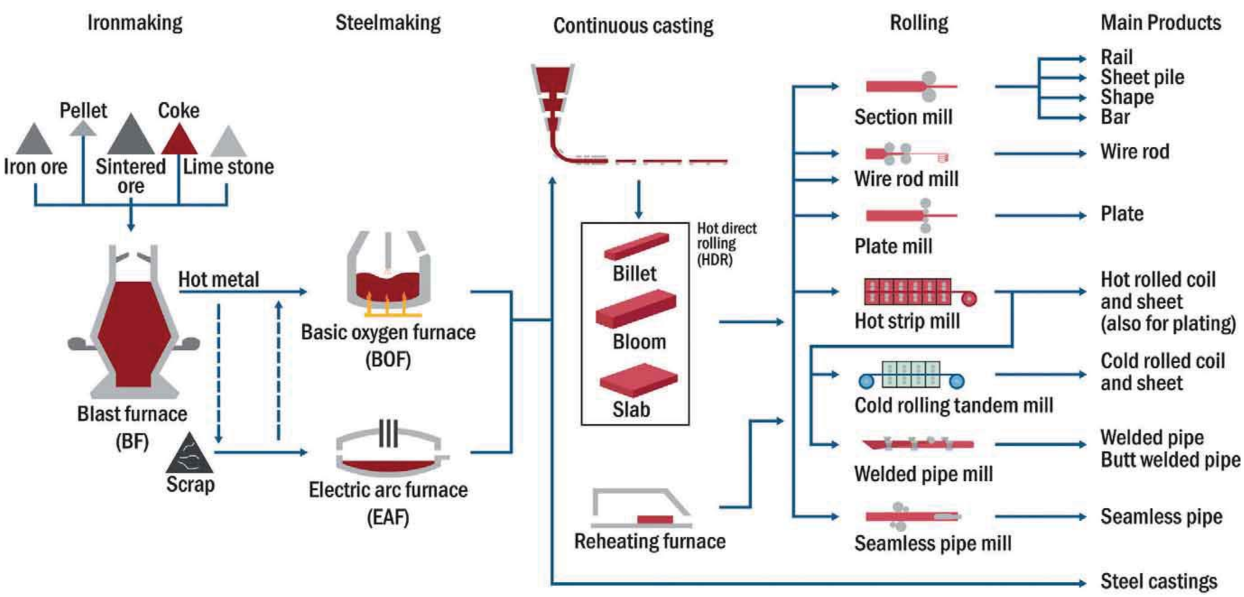
Alternatives to mineral oil based hydraulic fluids in steel production

Fire hazards are constantly present in the steel industry with operations involving heavy equipment and liquid or red hot steel, and when mineral oil based hydraulic fluids are being used. However, there are alternatives that can be utilized without jeopardizing the performance or productivity of the steel production line.



Rough schematic of the steelmaking process. Areas shown in red have the highest fire risk.

A fire is one of the events that, once experienced, leave a huge impression on the people involved. In addition to the risk of personnel injuries, there is a likelihood of loss in both capital and production. These losses not only include damage to the building and equipment, but also encompass interruptions in production that can idle production lines for days or even months.

One cause of fire in a steel production plant is the ignition of mineral oil hydraulic fluids. The highest fire risks in a steel production plant are at operations where the processed materials reach temperatures ± 1,652°F up to > 2,732°F (± 900°C up to > 1,500°C). In most of these processes, hydraulic units are used to operate the equipment, and in many cases a mineral oil based hydraulic fluid is used to fuel the hydraulic unit. While mineral oil has the definite advantage of a good cost-performance ratio, it is a distillate from crude oil, and not always the safest choice due to its tendency to catch fire easily. Fortunately, there are alternatives available to manage this risk and reduce the chance of an ignition without jeopardizing the performance or productivity.

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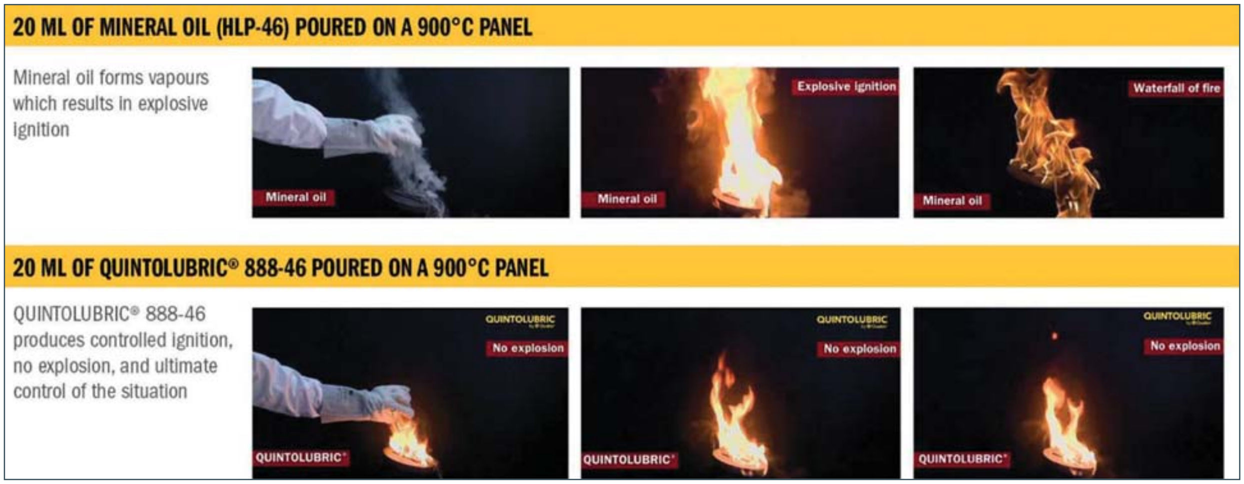
In the following, some examples are given where steel customers switched to a fire-resistant hydraulic fluid after having experienced the hazards of mineral oil based hydraulic fluids.

Case study 1. A customer was operating their billet caster with a standard mineral oil based hydraulic fluid. In this specific application, there were frequent hose ruptures that caused the oil to be splashed on the recently, still hot cast billets. Each time a rupture occurred, the fluid ignited into a massive fire with vapor clouds forming into fire balls. The fires were difficult to get under control and each one caused hours of production lost due to down time. After the customer switched to a fire-resistant hydraulic fluid, while the hose ruptures still took place (as it is induced by the surrounding environment), no more explosions of vapors took place and the situation was quickly under control.

Case study 2. In a customer's operations, leaks were causing the mineral oil based hydraulic fluid to form a pool on the plant floor. While the operation was running, liquid metal sparks would land in the oil pool and catch



A comparison of mineral oil and QUINTOLUBRIC® 888-46 when poured on a 900°C panel

fire. The fire would spread quite rapidly and although it caused no serious collateral damage, the potential threat was clearly demonstrated. Concerned with what could have potentially happened, the customer performed a test to compare hydraulic fluids for fire resistance. To do this, they placed a red-hot piece of steel into a bucket filled with mineral oil based hydraulic fluid and another into a bucket filled with water-free, fire-resistant hydraulic fluid. The bucket containing mineral oil burned until it was empty (more than one hour). The bucket containing water-free, fire-resistant hydraulic fluid extinguished in less than 60 seconds. Seeing the results, the customer converted to fire-resistant hydraulic fluid.

Case study 3. Although seen as a relative cold area many fires take place at the pickling line, specifically the hydraulic welder. Several accidents have been reported where hydraulic hoses ruptured and mineral oil based hydraulic fluid came as a jet stream, landing on the just generated weld or welding sparks and set the whole area on fire. This not only caused severe damage in the surrounding area, but also idled the production line for several months. By switching to a fire-resistant hydraulic fluid, the risk of fire spreading to other areas of the plant was strongly reduced, as was long, costly downtime.

Case study 4. A steel customer was using mobile equipment to transport hot slag from its steelmaking facility when an accident took place. The equipment's mineral oil based hydraulic fluid caught fire and the mobile equipment was burned beyond repair. All the customer's mobile units were immediately converted to a water-free, fire-resistant hydraulic fluid.

Types of fire-resistant hydraulic fluids

The standard hydraulic fluids used in steel production are mineral oil based. However, an alternative to mineral oil hydraulic fluids are fire-resistant hydraulic fluids, as described below using the ISO 6743/4 classification.

For each fluid type, there are both pros and cons. The performance properties for several hydraulic fluid types are considered important by both maintenance managers as well as purchasers. Here is more detail of properties by type:

Mineral oil provides good hydraulic fluid performance attributes at a reasonable price, as table 1 shows. However, because mineral oil is not biodegradable, it is not environmentally friendly. And mineral oil delivers a higher total cost of operation, when the risk of fire and worker safety is factored in the cost of use.

Phosphate ester (HFD-R) fluids, an older fluid technology, are fire-resistant by chemistry. However, they are formulated with materials considered to be CMR (carcinogenic, mutagenic, reprotoxic). The combustion fumes they produce are neurotoxic. While these phosphate ester based products provide good pump lubrication, they can limit the service life of servo valves. HFD-R fluids can be 10 to 15 times more expensive than mineral oil and need to be carefully maintained, as these products form aggressive acids as they age. Today, they are used mainly in power generation, although they are at times found in steel plants as well.

Water glycols (HFC) are widely used in steel plants as well as other industries representing approximately 50% of the total fire-resistant hydraulic fluids market. Because of their high-water content HFC fluids provide very good fire resistance. In price, its comparable to mineral oil and less expensive than water-free hydraulic fluids. However, HFCs don't measure up in performance attributes. Component service life generally is shorter, more fluid management is needed, and energy consumption is 10 to 20% higher compared to mineral oil or polyol ester based fire-resistant hydraulic fluids. All issues drive up the total cost of operation (TCO).

Polyol ester based fluids (HFD-U) are the best alternative to mineral oil. While they are more expensive than mineral oil (approximately two to three times more), they deliver a lower total cost considering the reduction in the risk of fire and improvement in the safety of workers. Also, with polyol ester based fluids, manufacturers don't sacrifice the fluid's performance and the polyol ester based (HFD-U) fluids are environmentally friendly.

Understanding the term "fire-resistant"

The term "fire-resistant" is often mistakenly understood to be the same as "fire-retardant" – or the ability to suppress a flame. The only hydraulic fluids that can truly be considered fire-retardant are the high-water content (HFA) fluids. Almost all fire-resistant hydraulic fluids will burn under certain conditions. HFC fluids will ignite if a certain amount of water evaporates. And while most HFD-U fluids will burn, they will not cause the ignition-like explosion that the mineral oil will that leads to an uncontrollable situation.

Fluids can be tested to determine their fire resistance. The most common and generally accepted tests are those used by Factory Mutual (FM Global), the testing and approval arm of a major industrial insurance underwriter (www.fmglobal.com). By using an FM Global approved hydraulic fluid, manufacturers can often reduce their insurance premium. Additionally, beyond FM Global, many other organizations and companies have developed fire resistance tests, usually to simulate a certain type of real-world accident.

A video on YouTube shows the comparison between ignition of mineral oils and HFD-U fluids – a problem that typically occurs when mineral oil comes into contact with a hot surface. The mineral oil evaporates easily, and therefore tends to build a vapor of oil droplets. Once ignition takes place, the oil droplets can catch fire and result in an explosion or fire ball. These two effects make the fire with a mineral oil dangerous and hard to control, as the fire ball can go to the roof or to cables and can ignite that area.

Water-based fluids		Water-free fluids	
HFA-E	Oil in water emulsions Water content > 80% Common use 1 to 5%	HFD-R	Phosphate ester based. These products are less used because of CMR reputation.
HFA-S	Synthetic aqueous solutions Water content > 90% Common use 1 to 5%	HFD-U	Based on other compounds, but mainly synthetic polyol ester and natural esters (renewable resources)
HFC water glycols	Water glycol solutions Water content > 35%		

Types of fire-resistant hydraulic fluids

With the polyol ester based HFD-U fluids, this evaporation does not take place and thus no explosion or fire ball will be generated. The HFD-U fluid might burn as well, but there is no vapor or explosion and it is limited to the place it comes in contact with, so the situation remains under control.

The heat of combustion of a mineral oil based hydraulic fluid is typically about 43 – 44 kJ/g, whereas an HFD-U, polyol ester fire-resistant hydraulic fluid has a heat of combustion of about 38 kJ/g. So chemically an HFD-U fluid generates 10 – 15% less heat during combustion.

QUINTOLUBRIC® 888 is Quaker's best-in-class, ester-based, synthetic, water-free, fire-resistant hydraulic fluid (HFD-U) with use today internationally in more than 60 presses. QUINTOLUBRIC® 888 is endorsed by multiple major hydraulic component OEMs and hydraulic press manufacturers worldwide.

Practice change-over experience

Polyol ester technology has been in use for about half a century, and in many fire hazardous applications in steel mills (from blast furnace to hot strip mill) has been successfully introduced as a fire-resistant alternative to mineral oil based hydraulic fluids. Nevertheless, in many potentially dangerous places, mineral oil based hydraulic fluids are still used. The reasons for that can vary from "not being aware this technology exists" to "only aware of HFD-R and HFC which are respectively not allowed or not suited" or "we never had a fire, so…".

If a manufacturer makes the decision to change to a polyol ester based fluid in their hydraulic system, the conversion process is not very complicated. Typically, no changes need to be made to the hydraulic unit when converting from a mineral oil or water glycol hydraulic fluid to a polyol ester flu-

Property	Mineral oil	Phosphate ester (HFD-R)	Water glycol (HFC)	Synthetic polyol ester (HFD-U)
Fire resistance	– –	+ +	+ + +	+
Environmental performance	–	+ –	+ –	+ +
Thermal stability	+ +	+ +	–	+
Fluid maintenance	+	– –	– –	+
Component life/system reliability	+	+ –	– –	+
Price	+ +	– –	+ +	+ –
Total cost of operation	–	–	– –	+

Hydraulic fluid comparison when used in fire hazardous situation

id. That said, the conversion must be done with care because there are several grades and qualities of polyol ester (HFD-U) fluids available on the market.

The important checks that must be performed are not only compatibility evaluations with the existing mineral oil, but also the paint inside the tank, seals, hoses, valves and pump. In the end, the tests will show that the type of paint is critical (single component paints can be incompatible) as well as pump approvals. Additionally, it is important to remember that several different suppliers exist for polyol ester (HFD-U) fluids, but most pump builders only approve some suppliers without any restriction on rpm and maximum pressure. Experience teaches that when the paint compatibility is good, no changes or restrictions are needed for the hydraulic system. To guarantee the fire resistance of the new fluid, less than 5% residual mineral oil should remain.

The QR code links to a video on YouTube showing the ignition of mineral oils and HFD-U fluids (http://www.youtube.com/watch?v=bEtlikCMRWM)

Conclusion

Steel production is an industry where situations occur every day that can be classified as dangerous. With operations involving heavy equipment and liquid or red hot steel, the danger of fire is ever present. And fire hazards are often exacerbated when mineral oil based hydraulic fluids are being used. Using water-free, polyol ester based fire-resistant hydraulic fluids instead can improve the safety in plants significantly, without jeopardizing the productivity and performance of the production line. ■