DoE PROJECT 10B
WATER ECONOMY

Report 11727/4

October 1995

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Department of the Environment

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No of pages:  i - iv of preamble
             37 of text

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SUMMARY

The research described in this report was undertaken for DWI in advance of changes to the Water Byelaws and compares the performance of a range of WCs sourced from Europe, Australia and the US with UK products. The main objective was to establish whether or not there is any significant case for the UK to maintain its current requirements for WCs to be fitted with valveless siphonic flushing as per Byelaw 74(a).

The flushing performance of the fifteen non-UK ie non-syphonic flushing products, assessed over a variety of tests based on current UK and other national standards, was found to be as good or better that the three 7.5 litre UK products used as the benchmark. The cheaper products generally performed as well as the more expensive ones.

Endurance testing of eight flush valve products under laboratory conditions suggested that while they would all eventually leak (after 100,000 cycles or more equivalent to 10 yrs typical domestic use) the leakage rates would initially be small ie equivalent to less than one flush per week. The key determinant of water wastage would be whether the user initiated remedial maintenance within a reasonable period of time after first detecting the leakage. The same consideration would apply to leaking inlet valves, whether on siphon or valve cisterns. This test did not however simulate ageing of the flush valve seals which may be a factor in their long term performance. In most cases, seals can easily be replaced by the user without the use of tools.

Four of the tested drop valves were subject to sticking which caused serious short term leakage but in actual installations this would have been very evident to the users who would have initiated rapid remedial action, particularly if water metered. In two cases the problem was permanently corrected by minor adjustments, emphasising the importance of correct installation. In the other two cases the valve mechanism was replaced.

Overall, there is no evidence from this research that allowing the use of non-siphonic products, tested to proposed European standards and correctly installed, in the UK would have a significant adverse effect on water conservation. The small amount of leakage that ultimately occurs would almost certainly be compensated by the better performance of valved cisterns at low flush volumes.

It is, however, recommended that prior to the establishment of suitable standards acceptable to the UK, non-siphonic cisterns be permitted only where there is water metering to ensure there is a financial incentive to quickly deal with any serious leakage that may occur.
ACKNOWLEDGEMENTS

BSRIA wishes to thank all those manufacturers who supplied products for testing and the British Bathroom Council and WRc for their helpful comments and contributions to this research.
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1. INTRODUCTION

The research described in this report was carried out by BSRIA on behalf of the Drinking Water Inspectorate to investigate the water economy of different WC flushing systems in advance of any changes to the technical requirements for WCs contained in the current Water Bylaws. The specific objective of the research was:

- to establish whether or not in the light of European and international technical developments there is any significant case for the UK to maintain its current requirements relating to the water efficiency of WCs.

The overall project included a world situation review to establish the currently available products, an import/export study to assess the implications of possible regulatory changes to UK industry and a practical laboratory evaluation of available products. The first two items are considered in separate BSRIA reports. This report is concerned only with the laboratory evaluation.

The method of approach to be adopted for the laboratory evaluation was detailed in the tender specification [1] and developed during subsequent discussions with DWI. It consisted of obtaining a representative selection of water efficient WCs from around the world and testing them against current UK products. The basic steps to be undertaken were:

- select and agree products to be tested;
- obtain representative products for testing;
- performance test those products;
- endurance test a selection of those products.

Product selection is discussed in Chapter 2, the test methodology in Chapter 3 and the results obtained in Chapter 4.
2. PRODUCT SELECTION AND SOURCING

The selection of products was based on guidance contained in the tender specification, the BSRIA report on WC types and flushing mechanisms currently being installed world-wide [2] and discussions with DWI. The final selections indicated in Table 1 include all the common types of flushing WC currently being installed in Europe and the USA. One Australian WC was included as an innovative product with particular water conservation features though it was not fully in production at the time of the test. The three UK 7 litre siphons were included as a benchmark. Individual descriptions of the products are given in Section 3.1.

In all cases, the WC cisterns and flushing mechanisms were obtained directly from the cistern manufacturers who also supplied compatible pans. The products tested were therefore completely representative of standard WC installations and all tests were carried out using the cistern and WC pan connected.
<table>
<thead>
<tr>
<th>VALVE TYPES</th>
<th>SUITE TYPES</th>
<th>Australia</th>
<th>USA</th>
<th>Europe</th>
<th>United Kingdom</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Cheap</td>
<td>Expensive</td>
<td>Suitable for: Pressure assisted</td>
<td>Conventional</td>
<td>UK export</td>
</tr>
<tr>
<td>AUS</td>
<td>Linked</td>
<td></td>
<td>(4)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dual</td>
<td></td>
<td>(11)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>USA</td>
<td>Pressure assisted</td>
<td></td>
<td>(18)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pressure flush valve</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Flap</td>
<td></td>
<td>(3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Europe</td>
<td>Pressure flush valve</td>
<td></td>
<td>(17)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drop pull</td>
<td></td>
<td>(12)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drop push</td>
<td></td>
<td>(5)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drop interruptable</td>
<td></td>
<td>(15)</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drop dual</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Drop cheap</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UK</td>
<td>Siphon 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Siphon 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Toals: 15 suite types, 13 flushing mechanisms, 18 flushing performance tests.*
*The figures in brackets refer to the reference number of the WC tested for each type (see Table 2).*
3. TEST METHODS

3.1 GENERAL CHARACTERISTICS OF PRODUCTS

The general characteristics of the selected products are outlined in Table 2. All of these products were performance tested as described in Section 3.2. Those marked with an asterisk were also endurance tested.

<table>
<thead>
<tr>
<th>Product</th>
<th>Country of origin</th>
<th>WC type</th>
<th>Pan type</th>
<th>Cistern volume L</th>
<th>Actuation</th>
<th>Water depth mm</th>
<th>Seal depth mm</th>
<th>Seal volume L</th>
</tr>
</thead>
<tbody>
<tr>
<td>WC1*</td>
<td>UK</td>
<td>Close coupled</td>
<td>Open rim</td>
<td>7.5</td>
<td>Handle/siphon</td>
<td>130</td>
<td>55</td>
<td>1.68</td>
</tr>
<tr>
<td>WC2*</td>
<td>Sweden</td>
<td>Close coupled</td>
<td>Open rim</td>
<td>6</td>
<td>Push button drop valve</td>
<td>120</td>
<td>50</td>
<td>1.20</td>
</tr>
<tr>
<td>WC3*</td>
<td>USA</td>
<td>Close coupled</td>
<td>Box rim siphonic trap</td>
<td>6</td>
<td>Handle/flap valve</td>
<td>130</td>
<td>60</td>
<td>1.10</td>
</tr>
<tr>
<td>WC4*</td>
<td>USA</td>
<td>Close coupled</td>
<td>Box rim siphonic trap</td>
<td>6</td>
<td>Push button pressure assisted</td>
<td>125</td>
<td>65</td>
<td>3.3</td>
</tr>
<tr>
<td>WC5*</td>
<td>UK export</td>
<td>Close coupled</td>
<td>Open rim</td>
<td>6</td>
<td>Push button drop valve</td>
<td>115</td>
<td>50</td>
<td>1.33</td>
</tr>
<tr>
<td>WC6*</td>
<td>UK</td>
<td>Close coupled</td>
<td>Open rim with plastic insert</td>
<td>7.5</td>
<td>Handle/ siphon</td>
<td>125</td>
<td>50</td>
<td>1.63</td>
</tr>
<tr>
<td>WC7</td>
<td>France</td>
<td>Close coupled</td>
<td>Open rim</td>
<td>6</td>
<td>Pull drop valve</td>
<td>125</td>
<td>55</td>
<td>1.67</td>
</tr>
<tr>
<td>WC8*</td>
<td>France</td>
<td>Close coupled</td>
<td>Open rim</td>
<td>6/3 dual</td>
<td>Push button drop valve</td>
<td>125</td>
<td>55</td>
<td>1.67</td>
</tr>
<tr>
<td>WC9</td>
<td>Swiss</td>
<td>Low level hidden cistern</td>
<td>Open rim</td>
<td>6 adj</td>
<td>Interruptable Push button drop valve</td>
<td>120</td>
<td>75</td>
<td>1.55</td>
</tr>
<tr>
<td>WC10*</td>
<td>Swiss</td>
<td>Low level hidden cistern</td>
<td>Open rim</td>
<td>6 int</td>
<td>Interruptable push button drop valve</td>
<td>130</td>
<td>60</td>
<td>1.48</td>
</tr>
<tr>
<td>WC11</td>
<td>Australia</td>
<td>Close coupled</td>
<td>Open rim</td>
<td>6/3 dual</td>
<td>Push button drop valve</td>
<td>125</td>
<td>55</td>
<td>1.49</td>
</tr>
<tr>
<td>WC12*</td>
<td>Italy</td>
<td>Close coupled</td>
<td>Open rim</td>
<td>6</td>
<td>Pull drop valve</td>
<td>120</td>
<td>50</td>
<td>1.53</td>
</tr>
<tr>
<td>WC13</td>
<td>UK</td>
<td>Close coupled</td>
<td>Box rim</td>
<td>7.5</td>
<td>Lever/ siphon</td>
<td>140</td>
<td>60</td>
<td>1.93</td>
</tr>
<tr>
<td>WC14*</td>
<td>Australia</td>
<td>Low level hidden cistern</td>
<td>Open rim</td>
<td>6/3 dual</td>
<td>Push button drop valve with interlock</td>
<td>124</td>
<td>55</td>
<td>1.22</td>
</tr>
<tr>
<td>WC15</td>
<td>Germany</td>
<td>Low level hidden cistern</td>
<td>Open rim</td>
<td>6</td>
<td>Interruptable push button drop valve</td>
<td>115</td>
<td>50</td>
<td>1.65</td>
</tr>
<tr>
<td>WC16</td>
<td>Slovenia</td>
<td>Low level hidden cistern</td>
<td>Open rim</td>
<td>6</td>
<td>Interruptable push button drop valve</td>
<td>115</td>
<td>50</td>
<td>1.65</td>
</tr>
<tr>
<td>WC17</td>
<td>Germany</td>
<td>Low level hidden cistern</td>
<td>Open rim</td>
<td>6 adj</td>
<td>Push button drop valve</td>
<td>115</td>
<td>50</td>
<td>1.65</td>
</tr>
<tr>
<td>WC18</td>
<td>USA</td>
<td>Flush valve</td>
<td>Box rim siphonic trap</td>
<td>6</td>
<td>Push button pressure flush valve</td>
<td>170</td>
<td>30</td>
<td>3.2</td>
</tr>
</tbody>
</table>
An explanation of the specific features and terminology of WC design is given in [2]. They are summarised here for completeness:-

**WC type**

Low level - the cistern and WC pan are separate and connected by a short length of flush pipe.

Close coupled - the cistern is fitted to the back of the WC pan and there is an internal connection from the cistern to the pan.

**Pan type**

Open rim - the rim of pan is an open channel around which the water flows and drops by gravity into the pan. This is the most common design.

Box rim - the rim of the pan is a semi-closed channel with holes to distribute the water. This provides more controlled distribution of water than the open rim but is costlier to produce.

Plastic insert - this is added to an open rim to provide the advantages of the box rim at lower cost.

Siphonic - in some pans the trap is designed on a siphonic principle to assist in the removal of the bowl contents.

The US siphonic pans have a large water area to reduce surface soiling. The European and Australian pans are of the washdown variety with a relatively small water area but the water flow from the rim is designed to remove any surface soiling.

**Actuation**

Siphon - the cistern contains an inverted bend above the static water level which prevents water flow out of the cistern into the flush pipe. Actuating the handle forces water over the bend creating a self-sustaining siphonic flow which continues until the cistern is emptied.

Drop valve - the flush pipe is connected to the base of the cistern. Water is prevented from discharging into the flush pipe by a cylindrical float and sealing ring, held in place by water pressure. Actuating the pull or push actuator button breaks the seal and allows the float to rise and the water to enter the flush pipe. The sealing ring reseats when the cistern is empty.

Flap valve - this is the ancestor of the drop valve where the flush pipe is sealed by a flap linked by chain to a submerged float which is also linked to the actuator handle. The mode of operation is similar to the drop valve.

Dual and interruptable flush - some flushing mechanisms are designed so that the flush can be immediately stopped by the user releasing the actuator and this is termed interruptible flush. Dual flush is where the mechanism provides two distinct flush volumes: a higher volume eg 6 litres for solids removal and a lower volume eg 3 litres for liquid only removal. The volume is typically selected by sustaining pressure on the actuator for a long flush or, in the latest designs, providing separate two buttons eg WC11.

Pressure assisted flush - WC4 is a unique design where the cistern contains a pressure vessel which is pressurised by the incoming water. When the button is actuated the contents of the
pressure vessel are discharged at high velocity into a specially designed pan with a siphonic trap.

Pressure flush valve - this is a valve which is directly connected to the mains water supply and does not use a cistern. These valves are generally only installed where cisterns would be undesirable since they require high water pressures and large diameter supply pipes to work effectively.

Inlet valves

All three UK siphon cisterns were fitted with long arm plastic float valves on the inlet. The European products were fitted with a variety of ball valves and equilibrium type inlet valves designed to minimise space requirements within cistern. One Australian product (WC14) was fitted with an interlock between the inlet valve and the flush valve such that that the cistern does not refill in the event of leakage through the flush valve seal.

All the tested cisterns (other than pressure assisted) incorporate an air gap between the inlet valve and the maximum level of water and conform to back siphonage standards similar to BS 6280:1982. The pressure assisted flush and pressure flush valves incorporate mechanical back siphonage protection.

Two basic types of inlet valve were found in the cisterns of the WC’s tested. The first was the ball valve, which uses the force induced by the rising water level on a float to shut off the incoming flow. The second was the equilibrium valve which also harnesses the force from the incoming water to shut off the flow.

The basic ball valve was found in all three of the UK siphonic WC’s tested. This type of valve is notoriously noisy and slow to shut off, because the incoming water supply reduces gradually as the water level rises. Complete shut off can take several minutes.

Several of the European WC cisterns used a modified version of the ball valve, which overcomes these problems. The main difference with this version is that the float is contained within a cup with a one way valve in the bottom. The inlet valve only shuts off when the rising water level brims over the rim of the cup to raise the float. This means that the inlet valve is either full on or off. Upon flushing, the inlet valve only opens when the water level falls beneath the cup, such that the cup empties and the float falls.

An equilibrium valve was present in the DAL, Porcher, Caroma and American Standard mechanisms. This also uses a float but relies on the pressure of the incoming water to finally close the valve. It is opened when the force of the weight of the falling float acting on the seal, is greater than the pressure of the incoming water. When the cistern has refilled, the valve shuts off almost instantaneously.

In the UK most WC’s are supplied with the basic ball valve, which is simple and cheap. Cup and float, and equilibrium valves are widely available as replacements, but these are more expensive. In terms of water conservation, it is better to have a valve which does not allow water to enter the cistern during flushing. This is why the UK cisterns delivered high volumes of discharge during use.
Figure 1 Section through typical ball valves

DIAPHRAGM BALLVALVE TO BS 1212 (PART 2)
Figure 2 Schematic showing section through cup and float assembly of modified ball valve
Figure 3 Section through typical equilibrium inlet valve

KEY
5 Cap
7 Float arm
15 Inlet
16 Silencer downpipe
17 Valve chamber
18 Valve body
19 Spindle
20 Rack
21 Pinion
23 Chamber opening
24 Outlet passages
Figure 4  Schematic showing section through typical drop valve

(1) VALVE CLOSED

VALVE HELD CLOSED BY PRESSURE OF WATER

WATER LEVEL
CISTERN FULL

FLOAT
SEAL

(2) VALVE OPEN

VALVE HELD OPEN BY STREAM OF WATER LEAVING CISTERN

WATER LEVEL
CISTERN EMPTYING
Applicable standards

Table 3 indicates the primary standards conformity claimed and listed in the manufacturers literature for the various products tested refer to the second project report [3] for a detailed description of the standards

<table>
<thead>
<tr>
<th>Product</th>
<th>Country of origin</th>
<th>Standards to which it conforms</th>
</tr>
</thead>
<tbody>
<tr>
<td>WC1*</td>
<td>UK</td>
<td>BS 1125, BS 5753</td>
</tr>
<tr>
<td>WC2*</td>
<td>Sweden</td>
<td>No standards applicable in Sweden but conforms to relevant Danish standards</td>
</tr>
<tr>
<td>WC3*</td>
<td>USA</td>
<td>ANSI/ASME A112.19 2M &amp; 6M 1990</td>
</tr>
<tr>
<td>WC4*</td>
<td>USA</td>
<td>ANSI/ASME A112.19 2M &amp; 6M 1990</td>
</tr>
<tr>
<td>WC5*</td>
<td>UK export</td>
<td>Conforms to relevant Danish standards</td>
</tr>
<tr>
<td>WC6*</td>
<td>UK</td>
<td>BS 7357</td>
</tr>
<tr>
<td>WC7</td>
<td>France</td>
<td>NF R076 AO DOC</td>
</tr>
<tr>
<td>WC8*</td>
<td>France</td>
<td>NF R076 AO DOC</td>
</tr>
<tr>
<td>WC9</td>
<td>Swiss</td>
<td>DIN 19542</td>
</tr>
<tr>
<td>WC10*</td>
<td>Swiss</td>
<td>DIN 19542</td>
</tr>
<tr>
<td>WC11</td>
<td>Australia</td>
<td>AS 1218-90, AS 1172.2 1993</td>
</tr>
<tr>
<td>WC12*</td>
<td>Italy</td>
<td>UNI 8949.1 &amp;2 1986</td>
</tr>
<tr>
<td>WC13</td>
<td>UK</td>
<td>BS 1125</td>
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<tr>
<td>WC14*</td>
<td>Australia</td>
<td>AS 1218-90, AS 1172.2 1993</td>
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<td>WC15</td>
<td>Germany</td>
<td>DIN 19542</td>
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<td>WC16</td>
<td>Slovenia</td>
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<tr>
<td>WC17</td>
<td>Germany</td>
<td>DIN 19542</td>
</tr>
<tr>
<td>WC18</td>
<td>USA</td>
<td>ANSI/ASME A112.19 2M &amp; 6M 1990</td>
</tr>
</tbody>
</table>

3.2 PERFORMANCE TESTING

The performance tests are briefly described below. In general the performance tests were based on, but not necessarily identical to, parts of existing UK, European or US standards as indicated below. The emphasis of the testing was to compare the relative performance of the WCs in use rather than establish compliance with any particular standard. The tests were therefore undertaken with the water supply connected (4 bar supply pressure) and the cisterns adjusted to fill to their marked volumes except where indicated in the results.
None of the tests undertaken addressed the issue of the effect of low flush volume or different rates of discharge on the movement of solids within the soil pipe and sewage system. An “after flush” test has been proposed in the draft European Standard prEN997 but it is not clear how the results of such a test should be interpreted for the UK.

A. Toilet paper BS 5503 Part 2:1977 EN 997 94

12 sheets of toilet paper, each loosely, are dropped into WC bowl one after the other within a time of 14 to 18 s. The flush mechanism is operated within 2 seconds of the last sheet being dropped. The trap and bowl are checked for any sign of the paper. The procedure is repeated 5 times and the pass rate is 80%.


A 43 mm ±0.5 mm diameter non-absorbent ball of relative density 1.075 - 1.080 is placed into the bowl and the flush mechanism operated. The pan is then checked. The procedure is repeated 5 times and the pass rate is 80%.

B2. Fifty plastic balls test EN 997 1994

Fifty 20 mm ±0.1 mm diameter non absorbent balls of relative density 0.85 - 0.90 are placed into the bowl and the flush mechanism operated. The pan is then checked and any remaining balls removed. The procedure is repeated 5 times and the pass rate is 85% overall.

C1. Wash of bowl (sawdust test) BS 5503 Part 2: 1977 EN997

The complete inner surface of the WC pan is moistened and immediately afterwards, fine dry sawdust is sprinkled evenly over it. The flush mechanism is then operated and the area of any unwashed surface measured. The procedure is repeated 5 times. The average of any unwashed area must be less than 50 cm² in order to pass.

C2. Wash of bowl (ink test) ASME/ANSI A112.19.6 (1990)

A water-soluble felt tip pen is used to ink a line around the circumference of the inner surface of the WC pan, 25-50 mm below the rim. The flush mechanism is then operated, and the line observed during and after the flush. The number and length of any remaining segments of the line are then recorded. The procedure is repeated 3 times. No individual segment should exceed 13 mm and the total length of segments should not exceed 50 mm in order to pass.

D1. Volume of discharge BS 7358:1990

The flush mechanism is operated in order to prime the WC pan sump to its normal working level. The cistern is refilled and the water supply stop valve closed. A measuring vessel is placed under the outlet of the pan and the flush mechanism operated. The average volume of discharge from 5 tests is recorded.

D2. Volume of discharge (BSRIA)

This version of the test is the same as above except that the water supply stop valve is left open during operation of the flush mechanism. This test gives a more realistic value for the volume of discharge in use.
E. Water change (dye test) ASME/ANSI A112.19.6 (1990)

The volume of the WC pan seal is determined and a measured quantity of concentrated dye solution is then added to the seal water and stirred. A sample is then taken from this solution and the concentration of dye is measured using a colorimeter. The flush mechanism is then operated, with the water supply stop valve closed. Upon completion of flushing, a further sample is taken from the WC pan seal and the concentration of residual dye measured using the colorimeter. A comparison of the concentrations reveals the dilution ratio of the system.

F. Rate of discharge test (BSRIA)

The British standard test simply gives the mean rate of discharge over a fixed time period. The BSRIA test produces a cumulative flow curve which can be used to calculate actual discharge rates during the flush.

A collection bucket is suspended from a digital force indicator and positioned to collect the discharge from a short length of soil pipe (with bend) connected to the WC pan. The soil pipe is fitted with a deflector to minimise the impulsive component of the discharge. The force indicator is connected to the computer which continuously records the collected mass of water at approximately 6 readings per second for the duration of the flush. The test is repeated 5 times.

G. Mixed media waste removal test ASPE/ANSI PROPOSED 1990

This test uses the following wet items:

- 3 artificial sponges, 19 x 19 x 50 mm;
- 3 natural sponges 50 mm nominal diameter;
- 1 latex cylinder 25 x 112 mm;
- 2 non-woven fabrics 140 x 165 mm
  (total wet mass approximately 232 g).

The above items are placed together into the WC bowl and the flush mechanism is operated. The trap and bowl are then checked for any remaining items. This procedure is repeated 5 times and the test is reported as a failure if any items are not removed after the initial flush.

H. Pan Scouring test (BSRIA)

5 small 'dobs' of Synthetic Faecal Material (SFM) are distributed over the dry pan surface, halfway between the water level and the rim, and the flush mechanism operated. The scouring efficiency is defined as a percentage removal with each 'dob' being worth 20%.

I. Actuation Force (BSRIA)

This test gives an indication of the minimum force required to successfully operate the flush mechanism. A digital force indicator is used to measure the force required to push the button or pull the handle. Five readings are taken, and the minimum force recorded.

3.3 ENDURANCE TESTING

The endurance test consisted of installing selected products (cistern and WC) on a purpose built test rig (Figure 1) where they could be supplied with cold water at approximately 7 bar and automatically flushed using pneumatic actuation of the handle or button. The design of the test
rig and level controls was such that any failure to flush would be likely to automatically suspend the test for that WC. The aim was to flush each WC at least 100,000 times and investigate the causes of breakage and/or any leakage of the flushing mechanism which might become apparent during the test.

The water used originated from the mains supply at BSRIA, Crowthorne and was cooled (<20°C), filtered and recirculated to conserve water during the test. The water was however completely replaced on a weekly basis. The expected composition of the incoming water (information provided by Mid Southern Water plc) is shown in Table 4.

Figure 5 Water, waste and control connections

* ACTUATOR DESIGN AND MOUNTING DEPENDS ON FLUSHING HANDLE/BUTTON
It would be expected that the performance of some types of seals used for both inlet and flushing valves would be affected by degradation of the material properties (elasticity, wear resistance etc) due to ageing. However, no attempt was made to artificially age the seals prior to the test as it was considered impossible to guarantee the same degree of ageing for the wide range of materials encountered.

### Table 4 Water composition

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.5</td>
<td>7.2</td>
</tr>
<tr>
<td>Conductivity μS/cm</td>
<td>760</td>
<td>650</td>
</tr>
<tr>
<td>Total dissolved solids @ 180°C mg/litre</td>
<td>470</td>
<td>420</td>
</tr>
<tr>
<td>Total hardness mg/litre CaCO₃</td>
<td>330</td>
<td>295</td>
</tr>
<tr>
<td>Total alkalinity mg/litre CaCO₃</td>
<td>270</td>
<td>235</td>
</tr>
<tr>
<td>Calcium mg/litre</td>
<td>129</td>
<td>112</td>
</tr>
<tr>
<td>Magnesium mg/litre</td>
<td>6.8</td>
<td>4.5</td>
</tr>
<tr>
<td>Sodium mg/litre</td>
<td>30</td>
<td>16</td>
</tr>
<tr>
<td>Potassium mg/litre</td>
<td>5.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Carbonate mg/litre</td>
<td>160</td>
<td>140</td>
</tr>
<tr>
<td>Sulphate mg/litre</td>
<td>65</td>
<td>30</td>
</tr>
<tr>
<td>Chloride mg/litre</td>
<td>55</td>
<td>30</td>
</tr>
</tbody>
</table>

Each week, the automatic flushing was stopped and three tests carried out on each of the WCs:

i  The inlet valves were checked for leaks by visually examining the level of water inside each cistern, and any changes over a period of time. Each float valve was then physically depressed and released to check whether the supply was completely stopped. Any defects or leaks were noted.

ii The cisterns were isolated and the water level in each cistern marked. The flushing mechanism was then checked for leakage by drying and marking the back of each pan with a water soluble pen. Any drips or leaks were noted, and the rate of leakage calculated, by topping-up the water level in each cistern after a measured time period e.g two hours.

iii The water supply was then restored and the mechanism tested by pushing the button, or pulling the handle, several times in order to check the complete operation, of all the components. Any defects with the mechanism or its operation e.g valves sticking, loose handles etc. were noted.

All WCs were examined on a daily basis and the completed number of cycles noted.
4. RESULTS

4.1 PERFORMANCE TESTS

4.1.1 Summary of Results

The results are detailed in Table 5 and summarised below.

Test A - Toilet paper test

All WCs passed this test

Test B1 - Single plastic ball

All WCs passed this test

Test B2 - 50 plastic balls

All of the non-UK products reached the test standard of 85% average removal of the floating balls from the bowl and all except one Swiss product (WC9) achieved over 90% average removal. The best performing of the three UK products achieved 78%.

This test is sensitive to water velocity through the trap and the result is thought to be due to the lower peak flow rates available from the siphon rather than fundamental differences in pan design. In some cases (eg the Australian pans used for WC 11 and WC14) a few balls can be trapped between the bowl and the outlet because of the shape of the trap but this is not considered within the pass/fail criteria of the test. It is likely that in actual use that any trapped floating material would be removed by a subsequent flush but since such material would not be visible to the user they would be unlikely to re-flush as in the case of material left in the bowl.

Test C1 - Wash of bowl - sawdust test

All except the two French products (WC7 and WC3) passed the sawdust test. The failures were due to the swirling pattern of the bowl washing water for French designs. In some cases the final patches of sawdust were removed right at the end of the flush. This test is intended to indicate the effectiveness of water distribution around the bowl but Test H is likely to provide a better indication of removal of soilings.

Test C2 - Wash of bowl - ink test

The two French products that failed the sawdust test also failed the ink test for the same reasons. One of the UK products (WC13) failed because of the pattern of holes in the box rim resulted in small segments of the ink line remaining dry. The same effect could be seen in the sawdust test but the area of sawdust remaining was less than the fail criteria.
<table>
<thead>
<tr>
<th>WC No.</th>
<th>VALVE TYPE</th>
<th>TEST A PAPER</th>
<th>TEST B 1 BALL</th>
<th>TEST B2 50 BALLS</th>
<th>TEST C1 SAWDUST</th>
<th>TEST C2 INK LINE</th>
<th>TEST D1 VOLUME CLOSED</th>
<th>TEST D2 VOLUME OPEN</th>
<th>TEST E1 DYE</th>
<th>TEST E2 AVERAGE FLOW</th>
<th>TEST E2 PEAK FLOW</th>
<th>TEST F1 MIXED MEDIA</th>
<th>TEST DOB</th>
<th>TEST H</th>
<th>TEST I FORCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>WC11 Aus</td>
<td>Dual Drop</td>
<td>pass</td>
<td>pass 91.2%</td>
<td>pass 91.2%</td>
<td>pass 91.2%</td>
<td>pass 91.2%</td>
<td>5.95 (2.79) L</td>
<td>6.74 (2.56) L</td>
<td>&lt;0.5%</td>
<td>3.7%</td>
<td>0.98 1/s</td>
<td>1.73 1/s</td>
<td>5/5</td>
<td>90%</td>
<td>17.8 N</td>
</tr>
<tr>
<td>WC14 Aus</td>
<td>Linked Dual Drop</td>
<td>pass</td>
<td>pass 90.4%</td>
<td>pass 90.4%</td>
<td>pass 90.4%</td>
<td>pass 90.4%</td>
<td>5.96 (3.31) L</td>
<td>6.87 (3.59) L</td>
<td>&lt;0.5%</td>
<td>4.2%</td>
<td>1.02 1/s</td>
<td>1.48 1/s</td>
<td>5/5</td>
<td>62%</td>
<td>15.7 N</td>
</tr>
<tr>
<td>WC3 USA</td>
<td>Flap</td>
<td>pass</td>
<td>pass 97.6%</td>
<td>pass 97.6%</td>
<td>pass 97.6%</td>
<td>pass 97.6%</td>
<td>5.03 L</td>
<td>6.31 L</td>
<td>&lt;0.5%</td>
<td>N/A</td>
<td>0.97 1/s</td>
<td>2.33 1/s</td>
<td>5/5</td>
<td>68%</td>
<td>13.3 N</td>
</tr>
<tr>
<td>WC5 UK</td>
<td>Drop Push</td>
<td>pass</td>
<td>pass 95.2%</td>
<td>pass 95.2%</td>
<td>pass 95.2%</td>
<td>pass 95.2%</td>
<td>4.94 L</td>
<td>5.23 L</td>
<td>&lt;0.5%</td>
<td>N/A</td>
<td>0.87 1/s</td>
<td>2.62 1/s</td>
<td>5/5</td>
<td>60%</td>
<td>11.1 N</td>
</tr>
<tr>
<td>WC12 Italian</td>
<td>Drop Pull</td>
<td>pass</td>
<td>pass 91.6%</td>
<td>pass 91.6%</td>
<td>pass 91.6%</td>
<td>pass 91.6%</td>
<td>5.82 L</td>
<td>6.68 L</td>
<td>&lt;0.5%</td>
<td>N/A</td>
<td>0.99 1/s</td>
<td>2.07 1/s</td>
<td>3/5</td>
<td>58%</td>
<td>9.3 N</td>
</tr>
<tr>
<td>WC15 German</td>
<td>Drop Inter.</td>
<td>pass</td>
<td>pass 97.2%</td>
<td>pass 97.2%</td>
<td>pass 97.2%</td>
<td>pass 97.2%</td>
<td>5.75 L</td>
<td>6.22 L</td>
<td>&lt;0.5%</td>
<td>N/A</td>
<td>0.98 1/s</td>
<td>1.8 1/s</td>
<td>4/5</td>
<td>60%</td>
<td>8.2 N</td>
</tr>
<tr>
<td>WC9 Swiss</td>
<td>Drop Push</td>
<td>pass</td>
<td>pass 85.2%</td>
<td>pass 85.2%</td>
<td>pass 85.2%</td>
<td>pass 85.2%</td>
<td>4.94 L</td>
<td>5.86 L</td>
<td>3.5%</td>
<td>N/A</td>
<td>0.79 1/s</td>
<td>1.42 1/s</td>
<td>0/5</td>
<td>82%</td>
<td>18.4 N</td>
</tr>
<tr>
<td>WC10 Swiss</td>
<td>Drop Inter.</td>
<td>pass</td>
<td>pass 92.8%</td>
<td>pass 92.8%</td>
<td>pass 92.8%</td>
<td>pass 92.8%</td>
<td>5.88 L</td>
<td>6.38 L</td>
<td>&lt;0.5%</td>
<td>N/A</td>
<td>0.93 1/s</td>
<td>1.7 1/s</td>
<td>5/5</td>
<td>78%</td>
<td>21 N</td>
</tr>
<tr>
<td>WC7 France</td>
<td>Drop Pull</td>
<td>pass</td>
<td>pass 91.0%</td>
<td>fail fail</td>
<td>fail fail</td>
<td>fail fail</td>
<td>5.84 L</td>
<td>6.28 L</td>
<td>&lt;0.5%</td>
<td>N/A</td>
<td>0.93 1/s</td>
<td>2.6 1/s</td>
<td>5/5</td>
<td>85%</td>
<td>12.4 N</td>
</tr>
<tr>
<td>WC8 France</td>
<td>Dual Drop</td>
<td>pass</td>
<td>pass 93.6%</td>
<td>fail fail</td>
<td>fail fail</td>
<td>fail fail</td>
<td>5.81 (2.78) L</td>
<td>6.13 (3.21) L</td>
<td>&lt;0.5%</td>
<td>1.9%</td>
<td>0.94 1/s</td>
<td>2.56 1/s</td>
<td>4/5</td>
<td>68%</td>
<td>18.9 N</td>
</tr>
<tr>
<td>WC16 Slovenia</td>
<td>Drop Cheap</td>
<td>pass</td>
<td>pass 96.4%</td>
<td>pass 96.4%</td>
<td>pass 96.4%</td>
<td>pass 96.4%</td>
<td>5.49 L</td>
<td>5.71 L</td>
<td>&lt;0.5%</td>
<td>N/A</td>
<td>0.9 1/s</td>
<td>1.92 1/s</td>
<td>5/5</td>
<td>63%</td>
<td>16.8 N</td>
</tr>
<tr>
<td>WC2 Sweden</td>
<td>Drop Pull</td>
<td>pass</td>
<td>pass 99.6%</td>
<td>pass 99.6%</td>
<td>pass 99.6%</td>
<td>pass 99.6%</td>
<td>5.77 L</td>
<td>5.92 L</td>
<td>&lt;0.5%</td>
<td>N/A</td>
<td>0.93 1/s</td>
<td>1.73 1/s</td>
<td>5/5</td>
<td>82%</td>
<td>10.7 N</td>
</tr>
<tr>
<td>WC4 USA</td>
<td>Pressure Assisted</td>
<td>pass</td>
<td>pass 100.0%</td>
<td>pass 100.0%</td>
<td>pass 100.0%</td>
<td>pass 100.0%</td>
<td>5.26 L</td>
<td>6.07 L</td>
<td>&lt;0.5%</td>
<td>N/A</td>
<td>0.93 1/s</td>
<td>3.23 1/s</td>
<td>5/5</td>
<td>27%</td>
<td>54.8 N</td>
</tr>
<tr>
<td>WC18 USA</td>
<td>Flushing Valve</td>
<td>pass</td>
<td>pass 100.0%</td>
<td>pass N/A</td>
<td>pass N/A</td>
<td>pass N/A</td>
<td>5.42 L</td>
<td>5.42 L</td>
<td>&lt;0.5%</td>
<td>N/A</td>
<td>0.87 1/s</td>
<td>1.95 1/s</td>
<td>5/5</td>
<td>44%</td>
<td>57.2 N</td>
</tr>
<tr>
<td>WC17 German</td>
<td>Flushing Valve</td>
<td>pass</td>
<td>pass 96.80%</td>
<td>pass N/A</td>
<td>pass N/A</td>
<td>pass N/A</td>
<td>5.90 L</td>
<td>5.90 L</td>
<td>&lt;0.5%</td>
<td>N/A</td>
<td>0.91 1/s</td>
<td>1.36 1/s</td>
<td>5/5</td>
<td>43%</td>
<td>49.2 N</td>
</tr>
<tr>
<td>WC 1 UK</td>
<td>Siphon</td>
<td>pass</td>
<td>pass 78.00%</td>
<td>fail fail</td>
<td>fail fail</td>
<td>fail fail</td>
<td>7.1 L</td>
<td>7.99 L</td>
<td>&lt;0.5%</td>
<td>N/A</td>
<td>0.67 1/s</td>
<td>0.97 1/s</td>
<td>5/5</td>
<td>88%</td>
<td>29 N</td>
</tr>
<tr>
<td>WC 6 UK</td>
<td>Siphon</td>
<td>pass</td>
<td>pass 36.80%</td>
<td>pass 36.80%</td>
<td>pass 36.80%</td>
<td>pass 36.80%</td>
<td>6.28 L</td>
<td>7.31 L</td>
<td>&lt;0.5%</td>
<td>N/A</td>
<td>0.76 1/s</td>
<td>1.08 1/s</td>
<td>4/5</td>
<td>72%</td>
<td>69.2 N</td>
</tr>
<tr>
<td>WC 13 UK</td>
<td>Siphon</td>
<td>pass</td>
<td>pass 60.40%</td>
<td>fail fail</td>
<td>fail fail</td>
<td>fail fail</td>
<td>6.87 L</td>
<td>7.83 L</td>
<td>&lt;0.5%</td>
<td>N/A</td>
<td>0.84 1/s</td>
<td>1.35 1/s</td>
<td>5/5</td>
<td>47%</td>
<td>60.3 N</td>
</tr>
</tbody>
</table>
Tests D1 and D2 - Volume of discharge

Test D1 is the volume of discharge with the cistern inlet valve closed, as per British standards, and test D2 is the volume of discharge with the cistern valve open as in normal use. The water levels in the cisterns were adjusted to the marked lines when available rather than the nominal volume. It is evident that the volume of discharge in use is in most cases significantly more than the static volume of discharge, typically around 11% for both siphons and drop valves, but 25% for the US flap valve. In all but one case the static volume of the cistern was less than its nominal volume. The average volume in use for the 6 litre cisterns was 6.2 litres and for the 7.5 litre cisterns it was 7.7 litres.

Tests E1 and E2 - Water change - dye test

All products passed the 5% residual colour criteria (test E1) and all except the Swiss WC achieved better than 0.5% residual colour. All of the dual flush cisterns when operated at reduced flush (test E2) passed the 5% criteria.

Tests F1 and F2 - Rate of discharge

The results in columns F1 and F2 are derived from analysis of the computer monitored discharge pattern of each WC. The F1 result is average rate of discharge (litres/second) measured over 6 seconds (similar to the BS test). The F2 result is the peak rate of discharge (litres/second) during the flush. It is evident that the peak rate of discharge is much higher for valves. Discharge curves are shown in Figures 6 to 13 where the results of 4 tests are superimposed to demonstrate the consistency of the result.

It is evident that the siphon produces a longer flush with lower peak rates of discharge than the other types of flushing. A high peak discharge rate has benefits for the removal of the solids from the WC pan but the research did not consider the effects on sewage transport beyond the outlet.

Test G - Mixed media removal

The results column indicates how many of the 5 trial flushes were successful in removing all the test items. One test item remaining would constitute a failure. Only two of the WCs (WC9 and WC12) failed to achieve at least 4 out of 5 successful flushes. In the case of WC9 this was because of a relatively narrow outlet which tended to block with some of the test items.

Test H - Pan scouring - dob test

This test was devised by BSRIA and used an instant mashed potato mixture coloured with food dye. Whereas the sawdust and ink line tend to be removed by a dribble of water, often at the end of the flush, the mashed potato requires a sustained stream of water for its removal. While the test has not been validated against human faeces the results were found to be reproducible. The results column indicates the proportion of dobs removed by the flush.

UK siphon and European WCs performed similarly, this test being mainly a test of pan design. The US WCs performed less well because the rim circumference was much larger than the UK and European designs and the available water is spread further. However, the larger water surface area of US designs means that the possibility of soiling is much reduced.
Figure 6 Discharge curves for WC1 and WC2

WC 1 U.K.

RATE L/s

WC 2 SWEDEN

RATE L/s
Figure 7 Discharge curves for WC3 and WC4

WC 3 U.S.A.

RATE L/s

WC 4 U.S.A.

RATE L/s
Figure 8 Discharge curves for WC5 and WC6

WC 5 U.K. EXPORT

RATE L/s

WC 6 U.K.

RATE L/s
Figure 9 Discharge curves for WC7 and WC8
Figure 10 Discharge curves for WC9 and WC10

WC 9 SWISS

RATE L/s

WC 10 SWISS

RATE L/s

TIME SECONDS

TIME SECONDS
Figure 11 Discharge curves for WC11 and WC12

WC 11 AUSTRALIA

RATE L/s

WC 12 ITALY

RATE L/s
Figure 12 Discharge curves for WC13 and WC14

**WC 13 U.K.**

![Discharge curve for WC13 U.K.](image)

**WC 14 AUSTRALIA**

![Discharge curve for WC14 Australia](image)
Figure 13 Discharge curves for WC15 and WC16

WC 15 GERMAN

RATE L/s

WC 16 SLOVENIA

RATE L/s
Figure 14 Discharge curves for WC17 and WC18

WC 17 GERMAN

RATE L/s

WC 18 U.S.A.

RATE L/s
Test I - Actuation force

This test measured the minimum sustained force required (at a representative point on the lever or button etc) to successfully initiate the flush. It is evident that drop valve mechanisms require typically 10 to 20 N. Mains flush valves and siphons typically require much higher forces. The siphon actuation forces ranged from 29 N to 69 N. The difference between siphons and the other types of valves is that for the siphon it is necessary to input energy to create the initial siphon effect. If the energy supplied by the user via the handle is insufficient then a partial flush can occur. In the other non-interruptable types the actuator button etc generally trips the valve which remains open until the flush is completed.

4.1.2 Discussion

The visual appearance and key dimensions (water depth, seal depth, trap volume etc) of the European WC pans used in the performance testing were similar to the UK pans and it is doubtful whether the casual user would notice any difference. US designs however tend to have a larger water area to minimise soiling at the expense of a narrower trap.

There is no evidence from the flushing performance tests carried out within this project that the UK siphon offers any performance advantages over the systems used in other countries. The only clear difference in performance was for the 50 ball test where the UK siphons tested did not generate sufficient water velocity to clear 85% of the balls from the pan.

Three of the tests (50 balls, mixed media and dob test) provide some indication of the likelihood of double flushing due to solids remaining in the bowl or surface soiling. The results of these three tests have therefore been combined to give an overall ranking as shown in Figure 3, where 100% would be perfect performance.

WC2 (Sweden) comes top of the overall ranking for flushing performance, though it suffered persistent problems during the endurance tests as discussed in Section 4.2. WC1 (UK siphon) ranks 5th overall but the other two siphons scored relatively poorly because of the 50 ball test.

WC4 (US pressure assisted with siphonic pan) scored poorly on dob removal, which is perhaps an unfair test for this design of bowl. The large rim circumference and large water surface compared to European designs are intended to reduce the incidence of soiling and the dobs were placed in an area unlikely to be affected in use. WC4 was very impressive in the removal of solids from the bowl and would be very unlikely to require double flushing in normal use.

Siphons cannot be properly flushed when the cistern has only partly refilled. While an attempted but unsuccessful flush may result in some water loss this is usually evident to the user by the lack of resistance to turning the flushing handle and characteristic noise, apart from the lack of water. Drop valves will discharge the contents of the cistern irrespective of the state of fill and a partial flush may not be evident to the user other than by its effect on the contents of the pan. There is therefore some danger of repeated unsuccessful attempts to re-flush before the cistern has fully refilled. It was noted however that all the non-UK cisterns were fitted with inlet valve arrangements which provided a much quicker refill than the standard UK long arm float valve.

There was no obvious relationship within the scope of these tests between likely product cost and flushing performance, with the cheaper designs performing better than some of the more expensive. The box rim pan designs did not perform significantly better than the open rim...
versions and the more complicated valve mechanisms did not perform significantly better than the simpler ones.

It is evident from the results of the tests where identical flushing valves were used with different pans that pan design has a significant influence on all the tests undertaken, including the rates of discharge tests. There is a possibility that some combinations of valve and pan, chosen at random, would not perform as well as in their intended application.

No specific back siphonage test was carried out since all the products had been tested to a standard similar to BS 6280 and back siphonage is not directly a water conservation issue. It is arguable that particularly for close coupled WCs siphons provide a better level of protection against supply contamination than flush valves because of the longer air gap between pan and cistern due to the siphon. Inlet valve performance is further discussed in Section 4.2.

WC’s 9 and 10 had adjustable drop valves which could be used to vary the rate of discharge if over splashing became a problem. It was noted that over splashing, with consequent hygiene implications, was not an obvious problem in any of the tests.

The German standard DIN19542 specifies a discharge rate, but this is for water leaving the cistern not for water leaving the trap. The US 100 ball drainline carry test is a more realistic assessment of the drainage issue. However, drainline carry was not felt to be directly related to the issue of water conservation, and was not examined during this work.

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**Figure 15 Overall performance ranking**

![product_graph](image)
4.2 ENDURANCE TESTING

4.2.1 General

Most of the WCs were installed and commissioned without difficulty. Some general points were noted for drop valves:

a) it is necessary to install the cisterns such that the drop valves are properly vertical otherwise the valve can stick;

b) some of the valve mechanisms require the actuator rod to be accurately cut to the correct length for the cistern during installation. If it is cut incorrectly then the valve may fail to operate or the actuator may stick;

c) if the hole in the lid is misaligned with the discharge hole, due to a manufacturing fault or the way the cistern is fixed to the wall, this may also cause sticking of the actuator button.

4.2.2 Detailed results

WC1

At day 91 of the test WC1 had completed 101,458 cycles. It was the slowest of all the WCs due to the long refill period and incidence of failed flushes, but there were no noted problems with the mechanism, or the inlet valve.

A failed flush is recorded when the handle has been turned, but the siphon has failed to empty the cistern. On the test rig this was due to the relatively high rotational speed of the handle required to ensure a full flush. The problem was alleviated by the introduction of a digital time switch, which re-set the actuators every 4 hours. No problems were encountered with manual flushing.

WC2

Initially there were no problems with WC2, but after 15,000 cycles it was noted that the outlet valve was occasionally sticking open, and the inlet valve float was sticking to the side of the cup and not closing when the cistern was full. The outlet valve could be reset by the user jarring the flush button but the inlet valve problem could only be rectified by taking the cistern lid off. These problems were caused by the close proximity of components within the narrow cistern aggravated by a slight misalignment of the lid, and are essentially design faults.

At 32,000 cycles it was noted that the seal of the drop valve had become detached, causing constant leakage, but this was easily re-positioned and the problem rectified.

At 58,000 cycles it was noted that the drop valve was leaking slightly, but the rate of leakage was too slight to be quantified. The leakage and mechanical problems persisted until the complete mechanism excluding the valve seat was replaced at 102,633 cycles.

The new drop valve has continued to leak at 100-200 ml per day. This is probably because the valve seat was not changed at the same time. Changing the valve seat would be unlikely to occur in normal use as it would require disconnection of the cistern from the pan.
The endurance performance of this WC was disappointing since it did very well in the flushing performance tests.

WC3

WC3 was one of the fastest cycling toilets on the rig and by day 15 it had already completed 48,000 cycles. At this stage however, the plastic handle snapped off at the point where it passed through the cistern wall. This did not result in water loss. The failed component was sent to WRc for investigation, and it was found to be a simple fatigue fracture, caused by a combination of poor design and a shrinkage cavity in the plastic. The actuator was then connected directly to the flap valve via a hole in the lid of the cistern for testing of the outlet valve to continue.

At 149,000 cycles, it was noted that the flap valve was leaking slightly, but the rate of leakage was too slow to be measured. This leak continued to increase and was quantified at 500ml per day, at 311,000 cycles. The rate of leakage was still 500ml per day at 360,000 cycles. There was no evidence that the inlet valve was leaking.

WC4

WC4 performed without any problems until day 84, when after 120,614 cycles, a small pin hole was discovered in the body of the pressure vessel. Water leaking through this pin hole, filled the cistern until it overflowed. The pressure vessel was returned to the manufacturer for an investigation of the problem which was suspected to be caused by a material defect.

WC5

From the beginning, there were problems with the drop valve in WC5 sticking open, causing a continuous leak. The problem could usually be rectified by pressing the button several times and seemed to be caused by poor tolerances between the components of the German mechanism and the hole in the lid for the push button.

At 20,730 cycles, the complete drop valve assembly was replaced, and this seems to have rectified the problem. When the new drop valve assembly had completed 50,000 cycles, a slight leak past the seal was noted. This leak was quantified to 400 ml per day after 132,000 cycles.

WC6

There were no problems with WC6 until it had completed about 80,000 cycles, when the incidence of failed flushes increased dramatically. It was found that the plastic lever which connects the shaft of the handle to the siphon mechanism had worked loose on the shaft.

The repeated cycling of the mechanism has caused the square metal shaft to enlarge the square hole in the plastic lever. The resulting play between the handle and mechanism significantly increased the incidence of failed flushes.

A failed flush may lead to the wastage of water, as some water leaves the cistern but has little effect on the contents of the bowl. This wastage of water could be quite considerable if the
incidence of failed flushes was high in real usage. There were no problems with the inlet valve.

**WC8**

WC8 was the fastest cycling toilet on the rig. There was no evidence of any problems until 142,000 cycles had been completed. Then it appeared that the inlet valve was leaking, but a closer investigation revealed that the float was sticking, and the inlet valve was not quite shutting off.

After 170,000 cycles it was noted that the seal of the drop valve had developed a slight leak. This leak persisted and was quantified after 328,000 cycles at 600 ml per day.

**WC10**

Initially there were problems with the float of the inlet valve jamming against the wall of the cistern, which kept the valve closed, but this was soon rectified. The mechanism had completed 90,000 cycles before a slight leak was noted, from the drop valve. This leak was quantified at 300 ml per day after 227,000 cycles. There were no other reported problems with WC10, and the drop valve has never stuck open making this one of the most reliable toilets tested.

**WC12**

Initially, there were problems with the drop valve failing to re-seat after a flush. This lead to continuous leaking until the problem was rectified. The problem was found to be caused by the hole in the lid being misaligned relative to the drop valve. This was solved by the removal of a plastic washer, which then allowed a greater freedom of movement of the drop valve shaft.

At 110,000 cycles a slight leak from the drop valve was noted. This leak was quantified at 300 ml per day after 286,000 cycles. The mechanism eventually completed 369,000 cycles, with no evidence of inlet valve problems.

**WC14**

This WC has successfully completed 241,000 cycles, without any problems at all. It was noted that after 152,000 that the drop valve had developed a slight leak of <100 ml per day. This leak had not increased after 240,000 cycles.

The “no-flo” interlock device inlet valve has been tested on a weekly basis, and was still fully functional at the end of the trial. There have been no mechanical problems with stuck valves, or floats, and there is no evidence of the inlet valve leaking. The results show this to be the most reliable of all the WCs tested.
4.2.3 Discussion

Only one of the WCs (WC2) developed a serious leak specifically due to the outlet valve seal and this could have been easily rectified by the user. All the other drop valve seals except WC14 developed slight leakage after 50,000 cycles but leakage rates remained small; equivalent to less than one flush per week. The cause of this slight leakage is thought to be a combination of scaling of the valve seat, wear and deterioration of the valve seal.

While the seal can easily be changed by the user without the need for tools or specialist knowledge replacing or descaling the valve seat, which may be necessary to completely eliminate leakage may require the services of a plumber. There is the potential problem that since the seals are proprietary items they may be difficult to obtain throughout the life of the installation which may be in excess of 20 years.

Significant short term leakage was caused by instances of the flush valve or inlet valve mechanism sticking open which affected four of the WCs. These problems were considered to be caused mainly by manufacturing tolerances and consequent potential misalignment of components. In two of theses cases (WC10 and WC12) the problems were noticed shortly after installation and rectified by minor adjustments. In the other two cases (WC2 and WC5) the drop valve mechanisms were changed.

Two of the WCs (WC3 and WC4) suffered mechanical failures. In WC3 the handle broke but this did not lead to water loss. In WC4 a hole appeared in the pressure vessel. While this did lead to an immediate loss of water it would have been very obvious to the user who would have had no option but to isolate the WC and arrange for an immediate replacement.

There was no obvious relationship between likely product cost and endurance, with the cheaper designs performing better than some of the more expensive. Product quality control, particularly of ceramics, is however an important issue since the satisfactory operation of some designs of flush valve cisterns is more sensitive to the correct alignment of components than would be the case with siphons.

The Australian dual flush WC with the inlet valve interlock (WC14) performed reliably despite the added complexity of the mechanism.

It has been argued that water monitoring would not help to ensure that householders quickly repair leaks since the flow of water resulting from seal wear would be too small to register on the meter. In fact if the leakage rates are too small to register on the meter then they are probably too small to have a significant impact on water use. The importance of water meters is to encourage the rapid repair of more serious leaks eg stuck valves, which would register on the meter.
5. SUGGESTED REQUIREMENTS FOR NON-SIPHONIC WCs SEEKING APPROVAL FOR UK INSTALLATION

The following requirements are suggested for inclusion in type testing requirements for non-siphonic products which may be installed in the UK. They are based on the tests undertaken during this project. BSRIA commends the following as requirements to ensure an adequate level of flushing performance with long term water economy and would be in addition to existing requirements for back flow prevention and the use of materials.

- Endurance testing to 200,000 cycles, with leakage rates equivalent to less than one flush per day.
- A pan scouring test (‘dob’ test) similar to the BSRIA ‘dob’ test for washdown pans, but not for syphonic trap pans.
- A modified fifty ball test with 85% of the balls clearing the trap, not merely clearing the bowl.
- The mixed media waste removal test, in place of the toilet paper test, (as the mixed media test is more stringent).
- The sawdust test and the ink line test give comparable results, we therefore see no point in changing the requirements and the sawdust test should remain.
- The water change (dye test).
- Instructions for changing the flush valve seal and a spare seal are to be attached to the underside of the cistern lid to encourage prompt replacement of leaking seals.

Test methodologies

Test B2. Fifty plastic balls test EN 997 1994

Fifty 20 mm ±0.1 mm diameter non absorbent balls of relative density 0.85 - 0.90 are placed into the bowl and the flush mechanism operated. The pan and trap are then checked and any remaining balls removed. The procedure is repeated 5 times and the pass rate is 85% overall.

Test C1. Wash of bowl (sawdust test) BS 5503 Part 2: 1977 EN997

The complete inner surface of the WC pan is moistened and immediately afterwards, fine dry sawdust is sprinkled evenly over it. The flush mechanism is then operated and the area of any unwashed surface measured. The procedure is repeated 5 times. The average of any unwashed area must be less than 50 cm² in order to pass.
Test E. Water change (dye test) ASME/ANSI A112.19.6 (1990)

The volume of the WC pan seal is determined and a measured quantity of concentrated dye solution is then added to the seal water and stirred. A sample is then taken from this solution and the concentration of dye is measured using a colorimeter. The flush mechanism is then operated, with the water supply stop valve closed. Upon completion of flushing, a further sample is taken from the WC pan seal and the concentration of residual dye measured using the colorimeter. A comparison of the concentrations reveals the dilution ratio of the system.

Test G. Mixed media waste removal test ASPE/ANSI PROPOSED 1990

This test uses the following wet items:

- 3 artificial sponges, 19 x 19 x 50 mm;
- 3 natural sponges 50 mm nominal diameter;
- 1 latex cylinder 25 x 112 mm;
- 2 non-woven fabrics 140 x 165 mm (total wet mass approximately 232 g).

The above items are placed together into the WC bowl and the flush mechanism is operated. The trap and bowl are then checked for any remaining items. This procedure is repeated 5 times and the test is reported as a failure if any items are not removed after the initial flush.

Test H. Pan Scouring test (BSRIA)

5 small 'dobs' of Synthetic Faecal Material (SFM) are distributed over the dry pan surface, halfway between the water level and the rim, and the flush mechanism operated. The scouring efficiency is defined as a percentage removal with each 'dob' being worth 20%.
6. CONCLUSIONS

In most cases the flushing performance of the 6 litre WCs with non-siphonic flushing arrangements was as good or better than the 7.5 litre WCs with siphonic flushing.

There was no evidence within the scope of the tests undertaken that low cost products were inferior in performance to the more expensive ones. Even the simple flap valve cistern (WC3) provided good flushing performance and endurance though the handle suffered a mechanical failure.

While most of the drop valve cisterns did eventually leak, the leakage rates due to seal wear etc were equivalent to less than one flush per week, even after 200,000 cycles which is considered to be equivalent to 20 years typical domestic use. However, the test did not simulate the polymeric degradation of the seal material which would occur over such a long period.

The onset of leakage from drop valve seals became evident long before the rate of leakage became significant in relation to overall water usage. The significance of leakage will ultimately depend on the likelihood of the user initiating appropriate maintenance. In this respect, flush valves are no different than inlet valves on both siphons and flush valve cisterns.

More serious short term leakage was caused for four of the WCs by sticking outlet valves, though in two cases this was easily rectified by adjustment after installation. The cause of these problems was considered to be mainly manufacturing tolerances leading to potential misalignment of components.

Drop valve performance is considerably more likely to be adversely affected by incorrect installation than siphons.

Siphons do not allow water to leak out of the cistern but in one case wear in the handle linkage may have increased the incidence of failed flushes in use.

Overall, there is no evidence from this research that allowing the use of non-siphonic products, tested to proposed European standards and correctly installed, in the UK would have a significant adverse effect on water conservation. The small amount of leakage that will inevitably occur may well be compensated by the improved flushing performance of the valve cisterns reducing the incidence of double flushing.

However, it is recommended that prior to the establishment of suitable standards acceptable to the UK, non-siphonic cisterns be permitted only where there is water metering to ensure there is a financial incentive to quickly deal with any serious leakage that may occur.
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