Thermal Fluid Systems

A Practical Guide for Safe Design, Operation and Maintenance

Ref: BG07

CEA
Combustion Engineering Association

This page is intentionally blank

Foreword

This document, Thermal Fluid Systems - A Practical guide for Safe Design, Operation and Maintenance (BG07) has been developed and written by the Combustion Engineering Association (CEA) in consultation with its Members and other stakeholders within the thermal fluid industry to help designers, owners, managers and operators of new and existing thermal fluid heating systems to install and operate safe systems, and to make health and safety and environmental improvements in the industry. The objective is to help users of thermal fluid systems manage their own risks and create safe and efficient installations.

This first Edition of BG07 incorporates up-to-date information and best practices relating to the design and operation of thermal fluid systems primarily fired using conventional gas and light oil burners. Other thermal fluid systems fired using solid biomass and electrical direct heating methods are available but not specifically covered, but much of the basic health & safety information and the system design information herein will be relevant.

There are currently few authoritative documents available that cover the wide range of opportunities and challenges that thermal fluid systems offer for many specialised industrial processes, so the CEA members who are most closely involved with the supply of thermal fluid heaters, systems and the fluids themselves have gathered together their combined knowledge and many years of experience in producing this guide.

This publication has been written with specific regard to the law and best practices in the UK. Readers from other jurisdictions will find the guidance useful but will need to consider relevant local laws and regulations.

This publication should not be regarded as an authoritative interpretation of the law in the UK, nor a mandatory legal requirement. Users must ensure that they are referring to the latest available legislation and guidance which can be found at hse.gov.uk, environment-agency.gov.uk, cea.org.uk and many other reliable sources. A list of many of the currently available reference documents is in the Appendix, along with a glossary of terms used.

The Combustion Engineering Association (CEA) is an educational charity which promotes the science of combustion engineering in the commercial and industrial sectors. The CEA is concerned with industry good practice and the safe and efficient operation of combustion related plant and equipment, and offers guidance and accredited training schemes that match the wide range of industrial combustion plant available today.

The CEA also produce a range of Guidance Notes for boiler house designers, installers and users, and these can be obtained through the CEA and are listed on their web site cea.org.uk.

In this document the following words convey specific meaning:

Should: Compliance with this clause is not essential to demonstrate compliance with this document where supported by risk assessment and/or design calculation.

Shall: Compliance with this clause is required in order to claim compliance with this document.

Must: Compliance with this clause is a legal requirement within the United Kingdom.

Unless otherwise stated, all pressures refer to gauge pressure.

Acknowledgements

A number of staff in the CEA and several CEA Member companies have freely given information and advice to enable this document to be produced and the CEA are grateful to all Members for their contributions.

- Babcock Wanson
- Energy and Environmental Solutions
- Fulton Boilers
- M&M Training
- SP Thermal Solutions Ltd
- Thermal Fluid Solutions

Cover image courtesy of Babcock Wanson

THERMAL FLUID - A LIQUID OR VAPOUR USED TO CARRY HEAT

i.e. A ‘HEAT TRANSFER MEDIUM’

TABLE OF CONTENTS: PAGE

1 INTRODUCTION

Thermal fluid heating systems are in common use across many sectors of industry and it is estimated there are at least 2000 installations of such heaters in the UK fired on natural gas and light oil, and many more, often smaller units, utilising direct electrical heating of the fluid. Biomass is also used in some installations as a fuel.

Thermal fluid heaters are available in a wide range of sizes to suit many different applications and temperature requirements. Units capable of delivering fluid temperatures to processes at up to 350ºC range from 100kW to around 17MW output, with smaller sizes for providing heat to individual process machines also being readily available. Some systems also include cooling capability to around minus 50ºC with the correct choice of fluid.

Users of these installations operate in a wide variety of industries including:

- Food and drink manufacturing, breweries and distilleries;
- Printing and coatings industries;
- Petrochemicals and bitumen reactors;
- Fine chemicals;
- Wood panel and composite panel manufacturing;
- Extrusion and moulding processes;
- Laundries.

This guidance is for users of thermal fluid systems to enable them to fully understand the capabilities of thermal fluid heaters and the way they can be integrated into their business. It will also be useful for designers and installers to remind them of emerging legislation and best practices that affect the installations they create, and it will help plant operators and maintenance contractors to keep the installations operating safely and at optimum efficiency.

There are a number of sets of legislation relating to the design, installation, operation and maintenance of industrial equipment such as thermal fluid heaters and associated systems, and reference is made to the most significant of these throughout the text. A list of suggested reference material is in the Appendix, along with a glossary of some of the terms used herein.

Typical multi-pump thermal fluid installation (Babcock Wanson)

2 SCOPE

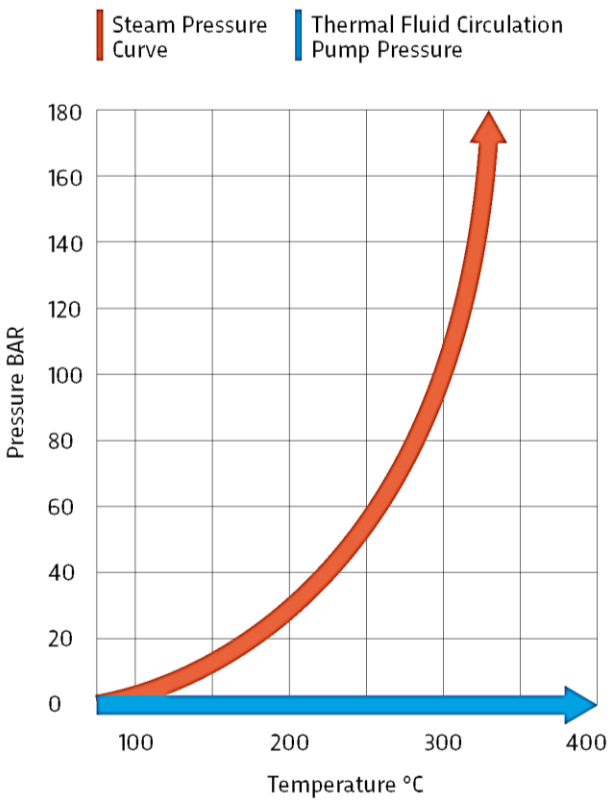
This guidance document is primarily aimed at designers and users of commercial and industrial thermal fluid heating systems fired on natural gas or light oil. Other fuels such as biomass and direct electrical heating are also in common use, but these technologies are not covered in any detail here. However, the general principles of safe and environmentally sound design and operation will apply to all thermal fluid systems.

It is quite common for thermal fluid heating systems to be used as 'unfired' steam generators where the thermal fluid is fed through a calorifier in order to generate steam for specific uses on site. This document does not cover the requirements for steam plant, and readers are directed to *BG01, Guidance on Safe operation of steam boilers* (published by the CEA and SaFed) for further information.

3 WHY THERMAL FLUID?

Many specialised industrial processes need a reliable and fast-acting source of heat. Sometimes this is provided by directly heating the product with air or steam (cement and other kiln applications, or autoclaves for example) and sometimes by utilising steam indirectly (e.g. in jacketed pans), but if heat at a higher temperature is required for the process, or if the heating system is dedicated to the process in a closed loop then a thermal fluid system can often be the best choice.

The choice between, a steam system and a thermal fluid system is often governed by the process requirements, and process temperature is one deciding factor. If the system's required temperature is above 0°C and below approx. 180°C, the choice is often steam. This is particularly relevant if the heating system must cover a wide range of process needs. However, if the required temperature is below 0°C or above 180°C, or if the system is for well-defined users in a closed loop, then thermal fluid may be a better solution. Thermal fluid systems will require a slightly larger heat transfer surface to be used, but the ability to operate at noticeably higher operating temperatures can compensate for this.



A key difference between steam and thermal fluid systems is that the vast majority of thermal fluid systems work completely in the liquid phase. There is normally no change in state (as is the case with water turning to steam) and as a consequence pressures experienced and required within the system are limited to those generated by the circulating pumps.

Left *Key difference in the pressure / temperature relationship between steam and thermal fluid.*

Temperatures up to 350ºC are possible from a well-designed thermal fluid system, significantly higher than can be achieved from a steam system in industry, and capital costs of thermal fluid installations are comparable. Real savings can be made from lower energy costs and lower operating and maintenance costs, and these are attractive to many users.

However, even though thermal fluid systems are generally simple in concept they do require careful design and installation and are not ‘fit and forget’. Maintenance requirements are generally lower than for a steam system for example, and even though the annual inspections associated with steam boilers are not required, the safe and reliable performance of the heater and the other components in the system and the longevity of the fluid itself will be improved by good design, thoughtful installation practices and thorough understanding of the system by operators and maintenance staff.

Thermal fluid heating systems have many advantages:

- Non-pressurised fluids, always in the ‘liquid phase’;
- Closed circuit installation, close to the point of use;
- No water treatment issues, and no ‘blowdown’ effluent or condensate losses;
- Unattended operation and/or automated start-up and shut down if suited to the site risk assessment;
- Rapid start up and shutdown routines, saving energy;
- Precise temperature control at users, with multiple users possible;
- Long service life for plant and fluids.

So the need for many of the complex engineering and safety elements associated with steam systems is negated, and a relatively straightforward pipework installation with a heater, a de-aerator/thermal buffer and expansion tank, and series of fluid pumps is all that is required.

No system is perfect, however, so users need to be aware of the limitations of a thermal fluid heating system. Fluid flow needs to be very carefully calculated at the design stage to ensure good distribution and accurate heat transfer; correct pipe sizing is essential. This means that later additions to the system will need to be carefully designed, and might involve significant pipe size changes.

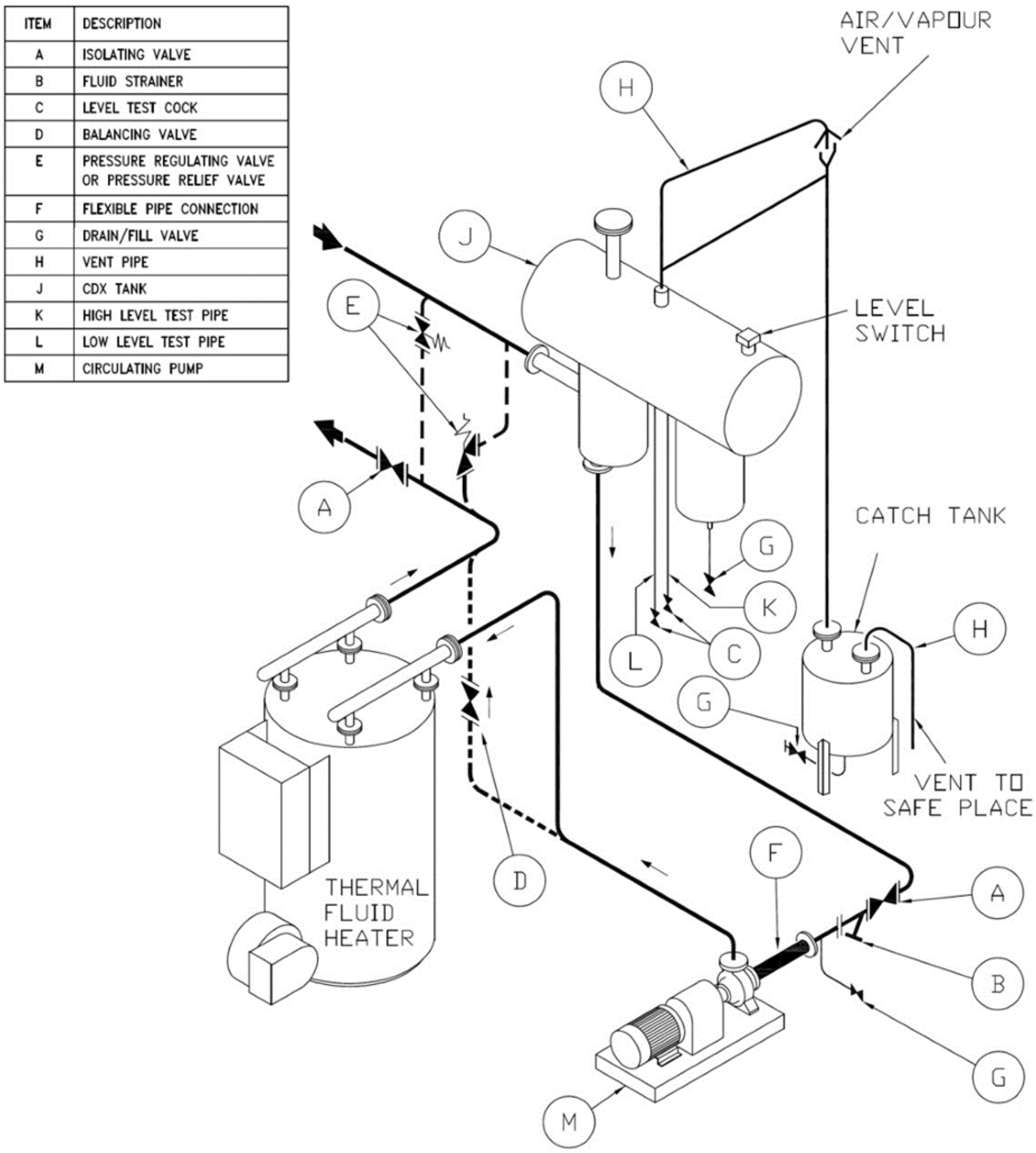
Risks of leaks from systems must be designed out at an early stage, so high standards of equipment selection and installation are essential. Thorough commissioning is also important to ensure long service life and safe operation, and regular fluid condition monitoring will significantly improve plant performance over time.

One of the most important parts of the system are the primary circulating pumps and the means provided for fluid de-aeration and expansion, and these must be carefully sized to allow for optimum performance.

4 SYSTEM DESIGN CONSIDERATIONS

At every stage of the design process it is highly recommended that equipment manufacturers are consulted and professional advice is obtained. There are many suppliers of fluids and components for thermal fluid heating systems who will all offer their best advice based on many years working in the industry.

The diagram below shows a typical thermal fluid system arrangement.



ITEM	DESCRIPTION
A	ISOLATING VALVE
B	FLUID STRAINER
C	LEVEL TEST COCK
D	BALANCING VALVE
E	PRESSURE REGULATING VALVE OR PRESSURE RELIEF VALVE
F	FLEXIBLE PIPE CONNECTION
G	DRAIN/FILL VALVE
H	VENT PIPE
J	CDX TANK
K	HIGH LEVEL TEST PIPE
L	LOW LEVEL TEST PIPE
M	CIRCULATING PUMP

4.1 Fluid

All thermal fluids require specialist handling and management, and manufacturer's instructions should always be followed, especially for fluid testing, topping up and ultimate disposal.

Do not confuse higher fluid temperatures with increased heater output. A heater can give full output at either say 200°C or 300°C; increasing the fluid working temperature does not increase the thermal output of the heater - the burner firing rate dictates the heater output.

TEMPERATURE	TYPICAL RANGE
LOW	-30 to 250°C
MEDIUM	50 to 300°C
HIGH	100 to 345°C

High temperature heat transfer fluids can be categorized by chemical structure into two primary groups:

"Mineral": Hydrocarbon fluids, which are either standard, solvent refined mineral oil based fluids or fluids based on hydrocracked or synthesized hydrocarbons.

"Synthetic": also referred to as 'aromatics', these are man-made fluids specifically tailored for heat transfer applications. They are formulated from alkaline organic and inorganic compounds.

MINERAL	
Normal maximum operating temperature up to 320°C	
ADVANTAGES	DISADVANTAGES
3-4 times less expensive than synthetic fluids	Lower maximum operating temperature
Either low toxicity or non-toxic	Less thermally stable than synthetics
Can be easily disposed of	May not have longevity of synthetic fluids
Readily available	

SYNTHETIC	
Normal maximum operating temperature 350°C	
ADVANTAGES	DISADVANTAGES
Increased maximum operating temperature – wider operating temperature range	3-4 times more expensive than mineral fluids
More thermally stable than mineral fluids leading to longer operational life	May require special system components
	Specialist disposal may be required

The correct choice of fluid for the system and the process is essential – three primary choices are usually available, mineral oil, synthetic fluid and food grade. Other grades are available for special purposes.

Mineral fluids

These are suitable for use in enclosed heating and cooling systems with expansion tanks and suitable de-aerators/thermal buffers in all types of industrial processes where the maximum bulk fluid temperature does not exceed 320°C and the maximum fluid film temperature does not exceed 340°C. However, at the highest operating temperatures the fluid life may become unacceptably short, maybe just a few years, so users should be aware of limitations where very high fluid temperatures are required.

The fluid will be formulated for oxidation stability and resistance to thermal cracking, and will provide excellent thermal stability, help prevent the formation of deposits and stabilise fluid viscosity for optimum system efficiency, giving extended service life and reduced system downtime. Mineral fluids are non-corrosive and non-toxic.

Synthetic fluids

These can be specified to operate at up to 345-350ºC, and will also work successfully as cooling fluids, some to as low as minus 70ºC. They will better resist solids formation and system fouling, providing more reliable operation, and temperature control can be very precise. The same limitations will apply – continuous very high fluid operating temperatures will significantly reduce the life of any fluid.

Food Grade fluids

These are pure mineral oils specially designed for use in food process plants, and will usually meet specified US NSF Regulations prior to use. They are considered to be non-toxic, and they are primarily for use in processes where there might be a risk of incidental or accidental contact with food products. However, some food grade fluids may be more susceptible to faster degradation, often because of the additives used in their formulation.

Flushing and cleaning

Suppliers of thermal fluids will also be able to supply flushing and cleaning fluids and additives that can be used in older systems to help clear the deposits and sludges that can arise after long periods of high temperature operation, and 'on-line' cleaning and restoration processes are also available to help restore the fluid's properties after many years of use. Thermal fluids should last 10 years or more with care and good management, and the key to longevity is correct initial design, operation and monitoring.

Flash Point

Thermal fluids degrade over time and this causes loss of thermal efficiency and a change in fluid characteristics, and ultimately system downtime and associated cost. Most thermal fluids operate above their "closed cup" and "open cup" flash points however, and the systems that contain them must therefore be treated on a risk assessment basis.

(see Appendix 2 for glossary of terms used)

Many users will be aware that any system that operates above the flash point of the thermal fluid falls under the 'Dangerous Substances and Explosive Atmospheres' Regulations 2002 (DSEAR). Many are unaware, however, that heat transfer fluids are likely to degrade over time. This can cause the fluid flash point to change considerably, meaning that the degree of risk will also change following a release to atmosphere. Regular thermal fluid testing and analysis will indicate the physical condition of the fluid and the degree of risk following a fluid release. Regular testing analysis is required to effectively assess and manage the changing levels of risk.

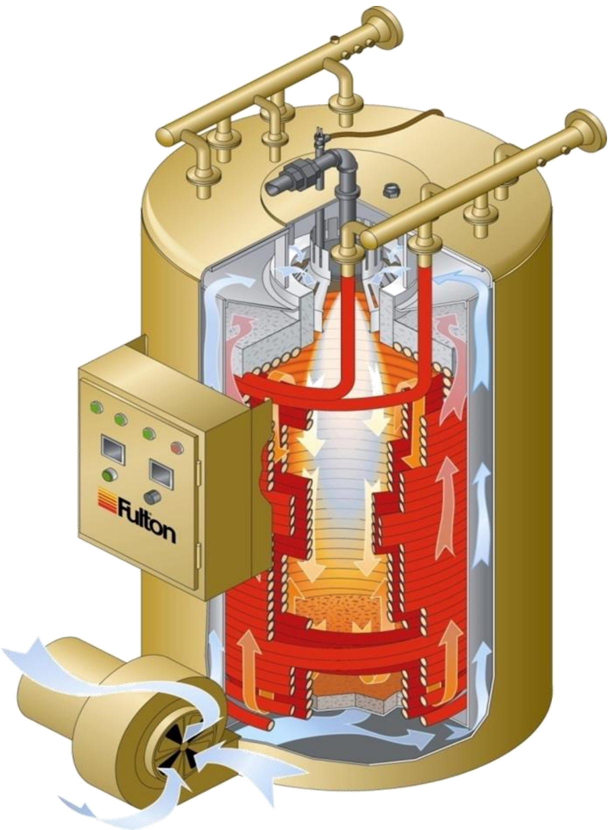
On ignition, volatile atmospheres can result in fires and explosions. In the UK the DSEAR Regulations stipulate requirements for the protection of workers against incidents arising from the presence of hazardous substances in the workplace. PUWER (Provision and Use of Work Equipment Regulations) also requires that all installations at work are safely maintained.

Heat transfer systems operating above the flash point of the fluid must be maintained according to legislation. All thermal fluids will degrade in use over time. Degradation can cause a fluid's flash point to decrease, as "light" compounds with lower flash points than the heat transfer fluid itself are produced, reducing the flash point of the bulk fluid. This can result in a greater fire hazard should it escape and create potential system inefficiencies and problems, such as pump cavitation and increased risk to the integrity of the heater coil.

Suppliers should be consulted for advice on the correct fluid for the application and the most cost effective solution for each installation.

4.2 Heat source

The most common heat source for a thermal fluid system in industrial installations is a gas or light oil fired thermal fluid heater. Alternatives, for mainly smaller installations, are electrically direct heated systems, and some industries such as those processing wood will use biomass fed heaters; waste heat is also an option where sufficient heat energy is available. This document concentrates on gas and light oil fired heaters.



Typical gas fired thermal fluid heater (Fulton Boilers)

The heater for the thermal fluid is only one component in the overall scheme, but it is important to ensure it is correctly specified. The size of the heater will be determined from the processes that it is designed to heat, and this requires the user to carefully specify the characteristics of each machine that the heater will supply and the relative locations of and distances from the heater to plant items and other components to allow correct pipework and pump specifications.

Heaters should be fitted with control and alarm devices that protect the heater and the rest of the system. These will be specifically designed and selected for each system, and should include:

- Fluid Flow or Differential pressure of fluid across the heater;
- Thermal fluid temperature at the inlet to the heater;
- Thermal fluid temperature at the outlet from the heater;
- Flue gas temperature;
- Normal fuel and burner safety devices;
- Circulating pump interlock;
- Expansion tank level interlock.

High fluid temperatures will lead to more rapid degradation of the fluid. It is essential that there is adequate flow across the heater at all times when it is operating, and for a period after the heat source is turned off.

Heaters come in many different shapes and sizes, some utilising a vertically mounted heating coil and burner arrangement and some firing horizontally. Concentrically wound coils with multiple gas passes and combustion air pre-heating can mean the best heaters are at least 90% thermally efficient (based on the Nett Calorific Value of the fuel).

Manufacturers will have a range of heater sizes available from under 100kW rating to around 17MW output, suitable for a wide range of processes and industries. Burner systems must be capable of complying with relevant emissions legislation and able to operate across a wide output range for accurate temperature control.

Heaters should be designed to allow for high fluid velocities and low film temperatures, which lead to longer service life.

Vertical heaters have an economical 'footprint' and may be accommodated close to production units, whereas the largest heaters will often require purpose built enclosures or plant rooms.

Typical thermal fluid heaters (Babcock Wanson)

Manufacturers will need to demonstrate compliance with a number of relevant Regulations including PUWER and the Management Regulations, and this will include provision of operating and maintenance instructions, and drawings to enable the installation to be carried out correctly and safely (PUWER ACOP Para 115).

Fired heaters will usually be supplied as complete packages ready for installation. The connections required on site will be limited to fuel supply, electricity supply, flue, and fluid flow and return. Installers will need to design the installation to meet a range of relevant regulations and guidance including IGEM publications for gas fired installations, IET Wiring Regulations, Clean Air Act and Environmental Permitting Regulations for emissions, DSEAR for limiting potentially explosive atmospheres, and possibly CDM Regulations for the construction project.

It is recommended that the ventilation rates for spaces with fired heaters are carefully calculated, especially if the heater is in a relatively enclosed space, since the higher operating temperatures of thermal fluid systems will probably lead to higher internal room temperatures, and traditional ventilation rates may not be sufficient.

4.3 Expansion and deaeration

Thermal fluid heating systems usually operate at relatively low pressures – they are closed loop 'no loss' systems where the fluid is circulated continuously through the heater, pump sets, process machines and pipework.

In order to provide a place for expansion and contraction to take place, and to provide a small reservoir of fluid for the overall system, an expansion vessel is typically installed at the highest point above all the users in the system.

On small to medium sized systems the expansion tank shall be of sufficient capacity to accommodate the expansion of the entire system contents at maximum working temperature.

On larger systems the entire expansion is often contained within two separate expansion tanks with a 'top-up' and 'spill back' system incorporated into the design.

Typical de-aerator (Thermal Fluid Systems)

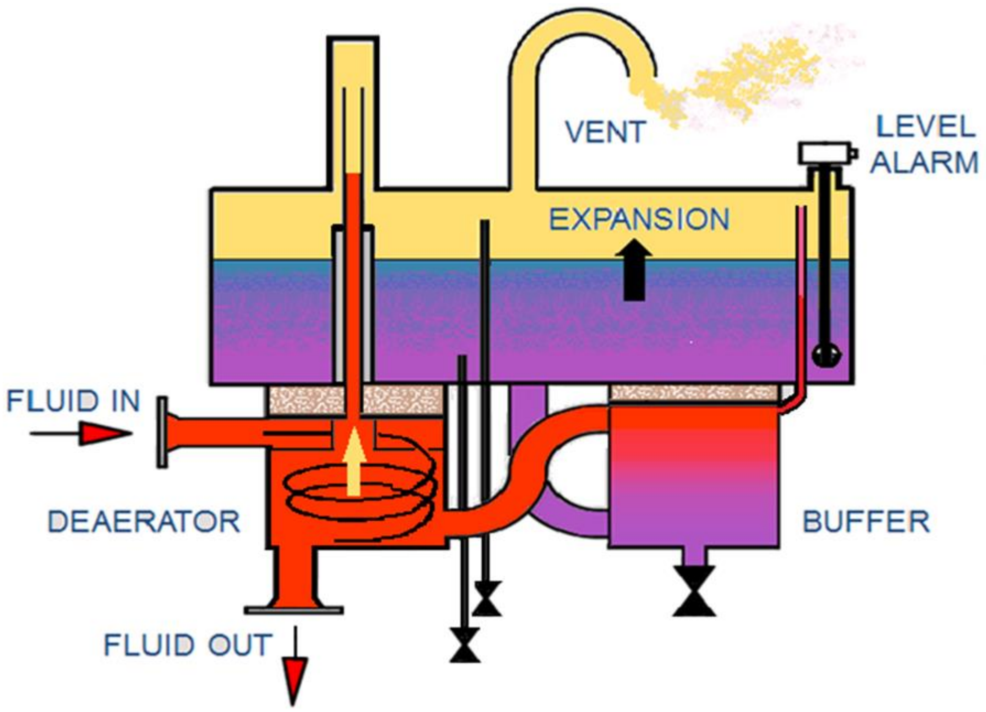
Thermal fluids will always be introduced into a new system as cold liquids, and as they heat up and are operated at their design temperature they will tend to release vapour. Any resulting gases may be vented using a suitable continuous de-aerator. Continuously operating the fluid at high temperatures leads to a natural degradation of the fluid itself and causes lighter fractions to develop from the fluid.

Effective combined fluid expansion and de-aeration systems are available that are also equipped with a thermal buffer and are highly beneficial for the good, long term operation of a thermal fluid system. A de-aerator/expansion vessel fitted with a suitable thermal buffer on the return circuit will usually be atmospheric which ensures the elimination of entrained air, vapour and light fractions before the thermal fluid re-enters the heater. If a thermal buffer is not available, consideration should be given to having a blanket of inert gas.

The correct sizing and specification of the means for de-aerating the fluid and controlling expansion is essential, and manufacturers should be consulted during the design process.

Most expansion tanks have a required minimum level (which should be possible to identify, even if there is no visual level indicator on the tank) which represents the minimum operating level below which a controller is likely to stop the circulating pump (and heater) from operating to mitigate against the potential for pump cavitation and flow problems.

This minimum level must be satisfied to allow the pump to operate and circulate cold fluid, so represents a practical minimum fill level for the overall system – otherwise it would not be possible to circulate fluid. Practical experience dictates however that a small extra volume is normally added above the minimum fill level, normally a proportion of the expansion tank volume, to allow for some fluid loss or air displacement during initial circulation and warm-up. If a large quantity of air is displaced on initial circulation then this would lead to a reduction in physical level of fluid in the expansion tank.



Combined De-aerator & Expansion Tank type CDX (Babcock Wanson)

4.4 Pumps

The centrifugal pumps that circulate the thermal fluid are the heart of the system. Many systems, especially those with several 'users' or lengthy pipe runs, may have several pumps for different duties, and it is essential that the pumps are correctly sized and matched to the various duties required of them. The specifications for the duty of the various users must be determined at an early stage in the design. Systems are typically operated at around 5-6 bar at the pump outlet to give 2-4 bar at users.

The primary circulating pump provides the flow in the system to take the heat from the heater and transfer it to the users. These primary pumps should be at the lowest points in the thermal fluid system and located just before the heater. Note that different fluid and operating conditions might mean the manufacturer selects different pump types, so it is essential to know the limitations of each component in the system.

Pump cavitation is a risk if the fluid is allowed to deteriorate, and this can destroy bearings and seals.

Pumps can be solidly fixed to the floor or other base supports, but should always allow pipework to expand and contract, and will often be fitted with a flexible pipework joint on the suction side. A strainer should be specified to be installed immediately before the pump, fitted with a mesh basket suitable for removing construction debris.

Consideration should be given to the use of duty/standby pumps as pumps (together with the burner) are the most common maintenance items in the system. Consideration should also be given to the effects of introducing very hot fluids into cold standby pumps; a bypass or 'bleed' arrangement may be required.

Basket removal after commissioning is recommended since fine carbon deposits and varnishes from degrading thermal fluids have been known to lead to blockages. The mesh basket should be retained so that it can be re-installed in the event of any future system modifications.

Typical multiple pump installation (Thermal Fluid Systems)

4.5 Pipework

Pipework installations in thermal fluid heating systems are relatively straightforward, especially when compared to steam systems. Pipe sizing is more critical, since the flow rates and velocities of the fluid in the system will need to be accurately calculated and the pipes sized accordingly; any changes to the number or size of thermal fluid users can adversely affect these calculations and might result in re-working the design.

All elements of the pipework circuit will have a resistance to flow which must be taken into consideration and can be expressed in terms of equivalent pipe length when designing the distribution pipework system. The designer must know how much fluid has to be delivered to each system user and the temperature of normal operation in order to carry the design quantity of heat; the resistance to flow can then be estimated in terms of an ‘equivalent length’ of straight pipe for each of the process users.

It is recommended that pipework is as short as practicable from the heater to the users. Pipework run at high level or in relatively inaccessible places should be fully welded. Flexible joints are discouraged except at the pump suction for vibration management. Expansion of the pipework at working temperature needs careful consideration and can often be allowed for by pipework loops. Bellows joints may be required but they must be carefully mounted and located where they are easily inspected if they are utilised.

All pipework should be suitable for a minimum operating pressure of 9 bar (130 psi) at the system design temperature unless stated otherwise. This is to withstand the total head that may be generated in the system by the circulating pumps in the event of an isolating valve being completely closed.

Where additional pumps are installed such that they can operate in series, the system must be suitable for the total aggregate head (against closed valve) of all these pumps, or suitable relief valves must be installed which discharge back to the common return header.

4.6 Ancillary items

The thermal fluid heating system will have a number of ancillary items associated as follows:

Flow sustaining valve/relief valve

A spring loaded flow sustaining by-pass valve with external spring is often used when there is a risk the overall thermal fluid system flow will reduce due to the use of two way control valves at the users. The flow sustaining valve needs to be designed such that it allows a constant minimum flow in the system under all operating conditions.

The valve should have flanged connections and be manufactured from either cast or forged steel, or nodular cast iron, and be designed and constructed for the specific operating conditions.

The flow sustaining valve usually acts also as a system relief valve. If this is not the case or if a flow sustaining valve is not fitted then suitable pressure relief devices shall be included in the installation to accommodate expansion that will occur under certain circumstances.

Isolating valves

Note: There must not be any isolating valves between the heater outlet, the flow sustaining/pressure relief valve and the expansion/deaerator vessel.

SG Iron valve bodies to PN16 standard are generally recommended for most thermal fluid installations. Under certain conditions the use of weld-end cast steel valves is preferred. The number of valves used in the system should be kept to a minimum commensurate with good maintenance practices and system usability.

Bellows sealed valves with back up glands have been proved to be the best choice and are strongly recommended. Any valve selected must be compatible with operational duty, temperature and pressure requirements. The types of valve selected for the application and where they are installed might mean that potential leaks from valves need to be assessed under DSEAR legislation.

Bellows sealed valve

Vent and drain valves

These should normally be 15 mm or 20 mm nominal bore valves with internals and seals made from materials suitable for use with thermal fluids. Where screwed vent and drain valves are used they shall be installed in dead legs or on stalks not less than 300mm long. Special jointing materials suitable for the duty (e.g. "TEFLON" tape) shall be used; such jointing methods will not be suitable for very high fluid temperatures (>200ºC) so careful design and installation is essential.

These valves shall be fitted with security plugs when not in use.

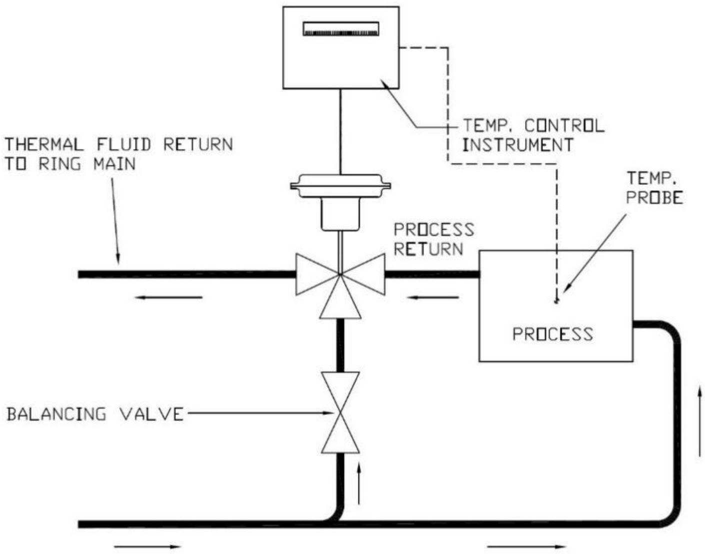
Automatic fluid control valves

Due to the very varied nature of applications and duties of thermal fluid systems, it is not possible to set down specific rules for the selection of automatic valves. Generally, they will have to satisfy the requirements already stated for other fluid control valves regarding materials and construction. The type of operation and design of porting will however be dependent on the particular process and degree of control required.

Designers and users should consult the heater and process equipment manufacturers and discuss the specifications for these valves before completing the design.

Left *3-way valve installation (Thermal Fluid Solutions)*

Right *3-way valve*



Outline fluid control schematic

Fire detection and suppression

Thermal fluids in well designed and well maintained systems will not usually leak. It has been found that systems that have failed were more as a result of poor installation or operational practices than the flammability of the fluid itself.

Nevertheless, basic fire (heat and smoke) detection and alarm systems for areas where thermal fluid systems are installed should be considered as part of the design.

Fire and smoke detection for the fuel installation should also be considered.

Fire suppression methods should be discussed with plant insurers at an early stage in the design.

Emergency stop facilities

It is essential to think through the need for emergency control devices, where they might be best located and what exactly they shut off. Emergency controls should be clearly labelled as to their function, segregated from other control devices, and never used as routine plant shut off controls.

Great care should be taken when designing and specifying the emergency controls.

Catch tanks

Catch tanks provide a safe location for unexpected fluid discharge from the system and they shall always be vented to a safe area. Discharges can occur during first start-up, if fresh fluid has been added to the system or, most commonly, if the fluid has become contaminated.

Catch tanks must not be confused with the use of storage tanks as it is usually not considered good practice to re-add fluid from a catch tank back into the thermal fluid system.

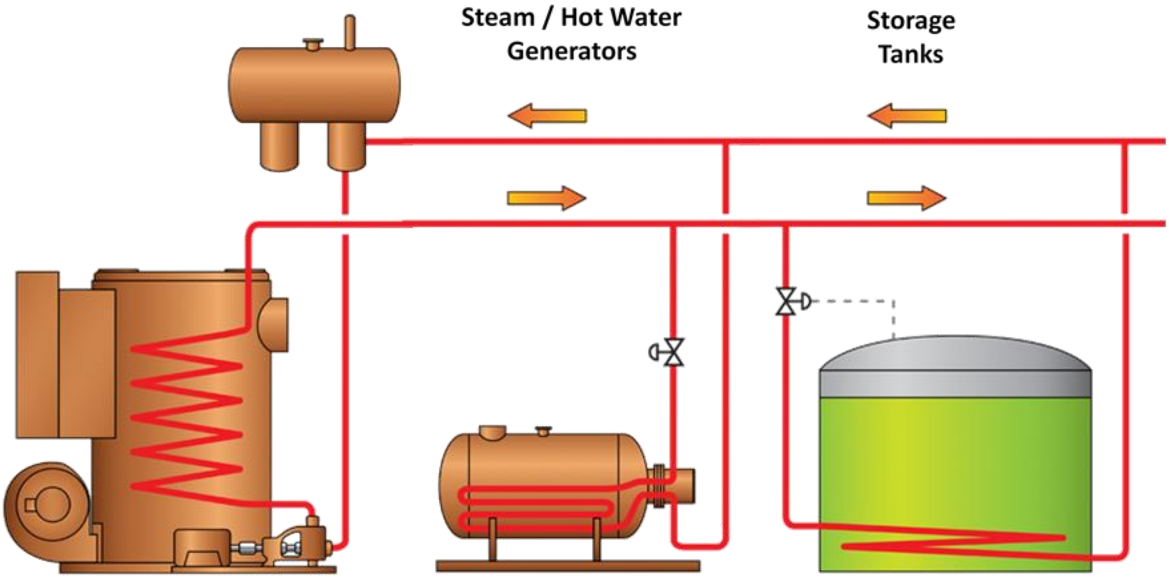
Great care must also be taken if consideration is given to the use of a system dump tank as the uncontrolled drainage of a hot system into a tank that may have not been in use for a considerable period of time can cause many operational problems. Dump tanks are not commonly used in the UK.

Storage tanks

System storage tanks are typically provided in larger systems where it may be desirable to provide a permanent facility for the cold drainage of fluid from the system. If utilised in this way, care must be taken in the system design to ensure drainage under gravity or by pumping is practicable.

Maintenance of all tanks is recommended to avoid unwanted ingress of contaminants or water.

The diagram below shows a typical arrangement of thermal fluid heater and storage tank.



5 INSTALLATION AND COMMISSIONING

5.1 Installation practices

Due to the enhanced temperatures found in thermal fluid heating systems, the installation of the pipework and any associated equipment and services must be carefully thought through. For example, it is not recommended to put thermal fluid pipework in close proximity to electrical cables or plastic pipework from other services, and it is also advisable to run thermal fluid pipes in places where they can be easily inspected, and not in covered or hidden in ducts, enclosed lofts or false ceilings.

Where it is unavoidable to run thermal fluid pipework through ceiling voids or spaces not subject to regular inspection it is very important to ensure it is of fully welded construction to minimise any risk of an undetected leak taking place.

Any vents, drains or overflows from the system shall be taken to a safe place well away from places where personnel might be, and suitably guarded to prevent splashing from hot fluids.

Pipework

Pipework will usually be seamless mild steel tubing to API 5L standard or equivalent, typically schedule 40 tube, or schedule 10 for stainless applications. Normal rules for supporting horizontal and vertical runs should be followed, remembering that the temperature differential from ambient to fluid operating condition could be up to 350ºC; thermal expansion should be calculated using 50°C above the maximum possible utilisation fluid temperature. Allowance for expansion should be by the creation of pipe loops in long runs, or allow for movement at changes of direction.

Joints should be minimised, and fully welded as far as practicable. Screwed joints shall be avoided as there will inevitably be leaks of fluid from threaded joints which are subject to the full operating temperature of the system due to the significant expansion and contraction as the temperature of the fluid changes. Where these cannot be avoided the joints must be located where they can be regularly inspected, and advice sought from the joint manufacturer. If screwed connections must be made, e.g. to items of equipment, then special jointing tape, suitable for use with fluids at elevated temperatures, shall be used.

Welding standards should be at least as good as those used for steam pipework, and the use of appropriately coded welders is highly recommended. Because the heating system will often have a number of pumps to cope with different circuits and users, the pipework and all joints shall be capable of withstanding the 'dead head' pressure assuming all available pumps are operating, or suitable relief valves must be properly installed.

Any flanged joints should be fully welded to the pipe and gasketed with a high specification, high temperature oil resistant material <2mm thick, and bolted securely using minimum 8.8 grade high tensile steel bolts correctly torqued. Bolts will become very hot and stretch in use, so flanged joints should be in places where they can be seen and checked.

Banding the flanged joint with a proprietary band system will increase safety in case of a leak. It is recommended that flanges are not insulated as this can increase the risk of fire should a leak occur. If flanges are "boxed in" then a suitable drainage hole should be provided to give an early warning of any leakage.

All pipes should be installed with a fall to facilitate draining and venting. Drain valves should be fitted at all "low" points, and venting valves should be fitted at all "high" points in the installation.

Flange banding installation

Insulation

Insulation is essential for personnel protection and energy efficiency, and a closed cell type of insulating material is recommended close to any potential leak areas since any thermal fluid leaking into insulation could create a significant risk if the fluid soaks in. Contaminated insulation materials must be removed and the leak source eliminated.

The expansion tank shall not be insulated, nor shall the buffer section of the de-aerator. Where a combined de-aerator and expansion tank is installed only the de-aerator section shall be insulated. Hot sections of uninsulated vessels must be suitably shielded for personnel safety or positioned so as not to pose any risk to personnel under normal conditions.

The hot exhaust gas duct or chimney must be insulated or shielded within the locality of the heater and, to achieve correct operating performance where certain fuels are used, it may have to be insulated throughout its entire length.

Heater units

Easy access all around the unit, typically no less than 1 metre, is essential for maintenance and safety of operating personnel. Clearance is necessary for pipework connections from the unit and for fuel controls on fired units,

Clearance should be provided all around the heater to allow for removal of the coil if necessary. Such clearances can either be by clear headroom or if this is not possible, particularly with the larger heaters, then the roof or ceiling construction over the heater should be removable.

Larger heaters will require an access ladder and gantry to be provided to allow clear access to the top of the heater for commissioning and maintenance purposes. Access provision must avoid possible personnel contact with hot pipework, flues etc.

Expansion and de-aeration tanks

Suitable supports for tank mounting in the correct location must be provided – full tanks are heavy and structural supports will be required to safely install the tank at high level. Access for maintenance must be provided as appropriate.

The vent pipe from the expansion tank shall be installed as manufacturer's instructions and rise continuously at full bore until final fall to its termination point which must be in a safe place, ideally outside the building. The vent must be completely free of obstructions, open to atmosphere to allow correct venting and arranged in such a way that in the event of a discharge of thermal fluid or vapour there is no danger to personnel or property.

Thermal fluid pumps

Thermal fluid circulating pump sets should be sited adjacent to the thermal fluid heater and as near as possible to the expansion tank/de-aerator. A flexible connection (typically a braided stainless steel flexible hose type) or other suitable device should be installed on the suction side of the pump to take up expansion and deflection of the piping.

Flexibles should be installed such that they are kept as straight as possible. Do not install flexibles under compression, tension or torque as premature failure may occur. Ensure that flexibles cannot rub against any objects nearby.

Pump failure is the most common system failure mode, and additional safety and detection devices for vibration, leak detection and bearing temperature should be considered.

Electrical installation

Electrical installations must comply with current IEE regulations and British Standards.

Unprotected electrical cables must not be run close to any hot surfaces or joints in the thermal fluid or fuel oil piping, due to the possible fire risk. Cable and conduit joints must be of a type to prevent ingress of thermal fluid or fuel oil. Under no circumstances should electrical services run adjacent to thermal fluid circulating pumps.

The heater and other electrically fed items (pumps, valve actuators etc.) must be suitably earthed.

All reasonable steps must be taken to ensure that equipment, fixtures, fittings, pipework and ductwork are adequately electrically grounded either directly or by cross bonding. Cross bonding must be completed in accordance with the appropriate relevant electrical installation regulations and IGEM guidance, and with respect to the nature of the installation, the site requirements and the application.

Fuel supply

Installation of the gas pipework must comply with the Institution of Gas Engineers document IGEM/UP/2 "Gas Installation pipework, Boosters and Compressors on Industrial and Commercial Premises". The installer or pipework contractor must ensure that the gas supply and controls assembly is adequately supported. A filter fitted in the incoming gas pipework is strongly recommended.

A risk assessment according to DSEAR is required for gas installations. This is usually satisfied by close attention to the requirements of IGEM/UP/16.

A filter, stop valve and fire valve assembly must be installed in a fuel oil installation, and if a two-pipe system is employed a non-return valve (i.e. not an isolating device) must be fitted into the return pipe.

Liquid fuel pipes must be of approved materials and shall be of a diameter suitable for the quantity of fuel being delivered to the burner's fuel pump and the static head available. The heater manufacturer will be able to provide the necessary fuel supply requirements.

Chimney

The thermal fluid heater must be connected to a chimney of suitable cross-sectional area and erected in accordance with applicable regulations. The chimney must be of sufficient height to satisfy both local regulations and to prevent down-draught. Installations of heaters with a nett rated thermal input of >1MW will require an Environmental Permit (see section 8.7), and the permit conditions may determine the height of the chimney that is required.

The exhaust ducting must be carefully considered and ideally should contain no more than two bends, each having a maximum angle of 45° and should rise continuously to the chimney connection. Right angle bends in the ducting, or at the junction with the chimney, shall be avoided. Horizontal runs of ducting shall also be avoided.

A draught regulator shall be fitted in cases where there is likely to be strong or irregular draught. A cowl should not normally be fitted to the chimney. If one is fitted it shall be at least one chimney diameter above the top of the chimney.

The chimney shall be constructed from a material capable of withstanding high temperature flue gases. Aluminium or fibreglass are not suitable.

A means of measuring flue gas temperature should be installed.

Adequate provision must be made for supporting the weight of the chimney and ducting to avoid load being imparted to the heater flue outlet. It is also important to make provision in the interconnecting ducting to accommodate thermal expansion at maximum working temperature.

Hot exhaust gas ducts must be insulated or shielded within the heater unit locality to ensure safety to personnel and, for certain fuels, the chimney should be insulated throughout its entire length, to minimise corrosion attack. The base of the chimney shall incorporate a drain to prevent water or condensation entering the heater and a soot clean-out door.

Shared flues are not recommended.

All chimneys and flues shall be regularly inspected by users to identify any damage, corrosion or leakage, paying particular attention to holding down bolts, guys and stays, and lightning conductors. Formal inspections using qualified steeplejacks are recommended every 3 – 4 years.

5.2 Commissioning

Pipework and equipment

Pipework should be commissioned in stages, starting with leak testing using an inert bottled gas (e.g. Nitrogen) or dry air. Never use water, or air that is not dried – water in thermal fluid pipework will be difficult to remove and cause significant operational difficulties and damage to the system.

- Following pressurisation to 1bar, leak test welds and flanges thoroughly. It is far better to find any small leaks before filling with thermal fluid.
- After resolving any leaks, fill with cold thermal fluid.
- Bleed pumps and ensure the expansion tank is filled to the correct initial level as directed by the manufacturer or supplier.
- Activate pumps in a planned sequence and pump the fluid through the whole system.
- Close valves as appropriate to subject the system to the maximum possible working pressure and thoroughly check the whole installation.
    - For further information on expansion tank operation, please see section 4.3.
- Resolve any issues arising.
- After completion of cold tests fit flange bands or lagging boxes if specified.
- When the system is ready to be fired up, start the heat source and circulate the hot thermal fluid, watching for any leaks as the temperature rises.
- Monitor heater gauges and alarms.

It is recommended to run the system for a period of time, typically 40-50 hours at normal operating temperatures and pressures and through a number of hot/cold cycles before fixing any remaining issues and adding the insulation to the pipework.

The heater manufacturer will provide instructions, and it is always desirable to have a specialist engineer from the heater manufacturer on site during commissioning of the heater and its associated ancillary equipment. Always follow the manufacturer’s instructions carefully.

Strainers

As a strainer is fitted in the fluid return, a close check must be made of the circuit pressure during the commissioning. An abnormal increase in the pressure or signs of local cavitation in the primary circulating pump may indicate that the strainer element requires cleaning.

Cleaning the strainer element may be required two or three times during the first few hours running. Do not attempt to remove the element without closing the isolating valve either side of the strainer and allowing the fluid to cool sufficiently for safe handling. On completion of commissioning of the installation and when all concerned are satisfied that the fluid is free from foreign bodies, the strainer element may be removed.

6 OPERATION AND MAINTENANCE

Operation

Thermal fluid heaters and associated systems are largely automatic in operation. The manufacturer should have provided all the necessary control and alarm devices relevant for the heater, and these should all have been tested during the commissioning process. Start-up of the system will normally be a simple action, and the system should automatically bring the fluid to the set working temperature and pressure in a short time, dependent mainly on system volume and overall rating.

Shutting down the heater must be managed, unless it is an automatic process. Selected pumps in the system must remain activated to circulate the hot fluid around the pipework for a minimum cooling period to avoid overheating the fluid that is left in the heater and ancillary components. Never stop the heater and the primary circulating pump together – a cooling down period is essential for plant safety and fluid longevity. A minimum run-on cool-down period will be defined by the manufacturer, typically a minimum of 15 minutes.

The primary means of protection for a thermal fluid system is to prevent fluid release by ensuring system integrity. Indicators that are routinely used include:

- Fluid Condition and Fluid Analysis by specialists (To identify parameters that are out of specification)
- Thermal fluid flow (Low)
- Thermal fluid temperature (High)
- Flue gas temperature (High)
- Thermal fluid level (Low)

Operators should be trained to observe and record these indicators, and be instructed to report any variances to supervisors or managers.

Record all inspections and interventions in a suitable log book.

Maintenance

There are few routine maintenance activities for a thermal fluid system. It is important for the plant to be viewed regularly to look for leaks, smoke or any signs of damage, excess vibration or overheating, for example, and a log book must be kept to demonstrate that regular inspections take place.

Factory insurers may have a view on the level and frequency of inspections required, and will expect to see that competent employees have carried them out and competent maintenance personnel have been employed for specific tasks. A schedule of likely point sources of potential failure will help to focus inspections on the highest priority areas.

Emergency procedures

There are some reasonably foreseeable emergency situations that might apply to any thermal fluid installation and these should all be assessed for the inherent and possible risks and a plan put in place to minimise the harm that might arise and control any residual risks for personnel safety and property integrity.

Never operate a valve (open or closed) if it is smoking. Smoke indicates a leak from the spindle gland, bellows seal or a flange joint and the possibility of a fire. Emergency procedures for the installation should have identified the correct course of action for this occurrence.

A primary means of managing risks is to ensure staff associated with the operation and maintenance of the thermal fluid system are adequately trained and provided with comprehensive operating and maintenance instructions, and that training is regularly refreshed.

	Effect Minimised by	**Residual Risk Controlled by**
Fluid leak	Sound installation practices. Welded joints, flange bands	Routine inspections and maintenance
Fire	Sound installation practices, smoke and heat detectors in selected areas, particularly where there is no regular human inspection	Routine inspections and testing of alarms and strategically placed fire extinguishers and fire suppression systems
Fluid over temperature	Temperature gauges and alarms Heater differential pressure alarm	Routine recording and trending
Product over temperature	Correctly positioned temperature gauges and alarms Optimised plant control system	Routine recording and trending
Electrical outage	Design for safe shutdown during mains outage	Consider UPS or standby power on items that are critical systems
Fuel leak	Gas detection or fuel oil fire detection and fuel shutdown. Ventilation of spaces	Regular visits to plant room Sound maintenance

Fluid maintenance

Over time, fluids tend to break down as a result of heating and cooling cycles and by reacting with atmospheric oxygen. The break down and oxidation leads to increased acidity, a change in viscosity, darker fluid colour, and can leave surface deposits and varnishes. A more viscous fluid is more difficult to pump, has less effective heat transfer capability, and an increased chance of deposit formation.

Thermal degradation can also occur when the fluid is overheated. This degradation actually starts at much lower temperatures, well below the stated maximum operating temperature of the fluid which is rarely likely to reach its own boiling point. Boiling the fluid leads to catastrophic localised breakdown and must be avoided by following established operational procedures.

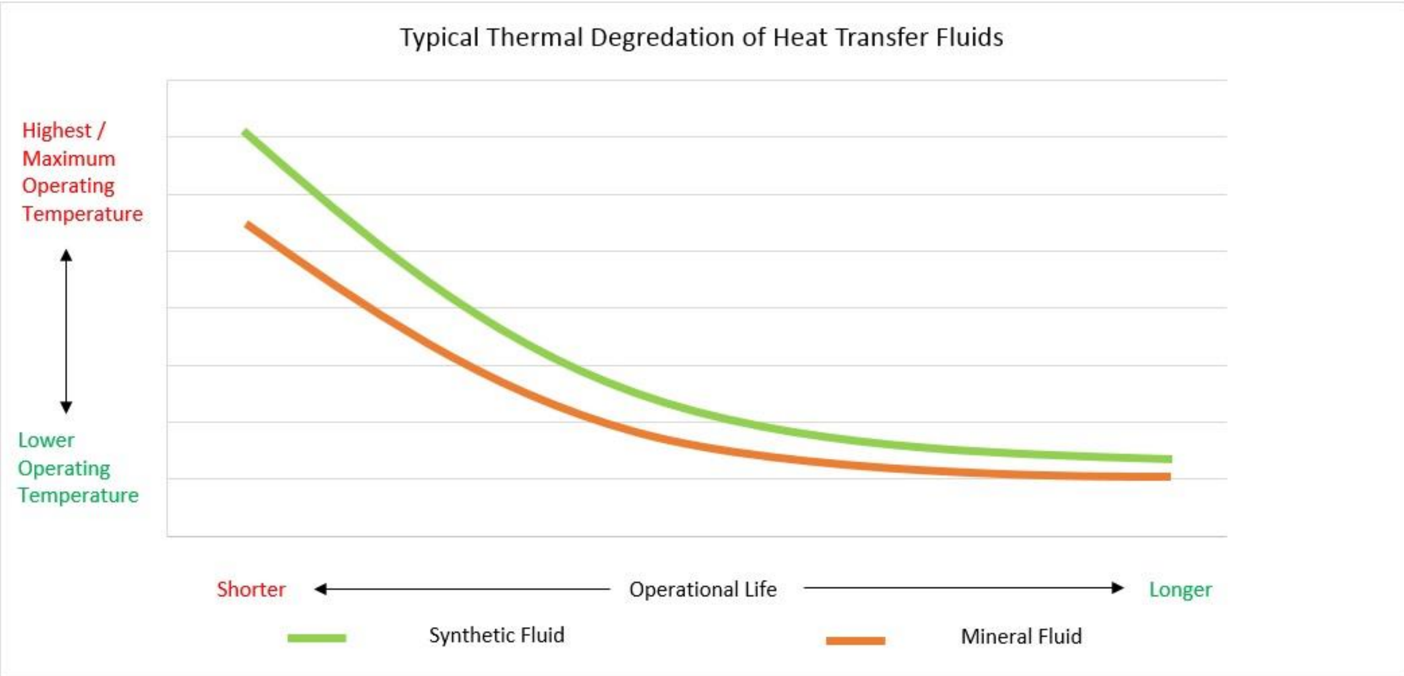
As the fluid breaks down it also produces lighter components in the form of light fractions and vapours. If these components are not allowed to escape by proper de-aeration they will lead to overall reduction in flash point, fire point and auto-ignition temperatures. In addition, the fluid viscosity will change and may lead to poor circulating pump performance. Correct deaerator performance is key.

The symptoms of thermal fluid degradation therefore can include:

- Reduced flow rates;
- High sludge content in filters;
- Changes in analysis results -
    - Increased carbon residue content;
    - Reduction in closed cup flash point;
    - Increase or decrease in viscosity;
    - Increase in total acid number;
    - Reduced system efficiency apparent.

The main consequences of thermal fluid degradation for the user are:

- Damage to the heater coil;
- A change in circulating pump seal and bearing performance leading to mechanical failure;
- An increased risk of system integrity failure resulting in leakages of fluid and potential safety issues;
- Loss of system efficiency & increased energy costs;
- Production loss due to maintenance downtime;
- Increased maintenance costs;
- Increased thermal fluid costs due to premature degradation;
- Increased disposal costs.



Thermal fluid degradation over time *(Thermal Fluid Solutions)*

Serious damage can be caused in the thermal fluid heater coil for example, where carbon deposits and sludges in the coil cause hot spots on the heat transfer surfaces which result in thermal fatigue and eventual failure.

Approximately 80% of particulate matter suspended in the fluid measures less than 20 microns, the minimum size addressed by conventional full flow filter mesh filtration techniques.

Carbon solids are formed due to the oxidisation of thermal fluids operating at high temperatures. They can abrade components such as pumps, seals, bearings and valves, compromising their performance. They form deposits, restricting flow and reducing the heat transfer capability of the system. If left unchecked, parts of the system can become completely blocked and cease to function.

Options for thermal fluid management include:

- Forced de-aeration;
- Light fraction removal for flashpoint recovery (continuous or at pre-arranged intervals);
- Filtration
- Water Removal
- Fluid Dilution
- Fluid Change

Specialised filtration units are available which are designed to be attached to working systems for short periods of time to pass the fluid through fine filters and remove solids without incurring any down time.

Testing the fluid

Never remove fluid from the system whilst the system is running or in its cooling down period unless through a properly designed sample cooler.

Sample station (Thermal Fluid Solutions)

It is recommended that a small sample of fluid is taken on a regular basis for testing. Annual tests are common, but users with particularly high temperature processes or large systems may reduce this to quarterly and some simple lower temperature systems will probably be tested every 2 years.

Samples shall be taken in small, clean bottles, filled to the top with a lid secured immediately the sample is taken. Samples must be representative and not be taken from a 'dead leg' or other area of low flow. A typical sample leg would be attached to the inlet of the primary pump.

A specialist in thermal fluid solutions shall be used to test the fluid samples. Tests must be specific to the type of fluid and its use. It is important to have a base line set of characteristics for the fluid in order to be able to determine degradation rates and critical conditions. An initial measure of the key parameters should therefore be taken soon after commissioning and the data stored in an easily accessible format for future comparisons.

The parameters that are typically measured in the test laboratory are:

Parameter	**Test**	**Warning Point**	**Action Point**
Viscosity	@ 40ºC	+15%	+20%
Flash Point (Closed Cup)	Pensky-Marten	125ºC	100ºC
Carbon residue	Ramsbottom %	0.5% wt	0.8% wt
Water Content	ppm	250	500
Oxidation	Total Acid No. (TAN) mg KOH/g	0.5	1.0

Waste fluids

Users should seek advice from the fluid supplier regarding safe disposal of old thermal fluid. It may be classed as hazardous and must be disposed of in accordance with waste management legislation which will require the services of a registered waste carrier and the production and retention of waste consignment notes.

7 TRAINING

All employees who are required to work with plant and equipment must be trained in safe operation of that equipment and should be able to demonstrate competence in operating and/or maintaining the specific items of plant they work with. Contractors who are appointed for installation and maintenance tasks must be similarly competent.

Training of personnel who are involved with the operation and maintenance of thermal fluid systems is essential. Historical data collected by a major insurer of such systems indicates that the three main reasons for claims in relation to incidents on such systems were:

Mal-operation	23%
System Design	23%
Maintenance	54%

Training for generic Health & Safety risks is routine in many organisations, but specific training for work with thermal fluid systems is less readily available. Manufacturers will frequently provide training on the detailed aspects of the equipment they have supplied for the system, but a comprehensive course with assessment that deals with the specific issues relating to thermal fluid systems is highly recommended.

The CEA have, for many years, operated the Boiler Operations Accreditation Scheme designed for Operators and Managers of steam boiler plant to be assessed as competent to work on a variety of types of steam and hot water boilers. This scheme has now been extended to cover the specific aspects of operating and maintaining thermal fluid heating systems, and courses are available from Training Providers accredited by the CEA to deliver relevant courses with assessment. For further details, please contact the CEA.

8 LEGISLATION

Thermal fluid heating systems are required to comply with different legislation, including a number of health and safety and environmental Acts and regulations, which are aimed at ensuring that new and existing systems are continually operated and maintained in a safe manner.

The principal sets of health and safety legislation that support the Health and Safety at Work etc. Act 1974 and apply to the use of thermal fluid systems covered by this guidance are:

- The Management of Health & Safety at Work Regulations 1999 (MHSWR);
- The Pressure Equipment (Safety) Regulations 2016 (PER);
- The Provision and Use of Work Equipment Regulations 1998 (PUWER);
- The Gas Safety (Installation and Use) Regulations 1998 (GSIUR); and
- The Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR).

With the exception of MHSWR and PER, all the regulations listed above are supported by Approved Codes of Practice (ACoP) and Guidance produced by the Health and Safety Executive (HSE), and available as free downloads from www.hse.gov.uk.

There are numerous sets of environmental legislation applicable to combustion plants, including the Clean Air Act, the Industrial Emissions Directive, and the Environmental Permitting Regulations (including the Medium Combustion Plant Directive). Relevant legislation is addressed in later text.

Refer to Appendix 1 for a list of currently applicable legislation. It is the reader's responsibility to ensure that they refer to the latest available version of any legislation or guidance.

8.1 The Management of Health and Safety at Work Regulations 1999 (MHSWR)

The Management of Health and Safety at Work Approved Code of Practice (ACoP – L21) has been withdrawn and is no longer available. If you are looking for information on how to manage risks in your business, HSE has a suite of guidance that will be able to help. Each level of guidance on HSE's website offers appropriately targeted information, focussed on making compliance as straightforward as possible.

If you need basic information or are getting started in managing for health and safety, then the best place to look is *Health and safety made simple: The basics for your business* (INDG449).

MHSWR apply to every employer and self-employed person who carries out any work activity whether or not they own or use a pressure system (all future references to employers in this guidance should be read to include self-employed persons).

They impose a duty to manage all risks from any work activity, not only within the workplace itself, but also any risks to all persons (including any non-employees) who may be affected by the activity in question.

Regulation 3 requires the completion of a suitable and sufficient risk assessment of the work activity in order to properly identify and adequately manage any risks. This is of central importance. The risk assessment must identify sensible measures to control identified risks that may otherwise result in injury or danger.

8.2 The Pressure Equipment (Safety) Regulations 2016 (PER)

PER applies to the design, manufacture and conformity assessment of pressure equipment and assemblies of pressure equipment with a maximum allowable pressure >0.5 bar. In cases where the thermal fluid system can reach an operating pressure >0.5bar these regulations will apply to the design of the heater and system.

All new and substantially modified pressure equipment (**including thermal fluid heating plant containing a relevant fluid**) comes within the scope of PER and they must comply with its requirements before they may be supplied for use.

The Regulations do not apply to:

- Excluded pressure equipment and assemblies (specified in Schedule 1 to PER); or
- Pressure equipment and assemblies placed on the market before 29 November 1999; or
- Pressure equipment or assemblies placed on the market on or before 29 May 2002 if they comply with the safety provisions in force in the UK on 29 November 1999 and do not bear a CE marking (unless required by another Community Directive or any indication of compliance with PED).

Schedule 2 of PER details the essential safety requirements (ESR) that qualifying vessels must satisfy. Additionally, there are details of how the different products are classified, the technical requirements that must be satisfied, and the conformity assessment procedures that must be followed.

To comply with the ESRs the manufacturer must either produce a technical file that addresses each ESR in turn, or manufacture the equipment using standards that have been listed in the EU's Official Journal which give a 'presumption of conformity' to specific ESRs.

The Department for Trade and Industry (DTI) produced a very useful guide:
PRODUCT STANDARDS Pressure Equipment – *GUIDANCE NOTES ON THE UK REGULATIONS APRIL 2005 URN 05/1074.* This document can be found through: https://www.gov.uk/guidance/pressure-equipment-manufacturers-and-their-responsibilities.

There is an easy-to-use flow chart in the DTI guide (Annex C) showing how equipment should be classified depending on, for example, what it is designed to contain and the operating pressure. This includes the conformity assessment procedure to be followed before placing the equipment on the market.

8.3 Provision and Use of Work Equipment Regulations 1998 (PUWER)

Any employer who either provides equipment for use at work (including thermal fluid systems) or has control over the way and manner in which equipment is used at work has a legal responsibility to comply with the relevant provisions of this regulation. An important, often overlooked, requirement under PUWER is that a maintenance logbook, when provided, must be kept up to date.

Under PUWER, all employees required to use equipment at work must be trained and competent to do so (Reg 9). This will therefore extend to the training and competence of operators and managers of thermal fluid heaters and all ancillary plant.

Other parts of PUWER of relevance to thermal fluid systems cover such topics as equipment suitability, maintenance, inspection, information & instructions, and control systems. This is not an exhaustive list.

8.4 The Construction (Design and Management) Regulations 2015 (CDM)

Although installing or replacing a thermal fluid system might not be a large enough project on its own to be notifiable under CDM, the principles of the regulations should still be followed, and if the system is part of a major installation the regulations will apply in full and must be considered at every stage of the project from conceptual design through installation to maintenance and ultimate demolition.

Clients must appoint a Principal Designer and a Principal Contractor to ensure that the CDM Regulations are properly followed.

8.5 The Dangerous Substances & Explosive Atmospheres Regulations 2002 (DSEAR)

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 substances and 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.

DSEAR applies to all heaters (not just gas fired) as incorrect combustion can lead to an explosive atmosphere in the heater itself or indeed in a separate combustor, and may also apply to system components as well, such as the expansion tank.

The owner of the system may assist the manufacturer by providing information from an assessment of the probability of the presence and the likely persistence of a potentially explosive atmosphere in the proposed working environment.

Equipment supplied for use in a potentially explosive atmosphere must also satisfy the relevant requirements of the *Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 2016*.

8.6 The Gas Safety (Installation and Use) Regulations 1998 (GSIUR)

GSIUR deals with the safe installation, maintenance and use of gas systems, including gas fittings, appliances and flues, mainly in domestic and commercial premises, e.g. offices, shops, public buildings and similar places. The regulations generally apply to any ‘gas’ as defined in the Gas Act 1986 (amended by the Gas Act 1995), apart from any gas comprising wholly or mainly of hydrogen when used in non-domestic premises. The requirements therefore include both natural gas and liquefied petroleum gas (LPG).

The Regulations generally apply to all domestic and commercial installations of gas appliances (usually described as residences where people could sleep or places where members of the public may be present), including any gas fired heaters in those locations, and they specify the way gas appliances are installed and maintained and the training and assessment of persons who can be deemed competent to work on such systems.

Registration of organisations, and competent employees in those organisations, are required through Gas Safe in order to demonstrate a suitable level of safety training in gas work has been achieved.

GSIUR do not apply in full to certain sectors, namely gas installations in factories, electricity generating stations, mines, quarries, construction sites, agricultural premises and means of propulsion. However, even if working at premises to which GSIUR does not apply, competence in carrying out gas work safely is required in order to comply with the general duties in sections 2 and 3 of the HSW Act.

ACS training for those who work on domestic gas installations is not always suitable for the larger commercial and industrial installations, so the CEA have developed a training and assessment scheme that fills this gap and ensures that persons working on gas equipment in locations where GSIUR do not normally apply are suitably trained and assessed as being competent. The Industrial Gas Accreditation Scheme (I-GAS) is supported by CEA members and the wider gas industry, and certification is available at several different levels to cover all the necessary safety requirements across a wide range of industrial gas installations, including thermal fluid heaters.

8.7 The Environmental Permitting (England and Wales)(Amendment) Regulations 2018

All combustion plants rated between 1 MW and 50 MW nett rated thermal input will be required to comply with the Medium Combustion Plant (MCP) Directive which has been transposed into UK legislation through changes to *The Environmental Permitting (England and Wales)(Amendment) Regulations 2018, The Pollution Prevention and Control (Scotland) Amendment Regulations 2017*, and *The Pollution Prevention and Control (Industrial Emissions) (Amendment) Regulations (Northern Ireland) 2018*.

This legislation requires the registration of all new combustion plants put into first use after 19 December 2018 and the registration of existing combustion plant before 1/1/2024 for plants individually 5 MW and above, and 1/1/2029 for plants rated from 1 MWth to <5 MWth. Where more than one new plant is on a site the new plants will be aggregated to a single MCP.

From the date of first use (in the case of new plants) and from 1/1/2025 (for existing 5-50 MWth plants) and 1/1/2030 (for existing 1-5 MWth plants) the emissions from those combustion plants must not exceed specified emission limit values (ELV) for NOx, SOx and dust (total particulates), and these will be measured at specified intervals along with CO (no limits currently set for CO). Plants rated 20 MWth and above will be measured annually, and plants below 20 MWth will be measured every 3 years.

The Environment Agency (EA) in England and their equivalents in the devolved UK administrations will administer the new legislation and will consult with Local Authorities where there may be a combustion plant in or close to a Local Air Quality Management zone. This may mean tighter ELVs will be applied. Sites that currently have environmental permits for other activities will have any MCPs added to their permits at the due date.

The EA and SEPA have produced detailed guidance on how these regulations will be applied.

9 APPENDICES

9.1 Glossary of Terms

An explanation of some of the terms used in this document.

Catch tank	Storage of spillage of thermal fluid from the system, not to be re-added to the system.
Closed cup	Using a closed vessel which is not open to the atmosphere, the lid is sealed and temperature of the thermal fluid is gradually raised. An ignition source is introduced into the vessel, noting the point at which the fluid/vapour ignites. This method allows for a closer approximation to real-life conditions where thermal fluids are enclosed in largely sealed tanks or pipes. This method generally produces lower flash points as the heat is contained and the substance is more likely to become flammable at an earlier stage.
Dead head	Pumping against a closed leg of a pipework system or into a closed valve with no circulation of the fluid.
Dump tank	Where system fluid can be temporarily stored in cases of full or partial drain down for maintenance activities, and the fluid can be subsequently returned to the system.
Flash point	A determination of the lowest temperature at which a volatile substance can become vaporised into a flammable gas.
Lighter fractions	Crude oil can be separated into different fractions using fractional distillation. Light fractions that are higher in the fractionating column have lower boiling points, lower viscosity and higher flammability.
Open cup	Using a vessel which is exposed to the air, the temperature of the thermal fluid is gradually raised and an ignition source is passed over the top of it until it reaches a point at which the fluid or vapour ignites.
SG or nodular CI	Spheroidal graphite cast iron is “ductile iron.” These castings are also known as S.G. iron castings or just S.G. iron. The name spheroidal graphite cast iron comes from the make-up of the ductile iron. One of the primary ingredients added to the iron is graphite (or carbon) in order to make it stronger. Ductile iron contains 3.2-3.6% carbon, and castings are very strong compared to regular cast iron (grey iron), so more suited to high temperature thermal oil installations.
Storage tank	Where clean unused thermal fluid is stored ready for use in the system as it is depleted over time.

9.2 References

The following is a list of applicable documents current at the time of preparation of this publication. The following should be noted:

- This is an indicative, not comprehensive list. Users should ensure they are working with the latest information available.
- Free copies of all legislation are available from gov.uk.
- Legislation marked with an asterisk is supported by Approved Codes of Practice and Guidance (ACoP) published by the HSE.
- Legislation marked with a double asterisk is supported by more than a single ACoP.

The Electricity at Work Regulations (EAW) 1989 are supported by a Memorandum of guidance published by the HSE.

1. Health and Safety at Work etc Act 1974.
2. Management of Health and Safety at Work Regulations (MHSWR) 1998 SI 1999/3242.
3. Provision and Use of Work Equipment Regulations (PUWER) 1998* SI 1998/2306.
4. Electricity At Work Regulations 1989 - SI 1989/635
5. Confined Spaces Regulations 1997* - SI 1997/1713.
6. Control of Substances Hazardous to Health Regulations (COSHH) 2002* SI 2002/2667.
7. Dangerous Substances and Explosive Atmosphere Regulations (DSEAR)** SI 2002/2776.
8. Control of Noise at Work Regulations 2005 - SI 2005/1643.
9. Construction Design and Management Regulations (CDM) 2015* - SI 2015/51.
10. Supply of Machinery (Safety) Regulations (SMSR) 2008 - SI 2008/1597.
11. Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 2016 - SI 2016/1107.
12. Pressure Equipment (Safety) Regulations (PER) SI 2016/1105.
13. Pressure System Safety Regulations (PSSR) 2000* - SI 2000/128.
14. Work at Height Regulations 2005 SI 2005/735.
15. The Regulatory Reform (Fire Safety) Order 2005 – SI 2005/1541.
16. The Gas Safety (Installation and Use) (Amendment) Regulations (GSIUR) 2018 * SI 1998/2451.
17. The Environmental Permitting (England and Wales)(Amendment) Regulations 2018 SI2018/110 (MCPD).
18. L5 The Control of Substances Hazardous to Health Regulations 2002. Approved Code of Practice and guidance.
19. L22 Safe use of work equipment Provision and Use of Work Equipment Regulations 1998. Approved Code of Practice and guidance.
20. L101 Safe work in confined spaces. Confined Spaces Regulations 1997. Approved Code of Practice, Regulations and guidance.
21. L108 Controlling noise at work The Control of Noise at Work Regulations 2005 Guidance on Regulations.
22. L122 Safety of pressure systems. Pressure Systems Safety Regulations 2000. Approved Code of Practice.

23. L138 Dangerous Substances and Explosive Atmospheres Regulations 2002. Approved Code of Practice and guidance.

24. L153 Managing health and safety in construction. Construction (Design and Management) Regulations 2015. Guidance on Regulations.

25. HSG253: The safe isolation of plant and equipment.

26. Permit-to-work systems HSE INDG98 ISBN 0 7176 1331 3

27. HSE Pressure Systems website http://www.hse.gov.uk/pressure-systems/index.htm

28. Business Innovation and Skills Pressure Equipment Guidance Notes on the UK Regulations - PRODUCT STANDARDS Pressure Equipment – GUIDANCE NOTES ON THE UK REGULATIONS APRIL 2005 URN 05/1074.

29. BS 799: Part 4:1991 Specifications for atomising burners (other than monobloc type) together with associated equipment for single burner & multiburner installations.

30. BS 5410-2:2013 Code of practice for oil firing - Part 2: Installations over 45 kW output capacity for space heating, hot water and steam supply services.

31. BS 5925:1991 Code of practice for Ventilation principles and designing for natural ventilation.

32. BS 7671 Requirements for electrical installations. IET Wiring Regulations.

33. BS EN 298:1994 Automatic Gas burners Control systems for gas burners and gas burning appliances with or without fans.

34. BS EN 676:1997 Automatic Forced Draught Burners for Gaseous Fuels.

35. BS EN 746:1997 Part 2 safety requirements for Combustion and Fuel Handling Systems.

36. IEC 61508 Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems.

37. Institution of Gas Engineers and Managers Utilisation Procedure IGE/UP/1A - Strength/tightness testing and direct purging (Small I&C) and IGEM/UP/1C - Strength/tightness testing and direct purging (Meters).

38. Institution of Gas Engineers and Managers Utilisation Procedure IGEM/UP/2 - Installation pipework.

39. Institution of Gas Engineers and Managers Utilisation Procedure IGEM/UP/10 Installation of gas appliances in industrial and commercial premises.

40. Institution of Gas Engineers and Managers IGEM/UP/12 Application of burners and controls to gas fired process plant.

41. Institution of Gas Engineers and Managers IGEM/UP/16 Design for Natural Gas installations on industrial and commercial premises with respect to hazardous area classification and preparation of risk assessments.

42. Institution of Gas Engineers and Managers IGEM/SR/25 - Hazardous area classification of Natural Gas installations.

Document Control – Amendments

Edition 2, First impression – June 2021

Additional information included, section 4.3.

Amended typing errors and reformat, section 5.1 and 5.2.

Thermal fluid heaters ready for despatch (Babcock Wanson)

This page is intentionally blank

The Combustion Engineering Association
NETPark
Thomas Wright Way
Sedgefield
Co. Durham
TS21 3FD
www.cea.org.uk

Thermal Fluid Systems - A Practical Guide for Safe Design, Operation and Maintenance

Ref: BG07 Edition 2 - Published June 2021 - © all rights reserved

RRP £50.00

CEA
Combustion Engineering Association