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Awareness of heat transfer fluid degradation in thermal oil heater in Malaysia manufacturing industries

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ABSTRACT

A thermal oil heater (TOH) is a heating system that is preferred in the manufacturing industries. However, the potential risk for fire and explosion from thermal oil heaters has often been neglected. Heat transfer fluid (HTF) degradation is one of major issues when operating TOH because the degradation alters its physical properties. This paper aimed to evaluate the level of awareness of HTF degradation in TOH safety in Malaysia and to develop a baseline safety guideline on HTF degradation and TOH safety for Malaysian industries. Interviews were conducted and a questionnaire was developed to determine four elements: TOH safety, HTF of choice, HTF degradation and consequence, and preparedness for fire and explosion. The level of awareness of HTF degradation in TOH amongst the factories in Negeri Sembilan was found to be poor with the overall level of knowledge scores for TOH safety, HTF of choice, HTF degradation, and preparedness for fire and explosion. Finally, a baseline for safety guideline on HTF degradation and TOH safety was proposed and presented.

Keywords: fire explosion hazard; fire risk assessment; heat transfer fluid; thermal oil degradation; thermal oil heater

1. INTRODUCTION

A thermal oil heater (TOH) is one of the best options for a heating system and indeed the best value in terms of maintenance cost, safety and having a small number of government regulations controlling its use. However, operating TOH without performing a risk assessment is extremely dangerous. In some literature, TOH is also known as thermal fluid heater or thermal fluid system. In this study, TOH is referred to as thermal oil heater to keep with the local definition of the system.

A heat transfer fluid (HTF) is an oil-based fluid that is used in thermal fluid systems such as heat exchangers, solar thermal collectors and thermal oil heaters. The function of the HTF in the TOH is to transport the heat from the furnace to the designated production line (Srivastva et al., 2015). The HTF has a higher boiling point compared to water and is, therefore, safer in terms of heat transfer. This property makes the HTF safer as it can be operated in a lower pressure system. The HTF also has a high flash point and therefore is not categorized as a flammable substance. This has caused the industries to neglect and be ignorant of the risks of fire and explosion that can be caused by HTF degradation (Grirate et al., 2016). Knowledge of HTF properties is very important in TOH operation and maintenance. Thus, to operate a TOH system, a standard operating procedure (SOP) is required to avoid accidents of fire and explosions. In practice, factories and plants have frequently ignored this potential risk by allowing this system to be operated with minimal attention and maintenance (Ennis, 2009).

A HTF is categorized as a non-flammable substance under physical hazard in a safety data sheet (SDS) because of its original high flash point value. The information in the SDS refers to the production sample that was tested in the laboratory. The SDS is the only information that is available to users for their reference on the safety of the HTF (Rainer, 2010). This physical hazard information may not be reliable once the HTF has been used for an extended period as degradation occurs. There is no available information in the SDS about the effect of HTF degradation or deterioration in time showing the resulting change in properties.

There have been several incidents related to TOH fire and explosion reported worldwide as well as the more recent incident in Subang Jaya, Malaysia. In the United Kingdom, the health safety executive (HSE) had issued prohibition notices to several companies involved in incidents related to TOH and they had declared the TOH as a fire and explosion hazard (Mckay and Franklin, 2011). On 5th February 2010, a TOH explosion was reported at the Eager plant in Brilon, Germany (EF News, 2010). This incident caused fatalities to three workers and damage to the facilities. Santon (2009) reported that at least four additional fire cases were reported to be caused by HTF. Additionally, Febo and Valiulis (1995) reported 54 fires and explosions costing $150 million in losses involving HTFs during a 10-year period of study. There was an incident that happened in Subang Jaya, Malaysia recently in 2017. According to TOH fire and explosion at a food chain's factory tragically caused three fatalities and three injuries. The company was fined by the Department of Occupational Safety and Health Malaysia (DOSH) because of the failure to carry out a risk assessment before operating the equipment.

HTF can become a fire and explosion risk by two ways. First, the fluid degrades which can dramatically decrease its flash point and second when operating under pressure it can form an explosive mist even at a temperature below the flash point (Mckay and Franklin, 2011). The mist created when operating HTF at high pressure could leak and cause an explosion in an enclosed area (Febo and Valiulis, 1996). The study by Huang et al. (2013) provided initial flammability criteria for a commonly used HTF as a mist fire hazard in terms of droplet size and volumetric concentration, discussed the observation of aerosol combustion processes, and summarized an ignition delay phenomenon. Lian et al. (2010) showed that the flame propagation of the HTF mist is influenced by its droplet size and concentration. Both studies have proven the explosion risks that can be potentially caused by HTF. Thermal breakdown or oil cracking is an occurrence that results in a lower flash point and lower boiling point in a HTF. It is caused when the HTF ages or operates at an elevated temperature (Grirate et al., 2014; Oyekunle and Susu, 2005). Another way the HTF can become a fire risk is via the formation of flammable by-products along with carbon and acid deposition. Such system must be flushed entirely to remove the deposition and prevent accidents (Wright, 2014b).

A proposed usage of the light-end removal kit (LERK) to remove hydrocarbon by-products from an aging HTF can help to prevent the build-up of the light-ends by constant removal of the by-products (Wright, 2014a; Wright, 2018). This is similar to system flushing for removal of residual deposits. The mist that can be created due to the high-pressure operations of HTF is an explosion risk when small amounts of the mist are confined in a small space or when large leaks happen. One way to prevent this is using nitrogen as an inert barrier in an expansion tank to avoid explosive mist leakage (Sloley, 2011). A Malvern diffraction particle analyzer was also used in the work of Krishna et al. (2003) to measure and provide information correlating aerosol droplet diameters to HTF parameters to predict the explosion hazard of HTF mist.

Besides, proper plant installation, maintenance and operating procedures are very important in the management of HTF degradation. Plant operators must realize that HTF does pose a fire and explosion risk and pay higher attention to HTF maintenance. A visual inspection of HTF could help with identifying aged HTF via color changes due to oxidization with an increase in total acid number for the HTF. An estimation procedure was studied to predict the degradation of HTF using a mathematical model for six samples of common HTF (López-González et al., 2013). The study found that a frequent sampling for total acid number (TAN) and flash point temperature would help to improve the overall condition of HTF under use. Wright et al. (2015) proposed a sampling frequency of more than once per year in order to increase HTF operating life as a proper management procedure.

Due to the lack of awareness of HTF degradation specifically in Malaysian factories, a proper guideline should be drafted by the government through its agencies to prevent another fire and explosion accident from happening. According to the SDS issued by the oil manufacturer, the HTF is not categorized under flammable substances because it has a flash point of over 200°C and an auto ignition temperature of 380°C. This information clearly shows that a clear guideline on safe operations of TOH is critically required and must be developed in Malaysia. Although the material is classified as a non-flammable, HTF is known to be the cause of fires and explosions due to its degradation effect altering its physical properties. A continual lack of awareness on TOH safety will result in more TOH accidents to occur due to failure in identifying HTF as a possible flammable substance. An assessment of the level of awareness on TOH safety and HTF degradation needs to be conducted and a baseline for safety guideline for TOH should be developed. TOH are used across all manufacturing sectors such as in agricultural products, food and healthcare products, rubber and plastic products, chemicals, and recycling. A total of 428 units of TOH in manufacturing plants are currently registered in Malaysia and, according to DOSH, this number is increasing.

The objectives of the study were to evaluate the level of knowledge in the manufacturing factories on HTF degradation and its consequence and TOH safety, and to propose a baseline for safety guideline on HTF degradation and TOH safety.

2. MATERIALS AND METHODS

The level of awareness of HTF degradation in manufacturing plants in the state of Negeri Sembilan was evaluated in this study. A total of 25 factories involved in the manufacturing industry were selected for the survey. HTF manufacturers were also interviewed to assist in developing the questionnaire and to gain a better understanding of the HTF handling and condition amongst the HTF suppliers for the selected factories.

2.1 Questionnaire survey

The structured questionnaire used in this study was developed based on literature review. The targeted groups consisted of the factory manager, engineer and the factory maintenance team. There are five main sections in the questionnaire, which are; (1) demographic information, (2) knowledge of TOH, (3) knowledge about their HTF of choice, (4) knowledge of HTF degradation and its consequences, and (5) preparedness for risk of HTF fire and explosion.

(1) Demographic Information

The demographic information of the respondents comprised age, gender, nationality, level of education, job position, general working experience, working experience with TOH, and annual sales turnover.

(2) Knowledge of TOH safety amongst the manufacturing industries

The questionnaire was designed based on the basic requirement of safety devices for TOH. Examples of safety devices that are important for fire prevention are the safety valve, flue gas temperature limiter, flame detector, thermal oil high temperature cut-off alarm, expansion tank oil-level cut-out, and thermal oil heater control system. Apart from these devices, the questionnaire also included the regulations on TOH safety and their responsiveness towards defects in the critical parts of a TOH.

(3) Knowledge about their HTF of choice used in operation

The respondents were asked about their understanding of the HTF used in their TOH. Therefore, the scope of the questionnaire focused on the information in the HTF technical and safety data sheet, the HTF hazards, the physical properties of the HTF (boiling point, flash point, auto ignition point, and fire point).

(4) Knowledge of HTF degradation and its consequences

The respondents were asked about their knowledge of HTF degradation and its consequences. For that reason, the questionnaire focused on the practice in monitoring HTF degradation and its procedures, the handling and storage of the HTF, as well as the consequences of mishandling HTF. It also covered the sampling and chemical analysis (SACA), the element of measurement to access the ageing HTF (flash point, TAN, viscosity and carbon level), and flushing procedure prior to refilling.

(5) Level of preparedness for HTF fire and explosion risk

The respondents were asked regarding their practice in handling the risk of fire and explosion to determine the level of preparedness towards HTF degradation and its consequence. The respondents were asked, using a rating scale, about their opinion on the adequacy of the training for emergency response planning, critical parameters while operating the TOH, HTF safety procedures and the need for established guidelines from the authorities.

2.2 Interview and site visit

Interviews and site visits were organized to gain information on the current practice regarding HTF in the factories in Negeri Sembilan. The interview sessions with factory managers and site visits were carried out prior to this study. Interviews were also carried out with technical specialists from every oil manufacturer involved with the factories in Negeri Sembilan. These interviews were unstructured questions to assist in developing the initial draft of the questionnaire and helped to further understand the current management of aged HTF in the factories.

2.3 Sample size

A total sample size of 25 manufacturing factories using TOH in Negeri Sembilan were available for the survey. All the factories have been registered for operating TOH under DOSH, Malaysia. The factories included those that manufactures gloves, tars, chemical, glue and sticker tape. The management of the factories had agreed to participate in the survey after understanding the objectives of the study.

The minimum sample for each factory was one respondent each from management and technical line. Towards this end, 55 respondents were selected to participate in this study. The 55 respondents were categorized as management staff (managers) or technical staff (engineers and technician). The selection of the sample size was made by referring to the table for determining the sample size for a finite population (Krejcie and Morgan, 1970; Sarantakos, 2013).

2.4 Pilot test

The first round of a pilot test was done to verify the questionnaire's suitability and clarity. The verifications were carried out with a manager from one of the manufacturing plants, an oil company specialist from the oil manufacturer and the director of DOSH for Negeri Sembilan. From this first round test, the feedback and comments received were used to improve the draft questionnaire. The improved draft questionnaire was run through a second pilot test with a registered TOH factory in the state of Selangor. Here, the questionnaire was tested on five respondents, which included engineers and technicians who were involved directly with the TOH at the factory. The time taken by the respondents to answer the questionnaire was about 20-30 minutes.

2.5 Statistical analysis

The data analysis was conducted using IBM SPSS version 23.0. All the answers from the questionnaire were coded into variables. The SPSS variable was given a score of 1 for aware and 0 for unaware, with the total number of variables of 10 for each section. The total scores for each section (B, C, D and E) were then calculated into percentages. Based on the results for every section was graded (A, B, C, D or E) and a level of performance allocated (poor, fair or good). The variable values in SPSS and the scoring format used in this study are shown in Table 1.

There were two types of analysis done in this study using SPSS for all of the sections in the questionnaire (TOH safety, HTF of choice, HTF degradation and its consequence and preparedness for risk of fire and explosion of HTF).

(1) Statistical analysis of the knowledge level of respondents on each section

The results were in percentage, before they were coded into performance level of poor (=1), fair (=2) and good (=3) in SPSS for statistical analysis. The outcome of this analysis reflected the level of knowledge for each section which finally translated into the level of awareness.

Table 1. SPSS scoring variable values and level performance format

Section	SPSS variable values[a]	Number of variables[b]	Formula	Grade	Level of performance[c]
A			Independent variable		
B	unaware=0, aware =1	10	$\frac{\sum \text{Variable value}}{\text{Total score}} \cdot 100$	0-59%=E	E-D=poor
C	unaware=0, aware =1	10		60-69%=D	C=fair
D	unaware=0, aware =1	10		70-79%=C	B-A=good
E	unaware=0, aware =1	10		80-89%=B	
				90-100%=A	

Note: [a]The values of variables in the SPSS were set as minimum '0' for unaware and maximum '1' for aware
[b]Number of questions in each section in the questionnaires
[c]The performance scale used is based on the CIMAH audit scoring format

(2) Gap analysis for the proposed baseline guidelines on each section

The level of knowledge on specific questions were calculated using the same formula as above. These were analyzed according to the responses to the specific questions by the respondents. For example, in section B, every question from B1 until B10 was calculated to determine the level of knowledge. The results were expressed in percentage, before they were coded into performance levels of poor, fair and good.

From the statistical results, the causes for the level of knowledge on a specific question being low or high were discussed. The questions that are rated poor will be given a priority to be included in the proposed guidelines. These are important in the establishment of HTF safety procedures and baseline elements of the framework.

3. RESULTS AND DISCUSSION

3.1 Respondent characteristics

Table 2 shows the respondents' characteristics. As a summary, amongst the 55 respondents, 98.2% were male and only 1.8% were female. Most of the respondents were between 41-50 years old (34.5%). 92.7% were Malaysian and the rest were non-Malaysian. In terms of education level, most of them were degree holders (41.8%). The rest had education levels, in descending number, of high school, diploma, certificate and lastly, master's degree. Almost half of the respondents had working experience of more than 15 years. The percentages of respondents according to position, starting from manager, engineer/executive, and technician were 49.1%, 21.8%, and 29.1%, respectively. In terms of annual sales turnover, 52.7% of the respondents worked at companies with over 40 million in annual sales while the rest (47.3%) of the respondents were with companies recording sales of under 40 million.

3.2 Knowledge level of respondents

Table 3 shows the results for each section of the questionnaire that consist of the knowledge level of respondents on TOH safety, their HTF of choice, HTF degradation and consequence, and on preparedness towards HTF fire and explosion risk. In each section in the questionnaire, there were 10 questions designed to measure the knowledge level of respondents. The survey showed that the majority of respondents were rated as having poor knowledge on TOH safety, poor knowledge on choice of HTF, poor knowledge on HTF degradation and its consequence, and poor preparedness on HTF fire and explosion risk.

3.2.1 The overall level of awareness on HTF degradation and its consequence

A total of 40 questions in four sections of the questionnaire were successfully answered by all 55 respondents to assess the level of awareness on HTF degradation. The questions focused on knowledge of TOH safety, knowledge of HTF of choice, knowledge of HTF degradation and its consequence, and preparedness for HTF fire and hazard risk. The pie chart in Figure 1 illustrates the average level of awareness (poor, fair and good) on HTF degradation evaluated from the respondents' answers. Overall, it is obvious that the survey showed that most respondents were rated as having poor knowledge on HTF degradation and its consequence.

Table 2. Respondents demographic information

Parameters	Frequency (n=55)	Percentage (%)
Gender		
Male	54	98.2
Female	1	1.8
Age		
21-30	11	20.0
31-40	17	30.9
41-50	19	34.5
>51	8	14.5
Nationality		
Malaysian	51	92.7
Non-Malaysian	4	7.4
Education		
High school	14	25.5
Certificate	7	12.7
Diploma	8	14.5
Degree	23	41.8
Master	3	5.5
Working experience		
1-5 years	11	20
6-10 years	8	14.5
11-15 years	11	20
>15 years	25	45.5
Position in company		
Technician	16	29.1
Engineer/Executive	12	21.8
Manager	27	49.1
Company annual sales turnover		
>40 million	29	52.7
≤40 million	26	47.3

Table 3. Knowledge level of respondents regarding TOH and HTF safety

Section	Element of knowledge	Poor (%)	Fair (%)	Good (%)
B	Knowledge level of respondents on TOH safety	70.90	14.55	14.55
C	Knowledge level of respondents on their HTF	58.18	21.82	20.00
D	Knowledge level of respondents on HTF degradation and consequence	81.82	9.09	9.09
E	Knowledge level of respondents on preparedness towards HTF fire and explosion risk	52.73	29.09	18.18

3.3 Interview with HTF oil manufacturers and factory managers

Table 4 and Figure 2 show the findings and information collected in the interviews with the factory managers and technical specialists from the HTF manufacturers. The findings show that there is a total of seven manufacturers who supply HTF to the manufacturing plants in Negeri Sembilan. These interviews revealed that all the HTF manufacturers recommended their clients to at least carry out the HTF sweetening process, instead of a full replacement when the HTF degrades. The HTF sweetening process is a practice where instead of a full replacement of HTF, only partial HTF replacement was performed. The percentage of replaced HTF in practice could either be 30% or 70% of the full HTF capacity. Table 4 shows the control and condition that are currently recommended by the HTF manufacturers in Negeri Sembilan.

Figure 2 illustrates the findings of the interviews regarding the current practice in handling the degradation of HTF. It showed that 47.83% of factories in Negeri Sembilan were currently not practicing the recommended method by the manufacturers and instead only performing the top-up method when their HTF level was low.

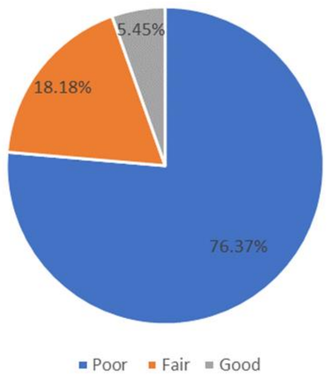

Figure 1. Respondents level of awareness of HTF degradation and its consequence

Table 4. HTF control and condition procedure recommended by the manufacturers

Manufacturer[a]	Skin temp (°)[b]	TOH condition[c]	Operating temperature (°)[d]	Handling aged HTF[e]
Manufacturer 1	340	Closed system	As stated in TDS (340)	Sweetening
Manufacturer 2	320	Closed system	Below flash point (<220)	Sweetening
Manufacturer 3	345	Closed and open system	Closed (315)	Sweetening
Manufacturer 4	330	Closed system	As stated in TDS (330)	Sweetening
Manufacturer 5	315	No information	Inadequate information	
Manufacturer 6	335	No information	As stated in TDS (325)	Sweetening
Manufacturer 7	N/A	Closed system	As stated in TDS (315)	Sweetening

Note: [a]Total of seven manufacturers who supply HTF to the manufacturing factories in Negeri Sembilan
[b]Recommended operating temperature at the fire side
[c]HTF products applicable based on condition of TOH (open or closed system)
[d]Operating temperature recommended by HTF suppliers in Negeri Sembilan
[e]HTF manufacturer recommended their clients to at least carry out the HTF sweetening process, instead of a full replacement when the HTF condition degrades

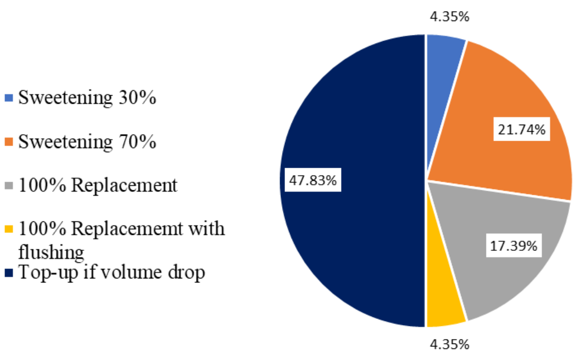

Figure 2. Current aged HTF maintenance action method in factories in the state of Negeri Sembilan

3.4 The proposed baseline of HTF degradation and TOH safety guidelines

The results showed that 76.35% of the factories had a poor level of awareness regarding the degradation of HTF. The interviews showed that there were several (32%) factories that have received inaccurate information on how to handle HTF degradation. Upon further investigation, the information obtained by the factories regarding the HTF was through the salesmen appointed by the manufacturers. There are no guidelines or industrial code of practice currently available in Malaysia to be referred to by the industries or HTF distributors. For this reason, it is likely that the information on safe practices in HTF handling may not be accurate and can be misinterpreted which can lead to a mishandling of HTF.

Knowledge of HTF degradation and its consequence was found to be the lowest, with 81.82% scoring poor on this section. Therefore, it is critical to have a further discussion on the safety issue of HTF degradation that may lead to a new guideline being written for HTF inspection and maintenance.

Even though some respondents (9.09%) had a good knowledge of HTF degradation, they still suggested a need for regulations or guidelines by DOSH or any other related enforcement body regarding the control measures for HTF degradation. Most respondents (81.36%) agreed that a guideline from DOSH was preferred. From the interviews, it was suggested that an established and standardized guideline from DOSH was important as a reference for HTF users and to avoid inaccurate information from the suppliers, which may be biased towards maximizing their profits.

Only 46.36% of the respondents agreed that DOSH inspectors enquired about HTF degradation. This result has proven that the DOSH inspectors were only focused on the integrity of the TOH during inspections and neglected to review the critical properties of HTF, as mentioned earlier in the literature review. This supported that the establishment of HTF guidelines by DOSH will enhance the inspection procedures related to HTF safety.

3.4.1 HTF degradation and the degradation effects

Five important elements regarding HTF degradation and the effect of HTF degradation that needs to be considered and discussed in building a guideline were:

(1) Cause and effect of HTF degradation

HTF degradation occurs when it is overheated, and the degradation will be enhanced when it is used for a long period without any monitoring. As the results, the respondents had poor knowledge in this matter. A HTF degradation cause and effect analysis should be carried out by the HTF guideline committee in the future. The proposed committee should include the DOSH, the manufacturing industries and the HTF manufacturers so that they can work collectively to discover the exact cause and effect of HTF degradation.

(2) The consequences of HTF degradation - fire and explosion risk

Mckay and Franklin (2011) reported that the HSE United Kingdom declared that the TOH operation is categorized under the fire and explosion risk. This study also showed that knowledge about the effects of HTF degradation was still poor amongst the Malaysian factories. Thus, enforcement and guidelines by DOSH are required to raise the awareness of the industries on this issue and to mitigate future accidents.

(3) SACA

It is proposed here that the practice on HTF safety and handling should include reference to SACA and reference to the critical physical properties of HTF. This study showed that most of the factories do not practice SACA for monitoring their HTF quality. Therefore, information from SACA regarding the minimum frequency, type of testing, testing method and HTF sample-taking procedure, as well as the critical physical properties should be included in the proposed guideline.

(4) Signs of HTF degradation

A decrease in volume without any leakage in the system is believed to be one of the signs of HTF degradation during operations. However, a significant number of factories were still unaware of this as a sign of degradation. The results showed that about 47% of the Negeri Sembilan factories topped up the HTF without performing any testing on it when the volume decreased rapidly.

In addition, the interviews indicated that a few experienced managers claimed that they could sense the level of degradation by physical assessment, i.e., the odor, color and tactile sensation of the HTF. The color of the HTF can change from lighter to darker during the degradation process. However, there are no evidence of changes in odor and tactile sensations as claimed by the interviewees that have been found in literature or written reports. Nonetheless, this information can be suggested for addition in the guidelines as an early physical assessment prior to laboratory testing. These subjective physical signs should not override the need for the proper replacement of HTF.

(5) Handling of aged HTF

The results of this study showed that knowledge on the handling of aged HTF was poor. The interviews conducted during this research also showed that there were different practices in handling aged HTF in the Negeri Sembilan factories. They either performed a full HTF replacement, full HTF replacement with flushing, 70% sweetening, 30% sweetening, or only topping up the fluid. Among these methods, only the method that was suggested by the manufacturer should be accepted for inclusion in the proposed guideline to avoid the premature degradation of newly replaced HTF (Ennis, 2009).

3.4.2 TOH safety requirements

The results showed that many respondents (70.91%) were still unaware of the TOH safety requirements. Hence, the elements of the TOH safety should be also considered in the guideline. Information on TOH safety that should be included in the guideline are:

(1) Critical safety devices

The respondents were unable to determine the more important critical safety feature between temperature and pressure. Therefore, the importance of critical safety features should be listed clearly according to their priority for user reference in the proposed guideline.

(2) Critical defects

Any tube leak in a TOH, especially within the furnace side, should be regarded as a major defect because the ignition source from the furnace may lead to an explosion. The list of critical defects in a TOH system and the acceptance criteria should be listed in the guideline.

(3) Open or closed system

The guideline should be able to define and differentiate whether the TOH is an open system or a closed system. This is vital as to avoid any mistake such as wrongly setting the operating temperature by referring to an incorrect property information in the TDS/SDS.

3.4.3 HTF requirement

(1) HTF technical data information by the manufacturers

In each of the product TDS, there are information provided regarding the type of TOH that is suitable for the HTF. Most HTF are only suitable for a closed system TOH. Only one manufacturer supplied HTF suitable for both closed and open systems and they provide the information on the operating temperatures for both systems. In the guideline, it is suggested that information on the operating temperature for HTF is provided for both open and closed systems.

(2) HTF properties

The guideline on HTF management, thermal oil heater temperature setting reference and other critical information such as the autoignition and flash points should be included in the proposed guideline.

3.4.4 Preparedness for fire and explosion risk

The proposed guideline should also include fire precautions, firefighting and equipment such as foam extinguishers, dry powder extinguishers, carbon dioxide extinguishers, color coding extinguishers, and uptake fire precaution.

3.4.5 Proposed baseline of HTF degradation and TOH safety guidelines

This proposed baseline was developed based on the gap found from the analysis of level of knowledge on specific questions and compared with the Hong Kong code of practice for thermal oil heater (Boilers and Pressure Vessels Authority, 1992). The proposed baseline guidelines consist of four sections and the section details are as in Table 5.

Table 5. The proposed baseline of HTF degradation and TOH safety guidelines

Section	Criteria to be included in proposed guidelines
Section 1: HTF degradation	*Cause and effect of HTF degradation* 1.1.1 HTF degradation due to period of usage 1.1.2 HTF degradation due to overheating 1.1.3 Effect of HTF degradation to safety (flash point drop), operation (viscosity and oxidation) *Fire and explosion risk information* 1.2.1 Fire and explosion consequence: Risky when flash point drops below 140°C 1.2.2 HTF operation procedures: Maximum limit of operation temperature not over the auto ignition temperature *HTF sampling and chemical analysis (SACA)* 1.3.1 Frequency of sampling and chemical analysis recommended to be done two times per year, however the user can justify according to their requirement 1.3.2 Chemical analysis and the rejected value of each testing. Minimum testing recommended are (1) flash point value (below 140°C) (2) TAN (over 0.5) and viscosity increase. *Signs of HTF degradation* 1.4.1 Level of volume rapidly dropping without any leakage detected is a sign of HTF degradation 1.4.2 Color transformation to a darker shade is a sign of degradation *Handling of aged HTF* 1.5.1 100% HTF replacement with flushing prior to replacement 1.5.2 100% HTF replacement without flushing 1.5.3 70% sweetening 1.5.4 30% sweetening
Section 2: TOH safety requirement	*Essential fittings* 2.1.1 Temperature controls: Flue gas temperature limiter, flame detector, HTF high temperature cut-out alarm, HTF heater control 2.1.2 Pressure controls: Pressure relief valve, HTF flow limiter and expansion tank low oil level cut-out *Operation and maintenance* 2.2.1 Observation during operation: Pressure, temperature, flow rate and expansion tank oil level 2.2.2 Routine maintenance: HTF sample check and testing, HTF record book, essential fittings regular testing (safety valve, HTF low flow cut-off alarm, maximum temperature cut-off alarm, flame failure cut-out alarm and flue gas high temperature cut-out alarm) *TOH open system and closed system* 2.3.1 Open system: TOH designed with an air vent at the top of the expansion tank 2.3.2 Closed system: TOH designed to be fully closed without any contact with ambient air, normally a nitrogen blanket is used in the expansion tank to block any air access into the system.
Section 3: HTF requirements	*HTF TDI by manufacturers* 3.1.1 Open system: Skin/film temperature and bulk temperature 3.1.2 Closed system: Skin/film temperature and bulk temperature *HTF properties information: Autoignition, boiling point, flash point, point fire and viscosity.*
Section 4: Preparedness for fire and explosion	*Precaution on firefighting and equipment* 4.1.1 Fire hazards: HTF vapor can form mixtures which will flash or explode if ignited. Elimination of all sources of ignition. Oil waste kept in metal drum filled with water. 4.1.2 Foam extinguishers, dry powder extinguishers, carbon dioxide extinguishers and information on the color coding of these extinguishers. *Training* 4.2.1 TOH operators training: Fire training requirement 4.2.2 Fire drill: Requirement to conduct small scale exercises for the boiler's operators once every three months at the minimum. *Emergency response plan* 4.3.1 Emergency response organization 4.3.2 Emergency response procedures 4.3.3 Emergency evacuation plan

4. CONCLUSION

In conclusion, the level of awareness of heat transfer fluid degradation in thermal oil heaters in Negeri Sembilan factories was investigated and found to be poor. The majority of the respondents are rated as having poor knowledge of HTF degradation and its consequence. Most of the respondents, i.e., 81.8% are in the poor category. About 58.2% of them are rated as having poor knowledge of their HTF of choice, 21.8% fair and 20% good. The analysis also revealed that the majority of the respondents are rated as having poor knowledge of TOH safety with 70.9% of them falling into the poor category. The study also revealed that the factories in Negeri Sembilan have a poor knowledge of thermal oil heater safety, the heat transfer fluid of choice, heat transfer fluid degradation and its consequence, and preparedness towards fire and explosion risk. These elements have been used as a baseline for the proposed guidelines.

This study also discovered that the industries need to be issued a guideline on the heat transfer fluid degradation in thermal oil heaters. A suitable guideline and enforcement by the authorities may increase knowledge and preparedness in the industries. This guideline is proposed to cover the aspect of heat transfer fluid maintenance including degradation monitoring and handling of aged fluid, thermal oil heater critical safety features and defects, the physical properties of HTF, and fire safety training.

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