Focus - water closets

best practice since the Water Fittings Regulations 1999.

"There is no problem, no matter how complex, which if looked at in the right way cannot be made even more complex."

Prof Bob Lowe, Leeds Metropolitan University.

Of the appliances that use water, the WC uses the most; about 30–40% of domestic water use and up to 90% for offices and public conveniences. Therefore, optimising the water used by a toilet can make the greatest savings, but what is current best practice for the environment-conscious designer or builder?

A brief recent history

UK WC cistern volumes were reduced from a generous 13 litres in the 1960's to 11 then to 9.5 litres with the option of dual flush. Pull and release gave a 'half' whilst pull and hold gave a full flush. This remained law until 1993 when 7.5 litres was introduced as the maximum flush volume and dual flush was banned because of concerns about double-flushing as the correct operation was not obvious.

From 1st January 2001 the Water Regulations (1999), which replaced the previous Water Byelaws, now specify a maximum flush of 6 litres. Actual flush volumes will usually be higher than this, as the measurement is done with the water supply turned off, whereas in reality water enters the cistern whilst it is still flushing. Dual flush is now allowed, provided a number of criteria are met. The performance tests[1] for WCs have now been made more exacting and, despite the reduction in flush volume, WCs that actually pass these tests should perform significantly better than many older models.

Valves and siphons

Perhaps the most controversial change in the UK has been the acceptance of valve flushing mechanisms, bringing the UK into line with the rest of Europe. The old UK Water Byelaws required WCs to be fitted with a valve-less cistern, i.e. a siphon. This effectively leak-free invention was introduced as a 'water-waste-preventer', since the earliest valve-flush cisterns would either leak or, in days before water metering[2], be jammed open to keep the WC 'fresh'.

Whilst the recent acceptance of valves was intended to eliminate a trade barrier, each European country still retains its own regulations and test methods, so approval by one country does not imply approval by another. The widespread confusion as to what is now allowed means that the floodgates (sic) are effectively open for the best and worst toilets from around the world.

So why valves? In the early days valves were the only option. Whilst simple 'flappers' are still widely used in the US, most other valve-WCs use the much more complex and expensive drop-valve. The main, and perhaps only real, advantage of such a valve is that they allow the use of a button rather than a lever. This enables the possibility of separate buttons for full and 'half' flush, thus solving one of the biggest problems with dual flush – user understanding. Advocates claim that valves give a more powerful flush but the best siphons seem to perform at least as well, if not better than, valves. Whilst valves can flush faster, this can leave solids, particularly paper, in the pan, especially on a 'half' flush. The same reasoning explains why siphons have been found to provide superior 'drain carry'[3], think of the trick where the tablecloth is whipped away and plates are left.

Certainly a siphon is more restrictive to flow than a valve and thus requires a higher cistern to achieve an equivalent flow rate. We have previously speculated[4] that the poor performance of many older close-coupled UK WCs is due to the imitation of a European close-coupled style with a UK siphon, an example of function failing to follow form.

Valves

The authors' initial enthusiasm for valves[5] has been tempered by our experience over the last seven years. We had initially discounted anti-valve arguments as protectionist propaganda for conservative UK manufacturers[6]. Whilst we acknowledged that valves would eventually leak, they are

Trial	WC Type	n WCs	Average Vol/flush (range)	Notes
Holmewood Bradford	4/2 dual	4	4.6 (3.1–6.1)	sticking mechanisms not identified during trial.
Holmewood Bradford	6/3 dual	6	4.6 (3.7–5.4)	sticking mechanisms not identified during trial.
Single House Hereford	4/2 dual	1	3.83	5 years trial to date, valve jammed twice fixed quickly.
Portsmouth Water Office	6/3 dual	2	6.1	Women's WCs.
Millenium Dome dual flush initial	6/3 dual	177	8.6 male 6.5 female	problems identified by analysis of logger data.
Millenium Dome dual flush after retrofit	6/3 dual	177	5.4 male 5.1 female	
Millenium Dome siphon flush initial	6 single	160	6.2 male 5.2 female	
Millenium Dome siphon flush after retrofit	6 single	160	5.5 male 5.5 female	water levels adjusted.

Table 1. UK WC trial results

tested for 200,000 flushes, which equates to nearly 30 years use for a typical WC.

So what changed? Well as some bright spark pointed out; 'in theory, theory and practice are the same, but in practice they are not.' What the accelerated laboratory testing of flush mechanisms does not address is the ravages of time and the human element. Another issue with testing is that we have to hope that the sample tested is representative of all the valves produced. The same argument applies to siphons, but the difference is in the failure mode. A worn or jammed valve will probably leak, whilst a worn or jammed siphon will simply fail to flush so well, hopefully prompting repair.

The UK experience has been too short for valves to fail with perished or fatigued seals, in the way that lab testing predicts. The only normal wear and tear we have seen has been overseas where leaky loos have been widely noted in homes, offices and hotels. Instead most of the problems we have seen in the UK have been due to valve mechanisms, rather than to seals. Unlike the humble siphon, which is hydraulically sophisticated but mechanically simple, the drop valve is hydraulically simple (a plug in a hole) but often mechanically complex. The sorts of problems that have been reported with a wide range of manufactures' valves include leakage caused by:

- Swarf or scale on the valve seat (obvious, but not common);
- Poor seating of valve due to incorrect installation;
- Poor seating of valve due to distortion of plastic cisterns during installation;
- Jamming of valve mechanism due to lime scale deposits;
- Partial opening of the valve due to incorrect adjustment or assembly of button mechanisms;
- Cracked plastic components (valves tend to use more rigid and brittle plastics than siphons because of the precision required);
- Accidental damage caused by curious plumbers and DIY enthusiasts.

Valve leakage may not be a problem in Germany or Switzerland, but in the UK we have a 'fit and forget' mentality and anyone with a wrench can call themselves a plumber (just as anyone with a business card can call themselves a water efficiency consultant!). Properly installed and maintained, valves will work well, but the householder or maintenance staff must carry out regular tests if leaks are to be spotted.

It is estimated that in the US about 20% of WCs leak at a rate of about 20,000 US gallons per year per WC (76m^3/year)[7] . A standard allowance for WC leakage in US textbooks is 15-30 litres per person per day[8] i.e. the water use of a 6 litre WC could be doubled due to leakage. If we assume 4 people sharing a single WC this equates to about 60-120 litres per WC per day. 60 litres per day is a lot of water but only equals 2.5 litres per hour, which is below the starting flow of domestic water meters. When this 0.04 litres/minute leak is simulated the resulting flow down the pan is not noticeable to the untrained eye

Dual flush

The problem of knowing how to operate a dual flush cistern is effectively solved by the introduction of a button-operated valve flush. Putting aside the previous concerns about valves, dual flush seems to make sense, as only one out of five visits to the WC warrants a full flush. Simple maths and sales literature suggests that a dual flush WC with 4 litre full and 2 litre 'half' (4/2) should average around 2.4 litres per flush, based on 4 half to 1 full flush. On the same basis 6/3 litre dual-flush WCs should average 3.6 litres per flush, whilst the more common 6/4 litre dual flush should average 4.4 litres per flush. However the UK trials to date suggest that savings are much less than predicted, see Table 1. Our own trial[8] of 4/2 and 6/3 litre dual flush WCs averaged 4.6 litres per flush.

A number of reasons have been identified for this discrepancy between theory and practice, whilst others will have to remain as speculation until m ore research is carried out, but the bottom line is that real-world performance is not guaranteed.

Inlet valves and overflows

Even 'valve-less' siphon cisterns contain an inlet valve and this will leak eventually. The old Water Byelaws required a visible external overflow, which provided effective warning of this. Internal overflows (down the pan) are now allowed. With flush valves, letting the overflow run into the pan makes some sense, as the user can learn to look in a single location for leaks. As overflows are usually regarded as a hassle, the regulations for siphons were changed to allow them to be used with an internal overflow in the same way as valves. This is simpler for installers and the reduced 'spill-over level' means that very little effort by the user is needed to start these new siphons. However slow inlet valve leaks will almost certainly go unnoticed, unless an optional external overflow or other warning device is fitted.

So, how low can you go?

It is generally accepted that with good pan design, full flush volumes down to 4 litres do not present a problem in terms of 'normal' drains and sewers being able to dispose of the solid and liquid wastes[10]. This can be achieved with a leak-free siphon, which begs the question: why risk dual flush and its associated valve?

Although none are currently approved in the UK, Scandinavian WCs are available with 4 and 2 litre dual flush. This should theoretically beat a 4-litre single flush WC, but as we have seen this is not guaranteed and for public toilets and commercial buildings we would recommend single flush rather than such a low volume dual flush.

Declaring our interest

As water efficiency consultants we occasionally develop or source technologies and products that are not otherwise available. This is how we got involved in the import of Swedish WCs. This led to the development of the Ifö Cera ES4, a 4 litre siphon-flush suite, initially as a stopgap to meet the old Water Byelaws. As our concerns about the effective operation of valves and dual flush WCs have increased, we have continued to refine the ES4 to turn our research into best practice.

The future

If the siphon does go out of fashion, then we can look forward to significant water wastage in the future from leaking toilets. Other leak-free systems have been developed, but none are currently available in the UK. A leak-free, dual-flush that is obvious in operation might offer some savings for domestic applications if it can be made to work at say 4 and 2.5 litres. Technical solutions to problems such as button-operated siphons or leak-detecting valves are possible, but seem unlikely to happen unless driven by regulations.

Until there is an independent water-use labelling scheme, don't assume that any toilet will do 'what it says on the tin'.

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Refs:

1 Water Supply (water fittings) Regulations 1999: WC Suite Performance Specifications. http://www.defra.gov.uk/environment/wsregs99/waterfit/wcspec/index.htm

2 Even today only about 15% of domestic properties in the UK have a water meter (Water Facts 2000, 98/99 data).

3 BRE. Personal communication; J Griggs

4 Sewage Solutions, Grant, Moodie and Weedon.

5 See Sewage Solutions first edition, Grant, Moodie and Weedon, CAT 1996 and 'Water and Sustainable Housing' Eco-Design, Vol V No. 2.

6 eg See Hansard 23 July 1997, Column 921, Mr. Michael Fabricant (Lichfield) Sanitaryware (Flushing Standards).

7 The Water Conservation Manager's Guide to Residential Retrofit, AWWA (American Water Works Association), Denver Colorado, 1993.

8 Metcalf and Eddy Inc. Tchobanoglous G. 1991 Wastewater Engineering: Treatment Disposal Reuse. McGraw-Hill.

9 Low Volume Dual Flush Toilet Trial, Holmewood, Bradford. Bradford M.D Council, Yorkshire Water, Elemental Solutions and North British Housing Association 1997/1998.

10 Lillywhite, MST, Webster, CJD and Griggs, JC. 1987. Low-water-use washdown WCs. BRE. Also the Holmewood Estate trial Bradford.