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Research Paper

The use of a flushing and cleaning protocol to remove foreign contaminants – a study from a newly built heat transfer plant with a capacity of 100 metric tonnes

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HIGHLIGHTS

- Cleanliness is critical to the effectiveness and safety of a heat transfer system.
- Flushing and cleaning fluids are recommended during the building of new systems.
- The current research assesses the effectiveness of flushing and cleaning protocols.
- Data highlight the value of monitoring water during a new system build.
- It is concluded that the presence of water may be an early sign of contamination.

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ABSTRACT

Heat transfer fluid (HTF) cleanliness is critical to the effectiveness and safety of an HTF system. Routine monitoring of HTF condition is a critical part of ongoing HTF system maintenance. However, the condition of any fluid introduced into a HTF system needs to be monitored closely to ensure that foreign contaminants are not introduced. Such contaminants act to accelerate the ageing of an HTF once in operation. The current research concerns the flushing and cleaning protocol that is used to remove foreign contaminants during the building of a new HTF system. The current study was performed in Scandinavia for a client building a new HTF system that had a capacity of 100 metric tons. The system was flushed with Globaltherm® C1 was used to flush and clean the system prior to filling with a synthetic HTF. The value of the protocol was assessed in terms of its ability to remove contaminants – water, environmental and system build contaminants. The protocol involved the use of a fine filter (15 microns pores) and laboratory analysis to assess cleanliness of the fluid. The results from nineteen fluid samples are presented herein. Results show the presence of water and particle contaminants (4, 6 and 14 microns in size) including silicon, aluminium, iron, calcium and zinc. The flushing and cleaning fluid works by suspending particles in solution and these are subsequently drained from the HTF system. The detection of particles in the fluid demonstrates that the flushing and cleaning fluid and the protocol are effective in removing finer particles from a system. Further analysis assessed the relationship between water and particle contaminants. Results showed a positive association between water and the presence of larger particles (i.e., 14 microns). No association was found between water and smaller particles (4 and 6 microns). These data highlight the value of monitoring both water and particle contamination, and that water may be a substitute method to measuring particles directly. The presence of water in a fluid can be observed and detected onsite, so this may be an early sign of other contaminants present in a newly build HTF system. To conclude, the flushing and cleaning protocol described herein is effective in the removal of contaminants during a HTF system build. This protocol has been shown to be effective by subsequent laboratory analysis. The presence of water may be an early sign of environmental contamination and the formation of rust.

1. Introduction

The global heat transfer fluid (HTF) market is projected to be worth around two and half million dollars by 2017, which is one and a half times its value in 2011 [1]. HTFs are used in a wide range

Abbreviations: HTF, heat transfer fluid; HTF system, heat transfer fluid system; SACA, sampling and chemical analysis of a flushing and cleaning fluid or heat transfer fluid.

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of industrial processes that use indirect heat to process foods and chemicals, and to derive electricity from concentrated solar power plants [2]. The cost and production efficiency of such plants is paramount [3] with interruptions or inefficient production leading to a reduction in overall output relative to increased production costs. Therefore, increasing or sustaining output relative to production cost is critical for the viability of an HTF plant. The maintenance of an HTF plant is central to maintaining plant operation and also ensuring the longevity and safety of the overall plant [4].

In every day practise, the condition of an HTF is assessed routinely and is an indirect measure of the condition and safety of the plant itself [5]. Indeed, routine samples drawn from a system can be subsequently analysed to assess the oxidative state, thermal degradation and contamination from foreign particles including water and wear particles [6]. This testing is conducted in a laboratory and use international test methods including those defined by the American Society for Testing and Materials (ASTM) [7]. Test results are then compared against the safety data sheet to determine if a particular parameter is in or out of specification and what intervention, if any, is needed [5].

However, testing is conducted after a fluid, for example an HTF or flushing or cleaning fluid, has been sampled and there is a lag between the time a fluid has been sampled and the time when the test results are available. The only way to reduce the lag between sampling and the time to results is to have a laboratory onsite where the fluid is sampled, although this will only marginally reduce the timeframe. The other way is to have technology, e.g., the Global Thermocare Sensor [8] that enables sampling and analysis to be done in real-time when on-site. Either way the testing is used to confirm the effectiveness of an intervention on the physical condition of a fluid or HTF [8]. The current case presents the data from a new HTF system build. Such systems are at potential risk from foreign contaminants as they are exposed to the environment whilst being built and there is an opportunity for contaminants such as water, soil and welding slag to ingress [9]. These need to be removed prior to filling with a virgin HTF as such contaminants accelerate the ageing [10] of an HTF and have a negative effect on the production-to-cost ratio. In this study case, a flushing and cleaning protocol was used to clear contaminants from the HTF system and data are presented to show that this approach is effective as shown by the extent of contaminants removed from the HTF system.

Hence, the objective of this work was to demonstrate the effectiveness of using a flushing and cleaning protocol prior to filling a newly built system with a virgin HTF. Moreover, the secondary aim was to explore the association between contaminants to see if the monitoring of water contamination is a global indication of HTF system contamination.

2. Experimental methods

2.1. Background

The current study was performed in Scandinavia for a client building a new HTF system with a capacity of 100 metric tons. The customer commissioned the flushing and cleaning of the system with Globaltherm® C1 [11]. The system was then subsequently filled with a virgin heat transfer fluid.

2.2. Flushing and cleaning a heat transfer fluid system

It is best practice to flush a newly built system prior to filling with a virgin heat transfer fluid. The reason being two-fold – heat transfer fluids are an expensive capital investment and if contaminated with foreign bodies, these can catalyse the thermal degradation of a virgin heat transfer fluid and shortening of the life of the fluid [10].

2.3. The flushing and cleaning process

Globaltherm® C1 was used to flush and clean the system. The purpose of flushing and cleaning is to suspend contaminants in the fluid so they can be removed through filtration and drainage of the fluid from the system. The flushing and cleaning methodology has been described previously [12] and described briefly herein.

Firstly, the low, high and dump lines of the HTF system header tank need to be identified. They are then checked to make sure they are not blocked and that the flushing and cleaning fluid is flowing. The flushing procedure is initiated by attaching a suction pump and hose to the dump valve on the HTF system header tank, which allows the flushing and cleaning fluid to be drained from the HTF system and for air to also be removed. The valve from the header tank is closed and the flushing and cleaning fluid is pumped into the system, from the lowest level of the system, and passes through the heater coils, the production line and to the header tank. Filling is stopped once a pre-defined fill level has been reached. The system is vented to atmosphere to stop air from being circulated around HTF system.

2.4. Taking a representative sample of the flushing and cleaning fluid

Prior to flushing the HTF system, the flushing and cleaning fluid was held in ISO storage tanks. From here the fluid was pumped into the HTF system until it was filled (125% of the system's volume). A stable circulation was then established.

Whilst in circulation the flushing and cleaning fluid was filtered using a mobile filtering unit with a pore size of 15 microns. This means that the size of the contaminating particles concerns only those less than 15 microns in diameter.

A 500 ml sample of the fluid was taken using a custom designed closed sampling device [5]. Nineteen samples were taken in total.

2.5. What analysis was conducted on the sampled flushing and cleaning fluid?

Samples were then sent for chemical analysis, which is conducted according to ISO14001 [13] and ISO17025 [14]. Water content, fluid cleanliness and contaminants contained in the fluid were conducted.

Chemical analysis was used to assess the water content in the fluid and conducted according to ASTM D6304. A new fluid has a typical water content less than 100 parts per million.

The fluid's cleanliness was assessed according to ISO cleanliness standard ISO 4406:1999) [15]. Particle size is quantified into three sizes: 4, 6 and 14 µm per ml (see Table 1) and expressed using this formula: XX/YY/ZZ to reflect the relative distribution of the three particle sizes in the sample. The fluid cleanliness for a new fluid needs to be defined with the customer, but is generally around 16/14/11 [12].

Insoluble materials (silicon, aluminium, iron, calcium and zinc) in the flushing and cleaning fluid were measured and graded on a scale from 1 (not present) to 4 (a major constitute).

2.6. Data analysis

Analysis focused on three aspects. The first was to assess the existence of a linear relation between water content and fluid cleanliness of the flushing and cleaning fluid. An x–y plot was used to visually inspect this relationship. A Pearson correlation (r-value) was calculated for the 19 paired samples and a P-value calculated to assess if the relationship reached statistical significance.

The second analysis focused on the comparison of values within groups. In this case particle size scores were compared using a single

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