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Low volume flush wc design

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ABSTRACT

Water usage by w.c. flushing can represent a major portion of the total water use in a dwelling and may be sufficient to prevent the introduction of such sanitary facilities in developing country applications where water is in short supply. The work reported has concentrated upon the development of a low cost 3-litre flush volume w.c. suitable for use in developing countries and has been funded by the UK Overseas Development Administration (ODA). This paper presents the team's approach to the problem of low water use w.c. design, in terms of the modifiable variables such as trap volume, water seal depth, cistern to bowl water distribution etc. Laboratory trials are reported to support the design decisions taken in respect of trap seal depth and volume. In order to both reduce bowl cost and provide the bowl with a pour flush capability, the bowl is rimless. The solution to the water discharge to the bowl and subsequent surface cleansing problem chosen is a water spreading nozzle connected directly to the cistern discharge and positioned at the rear of the bowl. Development of this "spreader bar" flow device is reported. Site evaluation in Botswana and Lesotho during 1985 and 1986 is also discussed.

INTRODUCTION

In January 1983 a research programme at Brunel University was initiated to design, develop, test and manufacture a low volume pour flush and cistern operated w.c. primarily for use in developing countries. The research is funded by the UK Overseas Development Administration. The design and testing of the model w.c's took place at Brunel University, with close consultation with Twyfords Limited to ensure the practicality and economy of the designs. Twyfords were also responsible for the production of various prototype models based on the design and development work at Brunel.

The Drainage Research Group at Brunel University have for some time been actively involved with water conservation design, both as it affects appliances and also in terms of its effect on long drainage pipelines (refs.1,2). Work was also undertaken on low flush volume w.c. design for the UK industry (ref.3).

LOW FLUSH VOLUME W.C. POTENTIAL AND DEVELOPMENT

As part of the research programme it was intended that site trials of some 200 of the final model w.c. would eventually take place in one or more developing countries. A study tour of Lesotho, Botswana, Zimbabwe and Kenya was undertaken in April 1983 to investigate the feasibility of water conserving w.c. designs. In all of the countries visited, the rural population were in general discounted as not being suitable for the provision of flush toilets. For many rural villages the flush toilet was simply not economic or practical. Cheaper, but nonetheless hygienic, alternative excreta disposal systems such as the ventilated improved pit latrine (ref.4) were to be recommended instead. Generally speaking, the flush toilet was considered suitable for the middle and higher income urban population, a group which represented 10-20% of the population in all the countries visited. This group could afford the costs associated with providing a w.c. and all its fittings, plumbing and running expenses. In this group, in particular, if the flush toilet was affordable it was by far the most popular means of excreta disposal and cheaper systems were not acceptable. A number of important factors emerged from studying this group. Though a minority of the urban population, this group were often responsible for the majority of the urban domestic water consumption. For example, in Gaborone, the capital of Botswana, it had been estimated by the Water Utilities Corporation that domestic water consumption in this group accounted for 80-90% of the total urban consumption. The flush toilet typically accounted for 40-50% of their total domestic consumption.

In Lesotho and Botswana there was strong local interest in the future use of w.c's that require 4.5 litres of water or less for flushing, rather that existing w.c's using 12-15 litres. There was concern that the rapid urbanization of towns like Gaborone and the subsequent increase of water consumption associated with it could lead to a future shortfall in available water supply. In particular, Botswana could benefit from the adoption of w.c. systems that place a low demand on the water supply system, as it is also affected by periodic droughts. By the end of the 1983 study tour, sites for 50 w.c's in Maseru, Lesotho and 100 in Gaborone,

Botswana had been identified as suitable for installation of the Brunel prototype w.c's in 1985/86. It had been intended to carry out site trials of pour flushed prototype w.c's in Malawi or elsewhere, but this subsequently proved impossible due to lack of suitable sites. Having established some initial design criteria based on choosing Lesotho and Botswana as locations suitable for low flush volume toilets, the development of the w.c. pan could commence.

The initial development work at Brunel University concentrated on two main themes: to minimise the volume of water required for flushing (flush volume); to develop an upgradable pour to cistern-flush operated w.c. The initial research was concerned with establishing the effect of the key w.c. design parameters on the efficiency of the w.c. pan, that is its ability to flush out solids, at reduced flush volumes. Based on the results of earlier research carried out at Brunel University (ref.3), it was decided to concentrate on four main w.c. design parameters: trap seal volume; trap seal depth; water surface area; minimum passage size. These parameters are illustrated in Figure 1.

The modelling was carried out on an existing production w.c. manufactured by Twyfords which had been modified for Brunel University. The w.c. was supplied without either the flushing rim or the ceramic back plate used to form the trap seal. Plasticine was used to reprofile the inner surfaces of the w.c. and reduce the trap seal volume. Perspex plates were fitted to vary the trap seal depth. The apparatus used for carrying out tests on the model w.c's is shown in Figure 1. A bucket was used to simulate the pour-flush operation, ie. the action of tipping a bucket to flush the toilet (ref.5).

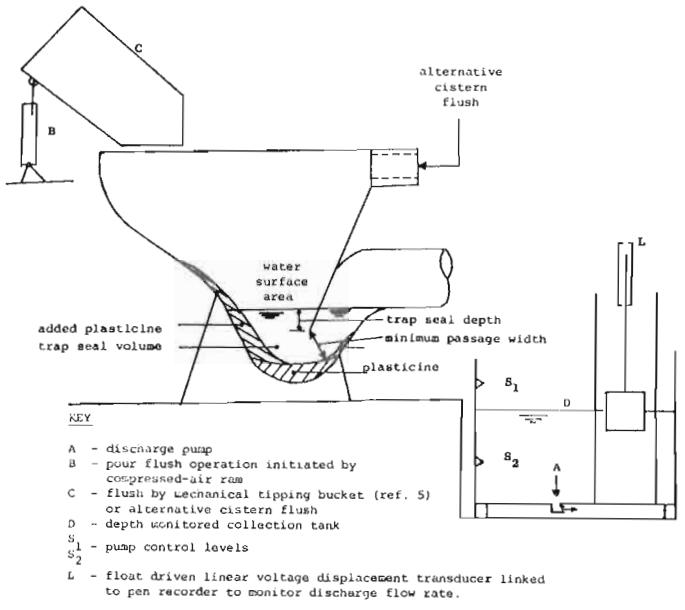


FIGURE 1. Initial trap modifications using plasticine, and schematic diagram of pour flush/cistern flush and discharge monitoring test apparatus.

The tests used to determine the effect of the w.c. parameters on reduced flush operation were: British Standard Ball; Single Density (0.83-1.1 specific gravity) Multiple (50) Ball (20mm diameter); Residual Trap Concentration; Solid Transport (refs.1,2).

It was confirmed (ref.3) that the efficiency of the w.c. pan, at flush volumes tested in the range 1.5-4.0 litres, was affected by the key w.c. design parameters by the following functional relationship:

$$\eta = \phi \left\{ \frac{\text{Flush Volume}}{\text{Water Seal Vol.}} \times \frac{\text{Min. Passage Size}}{\text{Trap-Seal Depth}} \right\}$$

From all the data collected, it was recommended that a minimum flush volume of 3.0 litres could be adopted. From the above equation, it is apparent that to obtain maximum efficiency, factors such as keeping the trap seal volume and the trap seal depth to a minimum, are necessary.

In the early development work, it was decided to omit the flushing rim. The omission of the flushing rim has the potential to significantly reduce the unit cost of the w.c. In addition, if the w.c. is used in its simplest form, as a pour-flush toilet, a flushing rim would not be kept clean by the regular discharging of the cistern. The next problem to solve was how to flush the w.c. when used in its upgraded form. A flushing rim performs two functions. Firstly, the water must thoroughly wash and clean all surfaces in the w.c. The second function of the flushing rim is that it ensures a sufficiently high flow rate to remove all solid and liquid contaminants form the w.c. bowl in a single flush. A device, eventually termed a "spreader bar", was developed as an alternative to the flushing rim, which would perform these two functions. The finalised Mark V design is illustrated in Figure 2. The spreader bar consists of two main parts, the holder and the flow diverter, which were machined from PVC rod. The spreader holder is pushed over the end of the flush pipe and the flow diverter fits into the holder. The

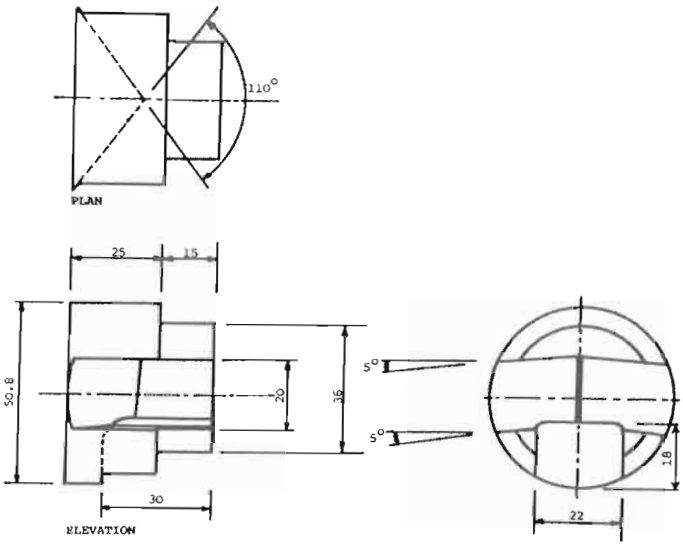
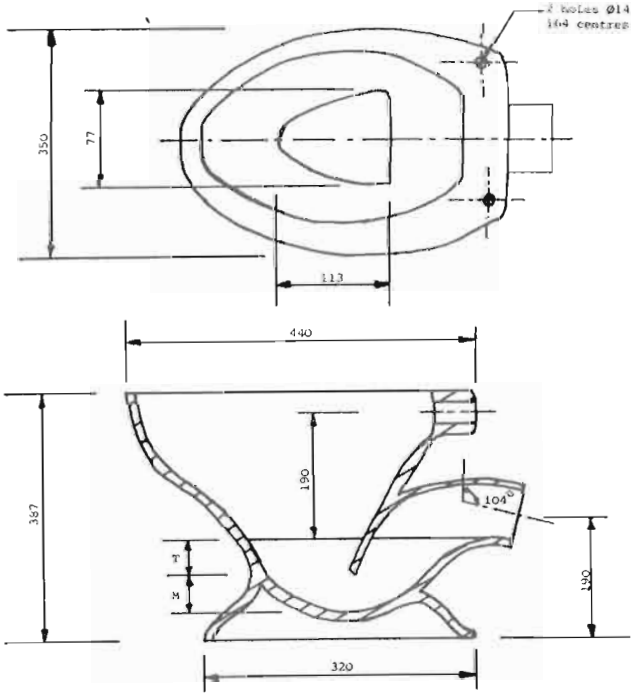


FIGURE 2. Mark V PVC Spreader Bar, all dimensions in mm.

flow diverter has a total of three slots used to guide the jets of water around the sides of the pan. There are two side slots milled at a relative angle of 110° in plan which ensure that the sides of the w.c. are washed thoroughly. The slots are also angled down at 5° to stop the water from splashing over the sides of the bowl. The bottom slot ensures that water is directed towards the back surfaces of the w.c. to ensure cleansing and to enhance momentum transfer of solids from the w.c. bowl.

The final Mark III model w.c. from which 220 were subsequently manufactured is shown in Figure 3. The w.c. has a 104° p-trap, rather than a horizontal outlet as advocated in BS 5503 (ref.6). The 104° p-trap is still adopted by South African w.c. manufacturers and thus was necessary for installation in Lesotho and Botswana. Significant changes, relative to BS 5503, were also made with respect to the hydraulic design parameters as summarised in Figure 3. The w.c. shown in Figure 3 was fully tested with the Mark V spreader bar, Figure 2, and a Geberit - manufactured drop-valve cistern. In figure 4, a comparison between the prototype w.c. and a conventional Twyfords washdown pan, both with the same cistern, is shown for the specific gravity 0.877 Multiple Ball Test. The prototype w.c. with a 3 litre flush volume matched the performance of the Twyfords w.c. pan set at a flush volume of 9.0 litres. The concentration test was also carried out. The 3-litre prototype gave an average residual concentration of less than



KEY W.C. DESIGN PARAMETERS

DETAIL	BS 5503	MARK III
Trap seal volume (litres)	1.8 measured	0.86
Trap seal depth T (mm)	52 minimum	35.5-36.5
Min. passage size M (mm)	75 minimum	63
Water surface (mm)	150 X 100	113 X 7

FIGURE 3. Mark III low flush volume w.c., final prototype design. Not to scale, all dimensions mm.

half that of the 9-litre flushed Twyfords pan. Obviously an efficient w.c. design should remove as much of the trap seal water contamination during the flush as possible, for hygiene reasons.

Having completed the laboratory tests, which confirmed the optimisation of the Mark III design of the w.c. and the Mark V spreader bar design, an installation was carried out on the Brunel University campus. This unit flushes with 3.0 litres from a drop valve cistern and has proved successful in the 24 months to date, requiring only marginally over one flush per visit.

BOTSWANA AND LESOTHO SITE TRIALS

The design and development phase of the research programme was completed in July 1985. By the end of the month, Twyfords had manufactured 220 of the prototypes. A local firm in Uxbridge manufactured 220 of the spreader bars for the prototype w.c's. To minimise transport costs it was decided to use locally available cisterns and fittings. A locally manufactured cistern was modified by drilling a lower water inlet to provide a 3-4.5 litre flush. Marley S.A. have provided, free of charge, a recently developed drop valve and inlet valve, for which due acknowledgement is gratefully recorded. In August 1985 the installation and site monitoring phase of the project commenced.

A total of 103 low flush volume toilets have been installed in Botswana: 63 in a self contained development of detached low income housing built in September 1984 in Gaborone West, where existing 9-12 litre flush toilets and cisterns were replaced in March 1986 with low flush volume w.c's flushing with 4 litres; 26 in a new low income housing development occupied since August 1986 in

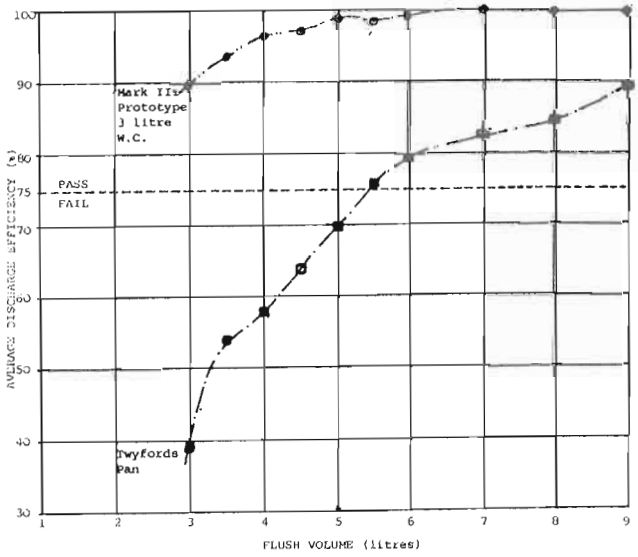


FIGURE 4. Single Density (specific gravity 0.877) Multiple Ball Test comparison between the low flush volume Mark III prototype w.c. with Mark V spreader bar and a Twyfords B.S. pan with conventional flushing rim, both flushed by a Geberit drop-valve cistern.

Broadhurst, Gaborone; 4 in the new Botswana Housing Corporation, Gaborone office block; 2 in a refurbished private house; and 8 retrofits in a secondary school in Gumare, discharging to a septic tank/soakaway. With the exception of Gumare School, all the low flush volume w.c's are sewer connected. The principle of the Botswana installations has been to prove: the reliability and operation of 3-4.5 litre flush; user acceptance of low flush volume w.c. operation in a broadly similar income and social group; any adverse effect on the drainage networks serving large housing developments fitted or retrofitted with 3-4.5 litre flush w.c's. No drain blockages, solid deposition problems or adverse user reactions have developed to date. There have been w.c. blockage problems at Gumare School, and these are being investigated.

In Lesotho, 53 low flush volume w.c's were installed during the period February to August 1986. The principle of the Lesotho installations has been to include a variety of sanitation disposal methods: 17 sewer connected; 11 septic tank/soakaway connected; 24 conservancy tank connected; 1 to a converted VIDP latrine. One installation at Semonkong is pour flushed with 2 litres. A variety of residential and institutional buildings have been fitted with 3-4.5 litre flush w.c's: 27 flat/house owner occupied; 17 flat/house tenant occupied; 4 in offices; 4 in schools; 1 in an hotel. Flush volumes have generally been set to 4 litres for institutional use and 3 litres for residential use. All installations are flushing efficiently and there has been no adverse user reaction.

In both Botswana and Lesotho, several leakage problems have developed due to misalignment of the drop valve relative to the cistern lid centre pull or incorrect fitting or faulty inlet or outlet valves. Site monitoring of all the low flush volume w.c's, and various conventional installations to provide a control for comparison, will involve: house water meter readings; readings of w.c. water meter where fitted; drain checking; conservancy tank emptying frequency where appropriate; and user reactions.

The existing ODA research contract jointly with Brunel and Heriot-Watt Universities, which ends at the end of March 1987, will probably be extended for a further six months to allow longer term monitoring of the low flush volume w.c's.

CONCLUSIONS

Research funded by the UK ODA at Brunel University, in conjunction with Twyfords at Stoke-on-Trent, has led to the development of a low cost w.c. pan which in general flushes as efficiently with 3-litres as a British Standard w.c. with 9-litres. The 3-litre w.c. has been designed to optimise the relationship between flush volume, water seal volume, trap passage size and trap seal depth within the constraints of a functional w.c. capable of low cost manufacture. A site trial at Brunel University has indicated no adverse user reaction and no significant reduction in bowl cleansing performance.

Site trials in Lesotho and Botswana have proved the potential for a low flush volume w.c. in a wide range of applications from sewer connected systems to septic tank and conservancy tank connected systems. Early indications suggest a reduction in overall household water consumption of 15% due to the installation of a low flush volume w.c. Site trials in Botswana and Lesotho incorporating tipping tanks (ref.7) are under way to increase the potential of the low flush volume w.c. to longer drain and sewer connections.

The 3-litre w.c. itself has a wide potential including any country which is prevented from adopting flush w.c's due to water usage restrictions and any location where foul discharge is restricted.

ACKNOWLEDGEMENTS

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