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Effective management of heat transfer fluid flash point temperatures using a light-ends removal kit (LERK)

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ABSTRACT

Heat transfer fluids (HTF) need to be regularly sampled to assess the extent of thermal degradation, oxidative state, the accumulation of short-chained light-ends and contamination by intrinsic or extrinsic particles. The build-up of light-ends in a HTF system presents a potential fire hazard. A light-ends removal kit (LERK) enables light-ends to be removed continuously, helping to push-up flash point temperatures. In the current case, the concentration of light-ends started to build-up in the client's system and a LERK was subsequently installed. Data is presented that shows how effective the LERK was in restoring mean closed flash point temperature to stable levels, similar to those seen for a virgin HTF. Closed flash point temperature was, in this case, more variable than open flash point temperature. This highlights the need to make direct measurements of closed flash point temperature as opposed to indirect measurements of open flash point temperature. This case emphasises the need for regular HTF sampling and analysis, and that the installation of a LERK can help maintain the condition and life of a HTF.
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1. Introduction

The transfer of heat energy between a heat transfer fluid (HTF) and process equipment is a basic requirement in a wide variety of industrial processes [1]. In order for this to be as efficient as possible, it is imperative that the HTF maintains the functional characteristics of a virgin HTF for as long as feasibly possible. This means maintaining low carbon residue levels and high flash point temperatures. In reality all HTFs breakdown down over time, but it is important to emphasise that regular sampling and analysis of a HTF can provide detailed insights into the extent of thermal degradation, oxidative ageing, the production of short-chained hydrocarbons (also referred to as "light-ends") and contaminants [2,3]. The current case deals with the intrinsic safety of HTF system. Indeed, at high operating temperatures the bonds between hydrocarbon chains start to break and short-chained light-ends are formed. As the concentration of these light-ends increases, the potential fire hazard for the system increases. This is because light-ends have a lower boiling point temperature and a lower ignition temperature. This represents a potential fire risk and is tested in the laboratory by exposing the sampled HTF to a flame [4]. Thus, if the laboratory analysis reveals a decreasing flash point temperature, relative to the flash point temperature of the virgin HTF, it reflects an increasing potential fire risk and this needs to be managed swiftly and effectively.

Abbreviations: HTF, heat transfer fluid; LERK, light-ends removal kit

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Therefore, a logical question is 'why do light-ends build up in a HTF system?' This may be explained by the natural operational ageing of the HTF at high temperatures. However, if light ends form rapidly and are difficult to control, this can indicate that the HTF is not venting properly and so light ends are not able to escape and vent from the HTF system. One approach to manage the build-up of light ends is to dilute the existing HTF, but this will not fix the problem if the issue concerns the design of the HTF system design. Another approach is to remove the light ends as they form. This can be done using a light-ends removal kit (LERK). Once installed this continuously removes light-ends. The current case deals with a client's HTF system that had low closed flash point temperature that persisted for nearly 3 years before a LERK was installed to manage the light-ends. The intention of stalling the LERK was to control the formation of light-ends in the HTF. Hence, the current analysis assessed this by comparing values recorded post-LERK installation with that pre-LERK installation. The objective of this research was to determine if the installation of a LERK was effective, or not, in the management of light-ends, which was determined by assessing mean flash point temperatures and assessing their variance.

2. Experimental methods

This section is presented in five parts: information on the client's HTF system and HTF; how the HTF was sampled; the test parameters; details of the LERK; and, the engineering analysis conducted.

2.1. Client's HTF system and HTF

The current case concerns a UK-based company that approached Global Group in March 2007 as they had detected that their HTF had a low flash point temperature and this presents a potential fire hazard that must be managed. The client's system measured 2500 l and contained a mineral-based HTF. Typical values for a virgin HTF are as follows: carbon residue, <0.05; total acid number <0.05 mg KOH/g; closed flash point temperature, 210 °C; open flash point temperature, 221 °C; fire point temperature, 255 °C; kinematic viscosity, 31 (i.e., mm²/s); water content, <100 ppm; ferrous debris score, <10; soluble (e.g., Fe), ppm <5 μm.

2.2. Sampling of the client's HTF system

HTFs can be sampled in 2-ways: whilst the HTF is hot (i.e., live) or when the HTF is at ambient temperature (i.e., through a cooling HTF device or during a HTF system shutdown) [4]. The current case sampled the HTF whilst the system was live. This is performed using a sampling container closed to air. Fig. 1 depicts the sampling device used in the current case. This isolates the sampled HTF and keeps the light-ends trapped in the sampled HTF whilst it cools to ambient temperature [4].

2.3. The HTF parameters analysed

The methods used in the current engineering analysis are based on routine laboratory tests. The laboratory operates to ISO14001 and ISO17025. The test parameters utilised in the current case are cited in Table 1. To conduct these tests, a sample of 500 ml is extracted from the clients system whilst the system is in operation. Samples are collected in a sampling pot that is closed to air to avoid contamination and to avoid contact with the live HTF. Once sampled, the HTF is allowed to cool to ambient temperature. The sampling technique has been published previously [4]. Once cooled, the test parameters cited in Table 1 are performed according to ASTM International, formerly the American Society for Testing and Materials, and International Petroleum (IP) standards.

In total, the HTF analysis results revealed 33 out of specifications. This rating is assigned to test results that are not satisfactory and carry a caution, action or serious rating according to values pre-defined by Global Heat Transfer for a mineral HTF. Of the 33 out of specifications, 30 occurred between 1st March 2007 and 9th January 2010 and this was prior to installation of the LERK. These out of specifications were as follows: 1, carbon residue; 1, total acid number; 2, appearance; 9, kinematic viscosity; and, 17, closed flash point temperature.

Based on this data, this report will primarily focus on flash point temperatures and kinematic viscosity. Fire point temperature and open flash point temperature were included for comparative purposes.

2.4. LERK

The LERK is permanently installed and allows light-ends to be collected and removed continuously. The LERK works by passing the HTF through a distillation vessel, which has a special spray-type evaporator. This means that light-ends are released from the HTF as a gas and then recollected in a condenser in a liquid form. Light-ends can then be drained, either manually or automatically, from the HTF system. Further details regarding the LERK can be found at the following [5].

2.5. Engineering analysis

The data collected from the test results in Table 1 were analysed retrospectively. Data is reported as mean or variance $\pm$ standard deviation (SD), unless otherwise stated. Means were compared using a two-tailed unpaired *t*-test.

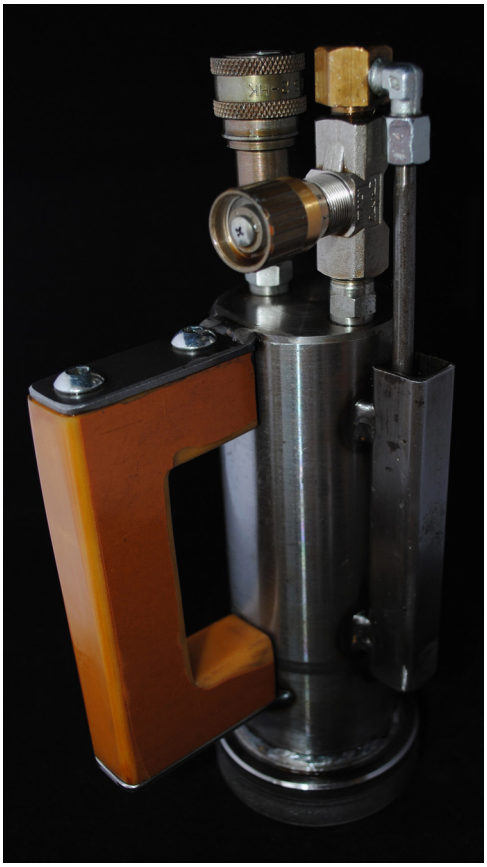

Fig. 1. The device used to sample the client's HTF.

Table 1
Chemical characteristics routinely measured.

Parameters	Unit or element	Test method
Appearance	Colour	Coded according to colour
Carbon residue	Percentage weight	IP14
Total acid number	Milligram of potassium hydroxide per gram (mg KOH/g)	IP139
Strong acid number	Milligram of potassium hydroxide per gram (mg KOH/g)	IP177
Closed flash point	Temperature (°C)	ASTM D93
Open flash point	Temperature (°C)	ASTM D92
Fire point	Temperature (°C)	ASTM D92
Kinematic viscosity	A square millimetre per second (i.e., mm²/s)	IP71
Water content	Parts per million (ppm)	ASTM D6304
Ferrous wear debris	Insolubles	PQ Analex Method
Elements	Iron, silicon	ASTM D5185

Variance was calculated using this equation: ([the sampled value—the group mean]/[the group mean])^2. Means, variances and standard deviations were calculated using Microsoft Excel 2007. A *P*-value less than 0.05 was taken as being statistically significant.

3. Results

The system sampled contained 2500 l of mineral-based HTF in March 2007.

3.1. Pre-LERK installation

The mean closed flash point temperature was 121.4 ± 32.9 °C (-42.2%, from a starting value of 210 °C). In contrast, the changes in open flash point temperature, fire point temperature and kinematic viscosity were less marked. Indeed,

Table 2
Test parameters measuring pre- and post-LERK installation.

Parameter	Unit	Mean		Variance	
		Pre-LERK	Post-LERK	Pre-LERK	Post-LERK
Time between samples	Months	1.7 ± 7.0	2.7 ± 10.6*	0.45 ± 2.08	0.29 ± 0.57
Closed flash point temperature	°C	121.4 ± 32.9	176.8 ± 11.3#	0.07 ± 0.33	0.004 ± 0.009*
Open flash point temperature	°C	196.8 ± 17.0	213 ± 5.8***	0.01 ± 0.03	0.001 ± 0.001***
Fire point temperature	°C	236.1 ± 11.2	247.0 ± 4.5**	0.002 ± 0.01	0.0003 ± 0.0004*
Kinematic viscosity	mm^2/s	28.7 ± 3.8	32.3 ± 1.5***	0.02 ± 0.08	0.002 ± 0.006**

Note: Data are presented as mean ± SD. 21 and 19 samples were taken pre- and post-installation of the LERK.
* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.
# $P < 0.0001$ when post-LERK values were compared with pre-LERK values using a using a two-tailed unpaired *t*-test.

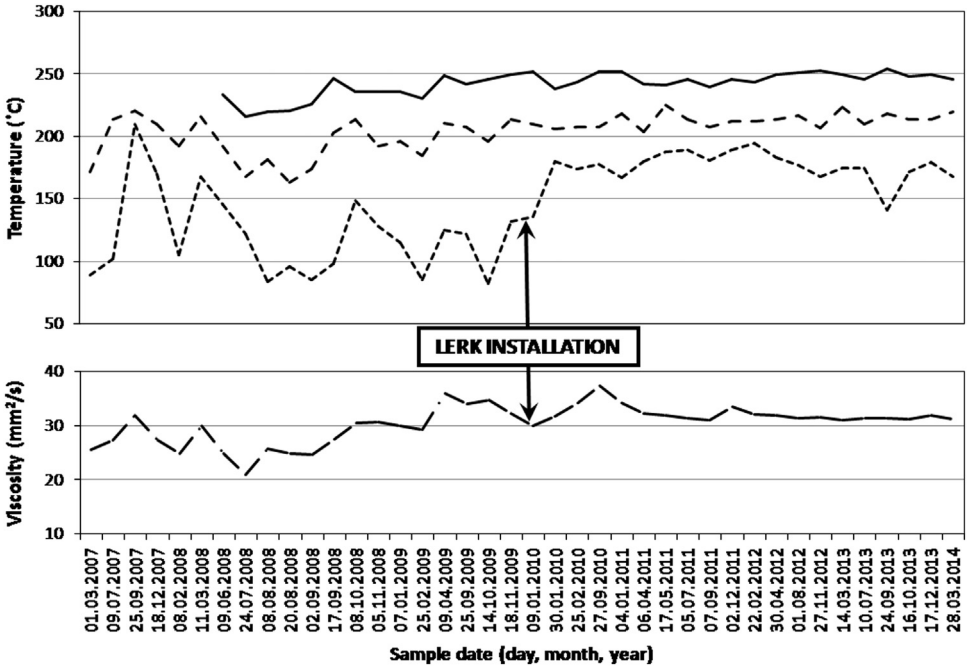

Fig. 2. The values for open flash (dashed line), closed flash, fire point temperature (solid line) and kinematic viscosity (bottom panel) between March 2007 and March 2014.

kinematic viscosity was 28.7 ± 3.8 mm^2/s (−7.4%, from a starting value of 31 mm^2/s), open flash point temperature was 196.8 ± 17.0 (−11.0%, from a starting value of 221 °C) and the fire point temperature was 236.1 ± 11.2 °C (−7.4%, from a starting value of 255 °C).

Calculations of variance revealed that closed flash point temperature had the highest variance (0.07 ± 0.33; Table 2), followed by kinematic viscosity (0.02 ± 0.08). Variances are reported in Fig. 2, which shows the analysed values for fire point temperature were considerably more stable than the other parameters plotted and this is supported by data reported in Table 2.

3.2. Post-LERK installation

Table 2 shows the mean values following the installation of the LERK. In every case, there was a significant increase in all test parameters and all remained within specification from the date the LERK was installed. For open flash point temperature, fire point temperature and kinematic viscosity, the difference versus the starting value was < 5%. The closed flash point temperature was 176.8 ± 11.3, which was 15.8% lower than the starting value of 210 °C. However, this was significantly higher and more stable than the values reported pre-LERK installation.

One of the key findings was that variance for all test parameters was reduced significantly and showed they were more stable (see Fig. 2). Indeed, the variance decreased by a factor of 6.7 and 17.5 for closed and open flash point temperature, respectively.

3.3. HTF sampling frequency

Prior to installation of the LERK, see Table 2, the HTF system was sampled every 1.7 months (~7-times per year). This frequency was reduced significantly following installation of the LERK with the HTF being sampled every 2.7 months (i.e., quarterly) in the 4 years and 2 months following installation of the LERK.

4. Discussion

The discussion is organised into three parts presented in the results sections: pre-LERK installation, post-LERK installation and sampling frequency. These three elements are discussed below and the key points are captured in the conclusions and recommendations section.

4.1. Pre-LERK installation

The current data is based on the analysis results from test results gathered between March 2007 and March 2014 (over 7 years). Data can be divided into two parts—pre-LERK installation and post-LERK installation. Data gathered prior to installation shows that the closed flash point temperature was 42.2% lower than the characteristic value for a virgin mineral-based HTF. Furthermore, it was not stable, as shown by its variance (see Table 2). Indeed, the variance for the closed flash point temperature was the highest for all the test parameters (0.07 ± 0.33) and was 3.5-times higher than kinematic viscosity; 7-times higher than the open flash point temperature; and, 35-times higher than the fire point temperature.

The relative instability of the closed flash point temperature is evident in Fig. 2. This clearly shows marked peaks and troughs between March 2007 and January 2010. The explanation for this is that during this period Global Heat Transfer were working with the client to restore, using HTF dilutions, closed flash point temperature to values > 130 °C and only achieving short-lived effects. In contrast, the rating for the open flash and fire point temperatures were more stable with values above those defined as being cautionary (i.e., > 160 and > 210 °C, respectively). This data, therefore, highlights the importance of monitoring both flash point temperatures and not assuming that changes in open flash point temperature reflect changes in closed flash point temperature. Furthermore, the current case highlights that changes in flash point temperature can occur independently of other test parameters routinely measured in the laboratory. Routine testing involves the following 11 tests: colour; carbon residue (IP14); total acid number (IP139); strong acid number (IP177); closed flash point temperature (ASTM D93); open flash point temperature (ASTM D92); fire point temperature (ASTM D92); kinematic viscosity (IP71); water content (ASTM D6304); ferrous wear debris (PQ Analex method); and, elements (e.g., iron, silicon; ASTM D5185).

4.2. Post-LERK installation

The LERK was installed in January 2014 (see Fig. 2) and all test parameters were increased and remained stable. In Table 2, it can be seen that installation of the LERK led to significant increases in all the test parameters reported with kinematic viscosity, and open flash point temperature and fire point temperatures being stabilised to within 5% of a virgin HTF. Closed flash point temperature was 15.8% (i.e., 176.8 ± 11.3 °C) lower than the starting value of 210 °C, but above the cautionary value of 130 °C. In excess of this level, closed flash point temperature is deemed satisfactory for a mineral-based HTF.

Table 2 shows the mean values following the installation of the LERK. In every case, there was a significant increase in all parameters tested and all test parameters remained within once the LERK was installed.

Perhaps the most important impact that the LERK had was the stabilisation of all test parameters. Table 2 shows that variance was significantly reduced in every case. Thus, the installation of a LERK can remove the peaks and troughs characterised by the closed flash point temperature plot seen in pre-LERK installation in Fig. 2. It is interesting that the variance of all test parameters improved once the LERK had been installed.

4.3. Sampling frequency

Table 2 shows sampling frequency decreased from 7-times per year to 4-times per year following the installation of the LERK. The increased sampling prior to the LERK installation being explained by kinematic viscosity and closed flash point temperature being out of specification (i.e., changing by $> 5\%$ and < 130 °C, respectively). It is important that sampling is conducted regularly to gain an understanding of flash point temperatures but this is only one aspect of HTF breakdown and contamination. Hence, further tests are needed to monitor other processes such as oxidative ageing, thermal degradation and contamination by intrinsic and extrinsic particles [3,4].

5. Conclusions and recommendations

HTF systems with low flash point temperatures present a potential fire hazard and should be monitored closely and regularly. This can be done by sampling the system's HTF and analysing the HTF to assess open and closed flash point temperatures. The current research assessed the data from a system in which the closed flash point temperature was persistently out of specification. To address this, a LERK was installed to help remove light-ends formed in the HTF system. Results showed that closed flash point temperature was stabilised following the installation of the LERK. Indeed, mean values were close to those for a virgin HTF and the variance between samples was markedly reduced. Both findings demonstrate the effectiveness of the LERK in the management of light-end formation and thus flash point temperatures. The overall benefit of this is that the safety of the client's HTF system was improved. It is recommended that a LERK should be installed if flash point temperatures are consistently out of specification. A further benefit of installing a LERK is that it helps to maintain the life of a HTF by avoiding the need for regular dilutions to raise flash point temperatures.

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