E L E M E N T A L   S O L U T I O N S

D E S I G N   F O R   S U S T A I N A B L E   W A T E R   M A N A G E M E N T

Water Regulations Review;
Water Efficiency Opportunities.

For The Environment Agency

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July 2008

Contents

Water Efficiency Opportunities under the Water Supply (Water Fittings) Regulations.

Scope

This document considers the potential for changes in the Water Regulations from the viewpoint of water and energy saving. Consideration is given to possible maximum volumes and flow rate requirements in line with WC flush volume limits.
Given that the CSH water requirements are to be mandatory for publicly funded homes (and may be used to map future regulatory changes), this has to be considered as an integral aspect of this work. I have touched on issues with the code in this paper and reviewed the CSH in some detail in a separate paper[1]. This review is available on request.

Summary of suggested recommendations for Water Supply (Water Fittings) Regulations

1. Showers
Showerheads to have a maximum flow rate of 9.5 litres per minute at 5 bar.

2. Basin and sink taps
Basin taps to have a maximum flow rate of 6 litres per minute at 5 bar.
Sink taps to have a maximum flow rate of 8 litres/minute at 5 bar.

3. Washing machines and washer-driers
Maximum volume requirements to be more in line with actual practice whilst acknowledging that efficiency will be driven by labelling.

4. Dishwashers
Maximum volume requirements to be more in line with actual practice whilst acknowledging that efficiency will be driven by labelling.

5. WCs
Retain 6 litre maximum flush volume but require this to be measured with a water supply of 5 bar connected. Consider requirements for leak detection of inlet and flush valves.

6. Urinals
Clarify and simplify the requirements for flush volume and frequency for automatically flushed urinals, i.e. 4.5 litre flush per urinal with a maximum of two flushes per hour and only when the building is occupied. Recommend that waterless urinals are considered. Apply to existing installations to clarify enforcement requirements.

7. Baths, hot tubs, spas
No recommendations on volume limits beyond the existing un-enforced notification limit of 230 litres. Clarification of how bath volumes are specified is required.

8. Hot water dead-legs
Current recommendations in the Water Regulations Guide for maximum lengths of un-insulated pipes to be replaced by a recommendation that all hot water pipes of 15mm or

[1] A Critique of the CSH Water Efficiency Requirements. Nick Grant, for the Good Homes Alliance.

greater outside diameter are to be fully insulated. Dead leg volume to be limited to 1.5 litres (without a pumped secondary circulation loop) and 0.5 litre for dead legs coming off a pumped secondary loop.

9. Water softeners

More research required but requirements need clarifying and harmonising with the CSH (or rather vice versa). Regeneration should be demand initiated and consideration should be given to correct specification and commissioning.

10. Other areas, for example cooling and low cost domestic fire sprinklers

If not already available, a catchall requirement for notification of non-standard uses for mains water should be established to anticipate the development of products that could lead to water wastage but which are not covered by any specific sections of the Regulations.

11. General recommendations

Consider aligning any flow or volume requirements with existing international standards to increase the availability of products. Consider point of sale regulation to reduce the chance of fittings being changed for higher flow ones.

Standards harmonisation and conflicts

The Water Regulations have typically driven a number of water efficiency measures and regulated against wastage and undue consumption. Other initiatives such as the energy label have pushed technical developments for white goods well beyond the minimum requirements of the Water Regulations. We now also have the Code for Sustainable Homes and the proposed revision to the Building Regulations Part G is to include water efficiency based on the Code methodology requiring all new dwellings to achieve a maximum daily internal water use of 120 litres/person based on the CSH Water Calculator[2]. Additionally, there are a number of performance requirements such as BS 6700 and the NHBC minimum specifications that might, for example, set minimum flow rates for taps and showers.

Unfortunately, whilst well intentioned, the compulsory water and energy sections of the Code are seriously flawed[3]. What we find is that the water use calculation tends to force unacceptably low tap and shower flow rates, particularly if a normal size bath is installed. Because of this, a number of designers and developers have concluded that grey or rainwater must be specified even to meet Code level 3. A review of the Code[4] considers whether this is desirable from an economics and sustainability perspective and also shows that greywater or rainwater will not necessarily deliver the required Code levels.

An issue, particularly relevant to this document, is that very low-flow tap outlets and shower heads can be fitted at low cost and then simply removed once a certificate has been awarded or when the householder becomes frustrated trying to fill a kettle or kitchen sink at 1.7 litres/minute or rinse long hair with a 3 litres/minute shower. Such extremely low flow fittings

[2] Although initial proposals suggest a slightly different methodology. For example where a range of different bath or WC volumes are installed the Building Regulations propose using the largest volume whilst the CSH averages out the volumes.

[3] E.g. see http://www.goodhomes.org.uk/downloads/news/101.pdf

[4] A Critique of the CSH Water Efficiency Requirements. Produced by NBT Consult for the Good Homes Alliance. Nick Grant June 2008. Most of the same points were made in a short report in June 2007.

are used in worked examples from BRE, WRc and others and are installed in the houses on the BRE Innovation Park and so cannot be seen as simple loopholes or mistakes.

The calculated whole-household performance approach was deliberately adopted after ‘stakeholder consultation’ in preference to performance standards for individual fittings. Ironically whilst the performance approach was probably seen as a soft option allowing a trade off between fittings, the reliance on the water calculation tends to force flow rates and volumes that are far lower than any appliance standard would have ever been likely to enforce. For example whilst 1.7 l/minute spray taps for the kitchen sink might be required to meet the Code, it is unlikely that a proposal for kitchen taps with a flow rate less than 8 litres/minute would have ever been personally accepted by any ‘stakeholder’.

Market harmonisation

A related issue that came up in conversation with one manufacturer is that the UK and even the European market is very small compared to, say, the US or China. Thus if specific shower or tap flow rates are required, consideration should be given to harmonisation with another country that already has a suitable standard. This argument is particularly relevant to low cost fittings such as tap outlets and showerheads where many units must be sold to recover development and tooling costs.

EN 1111

BS EN1111 is the standard for thermostatic mixing valves for taps and showers and a concern has been raised about the requirement for approved valves to achieve a flow rate of at least 0.33 l/s (12 litres/minute) at a pressure of 3 bar.

The standard does not preclude the addition of water saving devices such as flow regulators, ‘water saver showerheads’ or tap aerators but does require the valve to pass this flow rate test with such devices replaced by a specified standard restriction. In addition, for tapware fitted with ‘special equipment’ such as ‘a water economy device’, a minimum flow of 9 litres per minute is accepted subject to the operating pressure being greater than 1 bar.

> “10.5.3 Requirements
> The flow rate measured at 0,3 MPa (3 bar) shall, depending on the type of appliance for which the thermostatic mixing valve is intended, be at least equal to:
> 0,33 l/s (20 l/min) for baths;
> 0,20 l/s (12 l/min) for wash basins, bidets, sinks and showers.”

EN1111 should not be a barrier to any requirements for flow regulation below 12 l/min for showerheads or tap outlets (e.g. sprays and aerators). However the current standard requires that the actual mixer valve is capable of delivering 12 l/minute under test conditions.

It is possible that some thermostatic mixer valves might be more sensitive to variations in pressure (for example when another tap is opened) when used at low flow rates and this should be considered when setting new standards or revising EN 1111.

Other performance requirements

Various performance standards have been developed over the years to protect householders from flow rates that might not be fit for purpose. Such standards give consumers protection against poorly designed fittings or incorrectly designed plumbing systems.

Fitting	NHBC specified flowrate	BS 6700 recommendation
Shower head	Design flowrate = 12 l/ min Minimum flowrate = 6 l/min	3-12 l/min
Basin taps	Design flowrate = 9 l/ min Minimum flowrate = 6 l/min	6-9 l/min
Sink taps	Design flowrate = 12 l/ min Minimum flowrate = 6 l/min	6-12 l/min

General considerations relating to flow specifications

Figure 1 shows how flow rate increases with available pressure for a nominally 8 litre/minute aerating shower head, specified at 3 bar.

Whilst un-vented hot water systems are typically fitted with a pressure regulator limiting the static pressure to 3 bar, combis and thermal stores might operate at higher water pressures in some areas.

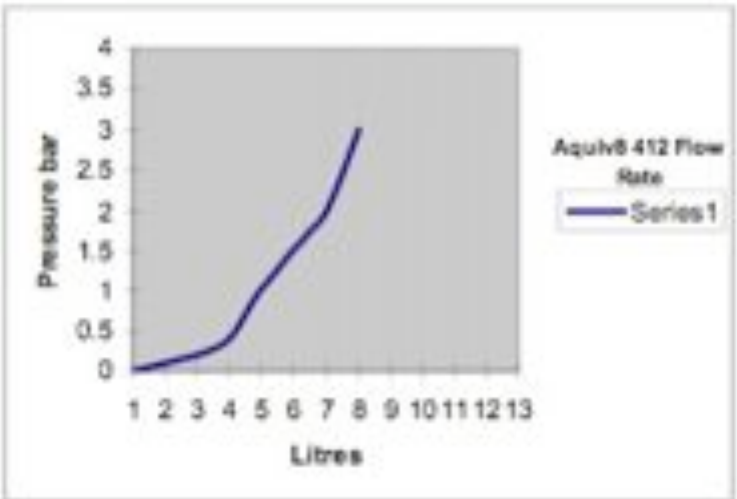

Figure 1. water pressure against flow rate for an 8 litre/minute shower head, Challis Water Controls.

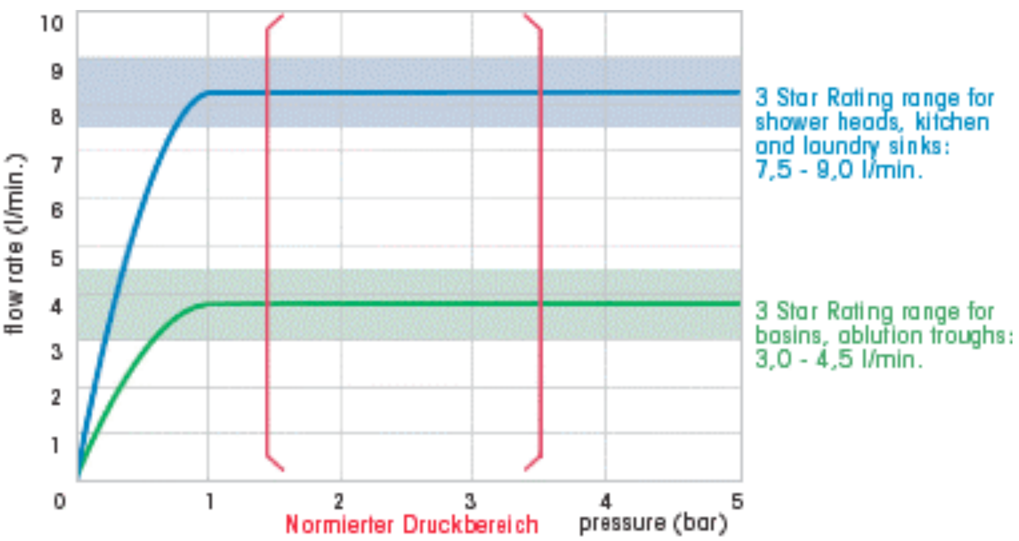

Figure 2 flow rate against pressure with a flow regulator. Neoperl UK.

For pressures greater than about 0.2 bar it is possible to incorporate a flow regulator for constant flow rate over a wide pressure range.

Flow rates could be specified as a maximum or as a range. For example a requirement could be for say 9 litres/minute maximum or to be in the range 7.5 to 9 litres/minute as in the figure 2 which illustrates the Australian water efficiency label requirements for AAA. A range is more suited to a labelling approach whilst a maximum flow rate is better suited to a regulatory requirement.

Gravity plumbing systems

The UK is unusual in having such a range of plumbing systems. Specifying flow regulated (rather than simply restricted) fittings for use with gravity systems is problematic and unnecessary as the flows will tend to be low anyway. However gravity systems must be considered when wording regulations.

The need to supply taps and showers with very low restriction for use with gravity systems does create a potential loophole for the supply of high water use fittings for mains pressure systems. Such a loophole is only likely to be seriously exploited if water saving products fail to perform. Products designed for mains pressure can exploit technologies such as aeration which should be seen as a positive feature.

Fitting specific considerations

1. Showers

WRc document CP337[5] reports a 14.5% increase in showering compared with earlier studies of un-metered older properties whilst bath use has remained similar. The sample is small (70 properties covering a range of types) and occupancy is unknown but this fits with the generally assumed trend of more frequent showering and higher shower flow rates[6]. CP337 found showering to represent the largest single use of warm water, which makes it an important target for energy and carbon savings. At the Passivhaus level of energy efficiency, the annual energy use for domestic hot water is greater than for space heating and most of this is for bathing.

It is often suggested that flow rate could influence duration. For example a high flow might run the risk of using up all the water in a cylinder so showers will be kept short or a low flow might require more time to rinse hair. Additionally where flows are low it is likely that the full flow rate will be used whilst where excess flow is available it might not always be used, or at least not all the time.

An additional factor considered elsewhere is cold water that is run to waste whilst the water runs hot. For showers, warm water is also wasted whilst the temperature and flow are adjusted. No data were found for the extent of this wastage in the UK but in the worst installations the issue is very significant.

[5] WRc portfolio project as referenced in MTB Briefing Note WAT28: water consumption in new and existing homes version 1.0.
[6] Whether due to mains pressure hot water systems, combi boilers or higher power electric showers.

Acceptable flow rates for showers

Very few people have any idea what flow rate their shower is and will judge it based on the experience rather than any measurement.

Whilst enthusiasts can achieve excellent energy and water savings by using short duration ultra low flow rate showers down to 2 to 3 litres per minute, most people would not consider such flows acceptable[7]. The risk with specifying too low a flow rate is that the fitting will be replaced by users, possibly with a much higher flow rate fitting. Where the user does not have choice about the shower fitting (gravity hot water, hotel guests, teenagers etc) baths might be taken in preference to a poor shower thus increasing water use compared with a slightly higher flow shower that might be used in preference to a bath.

Satisfaction depends greatly on user expectations and showerhead design and it seems unreasonable to expect that any flow rate chosen to promote water and energy efficiency will be acceptable to all users. However there seems to be enough evidence to suggest that most people should be satisfied with flow rates above about 6 litres per minute and almost all should be satisfied with 8 litres per minute[8]. Research into "Showers Types Use and Habits"[9] found that 92% of 104 people were satisfied with their electric shower. This is interesting since electric shower flow rate is limited by the fixed heat input which typically limits the flow rate to 3-6 litres per minute[10] (depending on rated power and water temperature rise required).

Critchley and Phipps[11] trialed aerated showerheads and found that 8 out of the 9 householders chose to keep the (7- 8.4 l/min) water saving head despite flow rate reductions (at full flow) averaging 27.5% (range 3-45% reduction). Interestingly the individual who chose not to keep the water saver shower had the highest flow shower (23.6 litres per minute) but gave it a satisfaction score of only 23 compared to the average score for the water saver showers of 33 (range 31-35).
A trial by Thames Water is currently looking at water savings and acceptability of 8 litre/minute aerated showerheads with a sample of over 1000 households. Unfortunately results[12] are not yet available.

Studies and anecdotal evidence suggests that the shower head design is important in ensuring user satisfaction at reduced flow rates and a number of attempts have been made to measure factors such as skin pressure, spray pattern and temperature effects. It is also likely that factors such as style, size and noise[13] will also influence users perception.

Interestingly aerated showerheads have proved popular with users despite the lack of skin pressure due to the soft aerated 'champagne' stream.

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[7] E.g. BRE and Liverpool John Moores University studies.
[8] This seems to be a common specification for a number of aerated showers that have been tested.
[9] Per Capita Solutions June 2006 for Essex and Suffolk Water.
[10] Flow (l/min) = 14.3 x P (kW) /Temperature rise (C).e.g. 14.3 x 8.9kW/32°C = 4 l/min (5 l/min for a 25°C temperature rise, e.g. in summer).
[11] Water Efficient Showers; Critchley and Phipps, Liverpool John Moores University for United Utilities April 2007.
[12] Personal communication Helen Chapman, Thames Water.
[13] This could be a positive or negative factor. Aerating showers sound powerful due to the entrained air.

In the USA the Federal Energy Policy Act of 1992 ANSI/ASME A112.18.1M-1996 requires shower heads to use no more than 2.5 US gpm at 80 psig (9.5 l/min at 5.5 bar). However this is not well enforced and websites include details of how to de-restrict a shower head. Additional loopholes exploited by manufacturers and individuals include the fitting of multiple 2.5 gpm heads and redefining the shower as a body spar, indeed anything but a shower. However it is not thought that these modifications are required because of poor performance at the regulation flow rate and regulations are being clarified to close some of the loopholes due to interpretation.

Another concern is that shower heads often have a much higher flow rate than the label suggests as shown in figure 4.

BS 6700 suggests a minimum flow of 3 litres per minute and the NHBC suggest a minimum of 6 litres per minute.

Figure 3. 3 x 2.5 US gpm shower heads! From a presentation by Biermayer 2006[7].

Manufacturer	Model #	Flow rate* (GPM)	Label (GPM)
Watermark	SH-FAL70	7.62	2.0
Watermark	SS-RH080	13.00	2.0
Watermark	SS-RH500	8.19	2.0
Watermark	SS-RH600	9.10	2.0
Nautilus	II	12.70	None

* [illegible]

Figure 4. Measured flow rates of water saver shower heads in the US from Biermayer 2006[14]

[14] http://www.cuwcc.org/faucets_showerheads/LBNL-ACEEE_Presents_Shower_Systems_Aug-2006.pdf

Practical issues

The large range of permutations of shower and plumbing systems in the UK has been widely documented. As already discussed electric showers are inherently flow-limited and so will not be considered further. Gravity hot water systems are becoming less common than mains pressure systems such as combi boilers, thermal stores or un-vented cylinders. Typically gravity fed showers have a low flow rate due to lack of pressure. Whilst a gravity system with a drench head could achieve very high flow rates, it might be difficult to specify a flow rate for gravity shower components over a wide range of heads as currently available dynamic flow regulators typically require about 1 bar to operate although some new designs are claimed to operate down to 0.2 bar[15]. Gravity systems can be restricted but this requires trial and error and so is not an option for point of sale product regulation. Available water saver regulated showerheads are designed for pressures above about 1 bar and are not suitable for gravity systems.

Regulated showerhead or regulated mixer valve?

The easiest technical solution is to regulate the flow within the showerhead. Whether this regulation is achieved as part of the physics of the showerhead or by an additional in-line flow regulator will depend on the design. For example aerating and atomising heads tend to require sufficient pressure to function. The addition of an additional flow regulator can in effect reduce the pressure at the shower head under dynamic conditions thus reducing performance.

This limits the scope for introducing the required flow regulation in the shower mixer valve. A reason to do so would be to make more difficult to simply swap a showerhead for a higher flow one whether to deliberately achieve a higher flow rate or for fashion.

It is possible that mixer valves could be required to deliver a maximum of say 13 litres per minute[16] at a specified pressure (perhaps 5 bar) by design with any further reduction achieved at the shower head.

This would make it more difficult to deliberately or accidentally achieve very high flow rates but would not guarantee water efficiency without a suitable water saving showerhead. Reducing this value would require a change in EN 1111 requirement that a thermostatic mixer valve must be capable of delivering 12 l/min at 3 bar.

A related issue is whether to regulate the hot and cold feeds to the mixer, for example using in line access valves with removable regulators[17] or the outlet. Some energy and water consultants prefer to specify separate hot and cold regulators arguing that they can be built into the plumbing and so removal might be less likely. However this makes it difficult to know what the total flow will be as it will depend on water temperatures (hot, cold and shower).

All this points to the need for point of sale regulations so that it is difficult to purchase a non-efficient showerhead.

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[15] Personal communication Noel Neath Neoperl UK.
[16] See discussion on BS EN1111.
[17] Aquaflow Regulators Access valve.

Shower backstop water use limits

Currently there is no specified upper limit for shower flow rates although, in theory, permission must be sought before connecting a pumped shower that will draw more than 12 l/min from the mains. However there is nothing to stop un-pumped mains pressure fed showers delivering any volume that the hot water system can deliver. Nor is there a limit on pumped systems drawing water from a storage tank (e.g. a pump added to a gravity hot water system).

The US FEPA regulatory limit of 2.5 US Gpm translates to 9.46 litres/minute and the Water Services Association of Australia (WSAA) National Water Conservation Labelling Scheme awards an AAA rating (High) for 9 litres/minute. Although this is not compulsory, labelling is. As discussed above, 8 litre per minute aerating showerheads are a proven technology and are available from a number of manufacturers.

Recommendation:
Based on the above evidence and overseas presidents, a suggested regulatory limit to flow rate for showerheads would be 9 litres per minute. Consideration needs to be given to the test pressure and whether this is a range[18] or fixed value such as the 3 bar specified in CSH. This figure could be raised to 9.5 to bring it in line with US regulations and products, however the US showerhead market is geared towards fixed heads.

Such a proposal is unlikely to be welcomed by the majority of the industry even though it is a far higher flow rate than would be implied by imminent CSH compliance.

13 litres per minute might make sense as a requirement for thermostatic shower valves and mixer taps because of the current EN1111 requirement for a minimum flow of 12 litres/minute with any restrictor removed. This would provide a fallback level of flow regulation should water saver shower heads be replaced or modified.

2. Basin and sink taps

Shower water consumption is proportional to frequency, flow rate and duration. The same is true of taps when used to wash hands or rinse items under flowing water but taps are also used to fill a basin, kettle or other vessel. In this mode the flow rate does not influence consumption in the same way. Thus tap flow rates need to be high for filling and low for rinsing operations.

Water brake taps cartridges and innovations such as Tap Magic attempt to address this issue but are not considered here in the context of regulatory requirements.

The Identiflow data[19] that has informed the CSH and MTP Briefing note indicates that average tap flow rates are already low at around 3.4 litres per minute presumably either because the water pressure is low (gravity hot water systems) or because people choose not to turn the tap onto full flow.

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[18] For example 1 to 5 bar would ensure adequate performance at lower mains pressures without allowing high flow at higher pressures.
[19] WRc 2005, Increasing the Value of Domestic Water use Data for Demand Management, Final Report P6832.

Practical issues

As with showers there is a possibility of providing flow regulation within the tap or within the outlet fitting, typically within an aerator or spray fitting. The increasing popularity of taps with standard metric outlet threads allows sprays and aerators to be fitted to suit usage. As with showers, regulation can be achieved for the hot and cold feeds to a mixer tap but this raises the same issue that the flow rate can then be up to twice the regulated flow to each side. The BMA water efficiency label specifies a maximum flow rate of 6 litres per minute for the hot and cold feeds. This is a different approach to the CSH which considers the mixed flow at the outlet. Where separate hot and cold taps rather than a mixer are fitted, the CSH calculates the average flow of the two. Whilst this makes more sense than adding both the flows it would be simpler to take the higher of the two flows.

The fitting of sprays and aerators to dual flow taps could lead to backflow if the hot and cold water pressures are imbalanced. In this situation check valves should be fitted to comply with the Water Regulations but such an arrangement is not compatible with a cold mains and gravity hot water feed. Such are the complications of UK plumbing.

Acceptable flow rates for taps

'The Energy Policy Act (EPAct) of 1992 and subsequent EPAct legislation have limited faucet flows to 2.2-US gpm at 60 psi (8.3 l/min at 4.1 bar). In public restrooms, the flow rate on faucets is limited by standards and codes to 0.5-gpm (1.9 l/min).'[20] A higher flow rate could be argued for kitchen sinks than for basins which are mainly used for hand and face washing of tooth brushing, although the latter might be filled for shaving.

The US EPA Water Sense Program is exploring the possibility of reducing the flow rate for basins:

> 'For these activities, discussions with faucet manufacturers and water utility representatives provided a general consensus that a reduction in the maximum flow rate from 2.2 gpm [8.3 l/min] (the current federal water-efficiency standard) to 1.5 gpm [5.7 l/min], as established by this specification, is not very noticeable for most users. The most noticeable differences are increased wait times when filling the basin or waiting for hot water. While decreasing a faucet's maximum flow rate increases user wait time for these activities, Water Sense determined the potential water savings gained from the primary use of lavatory faucets (i.e., washing and rinsing) outweigh any potential inconvenience caused by increased wait times and will not negatively impact overall user satisfaction.'[21]

[20] http://www.cuwcc.org/faucets_showerheads.lasso (accessed 14/07/08)
[21] High-Efficiency Lavatory Faucet Specification Supporting Statement. www.epa.gov/watersense/docs/faucet_suppstat_final508.pdf

Tap backstop water use limits

Recommendation:
The following values are suggested in light of the above evidence:

Basins 6 litres/minute (per pillar tap or per mixer outlet)
Kitchen sink 8 litres per minute.
Handwash only basins 1.7 litres/minute (but beware time to run hot)

3. Washing machines and washer-driers

Washing machine backstop water use limits

The current Water Regulations set a limit of 27 litres/kg per cycle for washing machines in accordance with the standard 60°C cotton cycle as chosen for Annex 1 of EU Directive 95/12/EC. This equates to 135 litres for a 5kg machine.

According to current statistics on the Waterwise website the average water efficiency for all machines listed is 8.8 l/kg, range 6.1 to 19.2 l/kg.

The limit for washer driers is 48 litres/kg in accordance with Annex 1 of EU Directive 99/60/EC. This equates to 240 litres for a 5kg machine. Some driers use cold water to condense the evaporated water which is why this figure is higher than for washing machines. Statistics equivalent to those presented for washing machines and dishwashers could not be found for washer driers.

Clearly the Water Regulations could be updated to at least come in line with currently available products but the function is likely to be as a backstop rather than as a driver for efficiency, which is covered better by the Energy label. There are numerous issues relating to trends in machine size and loopholes in the Energy label scheme but these will not be explored here.

4. Dishwashers

Dishwasher backstop water use limits

The current Water Regulations set a limit of 4.5 litres/place setting per cycle in accordance with Annex 1 EU Directive. Thus a typical 12 place setting machine would consume 45 litres. According to current statistics on the Waterwise website the average water efficiency for all machines listed is 1.3 l/place setting, range 0.7 to 2.5 l/ps. The Water Regulations could be updated but the function is likely to be as a backstop rather than as a driver for efficiency which is covered by the Energy label.
As with washing machines, the Water Regulations are unlikely to drive efficiency in the white goods sector but the current value could be reduced to bring it in line with current practice.

5. WCs

General issues

The current Water Regulations set a maximum flush volume of 6 litres measured with the water supply turned off. There is no minimum flush volume. Dual flush and ‘flush valves’ are allowed having previously been outlawed. Internal overflows are also permitted after a ruling that they are 'no less effective' than an external warning pipe or other clear indication of inlet valve leakage as was also previously required.

Actual flush volumes

It has long been recognised that actual flush volumes in use are typically significantly higher than that measured during testing with the water supply turned off. The exception to this rule is where refill is very slow and so the WC is flushed before it has fully filled.

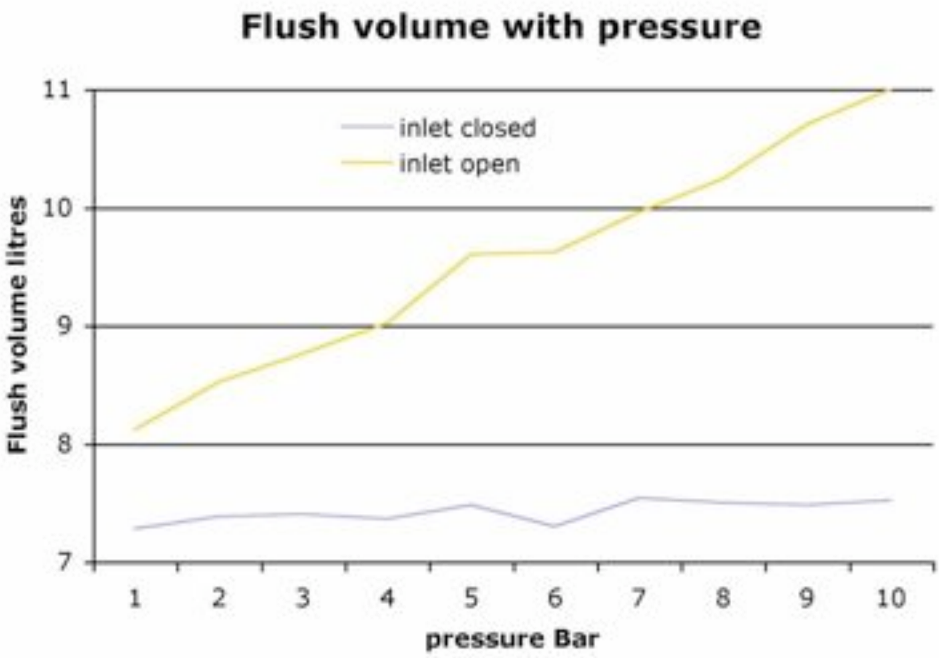

Figure 5. Variation in flush volume with pressure based on figures from WRc.

Evidence from a trial monitoring new properties by WRc for Esssex and Suffolk Water[22] found that:

'Of the twenty properties monitored, seventeen properties produced an average flush volume of > 6 litres, nine of these had a flush volume of > 8 litres. '

The maximum flush volume should have been 6 litres.

Another explanation given for such variation is variability between flushes with drop valve mechanism. This was first reported with the Millennium Dome monitoring by Thames Water but informal discussion with a product designer for a major manufacturer suggested that such variation is common and not only due to mechanical failure as might be assumed.

It is difficult to imagine a case for not requiring flush volumes to be measured with the water supply connected at a pressure of say 5 bar. Currently there are probably only two manufacturers producing WCs that meet this requirement but the issue has been publicised for many years now and the extra cost would be minimal.

[22] Identiflow® Monitoring of New Properties, WRc Ref: UC7129, May 2006. Creasey and Bujnowicz

Recommendation:
Flush volumes should be measured with the water supply connected and at a maintained pressure of 5 bar[23].

The Water Regulations avoid the issue of specifying an effective flush volume for WCs. This is wise as another discrepancy is in the assumed and measured ratio between full and part flush for dual flush WCs. Ratios as high as 1:4 have been used although 1:1 has been reported in trials. WRc have recommended using 1:1[24] and the CSH compromises at 1:2 whilst Ecohomes used 1:3.

Flush and inlet valve leakage

Whilst there is a large amount of anecdotal evidence for flush valve leakage, and mechanical failure, little research has been carried out in the UK. Systematic data was collected by Bournemouth and West Hampshire Water who recorded the cause of water leaks that led to undue consumption. Whilst 6% of leaks turned out to be due to leaking flush valves it is not known what percentage of properties were fitted with valve flush WCs. Further research is needed which could perhaps best be carried out by water companies.

Based on anecdotal evidence and the Bournemouth and West Hampshire Water data, inlet valve leakage is far less common but is likely to go undetected now that cisterns can overflow down the pan.

Given the history of the valve/siphon and internal/external overflow debate it seems unlikely that the current situation can be changed by regulations although there appears to be growing evidence of a serious water wastage issue emerging.

Whilst valves will always fail at some point, it is possible to incorporate a simple warning device or even a mechanism to prevent the cistern refilling if the flush valve is leaking. There is at least one commercially available device[25] that can achieve this plus a number of patents and public domain solutions that will not be implemented without an incentive or legal requirement.

A web search reveals a number of patents but many are complex and impractical. It has been said that flush valve leak detection is not practical[26] based on the assumption that any device has to detect a leak in the flush pipe or down the back of the pan, e.g electronically. However a better approach is to ‘look’ at the inlet valve which will open slowly in a leak situation but quickly in normal operation. A full patent and product search is beyond the scope of this paper but a number of solutions are possible.

Recommendation:
Cisterns should be fitted with a device or devices that provide a clear indication of inlet and (where fitted) outlet valve leakage.

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[23] There may be practical reasons for choosing a different pressure but 5 bar is suggested as a starting point for discussion.
[24] Assessing the Cost of Compliance with the Code for Sustainable Homes. WRc Ref: UC7231 for the Environment Agency. September 2006.
[25] Fluidmaster Leak Sentry.
[26] Personal communication with WRc before valve flush became legal.

If agreed in principle the details would need to be clarified to define what rate constitutes leakage (perhaps the current Secretary of State test criteria) as well as revisiting the issue of what constitutes a clear indication of leakage. This latter point is made more difficult by the previous ruling deciding that an overflow down the pan is equivalent to an external warning pipe.

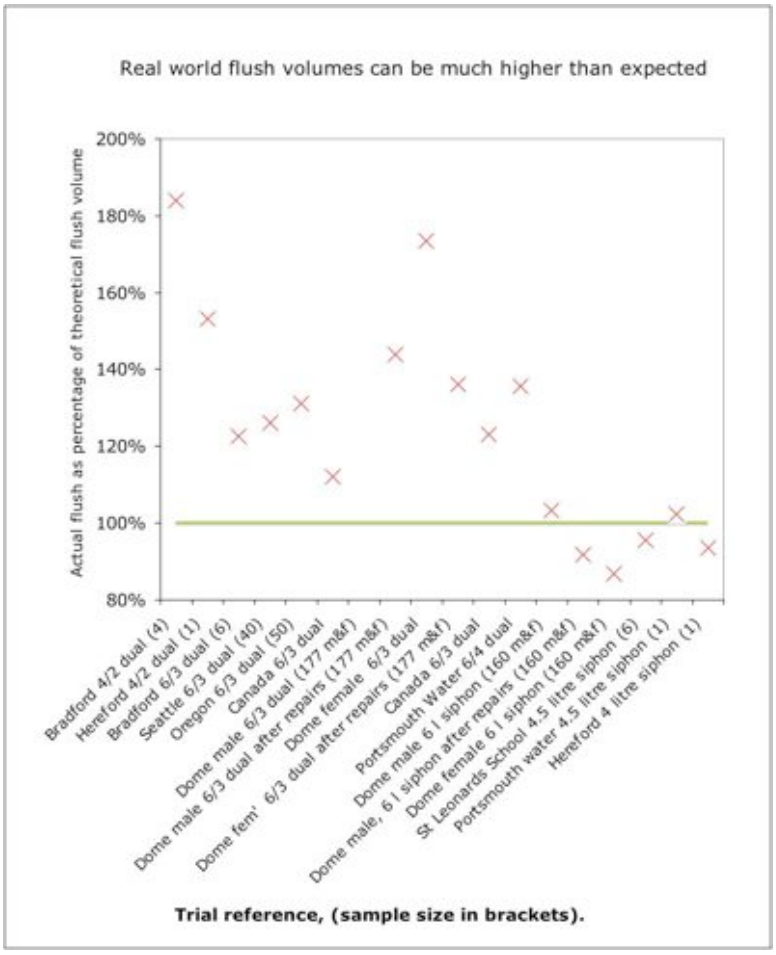

Figure 6. Flush volume as a % of nominal specified volume for a range of trials.

Figure 6 gives an indication of the large discrepancy between stated flush volume and that measured. This data suggests that simply lowering claimed nominal flush volumes might not be the best route to efficiency.

Dual flush operation

The clear identification of dual flush operation is a requirement of the current Regulations[27] and is important if savings are to be guaranteed. The toilet in the picture below is not unusual in having two similar halves of the button – how is the user supposed to tell which is which?

A fully prescriptive standardised design is unlikely to be acceptable to manufacturers or end users and so it is likely that a subjective judgement will have to be made as to whether the mode of operation is clear.

[27] Statutory Instruments 1999 No. 1148, The Water Supply (Water Fittings) Regulations 1999 section 25g.

A related issue is the operating logic of dual flush siphon cisterns. Traditionally a full flush was achieved by holding the lever down but this means that the cistern defaults to a partial flush if released too soon and this might fail to clear the pan. Siphons and dual flush retrofit devices are available which operate in this mode but some manufacturers changed their products in line with suggestions that siphons should default to full flush.

Both modes have advantages. The part flush default mode forces regular users to learn the operation of the cistern and so is likely to result in greater water savings but also some double flushing and embarrassed or dissatisfied users. The full flush default mode results in full pan clearance unless used by people familiar with the opposite logic. However such as cistern could be used for years without the users knowing that it has a dual flush function.

In theory cisterns should have an instruction sticker but these are rarely fitted or are usually removed.

Recommendation:
It seems reasonable that button design should be approved for unambiguous operation as part of performance testing.

Figure 7. Photo courtesy of the Environment Agency.

WC backstop water use limits

4 to 4.5 litre maximum full flush WCs have been installed in a range of applications in the UK and Sweden for many years now and 4 litres is generally considered to be the lower limit for well constructed conventional drains without the use of air pressure or other assistance to drain carry. To quote from an Environment Agency document "*The scenarios considered in this study have shown that there is an increased risk of solid stranding and blockages occurring in some drain/sewer systems if existing WCs are replaced with lower flush units*

(four litres or less). However, there will be other household/drainage system combinations where a lower flush WC should not be too problematic."[28]

In the USA the move to 6 litre WCs led to problems with pan blockage which brought in a requirement for MaP testing (Maximum Performance). This requires the flushing of 350g of simulated faecal material extruded from miso (soya bean paste).

Given the potential problems with some drainage systems and the potential savings to be achieved by addressing actual flush volumes and valve leakage, it is difficult to make a case for lowering the existing flush volume requirements far below 6 litres full flush.

Whilst a number of campaigning organisations have called for dual flush WCs to be a legal requirement this could act as a barrier to low volume single flush WCs which have outperformed dual flush WCs in trials[29].

6. Urinals

General issues

The current requirement with regards to water use for urinals is open to interpretation although the 'deemed to satisfy' guidance is clear:

> **5.** - (1) Subject to the following provisions of this paragraph-
> . . .
> (i) every urinal that is cleared by water after use shall be supplied with water from a flushing device which-
> (i) in the case of a flushing cistern, is filled at a rate suitable for the installation;
>
> (ii) in all cases, is designed or adapted to supply no more water than is necessary for effective flow over the internal surface of the urinal and for replacement of the fluid in the trap; and
>
> (j) except in the case of a urinal which is flushed manually, or which is flushed automatically by electronic means after use, every pipe which supplies water to a flushing cistern or trough used for flushing a urinal shall be fitted with an isolating valve controlled by a time switch and a lockable isolating valve, or with some other equally effective automatic device for regulating the periods during which the cistern may fill.
>
> 4) The requirement in sub-paragraph (1)(i) shall be deemed to be satisfied-
> (a) in the case of an automatically operated flushing cistern servicing urinals which is filled with water at a rate not exceeding-
>
> (i) 10 litres per hour for a cistern serving a single urinal;

[28] Less water to waste; Impact of reductions in water demand on wastewater collection and treatment systems, Science project SC060066, EA 2008.
[29] For example see figure 6 and the Millenium Dome water efficiency trials by Thames Water.

(ii) 7.5 litres per hour per urinal bowl or stall, or, as the case may be, for each 700mm width of urinal slab, for a cistern serving two or more urinals;

(b) in the case of a manually or automatically operated pressure flushing valve used for flushing urinals which delivers not more than 1.5 litres per bowl or position each time the device is operated.

Whilst 4 (a) is clear it is not clear how this rate is to be set or checked. A further complication is the requirement for (j) which is intended to prevent water waste when a building is not in use.

Urinal flush controllers appear to work on a range of principles. Some allow a quantity of water into the flushing cistern when a person or persons are detected either electronically or hydraulically via hand basin use. Others use a timer to shut off a dripping petcock out of hours or when no people have been detected for a period of time.

Whilst the petcock type system could theoretically be set up to meet the hourly flush volume requirements this would be very difficult to achieve in practice and the volume is likely to alter with blockage of the necessarily small orifice, variations in water pressure or intervention by staff worried by odour or blockage.

If we consider even a bank of 3 urinals requiring 7.5 x 3 = 22.5 litres/hour = 0.375 litres/minute and a single urinal would only require 10 litres/hour = 0.167 litres/minute. Setting and regulating such a low flow rate is unrealistic although the rationale for the 10 litre allowance for a single bowl is to make it easier to set such a low flow.

Systems that deliver a volume of water to the flushing cistern whenever a person is detected are thought to be more reliable but it is unclear how the current regulations apply.

The following are the first four methods of controlling urinal flushing found in manufacturer's literature:

Cistermiser PIR controller operating sequence:
On detection of movement in the washroom a pulse from the sensor opens the normally-closed solenoid valve and water flows to the cistern. The initial open period is 25 minutes. Any occupancy during the next 5 minutes will cause the cycle to repeat. If no occupancy is detected the solenoid valve is closed, shutting off the water supply until the next occupancy is detected. The integrated flow regulator within the valve allows the volume of water passing to the cistern during the 30 minute open period to be adjusted. Generally this should be set so that the cistern flushes once every time the valve is opened. i.e. every 30 minutes during occupation. If the sensor detects no occupancy in 12 hours it will automatically open the valve for 30 minutes to allow one flush to rinse the urinals and pipework.

Cistermiser hydraulic flush control valve operating sequence:
The valve is activated by short-term pressure drops created by use of taps and WCs on the same supply. The valve is normally closed; when it is activated it opens and water passes to the urinal cistern for a brief period of time. When the cistern is full the auto-siphon will flush. The installer or user can adjust the time the valve remains open and therefore how long the cistern takes to fill and how much water is used.

Dart Valley Systems Flushmatic operating sequence:
The time for the cistern to fill and automatically flush is measured and this time is set on the control board. A flush frequency is decided and the cistern fill time subtracted to give a required delay time. This is the time between a person being detected and the valve opening. Thus whilst people are detected the urinals will flush every 1 to 15 minutes (plus fill time) depending on the switch settings chosen. The fill time can be up to 15 minutes if the flow is restricted giving a maximum cycle of 30 minutes when the urinals are in use.

Arrow Valves PIR Controller operating sequence:
Installing and calibrating the unit is simple - requiring the setup switch to be operated for the filling period. There are no other controls or nozzles to fit. The cistern will flush 30 minutes (factory setting) after the first movement is detected. Flushing can be set to 1, 2, 3 or 4 times per hour.

Cistern volume

The Regulations do not specify a volume per flush except for flush after use urinals. However catalogues appear to list cisterns of 4.5 litres for a single bowl, 9 litres for 2 bowls and 13.5 litres for 3 bowls. Pre Water Regulations plumbing textbooks support this observation and suggest a flush of 4.5 litres/bowl, every 20 minutes[30] which equates to 13.5 litres per bowl per hour.

Thus assuming 4.5 litre of cistern capacity per urinal is standard, the required flushing rate to meet the current Water Regulations is 36 minutes, say twice an hour.

If manufacturers were required to demonstrate compliance with the Water Regulations water use limit as part of WRAS testing, this could lead either to modified instructions or controllers designed with adjustments limited to cistern fill time or cistern volume if a flow regulator is incorporated.

Flush per use versus timed flush

The graph below shows that despite their use in high use areas such as motorway service stations, flush per use urinals theoretically use more water than correctly set up timed flush urinals unless usage is low. However timed flush urinals can easily be set to much higher rates than specified in the Water Regulations. The graph is based on 30 male office workers per urinal. The inevitable variables in reality mean that is would be unwise to base a requirement for either type of urinal on such calculations alone.

[30] Mitchell's Environment and Services, 8th edition. Longman 1997.

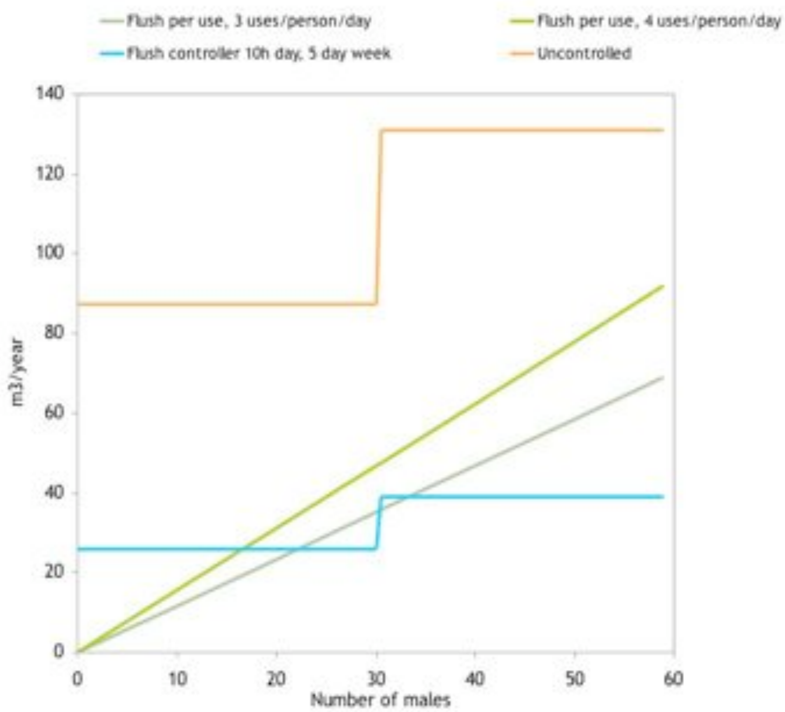

Figure 8. comparison of flush per use and timed flush from 'Conserving water in Buildings, EA 2007.

Waterless urinals

As waterless urinals are not connected to a water supply they do not come under the regulations. Currently there is nothing in the Water Regulations that acts as a barrier to the installation of waterless urinals.

Urinal backstop water use limits

It is unlikely that the specified volumes whether per flush or per urinal per hour can be reduced without changing the urinal trap design based on waterless practice, indeed it seems unlikely that current volumes are sufficient to clear traps. European urinals typically use around 2 litres and at a rate that actually flushes the trap like a WC.

A more important goal would be to clarify requirements for cistern volumes and flush frequency. Either the regulations need to reflect the very varied technology or vice versa.

Since an un-controlled urinal system will lead to undue consumption it seems reasonable that the Regulations should apply to historic installations. This would also get round the question of at what point an installation counts as new given that individual components might be replaced over a period of time.

Interpretation of where enforcement should be applied varies between water companies. Some consider constantly running urinals as outside the scope of enforcement, interpreting them as existing fittings. Others apply enforcement to all installations. There is a need to clarify this in the review.

Recommendation:
Clarify and simplify the requirements for flush volume and frequency for automatically flushed urinals, i.e. 4.5 litre flush per urinal with a maximum of two flushes per hour and only when the building is occupied. Recommend that waterless urinals are considered. Recommend that requirements apply to existing as well as new installations.

7. Baths, hot tubs and spas

General issues

The Water Supply (Water Fittings) Regulations 1999 impose a legal requirement to notify the local water supplier of the proposed installation of a bath with a capacity in excess of 230 litres (measured to centre line of overflow) although it seems unlikely that this has ever happened.

Unlike WCs, baths do not simply perform a ‘hydraulic’ function that requires a certain volume of water, large baths can be an aspiration. As long as spas and hot tubs are permitted renaming a bath as a spa can circumvent any limit on bath volume.

There are serious issues with the CSH water calculation method, particularly with respect to baths. However if the Code becomes an enforced requirement, either directly or via Part G of the Building Regulations, then the impact on bath size is very significant. In order to fit a 230 litre bath the following measures are required to meet the minimum requirements for Code level 1 or the proposed Part G of the Building regulations. This is at the limit of acceptability (taps and shower) and available technology (WC):

Item	Kitchen tap	Basin tap	Shower	Bath	WC		Wash m/c	Dish wash	Bidet	Water softner
					Full	Short			1/0	1/0
vol/flow	6.0	3.0	6	230	4.0	2.0	49	13	0	0
=	**21.2**	**10.6**	**18.0**	**36.8**		**12.8**	**16.7**	**3.9**	**0.0**	**0.0**
Rain	**0.0**	0%	60m2	0.6m/y						
Total PCC	**119.9**									
Credits	**1**									
Code	**2**									

Confusion about volume specification

The Code defines the bath volume as to the overflow and then assumes a water use of 40% of this per use to allow for displacement. Some European manufactures (e.g. German) quote a volume after subtracting 70 litres for a person. From conversations it seems that many specifiers, Code assessors and sales staff are unaware of this anomaly.

A standard approach seems unlikely but a minimum action would be to clarify that this double standard exists.

Figure 9. This 97 litre bath sounds very economical but it would be 167 litres filled to the overflow.

Bath backstop water use limits

It is difficult to imagine a reduction in the notification volume having any effect on installed bath sizes.

Reductions in volume by limiting bath length and width could be problematic for larger people. Reductions in depth could be achieved by lowering the overflow as is happening for the CSH. As with the CSH, any legal requirement for low bath volumes will be countered by measures such as variable overflows as people are likely to want baths that they can fully submerge themselves in.

Figure 10. Low cost device to increase bath water depth.

Recommendation:
The definition of bath volume needs clarifying at point of sale. For example the volume to overflow should be quoted as volume to overflow (assuming the UK does not Harmonise with Germany) and this could be followed by 'typical water consumption per use assuming a 40% fill is xxx litres.'

8. Hot water dead-legs

Dead-legs were not part of the brief but will be considered as a recommendation is given in the Water Regulations Guide and because they can lead to a very significant waste of water.

Figure 11. Energy and water wastage due to dead legs is a daily experience.

Cooled water in a pipe is run to waste when hot water is required. This is also a waste of energy as the hot water left in the pipe (and the pipe material) then cools.
Optimising the pipe size and length and adding insulation all help reduce this problem but there is no known research on the current water and energy wastage due to dead-legs in the UK. The German Passivhaus Planning Package (PHP 2007) calculates the energy loss due to dead legs based on the total volume of hot water dead legs and an assumption of 3 uses per person, per day. This energy is lost to the building even if the water is not run to waste.

The Water Regulations Guide provides the following table of 'recommended' maximum lengths for un-insulated hot water pipes but there is no recommendation relating to insulated pipes:

Outside diameter mm	maximum length metres
12	20
over 12 up to 22	12
over 22 up to 28	8
over 28	3

Whilst 12m is not unreasonable for 15mm pipe, a 22mm copper pipe 12m long will contain about 3.7 litres of water. If this water is at 60°C and is allowed to cool to say 24°C then the energy lost is 1.16 x (60-24) x 3.7 litres/1000 = 0.16 kWh. To put this in perspective in the context of 2016 energy standards, following the PHPP[31] assumptions this loss equates to 5kWh/(m^2.year)[32] which compares with a useful hot water consumption at the tap of 15kWh/m^2.

	10mm plastic	15mm plastic	15mm copper	22mm plastic	22mm copper
Litres/10 m pipe run	0.6 litres	1.1	1.5	2.4	3.1
Max length for 1.5 litre dead leg[33]	25m	13m	10m	6m	5m
Length for 30 second wait with 1.7 l/min spray fitting	14m	8m	6m	3.5m	3m

Figure 12. Dead leg volumes[33]. The suggestion of a 1.5 litre dead leg limit is from the EST Advanced Standard.

Backstop pipe lengths/volumes

The Energy Saving Trust Best Practice Specification recommends a maximum dead leg volume of 1.5 litres or 10m of 15mm copper pipe. The table above shows that whilst this represents good practice, the dead leg volume is still too large for a spray tap to be fitted on such a pipe run because of the unacceptable wait.

Pumped secondary recirculation solves the dead leg water wastage issue but introduces a potentially high energy loss.

Further work is needed before making firm recommendations relating to dead leg volumes but 1.5 litres has proved workable and encourages good layout. Interestingly a very similar figure has been suggested in the USA[34] along with a limit of 0.5 litres from the dead leg between a pumped secondary loop and a fitting.

It would be reasonable to require all hot and cold water pipes to be insulated regardless of length unless the diameter is less than say 15mm.

The main concern with setting too difficult a target would be that secondary circulation would need to be specified for non-compact plumbing layouts and this would incur energy costs.

Larger dwellings and hotels will require secondary circulation but regulation of this in terms of control and insulation is an energy issue which should be addressed under Part L of the Building Regulations and the CSH[35].

Recommendation:
As an interim measure I suggest replacing the current recommendations with a recommended dead leg volume limit of 1.5 litres and a requirement for pipes of 15mm or greater to be fully insulated. Where pumped loops are installed the dead leg between the loop and a terminal fitting should be 0.5 litres or less.

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[31] PHPP is used in preference to SAP for this comparison. PHPP actually assumes the water cools to 20C and includes a calculation for the pipe material heating and cooling which all leads to an even bigger heat loss.
[32] 35m^2/person.
[33] Conserving water in buildings; a practical guide. Environment Agency November 2007.
[34] Water-Efficient Single-Family New Home Specification, www.epa.gov/watersense/docs/home_suppstat508.pdf
[35] Dead legs and recirculation losses are calculated in PHPP.

9. Water softeners

Water softeners use water as part of the regeneration cycle of the ion exchange resin and this can lead to significant water consumption. Regulation 5 of water Fittings Regulations requires notification if a water softener is to be installed. The Water Regulations require that any fitting shall not waste or misuse water. The Regulator's specification for water softeners states that water softeners must use no more water than 18 times the volume of the ion exchange resin. Softeners manufactured to comply with BS EN 14743:2005 will satisfy consumption requirements. BS EN 14743 covers the performance of water softeners and includes the following requirements for water efficiency:

> **4.4.3 Regeneration water**
> The volume of water necessary for a complete regeneration shall not be more than 0,33 l per gram of $CaCO_3$ fixed between two regenerations (measured in accordance with 7.5.6).

It is not however clear is this is sufficient to force the need for demand initiated regeneration where water is metered and the backwash is only used after a set volume of water (for a given hardness) has been treated.

The CSH does not count water used by softeners provided:
'volume of water consumed per regeneration cycle does not exceed 4% of the total capacity of the water softener. The volume of water consumed per regeneration cycle must be specific to the region of the UK in which the development is located'[36]

If the water use is higher than 4% then the additional water must be calculated and added to the CSH water calculator:

$$\text{Additional consumption} = \left[1 - \frac{4}{S}\right] \times \frac{(RL)}{RD}$$

Where:
S = % of total capacity used per regeneration.
RL = litres of water consumed per regeneration
RD = average number of regeneration cycles per day.

This is very confusing and difficult to regulate and does not appear to encourage potential savings that could be made at installation.

From a sustainable design perspective it is clear that:

1. water softeners should be discouraged where they are not actually required.
2. where they are required the efficiency of the manufactured equipment should be maximised and this is probably best done by a mixture of Standards, regulations and perhaps labelling so that inefficient products are not available to install.
3. for a given installation further savings or conversely wastage can result due to installation and commissioning. For example the choice of which fittings are to receive softened water and whether the soft water is to be blended with untreated water to reduce the volume required.

[36] CSH technical Guide April 2008.

Water softener backstop water use limits

Water softeners were not part of the original brief and it is clear that some research would be required in order to come up with a sensible proposal relating to water efficiency in the context of the Water Regulations. However it is likely that the Regulations could influence both equipment design and correct installation and commissioning but more work is required.

Recommendation:
I recommend a requirement for demand initiated regeneration and a limit of water per regeneration cycle combined with an installation and commissioning requirement to limit what water is softened and to what degree.

10. Other areas, cooling and low cost domestic fire sprinklers

The possibility of mains water being used for building cooling has apparently been raised as a concern but no specific details could be found. Evaporative cooling is cheap and requires less energy than conventional refrigeration but only works well at low relative humidity. The use of the sensible heat capacity of cold mains water would be much less effective and so water consumption is likely to be unacceptable.

When researching this, another concern, low cost domestic fire sprinklers was raised[37]. The concern with the latter is that the proposed system is to utilise the coldwater distribution circuit and the need for larger pipes could result in warmed water being run to waste from the kitchen tap.

Recommendation:
Both these examples highlight the general case of the need to clearly define acceptable use so that any other proposed uses for water would require notification of the Water Supplier and justification of the proposed application.

Recommendations for further research

Dead legs and water softeners stand out as areas for more research. In particular it would be good to obtain data on actual water waste due to these.

[37] 8 part report to download at: http://www.communities.gov.uk/publications/fire/developmentlowercostsprinkler