PREHEATED DOMESTIC HOT WATER

STORAGE OF PREHEATED DOMESTIC HOT WATER AND POSSIBLE GROWTH OF LEGIONELLA BACTERIA

1 INTRODUCTION

The search for alternative energy sources which minimise carbon dioxide emissions is attracting manufacturers to seek WRAS Approval for heating systems for domestic premises which use heat pumps drawing energy from the ground or air, or solar panels, to pre-heat water to feed the domestic hot water system. The preheated water is held in a storage cylinder before being passed to the water heater and on to outlets. Where the water heater is a combination boiler, some systems are designed so that if the pre-heated water is hot enough (generally >60°C), the combi-boiler is bypassed. If pre-heated water is hotter than is required for domestic purposes, blending valves mix cold water to bring the temperature to the desired range. (see Figure 1).

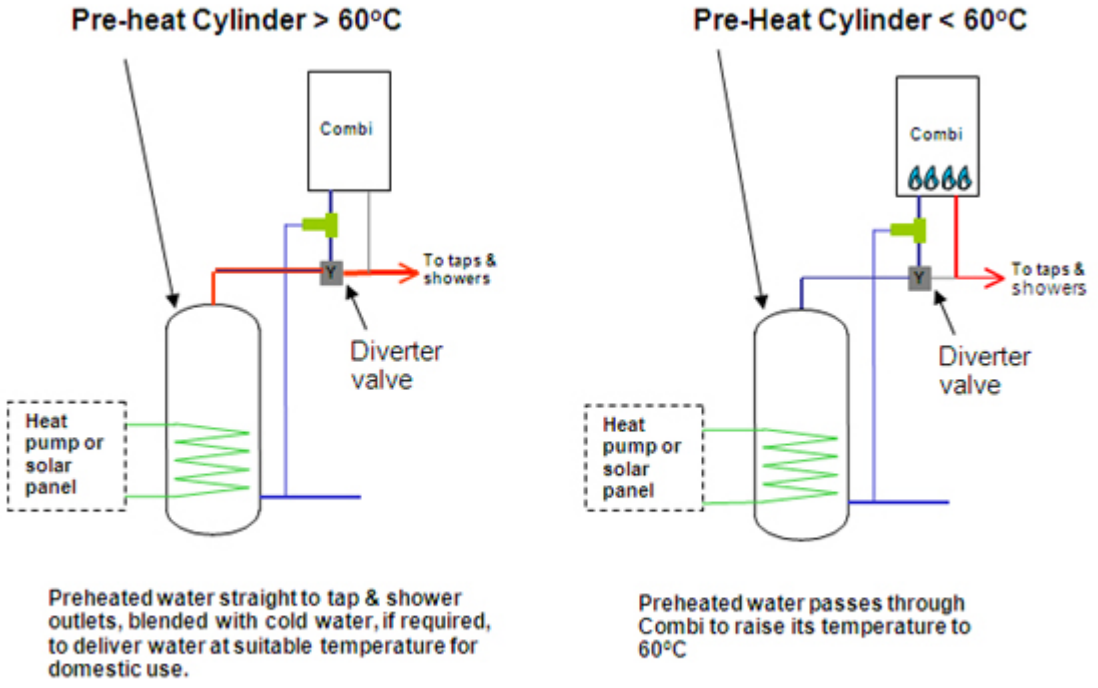

Figure 1: Use of pre-heated stored water for domestic hot water

2 CONCERN REGARDING LEGIONELLA

If the pre-heated water is stored at temperatures between 20°C and 45°C, which favours the growth of the *Legionella* bacteria, and large numbers of the bacteria develop, measures may be required to prevent these bacteria causing harm to health. The HSE Approved Code of Practice (L8) "The control of Legionella bacteria in water systems", applicable to the management of hot water systems in non-domestic premises, recommends for hot water storage cylinders that the whole contents should be heated to 60°C for one hour each day to prevent growth of Legionella bacteria in the cooler water at the bottom of the cylinder. Briefly raising the water temperature to 60°C is not effective.

If pre-heated water between 20°C and 45°C containing *Legionella* is subsequently passed through a combination boiler, its temperature does not usually exceed 60°C and it is held at that temperature only for seconds before being distributed and used. If hot water from taps or showers contained *Legionella* present in large numbers, it might create an aerosol of droplets which could be harmful to the health of those breathing in the droplets.

During the warm-up of a combination boiler up to 20 litres of water could be passed to outlets before the boiler achieves its pre-set water temperature (which in any case may be less than 60^{o}C.)

3 ASSESSMENT OF RISK FROM PRE-HEAT SYSTEMS

The WRAS Technical Committee members were concerned whether, under some circumstances, a health risk might occur in these pre-heat systems. A report was commissioned from an expert medical microbiologist to provide information about the possibility of *Legionella* growth in these systems. The Technical Committee agreed to publish the report to provide information which had not been easy to find elsewhere. For further details please refer to page 3.

4 WRAS APPROVAL

When considering WRAS Approval of the preheat systems, the Technical Committee concluded that relevant individual components of pre-heat systems, such as twin-coil storage cylinders, could quite properly continue to be approved where they met the test requirements under the Water Fittings Regulations, because as isolated components, they do not incur a contamination risk. However, because these components could be combined into a pre-heated stored water system, approval of the individual components should be qualified by a warning about the possible risk arising from prolonged storage of tepid water. Where WRAS-Approved, these components will carry the following note in their entries in the Water Fittings and Materials Directory:

"Compliance with the relevant requirements of the Water Supply (Water Fittings) Regulations 1999 has been assessed for this product only as a component of a heating system. If it is to be installed as part of a system using solar energy or ground- or air- source heat pumps for pre-heating water which is to be used as domestic hot water, the Water Fittings Regulations place a legal duty on the installer and user to ensure that the installation and operation of the complete system prevents contamination of domestic hot water by Legionella bacteria, which can grow in water stored at temperatures between 20^{o} and 45^{o}C.

Where disinfection by heating is relied on to meet this obligation, information on minimum conditions for thermal disinfection of Legionella bacteria can be found on the WRAS website - www.wras.co.uk."

WRAS Approval will still be granted for complete systems for pre-heating water where they have the means to maintain adequate thermal disinfection of the pre-heated water, if they comply with the Regulations in other respects. Where adequate thermal disinfection is not included, and in the absence of other means to prevent potential *Legionella* contamination, WRAS Approval will be withheld pending the outcome of the risk assessment.

WRAS, Oakdale, Last updated – September 2009

LEGIONELLA BACTERIA AND CONDITIONS FOR ITS GROWTH AND THERMAL DISINFECTION IN STORED, PRE-HEATED WATER FOR DOMESTIC PURPOSES

In hot and cold water systems Legionnaires' disease (also known as Pontiac Fever and Lochgoilhead Fever) can arise from any water system that supports the proliferation of *Legionella* bacteria.

Based on a report (**Legionella bacteria and solar pre-heating of water for domestic purposes,** below) the following information regarding the growth and thermal disinfection of legionella bacteria in water is summarised to assist those who are responsible for complying with the water fittings regulations by preventing contamination due to the bacteria.

TYPES OF LEGIONELLA BACTERIA

- Over 90% of cases of Legionnaires' disease are caused by *Legionella pneumophila.*
- Other types of *Legionella* bacteria behaved similarly to *Legionella pneumophila* regarding thermal disinfection, with the exception of *Legionella micdadei,* which is more tolerant to high temperatures.

GROWTH

- *Legionella* bacteria grow readily at temperatures in the range 20^{o}C to 45^{o}C.
- *Legionella* bacteria in concentrations of 100,000 colony forming units per litre (cfu/l) and higher are not uncommon at the base of conventional hot water storage vessels where temperatures of 20 – 45^{o}C are maintained.
  (For comparison HSE Code of Practice L8 recommends review of control measures where *Legionella* concentrations are in the range 100 to 1,000 cfu/l and corrective action where they exceed 1,000 cfu/l.).
- Under optimum conditions, *Legionella* bacteria can multiply from background numbers to dangerous concentrations in less than five days.

THERMAL DISINFECTION

- The effectiveness of inactivating *Legionella* bacteria using raised temperatures (thermal disinfection) depends upon the temperature and how long the bacteria are exposed to that temperature.
- Thermal inactivation of *Legionella* bacteria starts around 50^{o}C but is quicker at higher temperatures.
- *Legionella pneumophila* requires on average 3.2 minutes exposure to 60^{o}C to inactivate 90% of the bacteria.
- Where the water contains 100,000 cfu/l *Legionella*, the bacteria need to be held at 60^{o}C for approximately 10 minutes to reduce numbers to below the HSE action level of 100 cfu/l.
- Hot water storage cylinders that maintain a temperature of 60^{o}C throughout the whole storage vessel for a period of one hour daily should achieve satisfactory control of *Legionella* bacteria, in line with recommendations in HSE CoP L8.

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LEGIONELLA BACTERIA AND SOLAR PRE-HEATING OF WATER FOR DOMESTIC PURPOSES

Report by Dr T Makin[1] for the Water Regulations Advisory Scheme

1. Legionella bacteria are ubiquitous in all water systems and their growth occurs at temperatures in the range of 20 to 45^{O}C. Hot and cold water systems (HCWS) are particularly prone to colonisation by legionella bacteria and these water systems are now recognised as the commonest source of Legionnaires' disease. Temperatures within the range of 20 – 45^{O}C are commonly present at the base of calorifiers and other hot water storage vessels. Suitable growth temperatures and the accumulation of sediments of organic material and corrosion products at the bottom of hot water storage vessels provide an environment that is especially conducive to the accumulation of biofilm and legionella bacteria.

2. Control of legionella bacteria in hot water vessels and in peripheral parts of the distribution system can be achieved through raised temperatures. Thermal inactivation of legionella bacteria commences at 50^{O}C, and at 60^{O}C it is generally reported that the majority of legionella bacteria are killed within a few minutes. Where recommended temperatures are not achieved in hot water storage vessels, legionella bacteria normally resident at the base of the vessel may enter the distribution system and be directly discharged at outlets in the form of infectious aerosols. Viable legionella bacteria that escape thermal inactivation in calorifiers can colonise peripheral parts of the distribution system, and these become important secondary reservoirs of contamination within the HCWS.

3. One of the most comprehensive studies carried out on thermal inactivation of legionella bacteria was undertaken by Janet Stout et al. This study determined the D value for the various strains of legionella bacteria tested. The D value is the time required to kill 90% of the legionella bacteria exposed to a specific temperature. For example, a D value of 10mins at 60^{O}C (D60^{O}C = 10min) indicates that an exposure time of 10min is required to reduce the concentration of a suspension of organisms by 1 log (i.e. by 90%). Other recognised studies on thermal inactivation of legionella bacteria have not been as wide-ranging with regards to the number or diversity of legionella strains tested, but the more pertinent of these investigations reached similar conclusions to those arrived at by Stout et al (Schulze-Robbecke R et al, and Dennis PJ et al).

4. Stout et al. carried out thermal inactivation studies on a range of legionella bacteria including eight serogroups of *Legionella pneumophila* (40 strains) and nine different *Legionella* species (34 strains). Although there was a range of D values for the various strains of legionella tested, these ranges were generally narrow and were similar across the different serogroups of *L. pneumophila* and the various *Legionella*

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species, with the exception of *L. micdadei* which was more thermotolerant than other legionella bacteria tested. Over 90% of cases of Legionnaires' disease are caused by *L. pneumophila.*

5. The D60^{O}C values for *L. pneumophila* and other *Legionella* spp (with the exception of *L. micdadei),* ranged from **2.3 to 5 mins**. The mean D60^{O}C value for *L. pneumophila* was **3.2 mins**. The D60^{O}C for *L. micdadei* was **4.5 to 10.6min,** confirming this strain's thermal tolerance. In this study there was no observable difference detected between D60^{O}C values for clinical and environmental strains of legionella bacteria, or for *L. pneumophila* when suspended in sterile hot water or in sterile hot water containing calorifier deposits.

6. Any hot water storage vessel displaying thermal stratification and maintaining temperatures in the range of 20 to 45^{O}C is very likely to contain legionella bacteria in significant numbers, unless regular pasteurisation of the entire contents of the vessel takes place at temperatures of 60^{O}C or above. Solar pre-heat cylinders that are subject to thermal stratification would be equally susceptible to legionella contamination. Solar heated vessels that do not reach 60^{O}C and notably those maintaining temperatures below 45^{O}C would be particularly prone to contamination with high levels of legionella bacteria. Where these devices supply water via a combi-boiler in order to raise the hot water temperature to 60^{O}C, then according to the work of Stout et al., the boiler would need to maintain the water temperature at 60^{O}C for 3.2 mins to reduce the concentration of legionella bacteria by 1 log (90%).

7. In my experience, concentrations of legionella bacteria in the range of 10^5 cfu/l and higher are not uncommon at the base of hot water vessels where temperatures of 20 – 45^{O}C are maintained. If a combi-boiler receiving water from a solar pre-heat cylinder contaminated with legionella to 10^5cfu/l, maintained a water temperature of 60^{O}C for 3.2 mins this would reduce the concentration of viable legionella bacteria by 90% to 10^4cfu/l. This significantly exceeds the lower permitted limit of 10^2cfu/l for legionella bacteria in hot and cold water systems as recommended in the HSE Approved Code of Practice and Guidance on the control of legionella (L8). It also exceeds the upper limit of 10^3cfu/l at which level remedial action is required, including disinfection of the water system. Water with this level of contamination would need to be heated for an additional 3.2 mins to further reduce the legionella concentration from 10^4cfu/l to 10^3cfu/l. Consequently, a concentration of 10^5cfu/l of legionella bacteria would require exposure to 60^{O}C for approximately 10mins to reduce the number of viable cells to below the threshold recommended in L8.

8. Other more thermo-tolerant legionella bacteria such as *Legionella micdadei* would require still longer exposure to this temperature before being inactivated. The HSE recommendation to achieve a temperature of 60^{O}C in all parts of hot water storage vessels for a period of one hour daily, has taken into account the higher concentrations of legionella bacteria that may be present at the base of these vessels, and has also made allowance for the more thermotolerant species and for the protection afforded to legionella bacteria by deposits that accumulate in hot water storage vessels. Daily pasteurisation is proposed in L8 in order to control legionella bacteria that may survive this process (e.g. those protected within amoebal cysts or deeply embedded in scale deposits).

9. Solar pre-heat cylinders that maintain a temperature of 60^{O}C throughout the storage vessel for a period of one hour daily should achieve satisfactory control of legionella bacteria. In systems where combi-boilers receive water from solar pre-heat cylinders that are not able to raise the water temperature to 60^{O}C or above, then consideration should be given to programming the system to automatically activate the combi-boiler to heat the water to 60^{O}C and recirculate this through the pre-heat cylinder, at a pre-set time daily.

10. This should provide effective pasteurisation of legionella bacteria colonising the pre-heat cylinder. Where this pasteurisation programme is in place, the volume of potentially contaminated water that can pass through the heating system before a temperature of 60^{O}C is reached (approx 20 litres), should then present little risk of legionella infection. If this pasteurisation programme occurred daily, shorter contact times of less than one hour may still prove effective in controlling legionella bacteria in solar pre-heat cylinders, particularly in smaller systems. Alternatively, as legionella bacteria grow relatively slowly, even when at optimum growth temperatures, then less frequent cycles of pasteurisation (e.g. twice weekly) where the entire contents of the vessel are maintained at 60^{O}C or above for at least one hour, may also achieve satisfactory control of residual legionella bacteria. However, adopting control procedures that vary from the recommendations in L8 would require validating.

11. In twin coil storage cylinders a solar coil positioned at the base of the cylinder is used to pre-heat the water, and a boiler coil is fitted above the solar coil to raise the temperature of the water at the top of the vessel to 60^{O}C. This arrangement may permit temperature stratification that supports the growth of legionella bacteria at the base of the vessel. If the solar coil does not generate temperatures that bring about thermal inactivation of legionella bacteria, and if the residence time for water in contact with the boiler coil at 60^{O}C is less than that required to effect thermal inactivation, then it would be necessary to provide a further level of control e.g. consideration should be given to programming the boiler coil to heat the entire contents of the solar hot water cylinder once daily, preferably during a period when there is little demand for hot water. Where legionella control is not achieved through raised or lowered temperatures, alternative measures such as the use of appropriate biocides, should be considered.

12. It is worthy of note that prospective studies on the incidence of Legionnaires' disease have shown that our ability to diagnose this form of community acquired pneumonia is inadequate, and even in countries with effective health services and readily available diagnostic testing, approximately 90% of cases of Legionnaires' disease are missed. This is partly due to Legionnaire's disease being a relatively rare form of pneumonia that many GP's and hospital clinicians will not have encountered before and therefore may mis-diagnose. Furthermore, patients with Legionnaires' disease can present with a wide range of symptoms some of which (such as diarrhoea) may distract clinicians from the correct diagnosis. Given the particularly poor ascertainment of this disease, and the relatively low number of solar heated hot water systems compared to hot water systems fuelled by more conventional means, there is currently insufficient data available to determine if solar heated systems are a significant source of legionella infection.

13. However, it has been clearly demonstrated in HCWS and in many other varied water systems that Legionellosis (Legionellosis includes Legionnaires' disease, Pontiac Fever, and Lochgoilhead Fever) can arise from any water system that supports the proliferation of legionella, and which discharges the bacterium in the form of aerosols proximal to individuals who may be predisposed to such infection. It is therefore highly likely that those solar pre-heating water systems which support the growth of legionella bacteria and do not achieve thermal inactivation or control of legionella bacteria in some other equally effective way, are creating a health risk with regards to legionella infection. In the UK, manufacturers, suppliers, installers, and owners of such water systems as solar pre-heating systems, have a statutory obligation to assess such risks and implement measures that will effectively control those risks.

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