A Single Ignition: A Cautionary Tale

By Michael Tinnesand

It's easy to see what attracted Devon Byrd and Wade White to the rural oil production facility near their homes in Carnes, Miss. The collection of large storage tanks, used to collect crude oil from a nearby well, was isolated, unmanned, and wide open for anyone to visit. A wooden stairway provided access to a catwalk on top of the tanks. It's not known what Devon and Wade were doing there, but it was common for teenagers in the area to use sites such as this one to share a pack of cigarettes or just to socialize.

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An oil tank explosion in Carnes, Miss., blew this tank 60 yards away, killing two teenagers, Devon Byrd and Wade White.

What's clear is what happened next. At approximately 4 a.m. on October 31, 2009, one of the tanks exploded. The explosion propelled the huge tank 75 yards through the air and blew the two young men 40 yards. Both were killed as a result of blunt force injuries they suffered when the tank exploded.

Perhaps the most shocking fact about the accident was the total absence of any warning signs, fences, gates, or any other security measure to discourage entry. Since there were no surviving witnesses, there was no way to determine what ignited the tank.

Investigators estimate the storage tank was nearly empty and contained only 14 barrels of crude oil. One barrel contains 42 gallons of crude oil. Crude oil is a complex mixture of hydrocarbons, which are molecular compounds made of carbon and hydrogen atoms. The precise composition of crude oil varies, depending on where it is from. Crude oil itself is neither explosive nor very flammable. It is not easy to get crude oil to burn because it is so thick, unless its temperature is raised to 140 °F or more.

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From crude to refined

In order for crude oil to be useful, it has to be refined. The main step in refining crude oil is fractional distillation (Fig. 1). In this process, the raw petroleum is heated in a boiler with high-pressure steam to temperatures of about 1,100 °F. At this temperature, most substances in petroleum go into the vapor phase. The vapor then enters the bottom of a long column, called a fractional distillation column. As the temperature rises, the lightest and most volatile compounds in the petroleum mixture begin to vaporize.

These compounds are separated according to the temperature at which they go from liquid to gas, also called their boiling point. The refining process does not separate each compound in crude oil, but produces mixtures of compounds, called fractions—hence the name of the technique: "fractional distillation."

The smaller, lighter molecules that have the lowest boiling points are drawn off the top of the tower as gases. Fractions with larger molecules and higher boiling points condense to liquid lower down the tower. At the bottom, the heaviest and least volatile molecules remain.

As the crude oil sat in the Mississippi storage tank, something similar happened. The lighter and more volatile parts of the mixture vaporized, filling the upper part of the storage tank with a dangerous mixture of hydrocarbon gases. Given the right conditions, this vapor could react explosively.

The three ingredients necessary for most fires are fuel, heat, and oxygen. In this case, the volatile hydrocarbons provided the fuel, but what about the heat and oxygen?

Investigators were not able to determine the source of the heat that set off the explosion. It may have come from a discarded match or a lighter, if the students were smoking or playing with fireworks. Another possibility is a spark from, say, a tool hitting the metal tank or railing. Any of these heat sources might have set off the explosion.

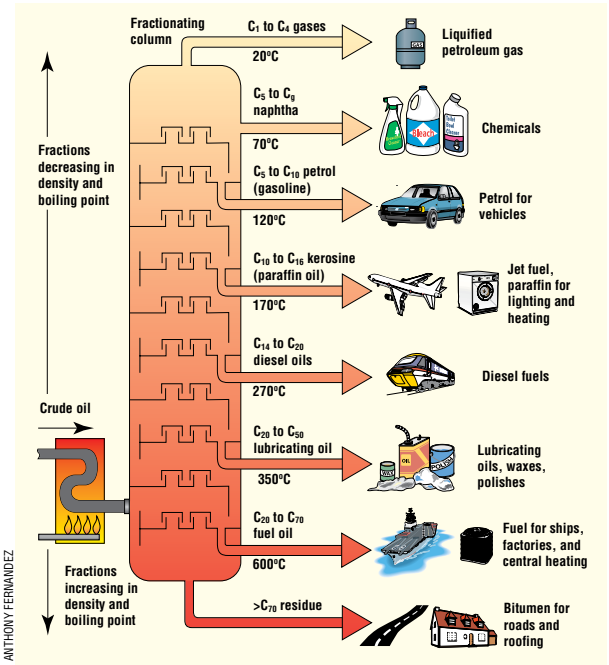

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Figure 1. Schematic illustration of fractional distillation

An explosive atmosphere

In order for an explosion to occur, the hydrocarbon-to-air ratio has to be 1%–6% (for example, 1% fuel and 99% air). This ratio varies depending on the specific hydrocarbons that are present.

Gasoline is one component of crude oil. It, too, is a mixture of hydrocarbons, ranging from 4 to 12 carbon atoms per molecule, but we can represent it as octane (C_8H_{18}) because it is in the median range of hydrocarbons making up gasoline.


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Rafael Moure-Eraso (left), chairman of the U.S. Chemical Safety Board, and investigator Vidisha Parasram tour the accident site in Carnes, Miss.

The equation for the combustion of octane is:

$$2\ C_8H_{18}\ (l) + 25\ O_2\ (g) \rightarrow 16\ CO_2\ (g) + 18\ H_2O\ (g) + \text{heat energy}$$

If there is too little oxygen, the fuel will not burn or will not burn completely. Too much oxygen, and there may not be enough fuel to sustain combustion. Somehow, enough air got into the tank to make the fuel burn explosively. For instance, holes or leaky seams may have allowed in air, or a hatch may have been left ajar.

It's one thing for a fuel to burn, but another for it to explode. What are the characteristics of an explosion? Explosions result from a rapid increase in volume and a large release of energy. Gasoline packs a lot of energy: It contains 10 times the energy of trinitrotoluene, a common explosive. But what about the increase in volume? Notice in the equation above there are 25 moles of gas on the left (reactants) side of the equation, but a total of 34 moles of gas on the right (products) side of the equation. This increase in volume can contribute to an explosion, assuming it happens rapidly enough. This is where the collection of vapor in the tank plays a role.

The rate of a chemical reaction depends on a number of factors, including the nature of the reaction, the physical state of the reactants (solid, liquid, or gas), temperature, pressure, and the amount of surface area—the area of exposed surface of chemical substances.


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In general, gases react more quickly than liquids, which react more quickly than solids. That's because gases are spread out more than solids or liquids, and this allows almost all of the particles to react at once.

So, the real danger wasn't the crude oil in the bottom of the tank, but the vapor that had collected in the space above it. When this vapor combines with oxygen and an ignition device, such as a match, a spark, or a firework, it explodes.

No barriers to danger

Given the circumstances, you might think this was a freak accident, but deaths from oil storage tank explosions are more common than most of us realize. According to the U.S. Chemical Safety Board (CSB), an independent federal agency, more than 40 people, most of them teenagers, have died in this type of accident since 1983.

In April 2010, a 24-year-old woman died and a 24-year-old man was injured in an explosion in New London, Texas. The ignition source was a cigarette lighter. In 2006, a teenager died and another was injured when they dropped a lit object inside a storage tank.

More could be done to warn people of the danger. Some jurisdictions require fencing and warning signs, many do not. CSB could not identify any federal, state, or local laws or regulations that would have required fencing or other security measures at the accident site in Carnes, Miss. Given the risk and danger involved, it should be clear that oil storage tank sites are no place to hang out.

SELECTED REFERENCES

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