การศึกษาปัจจัยความเสี่ยงของการระเบิดฝุ่นถ่านหินในโรงเก็บถ่าน

นางสาวลัตตานา จันทผาสุก

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
สาขาวิชาวิศวกรรมทรัพยากรธรณี ภาควิชาวิศวกรรมเหมืองแร่และปิโตรเลียม
คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย
ปีการศึกษา 2558

THE STUDY OF THE RISK FACTORS ON COAL DUST EXPLOSION IN WARE HOUSE

Miss Latana Chanthaphasouk

A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering Program in Georesources Engineering
Department of Mining and Petroleum Engineering
Faculty of Engineering
Chulalongkorn University
Academic Year 2015

Thesis Title	THE STUDY OF THE RISK FACTORS ON COAL DUST EXPLOSION IN WAREHOUSE
By	Miss Latana Chanthaphasouk
Field of Study	Georesources Engineering
Thesis Advisor	Assistant Professor Kreangkrai Maneeintr, Ph.D.

Accepted by the Faculty of Engineering, Chulalongkorn University in Partial Fulfillment of the Requirements for the Master's Degree

....Dean of the Faculty of Engineering
(Associate Professor Supot Teachavorasinskun, D.Eng.)

THESIS COMMITTEE

....Chairman
(Assistant Professor Sunthorn Pumjan)

....Thesis Advisor
(Assistant Professor Kreangkrai Maneeintr, Ph.D.)

....External Examiner
(Associate Professor Pinyo Meechumna)

ลัตตานา จันทผาสุก : การศึกษาปัจจัยความเสี่ยงของการระเบิดฝุ่นถ่านหินในโรงเก็บถ่าน (THE STUDY OF THE RISK FACTORS ON COAL DUST EXPLOSION IN WAREHOUSE) อ.ที่ปรึกษาวิทยานิพนธ์หลัก: ผศ. ดร.เกรียงไกร มณีอินทร์, 143 หน้า.

ปัจจุบันถ่านหินเป็นหนึ่งในพลังงานที่สำคัญหลักของโลก. อุตสากรรมหลายแห่งใช้ถ่านหินเป็นเชื้อเพลิงหลัก และมักจะเกิดการติดไฟและการระเบิดของฝุ่นถ่านหิน ซึ่งเป็นความเสียหายหลักของอุตสาหกรรม. การเกิดระเบิดของฝุ่นถ่านหินเกิดจากปริมาณความเข้มข้นของฝุ่นที่ฟุ้งกระจายและเกิดการสันดาษในอากาศทำให้เกิดการติดไฟได้ และจะมีความรุนแรงมากยิ่งขึ้นเมื่ออยู่ในระบบปิด. ในการประเมินการระเบิดของฝุ่นถ่านหินขึ้นอยุ่กับความเข้มข้นของ ปริมาณความเข้มข้นของฝุ่นที่ยอมรับให้เกิดขึ้นได้ (MEC) และ การคำนวณค่า MEC ขึ้นอยู่กับปริมาณความเข้มข้นของฝุ่นต่อปริมาตรพื้นที่บริเวณที่เกิดการระเบิด ดังนั้นจุดประสงค์ของการทำวิจัยในครั้งนี้คือ การวัดค่า MEC ที่มีผลต่อการระเบิดของฝุ่นถ่านหินที่สามารถเกิดขึ้นได้ โดยใช้เงื่อนไขคือ ขนาดของฝุ่นถ่านหิน (250, 180, 150, 106, 75,53, 45, และน้อยกว่า 45 ไมครอน), ความชื่นของถ่าน (0%, 3%, 6%, 9% และ 12%) การฟุ้งกระจายของฝุ่นโดยใช้แรงลม (0.5 kg/cm^2 ,1 kg/cm^2, 1 8 kg/cm^2) , ความหน่วงของการระเบิด (0.1s, 0.3s และ 0.5s) เพื่อหลีกเลี่ยงจากการจุดติดระเบิดของฝุ่นถ่านหิน และการประเมินการศึกษาแนวทางป้องกันของการเกิดระเบิดของฝุ่นถ่านหินในโรงเก็บถ่าน การวิจัยนี้พบว่า ฝุ่นถ่านหินขนาดเล็ก และ ความชื่นของถ่านหินต่ำ จะก่อให้เกิดการฟุ้งกระจายตัวได้มาก ซึ่งมีความเสี่ยงในการเกิดระเบิดได้ และความหน่วงของเวลาที่น้อย สามารถทำให้การจุดติดการระเบิดดีมากยิ่งขึ้นใรนบริเวณโรงเก็บถ่านหิน

ภาควิชา	วิศวกรรมเหมืองแร่และปิโตรเลียม	ลายมือชื่อนิสิต	....
สาขาวิชา	วิศวกรรมทรัพยากรธรณี	ลายมือชื่อ อ.ที่ปรึกษาหลัก	....
ปีการศึกษา	2558		

5770492621 : MAJOR GEORESOURCES ENGINEERING

KEYWORDS: COAL,COAL DUST EXPLOSION, RISK FACTORS, MINIMUM EXPLOSIBILITY CONCENTRATION

LATANA CHANTHAPHASOUK: THE STUDY OF THE RISK FACTORS ON COAL DUST EXPLOSION IN WAREHOUSE. ADVISOR: ASST. PROF. KREANGKRAI MANEEINTR, Ph.D., 143 pp.

Coal has been one of the major energy sources in the world. Many industries use coal as a main fuel. A coal dust explosion is one of the main hazards of coal utilization because of its massive damage. Coal dust explosion hazards involved the combustible fine dusts or other small particles that present a fire or deflagration hazard when suspended at a sufficient concentration in air or some other oxidizing medium. When such materials are contained in an enclosure, they present an explosion hazard. To eliminate the possibility of dust explosions by ensuring that the dust concentration does not exceed the minimum explosibility concentration (MEC) or the amount of dust per unit volume of air below which the dust cloud cannot propagate flame. Therefore, the objective of this work is measure the MEC for coal dust explosion with the various conditions of coal storage such as the particle size (250, 180, 150, 106, 75,53, 45, and less than 45 micron), moisture of coal(0%, 3%, 6%, 9% and 12%), degree of dispersion(0.5 kg/cm^2 ,1 kg/cm^2, 1 8 kg/cm^2) and delayed time (0.1s, 0.3s and 0.5s) of ignition source to prevent the coal dust explosion which aims to study and design the explosion safety measures for coal dust handing installations. The results show that smaller size of particle, low moisture in coal and high coal dust dispersion can increase the chance or risk of dust explosion. Also, the shorter time of dust dispersion exposes to ignition source can enhance the possibility of explosion in coal storage.

Department:	Mining and Petroleum Engineering	Student's Signature	....
		Advisor's Signature	....
Field of Study:	Georesources Engineering		
Academic Year:	2015		

ACKNOWLEDGEMENTS

The authors would like to acknowledge the ASEAN University Network/Southeast Asia Engineering Education Development Network (AUN/SEED-Net) for financial support of this research. Secondly, the author would like to thank Graduate School Thesis Grant and Chulalongkorn University to accommodate for research periods, and department of Mining and petroleum ,Faculty of engineering, Chulalongkorn university.The author wishes to sincerely express her gratitude to her advisor, Assistant professor Krengkrai Maneeintr, Ph.D for her supervision,advice, discussion and helpfull suggestions throughout the course of this work. Also, the authors would like to thank Siam Cement Group (SCG) for coal dust sample. Lastly many thanks to the research students from Rajamangala University of Technology Krungthep for helping the experiment.

CONTENTS

Page

Page

LIST OF TABLE

LIST OF FIGURE

CHAPTER 1
INTRODUCTION

1.1 Coal

Coal is composed primarily of carbon along with variable quantities of other elements, chiefly hydrogen, sulfur, oxygen, and nitrogen. Comparing to other energy resources, coal is cheaper and more abundant(U.S Energy Information Administration 2016). For these reasons, coal is a major energy source in the world, especially among many developing countries, and will continue to be so for many years. It is believed that coal utilization will be increased under any foreseeable scenarios and becomes the main energy sources in the future. Figure1.1 shows the coal reserve in many parts of the world (Massachusetts Institute of Technology 2007)

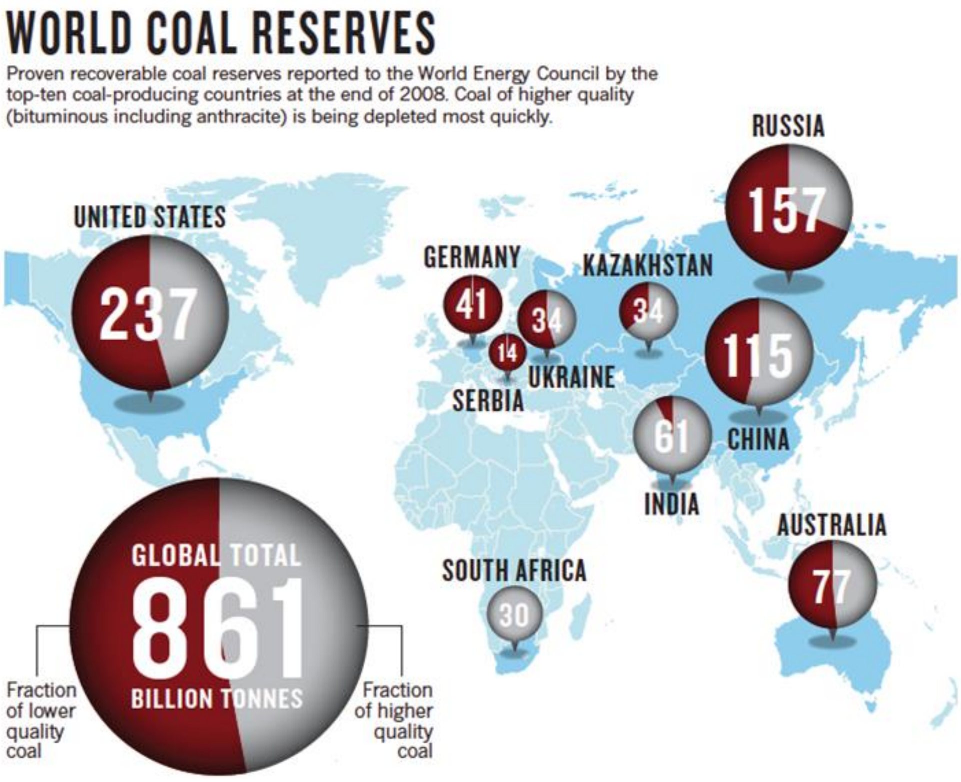


Figure 1.1 Coal reserve in the world (Fridley 2011)

In commercial operations, the price of coal not only reflects the quantity of coal but also reflects the relationship of a desirable property or a combination of properties performance of the coal under service conditions. Coal is found in deposits called seams that originated through the accumulation of vegetation that has undergone physical and chemical changes. Coal differ throughout the world in the kinds of plant materials deposited (types of coal), in the degree of metamorphism or coalification (rank of coal), and in the range of impurities include (grade of coal). The geochemical process that transforms plant material into coal called coalification and is often expressed as:

Peat → lignite→ sub-bituminous coal→ bituminous coal→ anthracite.

The geological phase of the coalification process in the application of the temperature and pressure over millions of years and it the most of the important factor of the coalification process.

There are three analyses which are used in classifying coal; two of which are chemical analyses and one is a calorific determination. The chemical analyses include proximate and ultimate analysis. The proximate analysis gives the relative amounts of moisture, volatile matter, ash (i.e., inorganic material left after all the combustible matter has been burned off), and indirectly the fixed carbon content of the coal. The ultimate analysis gives the amounts of carbon, hydrogen, nitrogen, sulfur, and oxygen comprising the coal. Oxygen is typically determined by the difference that is subtracting the total percentages of carbon, hydrogen, nitrogen, and sulfur from 100 percent because of the complexity in determining oxygen directly, however, this technique accumulates all the errors that occur when determining the other elements into the calculated value for oxygen. The third important analysis, the calorific value, also known as heating value, is a measure of the amount of energy that a given quantity of coal will produce when burned (Miller, 2001).

The properties of coal which have an impact on combustion and environmental performance often form the basis of sale contracts, and they include calorific value, volatile matter, moisture, sulphur, chlorine and ash (elemental composition) content of coal. These properties are all measured at samples taken during loading of the coal. The quality of coal is essential for the applications of that coal (EIA, 2014).

1.1.1. Coal Analysis

Coal is an organic sedimentary rock that contains varying amounts of carbon, hydrogen, nitrogen, oxygen, and sulfur as well as trace amounts of other elements, including mineral matter (van Krevelen 1961);(H.J. Gluskoter 1977);(Speight 2005) .

Coal is a solid, brittle, combustible, carbonaceous rock formed by the decomposition and alteration of vegetation by compaction, temperature, and pressure. It varies in color from brown to black and is usually a stratified source of the vegetation is often moss and other low plant forms, but some coals contain significant amounts of materials that originated from woody precursors.

Coal consists of more than 50% by weight and more than 70% by volume of carbonaceous material (including inherent moisture). Coal contains many trace elements, including arsenic and mercury, which are dangerous if released into the environment. Coal also contains low levels of uranium, thorium, and other naturally occurring radioactive isotopes, whose release into the environment may lead to radioactive contamination. Although these substances are trace impurities, a great deal of coal is burned, releasing significant amounts of these substances. Anthracite is the highest rank of coal, is used primarily for residential and commercial space heating. It is hard, brittle, and black lustrous coal, often referred to as hard coal, containing a high percentage of fixed carbon and a low percentage of volatile matter. The moisture content of fresh-mined anthracite generally is less than 15%.

Bituminous coal is a dense coal, usually black, sometimes dark brown, often with well defined bands of bright and dull material, used primarily as fuel in steam-electric power generation, with substantial quantities also used for heat and power applications in manufacturing and to make coke. The moisture content of bituminous coal is usually less than 20% by weight.

Sub-bituminous coal is coal whose properties range from those of lignite to those of bituminous coal, used primarily as fuel for steam-electric power generation. It may be dull, dark brown to black, and soft and crumbly at the lower end of the range, to bright, black, hard, and relatively strong at the upper end. Subbituminous coal contains 20 to 30% inherent moisture by weight.

Lignite is the lowest rank of coal, often referred to as brown coal, used almost exclusively as fuel for steam-electric power generation. It is brownish black and has a high inherent moisture content, sometimes as high as 45% (Speight 2005).

Coalification can be described geochemically as consisting of three processes: the microbiological degradation of the cellulose of the initial plant material, the conversion of the lignin of the plant into humic substance into larger coal molecule (Tatsch, 1980). The kind of decaying of vegetation, condition of decay, depositional environment, and movement of the earth's crust are important factors in determining the nature, quality and relative of the position of the coal seam (Speight 2005).

The physical forces exerted upon the deposits play the larger role in the coalification process. Variations in the chemicals composition of the original plant material contribute to the variability in coal composition. The vegetation of various geologic periods differed biologically and chemically. The conditions under which vegetation decayed are also important. The depth, temperature, degree of the acidity and natural movement of water in the original swamp are an important factor in the formation of coal (Mitchell, 1997).

The geological phase of the coalification process in the application of the temperature and pressure over millions of years and it the most of the important factor of the coalification process.

Prior to discussing the rank, type, grade and classification systems of coal a brief description of basic of coal analysis, upon which classification schemes are based, is provided. These analyses do not yield any information on coal structure but do provide important information on coal behavior and are used in the marketing of coals.

Three analyses are used in classifying coal, two of which are chemical analyses and one is a calorific determination. The chemical analyses include proximate and ultimate analysis. The proximate analysis gives the relative amounts of moisture, volatile matter, ash (i.e., inorganic material left after all the combustible matter has been burned off), and indirectly the fixed carbon content of the coal. The ultimate analysis gives the amounts of carbon, hydrogen, nitrogen, sulfur, and oxygen comprising the coal. Oxygen is typically determined by the difference that is subtracting the total percentages of carbon, hydrogen, nitrogen, and sulfur from 100 percent because of the complexity in determining oxygen directly, however, this technique accumulates all the errors that occur when determining the other elements into the calculated value for oxygen. The third important analysis, the calorific value, also known as heating value, is a measure of the amount of energy that a given quantity of coal will produce when burned (Miller,2005)

So the properties of Coal which have an impact on combustion and environmental performance are often from the basis of sale contracts, and they include Calorific value, volatile matter, moisture, sulphur, chlorine and ash (elemental composition) content of coal. These properties are all measured at samples taken during loading of the coal. The payment for the coal is based on the analytical results. And also knowing the quality of coal is essentially for the applications of that coal.

General coal analysis and testing include the following:

1. Proximate analysis: moisture content, ash content, volatile matter, fixed carbon.
2. Ultimate analysis: carbon, hydrogen, nitrogen, sulphur.
3. Ash analysis: major and minor of the element in coal and coal ash.
4. Calorific value (also know the heating value or specific energy).

In addition, special coal analyses may also be performed on trace elements, coal hardness, ash fusion temperature, chlorine, fluorine, boron, arsenic, mercury, selenium, phosphorus, size analysis, and so on. Standardization Of the procedures and conditions is essential for obtaining results that are comparable within any one laboratory and between different laboratories.

1.2 Coal Utilization

Coal is used for power generation, steel making, cement production and many other purposes. Each year, billions of tons of coal are traded in local and international markets.

The utilization of coal as an energy, both by of the steam engine and in the form of coke, was a major a characteristic of the first industrial revolution. Coal utilization by product improves the economics of power generation, conserves natural resources, avoids the consumption of increasingly scarce landfill space, and reduces emissions of carbon dioxide (CO_2) that would otherwise be required to produce. Coal-fired power plants, also known as power stations, provide over 42% of global electricity supply. At the same time, these plants account for over 28% of global carbon dioxide (CO_2) emissions. Insecurity Energy, the World Coal Institute looks at coal’s role in a balanced energy mix particularly regarding the security of supply in power generation and how the use of clean coal technologies and carbon capture and storage can allow those security benefits to be released while alleviating environmental impacts.

Coal users can benefit from utilizing their own indigenous resources, or by accessing affordable coal in a well-established market from a wide variety of countries and suppliers. Even taking into account the costs of transformation, coal-derived fuels can provide a hedge against the volatility of oil prices and facilitate greater economic independence through the stabilization of demands on foreign currency reserves. Liquid fuel from coal is not a new idea, but its development has been constrained by low oil prices typically oil prices need to be of the order of $35 per barrel or higher for coal to liquids to be economically attractive.

1.2.1 Effect of coal utilization

The dominant use of coal today is for electric power generation based on the combustion of pulverized coal. Coal based power plant emits air pollutions and create solid and liquid waste that can adversely affect air quality, terrestrial and water resource, human health and climate. Environment environmental management technologies that are already too widely available and in used can reduce most of these impact. The environmental effect of gaseous emission of various types which result from coal combustion. In deals with $NO_{x,}$ $SO_{x.}$ Fine particulate, photo chemical oxidant and acid precipitation as this pollutant effect involving two or more pollutant. Because of coal is abundant and relatively cheap when compared to natural gas and oil today, coal is often the fuel choice for electricity generation and perhaps for extensive synthetic liquids production in the future in many parts of the world. Its low cost and wide availability make it especially attractive in major developing of economic their pressing energy needs. On the hand, coal faces significant environmental challenges in mining, the air pollution. However, coal also can have significant adverse environmental impacts in its production and use. Over the past two decades major progress has been made in reducing the emission of so-called 'criteria' air pollutant: sulfur oxides, nitrogen oxides, and particulate from coal combustion plant(Sciences,2007). Beside that coal dust is produced during the coal mining processing plant, if it is entrained the coal dust present a dangerous explosion hazard.

1.3 Coal dust explosion

There are many industries which use coal as the main fuel such as power plants, coal mines, cement manufacturing plants, and other related activities. Other than the environmental concerns, these industries which handle pulverized coal suspension, have risks of coal dust explosions. Dust explosion hazards involve dust or other small particles that present a fire or deflagration hazard when suspended in a sufficient concentration in air or some other oxidizing medium. When such materials are contained in an enclosure, they present an explosion hazard. Dust explosions are serious problems because of the massive damages they may causes. Moreover, they can occur in many difference industries including agriculture, food product, chemicals, textiles, woodworking, metal processing, paper products, and coal related industries.

A dust explosion is the fast combustion of dust particles suspend in the air in an enclose location. Furthermore, coal dust explosion are a frequent hazard in a coal mine by the ways coal dust can occur where any powder combustible material is in the present in an enclosed atmosphere or in general in the high of enough concentrations of dispersed combustible particles in the atmosphere. Dust explosion was one of case accident in industrial with the development in the process industries, so dust explosion has a higher probability and a consequent is much severer than before. And clearly, accidental dust explosions are highly undesirable in any plants, and therefore, seeks less dramatic means of transferring knowledge and motivation. One way is the use of case histories that is detailed accounts of dust explosions that actually occurred elsewhere one of the severe case of dust explosion occurred at Dongfeng mine, Qintanhe, China on 27 November 2011, which caused 171 deaths. It is very significant to prevent and mitigate dust explosions intrinsically with the thinking of inherent safety(He, Mitri et al. 2011) One of earliest recorded dust explosions in the United States was in Grahamite country on February 9, 1871. And in addition, the environmental concerns, these industries which handle pulverized coal suspension, have risks of coal dust explosions. Dust explosions are serious problems because of the massive damages they may causes. Moreover, they can occur in many different industries including agriculture, food product, chemicals, textiles, woodworking, metal processing, paper products, and coal related industries. Coal dust explosions usually occur in storages, where coal dust is formed and kept.

Coal dust explosion is related to many parameters. The associated value is the lowest concentration of dust explosion. The minimum temperature in the ignition or explosion. The minimum energy to cause an explosion. And the concentration of oxygen. The permit is the values are as follows: Minimum Explosible Concentration (MEC) The minimum explosion concentration test determines the lowest concentration of dust cloud in air that can give rise to flame propagation upon ignition. And the concentration of dust in the air falls within the explosive limits and the mean minimum concentration of dust to dust in the air in a cloud of dust (or dust cloud) that can cause an explosion depending on the type of dust. Usually, if the dust concentration is less than MEC, it will not cause a dust explosion. The theory one could eliminate the possibility of dust explosions by ensuring that the dust concentration does not exceed this minimum limit which is called the minimum explosible concentration (MEC) which can be calculated by mass of particles divided by the volume of the area for the explosion.

The explosions are caused by the combustion of materials. Particle properties as fuel in the presence of adequate oxygen. The fire is ignited at a high enough energy. And in confined spaces or enclosed materials to the combustion, particles can be suspended or dust in the air for long enough. There are plenty of size and the combustion gasses to heat and pressure to increase the amount of particles that burn up and dispersed. The theory is based on the explosion of dust, which is called the theory of dust explosion pentagon and there are fuel (dust), dispersion of dust, confinement, ignition source, and oxygen or air which the detail will be discussed in Chapter two.

1.4 Objectives of this research

The purposes of this research are to study the risk factors of coal dust explosion in coal storages and offer some safety measures for coal-related industries by measuring the minimum explosion concentration (MEC). Therefore, the objectives of this work are to measure the MEC for coal dust explosion with the various conditions of coal storage such as the particle size, moisture of coal, degree of dispersion and delayed time of ignition source and to prevent the coal dust explosion which aims to study and design the explosion safety measures for coal dust handling installations in warehouse. For a given type of explosible dust, dispersed as a cloud in the air, there is a reasonably fixed minimum quantity of dust per unit volume of air below which the dust cloud cannot propagate flame.

The dispersion of dust happens with naturally as the coal is being moved. It's easy to create a dust dispersion over pipes, belt conveyor, floors, ceiling, machinery and another area. It became to coal dust hazards, dust explosion can cause death and injuries otherwise, it make the company lost of investment with combustible dust incident. So, these major of research provide to fundamental of coal dust explosion guidelines in coal storage to reduce of risk coal dust explosion is occurred in industries and these research have moved benefit to study further of information guideline for safety hazards in coal storage. Furthermore, the research to show guideline to reduce of fire situations to protection in industries.

Chapter 1 introduces the coal dust problem and presents about basic knowledge of coal information. Chapter 2 explains about dust explosion theory and literature review about dust explosion research. Chapter 3 presents the experiment to do on laboratory and methodology of coal dust explosion. Therefore Chapter 4 presents the results and discussion about the laboratory. In addition, Chapter 5 present on conclusion and recommendation for research on the topic: Study the factor on the risk of coal dust explosion in warehouse.

CHAPTER 2
THEORY AND LITERATURE REVIEW

2.1 Dust Explosion

An explosion is an exothermal chemical process that, when occurring at constant volume, gives rise to a sudden and significant pressure rise". In this text, the definition of an explosion shifts pragmatically between the two alternatives, focusing on either cause or effect, depending on the context. And the next the phenomenon named dust explosions are in fact quite simple and easy to envisage in terms of daily life experience. Any solid material that can burn in air will do so with a violence and speed that increases with increasing degree of subdivision of the material.

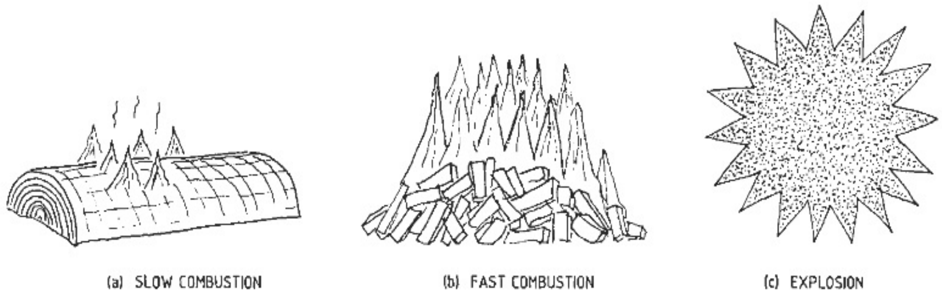


Figure 2.1 (a) Slow combustion, (b) Fast combustion, and (c) Explosion (Grossel 2004)

Figure 2.1 (a). Illustrates how a piece of wood, once ignited, burns slowly, releasing its heat over a long period of time. When cut in small pieces.

Figure 2.1 (b). The combustion rate increases, because the total contact surface area between wood and air has increased. Also, ignition of the wood has become easier

Figure 2.1 (c) .the explosion of wood.

The explosive combustion of dust clouds, cannot take place unless the dust concentration, i.e. the mass of dust per unit volume of dust clouds, is within certain limits. This is analogous with the combustion of homogeneous mixtures of gaseous fuels and air for which the upper and lower flammability limits are well established.

2.1.1 Explosive Material particles:

Dust explosions generally arise from the rapid release of heat due to the chemical reaction.

Fuel + Oxygen → Oxides + Heat.

In some special cases, metal dust can also react exothermally with nitrogen or carbon dioxide, but most often oxidation by oxygen is the heat-generating process in a dust explosion. These mean that the only materials not already stable oxides can give rise to a dust explosion. This excludes substances such as silicates, **sulfate**, nitrates, carbonates, and phosphates and therefore dust clouds of portland cement, sand, limestone, and the like cannot produce dust explosions. And the materials that can cause dust explosions include:

- Natural organic materials such as grain, linen, sugar, etc.
- Synthetic organic materials such as plastics, organic pigments, pesticides, etc.
- Coal and peat.
- Metals such as aluminum, magnesium, zinc, iron, etc.

The heat of combustion of the material is an important parameter because it determines the amount of heat that can be liberated in the explosion. However, when comparing the various materials in terms of their potential hazard, it is useful to relate the heat of combustion to the amount of oxygen consumed. This is because the gas in a given volume of dust cloud contains a limited amount of oxygen, which determines how much heat can be released in an explosion per unit volume of the dust cloud.

The Minimum Explosible Concentration: The minimum explosion concentration test determines the lowest concentration of dust cloud in air that can give rise to flame propagation upon ignition. And the concentration of dust in the air falls within the explosive limits and the mean minimum concentration of dust to dust in the air in a cloud of dust (dust cloud) that can cause an explosion. Usually, if the dust concentration is less than MEC will not cause a dust explosion by the MEC is about 50-100 g/m^3 to 2-3 kg/m^3 depending on the type of dust.

Equipment or processes that cause haze of dust that is usually found in higher concentrations MEC closed process equipment such as grinders or mixers, filters, pipes, pneumatic conveying equipment, dryers and separate dust etc. For a given type of explosible dust, dispersed as a cloud in the air, there is a reasonably welled find a minimum quantity of dust per unit volume of air below which the dust cloud cannot propagate flame. The theory, therefore one could eliminate the possibility of dust explosions by ensuring that the dust concentration does not exceed this minimum limit. In particle, however, most process equipment in the plant where powders are manufactured and handle always contain large quantities of power and hence this principle of preventing dust explosion is not a particle in general. However the principle may be adapted in the particle to some types of the process equipment, And other things for dust explosion have many cases of an explosion in the world, so this table will show to for explosion concentration of the material. For the calculate the minimum explicability concentration can found by mass of powder divided by volume of the area for explosion (the chamber of explosion explosive) as present in equation 2.1

$$MEC = \frac{m}{v} \tag{2.1}$$

m is the weighting of the dust sample, g

v is the volume of the chamber, m^3

2.1.2 The damage of dust explosion

In addition to the familiar fire triangle of oxygen, heat, and fuel (the dust), dispersion of dust particles in sufficient quantity and concentration can cause rapid combustion known as a deflagration. If the event is confined by an enclosure such as a building, room, vessel, or process equipment, the resulting pressure rise may cause an explosion. These five factors (oxygen, heat, fuel, dispersion, and confinement) as known as the “Dust Explosion Pentagon” as presented in Figure 2.2

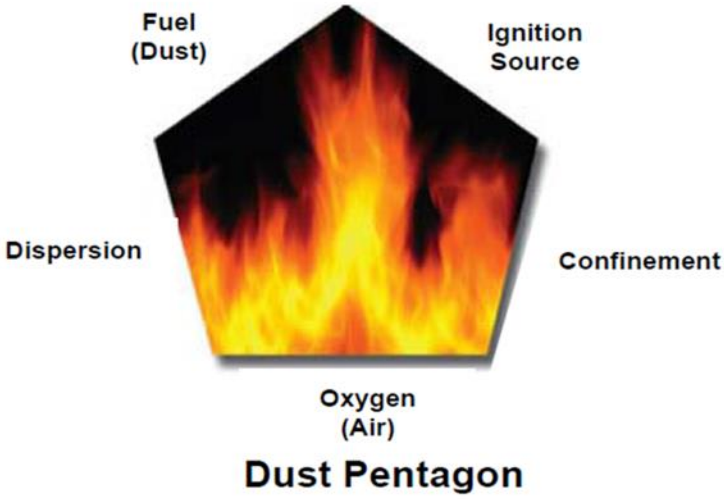


Figure 2.2 The pentagon of dust explosion (Industrial Fire Prevention,2010)

If one element of the pentagon is missing, an explosion cannot occur. And combustible dust explosion hazards exist in a variety of industries, such as agriculture, chemical, food (e.g., candy, sugar, spice, starch, flour, feed), grain, fertilizer, tobacco, plastic, wood, forest, paper, pulp, rubber, furniture, textiles, pesticides, dyes, coal, metal processing (e.g., aluminum, chromium, iron, magnesium, and Zinc), recycling operations, fossil fuel power generation (coal). Furthermore, there are many case studies for dust explosion occurring in the industries at transferring point like bucket elevator or enclosed conveyor. According to national data of 129 reported giant dust explosions in the United State since 1988 (Schoeff,1989), there are 64 cases in grain elevator and 48 cases in grain willing facilities (wheat, corn, and rice mills).

In January 2003, devastating fires and explosions destroyed a North Carolina pharmaceutical plant that manufactured rubber medicine delivery components. Six employees were killed and 38 people injuries, including two firefighters, are injured maiming in the storage, after that an explosion at an Imperial Sugar factory in Georgia killed 14 workers and injured dozens in 2008, US. (PORT WENTWORTH,2009) In China 2010, there are 21 cases of dust explosion reported This report shows 41 death and over 144 injuries, It has 6 cases related to Aluminum dust and 3 cases related to wood dust. Two cases are from coal and silicon dust explosion (Occupational and Environmental Health ,1999)

Methane trigged coal dust explosion-westray, coal mine (26 fatalities)

Aluminum of dust explosion-Hayes Lemmerz international –Hunting (1 fatality)

Polyethylene dust explosion- west pharmaceuticals (6 fatalities)

Sugar dust explosion imperial sugar company (14 fatalities)

Figure 2.3 Damage of dust explosion occurs in industries.

2.2 Parameters for coal dust explosion

Combustible dust is fine particles that present an explosion hazard when suspended in the air in certain conditions. A dust explosion can be catastrophic and cause employee death, injuries and destruction of entries building. In many combustible dust accidents, employers and employees are unaware that a hazard even exists. In addition to the fire triangle of oxygen, heat, and fuel (the dust), dispersion and confinement are known as the dust explosion pentagon. If one element of the pentagon is missing an explosion cannot occur. As shown in Figure 2.2, for a fire to be able to burn it needs to have three things present simultaneously: fuel, ignition, and oxygen. Take away any one of these and you cannot have a fire. In fire safety, this idea is known as the ‘Fire Triangle’, and is commonly used to help avoid industrial fires. Furthermore, more elements are needed to be added to the fire triangle to create the ‘Dust Explosion Pentagon’. The two new elements are confinement and dispersion. These elements are created when the fuel, in this case, combustible dust, is spread out as a dust cloud within a closed area, such as a factory or warehouse. There are five factors for the cause of dust explosion as shown below:

2.2.1 Fuel (Dust)

The dust fuels that can explode, must be able to be flammable. Such dust is smaller than 420 microns (0.42 mm) with the appropriate concentration depending on the type of dust which meets the requirements of the National Fire Protection Association (National Fire Protection Association, or NFPA).When a mass of the solid flammable material is heated it burns away slowly owing to the limited surface area exposed to oxygen in the air. The energy produced is liberated gradually and harmlessly because it is dissipated as quickly as it is released. The result is quite different if the same mass of material is ground to a fine powder and intimately mixed with the air in the form of the dust cloud. In these conditions the surface area exposed to the air is very great and if ignition now occurs, the whole of the material will burn with great rapidity, the energy, which in the case of the mass is liberated gradually and harmlessly, is now released suddenly with the evolution of large quantities of heat and, as a rule, gaseous reaction products (Info,2016).

In some cases, study the incidents is reported by Alameddin and Foster (1984). And the fire followed by an explosion occurs inside a coal silo of 900 tons capacity while the silo is nearly empty, and the remaining 85 tons of coal are being discharged the hot spot originated from smoldering combustion in the coal in the silo. This process liberates methane, carbon monoxide, and other combustible gasses from the coal. The explosion probably results from ignition of a mixture of combustible gas and airborne coal dust in the space above the bulk coal by the smoldering fire or glow when it reaches the surface of the coal deposit.

This is what actually ignites and provides a source for the fire or combustion to continue burning. In traditional fires this is something like wood or paper, and in some factories, even piles of accumulated manufacturing dust will catch fire and burn. In a dust explosion, it is the airborne dust that is providing the fuel and causing it to change from a fire to an explosion. The suitable way for combustible dust cleaning is one of the most effective ways to prevent a catastrophic dust explosion.

2.2.2 Dispersion of dust

The spread of dust (dispersion of dust) concentrations of dust blowing in the air during the burning or explosion will be in the range of about 50-100 grams per cubic meter up to 2-3 kg per cubic meter (World health organization, 1999). Whichever type of dust, the factors that influence the spread of dust, depend on the characteristics of each type of the particle of dust. The size of the dust particles results in the violence of the explosion increasing the concentration of dust, moisture, the spread of dust and minimum temperature to explode as well. The ease of spread depends on several factors such as the characteristics of the dust density, diameter, shape and the ability to stretch and pull the incorporation of dust and moisture. The accumulated dust is spread out over the air and creates a dust cloud. This can be caused when daily activities disturb accumulated dust and send it airborne, such as sweeping, exhaust from machinery, or cleaning using compressed air. Another cause of dust dispersion is when a small primary combustion occurs and sends shockwaves throughout the facility. These shockwaves can knock down dust that had settled on rafters or pipes, and spread it throughout the air. Once it has been dispersed, this dust can change from the initial fire to an explosion almost immediately.(Edwin G. Foulke,2007)

2.2.3 Confinement

When the dust cloud is contained within a closed area, which can be as large as a warehouse or factory, it causes issues with confinement. Dust particles can remain suspended in the confined air for days, causing the density of the dust cloud to be constantly increasing. When the dust cloud combustion, the confinement will cause intense pressure to build and push the explosion through every corner of the facility. Confined dust explosions have had the power to lift roofs from buildings or buckle solid concrete floors.

In the case of the Imperial Sugar dust explosion, being confined pushed the explosion through tunnels and halls that led it to other confined dust clouds. This caused a chain reaction of combustions, destroying the building and claiming several workers' lives. This is also a difficult element of the explosion pentagon to control since working in a located means it has to be a closed area. Environmental issues prevent manufacturers from releasing accumulated dust into the outside air, which means it stays confined inside the building. In this equipment and in the production of dust suspended in the air such grinder mixers, conveyors, silos, cyclones will increase the pressure on the area of the explosion.

2.2.4 Ignition source

A dust explosion will occur only if a dust is dispersed in the air or oxygen within the explosive range and if at the same time a suitable of an ignition source is present. Preventive measures are aimed at avoiding the present of either or preferably both these factors in this system. In addition, sources of heat or energy that can be found also:

1) Flames and hot surface: Open flames or hot surface are by far the most common sources of ignition in factory processes. The flames or hot surface may be produced inadvertently and for example, there could be a welding or cutting operation on or near to a vessel or plant containing flammable dust. The flame or hot surface may be there by design, as in the case of drying and heating plant associated with the processes and the factory building.

2) Spontaneous ignition: The storage of many dusts is liable to promote Spontaneous heating. If the heat is not dissipated the ignition temperature of the dust may be reached. The immediate result of Spontaneous ignition is fire, but explosion may following if the dust subsequently dispersed in the cloud. Materials particularly prone to spontaneous heating are an organic substance such as sewage sludge, cornmeal, fertilizers, fish meals and scraps rubber, especially when they are contaminated with unsaturated oils.

3) Friction spark: Many explosions has been caused as the result of foreign object to entering a grinding mill with the feedstock. The entry of ferrous tramp metals

should be prevented by the installation of a magnetic separator at a suitable point in the feed of the mill.

4) Electric plant: Flammable dust may be ignited by a spark generated by electrical equipment, for example, during the operation of the switchgear, when fuses blow or cables or equipment are damaged. Ignition may also occur if the surface temperatures of equipment are excessive, particularly if accumulations of dust are allowed surface.

5) Static electricity: It comes from the static friction between the dust and metal dust or air. A process often causes electrostatic separation measures including attrition, like pneumatic conveying In order to prevent damage caused by electrostatic must be grounded, the device is easy to accumulate static electricity, such as pipelines, conveyor, dust collector, etc. should be installed.

This is what actually causes the other elements to combust and create a dust explosion. The ignition source can range from something as small as a static electricity spark or lit cigarette, or a spark from metal parts scraping against each other. It could even be created when something just gets hot enough to ignite something nearby work place and this element can be contained to some extent by removing any open flames or potential for sparks to be created. It is also important to make sure machinery is clean and not getting too hot when it is operating. However, it is next to impossible to completely remove the risk for an ignition since it can be caused by such varied sources. No facility can completely ensure that there will be no static or other accidental sparks.

2.2.5 Oxygen

Oxygen will affect the speed of combustion. If the oxygen content of more than 21%, it will contact the fire quickly. If the oxygen content drops burning speeds reduced. However, it is difficult to control the amount of oxygen. Especially in open areas, But in enclosed spaces such as pipes, tanks, silos, etc. It can be easier. A fire needs oxygen to be able to burn, and this explosion element is present practically everywhere. It is the air workers are breathing in the facility and outside, the pressured air being used for cleaning, and in closed rooms unless they have been sealed and emptied of oxygen. Since oxygen is a component of air and is necessary for workers to breathe it is also the hardest element to remove from the explosion pentagon.

2.3 Mechanisms of dust explosion

In the production and management of combustible dust in industry. It is very important to know that these dust can be explosive or not in the factory. In fact of any kinds of dust can be combustible at any time, Therefore, explosion experiment will demonstrate the capability to explode. When testing any kinds of dust is performed and it is found that explosion should be measured of the parameters related to the explosion. And these parameters are the sensitivity of ignition showing the difficulty of the ignition. The associated value is the lowest concentration of dust explosion. Including minimum explosible concentration (MEC) helping design the safety measure to workplace, and to prevention the explosion.

2.3.1 Minimum explosible concentration (MEC)

The minimum explosible concentration (MEC) test determines the lowest concentration of dust cloud in air that can give rise to flame propagation upon ignition. And the concentration of dust in the air falls within the explosive limits and the mean minimum concentration of dust to dust in the air in a cloud of dust (dust cloud) that can cause an explosion. Usually, if the dust concentration is less than MEC will not cause a dust explosion, the MEC is about 50-100 g/m^3 to 2-3 kg/m^3 depending on the type of dust (Occupational and Environmental Health ,1999). And the information of MEC of the material as shown in Table 2.1 Equipment or processes that cause haze of dust that are usually found in higher concentrations MEC in closed process equipment such as grinders or mixers, filters, pipes, pneumatic conveying equipment, dryers and dust collection etc.

Table 2.1 Minimum Explosion Concentration of the material (Eckhoff,2003)

Type of dust	**MEC (g/m^3)**
Coffee	85
Corn	45
Cob	30
Grains mixed	55
Sugar	35
Wheat	55
whole wheat flour	25
Flour	50
Coal	30

For a given type of explosible dust, there is a reasonably welled find minimum quantity of dust per unit volume of air below which the dust cloud cannot propagate flame. From the theory, therefore, one could eliminate the possibility of dust explosions by ensuring that the dust concentration does not exceed this minimum limit. In particle, however, most process equipment in the plant where powders are manufactured and handled always contain large quantities of powder and hence this principle of preventing dust explosion is not a particle in general. However, the principle may be adapted in the particle to some types of the process equipment. And other things for dust explosion have many cases of an explosion in the world; so this table will show for explosion concentration of the material. The calculation of MEC can be achieved by mass of powder divided by volume of the area for explosion for this case (the chamber of explosion)

Other faction for dust explosion are mentioned as follow:

1. Minimum Ignition Temperature (MIT): The lowest temperature of the dust can be ignited or exploded by the MIT which is used to determine the maximum operating temperature of the electrical equipment and machinery of preventing (Ngo,2009)ignition own while measuring device.

2. Minimum Ignition Energy (MIE): The lowest energy that cause of dust explosion. Moisture, dust and the composition of the dust cloud can affect MIE. If there

is more moisture in dust, the ignition will be more difficult. And if dust is smaller, it can be easily ignited. Consequently, if the properties of dust have changed, the lowest energy used will change accordingly. The minimum energy that can ignite a mixture of a specified flammable material with air or oxygen, measured by a standard procedure. Depending on the specific application, there are several standard procedures for determining MIE of dust clouds, solvent vapors, and gasses. The common element in all procedures is that the energy is generated by an electrostatic spark discharge released from a capacitive electrical circuit. The exact circuit components and the arrangement of electrodes between which sparks are generated are the principle differences between the methods. In the following table, MIE is quoted for flammable substances mixed with air.

2.3.2 Pressure of dust explosion

If dust explosion occurred in the plant is high effect on harm and loss of work lives around there, the pressures resulting from an ignition in process equipment depend on the dust material, particle size distribution, and concentration distribution within the enclosure, and the size and location of equipment openings that allow the burning and unburned dust to be vented.

In principle, strengthening the equipment can prevent it from bursting, but in general, the structures required to achieve sufficient strength have to be so heavy that this approach is generally not recommended, either from the point of view of capital cost or with respect to running and maintaining the plant. Exceptions are cylindrical dust extraction ducting, which can be made pressure resistant with reasonable wall thicknesses, and certain types of equipment, which are heavy anyway, such as some mill types. Besides the concept of a fully pressure-resistant process plant is sometimes adopted, when the powders are highly toxic and; therefore, no circumstances can be allowed outside the equipment. In such cases, it is important to know the highest pressures to be expected, if a dust explosion occurs within the equipment. The maximum explosion pressure is generally proportional to the initial pressure therefore, be specified in a dust explosion in a fully confined, integrated system of various process items connected by comparatively narrow passages, pressure piling may easily occur.

These possibilities must be considered carefully before adopting laboratory test data for the maximum explosion pressure, which are normally based on atmospheric initial pressure.

2.4 Protection and mitigation

Coal is used in the manufacturing process, the majority must be reduced in size by grinding or milling into powder to make it easier to fire because there is more surface area, however, making coal a smaller effect on the control. Coal by making some small leaks from the production process. The conveyor belt through or from the collection in the event of a leak, it must be removed from the area to prevent the fire from a potential cause of sparks. The coal deposits in the area of the venue. When temperatures the atmosphere in the area high up. Coal may result in the ignition. This makes it likely caused the accident, the explosion of carbon particles. The accidents damage to life and property as well. And in addition, it is needed to study the details of the process used for unloading, storage, and transport of coal, and to evaluate, vulnerability to provide appropriate safety measures to the plant can operating safely and with effective security management. The details are as follows.

1) Dust: According to the study, and the results of international users it is found coal which a large size will be broken and therefore smaller coal pouring down from the transportation. Based on the result of the sampling, sub-bituminous coal dust on warehouse floors is passed through a sieve No. 40 (USNo.40), which is smaller than 420 μm according to 83.69 percent, coal dust in a bag house is smaller than 420 μm according to 99.09 percent, Before coal is present to guiding machine the size of coal will less than 420 μm is around 5-10 %, but after the guiding process, coal size with less than 420 μm can be achieve 99.93%. It can be conducted that coal dust can occur if the size is smaller than 420 μm.
2) Dispersion of dust: pouring coal can cause the dust to coal dust. For the rainy season will be somewhat less because dust gets wet. The building will find a pile of coal dust blowing and come into the ground or a building, structure or machinery. The study of Echoff (2003) shows that the lowest concentration of

explosive coal dust (MEC) is approximately 60g/m^3 based on measurements and calculations. It is found that in the process of unloading, storage, and transportation of coal, there is a risk that coal dust can explode off the dust dispersion is higher than MEC.

3) Confinement of the dust: From the study process of the unloading, storage and transportation of coal dust occur in a limited space such as the bag house as in a coal storage that can cause of dust explosion as well.
4) Oxygen: While coal conveyor belt would have gotten about 21% oxygen by volume, the amount of oxygen in the air is enough to assist in the fire, the fourth element is constantly at work.
5) Ignition source: In a more recent survey, Scholl (l989) concluded that the increased knowledge about ignition of dust layers and clouds permits the use of prevention of ignition sources as the sole means of protection against dust explosions, Provided adequate ignition sensitivity tests have shown that the required ignition potential, as identified in standardized ignition sensitivity tests, is unlikely to occur in the process of concern. Scholl distinguished between organizational and operational ignition sources. The first group, which can largely be prevented by enforcing adequate working routines, includes smoking, open flames, open light (bulbs), welding (gas or electric), cutting (gas or rotating disc), Grinding. And the another group arises within the process itself are including open flames, hot surface, Self-heating and smoldering nests, heat from mechanical impact between solid bodies (metals spark or hot sport), electric spark and electrostatic discharges. The tendency to self-heating in powder and dust deposits depends on the properties of the material. Therefore, the potential for self-heating should be known or assessed for any material before admitting it to storage silos or other parts of the plant where conditions are favorable for self-heating and subsequent further temperature rise up to smoldering and burning.

The study process is used to transport coal into the storage and transportation of coal. There is no point at high temperature of ignition. Therefore, care must be taken in the collection and use of coal as a source of ignition has occurred in the process of unloading, storing and transporting coal. The details are as follows:

- Sparks from static electricity while conveying coal dust caused by wind. Coal dust causes friction or friction with the pipe, causing electrostatic.
- Sparks from the first explosion. Pressure and heat or flame. Back at the pile of dust or other side effects.
- Sparks from mechanical or thermal spot. There may be pieces of metal attached to the coal, causing friction with the pipeline. Heat or sparks Friction and bearing. Belt, causing hot spots. The movement of the machine (Moving Parts) friction causes heat.
- Flame caused by welding or cutting. With an electric or gas welding. This occurs when repairing pipelines coal dust. Elevator conveyor tube coal storage silo bag house, cyclone separator size, etc., It causes a fire or explosion deflagration (Eckhoff,2003).

2.5 Literature Review

ASTM (2001), are standard test methods which cover the determination of ignition of a dust dispersed in air, within the closed vessel. These methods provide a measure of dust explosion pressure and rate of pressure rise. However, the only preferred method for the design of safety equipment is test method E1226. However, this standard does not purport to address all of the safety concern. The test method covers the determination of the ignition of dust dispersed in the air within a closed vessel provided the measure of dust explosion pressure and rate of pressure rise.

Ebadat. (2009), perform the approach to identifying dust cloud explosion hazard and ensure safety generally. This research recommended that the evaluation of the hazard of a combustible dust should be determined by the mean of actual test data by evaluating each situation and selecting an applicable test. According to NFPA 654. the factors that are sometimes are used to determine the deflagration hazard of a dust.

Yuan et al, (2011), measure experiments in required conditions and consequences of dust explosion considered in the framework. This work establishes the standard and the produce of non-electric apparatus for explosive atmospheres in China.

This case study shows that the principles of safety standard should set the value of MEC of combustible powder in the process as a guideline to reduce the risk of dust explosion.

Man (2005), conducts experiments using the National Institute for Occupational Safety and Health (NIOSH), Office Mine Safety and Health Research (OMSHR) standard: 20-L of gas cylinder and fire occupation 1-m^3 explosion chambers. Coal and rock dust samples are prepared by sieving and investigated the effect of particle size on explicability and inert effectiveness.

Zalosh (2010), shows the basic concepts of dust explosion. The first concept is the fact that small combustible particulates are burned rapidly when ignited. The second concept is that the higher the concentration of the suspended cloud of combustible particulates above the minimum concentration MEC, confinement of the cloud by enclosure or partial enclose, oxygen concentration rather than limit oxygen concentration LOC for the suspended dust could, the more chance of dust explosion can occur.

Tanthapanichkoon et al, (1996), the main objectives of the present invention project are to develop and improve the second prototype of the dust explosibility tester, to measure the lower explosion limit (LEL) concentrations of several Thai domestic dusts and to study the effect of the average particle size and the test results on the LEL values of the numerous dust, the pressure project also recommends measures for dust explosion prevention and measures for minimizing explosion damages in factory.

Wiriyaumpaiwong (1993), the main objectives of these research present are to measure the lower explosion limit (LEL) concentration several types of products and to study the effect of the average particle size and moisture content of domestic flours (cassava flour, rice flour, corn flour and wheat flour) on LEL. A prototype was successfully designed and constructed to carry out the experiment.

Norman et al, (2013), this research to study in the influence of enriched oxygen concentration is research on coal explosion characteristics of Indonesian (Sebuku) coal dust. The ignition sensitivity characteristics (minimum ignition energy and minimum ignition temperature) and explosion severity characteristics (maximum explosion pressure, Pmax and maximum rate of pressure rise, Kst) are determined in air.

Mittal (2013), reviews and analyzes the existing data on explosion parameters of coals and creating new sufficient quantitative explosibility data for safety design and operation of plants handling some specifically selected coal. This work determines minimum explosible dust concentration, maximum explosion pressure and a maximum of rate pressure rise limiting oxygen concentration and influence of oxygen mass fraction of explosion violence characteristics over a wide range of dust concentration of two type of coal from Jharia coal field.

CHAPTER 3
EXPERIMENT

3.1 Material

Coal dust for this study is obtained from the coal storage of the Siam Cement Group Company. The smallest size of this dust is less than 45 microns and largest of the particle size is 250 microns. The size distribution will show on Table 3.1 and Figure 3.1.

Table 3.1 Sieve analysis of coal sample database in percent of cumulative passing

sieve no	µm	Weight (g)	Weight (%) (%retained)	Cumulative % passing	Cumulative % Retained
60	250	592.1	63.22	100.00	0
80	180	130.7	13.95	36.78	63.21802264
100	150	41.4	4.42	22.83	77.17275251
140	106	78.8	8.41	18.41	81.59299594
200	75	36	3.84	9.99	90.00640615
270	53	25.2	2.69	6.15	93.85009609
325	45	4.3	0.46	3.46	96.54067905
pan		28.1	3.00	3.00	96.99978646
total	936.6	100			
	1000	100			

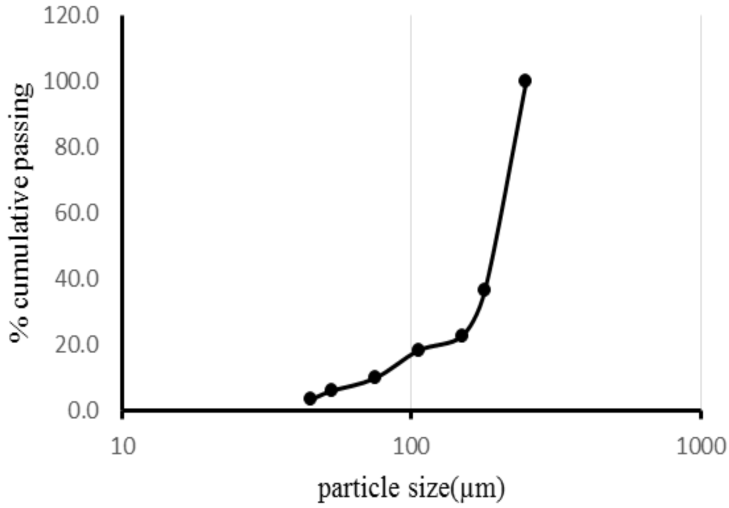


Figure 3.1 The particle size of coal dust powder

3.1.1 Material preparation

Before running the experiment, the coal powder is sieved for size analysis with the standard sieve screen size 250 μm, 180 μm, 150 μm, 106 μm, 75 μm, 53 μm, 45 μm and less than 45 μm. Then the coal powder is dried in the over about 100℃. First sieve standard will do in ambient temperature and its weight is recorded. Second the screen are set up in sequence of increasing aperture from bottom to the top, and then the sampled is placed from the top of screen. Next set up the time on 5 minutes and frequency of vibration screen in 5 Hz. After the vibration of screen is finished bring the coal sample for weighting as shown in Table 3.1

The experiment of dust explosion is conducted in 0.012297 cm^3 volume of tester chamber. The explosion tester is made from steel combustion chamber and has compressed the gas to disperse coal dust by clean compressed air with the pressure air. And dust is ignited by electric sparking in the chamber. To observe carefully whatever the dust explosion will be exploded or not and the procedure is followed as these: After checking the equipment to ensure that they are good at working conduct to the measurement of MEC and then loading of the powder in the explosion chamber volume. The calculation amount of powder weight by the microbalance, for example, the apparent test of powder concentration is 48 g/m^3 or 57 g/m^3, the amount of powder is

0.5955 g or 0.6945 g with using lycopodium powder (Association of Powder Process Industry and Engineering), with the size distribution of 32 μm.

In general, oxygen has moisture in the air. These experiment uses silica gel to reduce moisture content in the air compressor. Actually, when the temperature is decreased so the water it will flow down from compressor air. So it important to consider of the experiment.

3.2 Dust explosion tester

The equipment is called the dust explosion tester, composed of stainless chamber connected with an air tank to supply air for gas dispersion with the pressure up to 50 psi or 3.5 kg/cm^2 as shown in Figure 3.2. The combustion chamber has a length about 29cm and diameter about 7 cm, the experiment of dust explosion are conducted in 0.012297 cm^{3}chamber this equipment has to two separate parts, explosion chamber section, and compressed air supply section.

Explosion chamber section: The explosion chamber section includes of Pyrex tube, Spark Electrode, dust cup and mushroom. And the tube support by four rods, a piece of filter paper is placed on putting on the top of the tube. So the Pyrex tube is used as the explosive tube shown in Figure 3.2, a point to measure the required for flame propagation length is placed at 100 mm above in the discharge electrodes.

The design and the dimension of the explosion support plate are shown in Figure 3.3 The underside of this device is connected to the dust cup, it is designed to securely hold the entire explosion chamber section.

Dust cup and mashroom like a cup for dispersion of air, the dust cup is used to hold the powder of sample for testing. It’s the central hole inserting the dispersion of dust cup supporting rods. Compressed air enters the chamber through an annular gap between the central hole and the dispersion cup supporting of rods. The dispersion cup is designed the bend the compressed air towards the dust cup; therefore the test powder on the dust cup is dispersed upward in the tube to the uniform of the dust cloud.

Discharge electrodes are connected to the electricity to ignite. The delay timer is used to delay in discharge of electrical sparks to initiate of the explosion of the dust cloud. The electrode are made of two tungsten rods. The gap between the electrodes is 4-6 mm. For the sparks will take place at the tube central axis.

For the sparking delay time can be freely of controlled with the use of a timer. Then the typically set to activate the electrical discharge is 0.1 to 0.5 seconds. After that opening the electronic sparking the compressed air is introduced to disperse dust powder (Tanthapanichakoon et al, 1996)

Compressed Air supply Section: the compressed air supply section consists of an air compressor, an air tank, a pressure gauge, an electromagnetic valve, a check valve, air pipes as well as silica gel tank. The compressor supplies to require a pressure air with typically working pressure 12 kg/cm^2 disperse the test of powder in the explosion chamber. The air tank and the pressure gauge are stored off the standard amount of high-pressure air supplied from the compressor. Therefore, an electromagnetic valve and check valve are installed to prevent any possible backward flow of the air due to the flame propagation for a high pressure generate by the explosion.

The air pipes carry on the air from the tank to the explosion chamber and the diameter is about ¼ inch as shown in Figure 3.4

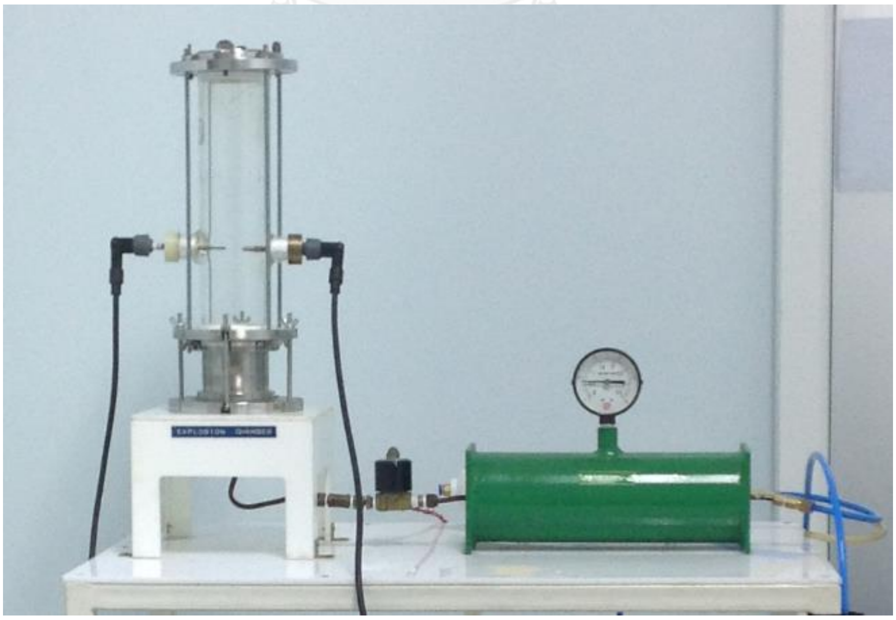


Figure 3.2 Chamber section.

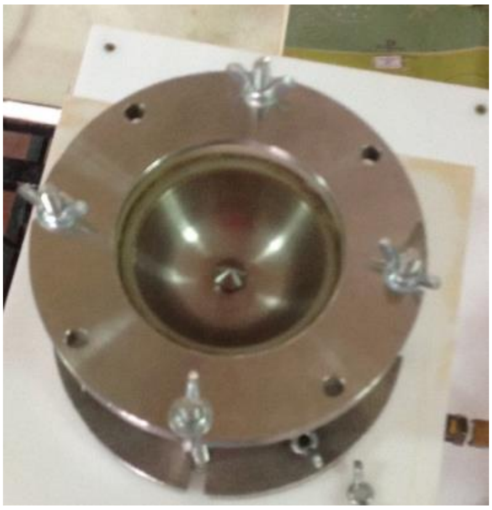


Figure 3.3 The Explosion support plate and Dust cup and mashroom.

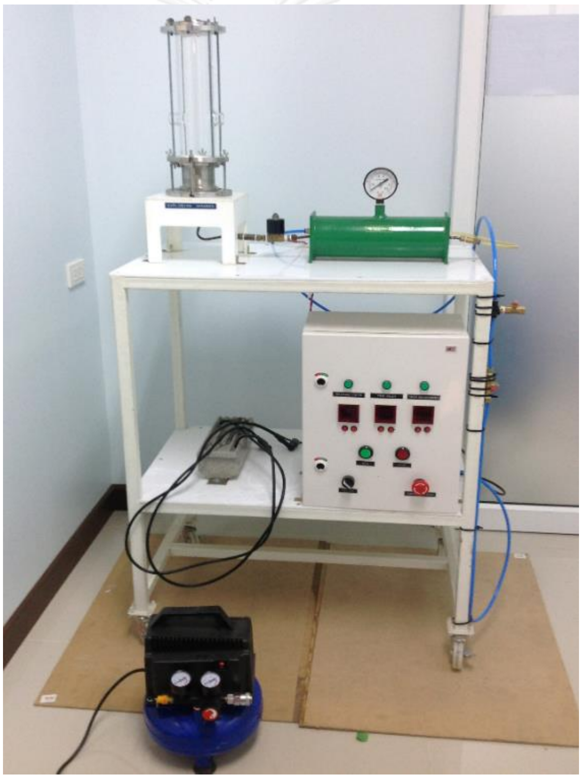


Figure 3.4 The compressed air and pipes of compressed air section.

The other equipment used in this experiment are a 4 litter air compressor model OL 1204 with the maximum of the compressor air at 8 bars from Scientific Company Limited to feed compressed air to the tank.

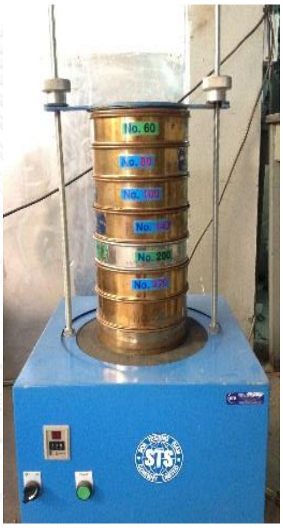
The high precision scale to measure the amount of coal dust comes from the OHAUS Company model PA214C with the readability of 0.0001 digits and the operating conditions from 10 °C to 40 °C at 10% to 80% relative humidity.

Sieve analysis model STS-S 414 from Soil Testing Siam Co. Ltd., is used to characterize and separate coal dust with different size from less than 45 microns to 250 microns. The moisture content is measured by using a moisture meter model MC7825PS with a digital display indicating the moisture condition of the material. Specification of the display is 4 digits, 10mm LED with measurement ranging 0% to 80%, and ±0.5% accuracy. The operating conditions are 0-50 °C of the temperature and humidity below 90% RH. Also, the oven used to control the moisture of coal dust or sample derives from Memmert with maximum temperature at 200 °C. This oven is operated at more than 100 °C for this study. The equipment used is presented in Figure 3.2-3.5.

The compressor air

The balance weight

The moisture meter model MC7825PS



Sieve analysis model STS-S 414

Figure 3.5 The equipment use in experimental.

3.3 Experimental procedure

The experimental procedure to obtain the MEC is described as follow. First humid coal dust sample is dried in the oven to control the humidity to the desired moisture. And after sieve analyses of coal sample, therefore the known quantity of coal dust is measured with balance weight and placed at the bottom of the dispersion nozzle. Coal dust is dispersed by compressed air and ignited by the high-voltage electric sparking (ASTM 1515). Coal dust can be exploded or burned in the chamber. The tests are performed 3 times with the same conditions to ensure that the results are correct.

After checking off each the apparatus to ensure that there are in good working. First, it should know the amount of dust and load the sample into the dust cup, the amount of the sample loaded predetermined base by the actual explosion chamber volume. The powder will disperse in the dust cup which is centrally located above the compressed air exhaust nozzle. The explosion tube is then installed, and a piece of paper filter is placed over the top of the explosion tube, in the present investigation, the paper is Whatman No. 93 of 11 cm diameter. Adjustment the compressor air is introduced the air from the tank up to the specified air pressure as indicated by a pressure gauge (shown in Figure 3.6). Typical air pressure is about 50 KPa (0.5 bars) gauge. If the test in ignition test above gives a lower explosion limit concentration of 45±5 g/m^3, the apparatus can be judged to be in satisfactory calibration as shown in Figure 3.7

Figure 3.6 The pressure gauge

Figure 3.7 Calibration MEC with lycopodium.

3.4 Methodology

To begin with, study on the literature review of dust explosion occurred in which conditions, and study and adjust the equipment for dust explosion in laboratory scale. After that calibration of the equipment with a standard method to verify the result of equipment with lycopodium powder, then to make sure for equipment is ready to study, as well as running the experiment on coal dust explosion with the parameter. There are several parameters to measure such as: moisture concentration (3%, 6%, 9%, 12%, and 15%), compressed air, the particle size (Sieve stand references 180, 150, 106, 75, 53, and 45 µm), delay time for sparking (0.1 Second, 0.3 Second and 0.5 Second) and concentration of dust and analyses of the result and discussion on experiment . The methodology to present in Figure 3.8.

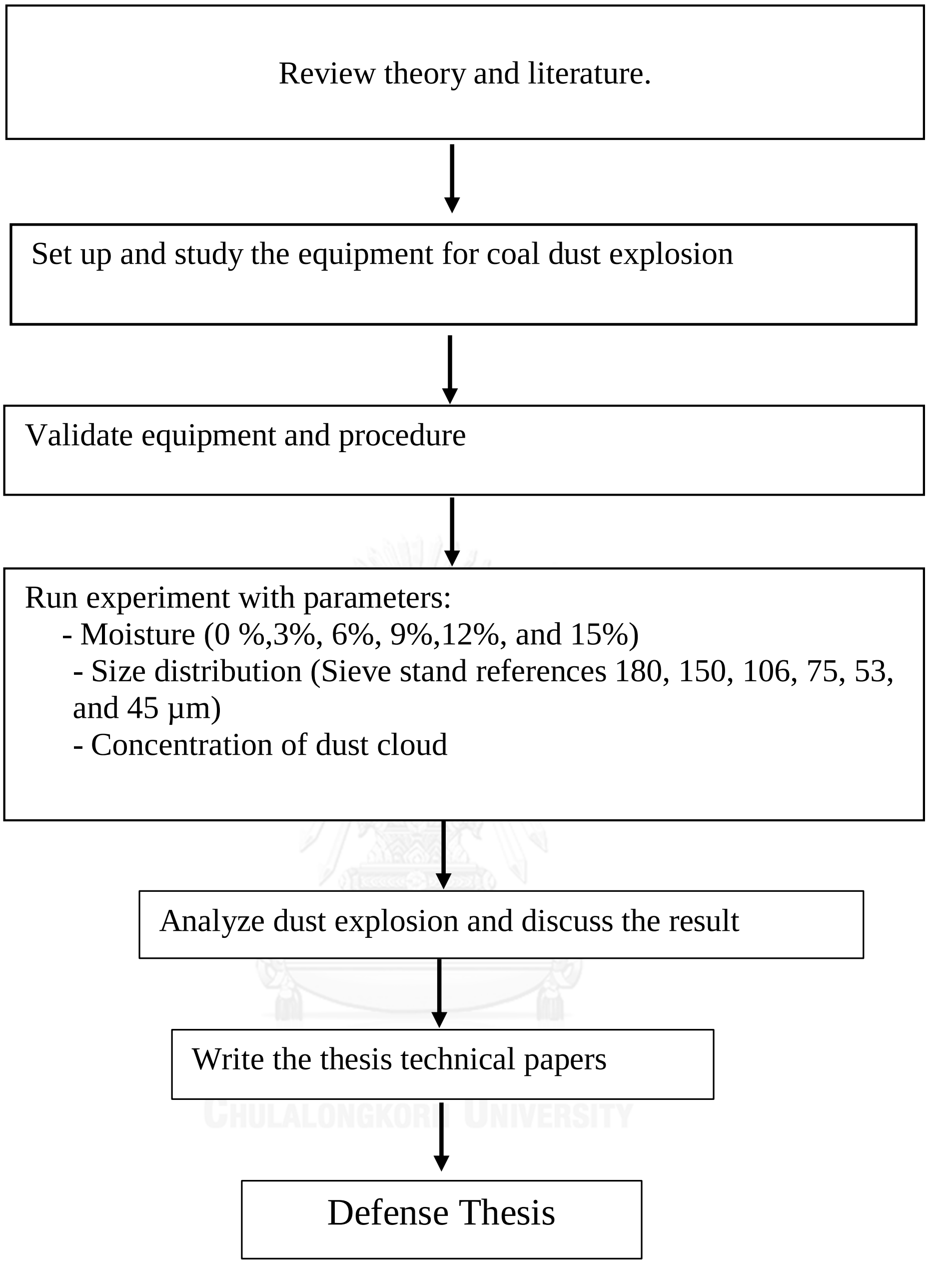


Figure 3.8 Methodology flowchart of the study

CHAPTER 4
RESULT AND DISCUSSIONS

4.1 Verification of equipment and procedure

Calibration of MEC is conducted by using lycopodium powder with the size of 32 µm at an ambient humidity of 35% to 55% the temperature at 25˚C, Beside, the preferred of moisture content in coal is below 0-2 %. The result of calibration as show in Figure 4.1 and Table 4.1 and 4.2 presents the MEC in the range of 48 g/m^3 to 57 g/m^3 when compered in literature which conform to standard value (± 45 g/m^3). Therefore these equipment are good to study in the future and it has 4.9 % deviation.

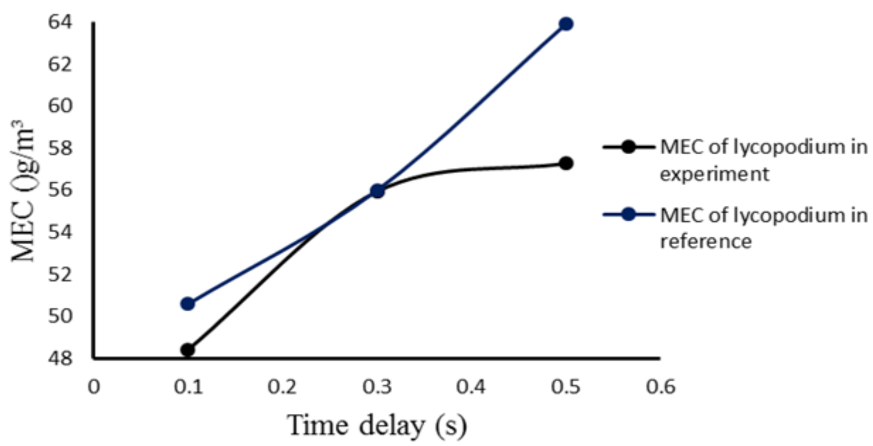


Figure 4.1 Verify of MEC with lycopodium powder

Table 4.1 The calibration with lycopodium powder

lycopodium	Delay time (second)	MEC (g/m^3)	Compressed air (kg/cm^2)	MEC (g/m^3)
Standard reference	0.1	50.6000	0.5	47.7000
	0.3	56.0000	1.0	47.2000
	0.5	63.9000	1.8	47.9000
Experiment	0.1	48.4346	0.5	47.1660
	0.3	55.9405	1.0	55.9405
	0.5	57.2823	1.8	48.2557

The experiment for calibration of dust explosion tester is doing in difference of the compressed air at 0.5, 1 and 1.8 kg/cm^2 and different delay times are average of the minimum explosible concentration (MEC)

Table 4.2 Summery of the calibration of with lycopodium with standard it presented in the table

Lycopodium powder		
Compressed air (kg/cm^2)	Experiment tester	48.2557
	Standard reference	47.0
Delay time (Second)	Experiment tester	48.4346
	Standard reference	50.6

The experiment for calibration of dust explosion tester is doing in 0.1 second, 0.3 seconds and 0.5 seconds and it is obvious that 0.1 s delay time is suitable for calibration of equipment because the result gets along well with the literature in standard of lycopodium powder in range ± 45 g/m³ (Tanthapanichakoon et al,).

Table 4.3 Experimental operating conditions for this study

Parameter	Value
Particle size (micron)	Less than 45, 45, 53,75,106 and 150
Coal humidity (%)	0, 3, 6, 9 and 12
Pressure of air (kg/cm^2)	0.5, 1, and 1.8
Time (s)	0.1, 0.3, and 0.5

4.2 Effect of particle size of coal

In the experiment, the results indicate that particle size effects on the amount of coal dust explosion or MEC in that MEC increase with a particle size of coal dust as shown in Table 4.4 to 4.7 and Figure 4.2 the smaller particles size is a higher chance to have coal dust explosion. Therefore, coal dust can be agglomerated to a bigger size to reduce or prevent the explosion.

Coal dust explosion in ambient 35% to 45 %, time delay 0.1 s and moisture of coal dust in 0%, 3% ,6% , 9% and 12 %, it get the result in Table 4.4 , 4.5, 4.6 and 4.7 as shown below:

Table 4.4 The experimental result with particle size less than 45 micron

particle size (μm)	times (s)	compressed air kg/cm²	Moisture (%)	minimum explosion concentration (MEC g/m³)
less than45	0.1 s	1.8 kg/cm²	0%	74.3271
			3%	74.3352
			6%	74.6849
			9%	74.7255
			12%	74.8313
		1 kg/cm²	0%	75.1443
			3%	74.8150
			6%	75.1708
			9%	74.9451
			12%	75.2297
		0.5 kg/cm²	0%	75.5144
			3%	75.3463
			6%	75.5001
			9%	75.2053
			12%	75.3598

Table 4.5 The experimental result with particle size 45 micron

particle size (µm)	times (s)	compressed air kg/cm²	Moisture (%)	minimum explosion concentration (MEC g/m³)
45	0.1 s	1.8 kg/cm²	0%	75.1321
			3%	74.882
			6%	75.1647
			9%	75.3029
			12%	75.5306
		1 kg/cm²	0%	75.1443
			3%	75.2867
			6%	75.1118
			9%	75.2053
			12%	73.3029
		0.5 kg/cm²	0%	75.2514
			3%	75.2053
			6%	75.2379
			9%	75.7055
			12%	75.7908

Table 4.6 The experimental result with particle size 53micron

particle size (µm)	times (s)	compressed air kg/cm^2	Moisture (%)	minimum explosion concentration (MEC g/m^3)
53	0.1 s	1.8 kg/cm^2	0%	75.4249
			3%	75.3802
			6%	75.5875
			9%	75.8044
			12%	75.6580
		1 kg/cm^2	0%	75.3720
			3%	75.5509
			6%	75.4086
			9%	75.5067
			12%	75.7014
		0.5 kg/cm^2	0%	75.4412
			3%	75.6363
			6%	75.7339
			9%	75.7854
			12%	76.0226

Table 4.7 The experimental result with particle size 75 micron

particle size (µm)	times (s)	compressed air kg/cm^2	Moisture (%)	minimum explosion concentration (MEC g/m^3)
75	0.1 s	1.8 kg/cm^2	0%	75.7380
			3%	75.6282
			6%	75.5591
			9%	75.6851
			12%	75.8478
		1 kg/cm^2	0%	75.4046
			3%	75.5266
			6%	75.7095
			9%	75.9535
			12%	76.0348
		0.5 kg/cm^2	0%	75.6268
			3%	75.8722
			6%	75.7908
			9%	No explosion
			12%	No explosion

In addition, when the show in the graph in 75 µm it will be increasing of minimum explosible concentration (MEC) as shown in Figure 4.2. From the figure, it observes that when the particle size is smaller so it is easy to occur with dust explosion because it can be moved in quickly more than the bigger size of coal dust

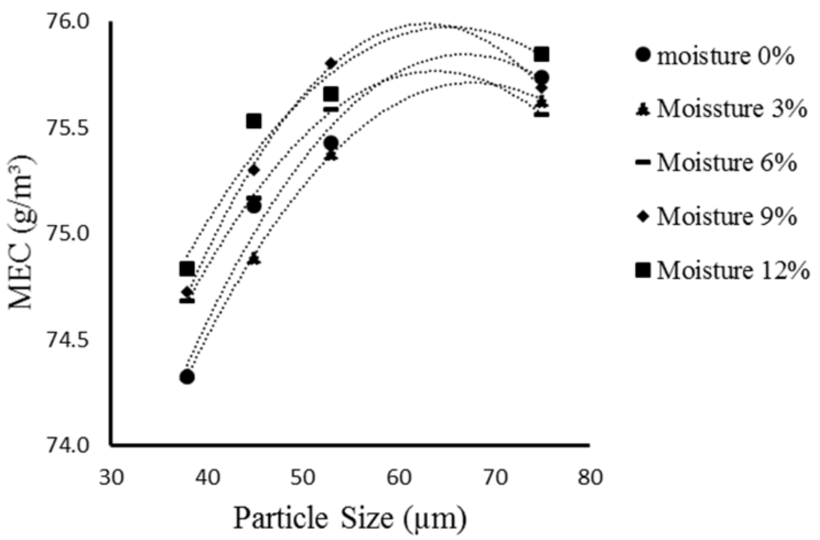


Figure 4.2 The effect of MEC with the particle size of coal

The experiment is tested in ambient condition at 39℃ of temperature, 38% humidity and 1.8 kg/cm^2 compressor air, 0.1 second delay time

From previous researches, it is found that MEC value increases while the particle of dust's size decreases. Moreover, many MEC data also show that the size distribution has influence over the ignition of combustible dust as well. Normally, the coal fine particles of coal dust can be ignited easier than the large of the particle size will occur in minimum explosible concentration in coal storage conditions. From the experiment, it is also found that particle size at up to 106 microns do not explode.

4.3 Effect of moisture content in coal

The effect of moisture content in coal is presented in Table 4.4-4.7 and Figure 4.3 to 4.6. From the Figure, it is obvious that coal humidity has less effect on MEC measurement. However, in term of ignition, humidity in coal is the key factor for coal explosion because, in many cases, coal is burned but not exploded. Therefore, with higher moisture content in coal, the risk for coal.

Usually, high moisture content in coal can make the ignition of dust cloud harder than those with lower moisture contents it called spontaneous combustion.

Therefore when the moisture content of coal increasing it difficult to ignite of coal dust explosion tester. And it presents as shown below

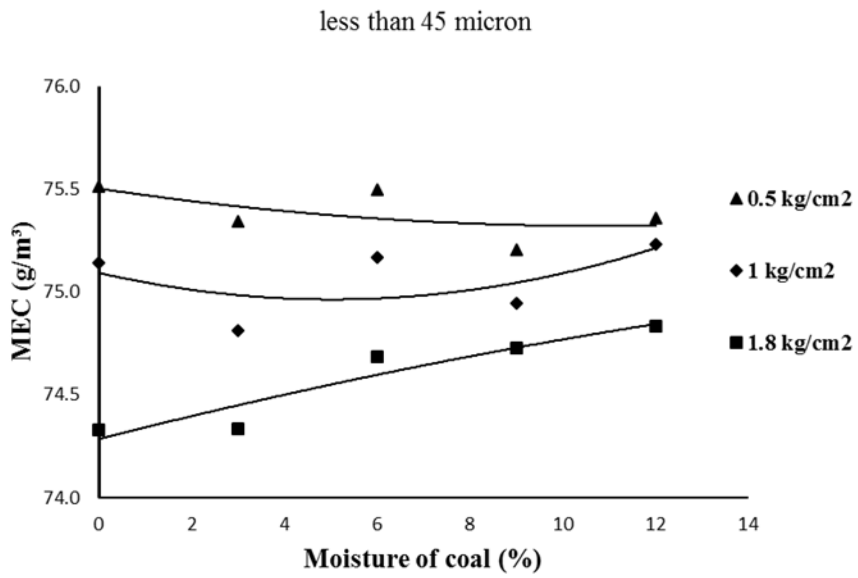


Figure 4.3The effect of MEC with the moisture content of coal dust explosion at particle size less than 45 micron

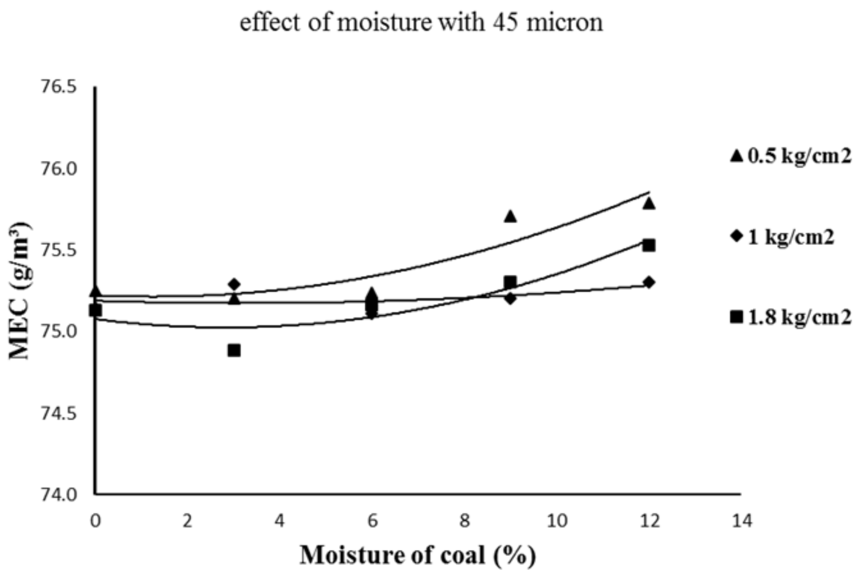


Figure 4.4The effect of MEC with the moisture content of coal dust explosion at particle size 45 micron

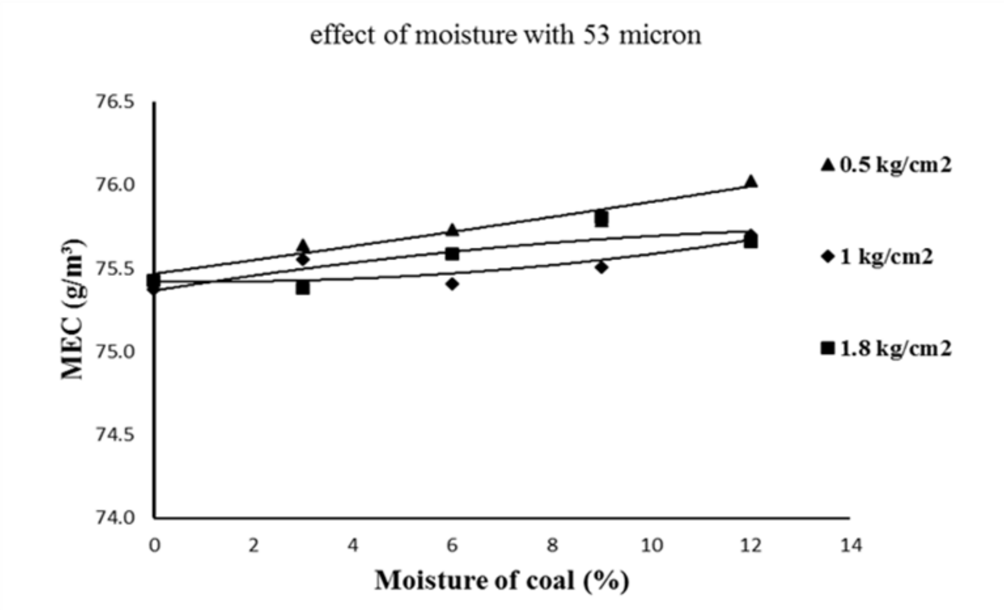


Figure 4.5The effect of MEC with the moisture content of coal dust explosion at particle size 53 micron.

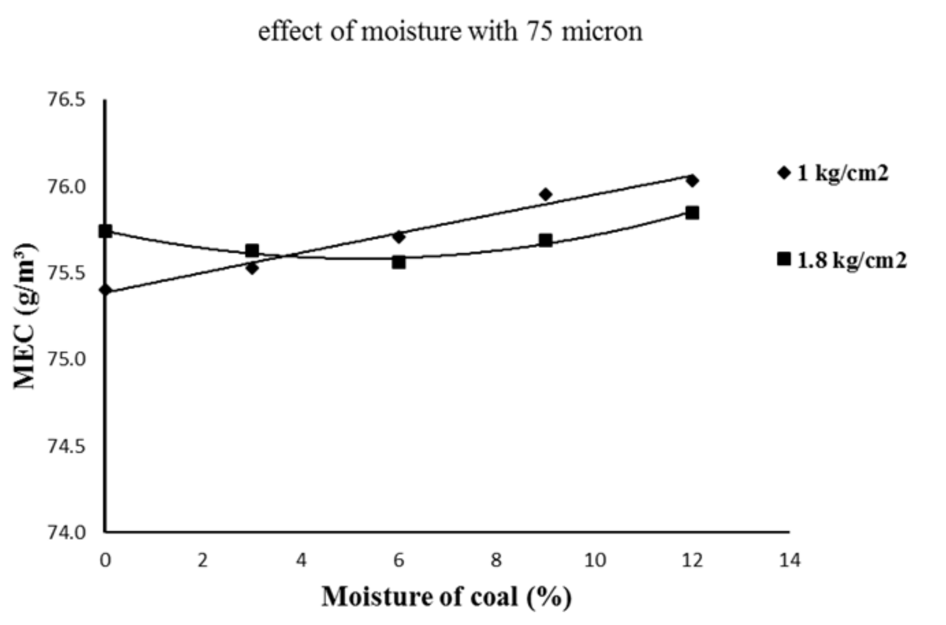


Figure 4.6 The effect of MEC with the moisture content of coal dust explosion at particle size 75 microns condition at 0.5 kg/cm^2, this is no explosion.

4.4 Effect of concentration of coal dust explosion

The concentration of coal effects on coal dust explosion. So, when the concentration of coal dust is increasing, the minimum explosible concentration will increase, As a result of the released compressed air, the amount of coal dust is higher.

Adjusting of the compressed air to lower level of the MEC will increase because less dispersion will occur and more coal is required to have explosion as Figure 4.7 to 4.10.

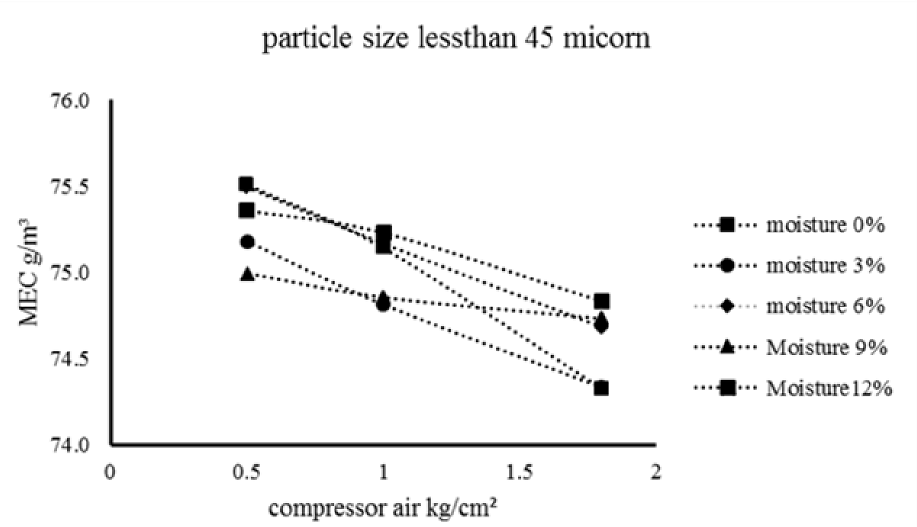


Figure 4.7 The effect of MEC with the concentration of coal dust explosion wit particle size less than 45 microns, delay t time 0.1 second, compressed air 0.5,1 and 1.8 kg/cm^2.

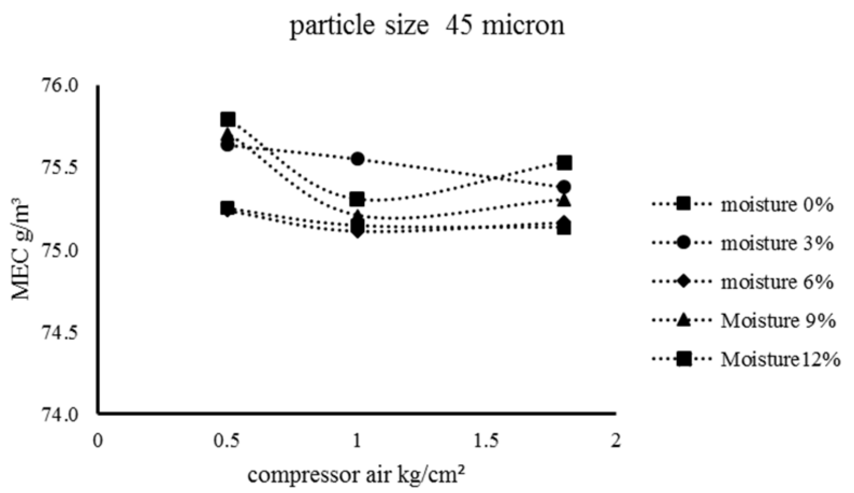


Figure 4.8 The effect of MEC with the concentration of coal dust explosion with particle size 45 micron, delay t time 0.1 second, compressed air 0.5,1 and 1.8 kg/cm^2.

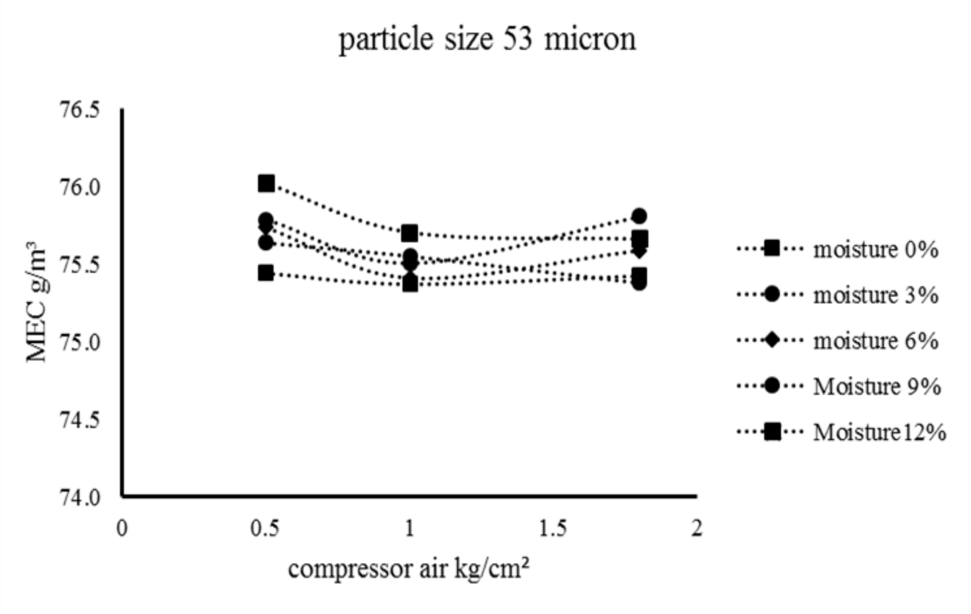


Figure 4.9The effect of MEC with the concentration of coal dust explosion with particle size 53 micron, delay t time 0.1 second, compressed air 0.5,1 and 1.8 kg/cm^2

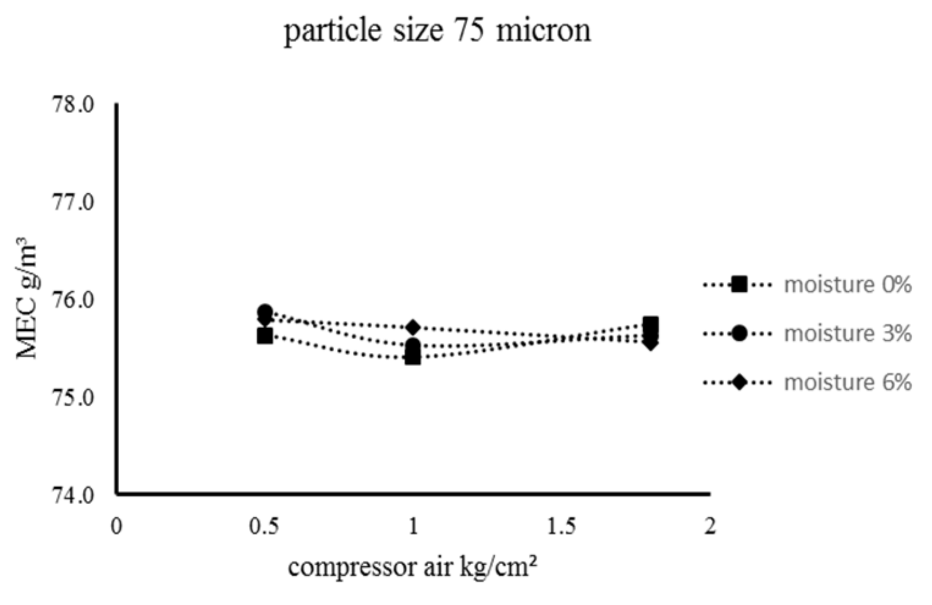


Figure 4.10 The effect of MEC with the concentration of coal dust explosion in particle size 75 micron, delay t time 0.1 second, compressed air 0.5,1 and 1.8 kg/cm^2.

Notice: with compressed air at 0.5 kg/cm^2 and the 9% and 12% of moisture content, coal dust is not exploded because of is low of compressed air and the high of the moisture content of coal dust and it might be harder for ignition.

The compressed air is used to disperse coal dust in a form of a cloud. Hence of air pressures are varied to study the effect of dust cloud dispersion in coal dust explosion. The air pressures used in the experiments are 0.5 kg/cm^2, 1 kg/cm^2 and 1.8 .kg/cm^2. These experiments study indifference of coal moisture content as a result.

4.5 Effect of Time delay of ignition

The sparking delay time or ignition is the parameter to investigate the explosion concentration and less delayed time can increase the chance for coal to ignite thus increasing the risk for coal dust explosion. For this study, the effect of time as presented in Figure 4.6 has less effect to measure MEC. However, the longer of delayed time will make less dispersion of coal because coal dust will drop down and the concentration of coal in the air becomes low. Then the ignition sources will start ignition with a low concentration of dust. Therefore, there is less chance of dust to get ignited. The difference of delay time to the dispersion of coal dust powder will delay the explosion. The short time of dust dispersion will measure the chance of explosion.

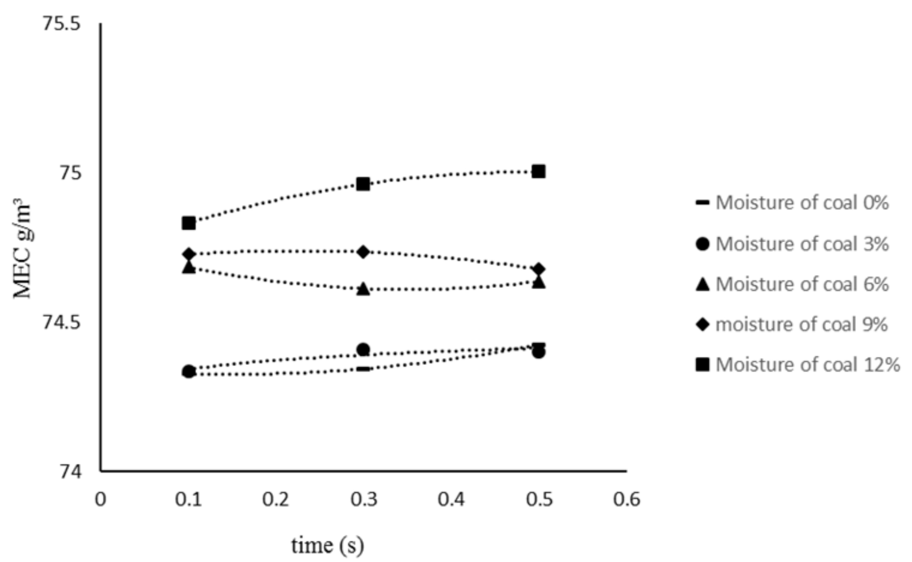


Figure 4.11The effect of MEC with a delay time of coal dust explosion with a particle size less than 45 microns. Compressed air 1.8 kg/cm^2.

The result of the experiment is benefit to design of the safety guideline basic information database use in industry such as to design the apart of the equipment to use in the safety to reference in this factor.

CHAPTER 5
CONCLUSIONS AND RECOMMENDATION

5.1 Conclusion

The difference of the coal particle size in this experiment is observed that the fine particle is easier to ignite more than the large of particle size. Furthermore, the result MEC with the effect of the particle size is measuring that the large particles are high of MEC values so the research to presents that the large particles size are hard to explode and in this experiment 106 micron and 150 microns do not an explosion. Therefore, it is clearly established from the literature the chance for that explosibility increases as the particle size decreases.

The concentration of the coal dust is effected for the explosion in the laboratory scale. Besides, when increasing the concentration of the coal powder effects the hight of the flame of fire in the chamber. It has more effect to explode off the coal explosion tester.

The moisture content in coal effects directly on the explosion at the high in moisture content (12%) it is difficult to have dust explosion. The result presents the moisture of coal has more effect for explosion.al dust explosion is reduced.

The difference of delay time to the dispersion of coal dust powder will delay the explosion. The short time of dust dispersion will measure the chance of explosion.

Coal dust explosion can cause lots of damage. To avoid this, the amount or concentration of coal dust per unit volume or MEC is measured with the various conditions of coal storage such as the particle size, moisture of coal, degree of dispersion and delayed time of ignition source to prevent the coal dust explosion which aims to study and design the explosion safety measures for coal dust handling installations. The results present that moisture content in coal has more effect on dust explosion. The smaller size of the particle, low moisture in coal and high coal dust dispersion can increase the possibility or risk of dust explosion. Also, the shorter time of dust dispersion exposed to ignition source can enhance relatively low the possibility of coal dust explosion.

Coal dust explosion can cause loss of damage. For this reason to avoid this amount of concentration of coal dust per unit volume or MEC is measured with the various conditions of coal storage. And to prevent the coal dust explosion in the warehouse explosion safety measurements from coal dust explosion are recommended for coal storage.

This remains a most important issue in all efforts to decrease the dust explosion hazard. An extensive fire prevention program is not only the housekeeping issue but also as well of address all work activities in which the condition for starting a fire are present for example hot surface work, electrical machinery, belt conveyor, giant dryer, and stacker. Adequate of prevention is an essential means of achieving this aim, as well as the operation and maintenance of engineered technical measurement, and the control of the human to work at there because of the unsafe of the human behaviors was the key to the risk management and enhancement of the safety rule management for workers.so human unsafe behavior will be weakened and the inherent safety of worker should be improved.

The author has suggestion about the guideline to reducing of risk management in the research to present that the Minimum Explosible Concentration of coal is 74.3271 g/m^3 this is a minimum of the coal explosion of case study only.

Dust control and dust are kept clean and neatness. Especially in the coal down usually, a dust and it has to be installed ventilation machine or collecting of coal dust to blowing to dust could. Coal storage facility conveyor belt or coal Elevator and conveyor tube walls need to be cleaned to reduce the accumulation of dust.

Risks in coal dust explosion increase in coal capture or storage in the building, and conveyor belt, therefore, measures of prevention is needed to eliminate the risk of accidents after to evaluate of risk factor from dust pentagon theory, there is some guideline presented in below:

- Installing water sprinkler system to inhibit the formation of the coal dust.
- Installing ventilation of air to reduce the concentration of coal dust that may occur.
- Installing sensor gas or explosive may occur in the plant.
- Installing the cover with a belt conveyor.
- Select stacking method of coal to reduce the formation of dust.

- When transportation coal with a conveyor belt into hopper tunnel, it should be installed the grounding system and both of water spray to controlled dust could.
- Check to the other situation to occur of dust explosion such as fried from smoking, methane gas and coal spontaneous combustion.
- Should be stop falling coal when has high a compressed air.
- Should check the machine and management of the maintenance system in the plant.
- Other measures.

For water springer to control of the dispersion of dust should be careful, normally the velocity of water spray about 15 meters per second or more than this and the moisture content less than 30 percent.

5.2 Recommendation

To improve the research, it should have more functioning of the equipment. For example, the sensor to the measure of moisture content in the compressed air should be installed and should be added more functions of the explosive violent sensitivity sensors for the database to improve for more information of next study in the future.

REFERENCES

.

Eckhoff, R. K. (,2003). Chapter 2 - Case Histories. Dust Explosions in the Process Industries (Third Edition). Burlington, Gulf Professional Publishing**:** 157-198.

Eckhoff, R. K. (,2003). Chapter 4 - Propagation of Flames in Dust Clouds. Dust Explosions in the Process Industries (Third Edition). Burlington, Gulf Professional Publishing**:** 251-IV.

Edwin G. Foulke, J. (,2007). " Portable Fire Extinguishers (Annual Maintenance Certification Record); Extension of the Office of Management and Budget's (OMB) Approval of Information Collection (Paperwork) Requirements."

Fridley, R. H. D. (2011). "The End Of Cheap Coal." Originally published November 18, 2010 in Nature **468**.

Grossel, S. S. (2004). "Dust explosions in the process industries, 3rd edition (2003): By Rolf K. Eckhoff, Gulf Professional Publishing, Burlington, MA, 719 pages, $125.00." Journal of Loss Prevention in the Process Industries **17**(3): 249-250.

H.J. Gluskoter, R. R. R., W.G. Miller, R.A. Cahill, G.b. Dreher, J.K. Kuhn (1977). Trace Elements in Coal occurrence and distibution.

He, X., et al. (2011). "ISMSSE2011Coal Dust Explosion Prevention and Protection Based on Inherent Safety." Procedia Engineering **26**: 1517-1525.

Industrial Fire Prevention (,2010). "The Fire Triangle, Fire Tetrahedron and Dust Explosion Pentagon." from http://industrialfireprevention.blogspot.com/2010/04/fire-triangle-and-fire-tetrahedron.html.

Info, D. E. (,2016). "Wood, coal, grain & sugar all have the potential to explode." from http://www.dustexplosion.info/index.htm.

Massachusetts Institute of Technology (2007). The future of coal.

Miller, B. G. (,2005). Coal energy systems.

Ngo, M. (,2009). DETERMINATION OF THE MINIMUM IGNITION ENERGY (MIE) OF PREMIXED PROPANE/AIR. Department of Physics and Technology, University of Bergen, Norway
Master of Science Program in Process Safety Technology.

Occupational and Environmental Health , D. o. P. o. t. H. E. W. H. O., Geneva (,1999). HAZARD PREVENTION AND CONTROL IN THE WORK ENVIRONMENT:AIRBORNE DUST.

PORT WENTWORTH, G. (,2009). "INVESTIGATION REPORT SUGAR DUST EXPLOSION AND FIRE
" (COMBUSTIBLE DUST HAZARD RECOGNITION ,MINIMIZING COMBUSTIBLE DUST ACCUMULATION IN THE WORKPLACE,EQUIPMENT DESIGN AND MAINTENANCE).

Schoeff, R. W. (,1989). Extension Grain Science and Industry Shellenberger Hall.

Sciences, t. n. A. o. (,2007). Coal research and development to support national energy policy.

Speight, J. G. (2005). HANDBOOK OF COAL ANALYSIS. CANADA.

U.S Energy Information Administration (2016). "International Energy Outlook 2016 (IEO2016)." Retrieved June 30, 2016, from www.eia.doe.gov/oiaf/ieo/index.html.

van Krevelen, D. W. (1961). Coal: Typology, Chemistry, Physics, Constitution, Elsevier Publishing Company.

APPENDIX

The experiment laboratory of lycopodium powder data for calibration with delay time 0.1 second

test date		Name	latana
Volume of glass	No 1: 0.012297 m^3		
name of test powder	lycopodium		weight……………g
particle size	32 micron		
Ambien	temperature (25 c°)		Humidity (37 %)
condition	Temperature (25 c°)	Moisture (0 %)	Spark delay time (0.1S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
Lycopodium	0.5910	48.0605	Explosion
	0.5955	48.4264	Explosion
	0.5955	48.4264	Explosion

The experiment laboratory of lycopodium powder data for calibration with delay time 0.3 second

test date		Name	latana
Volume of glass	No 1: 0.012297 m^3		
name of test powder	lycopodium		weight…………….g
particle size	32 micron		
Ambien	temperature (25 c°)		Humidity (37 %)
condition	Temperature (25 c°)	Moisture (0 %)	Spark delay time (0.3S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
Lycopodium	0.6584	53.5415	Explosion
	0.6582	53.5252	Explosion
	0.7165	58.2662	Explosion

The experiment laboratory of lycopodium powder data for calibration with delay time 0.5 second

test date		Name	latana
Volume of glass	No 1: 0.012297 m^3		
name of test powder	lycopodium		weight……….g
particle size	32 micron		
Ambien	temperature (25 c°)		Humidity (37 %)
condition	Temperature (25 c°)	Moisture (0 %)	Spark delay time (0.5S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
Lycopodium	0.6496	52.8258	Explosion
	0.7044	57.2822	Explosion
	0.7044	57.2822	Explosion

The experiment laboratory of coal with particle size less than 45 micron

test date		Name	latana
Volume of glass	No 1: 0.012297 m³		
name of test powder	Coal dust		weight……….g
particle size	Less than 45 µm		
Ambien	temperature (…37.8….c°)		Humidity (…37…%)
condition	Temperature (37.8 c°)	Moisture 0 %)	Spark delay time (0.1S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
PAN (less than 45 micron)	0.7285	59.24209	sparking
	0.9019	73.34309	sparking
	0.9140	74.3270	explosion

test date		Name	latana
Volume of glass	No 1: 0.012297 m^3		
name of test powder	Coal dust		weight…….g
particle size	Less than 45 µm		
Ambien	temperature (… 37.8…….c°)		Humidity (…37… %)
condition	Temperature (37.8 c°)	Moisture (3 %)	Spark delay time (0.1S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9282	75.4818	explosion
	0.9280	75.4655	explosion
	0.9367	76.17305	explosion

test date		Name	latana
Volume of glass	No ……1…………:	0.012297 m^3	
name of test powder	Coal dust		weight…………g
particle size	Less than 45 µm		
Ambien	temperature (… 37.8….c°)		Humidity (…37…… %)
condition	Temperature (37.8 c°)	Moisture (6 %)	Spark delay time (0.1S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9243	75.16467	explosion
	0.9243	75.16467	explosion
	0.9240	75.14028	explosion

test date		Name	latana
Volume of glass	No ……1…………:		0.012297 m^3
name of test powder	Coal dust		weight…………g
particle size	Less than 45 µm		
Ambien	temperature (37.8 c°)		Humidity (…37… %)
condition	Temperature (37.8...c°)	Moisture (9 %)	Spark delay time (0.1S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9189	74.7255	explosion
	0.9214	74.9288	Burning
	0.9657	78.5313	Burning

test date		Name	latana
Volume of glass	No ……1…………:	0.012297	m^3
name of test powder	Coal dust		weight…………g
particle size	Less than 45 μm		
Ambien	temperature (37.8.c°)		Humidity (…37… %)
condition	Temperature (37.8c°)	Moisture (12%)	Spark delay time (0.1S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9198	74.7987	Burning
	0.9203	74.8393	explosion
	0.9571	77.8319	explosion

The particle size less than 45 micron with delay time 0.3 second

test date		Name	latana
Volume of glass	No ……1…………:	0.012297	m^3
name of test powder	Coal dust		weight…………g
particle size	Less than 45 µm		
Ambien	temperature (… 37.8.c°)		Humidity (…37… %)
condition	temperature(37.8.c°)	Moisture (0 %)	Spark delay time (0.3S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9142	74.3433	explosion
	0.9167	74.5466	explosion
	0.9218	74.9613	explosion

<table>
<tr><td>test date</td><td></td><td>Name</td><td>latana</td></tr>
<tr><td>Volume of glass</td><td colspan="3">No ……1…………: 0.012297 m³</td></tr>
<tr><td>name of test powder</td><td colspan="2">Coal dust</td><td>weight…………………….g</td></tr>
<tr><td>particle size</td><td colspan="3">Less than 45 µm</td></tr>
<tr><td>Ambien</td><td colspan="2">temperature (37.8c°)</td><td>Humidity (…37…… %)</td></tr>
<tr><td>condition</td><td>Temperature (37.8 c°)</td><td>Moisture (3 %)</td><td>Spark delay time (0.3S)</td></tr>
<tr><td>distance sparking</td><td colspan="3">6 mm</td></tr>
<tr><td>compressor air</td><td colspan="3">1.8 kg/cm^2</td></tr>
<tr><td>amount of filter paper</td><td>1 piece</td><td colspan="2">type: Whatman No.93</td></tr>
<tr><td>Number of measurements</td><td colspan="3">3 times</td></tr>
<tr><td>Coal sample</td><td>weight (g)</td><td>MEC (g/m³)</td><td>remark</td></tr>
<tr><td rowspan="3">PAN (less than 45 micron)</td><td>0.9150</td><td>74.4083</td><td>explosion</td></tr>
<tr><td>0.9150</td><td>74.4083</td><td>explosion</td></tr>
<tr><td>0.9151</td><td>74.4165</td><td>explosion</td></tr>
</table>

test date		Name	latana
Volume of glass	No ……1…………: 0.012297 m^3		
name of test powder	Coal dust		weight…………….g
particle size	Less than 45 µm		
Ambien	temperature (37.8….c°)		Humidity (…37…… %)
condition	Temperature (37.8c°)	Moisture (6 %)	Spark delay time (0.3S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9175	74.6116	Explosion
	0.9179	74.6442	Sparking
	0.9198	74.7987	Sparking

test date		Name	latana
Volume of glass	No ……1…………:		0.012297 m^3
name of test powder	Coal dust		weight…………….g
particle size	Less than 45 µm		
Ambien	temperature (37…..c°)		Humidity (…37… %)
condition	temperature(37..c°)	Moisture (9 %)	Spark delay time (0.3S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9181	74.336	Sparking
	0.9190	74.7336	Explosion
	0.9232	75.0752	Sparking

test date		Name	latana
Volume of glass	No ……1…………:	0.012297 m^3	
name of test powder	Coal dust		weight………………g
particle size	Less than 45 µm		
Ambien	temperature (37.8 c°)		Humidity (37 %)
condition	Temperature (37.8 c°)	Moisture (12 %)	Spark delay time (0.3S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9207	74.8719	Sparking
	0.9218	74.9613	Explosion
	0.9230	75.0589	Sparking

The experiment of coal particle size less than 45 micron with delay time 0.5 second

test date		Name	latana
Volume of glass	No ……1…………:		0.012297 m^3
name of test powder	Coal dust		weight……………….g
particle size	Less than 45 µm		
Ambien	temperature (37.8 c°)		Humidity (37 %)
condition	Temperature (37.8 c°)	Moisture (0%)	Spark delay time (0.5S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9143	74.3514	Sparking
	0.9190	74.336	Explosion
	0.9190	74.336	Explosion

test date		Name	latana
Volume of glass	No ……1…………: 0.012297 m^3		
name of test powder	Coal dust		weight……….g
particle size	Less than 45 µm		
Ambien	temperature (37.8 c°)		Humidity (37 %)
condition	Temperatur e (37.8 c°)	Moisture (3%)	Spark delay time (0.5S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9149	74.4002	Sparking
	0.9158	74.4734	Sparking
	0.9162	74.5059	Explosion

test date		Name	latana
Volume of glass	No ……1…………:	0.012297 m^3	
name of test powder	Coal dust		weight…………g
particle size	Less than 45 µm		
Ambien	temperature (37.8 c°)		Humidity (37 %)
condition	Temperature (37.8 c°)	Moisture (6 %)	Spark delay time (0.5S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9178	74.6360	Explosion
	0.9178	74.6360	Explosion
	0.9210	74.8231	Sparking

<table>
<tr><td>test date</td><td></td><td>Name</td><td>latana</td></tr>
<tr><td>Volume of glass</td><td colspan="3">No ……1…………: 0.012297 m^3</td></tr>
<tr><td>name of test powder</td><td colspan="2">Coal dust</td><td>weight……….g</td></tr>
<tr><td>particle size</td><td colspan="3">Less than 45 µm</td></tr>
<tr><td>Ambien</td><td colspan="2">temperature (37.8 c°)</td><td>Humidity (37 %)</td></tr>
<tr><td>condition</td><td>temperature(37.8 c°)</td><td>Moisture (9%)</td><td>Spark delay time (0.5S)</td></tr>
<tr><td>distance sparking</td><td colspan="3">6 mm</td></tr>
<tr><td>compressor air</td><td colspan="3">1.8 kg/cm^2</td></tr>
<tr><td>amount of filter paper</td><td>1 piece</td><td colspan="2">type: Whatman No.93</td></tr>
<tr><td>Number of measurements</td><td colspan="3">3 times</td></tr>
<tr><td>Coal sample</td><td>weight (g)</td><td>MEC (g/m^3)</td><td>remark</td></tr>
<tr><td rowspan="3">PAN (less than 45 micron)</td><td>0.9177</td><td>74.6279</td><td>Explosion</td></tr>
<tr><td>0.9189</td><td>74.7255</td><td>Explosion</td></tr>
<tr><td>0.9189</td><td>74.7255</td><td>Sparking</td></tr>
</table>

test date		Name	latana
Volume of glass	No ……1…………: 0.012297 m³		
name of test powder	Coal dust		weight…………g
particle size	Less than 45 µm		
Ambien	temperature (37.8 c°)		Humidity (37 %)
condition	temperature(37.8 c°)	Moisture (12%)	Spark delay time (0.5S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9216	74.9451	Sparking
	0.9230	75.0589	Explosive
	0.9230	75.0589	Explosive

The experiment of coal particle size with Pan less than 45 with delay time 0.1 second and compressed air at 1.0 kg/cm^2

test date		Name	latana
Volume of glass	No ……1…………:		0.012297 m^3
name of test powder	Coal dust		weight……….g
particle size	Less than 45 µm		
Ambien	temperature (37.8 c°)		Humidity (37 %)
condition	Temperature (37.8 c°)	Moisture (0 %)	Spark delay time (0.1S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9196	74.7826	Sparking
	0.9222	74.9939	Sparking
	0.9253	75.2459	Explosion

test date		Name	latana
Volume of glass	No ……1…………:		0.012297 m^3
name of test powder	Coal dust		weight……….g
particle size	Less than 45 µm		
Ambien	temperature (37.8 c°)		Humidity (48 %)
condition	Temperatur e (37.8 c°)	Moisture (3 %)	Spark delay time (0.1S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9280	75.4656	Explosion
	0.9282	75.48182	Explosion
	0.9367	76.1731	Explosion

test date		Name	latana
Volume of glass	No ……1……:	0.012297	m^3
name of test powder	Coal dust		weight……….g
particle size	Less than 45 µm		
Ambien	temperature (37.8 c°)		Humidity (37 %)
condition	Temperature (37.8 c°)	Moisture (6 %)	Spark delay time (0.1S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9195	74.7743	Explosion
	0.9200	74.8149	Sparking
	0.9271	75.3923	Explosion

test date		Name	latana
Volume of glass	No ……1…………: 0.012297 m^3		
name of test powder	Coal dust		weight…….g
particle size	Less than 45 µm		
Ambien	temperature (37.8 c°)		Humidity (37 %)
condition	Temperature (37.8 c°)	Moisture (9 %)	Spark delay time (0.1S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9220	74.9776	Sparking
	0.9240	75.1402	Explosion
	0.9216	74.9451	Explosion

The particle size with Pan less than 45 with delay time 0.1 second and compressed air at 0.5 kg/cm^2

test date	06/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m^3	
name of test powder	Coal dust		weight……….g
particle size	Less than 45 µm		
Ambien	temperature (37.8 c°)		Humidity (48 %)
condition	Temperature (37.8 c°)	Moisture (0%)	Spark delay time (0.1S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9258	75.226	Sparking
	0.9286	75.5143	Explosion
	0.9259	75.2947	Explosion

test date	06/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m³	
name of test powder	Coal dust		weight……….g
particle size	Less than 45 µm		
Ambien	temperature (37.8 c°)		Humidity (48 %)
condition	Temperatur e (37.8 c°)	Moisture (3%)	Spark delay time (0.1S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
PAN (less than 45 micron)	0.9256	75.2703	Explosion
	0.9240	75.1402	Explosion
	0.93	75.6282	Explosion

test date	06/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m³	
name of test powder	Coal dust		weight……….g
particle size	Less than 45 µm		
Ambien	temperature (37.8 c°)		Humidity (48 %)
condition	Temperature (37.8 c°)	Moisture (6 %)	Spark delay time (0.1S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
PAN (less than 45 micron)	0.9255	75.0182	Explosion
	0.9244	75.1728	Explosion
	0.9329	75.8640	Explosion

test date	06/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m^3
name of test powder	Coal dust		weight…….g
particle size	Less than 45 µm		
Ambien	temperature (37.8 c°)		Humidity (48 %)
condition	Temperature (37.8 c°)	Moisture (9 %)	Spark delay time (0.1S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9244	75.1728	Sparking
	0.9248	75.2053	Explosion
	0.9228	75.0426	Sparking

<table>
<tr><td>test date</td><td>06/04/2016</td><td>Name</td><td>latana</td></tr>
<tr><td>Volume of glass</td><td colspan="3">No ……1……: 0.012297 m³</td></tr>
<tr><td>name of test powder</td><td colspan="2">Coal dust</td><td>weight……….g</td></tr>
<tr><td>particle size</td><td colspan="3">Less than 45 µm</td></tr>
<tr><td>Ambien</td><td colspan="2">temperature (37.8 c°)</td><td>Humidity (48 %)</td></tr>
<tr><td>condition</td><td>Temperature
(37.8 c°)</td><td>Moisture
(12 %)</td><td>Spark delay time
(0.1S)</td></tr>
<tr><td>distance sparking</td><td colspan="3">6 mm</td></tr>
<tr><td>compressor air</td><td colspan="3">0.5 kg/cm^2</td></tr>
<tr><td>amount of filter paper</td><td>1 piece</td><td colspan="2">type: Whatman No.93</td></tr>
<tr><td>Number of measurements</td><td colspan="3">3 times</td></tr>
<tr><td>Coal sample</td><td>weight (g)</td><td>MEC (g/m³)</td><td>remark</td></tr>
<tr><td rowspan="3">PAN (less than 45 micron)</td><td>0.9257</td><td>75.2785</td><td>Explosion</td></tr>
<tr><td>0.9289</td><td>75.5387</td><td>Explosion</td></tr>
<tr><td>0.9255</td><td>75.2622</td><td>Explosion</td></tr>
</table>

The experiment of coal particle size with Pan less than 45 with delay time 0.3 second and compressed air at 0.5 kg/cm^2

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m³	
name of test powder	Coal dust		weight……….g
particle size	Less than 45 µm		
Ambien	temperature (40 c°)		Humidity (48 %)
condition	Temperatur e (37.8 c°)	Moisture (0 %)	Spark delay time (0.3S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
PAN (less than 45 micron)	0.9233	75.0833	Sparking
	0.9250	75.2215	Explosion
	0.9250	75.2215	Explosion

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………: 0.012297 m^3		
name of test powder	Coal dust		weight……….g
particle size	Less than 45 µm		
Ambien	temperature (39.8 c°)		Humidity (48 %)
condition	Temperature (37.8 c°)	Moisture (3 %)	Spark delay time (0.3S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9245	75.18093	Explosion
	0.9264	75.3354	Sparking
	0.9264	75.3354	Sparking

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m^3
name of test powder	Coal dust		weight……….g
particle size	Less than 45 µm		
Ambien	temperature (39.8 c°)		Humidity (48 %)
condition	Temperature (37.8 c°)	Moisture (6 %)	Spark delay time (0.3S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9181	74.6604	Explosion
	0.9236	75.1077	Explosion
	0.9236	75.1077	Explosion

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m³
name of test powder	Coal dust		weight…………g
particle size	Less than 45 µm		
Ambien	temperature (39.8 c°)		Humidity (48 %)
condition	Temperatur e (37.8 c°)	Moisture (9 %)	Spark delay time (0.3S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
PAN (less than 45 micron)	0.9251	75.2297	Sparking
	0.9222	74.9939	Explosion
	0.9224	75.0101	Explosion

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m³
name of test powder	Coal dust		weight…………g
particle size	Less than 45 µm		
Ambien	temperature (41 c°)		Humidity (48 %)
condition	Temperature (37.8 c°)	Moisture (12%)	Spark delay time (0.3S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
PAN (less than 45 micron)	0.9268	75.3679	Explosion
	0.9259	75.2947	Explosion
	0.9259	75.2947	Explosion

The experiment of coal particle size with Pan less than 45 with delay time 0.3 second

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m³
name of test powder	Coal dust		weight……….g
particle size	Less than 45 µm		
Ambien	temperature (39.8 c°)		Humidity (48 %)
condition	Temperature (37.8 c°)	Moisture (0 %)	Spark delay time (0.3S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
PAN (less than 45 micron)	0.9209	74.8881	Explosion
	0.9223	75.0020	Explosion
	0.9224	75.0101	Explosion

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………: 0.012297 m^3		
name of test powder	Coal dust		weight………g
particle size	Less than 45 µm		
Ambien	temperature (39.8 c°)		Humidity (48 %)
condition	temperature(37.8 c°)	Moisture (3 %)	Spark delay time (03S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9193	75.7580	Explosion
	0.9209	74.8881	Sparking
	0.9209	74.8881	Sparking

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m³
name of test powder	Coal dust		weight……….g
particle size	Less than 45 µm		
Ambien	temperature (39.8 c°)		Humidity (48 %)
condition	Temperature (37.8 c°)	Moisture (6 %)	Spark delay time (0.3S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
PAN (less than 45 micron)	0.9157	74.4653	Explosion
	0.9190	74.7336	Explosion
	0.9190	74.7336	Explosion

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m³
name of test powder	Coal dust		weight…………….g
particle size	Less than 45 µm		
Ambien	temperature (39.8 c°)		Humidity (48 %)
condition	Temperature (37.8 c°)	Moisture (9 %)	Spark delay time (0.3S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
PAN (less than 45 micron)	0.9205	74.8556	Explosion
	0.9228	75.0426	Explosion
	0.9228	75.0426	Explosion

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m³
name of test powder	Coal dust		weight……….g
particle size	Less than 45 µm		
Ambien	temperature (39.8 c°)		Humidity (48 %)
condition	Temperature (37.8 c°)	Moisture (12 %)	Spark delay time (0.3S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
PAN (less than 45 micron)	0.9261	75.3110	Explosion
	0.9451	75.2297	Explosion
	0.9450	76.8480	Explosion

The experiment of coal particle size with Pan less than 45 with delay time 0.5 second and compressed air at 1.0 kg/cm^2

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m³	
name of test powder	Coal dust		weight……….g
particle size	Less than 45 µm		
Ambien	temperature (39.8 c°)		Humidity (48 %)
condition	Temperature (37 c°)	Moisture (0%)	Spark delay time (0.5S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
PAN (less than 45 micron)	0.9196	74.7824	Sparking
	0.9222	74.9939	Sparking
	0.9253	75.249	Explosion

<table>
<tr><td>test date</td><td>13/04/2016</td><td>Name</td><td>latana</td></tr>
<tr><td>Volume of glass</td><td colspan="3">No ……1…………: 0.012297 m³</td></tr>
<tr><td>name of test powder</td><td colspan="2">Coal dust</td><td>weight……….g</td></tr>
<tr><td>particle size</td><td colspan="3">Less than 45 µm</td></tr>
<tr><td>Ambien</td><td colspan="2">temperature (39.8 c°)</td><td>Humidity (48 %)</td></tr>
<tr><td>condition</td><td>Temperature
(37 c°)</td><td>Moisture
(3%)</td><td>Spark delay time
(0.5S)</td></tr>
<tr><td>distance sparking</td><td colspan="3">6 mm</td></tr>
<tr><td>compressor air</td><td colspan="3">1.0 kg/cm²</td></tr>
<tr><td>amount of filter paper</td><td>1 piece</td><td colspan="2">type: Whatman No.93</td></tr>
<tr><td>Number of measurements</td><td colspan="3">3 times</td></tr>
<tr><td>Coal sample</td><td>weight (g)</td><td>MEC
(g/m³)</td><td>remark</td></tr>
<tr><td rowspan="3">PAN (less than 45 micron)</td><td>0.9196</td><td>74.5629</td><td>Sparking</td></tr>
<tr><td>0.9196</td><td>74.7824</td><td>Explosion</td></tr>
<tr><td>0.9207</td><td>74.8719</td><td>Explosion</td></tr>
</table>

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m^3	
name of test powder	Coal dust		weight…………….g
particle size	Less than 45 µm		
Ambien	temperature (39.8 c°)		Humidity (48 %)
condition	Temperature (37 c°)	Moisture (6%)	Spark delay time (0.5S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9177	74.6279	Explosion
	0.9211	74.9044	Sparking
	0.9220	74.9776	Explosion

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………: 0.012297 m^3		
name of test powder	Coal dust		weight……….g
particle size	Less than 45 µm		
Ambien	temperature (39.8 c°)		Humidity (48 %)
condition	Temperature (37.8 c°)	Moisture (9 %)	Spark delay time (0.5S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	09191	74.7418	Explosion
	0.9185	74.6930	Explosion
	0.9185	74.6930	Explosion

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m^3	
name of test powder	Coal dust		weight……….g
particle size	Less than 45 µm		
Ambien	temperature (39.8 c°)		Humidity (48 %)
condition	Temperature (37.8 c°)	Moisture (12%)	Spark delay time (0.5S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9244	75.1728	Sparking
	0.9251	75.2297	Explosion
	0.9252	75.2378	Explosion

The experiment of coal particle size with Pan less than 45 with delay time 0.5 second and compressed air at 0.5 kg/cm^2

test date	13/04/2016	Name	latana
Volume of glass	No ……1……: 0.012297 m^3		
name of test powder	Coal dust		weight……….g
particle size	Less than 45 µm		
Ambien	temperature (39.8 c°)		Humidity (48 %)
condition	Temperature (37.8 c°)	Moisture (0 %)	Spark delay time (0.5S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9235	75.0996	Explosion
	0.9243	75.1646	Explosion
	0.9152	74.42	Explosion

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m³	
name of test powder	Coal dust		weight……………g
particle size	Less than 45 µm		
Ambien	temperature (39.8 c°)		Humidity (48 %)
condition	Temperature (37.8 c°)	Moisture (3 %)	Spark delay time (0.5S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
PAN (less than 45 micron)	0.9237	75.1158	Sparking
	0.9247	75.1972	Sparking
	0.9253	75.24	Explosion

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m^3
name of test powder	Coal dust		weight…………g
particle size	Less than 45 µm		
Ambien	temperature (39.8 c°)		Humidity (48 %)
condition	Temperatur e (37.8 c°)	Moisture (6 %)	Spark delay time (0.5S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9237	75.0589	Explosion
	0.9241	75.1484	Sparking
	0.9199	74.8068	Explosion

test date	13/04/2016	Name	latana
Volume of glass	No ……1……: 0.012297 m^3		
name of test powder	Coal dust		weight………g
particle size	Less than 45 µm		
Ambien	temperature (39.8 c°)		Humidity (48 %)
condition	Temperatur e (37.8 c°)	Moisture (9 %)	Spark delay time (0.5S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.9197	7.7905	Explosion
	0.9205	74.7905	Explosion
	0.9205	74.7905	Explosion

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m^3	
name of test powder	Coal dust		weight…………….g
particle size	Less than 45 μm		
Ambien	temperature (39 c°)		Humidity (48 %)
condition	Temperature (37.8 c°)	Moisture (12%)	Spark delay time (0.5 S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
PAN (less than 45 micron)	0.955	75.2622	Explosion
	0.9263	75.3273	Explosion
	0.9263	75.3273	Explosion

The experiment laboratory with particle size 45 micron.

test date	13/04/2016	Name	latana
Volume of glass	No ……1……: 0.012297 m³		
name of test powder	Coal dust		weight…………g
particle size	45 µm		
Ambien	temperature (39 c°)		Humidity (38 %)
condition	Temperature (37.8 c°)	Moisture (0%)	Spark delay time (0.5 S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
45 micron	0.9150	74.4083	Explosion
	0.9167	74.5466	Explosion
	0.9244	75.1728	Explosion

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m^3	
name of test powder	Coal dust		weight…………g
particle size	45 µm		
Ambien	temperature (39 c°)		Humidity (38 %)
condition	Temperature (37.8 c°)	Moisture (3%)	Spark delay time (0.5 S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
45 micron	0.9208	74.8800	Explosion
	0.9239	75.1321	Explosion
	0.9180	74.6523	Explosion

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………: 0.012297 m^3		
name of test powder	Coal dust		weight………………g
particle size	45 µm		
Ambien	temperature (39 c°)		Humidity (38 %)
condition	Temperature (37.8 c°)	Moisture (6%)	Spark delay time (0.5 S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
45 micron	0.9256	75.2703	Sparking
	0.9243	75.1646	Explosion
	0.9243	75.1646	Explosion

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………: 0.012297 m³		
name of test powder	Coal dust		weight………………g
particle size	45 µm		
Ambien	temperature (39 c°)		Humidity (38 %)
condition	Temperature (37.8 c°)	Moisture (9%)	Spark delay time (0.5 S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
45 micron	0.9256	75.2703	Sparking
	0.9243	75.1646	Explosion
	0.9243	75.1646	Explosion

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m^3
name of test powder	Coal dust		weight………………g
particle size	45 µm		
Ambien	temperature (39 c°)		Humidity (38 %)
condition	Temperature (37.8 c°)	Moisture (12%)	Spark delay time (0.5 S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
45 micron	0.9260	75.3029	Sparking
	0.9274	75.4167	Explosion
	0.9302	75.6444	Explosion

The experiment laboratory data with 45 micron. Delay time 0.1 Second, compressed air 1.0 kg./cm^2.

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m³	
name of test powder	Coal dust		weight……………….g
particle size	45 µm		
Ambien	temperature (39 c°)		Humidity (38 %)
condition	Temperature (37.8 c°)	Moisture (0%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
45 micron	0.9237	75.1158	Explosion
	0.9244	75.1728	Explosion
	0.9244	75.1728	Explosion

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m³	
name of test powder	Coal dust		weight………….g
particle size	45 µm		
Ambien	temperature (39 c°)		Humidity (38 %)
condition	Temperature (37.8 c°)	Moisture (3%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
45 micron	0.9271	75.3923	Explosion
	0.9248	75.2053	Sparking
	0.9258	75.2866	Explosion

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………: 0.012297 m^3		
name of test powder	Coal dust		weight……………….g
particle size	45 µm		
Ambien	temperature (39 c°)		Humidity (38 %)
condition	Temperature (37.8 c°)	Moisture (6%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
45 micron	0.9230	75.0589	Explosion
	0.9243	75.1646	Sparking
	0.9243	75.1646	Explosion

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………: 0.012297 m^3		
name of test powder	Coal dust		weight……………….g
particle size	45 µm		
Ambien	temperature (39 c°)		Humidity (38 %)
condition	Temperature (37.8 c°)	Moisture (9%)	Spark delay time (0.1S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
45 micron	0.9245	75.1809	Explosion
	0.9251	75.2297	Explosion
	0.9253	75.2459	Explosion

test date	13/04/2016	Name	latana
Volume of glass	No ……1…………: 0.012297 m^3		
name of test powder	Coal dust		weight………………g
particle size	45 µm		
Ambien	temperature (39 c°)		Humidity (38 %)
condition	Temperature (37.8 c°)	Moisture (12%)	Spark delay time (0.1S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
45 micron	0.9252	75.2378	Explosion
	0.9268	75.3679	Explosion
	0.9268	75.3679	Explosion

Measurement of MEC with coal moisture content and compressed air 0.5 kg/cm^2

test date	25/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m³
name of test powder	Coal dust		weight……………….g
particle size	45 µm		
Ambien	temperature (39.5 c°)		Humidity (38 %)
condition	Temperature (39.5c°)	Moisture (0%)	Spark delay time (0.1S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
45 micron	0.9253	75.2459	Explosion
	0.9268	75.3679	Explosion
	0.9268	75.3679	Explosion

test date	25/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m^3	
name of test powder	Coal dust		weight………………g
particle size	45 µm		
Ambien	temperature (39.5 c°)		Humidity (38 %)
condition	Temperature (39.5 c°)	Moisture (3%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
45 micron	0.9253	75.2459	Explosion
	0.9268	75.3697	Explosion
	0.9240	75.140	Explosion

test date	25/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m³	
name of test powder	Coal dust		weight……………….g
particle size	45 µm		
Ambien	temperature (39.5 c°)		Humidity (38 %)
condition	Temperature (39.5 c°)	Moisture (6%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
45 micron	0.9249	75.2134	Explosion
	0.9255	75.2622	Explosion
	0.9250	75.2215	Explosion

test date	25/04/2016	Name	latana
Volume of glass	No ……1…………: 0.012297 m^3		
name of test powder	Coal dust		weight…………g
particle size	45 µm		
Ambien	temperature (39.5 c°)		Humidity (38 %)
condition	Temperature (39.5 c°)	Moisture (9%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
45 micron	0.9301	75.6363	Explosion
	0.9318	75.7745	Explosion
	0.9318	75.7745	Explosion

test date	25/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m³	
name of test powder	Coal dust		weight……………….g
particle size	45 µm		
Ambien	temperature (39.5 c°)		Humidity (37 %)
condition	Temperature (39.5 c°)	Moisture (12%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
45 micron	0.9283	75.4899	Sparking
	0.9299	75.6200	Sparking
	0.9320	75.7908	Explosion

Measurement of MEC of coal particle size 53 micron with coal moisture content and compressed air 1.8 kg/cm^2

test date	25/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297	m³
name of test powder	Coal dust		weight……………….g
particle size	53 µm		
Ambien	temperature (39c°)		Humidity (38 %)
condition	Temperature (39 c°)	Moisture (0%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
53 micron	0.9263	75.3273	Sparking
	0.9272	75.4005	Explosion
	0.9278	75.4492	Explosion

test date	25/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m^3
name of test powder	Coal dust		weight……….g
particle size	53 µm		
Ambien	temperature (39c°)		Humidity (38 %)
condition	Temperature (39 c°)	Moisture (3%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
53 micron	0.9271	75.3923	Explosion
	0.9268	75.3679	Explosion
	0.9270	75.3842	Explosion

test date	25/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297	m³
name of test powder	Coal dust		weight……….g
particle size	53 µm		
Ambien	temperature (39c°)		Humidity (38 %)
condition	Temperatur e (39 c°)	Moisture (6%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
53 micron	0.9289	75.5387	Explosion
	0.9301	75.6363	Explosion
	0.9301	75.6363	Explosion

test date	25/04/2016	Name	latana
Volume of glass	No ……1…………: 0.012297 m^3		
name of test powder	Coal dust		weight……………….g
particle size	53 µm		
Ambien	temperature (39c°)		Humidity (38 %)
condition	Temperature (39 c°)	Moisture (9%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
53 micron	0.9281	75.4736	Sparking
	0.9316	75.7583	Explosion
	0.930	75.6282	Explosion

test date	25/04/2016	Name	latana
Volume of glass	No ……1…………: 0.012297 m³		
name of test powder	Coal dust		weight……………….g
particle size	53 µm		
Ambien	temperature (39c°)		Humidity (38 %)
condition	Temperature (39 c°)	Moisture (12%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
53 micron	0.9304	75.6607	Sparking
	0.9318	75.7745	Explosion
	0.9289	75.5387	Explosion

Measurement of MEC of coal particle size 53 micron with coal moisture content and compressed air 1.0 kg/cm^2

test date	26/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m³
name of test powder	Coal dust		weight…………g
particle size	53 µm		
Ambien	temperature (39c°)		Humidity (38 %)
condition	Temperature (39 c°)	Moisture (0%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
53 micron	0.9265	75.3435	Explosion
	0.9272	75.4005	Explosion
	0.9272	75.4005	Explosion

test date	26/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m^3	
name of test powder	Coal dust		weight……….g
particle size	53 µm		
Ambien	temperature (39c°)		Humidity (38 %)
condition	Temperature (39 c°)	Moisture (3%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
53 micron	0.9293	75.5712	Explosion
	0.9288	75.5306	Explosion
	0.9287	75.5224	Explosion

test date	26/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m^3	
name of test powder	Coal dust		weight……g
particle size	53 µm		
Ambien	temperature (39c°)		Humidity (38 %)
condition	Temperature (39 c°)	Moisture (6%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
53 micron	0.9267	75.3598	Explosion
	0.9279	75.4574	Explosion
	0.9270	75.3842	Explosion

test date	26/04/2016	Name	latana
Volume of glass	No ……1…………: 0.012297 m^3		
name of test powder	Coal dust		weight….g
particle size	53 µm		
Ambien	temperature (39c°)		Humidity (38 %)
condition	Temperature (39 c°)	Moisture (9%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
53 micron	0.9276	75.4330	Explosion
	0.9294	75.57940	Explosion
	0.9290	75.5468	Explosion

test date	26/04/2016	Name	latana
Volume of glass	No ……1…………: 0.012297 m³		
name of test powder	Coal dust		weight…………g
particle size	53 µm		
Ambien	temperature (39c°)		Humidity (38 %)
condition	Temperature (39 c°)	Moisture (12%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
53 micron	0.9296	75.5956	Explosion
	0.9322	75.8071	Explosion
	0.9320	75.7908	Explosion

test date	26/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m^3
name of test powder	Coal dust		weight……….g
particle size	53 µm		
Ambien	temperature (39c°)		Humidity (38 %)
condition	Temperature (39 c°)	Moisture (0%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
53 micron	0.9266	75.3517	Explosion
	0.9288	75.5306	Explosion
	0.9285	75.5062	Explosion

test date	26/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m³
name of test powder	Coal dust		weight……….g
particle size	53 µm		
Ambien	temperature (39c°)		Humidity (38 %)
condition	Temperature (39 c°)	Moisture (3%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
53 micron	0.9290	75.5468	Explosion
	0.9312	75.7257	Explosion
	0.9318	75.7745	Explosion

test date	26/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m^3
name of test powder	Coal dust		weight…………g
particle size	53 µm		
Ambien	temperature (39c°)		Humidity (38 %)
condition	Temperature (39 c°)	Moisture (6%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
53 micron	0.9291	75.5550	Sparking
	0.9306	75.6769	Sparking
	0.9313	75.7339	Explosion

test date	26/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m^3	
name of test powder	Coal dust		weight…………g
particle size	53 µm		
Ambien	temperature (39c°)		Humidity (38 %)
condition	Temperature (39 c°)	Moisture (9%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
53 micron	0.9291	75.5550	Sparking
	0.9314	75.7420	Explosion
	0.9353	76.0592	Explosion

test date	26/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m³
name of test powder	Coal dust		weight……….g
particle size	53µm		
Ambien	temperature (39c°)		Humidity (38 %)
condition	Temperature (39 c°)	Moisture (12%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	0.5 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
53 micron	0.9285	75.5062	Sparking
	0.9329	75.8640	Explosion
	0.9368	76.1811	Explosion

The measurement MEC of coal particle size 75 micron

test date	28/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m³	
name of test powder	Coal dust		weight…………g
particle size	75 µm		
Ambien	temperature (39c°)		Humidity (38 %)
condition	Temperature (39 c°)	Moisture (0 %)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
75 micron	0.9278	75.4492	Explosion
	0.9349	76.0266	Explosion
	0.9339	75.9453	Explosion

test date	26/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m³	
name of test powder	Coal dust		weight……………….g
particle size	75 µm		
Ambien	temperature (39c°)		Humidity (38 %)
condition	Temperature (39 c°)	Moisture (3%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
75 micron	0.9273	75.4086	Explosion
	0.9327	75.8477	Explosion
	0.9328	75.8558	Sparking

test date	26/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m³
name of test powder	Coal dust		weight……………….g
particle size	75 µm		
Ambien	temperature (39c°)		Humidity (38 %)
condition	Temperature (39 c°)	Moisture (6%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m³)	remark
75 micron	0.9273	75.4086	Explosion
	0.931	75.7095	Explosion
	0.931	75.7095	Explosion

test date	26/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m^3
name of test powder	Coal dust		weight……………….g
particle size	75 µm		
Ambien	temperature (39c°)		Humidity (38 %)
condition	Temperature (39 c°)	Moisture (9%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
75 micron	0.9289	75.5387	Sparking
	0.9307	75.6851	Explosion
	0.9300	75.6282	Explosion

test date	26/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m^3	
name of test powder	Coal dust		weight……………….g
particle size	75 µm		
Ambien	temperature (39c°)		Humidity (38 %)
condition	Temperature (39 c°)	Moisture (12%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.8 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
75 micron	0.9285	75.5062	Sparking
	0.9327	75.6607	Sparking
	0.9327	75.8477	Explosion

test date	26/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m^3
name of test powder	Coal dust		weight……….g
particle size	75 µm		
Ambien	temperature (39c°)		Humidity (42 %)
condition	Temperature (39 c°)	Moisture (0%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
75 micron	0.927	75.3842	Explosion
	0.9275	75.4249	Explosion
	0.9290	75.5468	Sparking

test date	26/04/2016	Name	latana
Volume of glass	No ……1…………:		0.012297 m^3
name of test powder	Coal dust		weight……….g
particle size	75 µm		
Ambien	temperature (39c°)		Humidity (42 %)
condition	Temperature (39 c°)	Moisture (3%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
75 micron	0.9290	75.5468	Explosion
	0.9285	75.5062	Explosion
	0.9276	75.4330	Explosion

test date	26/04/2016	Name	latana
Volume of glass	No ……1……:	0.012297	m^3
name of test powder	Coal dust		weight……….g
particle size	75 µm		
Ambien	temperature (39c°)		Humidity (42 %)
condition	Temperature (39 c°)	Moisture (6%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
75 micron	0.9276	75.4330	Sparking
	0.9290	75.5468	Sparking
	0.9310	75.7095	Explosion

test date	26/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m^3	
name of test powder	Coal dust		weight…………g
particle size	75 µm		
Ambien	temperature (39c°)		Humidity (42 %)
condition	Temperature (39 c°)	Moisture (9%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
75 micron	0.9289	75.5387	Sparking
	0.9320	75.7908	Sparing
	0.9340	75.953	Explosion

test date	26/04/2016	Name	latana
Volume of glass	No ……1…………:	0.012297 m^3	
name of test powder	Coal dust		weight…………g
particle size	75 µm		
Ambien	temperature (39c°)		Humidity (42 %)
condition	Temperature (39 c°)	Moisture (12%)	Spark delay time (0.1 S)
distance sparking	6 mm		
compressor air	1.0 kg/cm^2		
amount of filter paper	1 piece	type: Whatman No.93	
Number of measurements	3 times		
Coal sample	weight (g)	MEC (g/m^3)	remark
75 micron	0.9293	75.5712	Sparking
	0.9300	75.6282	Sparking
	0.935	76.0348	Explosion

VITA

Ms.LATANA CHANTHAPHASOUK was born on June 02.1992 ,she received Bachelor's degree in Mining engineering, Faculty of engineering, University of Laos in 2014 ,and she get the scholarship of AUN-SEED/Net from 2014 to 2016 in chulalongkorn University, faculty of engineering, Department of Mining and petroleum,Thailand