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From the Desk of Mike Bell

Each year accidents in the industrial world involving fires, explosions, poisonous gases, acids, bases, and hazards cause deaths, lost man-hours, and millions of dollars of losses in production and equipment. The interesting thing about the physical and chemical world that we are involved with is that it is not simple. In fact it is very complex. However, the fact remains that most of the accidents that occur are preventable.

Additionally, the Federal and State governments are regulating environmental and process safety issues for industrial plants. OSHA has mandated process safety guidelines for various chemicals. The MACT rules by the EPA require the best achievable technology be applied to various defined chemicals and processes to obtain defined reductions. Many of the changes required to achieve the mandated reductions involve flammable and explosive materials. The article in this newsletter examines the basics of combustion and explosive principles.

FREEDOM

A STATE OF MIND
A WAY OF LIFE

GOD BLESS AMERICA!

IN THIS ISSUE

Ninety percent of the friction of daily life is caused by the wrong tone of voice.

Lola Neff Merritt

Combustion and Explosive Basics

By Mike Bell P.E.

The purpose of this article is to examine the basic principles of what happens during the rapid chemical reaction between a fuel and oxygen. Combustible or explosive materials are a class of compounds or mixtures of compounds that undergo a change or, more accurately, a decomposition that results in the release of energy. An understanding of combustion and explosion principles is needed to properly address process safety issues in industrial processes.

Sufficient energy must be added to the process to get the reaction started or ignited. The **ignition temperature** is the point at which the oxidation reaction increases abruptly. The actual physics of the ignition process is very complex. However, the surface temperature of some part of the energetic material must reach temperatures high enough to volatilize it. Explosive materials volatilize at differing temperatures. For example, liquid nitroglycerin begins to volatilize at only 140 degrees F, whereas the solid, sulphur, requires approximately 500 degrees F to volatilize. Much of process safety is directed towards preventing ignition of volatile materials by various means.

If the reaction and rate of decomposition of the material is relatively slow then **combustion** or burning of the material is said to be taking place. In most cases of combustion, little pressure increase is experienced. The combustion process normally, but not always, produces a glow or **flame**. The intense heat provided by the combustion elevates the chemicals formed during the reaction to higher energy states. As these products return to lower energy states, some of the energy they lose is emitted in the form of light. The light is seen as a visible flame during combustion. Hydrogen, however, has no visible flame as it burns.

In the cases where the rate of reaction is greater than normal combustion, **deflagration** or super burning occurs. With deflagration, the combustion zone is propagated with a compressive wave at less than the speed of sound.

Materials and compounds that decompose through deflagration are termed **low explosives** and do not generate a shock wave. It is not common for a low explosive to experience detonation but it is possible under certain conditions.

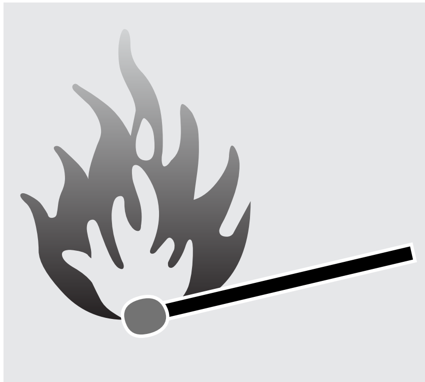
Once deflagration starts, the process takes on a layered configuration with deflagration zones. The flame zone is the heat source that perpetuates the volatilization of the explosive. As the flame zone temperature increases, then the rate of volatilization and decomposition increases. The gases produced by deflagration create a higher-pressure zone that expands into the surrounding media. The **rates of pressure** rise and **maximum pressure** are proportional to the rate of deflagration and the amount of confinement of the material. The maximum pressure for most industrial gases increases approximately 4 to 10 times the initial pressure of the process. The pressure drops rapidly to atmospheric pressure if the deflagration process is unconfined or in the open atmosphere.

When the deflagration process is confined, such as in a vessel or pipe, then it is possible for the deflagration to transition to detonation. This process is referred to as a **Deflagration to Detonation Transfer** (DDT). The pressure rise from the deflagration process can drive the flame front into the unreacted material increasing the rate of heat transfer and rate of deflagration. A deflagration process has a flame front velocity that depends on a number of variables including type of fuel, air-fuel ratio, initial temperature, turbulence, geometry, etc. The flame front is accompanied by a compressive wave that can transition to a shock wave in the transfer to detonation. The transition from deflagration to detonation is poorly understood within the industrial world. Many times there is no clear division between the two explosive processes. Deflagration and detonation can accompany one another as the reactive material is consumed. The compressive deflagration wave can be characterized as having the shape of a gentle hillside. The shock wave accompanying a detonation can be described as a cliff face.

Detonation has the propagation of the combustion zone in the unreacted medium at a velocity greater than the speed of sound. Detonation of an energetic material is initiated by a shock wave. The traveling, axial compressive effect of the juxtaposition shock wave produces a change of state in the material. The change of state provides an exothermic chemical decomposition giving off heat and travels through the material at a rate proportional to the speed of the shock wave.

A detonating energetic material is termed a **high explosive** whenever the decomposition occurs at a rate greater than the speed of sound. The **detonation velocity** is the actual speed at which the detonation travels through the material and is one means of classifying high explosives. Detonation velocities of high explosives can range from 3,300 fps to over 29,900 fps. However, most of the industrial world is not involved with high explosives and we will only briefly touch on the subject.

Typical industrial fuels and explosive materials can exist as solids, dusts or combustible particulate solids, liquids, and vapors. A hybrid mixture of different materials can be blended or mixed with air to produce flammable mixtures. A solid or liquid fuel will normally be volatilized during combustion or an explosion and will emit a gas. It is the emitted gas blended with air that supports the combustion or explosion. The **flashpoint** of a liquid is the temperature at which the liquid gives off enough vapor to form an ignitable mixture with the air above the liquid surface.



There exist two values of the mole percent of fuel in a fuel-air mixture–**Lower Flammable Limit** (LFL) or **Upper Flammable Limit** (UFL)–which is capable of igniting or exploding. The mixture range between the limits is called the flammable or explosive range. With explosive dusts we speak of the **Minimum Explosive Concentration** (MEC), which is the minimum concentration of combustible dust suspended in air, measured in mass per unit volume that will support a deflagration. The flammable limits for various fuels and combustible materials can be found in NFPA guidelines, Chemical Engineers Handbook, and other publications.

Gas-air mixtures with gas concentrations less than the LFL are not flammable because there is not enough fuel to support combustion. Gas concentrations greater than the UFL are not flammable because too much fuel has displaced the oxygen for the mixture to ignite.

Once ignited, the flame front moves in the direction of unburned fuels at a velocity termed the flame velocity. Most industrial fuels have a **flame velocity** of 1 to 4 fps. If the fuel is flowing in a pipe and the gas or dust velocity in the pipe is less than the flame propagation velocity, then the flame will travel back to the fuel source. The result is termed **flashback** and is extremely dangerous. Turpentine is a very unusual and dangerous industrial chemical because it has a flame velocity of approximately 500 fps.

This article has examined the mechanics of combustible and explosive materials. We have reviewed some of the basic phenomenon that occurs in combustion, deflagrations, and detonations.

These facts are invaluable to us as we design and modify industrial processes. Much of process safety for flammable materials is directed towards either preventing ignition from taking place or limiting the damage once ignition has occurred. If a material has the capacity to ignite or detonate then the appropriate design features should be incorporated.

Floor Rating

By Elvert Chisley P.E.

Adding and/or rearranging equipment, satisfying an OSHA requirement or deterioration of the floors are but a few of the reasons to have a floor rated. But perhaps the most eminent underlying reason for having a floor rated stems from a concern for safety. In any event, the unknown or uncertain capacity of the flooring system should be cause for a floor rating.

Rating a floor is a service performed to determine how much load a floor can support. It involves making a field check to examine the flooring, collecting and verifying drawings and making detailed calculations. Everyday activities such as the path taken by a forklift can be affected based on the outcome of the rating.

One of the most important things to consider when determining a floor's rating is the existing or modified flooring system. A typical floor consists of a concrete slab supported by steel members. These components are analyzed using the appropriate techniques and applicable codes to determine its capacity either together or independently.

Most requests involve the determination of a floor rating for an existing floor without structural modifications. However, in order to obtain a floor rating for a specified load, structural modifications may be needed and the sequential application of loads needs to be considered. Also, utilizing engineering

Floor Rating, Continued

judgment to determine how much of the building structure that requires analysis can be crucial.

The procedure for determining floor load rating involves strategically placing loads at defined locations on the floor in an effort to obtain the critical stress. These stresses are checked to make sure that they are less than the allowable stress provided by the applicable codes. In general, the load that produces the stress closest to the allowable stress would be the floor rating.

So as the reasons to have a floor rated may be numerous and may vary, the single goal is to provide a safe floor capable of carrying a load up to the specified floor-rating limit to avoid risking failure.

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The world famous Mardi Gras is celebrated in New Orleans, Louisiana. Mardi Gras is an ancient custom that originated in southern Europe. It celebrates food and fun just before the 40 days of Lent, a time of prayer and sacrifice.

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LOUISIANA FACT

The Superdome in New Orleans is the world's largest steel-constructed room unobstructed by posts.

Height: 273 feet (82.3 meters)
Diameter of Dome: 680 feet (210 meters)
Area of Roof: 9.7 acres
Interior Space: 125,000,000 cubic feet
Total floor footage: 269,000 sq. ft. (82,342 sq. meters)
Electrical Wiring: 400 miles (640 kilometers)

After innumerable delays in construction and constantly escalating costs, the original $35 million bond measure approved by voters will amount to more than $400 million by the time the bonds are paid off.

Due to damage by Hurricane Katrina in 2005, the cost to repair the roof has been put at $32 million.

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