

EXPLOSION MECHANICS IN HAZARDOUS AREAS WITH FRICTION IGNITION

1. INTRODUCTION

The Mechanics of Explosion in Hazardous Areas when ignition occurs due to Friction between Surfaces. In this chapter, we will explore the factors involved in this process and the prevention and mitigation measures that can be adopted to ensure the safety of workers and installations.

In hazardous areas where flammable substances are present, understanding the mechanics of explosion is essential to avoid serious incidents. An explosion occurs when there is a rapid release of energy in a confined space, resulting in a shock wave and a sudden expansion of gases. Ignition is the trigger for the explosion, and friction between surfaces can play a significant role in this process.

In this chapter, we will focus specifically on ignition by friction. When two surfaces are in contact and there is relative movement between them, energy is transferred in the form of heat due to the friction generated. In classified areas where flammable substances are present, the generation of heat from friction can be enough to raise the temperature of the environment to a level capable of initiating a combustion reaction.

For a complete understanding, we will explore the factors involved in the friction ignition process, such as the coefficient of friction, the speed and pressure of contact, and the exposure time. In addition, we will discuss the prevention and mitigation measures that can be adopted to reduce the risk of explosions in these situations.

Throughout this chapter, we will provide detailed information on these topics, including practical examples and step-by-step instructions for a better understanding. Our aim is to enable you to identify the risks associated with friction in hazardous areas and implement appropriate measures to ensure the safety of everyone involved.

2. THE IMPORTANCE OF FRICTION AS A SOURCE OF IGNITION

Friction between two surfaces is a phenomenon that occurs when there is resistance to relative movement between them. During friction, part of the mechanical energy is converted into heat due to the friction generated. In classified areas where flammable hydrocarbons are present, it is essential to understand the relationship between friction and the potential for ignition.

For a more precise analysis, it is important to consider the friction coefficients of the materials involved. The coefficient of friction is a measure of the resistance to relative

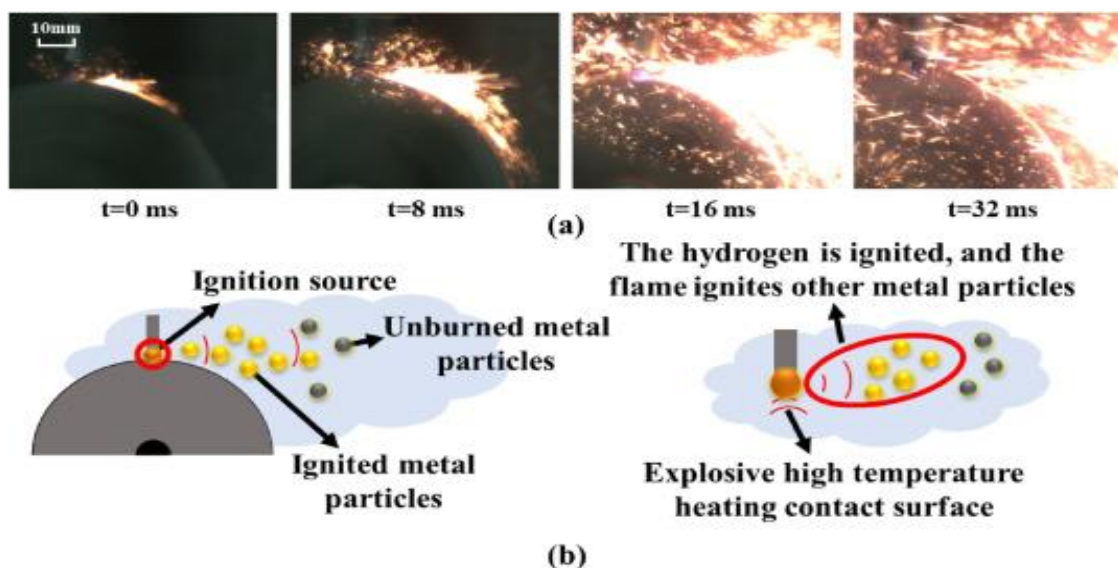
movement between two surfaces in contact. The higher the coefficient of friction, the greater the force required to overcome the resistance to movement.

Here is a table with the static friction coefficients (μ_s) of some common materials found in installations within hazardous areas:

Material	Coefficiente de Atrito Estático (μ_s)
Aço sobre aço	0,74
Aço sobre concreto	0,60 - 0,85
Aço sobre madeira seca	0,50 - 0,80
Aço sobre borracha seca	0,62
Aço sobre gelo	0,03
Aço sobre graxa	0,10 - 0,15
Aço sobre óleo lubrificante	0,10
Aço sobre vidro	0,94
Aço sobre plástico	0,30 - 0,60

It is important to remember that these values are only a general reference and can vary depending on specific surface conditions, such as roughness, humidity, and the presence of contaminants.

When carrying out design, operations, or maintenance on installations within hazardous areas, it is crucial to consider these coefficients of friction in order to assess the risk of excessive heat generation and the possibility of ignition. Appropriate prevention and mitigation measures must be implemented based on this information.



3. FACTORS INFLUENCING THE OCCURRENCE OF FRICTION IGNITION

3.1 Coefficient of friction: The coefficient of friction is an important factor in the generation of heat during friction between surfaces. Materials with higher coefficients of friction are more likely to generate enough heat to cause ignition in hazardous areas. For example, if two surfaces with a high coefficient of friction, such as metal and metal, are in contact and there is relative movement between them, the amount of heat generated will be greater compared to surfaces with lower coefficients of friction, such as metal and plastic.

3.2 Contact pressure: The contact pressure between surfaces is another factor that influences frictional heat generation. Increases in contact pressure can result in greater heat generation and, consequently, a greater risk of ignition. For example, if surfaces are subject to a higher contact pressure due to applied loads or external forces, the amount of heat generated during friction will be greater. This is due to the increased contact area and the greater frictional force involved.

3.3 Sliding speed: The sliding speed between surfaces also plays a crucial role in heat generation and the risk of ignition. The higher the sliding speed, the greater the heat generation during friction. This is because the kinetic energy transformed into thermal energy is directly proportional to the sliding speed. Therefore, if surfaces are moving quickly relative to each other, there will be a significant increase in heat generation and, consequently, in the risk of ignition in hazardous areas.

These factors - **coefficient of friction, contact pressure and sliding speed** - are fundamental to understanding the risk of frictional ignition in hazardous areas. It is important to consider these factors when analysing and assessing the safety of installations and processes in environments where flammable substances are present.

4. PREVENTION AND MITIGATION OF FRICTION IGNITION

Selection of materials: The proper selection of materials in hazardous areas is crucial to reducing the risk of excessive heat generation due to friction. Using materials with suitable friction coefficients that are compatible with each other can help minimise the amount of heat generated during friction. For example, if there is a need for two surfaces to be in contact in the classified environment, choosing materials with lower coefficients of friction can reduce the risk of ignition.

Lubrication: The application of suitable lubricants between the surfaces in contact is an effective measure to reduce friction and, consequently, the risk of frictional ignition. Lubricants form a protective layer between surfaces, reducing the coefficient of friction and minimising the heat generated during relative movement. It is important to choose

lubricants that are compatible with the materials involved and to take environmental conditions into account to ensure their effectiveness.

Temperature monitoring: Carrying out continuous temperature monitoring in areas with friction potential is an important preventative measure. This can be done using temperature sensors installed in critical locations. Monitoring makes it possible to identify situations of imminent risk, where the temperature is rising dangerously due to friction. In this way, corrective action can be taken before an ignition occurs.

Training and awareness: Providing workers with adequate training is essential to ensure safety in hazardous areas. It is important that they are aware of the risks associated with friction ignition and understand the importance of preventive measures. Training should cover topics such as the proper selection of materials, the correct application of lubricants and the need to monitor temperature. In addition, workers should be instructed on the actions to be taken in the event of detecting a rise in temperature or an imminent risk of ignition.

These friction ignition prevention and mitigation measures are fundamental to ensuring safety in hazardous areas. By adopting these measures, it is possible to significantly reduce the risk of explosions and protect both workers and installations.

5. REFERENCE STANDARDS

There are a number of standards and procedures relevant to the prevention of explosions in hazardous areas.

Some examples include:

- **ABNT NBR IEC 60079-32-1 standard:** This standard specifies the requirements for the prevention of explosions by ignition of combustible materials in contact with electrical equipment in hazardous areas.

- **NFPA 70 standard:** This National Fire Protection Association (NFPA) standard is widely used to ensure the safety of electrical installations. It establishes minimum requirements for the design, installation, inspection, and maintenance of electrical equipment in buildings, structures and installations.

- **NFPA 652 standard:** This National Fire Protection Association (NFPA) standard provides general guidelines for combustible dust safety, including explosion prevention measures in hazardous areas.

- **IEC Standard 60079-10:** This standard provides requirements for the selection and installation of electrical equipment in explosive atmospheres.

- **IEC Standard 60079-0:** This standard establishes the general requirements for electrical equipment used in explosive atmospheres, including classified areas with the presence of hydrocarbons.

- **API PSD 2214 standard:** This American Petroleum Institute (API) standard establishes guidance on the spark ignition properties of hand tools used in hazardous areas.

- **OSHA Standard 29 CFR 1910.120:** This standard establishes guidelines for occupational safety and health in hazardous areas.

These standards provide specific guidance on equipment selection, electrical installation design, maintenance requirements and other aspects related to explosion prevention in hazardous areas. It is important to consult and follow the appropriate standards to ensure compliance and safety.

6. CHEMICAL DETAILS

To better understand the mechanics of explosion in hazardous areas with friction ignition, it is important to consider the chemical properties of the flammable hydrocarbons involved.

Knowledge of these chemical properties is fundamental to understanding how friction ignition can occur in hazardous areas and to taking appropriate preventative measures.

Some relevant aspects include:

6.1 Flash Point: The flash point is an important property to consider when dealing with flammable hydrocarbons. It represents the minimum temperature at which a liquid releases enough vapour to form a flammable mixture on contact with an ignition source, such as friction. It is a crucial measure for determining the risk of ignition by friction, as it indicates how easily the liquid can generate flammable vapours. The lower the flash point, the greater the risk of ignition by friction.

Measuring flash point

The flash point is measured using a device called a closed vessel. The liquid to be tested is placed in the vessel and heated slowly. A flame is then introduced into the vessel. If the liquid releases enough vapour to ignite the flame, the flash point is recorded as the temperature at which this occurs.

Classification of flammable liquids by flash point

Flammable liquids are classified by their flash point according to the NFPA 30 standard:

- **Class I:** Liquids with a flash point below 60 °C (140 °F).
- **Class II:** Liquids with a flash point between 60 and 93 °C (140 and 200 °F).
- **Class III:** Liquids with a flash point above 93 °C (200 °F).

Risk of friction ignition

The risk of ignition by friction increases as the flash point of the liquid decreases. Liquids with very low flash points, such as petrol, are highly flammable and can be easily ignited by friction.

For example, a hydrocarbon with a low flash point, such as petrol, presents a higher risk of ignition during friction compared to a hydrocarbon with a higher flash point, such as diesel oil.

6.2 Activation Energy: Activation energy is an important property of a chemical reaction. It represents the minimum amount of energy needed to start the reaction. Activation energy is determined by the nature of the substances involved in the reaction and the environmental conditions.

In the case of ignition by friction, activation energy can be provided by the heat generated during friction between surfaces. The heat generated by friction can break the chemical bonds of the flammable hydrocarbon molecules, forming free radicals. Free radicals are molecules or atoms that have one or more unpaired electrons. Free radicals are highly reactive and can initiate chemical reactions, including combustion.

Activation energy and ignition by friction

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How activation energy affects friction ignition

The lower the activation energy of the flammable hydrocarbon, the easier it is for the heat generated by friction to break the molecules' chemical bonds and form free radicals.

This means that flammable hydrocarbons with lower activation energies are more likely to be ignited by friction.

For example, petrol has an activation energy of **11.2 kcal/mol**, while diesel oil has an activation energy of **42.8 kcal/mol**. This means that it is easier for the heat generated by friction to break the chemical bonds of petrol molecules than diesel molecules.

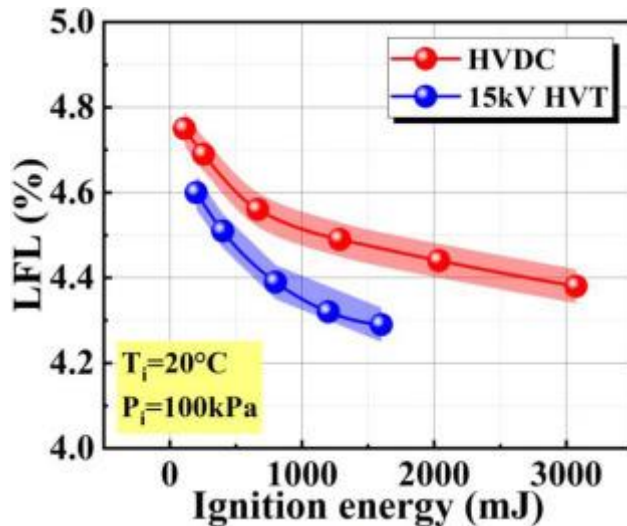
Activation energy spreadsheet for some petrochemical products

Product	Activation energy (kcal/mol)
Gasoline	11,2
Diesel oil	42,8
Paraffin	28,5
Naphtha	22,4
Benzene	12,4
Toluene	14,3
Xylene	14,2
Methanol	11,0
Ethanol	11,6
Acetone	18,7
Acetylene	52,0
Chlorine	29,2
Fluorine	37,0
Nitrogen	23,3
Oxygen	29,4
Sulphur	26,0
Phosphorus	31,0

The activation energy can vary depending on specific conditions, such as temperature, pressure, and the presence of catalysts. In addition, activation energy values can be influenced by the presence of other components in a mixture.

However, it is important to understand that activation energy represents the minimum amount of energy needed to start a chemical reaction, such as the combustion of a flammable hydrocarbon. Generally, lighter hydrocarbons such as methane and ethane have relatively low activation energies, making them more susceptible to ignition. On the other hand, heavier hydrocarbons, such as diesel oil and paraffin, may require higher activation energies to initiate the combustion reaction.

Remember that activation energy is only one of the factors to consider when assessing the risk of friction ignition. It is essential to follow good safety practices, such as avoiding contact with flammable surfaces, using suitable lubricants, and monitoring the temperature to ensure safety in hazardous areas.



Examples of friction ignition

Friction ignition can occur in a variety of situations, including:

- **Rotating parts**

When parts are rotated, they can come into contact with each other and generate heat. If the heat is sufficient, it can break the chemical bonds of the molecules of a flammable hydrocarbon present on the surfaces of the parts, forming free radicals. The free radicals can then initiate a combustion reaction.

- **Impact between parts**

When parts are impacted against each other, they can also generate heat. The heat generated by the impact can be enough to break the chemical bonds of the molecules of a flammable hydrocarbon present on the surfaces of the parts, forming free radicals. The free radicals can then initiate a combustion reaction.

- **Friction between sliding surfaces**

When surfaces slide past each other, they can generate heat. The heat generated by friction can be enough to break the chemical bonds of the molecules of a flammable hydrocarbon present on the surfaces of the parts, forming free radicals. The free radicals can then initiate a combustion reaction.

6.3 Flammability limits: Flammability limits are another property to consider. They refer to the minimum and maximum concentrations of a hydrocarbon in air that can result in an explosive mixture. These limits are expressed as a percentage of volume. The concentration below the lower flammability limit is not sufficient to sustain combustion, while above the upper flammability limit the mixture is too rich in hydrocarbons for combustion to occur. Knowing these limits is essential to avoid operating in explosion-risk conditions.

Below is a table with the flammability limits of the main hydrocarbons and petrochemical products. It is important to remember that these values can vary depending on environmental conditions such as temperature and pressure. This table provides a reference for the flammability limits of the main hydrocarbons and petrochemical products, but it is essential to consult the safety data sheets of the specific products for accurate and up-to-date information.

Hydrocarbon / Petrochemical Product	Lower Flammability Limit (%)	Upper Flammability Limit (%)
Methane	5	15
Ethane	3	12
Propane	2.1	9.5
Butane	1.9	8.5
Pentane	1.5	7.8
Hexane	1.2	7.3
Heptane	1.0	7.0
Octane	0.9	6.7
Benzene	1.2	7.8
Toluene	1.2	7.1
Xylenes	0.9	7.1
Methanol	6	36
Ethanol	3.3	19
Acetone	2.6	12.8
Petroleum Ether	1.9	8.5
Gasoline	1.4	7.6
Kerosene	0.7	5.0
Diesel Oil	0.6	5.0
Natural Gas	4	14
Liquefied Petroleum Gas (LPG)	1.5	9.5

These aspects - flash point, flammability limits and activation energy - are fundamental to understanding the mechanics of explosion in hazardous areas with friction ignition. By considering these chemical properties of the flammable hydrocarbons involved, it is possible to assess the risk of explosion and implement appropriate safety measures.

The process of friction ignition begins when friction between two surfaces generates heat. The heat generated can be sufficient to raise the temperature of the explosive atmosphere to its ignition point. When the temperature of the explosive atmosphere reaches its ignition point, the chemical combustion reaction begins.

The chemical combustion reaction of an explosive atmosphere is an exothermic reaction, which means that it releases heat. The heat released by the chemical reaction accelerates the reaction, which can lead to an explosion.

An explosion is a sudden release of energy that can cause significant material and human damage. The explosion can be accompanied by a fire, which can cause even more damage.

6.4 Chemical Breakdown of Friction Ignition

Friction ignition can be divided into two main stages:

6.4.1 Formation of Free Radicals

The first stage of friction ignition is the formation of free radicals. Free radicals are molecules or atoms that have one or more unpaired electrons. Free radicals are highly reactive and can initiate chemical reactions.

The formation of free radicals can occur by a variety of mechanisms, including:

1. Thermal Breakdown: Thermal breakdown is a chemical process in which a molecule is broken down into two or more smaller molecules, or free radicals. Thermal breakage can be caused by a variety of factors, including heat, radiation, or electricity.

In the context of fretting ignition, thermal breakdown is an important mechanism for the formation of free radicals. Free radicals are molecules or atoms that have one or more unpaired electrons. Free radicals are highly reactive and can initiate chemical reactions.

Thermal breakage can occur when the heat generated by friction is enough to break the chemical bonds of a molecule. The heat generated by friction can be high, depending on the speed and intensity of the friction.

The thermal break process can be divided into two stages:

- **Heating:** The heat generated by friction causes the kinetic energy of the molecules to increase.
- **Chemical bond breaking:** When the kinetic energy of a molecule is high enough, it can break a chemical bond, forming two free radicals.

The type of molecule that is broken by thermal cracking depends on the nature of the explosive atmosphere. In petrochemical areas, explosive atmospheres are generally composed of hydrocarbons. Hydrocarbons are organic molecules containing carbon and hydrogen atoms.

The thermal breakdown of hydrocarbons can produce a variety of free radicals, including:

- **Hydroxyl radical (OH)**
- **Alkyl radical (R)**
- **Carbene radical (C)**

The free radicals formed by thermal breakdown can initiate chemical reactions, including combustion.

The speed of thermal breakdown depends on a number of factors, including:

- **The nature of the molecule:** The nature of the molecule will affect the energy needed to break the chemical bonds.
- **Temperature:** Temperature will affect the kinetic energy of the molecules.
- **Pressure:** Pressure will affect the strength of the chemical bonds.

Thermal breakage is an important mechanism for fretting ignition in classified or petrochemical areas. Understanding the thermal break process is important for preventing explosions.

2. Oxidation-Reduction Reaction: An oxidation-reduction reaction, also known as a redox reaction, is a chemical reaction in which an atom or molecule loses electrons (oxidation) and another atom or molecule gains electrons (reduction).

In oxidation, an atom or molecule loses one or more electrons, becoming more positive. In reduction, an atom or molecule gains one or more electrons, becoming more negative.

Oxidation-reduction reactions are important in a variety of chemical processes, including combustion, corrosion, and electrolysis.

In the context of fretting ignition, the oxidation-reduction reaction is an important mechanism for the formation of free radicals. Free radicals are molecules or atoms that

have one or more unpaired electrons. Free radicals are highly reactive and can initiate chemical reactions.

The oxidation-reduction reaction can be caused by friction between two surfaces that have different oxidation-reduction potentials. The oxidation-reduction potential is a measure of the tendency of an atom or molecule to lose or gain electrons.

When two surfaces with different oxidation-reduction potentials come into friction, electrons can be transferred from one surface to the other. This transfer of electrons can cause the formation of free radicals.

The type of free radical that is formed by the oxidation-reduction reaction depends on the materials of the surfaces that are in friction. In petrochemical areas, the surfaces are usually made of metals or hydrocarbons.

The oxidation-reduction reaction between metals and hydrocarbons can produce a variety of free radicals, including:

- **Hydroxyl radical (OH)**
- **Alkyl radical (R)**
- **Carbene radical (C)**

The free radicals formed by the oxidation-reduction reaction can initiate chemical reactions, including combustion.

The speed of the oxidation-reduction reaction depends on a number of factors, including:

- **The nature of the materials:** The nature of the materials will affect the oxidation-reduction potential.
- **The speed and intensity of friction:** The speed and intensity of friction will affect the amount of electrons that are transferred.

The oxidation-reduction reaction is an important mechanism for fretting ignition in classified or petrochemical areas. Understanding the oxidation-reduction reaction process is important for preventing explosions.

Here are some examples of how the oxidation-reduction reaction can cause fretting ignition in petrochemical areas:

- **A worker uses a screwdriver to tighten a screw in a steel pipe. The friction between the screwdriver and the pipe can cause electrons to transfer from the steel to the hydrocarbon in the pipe. The free radicals formed**

by the oxidation-reduction reaction can initiate combustion of the hydrocarbon.

- **A hydrocarbon tanker collides with another vehicle. The friction between the two vehicles can cause the transfer of electrons from the metal of the vehicles to the hydrocarbon in the tanker. The free radicals formed by the oxidation-reduction reaction can initiate the combustion of the hydrocarbon**

3. Tribochemical effect: The tribochemical effect is a chemical phenomenon that occurs when two surfaces come into friction. Friction can cause the formation of free radicals, which are molecules or atoms that have one or more unpaired electrons. Free radicals are highly reactive and can initiate chemical reactions, including combustion.

The tribochemical effect is an important mechanism for friction ignition in classified or petrochemical areas. In petrochemical areas, surfaces are usually made of metals or hydrocarbons. Friction between these surfaces can cause the formation of free radicals, which can initiate the combustion of an explosive atmosphere.

The tribochemical effect can be divided into two stages:

- **Formation of free radicals:** Friction can cause molecules to break down, forming free radicals.
- **Reaction of free radicals:** Free radicals can react with other atoms or molecules, initiating chemical reactions.

The formation of free radicals by the tribochemical effect can occur by a variety of mechanisms, including:

- **Thermal breakdown:** The heat generated by friction can cause molecules to break down.
- **Oxidation-reduction reaction:** Friction can cause the transfer of electrons between two surfaces, forming free radicals.
- **Electron delocalisation: Friction can cause the delocalisation of electrons within a molecule, forming free radicals.**

The speed at which free radicals are formed by the tribochemical effect depends on a number of factors, including:

- **The nature of the materials:** The nature of the materials will affect how easily molecules are broken or electrons are transferred.
- **The speed and intensity of friction:** The speed and intensity of friction will affect the amount of heat or electron transfer that takes place.

The reaction of free radicals formed by the tribochemical effect can lead to the ignition of an explosive atmosphere. The reaction of free radicals can occur rapidly and uncontrolled, leading to an explosion.

6.4.2 Chain reaction

A chain reaction is a chemical reaction in which the products of the initial reaction catalyse the subsequent reaction. This means that the products of the initial reaction help initiate the next reaction, making the process faster and more efficient.

In the context of friction ignition, the chain reaction is the step that leads to the combustion of an explosive atmosphere. The chain reaction can be initiated by the reaction between a free radical and a fuel molecule.

A free radical is a molecule or atom that has one or more unpaired electrons. Free radicals are highly reactive and can initiate chemical reactions.

A fuel molecule is a molecule that can be oxidised, i.e. it can lose electrons.

When a free radical reacts with a fuel molecule, an oxidation-reduction reaction occurs. The oxidation-reduction reaction produces a new free radical and a combustion product.

The new free radical can then react with another fuel molecule, starting another reaction. This process continues in a chain until the reaction is interrupted by some mechanism, such as a lack of fuel or the removal of free radicals.

The chain reaction is a self-propagating process, which means that it doesn't require an external source of energy to continue. The energy needed to start the chain reaction is provided by the activation energy of the initial reaction.

The speed of the chain reaction depends on a number of factors, including:

1. The concentration of the explosive atmosphere: The concentration of the explosive atmosphere is the amount of fuel present in the air. Atmospheres with higher fuel concentrations are more likely to be ignited by friction.

This is because the likelihood of a spark coming into contact with an explosive atmosphere increases as the fuel concentration increases. In addition, the amount of heat required to ignite an explosive atmosphere decreases as the fuel concentration increases.

2. The speed and intensity of friction: The speed and intensity of friction determine the amount of heat that is generated. The heat generated by friction is the source of energy that is used to form free radicals.

The greater the speed and intensity of friction, the greater the amount of heat generated. This means that friction is more likely to cause the formation of free radicals at higher speeds and intensities.

3. The Nature of Friction Surfaces: The nature of the surfaces in friction will affect the likelihood of free radical formation. Different surfaces have different chemical properties, which can affect how easily molecules are broken or electrons are transferred.

Surfaces that are more likely to break molecules or transfer electrons are more likely to cause the formation of free radicals.

4. The Concentration of Free Radicals: The concentration of free radicals determines the likelihood of a reaction between a free radical and a fuel molecule. The higher the concentration of free radicals, the more likely it is that a reaction will occur.

The concentration of free radicals can be affected by a variety of factors, including the speed and intensity of friction, the nature of the friction surfaces and the presence of other gases or vapours.

7. CHECKLIST FOR DRAWING UP A PROJECT AND CHECKING INSTALLATIONS

7.A. Project Phase

1. Area classification

- Identify the expected concentration of flammable vapours and gases in each area of the installation.
- Classify each area according to the applicable standard (e.g. NFPA 70, IEC 60079-10) as Zone 0, Zone 1 or Zone 2.
- Document the classification of areas in project plans and reports.

2. Identification of friction Ignition sources

- Analyse the processes, equipment and activities that take place in each classified area.
- Identify potential sources of ignition by friction, such as:
 - o Impact between metal parts.
 - o Friction between sliding surfaces.
 - o Rotation of metal parts.
 - o Electrostatic discharge.
 - o Defective electrical and mechanical equipment.

3. Assessing the risk of ignition by friction

- Consider the following factors to assess the risk of ignition by friction:
 - o Type of hydrocarbon present.

- o Hydrocarbon concentration in the atmosphere.
- o Activation energy of the hydrocarbon.
- o Speed and intensity of friction.
- o Nature of the friction surfaces.
- o Presence of free radicals.
- o Ambient temperature.
- o Presence of other ignition sources.

4. Selection of control measures

- Based on the risk assessment, determine the control measures needed to prevent friction ignition. Control measures can include:
 - o Engineering:
 - Elimination or replacement of equipment that generates friction.
 - Shutting down or sealing equipment to prevent hydrocarbon leaks.
 - Installation of ventilation systems to reduce the concentration of hydrocarbons in the atmosphere.
 - Use of antistatic materials and coatings.
 - o Administrative:
 - Implementation of safe working procedures.
 - Training programmes for employees on the risk of ignition by friction.
 - Preventive maintenance of equipment.
 - Access control to classified areas.
 - o Protection:
 - Installation of electrical and mechanical equipment certified for use in hazardous areas.
 - Use of explosion protection systems.

5. Documentation and verification

- Document the selected control measures and safe working procedures.
- Check the implementation of the control measures in accordance with the applicable standards and regulations.
- Carry out tests to verify the effectiveness of the control measures, if necessary.

7.B. Operation and Maintenance Phase

1. inspections and maintenance

- Carry out regular inspections of equipment and installations to identify possible sources of ignition by friction.
- Carry out preventive maintenance on equipment in accordance with the manufacturer's recommendations.
- Document the inspections and maintenance carried out.

2. Safe working procedures

- Implement and follow safe working procedures for handling hydrocarbons.
- Provide training to employees on safe work procedures.
- Supervise the work of employees to ensure compliance with the procedures.

3. Emergency control

- Develop an emergency plan to respond to explosions in classified areas.
- Train employees on the emergency plan.
- Keep fire-fighting equipment ready for use.

4. Audits and reviews

- Carry out periodic audits to assess the effectiveness of the safety management system.
- Review the design of the installation and safe working procedures, if necessary.

7.C. Recommendations

- Keep up to date with applicable standards and regulations.
- Consult process safety experts for advice.
- Take part in training programmes and workshops on process safety.
- Share best practices with other companies in the sector.

7.D. Normative references

- See item 5. STANDARDS AND PROCEDURES

8. FRICTION IGNITION EXPLOSION PREVENTION

Detailed study on the prevention of friction ignition explosions in petrochemical áreas

Introduction

Explosions in petrochemical areas are a serious safety risk and can cause material damage, human losses, and serious economic damage. One of the main causes of explosions in petrochemical areas is friction ignition.

Friction ignition occurs when the heat generated by friction between two surfaces is sufficient to initiate a combustion reaction. This type of ignition can occur in a variety of situations, such as:

- Impact between metal parts;
- Friction between sliding surfaces;
- Rotation of metal parts;
- Electrostatic discharge.

Prevention measures

Friction ignition in petrochemical areas can be prevented through a variety of measures, including:

- Elimination of the ignition source: The ignition source can be eliminated by using equipment and materials that do not cause friction. For example, using non-stick materials or coating surfaces with materials that reduce friction can help eliminate the ignition source.
- Isolating the ignition source: The ignition source can be isolated from the explosive atmosphere by means of physical barriers or protective devices. For example, the use of physical barriers, such as fences or walls, can help isolate areas where there is a risk of ignition by friction.
- Reducing the concentration of the explosive atmosphere: The concentration of the explosive atmosphere can be reduced through ventilation or by reducing the amount of fuel present. For example, installing ventilation systems can help reduce the concentration of flammable hydrocarbons in the air.

Control measures

In addition to prevention measures, it is also important to take control measures to reduce the risk of ignition by friction. These measures include:

- Use of flammable hydrocarbons with higher activation energies: The lower the activation energy of a flammable hydrocarbon, the easier it is for the heat generated by friction to break the chemical bonds of the molecules and form free radicals. Free radicals are highly reactive and can initiate a combustion reaction. Therefore, the use of flammable hydrocarbons with higher activation energies can help reduce the risk of ignition by friction.
- Reducing friction between surfaces: Friction can be reduced through the use of lubricants, non-stick coatings, or smooth surfaces. Lubricants help reduce friction between two surfaces, while non-stick coatings and smooth surfaces can also help reduce friction.
- Controlling environmental conditions: Environmental conditions, such as temperature and humidity, can affect the activation energy of flammable hydrocarbons. Therefore, controlling environmental conditions can also help reduce the risk of ignition by friction.

Addition of a chemical product to alter the chemical ignition properties

In addition to the prevention and control measures described above, it is also possible to use an additional technique to reduce the risk of ignition by friction: the addition of a chemical product that alters the chemical ignition properties of flammable hydrocarbons.

These chemicals, known as ignition inhibitors, act in different ways to reduce the risk of fretting ignition. Some inhibitors act by altering the molecular structure of flammable hydrocarbons, making them more difficult to ionise by the heat generated by friction. Other inhibitors act by forming a protective layer on surfaces that may come into contact with flammable hydrocarbons, which reduces friction and heat generation.

The addition of ignition inhibitors is an effective measure to reduce the risk of friction ignition in petrochemical areas. This measure can be used in conjunction with the other prevention and control measures described above to achieve an even more effective effect.

Recommendations

In addition to the measures described in this study, it is also important to adopt the following recommendations to increase safety in petrochemical areas:

- Carry out regular inspections of facilities to identify and correct possible sources of ignition by friction.
- Train employees on the risks of ignition by friction and prevention and control measures.
- Develop an emergency plan to respond to explosions.

In addition to the measures described in this study, it is also important to adopt the following recommendations to increase safety in petrochemical areas:

- Carry out regular inspections of facilities to identify and correct possible sources of ignition by friction.

Regular inspections of facilities should be carried out by qualified and trained personnel. Inspections should include checking the condition of surfaces that may come into contact with flammable hydrocarbons, identifying possible sources of friction and verifying the use of prevention and control measures.

- Train employees on the risks of ignition by friction and prevention and control measures.

Training employees is essential to ensure that they are aware of the risks of ignition by friction and know how to prevent and control this type of ignition. Training should include information on the causes of friction ignition, prevention and control measures and the procedures to be followed in the event of an accident.

- Develop an emergency plan for responding to explosions.

An emergency plan is essential to ensure a rapid and effective response to an explosion. The plan should include procedures for evacuation, firefighting and first aid.

By adopting these measures, companies in the petrochemical sector can contribute to reducing the risk of accidents and protecting life and the environment.

Adding ignition inhibitors

The addition of ignition inhibitors is an effective measure to reduce the risk of friction ignition in petrochemical areas. These chemicals act in different ways to reduce the risk of fretting ignition. Some inhibitors act by altering the molecular structure of flammable hydrocarbons, making them more difficult to ionise by the heat generated by friction. Other inhibitors act by forming a protective layer on surfaces that may come into contact with flammable hydrocarbons, which reduces friction and heat generation.

Ignition inhibitors can be added to flammable hydrocarbons in different ways, such as:

- Direct addition to the flammable hydrocarbon.
- Applying a protective coating to surfaces that may come into contact with the flammable hydrocarbon.
- Incorporating the ignition inhibitor into the material of the surfaces that may come into contact with the flammable hydrocarbon.

Choosing the best way to add the ignition inhibitor depends on factors such as the type of flammable hydrocarbon, environmental conditions, and specific applications.

Effectiveness of ignition inhibitors

The effectiveness of ignition inhibitors varies according to the type of inhibitor, the concentration of the inhibitor and the environmental conditions. In general, ignition inhibitors are effective at reducing the risk of friction ignition in a wide range of conditions.

Applications

Ignition inhibitors can be used in a variety of applications in petrochemical areas, such as:

- **Transport lines for flammable hydrocarbons.**
- **Equipment and machinery that may come into contact with flammable hydrocarbons.**
- **Areas where there is a risk of spilling flammable hydrocarbons.**

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