

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 typically 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 $>60^{\circ}\text{C}$), 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).

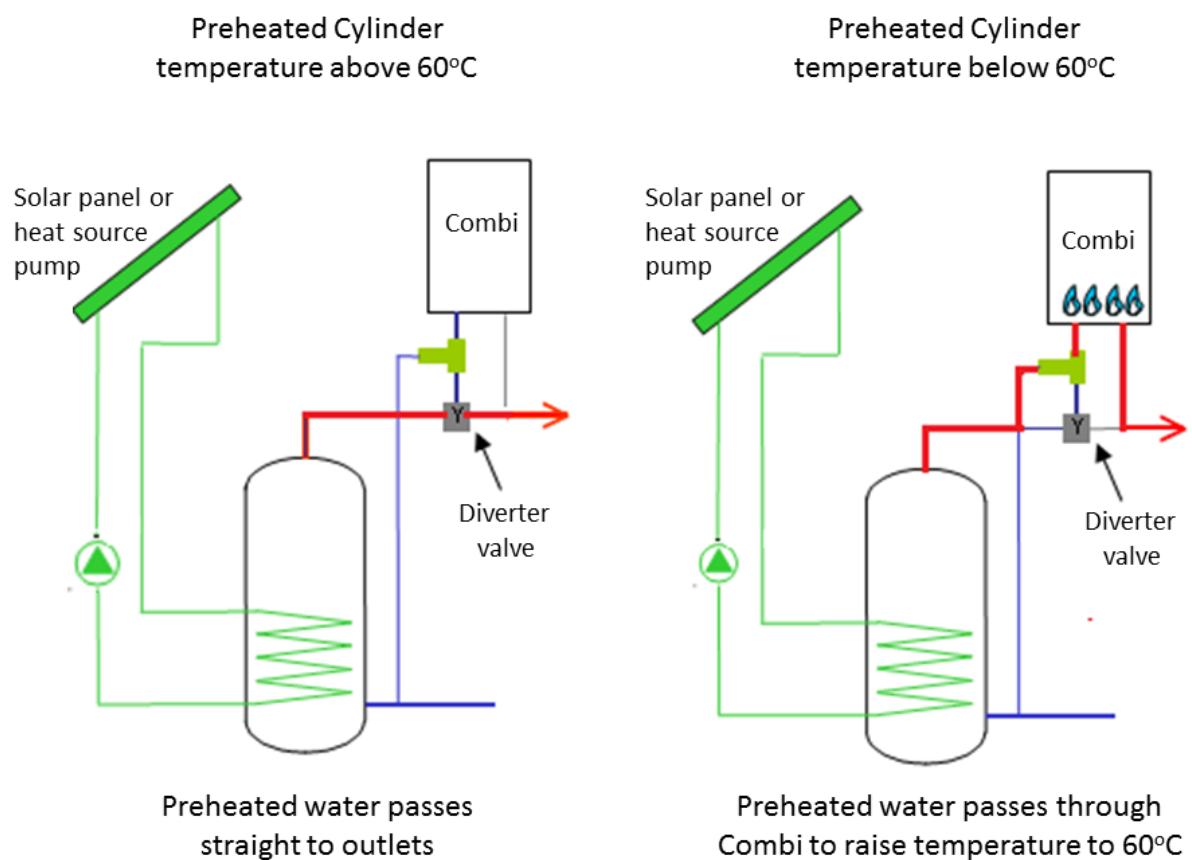


Figure 1: Typical arrangement for pre-heat systems, e.g. from solar or heat pumps, for domestic hot water

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 technical guidance to the HSE Approved Code of Practice (L8) "The control of Legionella bacteria in water systems", for 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 considered 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 would only be held at that temperature 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°C.)

3 ASSESSMENT OF RISK FROM PRE-HEAT SYSTEMS

The WRAS Technical Committee was 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 and the conditions required for effective disinfection by heating the water (thermal disinfection). The Committee agreed to publish the report to provide information which had not been easy to find elsewhere. A summary of the findings is presented on page 3 and the full report is on pages 4-6 in this document. The WRAS Technical Committee accepts all effective methods for controlling contamination caused by growth of *Legionella*.

4 WRAS APPROVAL

When considering WRAS Approval of the preheat systems, the WRAS 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 drawing attention to the possible risk arising from prolonged storage of tepid water. Where WRAS-Approved, these components will carry an additional note in their entries in the Water Fittings and Materials Directory.

If they comply with the Regulations in other respects, WRAS Approval may be granted for complete systems for pre-heating water where the WRAS Product Assessment Group (PAG) is satisfied that the systems have adequate means to prevent contamination of stored water by *Legionella*. Applicants for WRAS Approval may be asked to provide a risk assessment by an independent specialist to demonstrate the effectiveness of the means to prevent potential *Legionella* contamination.

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

A SUMMARY

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. WRAS acknowledges that as well as thermal disinfection, there are other effective methods of controlling *Legionella* which may be deemed equally suitable under the regulations.

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°C to 45°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°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°C but is quicker at higher temperatures.
- *Legionella pneumophila* requires on average 3.2 minutes exposure to 60°C to reduce the bacteria count by a factor of 10. That is to say 3.2 mins to reduce from 100,000 to 10,000; a further 3.2 mins for 10,000 to 1,000; and 3.2 mins for 1,000 to 100 cfu/l which would be considered an acceptable level.
- Where the water contains 100,000 cfu/l *Legionella*, on average the bacteria need to be held at 60°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°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.

ooOOoo

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

Report by Dr T Makin¹ 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°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°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°C, and at 60°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°C (D_{60°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* 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 D_{60°C} values for *L. pneumophila* and other *Legionella* spp (with the exception of *L. micdadei*), ranged from 2.3 to 5 mins. The mean D_{60°C} value for *L. pneumophila* was 3.2 mins. The D_{60°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 D_{60°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°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°C or

¹ Dr T Makin, Directorate Manager, Medical Microbiology, Medical School, Royal Liverpool University Hospitals. Co-author of the HSE ACoP and Guidance (L8), and the Health Technical Memorandum HTM04-01 providing guidance on the control of Legionella bacteria in health care premises.

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°C and notably those maintaining temperatures below 45°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°C, then according to the work of Stout et al., the boiler would need to maintain the water temperature at 60°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 10⁵ cfu/l and higher are not uncommon at the base of hot water vessels where temperatures of 20 – 45°C are maintained. If a combi-boiler receiving water from a solar pre-heat cylinder contaminated with *Legionella* to 10⁵cfu/l, maintained a water temperature of 60°C for 3.2 mins this would reduce the concentration of viable *Legionella* bacteria by 90% to 10⁴cfu/l. This significantly exceeds the lower permitted limit of 10²cfu/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 10³cfu/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 10⁴cfu/l to 10³cfu/l. Consequently, a concentration of 10⁵cfu/l of *Legionella* bacteria would require exposure to 60°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°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°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°C or above, then consideration should be given to programming the system to automatically activate the combi-boiler to heat the water to 60°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°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°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°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°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 GPs 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.

Dr T Makin

Directorate Manager

Medical Microbiology Medical School

Royal Liverpool University Hospitals

Papers cited in this report

Stout JS, Best MG, and Yu VL. 1986. Susceptibility of members of the family *Legionellaceae* to thermal stress: Implications for heat eradication methods in water distribution systems. *Applied and Environmental Microbiology*. 52:396-399.

Schulze-Röbbecke R, Rodder M, Exner M. 1987. Multiplication and killing temperatures of naturally occurring *Legionellas*. *Zentralbl Bakteriol Mikrobiol Hyg*. 184(6):495-500.

Dennis PJ, Green D, Jones BP. 1984. A note on the temperature tolerance of *Legionella*. *Applied Bacteriology*. 56(2):349-50.