FIRE AND EXPLOSION HAZARDS WITH THERMAL FLUID SYSTEMS

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Incidents relating to thermal fluid systems are unfortunately more common than we might realise, and can be extremely serious. The fire and explosion hazards with thermal fluid systems have been re-emphasised by recent incidents. These incidents have a direct bearing on the estimated 4,000 UK companies that operate thermal fluid systems.

Water or steam can be used as heat transfer fluids, but when high temperatures are needed organic fluids, which are capable of forming explosive atmospheres, are often used. Although fire and explosion hazards of low flash point flammable liquids are generally recognised, similar hazards with high flash point materials, such as thermal fluids, are often missed. These heat transfer fluids are often handled at temperatures above their flash point.

The Health and Safety Executive recently issued a prohibition notice to a UK company following a major thermal fluid incident and significantly, following that incident, has identified thermal fluid systems as a fire and explosion hazard. There have been other serious incidents this year. Although not under HSE jurisdiction, there was a recent thermal fluid-related explosion and fire at a German panel products plant which tragically caused three fatalities.

Most companies will be aware that any system that operates above the flash point of the thermal fluid falls under the "Dangerous Substances and Explosive Atmosphere" Regulations 2002 (DSEAR). However, many people are unaware that heat transfer fluids based on mineral oils degrade over time. This degradation can cause the fluid's flash point to decrease dramatically, so that thermal fluids which were not flammable at the operating temperature when they were initially installed may, over time, become flammable at the operating conditions. Also, high flash point materials (such as thermal fluids), can form explosive mist atmospheres when handled under pressure, even at temperatures below the flash point.

The DSEAR regulations require that the risk from dangerous substances (flammable materials) is assessed and eliminated or reduced. Systems need to be put in place to reduce the risk and manage the residual risk. The ATEX directives require the hazardous areas to be identified.

Regular thermal fluid testing and the results obtained will indicate the physical condition of the fluid and the degree of risk in the event of a fluid release. However, flash point testing alone is not enough to comply with DSEAR. Procedures are also needed to change out the thermal fluid, or remove the lower flash point components from the thermal fluid. Many companies operating thermal fluid systems may not be aware of this.

This paper discusses recent incidents of fires and explosions which have occurred in thermal fluid systems, and makes practical recommendations for how such incidents can be avoided. These include carrying out Area Classification on thermal fluid systems, methods to avoid or limit mist formation, avoiding ignition sources and installing proprietary equipment which removes the lower flash point components from the thermal fluid.

INTRODUCTION

The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR) are concerned with protection against risks from fire, explosion and similar events arising from dangerous substances used or present in the workplace. They set minimum requirements for the protection of workers from fire and explosion risks related to dangerous substance and potentially explosive atmospheres.

The Regulations implement two European Directives: the safety aspects of the Chemical Agents Directive 98/24/EC (CAD) [EC 1998] and the Explosive Atmospheres Directive 99/92/EC (ATEX 137) [EC 2000] which requires similar legislation throughout the European Union (EU) on work involving hazardous chemical agents and explosive atmospheres. (There is also an ATEX Product Directive 94/9/EC [EC 1994], more often known as the "ATEX 100a" or "ATEX 95" Directive, concerning equipment and protective systems intended for use in potentially explosive atmospheres).

The key requirements in DSEAR are that risks from dangerous substances are assessed and eliminated or reduced. Employers are required to:

1) Prevent the formation of an explosive atmosphere, avoid its ignition, and/or mitigate the effects.
2) Assess the risk to employees from the dangerous substances (gases, liquids or dusts).
3) Identify where an explosive atmosphere may occur by carrying out hazardous area classification.
4) Select equipment and protective systems suitable for use in explosive atmospheres, on the basis of the requirements set out in the Equipment and Protective

Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996(a).

5) Draft a document (equivalent to an Explosion Protection Document) which contains the risk assessment, hazardous area classification and measures taken (organisational or technical) to reduce the risk.

APPLICATION OF THE DSEAR REGULATIONS

Dangerous substance means any material classified as explosive, oxidising or flammable, or any dust which can form an explosive atmosphere with air. Normally this means any flammable gases or dusts, or liquids being handled above their flash point. However, it also applies to materials being handled below their flash point but under pressure, such that a flammable spray or mist is formed which can form an explosive atmosphere. Heat transfer fluids can form explosive atmospheres either by operating at temperatures above their flash point, or due to mist formation.

PROjEN has carried out hazardous area classification exercises and DSEAR risk assessments of the fire and explosion hazards associated with operations involving a variety of materials which are flammable at the handling temperature, and explosive mist atmospheres. But how reliable are the flash points of the materials being handled?

FLASH POINT VARIATION

Flash points vary depending on the constituents of the material being tested. However, many people are unaware that heat transfer fluids thermally degrade over time, especially if they are handled near to or above their recommended maximum temperature. This degradation results in the generation of 'light' (low flash point) materials with lower flash points than the heat transfer fluid itself. Therefore, this causes the flash point of the heat transfer material overall to reduce. The degradation of the heat transfer fluid can cause the fluid's flash point to decrease dramatically, so that thermal fluids which were not flammable at the operating temperature when they were initially installed may, over time, become flammable at the operating conditions.

Experience of handling heat transfer fluids has shown many instances of flash point reduction over time. Some of the reported examples include:

- In the UK, a decrease in the flash point of a thermal fluid from 160°C to 32°C.
- In Switzerland, within one year of service the heat transfer fluid flash point had decreased from 120°C to 60°C.

As a result of such instances some suppliers of heat transfer fluids recommend regular evaluation of the heat transfer fluid, it is suggested annually. [UK CRHF]

MIST FORMATION

In many thermal fluid systems the heat transfer fluid is handled under sufficient pressure so that a mist or spray can be formed, particularly around leak points such as flanged joints, around valves and at connection points in the pipework. These mists can result in explosive atmospheres being formed outside the pipework where ignition sources such as motors, pumps and electrical equipment may be present.

Therefore, explosive atmospheres may be present both inside and outside thermal fluid systems, which can be ignited, resulting in a fire or explosion.

INCIDENTS OF FIRES & EXPLOSIONS IN THERMAL FLUID SYSTEMS

Recent instances of explosions in thermal fluid systems include the following examples:

1) A polystyrene manufacturing facility in Greater Manchester was operating with 22,000 litres of Essotherm 500 (Mineral Oil) at 285°C. Although the plant had defined hazardous areas the thermal oil system was operated as a utility with no formal risk assessment. No formal training had been undertaken with the maintenance personnel having little knowledge of the risks associated with high temperature oil systems.

The thermal oil system was a closed loop system with no deaeration facility, which meant that as the fluid degraded the gaseous VOCs generated could not be removed easily from the fluid stream. The result was that the system 'lack of circulation' warning would regularly trip causing production disturbance. Without understanding the significance of the 'lack of circulation' trip, an engineer 'wired out' the switch to prevent the recurrence of the alarm.

Recurring differential pressure alarms is an indication of rapidly dropping flash points and increasing vapour pressure. In this instance the switch also acts as back up to the low level switch in the expansion tank.

On this site, following routine maintenance, some fluid was lost from the system and as the low level switch indicated that there was oil in the expansion tank, the system was started up as normal.

Unfortunately, the low level switch had failed and air was being drawn into the system on the suction side of the circulation pump. This condition would normally have been detected by the differential pressure switch. However, as the switch had been disconnected the system ran as normal.

The air introduced into the system caused cavitation of the pumps and oil vapour was released back into the expansion tank where it condensed. The cavitation caused rapid degradation of the fluid eventually resulting in an explosion which tore the expansion tank apart, spraying hot oil over the plant.

When samples of the fluid were taken from the expansion tank after the event, the fluid had a flash point of 42°C with an auto ignition temperature of just 140°C. For new fluid the flash point would be 210°C and the auto ignition temperature in excess of 350°C. These measurements indicate that the fluid had degraded dramatically.

2) A frozen food company manufacturing Yorkshire puddings based in Leeds were operating two serpentine ovens, using thermal oil in plattens to provide the heat inside the ovens. The operation was dedicated to producing

the highest possible output from the ovens. This resulted in the thermal fluid being operated to the maximum operating limit.

The thermal oil, Gulftherm 32, is a mineral oil which states in the technical data sheet that the fluid can be operated to 316°C in closed, indirect heating systems (up to 180°C in open heating systems). As a result the company set their thermal oil circuits to 315°C in the belief that this would be both reasonable and acceptable.

The rapid degradation at these temperatures resulted in lowering flash and fire points, reduced viscosity and increased vapour pressure, and subsequently, an explosion.

The cause of the explosion is still being investigated though it is enough to say that the fluid had a flash point of below 30°C, and was operating at 315°C! (The flash point of Gulftherm 32 is quoted as 230°C).

3) Three workers were killed in the explosion of a thermal oil boiler at a plant in North Rhine-Westphalia in Germany in February 2010. The plant produces timber, chipboard and laminate flooring, and the accident occurred in the biomass heating plant. A replacement boiler, approved by a certified company, had been installed in place of the normal boiler. The explosion, in which the three workers died, was followed by a fire, which 47 fire-fighters were able to extinguish within 90 minutes. The cause of the explosion is currently under investigation.

LAGGING FIRES

Fires in thermal oil systems often occur in insulation. Fluid leaking from a valve, flange or instrument port into "open" types of insulation materials, such as glass fibre or mineral wool, migrates from the source of the leak and disperses within the insulation. If the insulation is removed or punctured, spontaneous ignition of the thermal oil can occur due to an increase in the oxygen available. Spontaneous ignition can also be caused by an abrupt increase in operating temperature. [Oetinger 2002]

METHODS OF AVOIDING FIRES & EXPLOSIONS IN THERMAL FLUID SYSTEMS

There are several different ways in which fire and explosion hazards in thermal fluid systems can be avoided:

1. Hazardous Area Classification and correct Equipment Selection.
2. Regularly replace the thermal fluid.
3. Monitor the flash point of the thermal fluid regularly.
4. Install fluid conditioning equipment in the thermal fluid system.
5. Reduce the extent of mist formation by fitting mist guards.
6. Avoiding lagging fires.

HAZARDOUS AREA CLASSIFICATION AND CORRECT EQUIPMENT SELECTION

The potential for explosive atmospheres (hazardous areas) inside and around leak points on thermal fluid systems needs to be recognised. The explosive atmospheres may be present around leak points due to flammable mist formation, or because the thermal fluid flash point has decreased over time and it is being handled above its flash point. If the explosive atmospheres cannot be avoided, the location and extent of the hazardous areas need to be identified by carrying out a Hazardous Area Classification Exercise.

Once the hazardous area extents have been identified, an inventory of any equipment in these areas needs to be carried out, to ascertain whether there is any equipment in the area which could constitute an ignition source. Although this is standard practice within the chemical industry, it is not always recognised as being necessary with thermal fluids. In many cases thermal fluid systems have been supplied to companies with standard (i.e. not ATEX-rated) motors. This is despite the fact that the connection point for the motor into the thermal fluid pipework is a leak source around which an explosive atmosphere may be formed. Therefore, the pump, motor and any other electrical equipment in the hazardous area needs to be suitable for use in an explosive atmosphere.

REGULARLY REPLACE THE THERMAL FLUID

To prevent the degradation of the thermal fluid over time, (which will result in the reduction of the flash point), the thermal fluid should be regularly replaced. Suppliers of thermal fluid systems recommend that the thermal fluid is replaced annually, to prevent the dramatic reduction in flash point (see Figure 1).

However, although replacing the thermal fluid will avoid the formation of explosive atmospheres when handling the fluid at atmospheric pressure, the formation of a flammable mist atmosphere is still possible if the fluid is handled under pressure.

REGULAR MONITORING OF THE THERMAL FLUID FLASH POINT

To prevent the reduction of the flash point over time via degradation, the thermal fluid needs to be sampled regularly, and the flash point of the sample determined. If the flash point has reduced considerably, then the thermal fluid will need to be replaced.

However, as stated above, although replacing the thermal fluid will avoid the formation of explosive atmospheres when handling the fluid at atmospheric pressure, the formation of a flammable mist atmosphere is still possible if the fluid is handled under pressure.

It is important to emphasise that flash point testing alone is NOT sufficient to comply with DSEAR. Some companies are offering to test the flash point of a customer's thermal fluid, giving them the impression that if this is done, the customer will be compliant with the DSEAR regulations. This is not the case.

INSTALL FLUID CONDITIONING EQUIPMENT

If the flash point has reduced to an unacceptably low level, an alternative to replacing all the thermal fluid is to remove

Figure 1. Typical thermal fluid installation (reproduced by permission of Heat Transfer Systems Ltd)

only the light end materials which are responsible for reducing the overall flash point. This can be done by installing proprietary fluid conditioning equipment, designed to remove the VOCs, as part of the thermal fluid system (see Figure 2). Fitting fluid conditioning equipment has the potential to extend fluid life considerably, which can result in significant savings compared with fluid replacement.

AVOID/LIMIT MIST FORMATION

Although explosive mist atmospheres may be formed where the thermal fluid is handled under pressure, the extent of the hazardous area created by the mist can be limited by fitting mist guards around any leak points, such as flanges. These guards will limit the extent of the hazardous area to within the area inside the mist guard, which should be away from any sources of ignition.

However, it is important that if the fitting of mist guards is used to reduce the hazardous area extent, then procedures must be in place to ensure that the mist guards are replaced after any maintenance work.

AVOIDING LAGGING FIRES

Lagging fires can be avoided by a variety of methods. First, only use high temperature, closed-cell glass insulation in leak-prone areas, e.g. near valves, flanges and instrument ports. Alternatively, remove the insulation from these areas completely.

When installing the thermal oil system, pay attention to the following areas:

i) System cleanliness – ensure equipment is clean and dry. Contamination can result in low flow, which can cause overheating and thermal fluid degradation.
ii) Component orientation – ensure valves are mounted stem-downward so leakage cannot enter nearby porous insulation.

Figure 2. Fluid conditioning equipment for VOC removal (reproduced by permission of Heat Transfer Systems Ltd)

iii) System tightness – to avoid leakages.
iv) Allow for thermal expansion and contraction – by installing expansion joints and expansion loops in the piping. Avoid threaded fittings as these may result in leaks.

[Fuhr 1992]

CONCLUSIONS

This paper provides case studies where explosions have occurred in thermal fluid systems, and the flash point of the thermal fluid was found to have decreased below the operating temperature.

The paper emphasises the need to consider thermal fluid systems under the DSEAR regulations, including assessing the fire and explosion risks and identifying where explosive atmospheres may occur. It also highlights the fact that where thermal oils are handled under pressure, explosive mist atmospheres may be formed at temperatures below the flash point.

A variety of methods for avoiding fire and explosions in thermal fluid systems is also presented.

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