SAFETY ASSESSMENT FEDERATION

# Fact Sheet

## Pressure Systems

## Potential Hazards from Water Hammer and Risks from Failure at Dead Legs

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## CONTENTS

## 1. Background

The original Safed FS1 issued in 1997 covered the potential for water hammer failures in steam system pipework resulting into serious and several fatal injuries. Following a number of recent incidents, this information has been updated and extended to cover the potential risks at dead legs. In this regard the HSE has issued a Safety Bulletin available on the website: https://www.hse.gov.uk/safetybulletins/catastrophic-rupture-dead-leg-pipe-work.htm

The parts of a pipework constituting dead legs are listed in this safety bulletin.

There is a significant reduction in the use of steam. This has led to reduced number of properly trained and experienced operators. Often existing systems require modifications, which may not always be technically sound and therefore can result into both water hammer and dead legs. This is further aggravated, as steam plants are ageing and, in many cases, maintenance is not given due importance.

Though this document is primarily concerned with steam pipework, failures at dead legs can occur with other fluids.

## 2. Causes and Effects of Water Hammer

- Water hammer is most frequently caused during the introduction of steam into cold pipework that has not been sufficiently drained, it may happen as follows:

A. **Condensate driven by steam**

When steam is admitted via an isolation valve into cold pipework containing water, the steam which is travelling faster than the water – causes the water to form a plug which is accelerated along the pipework until it meets the next downstream closed valve or obstruction like a "hammer" and rebounds back into the vacuum created by the condensing steam.

B. **Condensate moving into a vacuum.**

When steam is admitted into a cool space or if it is in contact with water it may condense rapidly and create a vacuum. If the steam has been trapped e.g. against an isolating valve - condensate may be drawn into the vacuum at a speed high enough to deliver a "hammer" blow to the valve.

- The speed at which an isolation valve is opened in order to introduce steam into cold pipework is instrumental in dictating the likelihood of creating water hammer; should a valve be opened too quickly without allowing time for the cold pipework to warm though gradually – there is a risk that water hammer will result.

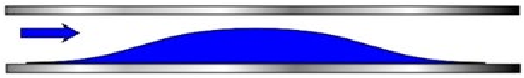
- If an isolating valve is manufactured from a brittle material, such as cast iron, any resulting water hammer is highly likely to cause the valve to shatter with the potential to cause severe, if not fatal, injury to anyone in the vicinity.

- Another factor contributing to the number of incidents is the practice of operating boilers. In many plants the boilers are not run 24/7 and are often shut down overnight and at weekends. This necessitates more frequent warming through and increases the risk of introducing steam into insufficiently warmed pipework.

- The lack of maintenance of steam traps is another factor. Frequent shut-downs and start-ups put a higher demand on the traps and require better maintenance regime.

- **An Example:**

**Note:** The below calculation has been done for a slowdown distance of 0.5 m for comparison purposes only. However, water hammer will involve very short slow down distances, consequently much larger forces (For no slowdown distance of the impact force will be infinite).



1 litre of water ≈ 1kg

Impact Force≈625N or ≈141 lbf.

The significance of this force can be appreciated from the fact that a mass of 1 Kg falling freely will create a force of 9.8 N.

## 3. Reducing the Known Hazards Associated with Water Hammer

- BSEN12953 Para 4.2 disallows the use of valves manufactured from grey cast iron.
- Regulation 4 (2) of Pressure Systems Safety Regulations 2000 (PSSR) requires: *(2) The pressure system or article, as the case may be, shall be properly designed and properly constructed from suitable material, so as to prevent danger.*
- The HSE Approved Code of Practice to PSSR in para 66 of HSE Publication L122 points to Water Hammer while referring to the forces acting on pressure systems.
- In light of the above and taking into account the firm stance adopted by HSE at prosecutions involving the failure of cast iron crown valves caused by water hammer **SAFed strongly recommends the replacement of cast iron crown valves on steam boilers with valves manufactured from more ductile materials e.g. spheroidal graphite (SG) cast iron or cast steel.**
- Although the first priority must be to remove the cause of water hammer, yet this may not be always practicable. Therefore, the use of valves of ductile materials must be adopted as a standard practice.

## 4. Action Plan to Minimise the Hazards of Water Hammer.

In addition to the precautions outlined in the previous section, the following basic steps are recommended.

A. **Removal of liquid from the Pipework.**

i. **Pipework Installation and drainage** – Ensure the pipework has a suitable fall in the direction of flow and that drainage points are located in appropriate positions (in addition to steam traps on supply runs); in particular check that the system permits complete drainage when cold. Always drain system before start-ups.

ii. **Condensate Collection** – Reduce or eliminate points where condensate could collect e.g. sagging lengths of pipework between supports, vertical lengths, changes of slope dead ends, fittings in pipes etc. Where they are unavoidable should be fitted with suitable drainage (and traps).

B. **Steam Traps** – Maintain steam traps in accordance with the manufacturer's instructions. This should include routine testing for correct functioning.

When a steam system has cooled down, a large quantity of condensate may remain in the system, which the automatic draining arrangement is unable to handle. In such a case an additional or by-pass manual drain should be fitted, left open during warming or start-up stage and closed only when water has completely drained.

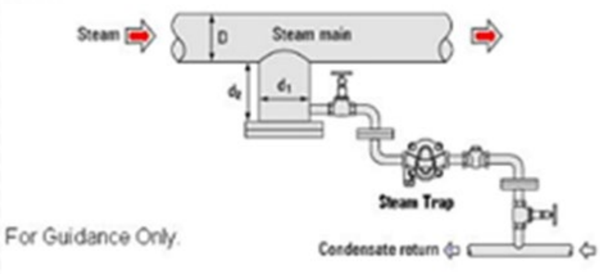
C. **Isolation Valves** – Ensure that suitable valves are fitted to permit gradual warming of the system. On large valves often a smaller diameter warm up valve can be fitted for supply of small amounts for this purpose.

D. **Enhanced Training of Boiler Operators** – To avoid the risk of thermal shock and reduce the chance of water hammer. The boiler operators should be trained to warm a system gradually. They should also understand the significance of loud banging, and the actions to be taken should this occur.

E. **Modifications** – It is now common for steam pipework modifications to take place. Common causes of failure are from the inadvertent removal of drainage/traps from isolated lines. Changes of direction of flow can render steam traps ineffective or inefficient.

## 5. Dead Legs and Low Flow Areas.

The presence of dead legs is not uncommon in steam systems, in particular after modifications. If not properly managed due to no/low flow condensation will take place and will create a thermal gradient. This will cause localised and severe internal corrosion. Deposits and liquid interfaces are other sources of corrosion. Cooler condensation locations (such as supports and clamps) are also vulnerable to corrosion under insulation. Blocked condensate traps subject to poor maintenance regime are a source of condensate collection in the dead leg.




The localised corrosion of dead legs will cause severing when subjected to a force larger than their residual strength. These forces could be the result of water hammer.

Above mentioned HSE Safety Alert has advised actions in regard of Dead Legs, which are reproduced below:

*Dead legs are eliminated wherever possible, and minimised thereafter;*

*The risk assessment and associated examination regime takes account of conditions which may be peculiar to dead-legs, including thermal gradients, interfaces, solid/corrosion deposits, condensation points etc., and that the frequency of examination and level of scrutiny reflects potentially aggressive and localised deterioration. Where there is additional environmental threat, an absence of secondary/tertiary containment should influence the risk assessment.*

*The integrity regime should monitor pipework wall thickness so that localised deterioration is captured, checks are undertaken with sufficient frequency, and repair or retirement and replacement is undertaken in good time.*

*Process lines which are redundant but retained for future use are left in a safe state, and thoroughly checked for integrity before being reinstate.*