FUEL RESEARCH INSTITUTE OF SOUTH AFRICA

TECHNICAL MEMORANDUM NO. 2 OF 1965

LABORATORY PROCEDURES AND EQUIPMENT FOR TESTING THE EXPLOSIBILITY OF COAL DUSTS

by

J.A.K. DU PLESSIS

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INTRODUCTION

During the long history of research on methane and coal dust explosions in the old coal mining countries, test procedures and equipment for evaluating the explosibility of dusts were developed that can be regarded as "standard" today.

These methods were developed by correllating laboratory tests with information obtained from accidental explosions in mines and initiated explosions in test galleries.

Similar information on South African coals and conditions is not available, and since the parameters of explosibility are related to the equipment used and to the definitions of the criteria, it is advisable to follow the proven techniques when attempting to assess the explosion hazard in local mines. This procedure would permit direct comparison* of the characteristics of South African coals with those of overseas countries.

As the first step in initiating the research programme on the explosion hazard in South African collieries, it was decided to extract from the literature those test procedures that are most commonly employed in the different coal mining countries.

The equipment and test procedures described in this report are, however, mainly from American and British literature. It is by

no/...

* It must be emphasized, however, that coal characteristics alone do not determine the relative explosion hazard in a particular mine; environmental conditions, for instance, are equally important. It is necessary to consider all the relevant criteria before conclusions can be drawn.

no means a complete list of all the techniques used to assess the explosion liability of coal dusts. Furthermore, the literature reveals that research and development work, aimed at improving the reliability of the tests, is still being done in all the larger coal mining countries.

A glossary of the terminology and definitions in common usage[1, 2, 3, 4)] in explosion studies is given in the first section of this report.

DEFINITIONS

(a) Detonation[4] - a chemical reaction which propagates into the reacting medium at a supersonic rate.

(b) Explosion[2, 4] - the rapid release of pressure without regard to its source.

(c) Ignition delay[4] - time interval between contact of an oxidant and a combustible and ignition.

(d) Ignition temperature[3] - temperature to effect ignition of a combustible oxidant system at a specific pressure; in general, the minimum pressure is implied.

(e) Minimum ignition energy[4] - the minimum ignition energy required for the ignition of a particular flammable mixture at a specific temperature and pressure.

(f) Limits of flammability[3, 4] - extreme concentration limits of a combustible in an oxidant through which a flame, once initiated, will continue propagating at a specific temperature and pressure.

(g) Low pressure limit[4] - the lowest pressure at which flame propagation can be obtained through a combustible-oxidant system at a fixed temperature in a particular chamber.

(h) Relative flammability[1, 2] - the percentage of inert required to suppress flame propagation in a dust cloud.

APPARATUS/...

APPARATUS

The following is a brief description of the apparatus necessary for the explosion studies of coal dust and gases.

(a) Godbert-Greenwald Furnace[6, 7, 8, 11, 12, 14]

This furnace consists of a vertical alumdum tube, 9 inches long and $1^{7}/_{16}$ inch in diameter, wound with nichrome wire, and mounted between two ½-inch thick transite plates in a 6-inch diameter sheet-metal cylinder with Kieselguhr packing between the alumdum tube and sheet-metal shell. The top of the tube is connected by a glass adapter to a small brass chamber with a hinged lid for inserting the dust. The dust in the chamber is dispersed through the furnace by a single blast of compressed air. The temperature in the furnace is measured with a chromel-alumel thermocouple and the temperature is maintained at the desired value by automatic control. The ignition temperature determined with this apparatus is defined at the minimum furnace temperature at which flame appears at the bottom of the furnace in one or more trials in a group of four.

This apparatus can be used to determine the ignition temperature of dust clouds, the relative flammability of a dust cloud and, in a modified form, the ignition temperature of a dust layer.

(b) Hartmann Apparatus[8]

It consists of a vertically mounted lucite tube, 12 inches long and 2¾ inches in diameter, and auxiliary equipment for producing dust dispersion, which is accomplished by a single blast of air. The tube is attached to a cylindrical metal base or dispersion cup.

An ignition spark passes between two pointed electrodes, a ¼-inch apart and 4 inches above the base of the tube. The spark is obtained from the discharge of oil-impregnated paper-dielectric condensers with a capacitance range of 2 to 100 microfarads through a luminous-tube transformer. An electronic timer, with adjustable delay, controls the spark discharge during dust dispersal.

Pressure and rates of pressure rise developed by dust

explosions/...

explosions are determined in a closed steel Hartmann tube. The pressure is measured with a Bureau of Mines manometer or with electronic transducers.

This apparatus can be used to determine the electric energy for ignition and the explosion pressure and rates of pressure rise of a coal-dust explosion.

(c) Gas-dust Explosion Apparatus[17]

Instead of using a Hartmann apparatus with a capacity of 0.043 cubic feet, a sealed 0.33 cubic feet chamber can be used for the determination of pressure and rates of pressure rise of coal-dust explosions in atmospheres containing low percentages of methane. The chamber is 12 inches high and $7\frac{3}{4}$ inches in diameter. An electric spark between two electrodes, 5/16 inch apart, ignites the dust cloud. A 12,000 V transformer, operating at 30 ma, provides the voltage for the ignition spark, and a Bureau of Mines manometer can be used to obtain the pressure-time curve.

The high-velocity dispersing gas from an orifice in the bottom of the chamber impinges on the underside of a mushroom-like cap and disperses a dust layer from a hemispherical cup into the chamber.

(d) Ignition Temperature Apparatus[9, 15]

This apparatus (I-8) consists of a 1200-watt electric furnace with a well of 5 inches diameter and 5 inches depth. A 200 cc glass Erlenmeyer flask is placed in the well and a 12-point electronic temperature recorder continuously records the temperature.

When the apparatus is at the desired temperature, the liquid, or liquified gases, is introduced into the flask with a syringe. This apparatus makes the determination of minimum spontaneous ignition temperatures more rapid, accurate, and economical.

(e) Hot-Gas Ignition Apparatus[7]

With this apparatus the ignition of mixtures of coal-dust-

methane-/...

methane-air by hot jets can be studied.

The explosion vessel consists of two chambers; a small chamber (76 cu. cm) opens into a large chamber (2. 1 liter) by means of an interchangeable cap having a cylindrical channel through which the products of explosion from the inner chamber pass into the outer chamber. An electric spark between two electrodes ignites the contents of the smaller chamber, whereupon the hot gas formed ignites the mixture in the outer vessel.

(f) Coal-Dust Disperser[7]

In most of the standard laboratory coal-dust explosion tests, dust dispersion was obtained by a blast of gas or by a high-velocity gas stream that, after impinging on the underside of a mushroom-like cap, dispersed a dust layer from a hemispherical cup.

The following is a description of a disperser that proved to be efficient. Airflows of approximately 140 cu. cm/sec at driving pressures of 1. 4 Kg/cm^2 through two hypodermic needles impinge on coal dust that is on the rotating bottom of the apparatus. Concentration changes of the flowing dust cloud can be achieved by varying the rotation speed of this bottom. The apparatus vibrates continuously to facilitate dust movement and to prevent dust deposition on the exit tube wall.

Coal-dust concentrations in the explosion chamber can be obtained by filtering the upward coal-dust flow through a glass-wool cartridge and measuring the weight gain after a given time period. Methane-air concentrations in the explosion chamber can be checked by mass spectrometric analysis.

(g) Gas Chromatographic Equipment[10, 19]

This is one of the most powerful tools for the analysis of volatile coal products and the products of coal-dust/methane-air explosions.

(h) / . . .

(h) Mass Spectrometer[10]

Mass spectrometry is a rapid method for the analysis of volatile organic mixtures, gas, and vapours, and it needs only a small sample to do the analysis.

(i) Cameras[5, 7, 15]

An installation of high-speed photographic equipment is a fundamental requirement for rapid combustion and detonation studies.

The following are a few cameras used in this type of study: Singer, as well as Grant and Mason, used a Fastax(16 & 8 mm resp.) camera operated at 7,500 frames per second. Schlieren photographs were obtained by the 2-mirror Schlieren system, using the Fastax camera with the prism removed in conjunction with a stroboscopic flash lamp operating at 6,000 flashes per second.

Brinkley and Van Dolah are going to use a streak camera with a writing speed of 5 mm/μsec and a high-speed framing camera which operates at 1.25 million frames per second.

(j) Temperature Controller[8, 14]

Automatic temperature controllers are necessary to maintain the temperatures of the furnaces used at the desired temperature levels.

(k) Recorders[8, 9]

Recorders are necessary for time-temperature and time-pressure records.

(l) Pressure Measurements[16, 8, 13, 17]

Measurements of pressure and rate of pressure rise can be done with a Bureau of Mines manometer or with electronic transducers.

TEST/...

TEST PROCEDURES[8, 18]

1. Preliminary examination:
   (a) Sample ground and screened through a 200 # sieve.
   (b) Determination of moisture, ash and volatile content.
   (c) Examination under microscope (100 x - 400 x) to ascertain the shape and size and other physical characteristics of particles.
   (d) Density of dust in Scott volumeter.
   (e) Chemical analysis, mass spectrometer, X-ray.
2. Ignition temperature of dust cloud (Godbert-Greenwald apparatus).
3. Ignition temperature of dust layer (modified Godbert-Greenwald apparatus).
4. Minimum energy required for ignition of dust clouds (Hartmann apparatus).
5. Minimum energy required for ignition of dust layer.
6. Minimum explosive concentration or lower explosive limit (Hartmann apparatus).
7. The maximum explosive pressure and rates of pressure rise (Hartmann apparatus).
8. The relative flammability of a dust cloud (Godbert-Greenwald apparatus).
9. Experiments in a controlled atmosphere (Godbert-Greenwald apparatus).

The abovementioned tests are for coal-dust/air mixtures.

Because more or less everything is known about methane and methane/air explosions, only coal-dust/air and coal-dust-methane-air mixtures are going to be investigated.

The following are the tests for coal-dust-methane-air mixtures:

1) Ignition temperature of the mixture (Godbert-Greenwald).
2) Minimum energy required for ignition of mixture (Hartmann).
3) Minimum explosive limit (Hartmann).

4)/...

4) Maximum explosive pressure and rates of pressure rise (Hartmann).
5) The relative flammability of the mixture (Godbert-Greenwald).
6) Influence of other gases, e. g. N_2 (Hartmann).

Reference was made only to Godbert-Greenwald and Hartmann apparatus because most of the work was done with these apparatus.

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PRETORIA,
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