Ignition Sources

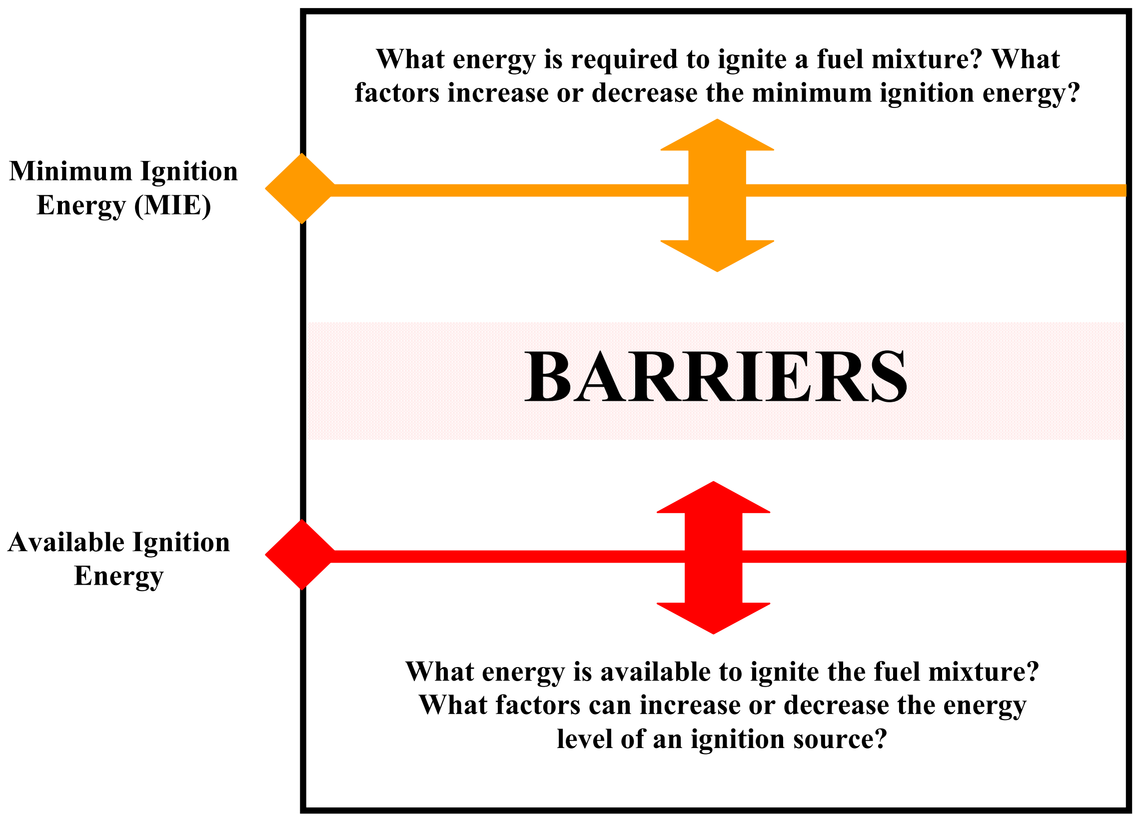
The information on this section of the site looks at the many possible ignition sources found in the upstream oil and gas industry. Some are well understood and readily identified, while others deserve further examination.

Identifying Ignition Sources

Once fuel and oxygen are present, an ignition source is needed to complete the fire triangle. Hydrocarbons can be ignited in two ways:

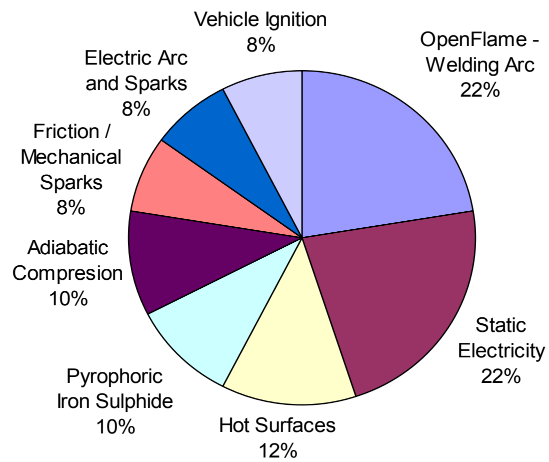
- When an external ignition source with sufficient energy to ignite the fuel-oxygen mixture is available (e.g., flames, sparks).
- When the temperature is raised above the auto-ignition temperature (e.g., the compression ignition of a diesel engine).

This diagram shows that consideration must be given to the factors that can change the minimum ignition energy and the available ignition energy.



Forced ignition (i.e. external / piloted) is the most common form of accidental ignition. An external ignition source is classified as anything that can deliver enough energy in the form of heat to ignite a substance. This category includes sources such as open flames, electric arcs and sparks and mechanical sparks.

Many of the fire and explosion case studies reviewed on this website were attributed to ignition sources that were difficult to identify. The most likely or apparent ignition source was assumed in these instances. The graph below outlines the ignition sources from the case studies.



Types of Ignition Sources Identified in Website Case Studies

Hot Work

Hot work has been defined as any operation that can produce enough heat from flame, spark or other source of ignition, with sufficient energy to ignite flammable vapours, gases, or dust [22:4]. Welding, cutting, grinding, brazing, flaming, chipping, air gouging, riveting, drilling, and soldering are all forms of hot work that can create sparks or high temperatures [22; 23].

References on this topic speak of the many precautions necessary during such operations. The conditions and equipment in areas next to the work area need to be considered when planning activities [22]. The fact that conditions can change and new hazards can be created during the operation also needs to be taken into account. For example, hydrocarbons can vapourize from the heat produced during hot work [22].

Case Study: A worker was using a cutting torch near an open vessel, which contained lube oil. The lube oil was not very volatile, therefore, it was not considered to be a risk to anyone. Before work commenced, LEL readings were taken at the opening of the vessel and it was deemed safe to perform hot-work operations. As the work progressed and the vessel heated up from the heat of the cutting torch, vapours from the heated lube oil formed an explosive atmosphere with the air in the vessel. The torch ignited the vapours causing an explosion.

Static Electricity

Definition

"Static electricity is the electrical charging of materials through physical contact and separation and the positive and negative electrical charges formed by this process. [3:6.12.1]." If the process is not or cannot be properly grounded, allowing the charge build-up to be safely dissipated, the charge may build up to the point where it will discharge with a static arc, which may provide an ignition source to a nearby mixture of fuel vapour and air. This is shown schematically in the Static Charge Generation diagram later in this section. Static electricity can be generated in many different ways.

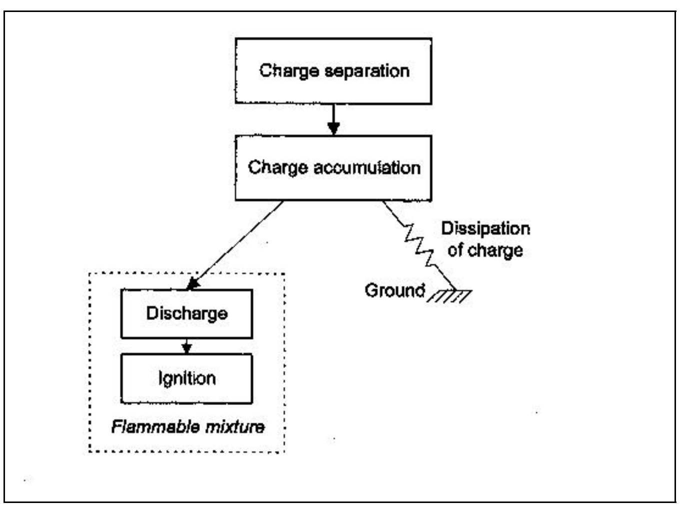
Case Study: Mud tanks containing a hydrocarbon-based fluid caught fire due to a static electric discharge from a plastic downspout off the centrifuge. The flow of the fluid through the plastic non-conductive pipe created a build up of charge until it was large enough to arc, resulting in an ignition. There were no proper bonding and grounding procedures in place.

Nonconductive Liquids

A common source of static electricity is the movement and transport of nonconductive liquids. **When liquids are filtered, sprayed, pumped, mixed, or flow through pipes, static electricity can be generated. This type of "internal" static charge cannot be eliminated by bonding or grounding.**

If there is a sufficient potential difference between the surface charge and the metal tank shell, when an object is lowered into the tank or well, a static arc may occur. This is of particular concern if there is a vapour space above the surface of the liquid. For example, the static arc created by well-servicing tools contacting the fluid in a well has ignited this type of air-vapour mixture. [3]

The following simplified diagram helps to highlight the critical issues related to static charges.



Static Charge Development [34]

Minimum Ignition Energy

For a discharge to ignite an explosive atmosphere there must be enough energy. The minimum ignition energies for most hydrocarbon gases and vapours range from 0.1 - 1 mJ (milliJoule). The level for methane is 0.29 mJ for example. A person walking across a carpeted floor can develop a potential difference large enough for a 40 mJ discharge – more energy than it takes to ignite methane. Humans generally only sense discharges of 0.6 mJ or more, which means that discharges we can't detect may carry enough energy to ignite a flammable mixture.

Discharges from humans generally need to be greater than the fuel's minimum ignition energy to be an ignition source. This is because conditions such as temperature, humidity and surface shape all affect the energy of the discharge. Increasing the oxygen levels and/or the pressure can increase the minimum ignition energy.

Switch Loading

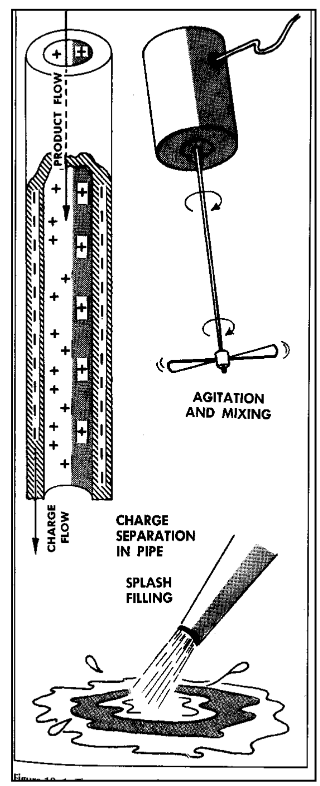
Switch loading is when a product is loaded into a tank or vessel that previously held a different product with a lower flash point. The concern with switch loading is that residual low flash point liquid from the previous load could form a vapour-air mixture in the tank or vessel. Even when there is no standing liquid from the previous load, an explosive vapour-air mixture can be created. Static generated during the transfer of the new product may discharge and ignite the vapour-air mixture. [3; 16]

To prevent the generation of charge:

- splashing and misting operations should be avoided
- initial fill rates and maximum flow rates should be limited
- hydrocarbons with dispersed water or solids should not be pumped or flowed [16]

To prevent charge accumulation:

- conductive fluids should be grounded while insulated containers are being filled conductive parts should be bonded and grounded
- a sufficient residence time downstream of filters and pumps should be used
- antistatic additives can be added to low conductivity fuels. [16]



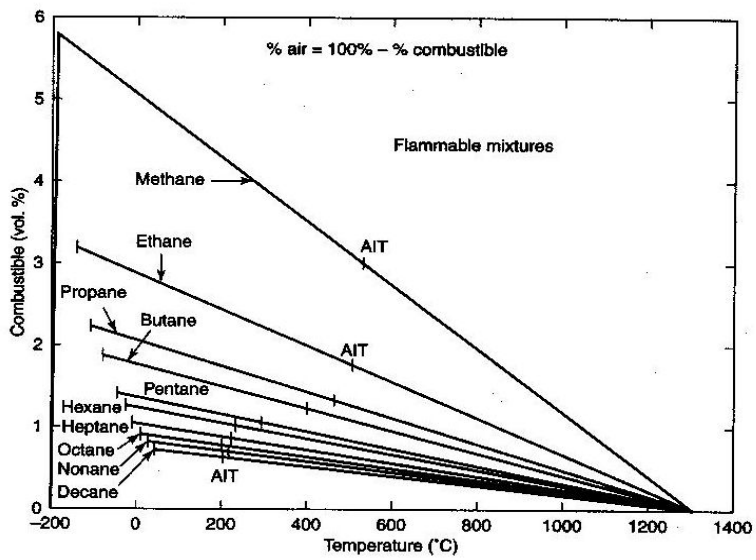
Static Charge Generation [37]

Effects of Humidity
The air's relative humidity can act as a suppressant to static electricity because higher moisture content allows static charges to dissipate more readily. A study [41] was done to determine if the electrical potentials on different garment fabrics were great enough to detonate sensitive flammable gases at a temperature of 75° F and various levels of relative humidity.

Relative Humidity	**Effect on Electric Potentials**
65% or more	Not enough electric potential for ignition
35%	Enough potential for some sensitive mixtures to ignite
25%	Higher potentials produced capable of providing a significant ignition source.
20% or less	Dangerous voltages; levels able to ignite most hydrocarbons.

In some cases, it may be possible to spray a coating on materials that can generate a static charge. The coating will make the material more conductive allowing the charge to flow more easily rather than accumulate.

Hot Surfaces [21]
Surfaces that exceed the minimum auto-ignition temperature of a hydrocarbon have the potential to ignite hydrocarbon vapours.



*W. Jost and H.O. Croft, *Explosion Processes in Gases*, New York, McGraw-Hill Book Company, 1946.

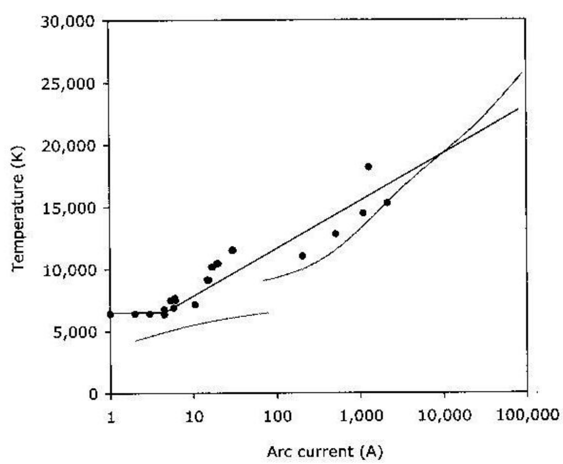
Effects of Temperature on Lower Limits of Flammability of 10 Paraffin Hydrocarbons in Air at an Atmospheric Pressure* [34]

Experience and studies have shown, however, that published minimum auto-ignition temperatures must be exceeded by hundreds of degrees to ignite a flammable air-hydrocarbon mixture in the open air. This is because field conditions are much different from the controlled laboratory conditions created for traditional ignition temperature tests. In the open air, wind and convection currents prevent the air-hydrocarbon mixture from contacting the hot surface for long periods. With the result that a hot surface in the open air needs to exceed the minimum ignition temperature of the hydrocarbon by about 200^{o}C for ignition to occur.

Electric Arcs and Sparks
Sparks are the discharge of electrons that may or may not expend all of the energy in a single discharge. An arc is a continuous stream of electrons bridging a gap between two conductive surfaces in close proximity.

The size or intensity of arcs and sparks depends on the resistance of the substance between the points of discharge. Once the voltage is high enough to overcome the dielectric strength of the air, the air will ionize allowing a conductive path for electricity to flow. Due to the high resistively of air, there will generally be enough energy dissipated in an arc or spark to ignite a flammable vapour.

The current or amount of electricity that is flowing will dictate the temperature of the arc. The higher the current, the higher the temperature. [34] As shown below even arcs with lower currents have enough heat energy that the likelihood of ignition is high.



Temperature of arcs in ambient-pressure air, along with predictions from the theory of Lowke and an experimental data fit [34]

Some common examples of arcs and sparks as an ignition source are listed below.
- Sparking of electric motors, generators, or other electrical rotating equipment
- Arcing between contacts (i.e. switches and relays)
- Arcs due to broken, inadequate, or failed insulation
- Lightning strikes
- Discharge of a charged capacitor through a gas

- Poor contacts between conductors, such as poorly fitted light bulbs and their sockets
- Arcs intentionally created during electric welding [35]

Case Study: An explosion-proof trouble light was rented for the cleaning of a tank that contained hydrocarbons. The light had been altered, compromising its explosion-proof abilities. When the globe in the light failed, the resulting spark ignited the atmosphere. This explosion injured five workers.

Pyrophoric Iron Sulphides

Pyrophoric iron sulphides form when iron is exposed to hydrogen sulphide, or any other compound that contains sulphur, in an oxygen deficient atmosphere [17; 18]. They are found frequently in vessels, storage tanks, and sour gas pipelines [17; 19]. Pyrophoric iron sulphides present a hazard when equipment and tanks are opened for cleaning, inspection, and maintenance. As the iron-sulphide compounds dry out and come in contact with air, they react with the oxygen and spontaneously ignite [18].

Case Study: A partial inspection was taking place in a vertical test treater at an oilfield battery site. The vessel contained pyrophoric iron sulphides. When purging the vessel, the iron sulphides dried out and started to react with the air. This created enough heat to ignite the atmosphere resulting in a fatality and another serious injury.

The reactivity of an iron sulphide depends on the type of iron oxide from which it was derived [20]. Reactive iron sulphides can be deactivated when wetted with oil, therefore, rusted surfaces that are below the oil level are at low risk of causing an explosion [19]. Chemical and mechanical methods are available to remove iron sulphides. The use of potassium permanganate is gaining acceptance for this purpose because it improves safety, saves significant cost and increases productivity [17]. Other treatments include acid washing, chemical suppression, and the use of high-pH reagents [17].

Pressure (Compression Ignition)

When gases are compressed, heat is generated, or more accurately, energy is transferred. If the rate of heat generation within a system exceeds the rate of heat loss (energy transfer) to the surroundings, the temperature of the system will rise. If the rate of compression is rapid enough such that the heat loss may be considered negligible, resulting in "adiabatic compression", the temperature rise will depend on compression ratio. Diesel engines work on this basic principle.

Case Study: The pressure in a gas well was allowed to rise, with pressure readings being taken every five minutes. After half an hour, there was a down hole explosion which ruptured the surface casing and caused a fracture in the ground at surface. It is believed that the rapidly rising pressure along with residual produced oil in the well caused this explosion.

The rate of pressure rise is generally relatively slow in snubbing operations. This allows heat (energy) to dissipate to the surroundings. Typical timing for compression to a maximum pressure is in the order of several hours as opposed to a fraction of a second (ms) in diesel engines. Sudden compression, however, may be an ignition source (e.g. when a valve is suddenly opened resulting in the rapid compression of an air-hydrocarbon mixture) and is worth consideration when analyzing snubbing incidents.

A compression ratio of 18:1 for air initially at ambient temperature produces temperatures of 674°C, which can ignite dry tinder.

A liquid with gas bubbles can also ignite due to rapid compression. Here's why. The volume of gas bubbles will change at a faster rate than the volume of the liquid, resulting in the bubbles becoming hot spots and a potential ignition source. [34]

Friction and Mechanical Sparks
Mechanical sparks occur when there is excessive friction between metals or extremely hard substances. As the two substances rub against each other, small particles are torn off the surfaces. This tearing is due to the large amount of friction.

For a metal to spark, it must satisfy three conditions:

- The energy, which supplies the tearing off of the particles, must be sufficient to heat the metal to high temperatures. Softer metals usually deform before they spark.

- The metal must be able to oxidize and burn easily. Generally, a metal's sparking temperature is the same as its burning temperature.

- The metal's specific heat is the last factor. A metal with a low specific heat will reach a higher temperature for the same amount of energy input. [35]

Safer in Cold Temperatures
Energy from a mechanical spark may heat a small volume of gas to its auto-ignition temperature. If the spark cools before the auto-ignition temperature is reached, the gas will not ignite. Mechanical sparks are, therefore, safer in cold temperatures.

Caution Down Hole
Examples of mechanical sparking include dropping metal tools or chains, and grinding metal with an abrasive disk. Caution should be used when lowering or raising metal wire-line tools in a well as less friction is needed to cause sparks at down hole temperatures.

Lower Melting Point Metals Safer
If the temperature reached during the contact of metals exceeds the lower melting point of the two metals then the surface will tend to melt rather then tear and spark. Generally lower melting point metals will be safer.

Incidents in which gases or dust clouds have been ignited due to friction or mechanical sparks can be divided into three categories.

1. Low energy; can be caused by hand tools. Typical energy 10J.

2. Medium energy; can be caused by powered hand tools. Typical energy: 1kJ
3. High energy; can be caused by major collisions on land or sea. Typical energy 1MJ. [34]

Sudden Decompression

Sudden Decompression of air-hydrocarbon mixtures, particularly air-liquid hydrocarbon mixtures, is not well understood. In the presence of air, liquid hydrocarbons may oxidize forming products such as hydroperoxides, aldehydes, ketones etc. Higher temperatures and pressures will increase this reaction rate. Some of these compounds are highly unstable especially when subjected to sudden pressure and temperature changes. Decomposition of such products can yield significant energy rapidly and may provide an ignition source for the air-hydrocarbon mixture. In addition, during sudden decompression of air-hydrocarbon mixtures, the release of dissolved gases within the liquid hydrocarbons may atomize the liquid hydrocarbons thus enhancing their reactivity

Catalysts

When added to hydrocarbons, some chemicals may substantially increase the reactivity of the mixture. Some metals may also act as a catalytic surface.