and not a part of the machine. In the latter case, these machines are known as separately- or forced-ventilated machines.

2.3.3.3 Classification of Insulation

There are presently four classes of insulation used in the manufacture of electric motors: A, B, F, and H. The characteristics of each establishes specific temperature limitations when used in electric motors, based on a maximum ambient temperature of 40 °C, as shown in Table 2.2.

Table 2.2

Temperature Limits for Integral-Horsepower Motors

Insulation Class	Permissible Temperature (°C)*					
	Open Drip Proof			TEFC		
	Rise**	Hot Spot	Total	Rise**	Hot Spot	Total
A	50	15	105	55	10	105
B	70	20	130	75	15	130
F	90	25	155	95	20	155
H	110	30	180	115	25	180

* Based on 40 °C ambient temperature

** Temperature rise that appears on motor name plate

2.3.4 Underwriters' Laboratories Requirements

Underwriters' Laboratories, Inc. (UL) tests and lists electric motors which may be used in hazardous locations as classified by the National Electrical Code. Standard UL 674 (A), which is also adopted by ANSI (C 33.93-1973) covers "Electric Motors and Generators for use in Hazardous Locations, Class II, Groups E, F, and G." Standard UL 674 (B), which is also ANSI's standard C 33.73-1973 covers "Electric Motors and Generators for Use in Hazardous Locations, Class I, Groups C and D." UL 913 is a general Standard for Safety which covers "Intrinsically Safe Electrical Circuits and Apparatus for Use in Hazardous Locations and its Associated Apparatus."

All of these standards provide details of tests and criteria that must be met by electrical equipment so that it may be used in the designated hazardous locations for which it was tested. UL publishes an annual list of equipment that had met the UL Standards requirements and which continue to meet the necessary criteria on an annual random sampling and testing basis. It is interesting to note that motors listed for use in Class II, Group F (coal dust) locations must undergo dust penetration tests with -100 mesh grain dust as well as magnesium dust of a specific size distribution. In addition, a dry-dust blanket test is described in which the surface temperature of a Class II, Group F motor shall not exceed 200 °C with grain dust. It should be noted that the layer ignition temperature for coal varies between 170 °C (37% volatiles) to 240 °C (12% volatiles). Therefore, it is conceivable that a motor which had been tested and listed by UL for use in Class II, Group F locations will ignite an accumulated layer of a coal with a high percentage of volatiles. The requirements for Class II, Group F classification do not include any ignition or explosion tests.

To meet the requirements for UL listing in Class I, Group D (methane), the external temperature of a motor must not exceed 215 °C which is well below the ignition temperature of methane (530 °C) but above that of layered coal (~170 °C). In addition, the motor is subjected to a series of explosion tests with a specified gas (in this case methane) to check for flame propagation from the interior to the surrounding explosive atmosphere.

The standard for Intrinsically Safe Electrical Circuits and Equipment (UL 913) is limited to devices, instruments, wiring, etc. which are rated 600 volts or less and intended for use in hazardous locations as classified in the NEC. It provides requirements for mounting, corrosion protection, temperature limits, spacings, grounding, etc.

3. HAZARD ANALYSIS

3.1 PLANT VISITS

3.1.1 Selection of Plants

As part of this program, a number of bituminous, lignite, and anthracite coal preparation plants were visited. The selection of the plants was made to provide as wide a coverage as possible in years of operation, geographic location, throughput, designers, coal seams, and unit operations.

Seventeen of the plants visited operated on bituminous and sub-bituminous coal, three on anthracite and two on lignite. One of the lignite plants started operation in 1951 and the other in 1965. The three anthracite plants were put into operation in the mid-1940's. The oldest bituminous plant started operation in the late 1920's, while the newest started in 1975. The plants were designed by fourteen different companies. Raw coal capacities ranged from 70 tph to 7,000 tph. The coal processed by these plants came from over 15 different coal seams in West Virginia and Pennsylvania and, two different seams in North Dakota, and four different seams in the Northwestern states. Practically all types of unit operations were observed. Dust samples were taken near electrical equipment at four or five different locations in a plant. Methane concentrations were also measured at selected locations. Ventilation rates were recorded at various points.

During a typical visit, an inspection was made of the types of electrical equipment used in various locations. Plant managers or superintendents were asked about their experiences with fires and/or explosions related to electrical equipment. Summaries of the observations made at these plants are given in Appendix A.

3.1.2 General Observations

3.1.2.1 Electrical Equipment

Explosion-proof motors were used in very few of the plants visited. The majority of plants employed TEFC motors. Some plants employed a few open motors while one had all open motors except for one explosion-proof motor in the dumping area. In most cases, the operators would replace a failed motor with what was available at the plant or order a duplicate of the failed motor with no effort to update equipment.

Most of the switchgear was dust-tight. In a few plants, the switchgear was placed in separate rooms. Almost half the plants enclosed the controls in a separate room which was usually air conditioned or had a slight positive pressure to minimize dust infiltration. The majority of control panels were of dust-tight design.

3.1.2.2 Maintenance and Housekeeping Programs

As a general practice, routine maintenance was carried out during or immediately following a working shift. In some cases, it was held off until the weekend. Most plants did not have a formal maintenance schedule but relied on the supervisor's memory as to when a machine was last serviced. Items requiring maintenance which could not be serviced during normal working shifts were noted and the work completed at the earliest opportunity. The majority of maintenance and housekeeping programs were limited to sweeping, washdown to control the dust problems, and lubrication. Three of the plants visited did not perform methane checks. The plants that checked for methane usually did so before each shift at the silo, storage areas, or dumping pits.

Repair work at the plants visited was usually performed immediately since equipment in need of repair generally would fail to operate and shut down the process. In most cases, electrical equipment that failed was replaced with an identical unit which was either a spare or purchased second hand. When repair work was required and the process was shut down, other items requiring maintenance were also checked.

Many of the plants kept electrical repair log books, but did not keep mechanical repair records.

3.1.2.3 Accident and Electrical Failure History

None of the plant superintendents visited could recall any dust or methane explosions or fires due to electrical failures. One operator recalled two dust explosions which were caused by problems in the thermal drying system. Almost all the plants have had motor failures. The plants that used wet processing considered water to be a greater problem than coal dust in that water enhanced the electrical conductivity of coal and increased the probability of shorting.

3.1.3 Dust, Methane, and Ventilation

3.1.3.1 Dust

During the plant visits, measurements were made of airborne dust concentrations. Dust samples were taken in areas that appeared to have the dustiest atmosphere. The dust measurements were made by drawing a known volume of air across a preweighed PVC dust filter with a pore size of approximately 2 μm. The airborne dust concentrations were calculated from the change in filter weight and the sampled air volume. Appendix B summarizes the data collected at each plant.

It was visually obvious that the processes that used large quantities of water (e.g., Diester tables, jigs, wet screens) created the least amount of dust. The visits to lignite coal preparation plants indicated that the soft lignite coal was very susceptible to coal dust generation. When stockpiled lignite that had been dried by the sun is processed, the operations can become very dusty. Bituminous coal preparation plants had both "clean" and dusty operations, depending upon the amount of water used and/or ventilation systems employed. Sub-bituminous plants in the Northwestern states did not utilize any water cleaning operations because of potential freezing problems. However, during early spring (when the visits were conducted) the coal dust levels were relatively low. This was attributed to the fact that water applied to raw coal in the mine was still frozen to the coal surface thus preventing dust formation. According to the plant operators, summer operations generate greater quantities of dust. At that time water sprays are used in the crushing operations to reduce the dust concentration in the plant. Anthracite plants did not exhibit any dusty operations because they depended upon water for the sizing/screening operations and to move the coal throughout the plant as a slurry. Table 3.1 shows the maximum dust concentrations found at the

Table 3.1

Maximum Dust Concentrations Found at Different Coal Preparation Plants

	Concentration (mg/m^3)
Lignite	1,100
Sub-Bituminous	2,180
Bituminous	1,200
Anthracite	30

Table 3.2

Maximum Dust Concentrations Found at Various Operations

Location	Concentration (mg/m^3)
Diester Tables	<10
Wet Crushing	<10
Wet Screens	<10
Reclaim Tunnel	47
Storage Bins	52
Dry Screens	130
Breaker	130
Load-out Building	225
Crushing	647
Dumping Bins	940
Silo	1,100
Thermal Dryer	1,200
Sampling Area	2,023
Conveyor	2,180

Four types of coal cleaning plants. The effect of using water is clear as shown by the low levels of dust found at the anthracite plants.

Table 3.2 shows the maximum dust levels found for different unit operations in coal preparation plants. Again, the effect of water can be seen in the lower dust levels at the Diester tables, wet crushers, and wet screens compared with the higher values for dry processes such as thermal drying, storage silos, and dry screens.

In general, plants that used large quantities of water did not have large accumulations of dust on equipment or structural members except where there were spills or excessive splashing and spraying of coal slurries. After these spills had dried, they would leave layers of caked coal dust. The majority of plants with dry operations had layers of accumulated coal dust on light fixtures, structural beams, braces, and operating equipment including electric motors and switch gear. In the course of one working shift where the plant had been cleaned beforehand, layers of dust up to 1/2" could be found. There were areas where everyday housekeeping did not manage to keep up with dust accumulation. These areas which generally had poor accessibility included tops of light fixtures, structural beams, and tops of tall equipment.

3.1.3.2 Methane

Methane concentrations were measured at various locations in seventeen different coal preparation plants. The results are given in Appendix C. The highest concentration found was 0.2% methane in air or 4% of the lower explosive limit for CH_4. The majority of measurements were made at locations where coal was either stored or crushed. Measurements were also made at other locations throughout the tipple. Table 3.3 lists some of the higher methane levels found during the visits to the coal preparation plants. The highest value found was at a storage silo (0.2%). Some of the methane levels found at operations that did not store or crush coal (e.g., conveyors, centrifuges) may have been due to their proximity to processes where coal was stored or crushed.

Table 3.3

Maximum Methane Levels at Various Locations in Coal Preparation Plants

	Concentration (% in air)
Storage Silo	0.20
Reclaim Tunnel	0.19
Storage Bin	0.18
Crushers	0.15
Screens	0.14
Top of Tipple	0.125
Conveyors	0.125
Dumping Bin	0.12
Baghouse	0.10
Centrifuges	0.085
Load out	0.05

Although the measurements showed low concentrations of methane at the times of the visits, several operators admitted that higher concentrations have been occasionally observed during their regular methane checks. The situation was easily corrected by introducing or increasing the rate of forced ventilation.

3.1.3.3 Ventilation

Table 3.4 shows the types of ventilation that were found in the different plants visited. In many of the plants, there was no forced ventilation in the tipple or storage silos. Ventilation was almost entirely dependent upon the local wind conditions and the amount of openings in the building (e.g., windows and doors). As would be expected, this type of natural ventilation was found to be quite variable. Table 3.5 shows the velocity of air moving through some of the building apertures during the visits. Generally, the number of building openings was small and not enough to create any significant air movement. There was noticeable air movement in the immediate vicinity of an opening when there were sufficient ambient winds, but there was little or no air movement in the areas beyond those openings (e.g., greater than 10 ft away). In many cases the wind would carry coal dust from outside stockpiles into the building or raise coal dust that had settled on equipment or structures and create a dustier atmosphere than if the opening had not been present . During the winter months when doors and windows would be closed, or during calm days, there would be virtually no air movement in these plants.

About one third of the plants visited provided a separate room for controls and/or switch gear that was ventilated or had a slight positive pressure to prevent dust penetration. This method for protecting equipment against dust appeared to be quite effective and the rooms and equipment within were free from dust.

Equipment with air-tight connections such as hooded screens or crushers, did an excellent job of stemming the dust problem as opposed to equipment that operated in ventilated process rooms or enclosures. The latter type of ventilation removed only room air allowing dust to settle on structural

Table 3.4

Types of Ventilation Employed

Type of Ventilation	Number of Plants Employing this Type
Natural ventilation only	7
Control/switch gear room ventilation*	8
Process ventilation (e.g., hooded systems for crushers)	8
Building ventilation (exhaust fans on tipple roof)	4

* Includes air conditioning and positive pressure systems.

Table 3.5

Air Velocities at Different Building Openings

	Air Velocity, fpm
Doorway bottom of tipple	200-300
Doorway top of tipple	0-300
10' x 6' opening top of tipple	30- 60
Conveyor tunnel (12' diameter)	50-100
Reclaim tunnel	0- 90
Dumping Bin (6' x 3' opening)	150-200
Doorway to load-out area	0-200
Conveyor	100-200
Storage bin (6' x 7' opening)	0-500

members and equipment. Similarly, building exhaust fans appeared to have no noticeable effect in removing coal dust from the building. These were basically used to move air and to help cool the building during hot weather.

3.2 ANALYSIS OF ACCIDENT DATA

To establish the nature and causes of fires and explosions in coal preparation plants, descriptions of 65 accidents that were provided by MESA and which covered the period 1952 to 1974 were analyzed. Table 3.6 summarizes the causes and combustible media of these fires and explosions. It can be seen that "electrical" sources were responsible for only about one sixth of the ignitions. Detailed analysis of the eleven "electrical" ignitions are given in Tables 3.7 and 3.8. Arcs from electric welding and broken light bulbs caused three accidents each. Two ignitions were attributed to switch gear. Methane was involved in five of the explosions while coal dust was involved in three. Three of the accidents occurred in the conveyor tunnel under coal storage piles and all three involved methane gas.

It is interesting to note that coal dust explosions (about two thirds of the reported accidents) were mostly in the drying system. Their causes, however, were not related to electrical systems or components. Only three incidents involved coal dust and electrical equipment. In one, coal dust was ignited by a breaking light bulb and in two by sparks from an electric welding machine.

These data appear to support the general concensus of opinion derived from our discussions with plant operators that the frequency and severity of electrically - related fires and explosions in coal preparation plants are minimal. This may be attributed to two factors:

- A conservative attitude in interpreting the NEC and selecting and using electrical equipment and/or
- An over-estimate of the hazards due to methane and coal dust in coal preparation plants.

Table 3.6

Causes and Combustible Media Fires and Explosions at Coal Preparation Plants

Ignition Sources	No. of Ignitions and/or Explosions
Thermal Dryer (excessive heat, open flames, hot clinkers)	23
Acetylene Cutting or Welding	15
Electrical	11
Unknown	4
Friction (sparks or heat)	3
Others	9
	65

Combustible Media	
Coal Dust	40
Methane	8
Gasoline	4
Acetylene	3
Methane and/or Dust	3
Others	7
	65

Table 3.7

Relationship Between

Locations and Media of Electrical Ignitions

Location	Methane	Coal Dust	Hydrogen Gas	Gasoline, Possible Black Pellet Powder	Acetylene	Total
Conveyor Tunnel	3					3
Coal Hopper		1				1
Supply House			1			1
Coal Chute at Vibrator Feeder		1				1
Raw Coal Storage Silo	1					1
Combination Repair Shop, Truck Storage					1	1
Raw Coal Conveyor Belt		1				1
Deep Well Pump House	1					1
Combination Hoist House, Office, Scale House				1		1
Total	5	3	1	1	1	11

Table 3.8

Relationship Between

Ignition Sources and Media of Electrical Ignitions

Ignition Source	Methane	Coal Dust	Hydrogen Gas	Acetylene	Gasoline or Possibly Black Pellet Powder	Total
Light Bulbs (Breaking, Shorting)	2	1				3
Electric Welding Arc		2			1	3
Short Circuit (cables)	1		1			2
Open Type automatic switch (water pump)				1		1
Electric arc in switch box	1					1
Unknown	1					1
Total	5	3	1	1	1	11

3.3 INTERPRETATIONS OF THE CODE

3.3.1 Designers' Interpretation

Several companies which specialize in designing coal preparation plants were visited. Their staff who are concerned with the selection of electrical equipment indicated that they have difficulty in determining which areas within a plant should be designated as Class I or Class II hazardous locations. They felt that the NEC and the Federal Regulations should be more specific as to how various operations should be classified. The major difficulty stems from the opinion (shared by operators) that methane is not really a major problem in a coal preparation plant. As a result, they felt that there should be no Class I locations in any of these plants. However, their general attitude has been to take a conservative attitude, resulting in higher costs for the client. Dust and water were considered to be the primary problems and are generally given greater attention.

In general, designers' interpretations of the Federal Regulations resulted in the location/class/equipment relationships shown in Table 3.9. Obviously, there are variations among these relationships, depending on conditions at particular locations in individual plants. However, designers appeared to agree in general with these classifications.

Field visits revealed instances which were at variance with the foregoing, particularly in older plants. In fact, several older installations utilized open type motors in extremely dusty locations. The motors were covered with as much as 1/2" to 3/4" of dust and some have been operating for 20-25 years.

3.3.2 Insurance Company Interpretations

Preparation plants with open storage facilities were considered by insurance company representatives to be Class II, Division 1, Group F locations because of the presence of coal dust, which they considered both conductive and explosive. Enclosed storage silos, where methane may accumulate, as well as conveyors under silos or storage piles were

Table 3.9

Designers' Interpretation of the Federal Regulations

Location/Process	Class	Equipment
Raw Coal Storage	I if enclosed	Explosion proof
	II if open	Dust tight or dust-ignition proof
Dumping Bin	I if closed	Explosion proof
	II if open	Dust tight or dust-ignition proof
Conveyors under silos	I	Explosion proof
Screening/Crushing	II	Dust tight or dust-ignition proof
Wet Preparation Plant	II	Dust tight or dust-ignition proof
Control rooms	Ordinary if under positive air pressure	NEMA 1 enclosures for switches, etc.
Transfer points	II	Dust tight or dust-ignition proof
Load-out	II if enclosed	Dust tight or dust-ignition proof

considered Class I, Division 1, Group D. Where methane may be present, explosion-proof motors and NEMA Type 10 enclosures for controls and switches were generally recommended.

New facilities were reviewed during the design phase by the insurance company engineers and recommendations for equipment were made based on past experience and judgment. For existing facilities being reviewed prior to acceptance for insurance, inspectors would recommend changes or additions based on their personal judgment, an evaluation of existing conditions, and the guidelines available from the insuring company.

3.3.3 Manufacturers' Interpretations

Manufacturers of electrical components used in coal preparation plants have little input in the selection of equipment unless they are specifically asked to do so. In such cases, they tend to be conservative as long as they feel that they can remain in a competitive position. Manufacturers appeared to stay away from interpreting the codes, leaving that judgment to the designers and operators of coal preparation plants.

Manufacturers indicated that UL-listed explosion-proof motors with a rating greater than 300 hp are not generally available "off-the-shelf." If an explosion-proof motor is requested with a high horsepower, a special motor is built and individually tested and certified at Underwriters' Laboratories. An explosion-proof motor certified in this manner is rather expensive and the tendency for designers has been to select TEFC motors and place them away from the hazard source to preclude dust or methane ignition.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

1. An analysis of available data on fires and explosions in coal preparation plants indicated that electrical equipment do not appear to contribute significantly to the ignition of methane or coal dust. The very few instances where ignition was attributed to electrical devices involved broken light bulbs and sparks from electric arc welding.

2. Although concentrations greater than 1% methane have been reported by operators and MESA inspectors, the maximum methane concentrations measured during the course of this program in several plants and at various locations within each plant were less than 0.2%.

3. Potentially dangerous methane concentrations may accumulate in coal storage areas such as silos and in tunnels below stockpiles, silos and surge piles.

4. Airborne dust concentrations sampled at several plants varied with the degree of wetness of coal and the type of operation. Maximum concentrations (of up to 2,200 mg/m^3) were encountered in dry coal operations involving crushing and breaking.

5. Coal preparation plant operations in which a minimum of 75 gallons of water was present for each ton of coal processed appeared to generate little or no airborn dust. On the other hand those with less than 10 gallons of water per ton of coal appeared to be dusty.

6. Designers appear to take a generally conservative approach in selecting electrical equipment for coal preparation plants.

7. There is little guidance in the Federal Regulations or NEC in determining the classification of areas "adjacent" to hazardous locations.

8. Neither the Federal Regulations nor the NFPA Standard for Coal Preparation Plants (Standard 653) provide adequate guidance as to what constitutes an allowable layer of coal dust on heat-generating electrical equipment in coal preparation plants.

9. The use of .03 oz/cu ft for the overall assessment of coal dust hazard in an enclosure is inadequate because it allows the presence of a relatively thick layer in the vicinity of a potential ignition source and a thin layer in the remainder of a large enclosure.

10. There appears to be a general disagreement among the NEC, the scientific literature and coal plant operators relating to the electrical conductivity of coal and the role that it could play as a fire hazard.

4.2 RECOMMENDATIONS

1. It is recommended that an experimental program be designed and conducted for the following purposes:

a. To examine the electrical conductivity of coal dust under realistic plant conditions and the role that electrical conductivity plays in creating a fire or electrical shorting hazard.

b. To determine maximum allowable coal layer thicknesses on electrical equipment subject to heat accumulation.

2. It is recommended that until such data are developed, a thickness of 1/16 inch be used for the maximum allowable accumulation on heat-generating electrical equipment, as long as the surface temperature does not exceed 170 °C.

3. It is recommended that the following guidelines be adopted for the allocation of electrical motors to hazardous areas:

Area Classification	Motor Type	Insulation Class	Service Factor
I	XP		
II	TEFC/DIP	B	1.0 or 1.15
	TEFC/DIP	F	1.15 only

4. It is recommended that Figure 2.2 in this report be used as a guideline for determining the classification of areas adjacent to Class I, Division 1 locations.

5. The Bureau of Mines and MESA should consider the feasibility of requiring manufacturers of electrical equipment intended for use in coal preparation plants to include the NEMA classification on the name plate.

APPENDIX A

SUMMARY SHEETS OF PLANT VISITS

PLANT A

Plant Location:	Near Pittsburgh, PA
Designer:	Designed by Owners
Date of Start Up:	1928
Type of Coal:	Bituminous
Seams Mined:	Pittsburgh
Output:	Over 1000 tph
Types of Operations:	Diester tables, Baum jigs, heavy media
Electrical Equipment:	Minimal number of explosion-proof equipment. Incandescent lighting, light bulbs not enclosed. Most connections were in conduit, however, there were many cases of long runs of Greenfield and rubber covered cable. The operator control room was in the process area, partially enclosed and had dust curtains at entrance and exit areas.
Maintenance:	They use a cardex file to log total history of both routine and preventive maintenance. The master time clock which records total hours of plant operation is used to determine operating hours on equipment.
Comments:	There is a spare for each piece of life line equipment. Plant was not in operation when visited.

PLANT B

Plant Location:	Near Minot, ND
Designer:	McNally Pittsburgh Mfg. Co., Pittsburgh, PA
Date of Start Up:	1951
Type of Coal:	Lignite
Seams Mined:	Coteau (strip)
Output:	415 tph
Types of Operations:	Crushing, shaking, screening
Electrical Equipment:	Motors mostly open type, with class A or B insulation, NEMA B or C design. Enclosed NEMA 4 dustproof main breakers, switchboxes not dust-tight.
Maintenance:	There is no rigid maintenance program. Equipment maintenance is performed only when there is a failure. A methane check is performed daily in the loading area. Throughout the plant, there were large accumulations of dust.
Maximum Dust Concentration:	10 mg/m^3, conveyor from main crusher
Maximum Methane Concentration:	trace
Comments:	The operation was dry with many dusty locations throughout the plant. We were informed that when stockpiled coal is used, the operation can become so dusty that visibility is impaired.

PLANT C

Plant Location:	Near Bismark, ND
Designer:	Allen Garcia
Date of Start Up:	1964-65
Type of Coal:	Lignite
Seams Mined:	Lignite (strip)
Output:	1000 tph
Types of Operations:	Crushing, shaking and screening
Electrical Equipment:	Motors mostly TEFC and NEMA B design, switches and motor controllers in crusher pit enclosed but not sealed or dusttight. In tipple they were in an enclosed room relatively free from dust. Enclosures not sealed or dusttight.
Maintenance:	General housekeeping is done daily on the offshift. Equipment is checked periodically but not on a scheduled basis. There is a monthly inspection by electrical and mechanical supervisors on each shift to detect repair/maintenance work.
Maximum Dust Concentration:	1,100 mg/m^3, conveyor at silo
Maximum Methane Concentration:	0.15%, bottom of main crusher pit
Comments:	Lack of water in process created many dusty locations.

PLANT D

Plant Location:	Near Pittsburgh, PA
Designer:	Roberts and Shaeffer, Chicago, IL
Date of Start Up:	1948, addition in 1968
Type of Coal:	Bituminous
Seams Mined:	Pittsburgh
Output:	600 tph raw coal capacity, 20% waste
Types of Operations:	Chance Cone, Diester tables, Froth flotation, Centrifugal drier
Electrical Equipment:	All TEFC NEMA design B or C, insulation class A or B. Approximately 5% were open type motors, will be replaced with TEFC. NEMA 4 dusttight enclosures design for controls and switchgear.
Maintenance:	There is a regular maintenance schedule for all major equipment based upon operating hours. Housekeeping is done by a maintenance man and consists of wet washdown and sweeping. Switch boxes, controllers and main switch gear are vacuumed out quarterly to remove any dust that might have accumulated.
Maximum Dust Concentration:	7 mg/m^3, conveyor belt carrying dried fines from centrifuge
Maximum Methane Concentration:	0.08%, breaker and bottom floor of breaker
Comments:	The plant appeared extremely clean. This can be attributed to the large quantities of water that were used.

PLANT E

Plant Location:	Near Pittsburgh, PA
Designer:	Roberts and Shaeffer, Chicago, IL
Date of Start Up:	1953
Type of Coal:	Bituminous
Seams Mined:	Pittsburgh
Output:	600 tph raw coal capacity, 20% waste
Types of Operations:	Crushing, Water jigs, froth flotation
Maintenance:	Maintenance is based on past experience and performed daily or weekly as experience dictates. General housekeeping (washdown and sweeping) is done every shift by an assigned maintenance man.
Maximum Dust Concentration:	< 1 mg/m^3, conveyor (not operating)
Maximum Methane Concentration:	0.15%, bottom of silo (not operating)
Electrical Equipment:	All NEMA B or C, insulation class A or B; most were open type motors, will be replaced with TEFC. NEMA 4 dust-tight enclosure design for controls and switch gear.
Comments:	The plant was not operating during our visit due to change in shifts. The plant appeared very clean.

PLANT F

Plant Location:	Near Pittsburgh, PA
Designer:	Jeffrey Mfg. Co. installed by Erwin-McElvery
Date of Start Up:	1961-62
Type of Coal:	Bituminous
Seams Mined:	Pittsburgh
Output:	350 tph raw coal capacity, 22% waste
Types of Operations:	Originally dry process. Converted to washing plant utilizing diaphragm separator, dewatering screens, fines flotation tank and centrifugal dryer.
Electric Equipment:	Motors essentially all TEFC, NEMA design B, insulation class A or B. Controls and switch gear have dusttight enclosures.
Maintenance:	There is no established program of maintenance at the plant. Oiling/greasing is done as required during operating shifts. Necessary repairs are done off-shift unless a plant shutdown has occurred. Regular clean up is done by operators during each shift.
Maximum Dust Concentration:	300 mg/m^3 inside crusher
Maximum Methane Concentration:	0.125%, crusher
Comments:	The difference in dust concentrations between the crusher room/conveyors gallery and the washing plant clearly indicate the effect of water in suppressing dust. The major problem relative to electrical equipment is water and mechanical failure according to plant operators.

PLANT G

Plant Location:	Near Pittsburgh, PA
Designer:	Jeffrey Mfg. Co.
Type of Coal:	Bituminous
Output:	7,000 tph capacity
Types of Operations:	Fine and coarse jigging, crushing, centrifugal drying.
Electrical Equipment:	Motors essentially all TEFC, NEMA and design B, insulation class A or B. Controls and switch gear have dusttight enclosures.
Maintenance:	Plant was not in operation during visit.

PLANT H

Plant Location:	Near Logan, WV
Designer:	McNally-Pittsburgh, Pittsburgh, PA (original); Dravo Corporation, Pittsburgh, PA (additions)
Date of Start Up:	early 1940's, 1972-73 heavy media system added
Type of Coal:	Bituminous
Seams Mined:	Chilton, Island Creek, Winifrede, Coalburgh
Output:	800 tph raw coal capacity
Types of Operations:	Heavy media, crushing, screening, thermal drying
Electrical Equipment:	Both open and TEFC motors were used, generally of NEMA design B or C with insulation class A or B. Motors in the dustiest locations were open type, installed when the plant was built originally.
Maintenance:	There are three shifts, each 7-1/4 hours, two of which are maintenance shifts when major maintenance and cleaning are performed. Cleaning consists of sweeping and washdown.
Maximum Dust Concentration:	1,200 mg/m^3, thermal dryer conveyor
Maximum Methane Concentration:	0.16%, silo
Comments:	When a motor fails, it is replaced with what is available at the plant. If another motor has to be ordered, it is done according to the latest code, which is interpreted as meaning TEFC motors for replacements.

PLANT I

Plant Location:	Near Beckley, WV
Designer:	Roberts and Shaeffer
Date of Start Up:	1972
Type of Coal:	Bituminous
Output:	500 tph raw coal capacity. Approximately 30% waste
Types of Operations:	Crushing, screening, hydroclones, centrifugal drying
Electrical Equipment:	All motors were TEFC NEMA design B with insulation class B. Control equipment and switch gear were enclosed in separate air conditioned rooms. All dusttight enclosures used.
Maintenance:	Records are kept on electrical repairs and greasing of equipment. The electrical boxes in the control room are cleaned every three months and inspected monthly.
Comments:	Plant was not in operation during visit due to change in shifts. The tour through the tipple did not reveal any large accumulations of dust.

PLANT J

Plant Location:	Near Charleston, WV
Designer:	Daniels
Date of Start Up:	1966
Type of Coal:	Bituminous
Seams Mined:	No. 2 Gas
Output:	300 tph capacity
Types of Operations:	Screening, crushing, heavy media
Electrical Equipment:	Motors were a mixture of both open and TEFC, NEMA design A, B, and C, insulation class A and B. Control/switch gear was enclosed in a separate room. Most enclosures NEMA 4, some simply sealed with felt gasket.
Maintenance:	General housekeeping consisted of sweeping down the plant once a day during the work shift and wash down about every couple of months.
Maximum Dust Concentration:	19 mg/m^3, tunnel under silo
Maximum Methane Concentration:	0.08%, tunnel under silo and wet screens
Comments:	Again the effect of water on suppressing dust was evident. When motors have to be replaced, they use what is available. If motors have to be purchased, a duplicate of the failed motor is used. The replacement of switch gear is done in the same way except that if the equipment has to be purchased, they sometimes replace it with updated equipment.

PLANT K

Plant Location:	Near Charleston, WV
Designer:	J.O. Lively Manufacturing and Equipment Company
Date of Start Up:	1971
Type of Coal:	Bituminous
Seams Mined:	Eagle, Winifrede
Types of Operations:	Heavy media, thermal drying
Electrical Equipment:	All but one motor are TEFC NEMA design B or C, with insulation class A or B. The one exception was an explosion-proof motor on the new coal conveyor which was a NEMA B motor with Class B insulation. Control/switch gear were both contained in separate air conditioned rooms with slight positive internal pressure to minimize dust infiltration. Enclosures are all dusttight.
Maintenance:	There are three shifts, two production and one maintenance. Maintenance includes sweeping and wash down to keep the level of dust down. There is a scheduled greasing procedure based on time in lieu of operating hours.
Maximum Dust Concentration:	7 mg/m^3, bottom of silos
Maximum Methane Concentration:	0.08%, bottom of silos
Comments:	Replacements of electrical equipment are made with the same type of unit. Dust levels throughout the plant were very low.

PLANT L

Plant Location:	Near Central City, PA
Designer:	Designed by Owners
Type of Coal:	Bituminous
Seams Mined:	Lower and Upper Kittanning
Output:	130-140 tph
Types of operations:	Heavy media, Deister tables
Electrical Equipment:	All motors are TEFC motors except one which is an open motor located under the raw coal dumping bin to drive the bin gate. Switch gear is in a separate though not tight room. Air conditioning and a slight positive pressure are used to minimize dust infiltration. Control panel is open to the process in dust-tight enclosures.
Maintenance:	Housekeeping performed during the production shift consisted of sweeping and wash down. Dust is sometimes moved with air from compressed air lines. During maintenance, equipment is greased, and any work such as process changes is performed. Maintenance is not scheduled. Personnel try to "catch" any failures before they happen.
Maximum Dust Concentration:	940 mg/m^3, dumping bin
Maximum Methane Concentration:	0.11%, dumping bin
Comments:	If a motor has to be replaced, it would be replaced with a TEFC motor because of the large amounts of water present throughout the plant.

PLANT M

Plant Location:	Near Central City, PA
Designer:	Ridge Equipment
Date of Start Up:	1962, 1974 second air jig added
Type of Coal:	Bituminous
Seams Mined:	Upper, Lower and Middle Kittanning, Upper and Lower Freeport
Output:	70-80 tph
Types of Operations:	Screening, breaking, air jigging
Electrical Equipment:	All motors accessible to inspection where TEFC NEMA design B insulation class A or B (one motor was class F). Control/switch gear was generally located adjacent to equipment to be operated. Enclosures were mostly dust-tight.
Maintenance:	Maintenance is done as needed. Electrical boxes are cleaned about once per week.
Maximum Dust Concentration:	130 mg/m^3, breaker, dry screens
Maximum Methane Concentration:	0.09%, breaker
Comments:	Motor replacements are made with duplicate equipment.

PLANT N

Plant Location:	Near Scranton, PA
Designer:	Designed by Owners
Date of Start Up:	1945
Type of Coal:	Anthracite
Output:	110-115 tph
Types of Operations:	Scalping screens, Diester tables, hydro separation
Electrical Equipment:	Motors within the plant were either open drip proof or TEFC, in a ratio of approximately 2 to 1 TEFC. Switches-starters and control boxes are dust-tight.
Maintenance:	There is no prescribed maintenance schedule for any equipment. Oiling/greasing is performed as required during operation, as is any cleanup work necessary to eliminate hazardous conditions.
Maximum Dust Concentration:	2 mg/m^3, picking table
Maximum Methane Concentration:	Trace in storage bin, screens, picking table.
Comments:	Failed motors are replaced with a similar size TEFC motor. These new motors are largely NEMA design B. Very little airborne dust was present. There were patches of coal sludge due to spills. Much of the existing wiring was not run in conduit.

PLANT O

Plant Location:	Near Scranton, PA
Designer:	Designed by Owners
Date of Start Up:	1947
Type of Coal:	Anthracite (strip mined)
Seams Mined:	Primrose, Holmes, Four-Foot Vein
Output:	300 tph raw coal capacity (approximately 50% waste)
Types of Operations:	Heavy media washer, screens
Electrical Equipment:	Explosion-proof, TEFC and open motors are used in tipple
Maintenance:	Saturdays and Sundays are maintenance days, both scheduled and general repairs are performed. General housekeeping is done during the production shift. No methane checks are made.
Comments:	The plant was not in operation during the visit due to equipment failure. When there is equipment failure, replacements are made with what is available.

PLANT P

Plant Location:	Near Scranton, PA
Date of Start Up:	1947, 1960 changed to heavy media system, 1970 Diester tables added.
Type of Coal:	Anthracite
Seams Mined:	Mammoth Vein (both splits) and Skidmore Vein
Output:	100 tph raw coal capacity, approximately 25% waste.
Types of Operations:	Heavy media, Diester tables
Electrical Equipment:	Motors are either open or TEFC, NEMA design B and on newer motors insulation class B. Switches/control panels are enclosed, some are dust-tight. Those dating from the original installation did not appear dust-tight.
Maintenance:	There is no regular schedule for equipment maintenance. Oiling/greasing are performed during and after operating shifts are required. Clean up to remove spills or other dirt/grease/oil is done as required during shifts. A general plant cleaning is done after shifts and consists mainly of a sweep down.
Maximum Dust Concentration:	30 mg/m^3, dry screens, breaker
Maximum Methane Concentration:	0.09%, coal storage area
Comments:	Electrical equipment is kept up to date with codes by an agreement with the motor sales people, who guarantee that the motors will meet the approval of the inspectors.

PLANT Q

Plant Location:	Near Beckley, WV
Designer:	Roberts and Shaeffer
Type of Coal:	Bituminous
Seams Mined:	Pocahontas 3 and 4
Output:	230 tph clean coal
Types of Equipment:	Froth cells, Centrifugal dryers, thermal dryers, heavy media, screens, crushers, clean coal storage.

The purpose of this visit was to inspect a preparation plant which had been cited by MESA for having a high methane concentration. The inspection was made with a MESA electrical inspector. Maximum methane concentrations encountered were 0.2% in the silo.

PLANT R

Plant Location:	Near Billings, Montana
Designer:	J. O. Lively Manufacturing and Equipment Company
Date of Start Up:	August 1972
Type of Coal:	Sub-Bituminous
Seams Mined:	Dietz (52 in)
Output:	3,000 tph at tipple, 6,000 tph at load out
Types of Operations:	Crushing, screening, storage and unit train load out
Electrical Equipment:	Switch gear are normal enclosures in pressurized rooms. There are no explosion-proof motors, mostly TEFC. On top and bottom of the silo are dust ignition-proof motors. There is a continuous methane monitoring system under the storage silos. At a CH_4 level of 0.8% of air, there is a warning and at 1.8% the system shuts down the feeder under the silo.
Maintenance:	Methane checks are conducted at different locations three times a day, one at the beginning of every shift. Housekeeping is done every shift. Washdown is carried out during nine months of the year. During winter the plant is swept. Silos are swept and cleaned after every train if possible. Equipment maintenance is done every night.

Maximum Dust Concentration:	2,180 mg/m^3, Conveyor
Maximum Methane Concentration:	0.16%, top of silo
Comments:	Two of the plant electrical supervisors thought that below and on top of a silo should be Class I, Division 1 (and if ventilated Division 2). Everywhere else should be Class II. In the summer months, operations can become so dusty that visibility is impaired.

PLANT S

Plant Location:	Near Billings, Montana
Designer:	Designed by Owner
Date of Start Up:	Tipple 1969, added coal storage and unit train load out 1974.
Type of Coal:	Sub-Bituminous
Seams Mined:	Rosebud (32 in)
Output:	1,200 tph at tipple, 4,000 tph at load out
Types of Operations:	Crushing, screening, storage, unit train load out.
Electrical Equipment:	General purpose switch gear and controls are installed in pressurized rooms. Explosion-proof equipment is used in the reclaim tunnel, plow area, and for fans in the load out area and reclaim tunnel. Tube cooled totally enclosed motors are used in the load-out area. Lights are vapor tight except for the reclaim tunnel where explosion-proof lights are used. Totally enclosed dust ignition-proof motors are used above the silo. The tripper motor is both explosion proof and dust ignition proof. Outside motors are totally enclosed, drip- and weather-proof.
Maintenance:	Methane checks are conducted once per shift. The plant is washed down every shift and after every train. In freezing weather, sweeping and shoveling are performed in lieu of washdown. There is no scheduled maintenance program. When production stops the crew works on maintenance. A continuous methane monitor system is used in the coal storage area.

Maximum Dust Concentration:	122 mg/m^3, Silo conveyor
Maximum Methane Concentration:	0.14%, top of silo
Comments:	Water is added at the screens, head pulley and after the crusher. The operator feels that the tunnel and above the coal storage area should be Class I, Division 1. The train load-out surge bin and conveyors should be Class II, Division 1.

PLANT T

Plant Location:	Near Gillette, Wyoming
Designer:	McNally Pittsburgh, Pittsburgh, PA
Date of Start Up:	1957
Type of Coal:	Sub-Bituminous (12 x 5; 6 x 3; 1 1/2 x 3 nut; 1 1/2 x 0 slack; 1 1/2" and 1" stoker; 1 1/2" pea, 2 x 0)
Seams Mined:	Armstrong (50 in), Monarch (50 in)
Output:	700 tph capacity
Types of Operations:	Crushing, screening, unit train load out
Electrical Equipment:	About one third was explosion-proof motors, a third dust-proof and the remainder open motors.
Maintenance:	Methane checks are conducted first in the morning, before start up in the crusher area and top end of feedbelt. There is no scheduled equipment maintenance. It is done as necessary. Housekeeping which consists of sweeping and shoveling is conducted once a week.
Maximum Dust Concentration:	52 mg/m^3, below storage bin
Maximum Methane Concentration:	0.18%, bottom of storage bin
Comments:	The company interprets the NEC to allow open motors in open areas and dust-proof motors in confined areas. Water is added just before the crusher and at the mining pit if needed. The plant can get very dusty, especially during the first five minutes of start up. The winter months are not very dusty. Oil is sprayed on the coal just before load out to keep down dust levels in domestic coal deliveries.

PLANT U

Plant Location:	Near Billings, Montana
Designer:	Sterns, Roger, Denver and Robbins Construction and Engineers, NJ
Date of Start Up:	1975
Type of Coal:	Sub-Bituminous (1 1/2 x 0)
Seams Mined:	Rosebud (280 in)
Output:	2,500 tph at tipple, 4,000 tph at load out
Types of Operations:	Crushing, screening, unit-train load out.
Electrical Equipment:	Reclaim tunnel equipment all is Class I Division 2. The rest of the equipment is Class II. Switch gear and controls are in pressurized rooms.
Maintenance:	Methane checks are conducted once per shift in the reclaim tunnel. Switch boxes are vacuumed as necessary. The load-out area is washed down after every train. The rest of the plant is cleaned as necessary.
Maximum Dust Concentration:	436 mg/m^3, below dumping bin
Maximum Methane Concentration:	0.11%, dumping pit
Comments:	A forced ventilation system for the reclaim tunnel will soon be installed. Before construction was started, the company approached MESA with the drawings to see how MESA expected to classify their plant. The plant can be very dusty in the summer when the processed coal is dry. No water is used for dust suppression. Foreman said that the operation can become so dusty that visibility is impaired.

PLANT V

Plant Location:	Near Steamboat Springs, Colorado
Designer:	Designed by owner
Date of Start Up:	December 1974
Type of Coal:	Sub-Bituminous (3 1/2 x 0 and stoker)
Output:	125 tph
Types of Operations:	Crushing, screening, unit train load out
Electrical Equipment:	In the tipple all motors are dust-tight except one open drip-proof motor. In the finished coal reclaim tunnel only explosion-proof equipment is used. Control boxes are all dust tight NEMA 12.
Maintenance:	Methane checks are done only when the reclaim system is started. A daily maintenance book is kept by the company. A complete plant washdown is done once per week. Equipment maintenance, lubrication and electrical equipment maintenance are performed once per month.
Maximum Dust Concentration:	225 mg/m^3, load-out building
Maximum Methane Concentration:	0.19%, draw-off tunnel (not operating)
Comments:	If a motor fails, the motor would be replaced with its duplicate. The company relies upon an outside electrician to interpret the NEC. MESA has classified the plant as Class II, Division 1.

Appendix B

Dust Levels at Preparation Plants

	Dust Concentration mg/m^3
Plant A	
No measurements were taken. Plant not operating	
Plant B	
Dumping bin	8
Dumping bin (near motor)	4
Conveyor from main crusher	10
Conveyor from main crusher to shaker	6
Main control board	2
Transfer conveyor following shut down	5
Plant C	
Crusher (not operating)	13
Crusher (operating)	40
Crusher (near motor, operating)	13
Conveyor from crusher	120
Conveyor at silo	1,100
Plant D	
Conveyor (carries dried fines from centrifuge)	7
Bottom floor of tipple	3
Plant E	
Conveyor (not operating)	<1
Plant F	
Centrifuge (2' from motor)	3
Clean coal conveyor	1
Raw coal conveyor	33
Crusher (next to motor)	13
Crusher (inside crusher)	300
Plant G	
Measurements were not taken because plant was not operating	

	Dust Concentration mg/m^3
Plant H	
Raw coal silo (motors on top, explosion-proof switches inside)	14
Raw coal transfer tunnel (explosion-proof lights inside)	3
Thermal dryer conveyor	1,200
Clean coal crusher (open motor)	32
Plant I	
Measurements were not taken because plant was not in operation	
Plant J	
Clean coal conveyor	11
Wet screens	3
Bottom of breaker	<1
Raw coal silo draw off tunnel (1' from electric box)	19
Plant K	
Bottom of silos	7
Raw coal conveyor belt	3
Diester tables, wet crusher	<2
Plant L	
Dumping bin (1' from belt roller, disturbing dust layer)	940
Dry screen (1' from motor)	55
Plant M	
Breaker (3' from electrical box)	95
Dry screens and breaker	130
Air tables	80
Air table cyclone	<5
Plant N	
Screens	<2
Picking table	2
Under picking table	<2
Plant O	
Measurements were not taken because plant was not in operation	

	Dust Concentration mg/m^3
Plant P	
Dry screens, breaker	30
Plant Q	
Measurements were not taken.	
Plant R	
Below crusher (load out)	647
Conveyor to silo (near roller)	2,180
Sampling area	2,023
Plant S	
Reclaim tunnel	47
Dumping pit	63
Conveyor to silo	122
Inside Silo (at level of coal)	28
Plant T	
Dumping pit	39
Below storage bin	52
Plant U	
Below dumping bin	436
Above stockpile at end of load-out conveyor (windy conditions)	14,741*
Plant V	
Below raw coal dumping bin	73
Below primary crusher	154
Load-out building	225

* Sample contaminated with large pieces of coal

Appendix C

Methane Levels at Preparation Plants

	% Methane in air*
Plant A	
Measurements were not taken. Plant not in operation.	
Plant B	
Below main crusher	trace
Transfer conveyor from main crusher to shaker	trace
Main control board	trace
Plant C	
Main crusher (not operating)	trace
Main crusher (operating)	0.08
Main crusher (near motor)	0.12
Bottom of main crusher pit	0.15
Tipple crusher	0.065
Conveyor at silo	0.065
Plant D	
Belt conveyor (carries dried fines from centrifuge)	0.08
Top floor of breaker	0.065
Bottom floor of breaker	0.08
Plant E	
Conveyor (top floor of plant)	0.125
Bottom of silo (not operating)	0.15
Plant F	
Under centrifuge dryer (2' from motor)	0.08
Clean coal conveyor	0.08
Raw coal conveyor (5' from conveyor motor)	0.115
Crusher	0.125

* Less than 0.05% methane in air recorded as trace

	% Methane in air
Plant G	
Measurements were not taken because plant was not in operation	
Plant H	
Transfer House	trace
Silo	0.16
Long storage silo	trace
Finished coal crusher (3 sides enclosed)	trace
Plant I	
Measurements were not taken because plant was not in operation	
Plant J	
Sump room	trace
Clean coal belt	trace
Wet screens	0.065
Bottom of breaker	0.08
Top of breaker	0.065
Draw off tunnel under silo	0.08
Plant K	
Bottom of silo	0.08
Froth tanks	0.06
Wet coal crusher (wet coal)	0.065
Raw coal divider shute	0.065
Plant L	
Dumping bin	0.105
Dry screens	0.08
Top of 3 silos (about 2/3 full)	0.09
Plant M	
Dumping bin	trace
Breaker (3' from electrical box)	trace
Breaker (near motor)	0.09
Air table	0.08
Plant N	
Storage bin	trace
Screening (not operating)	trace
Picking table	trace

	% Methane in air
Plant O	
Measurements were not taken because plant was not in operation	
Plant P	
Dry screens-breaker	0.08
Storage area	0.09
Plant Q*	
Top of silo	0.20
Plant R	
Above crusher, below truck dumping pit	trace
Top of silo	0.16
Plant S	
Reclaim tunnel	trace
Load out building	0.09
Dumping pit	0.09
Conveyor to silo	trace
Top of silo	0.14
Plant T	
Dumping pit	0.09
Bottom of storage bin	0.18
Top of screening building	0.14
Plant U	
Dumping pit (2nd level)	0.12
Dumping pit (1st level)	0.08
Plant V	
Below raw coal dumping bin	0.05
Above raw coal dumping bin	0.10
Below primary crusher	0.10
Bag house (not operating)	0.10
Load out building	0.05
Reclaim tunnel (not operating)	0.19

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* This plant had been cited by MESA for having a high methane concentration.

APPENDIX D

Calculation of the Safe Separation Distance from a Methane Source

The safe separation distance* from the top of a silo into which coal is being conveyed was calculated for various coal flow rates and silo methane concentrations using an analytical vapor dispersion technique called the "virtual source model."

The system under consideration is a silo into which coal is conveyed at a certain mass flow rate. As it falls, the coal replaces an equal volume of the air/methane mixture present in the silo. The air/methane mixture leaves the top opening of the silo and is dispersed by the prevailing wind. Of particular concern here is the maximum distance from the source of methane (top of silo opening) to where the concentration drops to a safe level. This calculation is highly dependent on the assumed methane concentration in the silo, the concentration considered to be the safe level and weather conditions.

Three methane concentrations in the silo were considered: 5, 10 and 15% (by volume). These values were chosen because they were believed to be typical of those encountered in practice.

The safe concentration for methane in air was taken as 1%. This is the value used by MESA for determining compliance with present Federal Regulations. Although the lower flammable limit for methane in air is about 5%, a lower safe level of 1% allows for concentration fluctuations in air and provides a conservative estimate of safe separation distances.

The weather conditions were chosen so that maximum safe separation distances are calculated for the dispersion of a vapor in air. In air pollution studies, these conditions are considered to be a low steady

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*Defined as the distance between a source of flammable gas emission and the point at which ignition sources may be present with little likelihood of ignition.

wind speed of about 2 meter/second and a moderately stable atmosphere (atmosphere F).

The virtual source technique considers the methane at the silo opening to be coming from a fictitious (virtual) point source somewhere upwind of the area source (see Figure D.1).

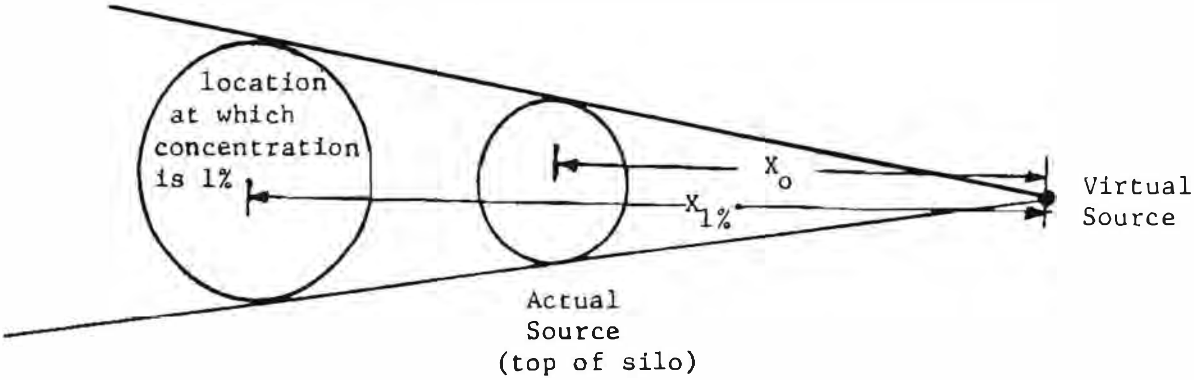

Figure D.1: Virtual Source Technique

The certerline (maximum) concentration away from an elevated point source is given by

$$\bar{C} = \frac{\dot{Q}}{2\pi\sigma_y\sigma_z\bar{U}} \qquad \text{D.1}$$

where: $\dot{Q}$ = rate of methane generation at the source (g mole/second)

$\bar{U}$ = wind speed (meter/second) = 2 m/s

σ_y, σ_z = dispersion coefficients (m)

$\bar{C}$ = concentration of methane (g mole/m^3)

The dispersion coefficients σ_y and σ_z are functions of the atmospheric conditions and downwind distance from the source. These coefficients are given in the literature*. For moderately stable atmosphere F, the relationship between distance and the product $\sigma_y\sigma_z$ is given by

$$X = 24\ (\sigma_y\sigma_z)^{0.6} \qquad \text{D.2}$$

The value of $(\sigma_y\sigma_z)_o$ at the virtual source was calculated from:

$$(\sigma_y\sigma_z)_o = \frac{\dot{Q}\ (\text{g mole methane/s})}{2\pi(2\text{m/s})\ (\bar{C}_s\ \text{g mole/m}^3)} = \frac{\dot{V}}{2\pi} \qquad \text{D.3}$$

where $\dot{V} = \frac{\dot{Q}}{\bar{C}_s}$ = volumetric flow rate of air at the source (m^3/second)

$\bar{C}_s$ = concentration of methane at the source (g mole/m^3)

The air/methane emission from the silo opening is directly related to the rate of coal introduction into the silo. For a given mass flow rate of coal, and using an average density of 75 lb/cu ft for coal, the volumetric flow rate is calculated. This flow rate is equivalent to the volumetric flow rate of air out of the silo, $\dot{V}$ (m^3 of air/s).

For a given coal mass flow rate the following procedure was used:

1. Calculate the volumetric flow rate of coal, $\dot{V}$ (m^3/s)
2. Substitute in equation D.2 and calculate $(\sigma_y\sigma_z)_o$
3. Using equation D.3 calculate X_o between the actual and virtual sources.
4. Calculate $\dot{Q}$ (g mole methane/s) at the source
   $\dot{Q} = \dot{V}\ (m^3/s) \times \bar{C}_s\ (g\ mole/m^3)$

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*See Chapter 3-3: "Atmospheric Diffusion Models and Applications in Meterology and Atomic Energy 1968", David H. Slade, eidtor, U.S. Atomic Energy Commission, Division of Technical Information, TID-24190, (1969).

5. Calculate $\sigma_y \sigma_z$ from equation D.1 where C is the equivalent (in g mole/m^3) to 1.0 mole %.
6. Using equation D.2 calculate $X_{1\%}$, where $X_{1\%}$ is the distance between the point at which the safe level of 1% is reached and the virtual point source.
7. The difference between $X_{1\%}$ and X_o is the safe separation distance from the actual source (refer to Figure D.1 for distance identification).

Figure D.2 summarizes the results of these calculations.

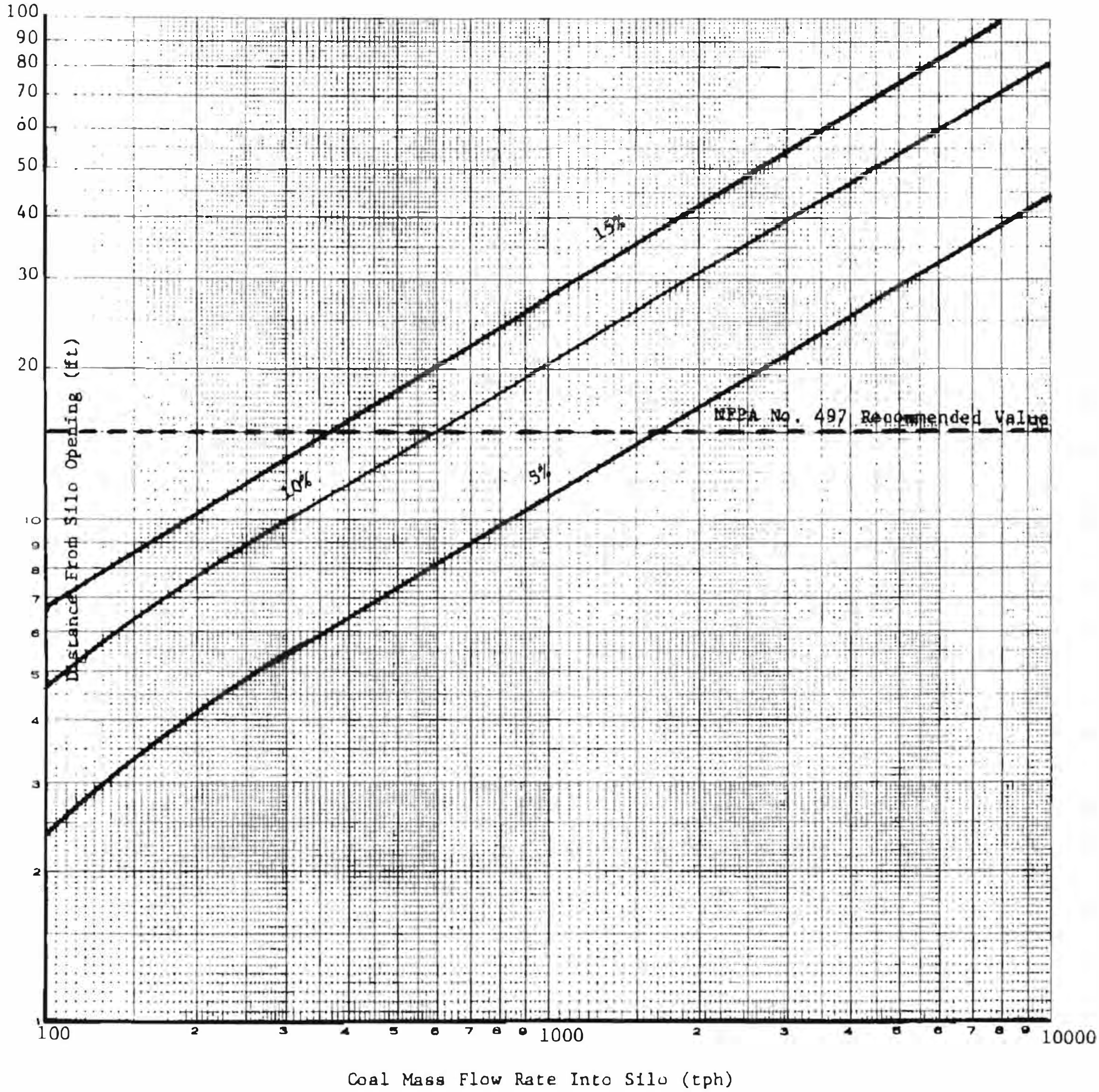

FIGURE D.2 DISTANCES AT WHICH METHANE CONCENTRATION IS 1%

PART II

RECOMMENDED GUIDELINES

1. INTRODUCTION

The inherent presence of airborne and layered coal dust in coal preparation plants and the potential for methane generation and accumulation within certain locations make it imperative that the appropriate electrical equipment be selected and used and that it be continuously maintained in a safe condition. Although to date there has been very few serious fire or explosion incidents involving electrical equipment in coal preparation plants, the potential for an incident resulting in injury to life and damage to property is high.

Title 30, Chapter 3, Part 77 of the Code of Federal Regulations "...sets forth mandatory safety standards for bituminous, anthracite, and lignite surface coal mines, including open pit and auger mines, and to the surface work areas of underground coal mines, pursuant to Section 101 (i) of the Federal Coal Mine Health and Safety Act of 1969." Surface work areas are interpreted to include coal preparation plants.

Several references are made in Subparts C and F of these Regulations to the selection, use and maintenance of electrical equipment at these facilities. The Regulations refer to the National Electrical Code for the classification of hazardous locations. However, the definitions provided in the National Electrical Code for Class I and II hazardous locations are subject to personal interpretation when applied to coal preparation plants.

The following recommended guidelines for classifying hazardous locations in coal preparation plants are intended primarily for the use of MESA inspectors. However, the guidelines should be equally useful for operators and designers of these facilities.

It is not the intent of these guidelines to comment on specific sections of the National Electrical Code or to supercede other guidelines issued by MESA. The intent is to furnish clarifications to MESA inspectors, operators and designers relating to the electrical classification of hazardous areas, the permissible electrical equipment that may be used and the techniques that may be implemented for downgrading a hazardous location.

Reference is made in the following sections to various NEMA classifications for industrial control apparatus enclosures. The purpose is to identify specific types of equipment which may be used in hazardous locations. For those items which have no designated NEMA classification, approval or listing by recognized testing laboratories (e.g., Factory Mutual, Underwriters' Laboratories) for use in specific hazardous locations is acceptable.

It should be kept in mind that an "approved" electrical device or equipment <u>must</u> be maintained in a condition similar to that under which it was originally tested and approved. Improper maintenance and repair constitutes an invalidation of the original approval. Inspectors should, therefore, ensure that an electrical device or equipment meet the requirements implied by the rating or classification imprinted on it.

2. CLASSIFICATION OF HAZARDOUS LOCATIONS

2.1 GENERAL CONSIDERATIONS

Obviously, no fast and hard rule can be specified for classifying hazardous locations in all coal preparation plants. The types of unit operations employed at these plants differ. The layouts, ages and types of coal processed vary from one plant to another. Furthermore, certain plants employ hazard mitigating techniques while others do not. It is important, therefore, to consider each room, section, or area of every coal preparation plant individually to determine the classification suitable under the conditions existing or proposed for that plant.

2.2 CLASS I HAZARDOUS LOCATIONS

2.2.1 Class I, Division 1

Class I, Division 1 locations in coal preparation plants are those in which hazardous concentrations of methane may exist continually, intermittently, or periodically under normal operating conditions. Typical Class I, Division 1 locations in coal preparation plants are:

- Unventilated pits and conveyor tunnels below coal storage silos, stock-piles and surge piles;
- Unventilated coal storage silos;
- Unventilated pits or buildings containing raw coal (primary) crushers;
- Unventilated enclosed buildings on top of storage silos.

2.2.2 Class I, Division 2

Class I, Division 2 locations include those locations where hazardous concentrations of methane would occur in the case of an accident or unusual operating condition. Typical locations would include areas which may be "properly ventilated" but in which hazardous concentrations could accumulate if the ventilation system accidentally failed. Also, areas which are "adjacent" to Class I, Division 1 locations are considered Class I, Division 2 locations. These are usually encountered:

- near the tops of silos;
- at the end of raw coal conveyor tunnels below stock piles, silos, surge piles and coal storage areas;
- enclosed rooms, such as control rooms.

2.2.3 Electrical Equipment for Class I Locations

Electrical equipment for use in Class I locations at coal preparation plants must either be:

- explosion-proof and approved for use in methane (Group D) atmospheres (refer to Section 2.5 for definition of explosion-proof); or
- of special design and construction, such as the purged-type, where the introduction of clean air or an inert gas prevents the entrance of methane into the equipment; or
- intrinsically-safe, designed to be incapable of releasing sufficient electrical energy under normal or abnormal conditions to cause ignition of methane.

Imaginative layout of electrical installations for Class I locations frequently allows the downgrading of the hazard classification, thus reducing the need for special equipment. This may be accomplished as follows:

- Location of motors outside a Class I area coupled to a driven machine by belts or other coupling devices if the area is segregated from the remainder of the process.
- Location of lighting outside a Class I area with illumination provided through transparent panels.
- Location of switches, controllers, circuit breakers, instruments, relays and meters in a separate room which is provided with protection against infiltration of methane. This is achieved by using separate enclosed rooms with positive air pressure or adequate ventilation.
- Installation of forced ventilation systems in enclosed areas which will prevent methane concentrations from exceeding 1.0 percent.

Such a system is usually combined with a continuous air monitoring system for methane with provisions for interrupting electrical supply to all electric equipment in the area if methane concentration exceeds 1.0 percent.

- Positive ventilation in hazardous areas such as enclosed storage silos, enclosed pits or tunnels below storage piles or silos, and pits or buildings containing raw coal crushers. Such ventilation should include a positive electrical interlock which will shut down the entire process if a component of the ventilation system fails.

Where the process configuration and physical layout permit these arrangements, considerable savings in equipment cost can be realized while accomplishing the desired functions.

Questions now arise as to what constitutes "adequate" or "proper" ventilation and what is a safe distance from a Class I, Division 1 location. Since these and other questions also arise in classifying Class II locations, Section 2.5 below should be consulted for definitions.

Tables G 2.1 and G 2.2 summarize the general requirements for equipment to be installed in Class I, Division 1 and Division 2 locations. It should be noted that the use of cable trays or enclosed busways is not recommended for Division 1 locations (see Wiring). For Division 2, enclosed gasketed busways or cable trays are recommended to minimize infiltration of hazardous concentrations of methane. Where busways or cable trays leave hazardous locations, gas-tight seals are recommended.

2.3 CLASS II HAZARDOUS LOCATIONS

Class II consists of two divisions each dealing with three Groups of combustible dusts. Within coal preparation plants, the concern is with Group F dusts which include coal dust. Division 1 includes locations where combustible dust is airborne either under normal conditions, or as a result of mechanical failure or abnormal operations; or locations where electrically conductive dusts may be present. Division 2 includes loca-

TABLE G 2.1

Recommended Equipment for Class I Group D Division 1 Locations

EQUIPMENT	REQUIREMENTS
Motors	- Explosion-proof approved for Class I - Totally-enclosed forced-air ventilated - Totally-enclosed inert gas filled with a source of inert gas to pressurize the enclosure and automatic de-energization if the pressure fails.
Switches, controllers Circuit Breakers	- Enclosure approved as a complete assembly for use in Class I locations (NEMA Type 7, 8, or 10)
Fuses	- Enclosure approved as a complete assembly for use in Class I locations (NEMA Type 7, 8, or 10)
Lighting Fixtures	- All fixed and portable units must be approved as a complete unit for Class I locations. Should have guards around the globe or be located so as to prevent damage.
Transformers and Capacitors	- Units containing flammable or non-flammable liquid to be installed in approved vaults having no opening to hazardous areas. - Explosion-proof units approved for Class I locations for units that do not contain a liquid that will burn.
Instruments, Relays Meters	- Enclosure must be approved for Class I location. (NEMA 7, 8 or 10)
Wiring	- Threaded rigid metal conduit, or - Type MI cable - Explosion-proof boxes and fittings. - Seals to be used to prevent transfer of gases or flames from one area to another through conduit.
Heaters	- Portable or fixed units shall be approved as a complete unit for Class I locations. The surface temperature of the heating elements shall not exceed 800°F and controls shall be provided so that the heating element is de-energized when the fan or blower is inoperable or not in operation.

TABLE G 2.2

Recommended Equipment for Class I Group D Division 2 Locations

EQUIPMENT	REQUIREMENTS
Motors	- Class I approved enclosure where sliding contacts, centrifugal or other switches or integral resistors are used unless such contacts switches or resistors have Class I approved enclosures.
Switches, controllers Circuit Breakers	- Enclosure approved as a complete assembly for use in Class I locations (NEMA 7 or 10) unless current interruption occurs in a hermetically sealed chamber or unless contacts are oil-immersed and device is Class I, Division 2 approved. (NEMA 8) - General purpose enclosures are permitted for non-fused isolating or disconnecting switches which do not interrupt current (NEMA 4 or 12).
Fuses	- For fuses protecting motors, appliances and portable lamps, enclosure approved for Class I locations (NEMA 7 or 10) unless oil-immersed or hermetically sealed. (NEMA 8) - General purpose enclosures permitted for fuses or circuits to fixed lamps. (NEMA 4 or 12).
Lighting Fixtures	- Fixed enclosed globes or other protective means where sparks from lamps or fixtures might ignite local concentrations of flammable gas or vapor. - Lamps for which surface temperature does not exceed 80% of the gas or vapor ignition, temperature, or - Fixed fixtures approved as a complete unit for Class I locations. Fixed lighting fixtures should have guards or be located so as to prevent physical damage. - Portable lamps should be approved as a complete assembly for Class I locations
Transformers and Capacitors	- Installation should be in accordance with rules for non-hazardous locations.

TABLE G 2.2

(Continued)

EQUIPMENT	REQUIREMENTS
Instruments, Relays Meters	- Enclosure for equipment containing air break contacts must be approved for Class I locations. (NEMA 7 or 10) - General purpose enclosure permitted if contacts are oil-immersed or hermetically sealed (NEMA 8) - General purpose enclosure permitted if contacts are in circuits which do not release sufficient energy to ignite hazardous vapors or gases. (NEMA 4 or 12)
Wiring	- Threaded rigid metal conduit, or - Enclosed gasketed busways, or - Cable types ALS, CS, MI, MC, SNM, TC. - Seals required where explosion-proof equipment is necessary and conduit leaves hazardous area. - Wiring methods suitable for use in ordinary locations are acceptable IF the wiring will not release sufficient energy under normal conditions to ignite methane.
Heaters	- Portable or fixed units shall be approved as a complete unit for Class I locations. The surface temperature of the heating elements shall not exceed 800°F and controls shall be provided so that the heating element is de-energized when the fan or blower is inoperable or not in operation.

tions where airborne dust does not occur in explosive mixtures under normal conditions, but where dust accumulation may interfere with heat dissipation in heat producing equipment or where such layers might be ignited by sparks or arcs from electrical equipment.

Class II, Division 1 locations in coal preparation plants include:

- crushing or breaking operations;
- inside dust collection systems and equipment;
- air tabling operations;
- thermal dryers;
- dry or moist scalping operations;
- coal bins or hoppers during loading or unloading; and
- any enclosed container where coal is processed or stored.

Division 2 locations include areas which are immediately adjacent to Division 1 areas. Coal preparation plants with open flooring between levels can, therefore, be classified as Class II, Division 2 locations except where there is sufficient water used in the process to eliminate dust. Generally, this would apply to "wet" processes but not to dry or moist processes. Tables G 2.3 and G 2.4 contain listings of equipment recommended for use in Class II, Division 1 and Division 2 locations.

All electrical equipment for use in Class II, Division 1, Group F locations must be of a type approved for this classification (i.e., dust-ignition-proof, refer to Section 2.5 for definitions).

Class II, Division 2, Group F areas require control of airborne dust generated by the process. Such control can be accomplished by employing the following techniques individually or in combination:

- Adequate ventilation throughout the plant.
- Ventilation or dust-collection points at coal crushing or transfer points.
- Water or oil sprays at transfer points, crushing operations or other dust generating locations.
- Hoods at transfer points.

TABLE G 2.3

Recommended Equipment for Class II, Group F, Division 1 Locations

EQUIPMENT	REQUIREMENTS
Motors	- TEFC Dust-ignition proof approved for Class II - Totally enclosed forced air ventilated approved for Class II
Switches, Controllers Circuit Breakers	- Enclosure approved as a complete assembly for Class II locations if device interrupts current or if dust is electrically conductive. (NEMA 4, 9, or 12) - Non-fused, non-current interrupting isolating or disconnecting switches should have tight metal enclosures and covers to minimize entrance of dust and prevent escape of sparks. (NEMA 4)
Fuses	- Enclosure approved as a complete assembly for Class II locations. (NEMA 4, 9, or 12)
Lighting Fixtures	- Fixed and portable units should be dust ignition proof approved for Class II locations; with guards or located so as to prevent physical damage. (Enclosed gasketed or dust ignition proof.)
Transformers and Capacitors	- Units with flammable liquid in approved vaults with double, self sealing, self closing file doors on all openings to hazardous areas. Vent-openings and pressure relief openings should be open to outside air. - Units not containing liquids that will burn in approved vaults. - Units that are approved as complete assembly for Class II locations.
Instruments, Relays Meters	- Enclosure must be approved for Class II locations. (NEMA 9)
Wiring	- Threaded rigid metal conduit, or - Type MI cable. - Boxes or fittings: use units approved for Class II if they are to contain taps, terminate connections, or joints; or if dusts are electrically conducting or combustible. - When connecting dust-ignition proof and non-dust-ignition proof enclosures, seals are required to prevent migration.

TABLE G 2.3

(Continued)

EQUIPMENT	REQUIREMENTS
Heaters	- Portable or fixed electrical heaters shall be approved for use in Class II locations. The surface temperature of the heating element shall not exceed 800°F and controls shall be provided so that the heating element is de-energized when the fan or blower is inoperable or not in operation.

TABLE G 2.4

Recommended Equipment for Class II, Group F, Division 2 Locations

EQUIPMENT	REQUIREMENTS
Motors	- TEFC Dust ignition proof or forced air ventilated, maximum surface temperature not to exceed 120 °C.
Switches, Controllers Circuit Breakers	- Enclosures should have tight metal body and cover to minimize entrance of dust and prevent escape of sparks. (NEMA 12)
Fuses	- Same as for switches, controllers and circuit breakers.
Lighting Fixtures	- Fixed; enclosed gas heated fixture which maintains surface temperature below 165 °C. Provide guards or locate to prevent physical damage. - Portable dust-ignition proof approved for Class II locations.
Transformers and Capacitors	- Units with flammable liquid in approved vaults. - Dry type operated at less than 600 volts in vaults or tight metal enclosure without openings. - Units with non-flammable liquid in accordance with rules for non-hazardous locations with at least six inches between transformer case and any adjacent combustible material.
Instrument, Relays Meters	- Use tight metal enclosure with cover to minimize dust infiltration and escape of any sparks or burning materials. (NEMA 12)
Wiring	- Rigid metal conduit, or - Electric metallic tubing, or - Cable types ALS, CS, MC, MI, SNM. - Enclosed, gasketed, dust-tight busway approved for Class II. - Sealing requirements are the same as Division 1.

- Tight (sealed) covers installed on coal feeders and crushers.

Enclosed areas within or adjacent to a Class II, Division 2, Group F area and which do not contain coal processing or storage equipment can be classified nonhazardous if:

- the enclosed area is sealed off from the Division 2 area and kept free of any coal dust accumulations by maintaining a positive pressure on the inside of the enclosure; and
- the area is purged and pressurized in accordance with NFPA No. 496 Type 2 purging.

There are several methods by which the dust hazard within a Class II area can be reduced by rigorous attention to housekeeping within the plant.

It is expected that housekeeping would include the following:

- daily wash and sweepdown of all working levels;
- periodic (weekly, not more than monthly) cleaning of all enclosures containing electrical apparatus;
- weekly cleaning of all protected but not enclosed surfaces (lights, wiring, motor surfaces) that cannot be washed.

The need for special equipment can be minimized or eliminated by locating electrical equipment outside Class II areas or utilizing the other suggestions described in Section 2.2 above for Class I areas.

Sections where "wet" coal is handled shall be considered nonhazardous provided that no "dangerous" dust accumulations are allowed to remain on heat-generating electrical equipment. (Definitions of "wet" coal and "dangerous" dust accumulations are provided in Section 2.5 below.)

2.4 CLASS I AND II HAZARDOUS LOCATIONS (DUAL CLASSIFICATION)

Certain areas within coal preparation facilities such as an enclosed pit below a coal storage area, may be classified hazardous as a result of both methane and coal dust. A solution to this problem would be to ventilate the enclosed area mechanically and continuously monitor the air for methane as outlined in Section 2.2 relating to Class I locations. Electrical equipment would then only have to comply with Class II, Division 2 requirements.

A second solution is to obtain electrical equipment which carries a dual classification i.e., is approved for use in both Class I and Class II areas. Devices approved for Class I locations are not always necessarily in compliance with requirements for Class II locations.

Where water is used to clean up working areas or used during normal housekeeping or operation of the plant, consideration should be given to the design of equipment, especially in Class II, Division 2 areas. All electric enclosures such as splice and pull boxes, enclosed panels and similar equipment should be provided with tight-fitting or gasketed covers or otherwise be sealed against moisture. In areas where the equipment is subjected to saturation with water, the equipment should be approved for wet locations or, if warranted, should meet the requirements of the proper NEMA design (NEMA 4, 4X, or 6).

2.5 DEFINITIONS

2.5.1 Explosion Proof

Explosion-proof electrical equipment is suitable for use in Class I hazardous locations. The term "explosion-proof" means that the device has an enclosure which is capable of withstanding an internal explosion of a specified gas or vapor without igniting a similar external mixture. Also maximum external surface temperatures are below the ignition temperature of the materials to which the enclosure may be exposed.

2.5.2 Dust-Ignition Proof

Dust-ignition proof electrical equipment is suitable for use in Class II hazardous locations. The term dust-ignition proof means that the device has an enclosure which will exclude ignitible amounts of dust. Also the enclosure will not permit arcs, sparks, or heat generated inside the enclosure to ignite exterior accumulations of dust.

2.5.3 Adequate Ventilation

An area may be classified nonhazardous if it has adequate forced or natural ventilation.

The minimum acceptable requirements for adequate forced ventilation of control rooms and other enclosures housing electrical equipment which are in or adjacent to Class I, Division 1 areas are derived from the National Fire Protection Association Standard No. 496 "Purged and Pressurized Enclosures for Electrical Equipment - 1974."

a. The ventilation system shall maintain at least 0.1 inch of positive water pressure in the area with all openings closed.
b. The ventilation system shall provide a minimum velocity of 60 feet per minute outward through each opening with all openings open at the same time.
c. The ventilation system shall be interlocked to de-energize all power to the area in event of failure of the ventilation system, or the admission of methane at a concentration greater than 1% in air.
d. The source of air for ventilation shall be free of coal dust.

An area shall be considered to have adequate natural ventilation if it is open to the elements and is at a safe distance (see §2.5.4 below) from a methane hazard source. The maximum number of boundaries in a naturally ventilated area shall be limited to a ceiling, floor and one wall, provided that these boundaries do not interrupt natural ventilation to the extent that methane could accumulate.

2.5.4 Safe Separation Distances

The classification of a Class I, Division 2 hazardous location may be downgraded to nonhazardous if electrical equipment is placed at a safe distance from the potential source of methane.

For convevor tunnels under stock-piles, silos, or coal storage areas, a distance of 15 ft from the end opening shall be considered as a minimum safe separation distance. Electrical equipment placed at points closer than 15 ft to either end of such tunnels shall be approved for use in Class I, Division 2 locations.

Safe distances from the dumping area on top of a silo shall be determined from Table G 2.5 if the coal is considered particularly gassy. For nongassy coals or where an automatic 5% alarm is installed on the silo, the appropriate curve in Figure D.2 may be used.

2.5.5 Wet Processes

A "wet" process shall be so classified provided that the ratio of process water applied to or mixed with coal (regardless of its inherent moisture) is in such proportion as to prevent the generation of airborne dust.

2.5.6 Dangerous Dust Accumulations

A dangerous amount of coal dust is generally interpreted to mean an average accumulation of 0.03 ounces or more of coal dust per cubic foot of enclosed air volume. This quantity is difficult to measure or estimate except for easily accessible enclosures. Furthermore, the interpretation allows large accumulations in some location with little or no accumulation elsewhere so that the average may be acceptable.

It is recommended that the thickness of a coal dust layer on all heat-generating electrical equipment (including motors and light fixtures) be not allowed to exceed 1/16 inch in thickness.

TABLE G 2.5

Safe Separation Distances From

Silo Opening*

Coal Rate (tph)	Distance (ft)
<100	7
200	10
300	14
400	16
500	18
600	20
700	22
800	24
900	26
1000	28
2000	41
3000	54
4000	65
5000	75
6000	83
7000	91
8000	100

*These distances assume a gassy coal with a potential methane concentration in the silo of 15%.