"Legionella and Legionnaires' Disease (LD): Preventive Measures for its Outbreak & Risk Mitigation steps in Domestic Hot & Cold Water Storage and Distribution Systems"- (*Paper for Advanced Society for Science & Technology's National Conference on 'Innovation and Entrepreneurship in Health, 06-07 April 2012, at India International Centre, New Delhi*) by Homi R. Mullan.

Abstract

Legionnaires' disease (LD) is a bacterial Pneumonia, caused by an acute infection of the lower respiratory track by a bacterial pathogen ***Legionella,*** which are common to aquatic, especially warm water environments and some soils. Legionnaires' disease and Pontiac fever are the two most common types of ***Legionellosis***, with Legionnaires' disease (LD) being the more serious and primary one focus. LD Exposure is most likely to occur via: 1) **Inhalation** of aerosols, fine sprays, mist or other microscopic droplets of water contaminated with Legionella – providing direct access in to the lungs; and/or, 2) **Aspiration** which may occur when choking or spontaneously during the drinking, ingesting, swallowing process, leading to water entry into the respiratory tract and lungs. The disease is a potentially fatal, multi-system respiratory illness with an average mortality rate of 15% to 20%. It is selective in attack and infects only 2% to 5% of those appropriately exposed to the bacteria. *Legionella* bacteria are among the top three causes of sporadic, community acquired pneumonias (CAP). It is also the cause of hospital acquired (Nosocomial) cases of pneumonia. The **concern is** that many LD cases go undiagnosed because the disease is difficult to distinguish from other forms of pneumonia, and besides under-detecting, they are also under reported in the US and UK; and, whereas in India: there is very little awareness, and selective work done; no Risk assessment measures are in place by the Operators of Hospital, Hotels, Commercial & offices buildings, Housing & Residential Complexes, Industrial Plants, Swimming pools, Spas, Shopping Malls, Fountains, Cooling Towers, Air conditioning plants, Prisons, Old age homes and the likes; and, furthermore there is no known regulatory body or Law in place in India and its States to protect the workers and public infected by LD. The CDC in US has estimated that the disease infects 10,000 to 15,000 persons annually. OSHA estimates that over 25,000 cases of the illness occur each year, causing more than 4,000 deaths.

There are numerous water usage areas where the water is to be treated for Legionella, and there are several treatment methods including Biocide treatments, Chemical treatments, Copper-Silver Ionization, Ozone & UV treatment. This paper deals with the **'Hot Water Temperature Maintenance in Storage & Distribution Piping System'**, which employ ***Irradiated Conductive Polymer Heater Technology***, as Hot water systems present the greatest risk in environments which allow the proliferation of Legionella. It deals with the temperatures at which the Legionella are dormant, at which they colonizes and at which they are killed.

Legionnaires' disease is an environmental disease and an environmental issue, with safety and health responsibilities to be addressed by many. Regulatory system, penalties and labour laws are to be in place. Owners' should be aware of their Responsibility. Risk assessment management team to be formed comprising of Director, Infection Control, Facilities Manager & Engineer, Facilitator and equipment suppliers to share the responsibility.

Preamble:

Going by the understanding of widely published and established reports in the UK, USA, Europe, Australia, that the Thermal water systems (Hot water Storage & distribution piping), including hot tubs and display spas, have been responsible for large outbreaks of *Legionnaires' disease* (LD); in context this paper deals with Temperature Maintenance of domestic Hot Water Storage Tanks and distribution piping network, to mitigate the LD Risk, and as a preventive measure against its outbreak. *Trace heating* method is employed, using Electric Surface Heat Tracer (ESHT) in conjunction with thermally insulated heated surfaces of tanks, pipelines and its fittings. The type of ESHT considered and recommended is ***Self-limiting Self-regulating*** (SLSR) Conductive Polymer heating core heating cables, which has features and benefits such as; cut-to-any-length due to parallel circuit heating design, Burnout proof, Easy to Install & Maintain, Reliable & Safe, having an operating Life in excess of 20 to 40 years; and these trace heaters are in use in Industrial plant in India since 1978, very successfully. However, there are other wide variety and types of ESH Trace heating cables available, working on principle of series resistance, Zone heaters which provide constant watt heat, and these could also be considered.

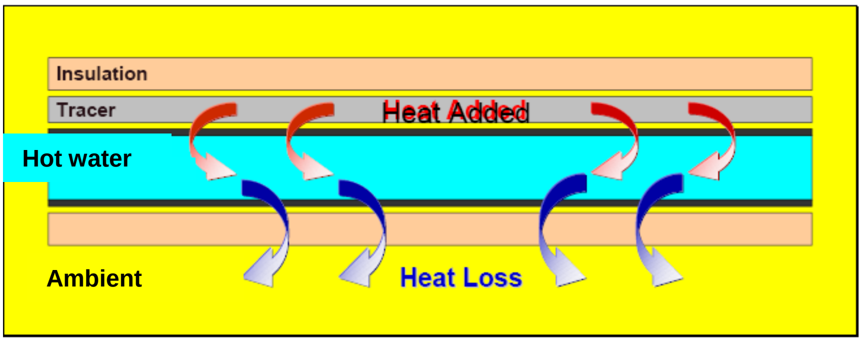
Legionella bacteria (LB) are present in natural surroundings like rivers, ground water, sea water, soil, municipal water mains, plants and other natural surroundings. The ideal way to controlling of Legionella in Domestic Hot Water is to destroy the Legionella Pneumophila (*L. Pneumophila*) bacteria, and to eliminate where Legionella bacteria will amplify and multiply rapidly in the man made surroundings, wherein they colonise and amplify. Primarily, *Legionella* bacteria LB require: a) Water, b) Warm temperature, and c) Food source. Water temperature is crucial factor in the colonization of *Legionella* bacteria (LB) in the water distribution system; along with other LB protective natural source materials in the distribution system, such as algae, sediment, sludge, hemp, rubber components, scale, which are also to be eliminated by proper material selection and cleaning maintenance. For *trace heating* option to control *Legionnaires' disease* (LD), let us view the temperatures: at which the bacteria *Legionella Pneumophila* are *dormant*; at which they *colonize* to multiply; and at what temperatures they are *killed*. The below tabulated values will enable suitable temperature parameter for design of trace heating system.

AT WATER TEMPERATURES OF:	**LEGIONELLA BACTERIA:**
90 deg.C	Pasteurisation / Sterilisation / Kill
70 to 80 deg.C	Disinfection range
66 deg.C	Die within 2-minutes
60 deg.C	Die within 32-minutes
55 deg.C	Die within 5 to 6 hours.
50 deg.C & above	Survive, but do not multiply.
35 to 46 deg.C	Ideal growth range.
20 to 50 deg.C	Growth range.
Below 20 deg.C	Survive, but do not multiply.

Hot water under conditions of : stagnation, temperature stratification in storage tanks, very low flow rate, long length pipe runs from hot water storage point to discharge outlet points, and where dead legs are present in piping system, results in progressive fall in temperature, that causes multiplication and colonisation of legionella bacteria. One of the method to mitigate this risk is to *trace heat* the hot water system, which ensures that the desired design maintain temperatures are ensured continuously at all times throughout the domestic hot water system. Hot water at the storage point should be maintained at and above 70-deg.C, and inside the distribution pipe network to be maintained above 66 deg.C, and the temperature of water being discharged at the usage outlet should be 46 - 50 deg.C, to prevent ***Scalding*** accident.

TRACE HEATING

Trace heating of vessels and pipelines is a science practiced to retard the rate of heat flow from the hot surfaces of vessels and pipelines to the surrounding low temperature ambient, in conjunction with *thermal insulation* covering the area of heat loss surfaces. Trace heating is subject of compensating the slow rate of heat loss taking place from insulated surfaces, by appropriately replacing the heat, by the *trace heating* cables, at an equal or greater amount of heat then the rate of heat loss taking place. Thus the rate of heat loss taking place, from the surface of pipes and vessels, is to be replenished by *trace heating* cables at the point of heat loss occurring. An efficient Thermal insulation with optimised thickness does 85% work of heat retention, and the balance 15% heat is added to compensate rate of heat loss is done by means of energy efficient trace heating cables.



INNOVATIVE TECHNOLOGY OF 'CONDUCTIVE POLYMER' TRACE HEATER

Let us touch upon Conductive Polymers technology. All polymers are very good electrical insulation material, whereas the innovative conductive polymers permit the flow of electrical current to flow through it.

All polymers which are thermoplastic materials, when heated, their crystalline bonds soften, and the polymer chains begin to melt and flow. But, when these thermoplastic materials are cross-linked by irradiation, they become thermoplastic material, after which they will not melt and flow when heated. The polymer chains are held together by the cross-linked bonds when in heated state.

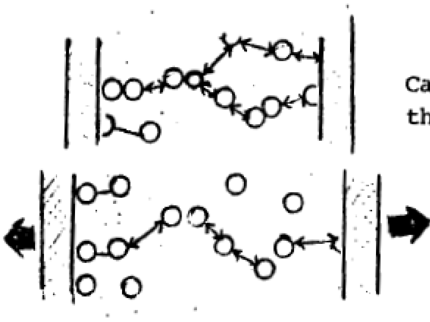
"cool"polymer

"cool" crosslinked polymer

"warm" polymer

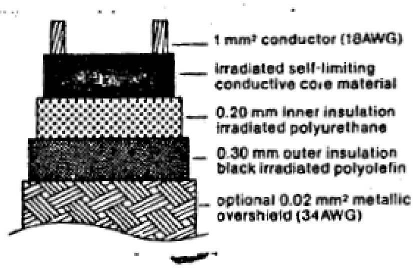
"warm" crosslinked polymer

When the polymers are mixed and blended with carbon particles, and placed between the positive and negative electrode bus-wires, the parallel current flow path is created between the bus-wire spacing. When, energised, the current will flow through the parallel conductive polymer circuit path, and would result in generation of heat. The conductive polymer, after extruding process along with the bus-wires, are cross-linked by controlled irradiation, forms a stable conductive polymer heater. The particulate carbon chain particles when the trace heater is cold, they are denser; allowing greater amount of current to flow, and heating process begins. With the increase in tracer core temperature, the carbon chain particles begin to disperse, and lesser amount of current flows through it. When the trace heater reaches its *limiting temperature*, no current flows in between the bus-wires. On cooling, the carbon particle chain returns back to its position with its 'elastic-memory' feature.

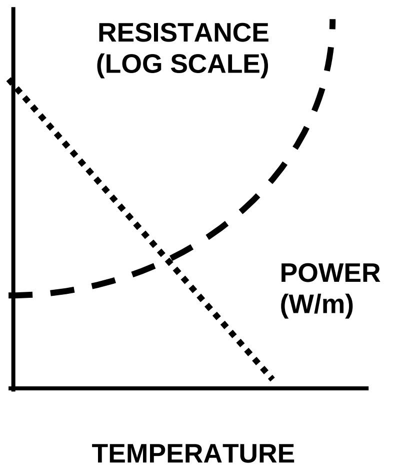


Carbon chains before thermal expansion

Carbon chains after thermal expansion

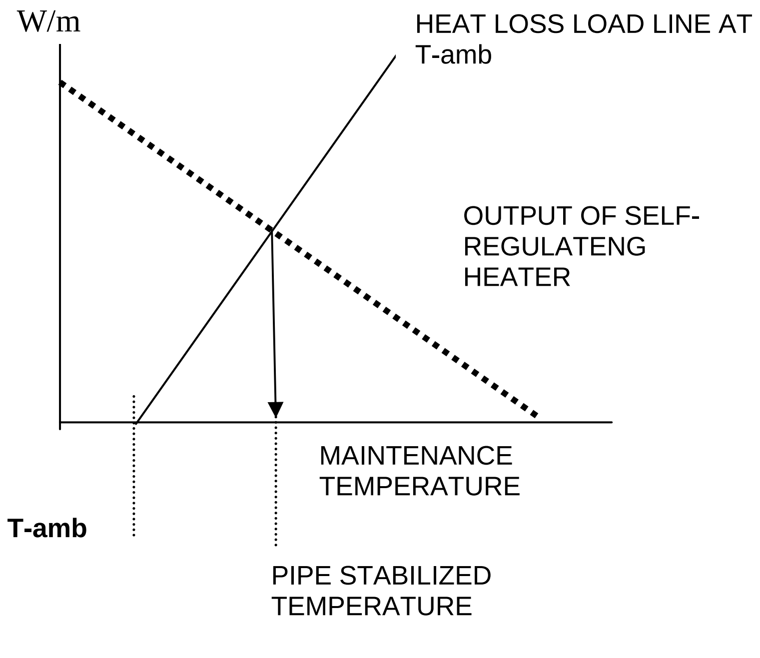


In electrical terms, the Self-limiting heater is said to have a *Positive Temperature Coefficien*t (PTC) characteristic; i.e., its resistance increases logarithmically with the rise in temperature, and the resistance reduces with fall in temperature.



As the temperature increases, the tracer resistance increases logarithmically, thus lowering the Power output rate (W/m). Likewise, with the drop in pipe temperature, the resistance decreases with the drop in pipe temperature, increasing the power output rate.

Heat loss rate (W/m), for a given set of stable conditions for pipe size, insulation thickness, ambient temperature, hot water pipe temperature will remain at a constant gradient, and it is a straight line. When the heat output rate of a Self-regulating tracer, matches with the heat loss rate, at this point the pipe will attain a stabilized temperature condition. The Self-regulating trace heater self-stabilizes at the pipe temperature.

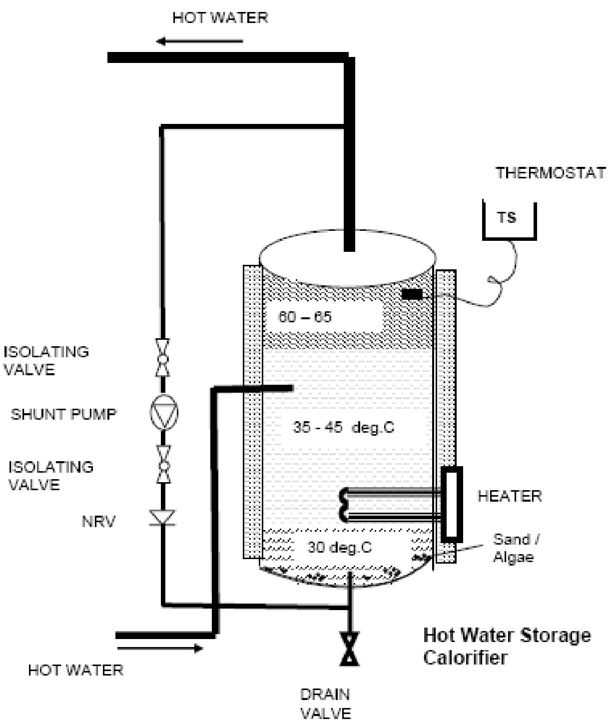


<u>TRACE HEATING OF HOT WATER SYSTEM FOR PREVENTION OF LEGIONNAIRES' DISEASE</u>

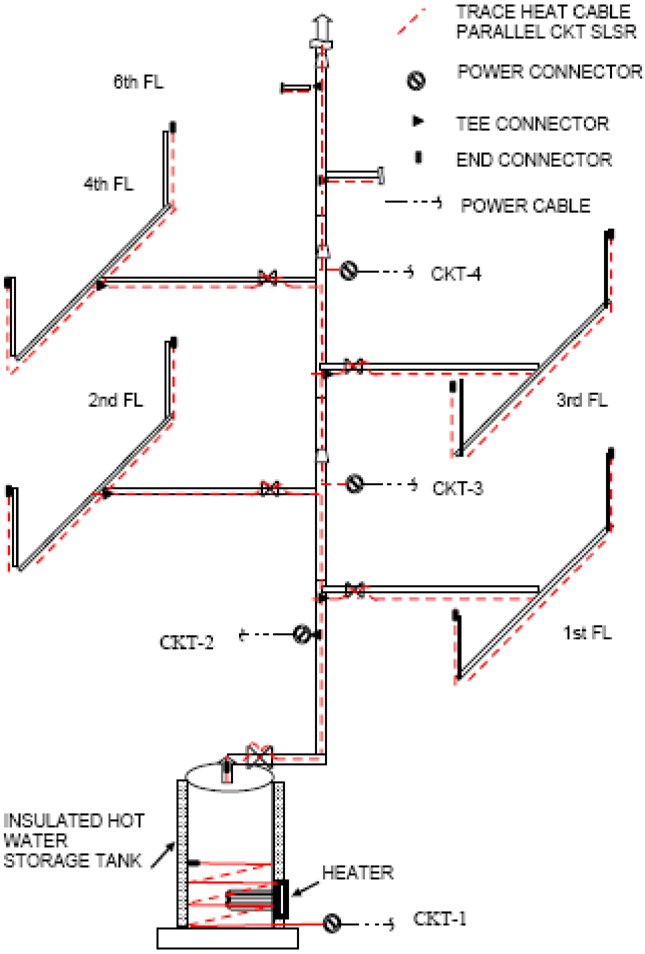
The two areas where legionella bacteria will colonise and multiply when hot water is stagnant between temperatures of 20-deg.C to 46-deg.C is: in hot water Storage Vessels / Calorifier / Tanks, and, in the distribution pipe system network.

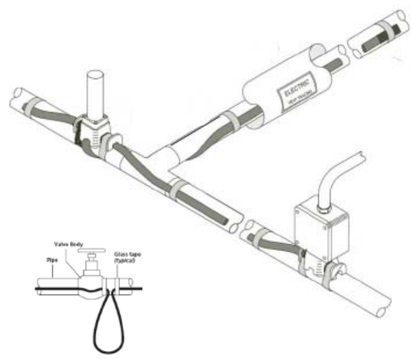
<u>Hot water Storage Vessels/Calorifier/Tanks.</u>

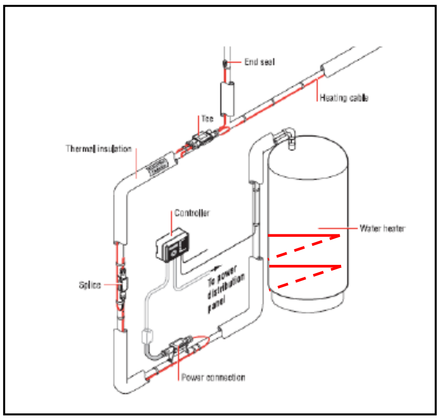
Due to hot water stagnation inside vessels, calorifiers, tanks, the temperature gradually comes down from 65-70 deg.C to below 46-deg.C. Even if the immersion heaters (Steam or Electric) are installed, the water temperature below the heating surface will begin to fall as the heat tends to propagate upwards and not downwards. Due to convective current, the hot water rises and cold water comes down. To ensure that the hot water is not pumped beyond the design set requirement of 65-70 deg.C, the Thermostat sensor is installed on the upper water layer in the calorifier, which controls the heater operation. This results in temperature stratification inside the storage calorifier / tank. The stagnant water below the heater surface cools down. Shunt pump is also used periodically for circulating the water inside of calorifier / tank, but this does not ensure fully that the temperature inside will be at 65-deg.C and above. To ensure that during stagnant periods the hot water in an insulated calorifier / tanks is retained is to *trace heat* these equipment with *Electric Surface Trace Heaters*.



Hot Water Distribution System



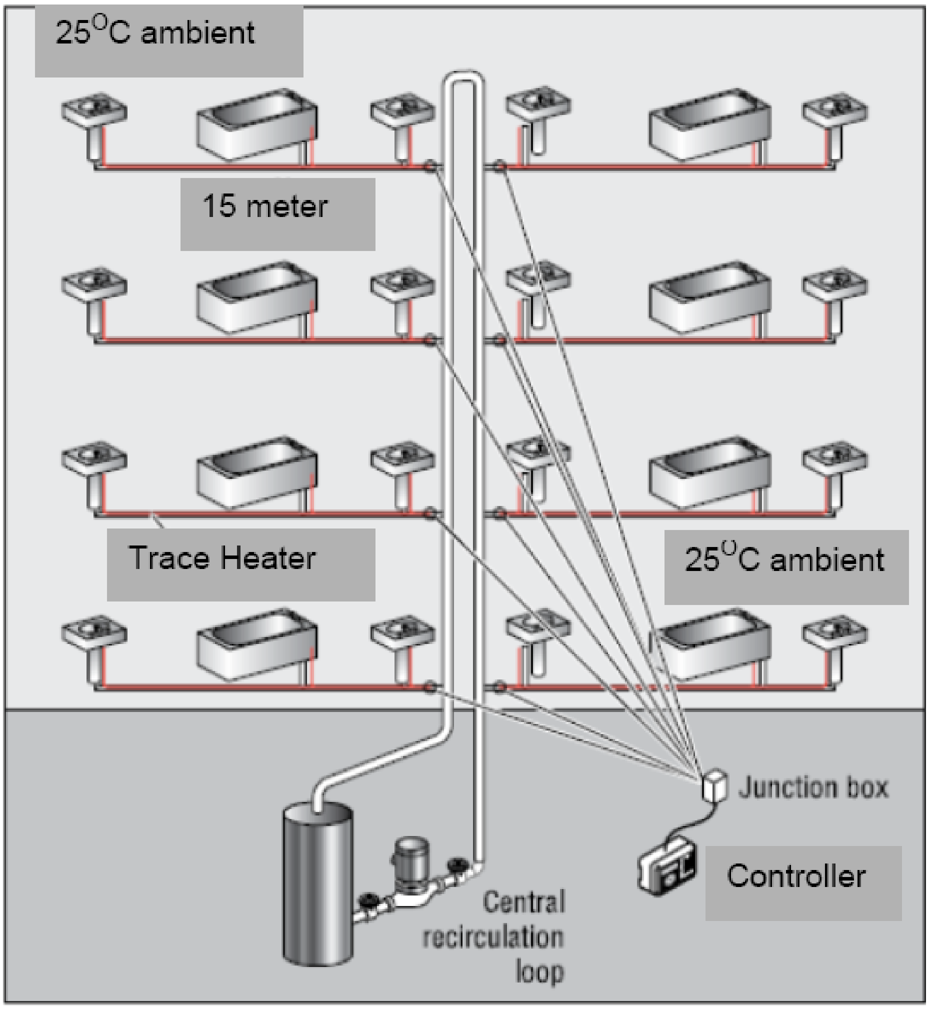




Electric Trace Heated Non-Circulatory Hot Water Distribution System

The temperature of hot water needs to be high enough (above 70 deg.C) to stop naturally occurring Legionella multiplying to a level causing health problems, Legionnaires' disease in particular. Temperature of hot water begins to fall when the lines are not effectively thermally insulated; the water is stagnant during prolonged no-flow periods; facility areas not occupied and kept shut; the distance between the hot water release point being very far to the end using point, very low flow rate, and at dead legs location. By *trace heating* the pipe in conjunction with thermal insulation, using Self-limiting Self-regulating electric trace heating cable, ensures that each point in the pipe distribution network and its fittings, is maintained at the required design temperature at all times. The above diagram shows that the non-circulatory hot water pipeline being electric *trace heated*, right up to the points of usages, in a multi storied building. The above piping arrangement shown is a non-circulatory pressure flow system, with no circulation of water back to the plant. Electric Trace Heating arrangement in a non-circulatory hot water flow system eliminates the return circulation pipe with thermal insulation, and eliminates circulating pumps used in a conventional hot water distribution system.

<u>Electric Trace Heated Circulation Hot Water Distribution System</u>



In a Circulated hot water system, the water in branch lines from the circulating mains tapings will remain stagnant during no flow periods, and the hot water will progressively cool down. These branch water supply lines should be *trace heated* in conjunction with thermal insulation. For Legionella growth preventive measure, the circulating main lines are preferably heat traced along with insulation.

<u>Scalding</u>

Another factor relevant to Safe water temperature is ***scalding***, as vulnerable people such as children and elderly may get burned, because their skin is thinner and less tolerant. This is conflicting as primarily the temperature of hot water system needs to be high (65-70 deg.C) to stop naturally occurring Legionella multiplying to a level that will cause health problems.

Therefore, at the point of usage the hot and cold water mixing should be carried. Automatic temperature controlled 'Thermostatic Mixing Valves' should be used, at the usage point.
Hot water temperature affects the skin to the extent of:-
65^{O}C a partial thickness burn in about 2-seconds;
60^{O}C a partial thickness burn in about 5-seconds
55^{O}C a partial thickness burn in about 15-seconds
50^{O}C a partial thickness burn in about 90-seconds
As water must be stored hot enough to eliminate Legionella, yet be cool to prevent scalding, at the point of usage 'thermostatic mixing valves' are one solution to the problem.

Thermostatic Mixing Valve

Maximum Outlet Temperature Requirements

Bidet	38^{O}C
Shower	41^{O}C
Washbasin	41^{O}C
Bath	44^{O}C
Supervised bath	46^{O}C

Temperature should never exceed 46^{O}C

Design: Trace Heater Output Rate to Compensate Heat Loss Rate from Insulated Pipes

Ambient temperature	25^{O}C
Maintain temperature	65^{O}C
Differential temperature	40^{O}C
Pipe	metal
Insulation	Fibreglass
Location	Outdoor (wind speed 8.9 meter/sec)
Design Margin	10%

[BS: 6351 Part: 2 1983, Appendix A]

Pipe Size: Inches (mm)	*Insulation thickness (mm)*	*Design Heat Loss (W/m)*
0.5" (15mm)	20mm	9.5
0.75" (20mm)	20mm	10.9
1" (25mm)	25mm	11.0
1.25" (32mm)	25mm	12.9
1.5" (40mm)	25mm	14.1
2" (50mm)	40mm	12.9
2.5" (65mm)	40mm	13.7
3" (80mm)	50mm	13.4
4" (100mm)	50mm	16.1
6" (150mm)	50mm	21.7

Heat Loss Factors: Valve (Gate / Globe) 1.3; Valve (Ball) 0.8; Rock Wool (.038 W/m.C) 1.06; Mineral Wool (.043 W/m.C) 1.2; Indoor 0.9. The above table values could be used for initial estimate for *trace heating* load plan.

Temperature Measurement

Since water temperatures are advocated as the principal method of controlling legionella in hot and cold water services systems, a large part of the site procedure will involve temperature checks throughout the system. These will be carried out to determine whether water systems meet the operational guidelines for hot and cold water services that prevent the proliferation of legionella, as tabulated in the earlier part of this table. The risk from water services should be assessed for periods of normal use including maintenance, breakdown, commissioning and known occurrences of abnormal operation or unusual circumstances.

Cold water supply to the buildings should be below 20-deg.C. Cold water service would experience external solar heat gains in sub-tropical and tropical regions in summer months. Measurement therefore should be conducted during the same period of normal usage as the hot water services.

Temperature measurements taken as part of routine inspection and / or continuous monitoring should be recorded during a period similar to that chosen for the initial risk assessment. The result of the risk assessment may then be used as a comparator to indicate whether the performance of the system has changed. Water temperature may be measured also at the fittings. Recommended temperature measurement points should include: base water temperature at bottom of storage vessels, supply outlet from storage calorifier, cold feed temperature, water flow points, water usage at furthest end points, hot water service return lines (where circulation system is installed) and at selected test points including the final discharge usage points.

Innovation & Entrepreneurship

The paper has explained the Innovation in Conductive Polymer *trace heating* cables for temperature maintenance in hot water storage and distribution system. On realisation of risk associated with Legionnaires' disease by all the stake holders, several entrepreneurship avenues are open. To name a few, the opportunities are in:

- Legionella detection laboratory and field testing services.
- Legionella Cleaning and Disinfection specialised services.
- Trace heating designs, material supply, installation and maintenance service.
- Temperature monitoring devices, design, and services.
- Thermo Mixing Valves, Heated Showers.
- New Plumbing and Thermal insulation materials.

Conclusion

This paper has summarised in a nutshell the awareness of community at risk of Legionnaires' disease, caused by releasing of legionella bacteria *L. pneumophila* from domestic hot water systems, and the way to *trace heat* the hot water storage and distribution system, to control and prevent legionella colonisation and amplification, which are released to atmosphere along with aerosols, sprays formed in showers, decorative fountains, basins, swimming pools, spas and the likes. For total overview of Legionnaires' disease caused by other sources of water at Cooling towers, humidifiers, HVAC system, the Risk assessment plan and checks, the documents and papers referred in reference list may be studied and/or referred to.

The revised Approved Code of Practice (ACOP) issued by the UK Government's Health & Safety Executive (HSE) significantly extends the scope of guidance on control of legionella bacteria in water. The code now applies to all hot and cold water systems in the workplace. Whilst domestic systems may represent a risk, the code only applies to the risk arising from a work activity. That means that all employers who manage premises with hot/cold water systems and/or wet cooling systems have a legal responsibility to identify any risk of contamination and to prevent or control it.

The challenge lies ahead of Health, Environment, Labour, Legal, Government and Civic bodies in conducting and assessing the epidemiological risk of Legionnaires' disease, to plan to control and mitigate the risks. Scientific, Technology and Engineering solutions are available, and the stake holders in State and Central may use these resources to study and implement in line with regulatory work done in Europe, North America, Australia and other industrialised countries.

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23. Acknowledgement: Thermon Manufacturing Company, San Marcos, Texas, USA

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