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Brunel University

Building Technology

Proceedings of

DRAINAGE AND WATER SUPPLY FOR BUILDINGS

A TWO DAY SEMINAR ON CURRENT RESEARCH AND FUTURE NEEDS AND OBJECTIVES.

BRUNEL UNIVERSITY, UXBRIDGE, ENGLAND

JUNE 3 AND 4 1980.

Organised by DReG drainage research group

in conjunction with CIB W62

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PROCEEDINGS

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DRAINAGE AND WATER SUPPLY FOR BUILDINGS

A TWO-DAY SEMINAR ON CURRENT RESEARCH AND FUTURE NEEDS AND OBJECTIVES.

This seminar was held at Brunel University, Uxbridge, on June 3rd and 4th 1980 and was organised by the Drainage Research Group, Department of Building Technology, Brunel University, in conjunction with Commission W62 of the International Council for Building Research Studies and Documentation.

This volume contains the 8 papers presented at the Seminar, together with a record of the oral discussion, authors and contributors index and a delegates list.

ACKNOWLEDGEMENTS

The invaluable assistance of CIB W62 in the successful organisation of the seminar is gratefully acknowledged, as is the patience and helpfulness of the delegates, authors and discussion contributors.

Details of the current research being undertaken by the Drainage Research Group can be obtained from Dr. J.A. Swaffield, Department of Building Technology, Brunel University, Uxbridge. Telephone: Uxbridge 37188 Ext. 217.

DRAINAGE AND WATER SUPPLY FOR BUILDINGS

A TWO-DAY SEMINAR ON CURRENT RESEARCH AND FUTURE NEEDS AND OBJECTIVES.

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DRAINAGE AND WATER SUPPLY FOR BUILDINGS

A TWO-DAY SEMINAR ON CURRENT RESEARCH AND FUTURE NEEDS AND OBJECTIVES.

JUNE 3 AND 4 1980

PAPER NUMBER 1.

THE POTENTIAL FOR THE USE OF STOCHASTIC MODELLING OF WATER SUPPLY IN BUILDINGS

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Organised by

DRAINAGE RESEARCH GROUP
DEPT OF BUILDING TECHNOLOGY
BRUNEL UNIVERSITY
UXBRIDGE
MIDDLESEX

in conjunction with CIB W62.

K.P.DONNELLY,
WM. CARSON.

S U M M A R Y

The paper contains a discussion of some of the reasons why statistical modelling should be finding increasing application in the design of hot and cold water supply systems for buildings. Some of the tools available - probability distributions, stochastic processes and computer simulations - are described. Finally, the need for well documented consumption data is stressed.

R E S U M E,

Cette communication contient une discussion de plusieurs raisons pourquoi les modèles statistiques devraient s'appliquer de plus en plus souvent à la conception de systèmes d'alimentation en eau chande et froide destinés aux bâtiments de toutes sortes. Quelques - uns des instruments de travail dont on pourrait se servir sont décrits: les lois de probabilité, les processus stochastiques et les simulations utilisant un ordinateur. Enfin nous soulignons, pour l'application de ces méthodes, le besoin de données de consommation bien documentées.

K.P.DONNELLY,
Wm. CARSON.

We believe that statistical methods are of increasing importance in modelling water supply to buildings. Before describing the statistical tools available, we list a few uses for statistical modelling and some of the reasons why it should be increasing in importance.

WHAT CAN STATISTICS BE USED FOR?

Statistical analysis of patterns of hot and cold water use can be used for:

- Design - Choosing the minimum size of tanks, pipes, water heaters, or waste-heat recovery units necessary to satisfy specified reliability requirements.
- Economics - Assessing the economics of solar systems or waste-heat recovery units; calculating optimal tank sizes or thicknesses of insulation.
- Supply Planning - Deciding energy and water supply system requirements; setting regulations to minimise detrimental effects on utilities of design decisions.

WHY IS IT BECOMING MORE USEFUL?

Increasing benefits

Component prices continue to increase.

Energy prices are expected to continue to rise - boilers are more efficient if not oversized.

New developments such as waste heat recovery, renewable energy sources, and load control require economic appraisal.

Improved data collection

Data-logging equipment has improved greatly, and is becoming more computer compatible so that the amount of work in data handling is reduced.

Improved analysis methods

Statistical techniques have continued to improve steadily, both mathematically and from experience of applications.

Computers have dramatically eased the problems of data management and statistical analysis in recent years, and will continue to do so.

Software - the body of programs used to do things on a computer - has become more "user-friendly", making it easy for the layman to use computers.

Computer graphics will make it easy to visualise data in different ways. This will be of great value to the layman, but can also be combined with statistical analysis.

Networks of computers will make it possible to obtain quickly and easily copies of data-sets from different parts of the country and, eventually, internationally.

WHAT TOOLS ARE AVAILABLE?

Means and variances

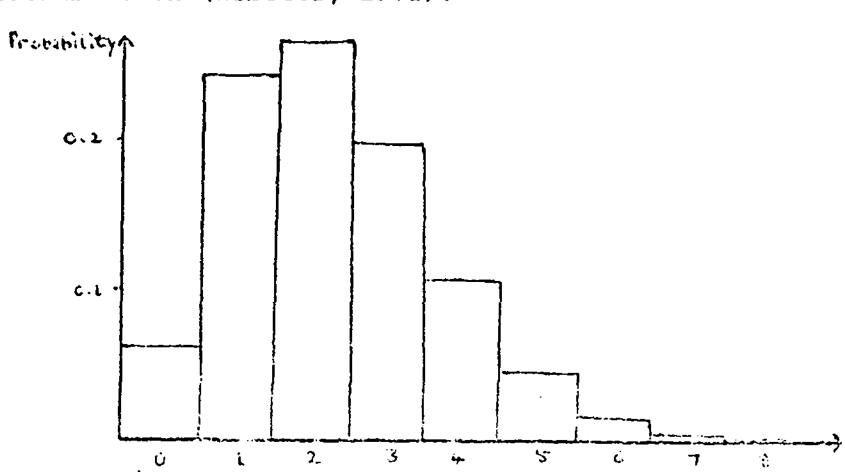
Statistics originally meant collecting numbers and calculating a few averages. The first real development was the calculation of variances (or standard deviations) to allow for uncertainty in the data. This also allowed an estimation of the uncertainty in means calculated from small amounts of data.

Means and variances are still important. Much more data is required, for example, on variability between households, in domestic hot water consumption and the reasons for this variability. A well insulated house can use as much energy for heating domestic hot water as for space heating to a constant 20° C.

Distributions

The distributions usually encountered divide into discrete distributions and continuous distributions.

Discrete distributions are described by a histogram giving the probabilities of a quantity taking certain discrete values. For example, we might try to describe the probability of certain numbers of water outlets being in use at a given time by a Poisson distribution (Webster, 1972).



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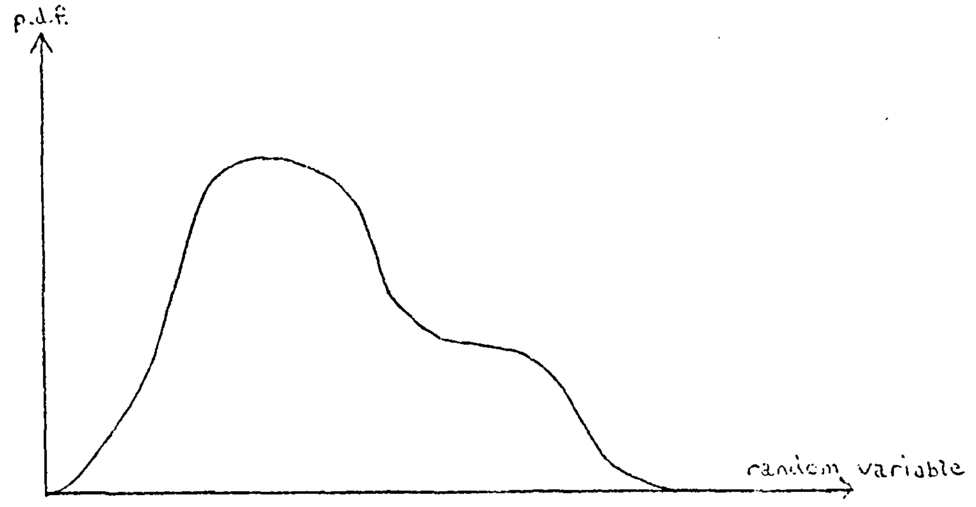
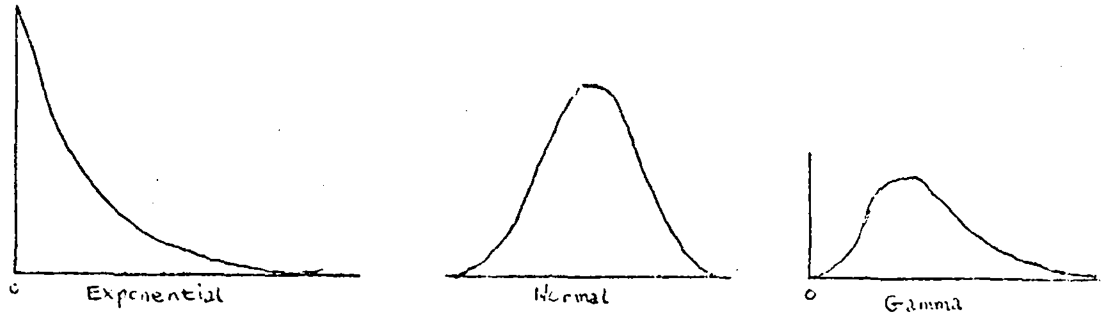
Continuous distributions are described by a "probability density function" (pdf) which specifies the relative likelihood of a quantity, such as the amount of hot water used in a day, taking various values in a continuous range.



We may want to use a distribution which is a mixture of continuous and discrete. For example, there is a discrete probability of the amount of hot water used being exactly 0. Thinking about representing distribution on a computer, we see that we need to store a large array of numbers to represent a histogram, or an even larger array of numbers to represent a pdf, depending on what accuracy we want, so we see that the potential increase in complexity is very large compared to dealing only with means and variances. Usually, however, we try to model things by certain standard distributions, such as the exponential distribution, which is described by its mean, or the Normal or Gamma distributions which can be described by their mean and variance.



Distributions can be useful for design purposes. For example, we may want to be satisfied that the probability of six or more outlets being in use at the same time is less than 1 in 1000, yet have only 500 items of data in which six or more outlets never occurred. If a histogram of the 500 items of data agrees well with a Poisson distribution, then we can estimate the mean of the Poisson distribution and use this to estimate the probability of 6 or more occurring.
We may still be less than confident that the apparently good agreement was not an accident and would not be applicable to the tail of the distribution. However, there may also be some physical reason for suggesting that a Poisson distribution is appropriate. If the event of any particular outlet being in use is independent of the use of other outlets, then mathematic reasoning tells us that the number of outlets in use does have a Poisson distribution. If we think that this indepndence is plausible, then we can proceed with much more confidence.
The use of design values based on the tails of probability distributions, using some specified maximum failure rate, such as 1 in 1000, is much more elegant than the use of design values based on the worst case of observed data. The latter have the undesirable feature of being stricter when they are based on more observed data. They are also not directly comparable between surveys with different amounts of data.

STOCHASTIC PROCESSES

This term just means "random things which are varying with time". Stochastic processes represent yet another step in the complexity of statistical modelling. The random quantity can be either discrete or continuous, and time can also be considered to be either discrete or continuous. Some examples are:

	Discrete time	Continuous time
Discrete variable	Maximum number of outlets in use on successive days.	Number of outlets in use, as monitored continuously.
Continuous variable	Total volumes of water used on successive days.	Rate of water use, monitored continuously.

Stochastic processes are useful for modelling situations where both randomness and time are important and are mixed up in the sense that the value of the random quantity at any one time depends in some way on its values at previous times. People have in the past tried to get around the randomness in situations like this by devising standard sets of data called a "design day" or a "design year", which are meant to represent either a near average case or an extreme case. However, this solution is generally not very elegant or satisfactory. A set of data which is "average" in one way will no doubt be non-average in others, and any attempt to make it average in lots of ways will only succeed in making it atypical. Likewise, an attempt to devise data which is extreme in a variety of ways can produce some very odd results.

To describe a general stochastic process we require not only a distribution for the quantity at each possible time, but a distribution conditional on every possible value at each of any number of previous times. We would need to know, for example, not only the probability that the maximum number of outlets used on a given day way, say 6, but the probability of 6 given that yesterday's maximum was 3, and the probability of 6 given that yesterday's was 3 and the day before was 4, and so on. In practice, we would not have to go on forever like this because the dependance would diminish as we w t further back, but still we see that the step in complexity in going from distributions to stochastic processes is at least as large as the step in going from means and variances to distributions.

Again, however, the stochastic processes we use in modelling are only very special simple ones. The simplest kind of discrete-time stochastic process is where the distribution is the same for each time and is independent of the values at all previous times. Haslett (1977), for example, in modelling solar heating systems assumed that the total amount of solar radiation falling on the panel on any day had a Normal distribution and was independent of the amounts on previous days. This is unrealistic, and a more accurate model would have the amount correlated with the amounts on previous days, but nevertheless, useful results were obtained.

The variety of stochastic process models is very great and different branches of the theory have arisen from different applications. However, each branch usually turns out to be applicable in numerous fields.

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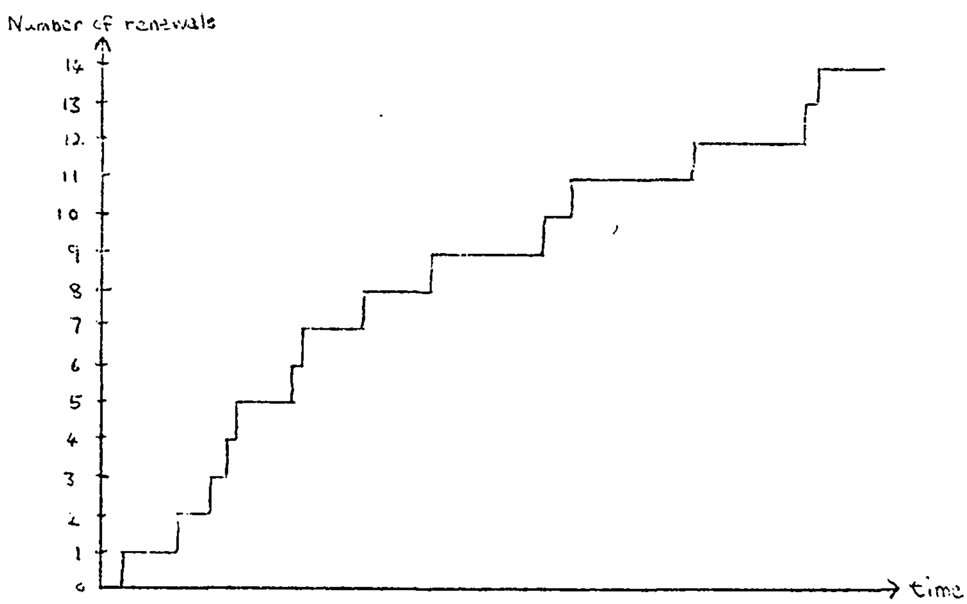
Stochastic processes with discrete-time and a continuous random variable, such as the volume of water used on successive days, are sometimes referred to as "time series". Time series have been studied extensively in economics because of their use in modelling the change in economic indicators from year to year.

Renewal theory was originally devised to deal with the renewal of such things as fluorescent light tubes, whose lifetimes could be assumed to be independent and to have a specified distribution. It is designed to answer questions such as how many renewals might be required in the first year, or what is the optimal strategy for sending workmen to replace fluorescent tubes. It might also be applicable to such things as the replacement of tap washers. The stochastic process underlying renewal theory is the number of renewals since a specified time. This is a continuous-time, discrete-variable process.



The theory of dams, or theory of reservoirs, was originally devised to calculate the probability of dams overflowing and bursting or of reservoirs running dry. It is obviously applicable to tank sizing. This is what Haslett used in modelling solar systems, the relevant quantity being the amount of heat in the tank.

There are many other branches of the theory of stochastic processes. Queueing theory is another, for example. In recent years continuous-time continuous-variable processes have become more popular, partly because computers and graphics facilities have become available to manipulate and visualise them, and partly because mathematicians have developed the tools to overcome the original conceptual difficulties they had in dealing with them rigorously. Once the conceptual difficulties are overcome, many continuous-time processes turn out to be very simple and beautiful. Graph 1 shows a realisation of what is probably the most fundamental of all stochastic processes, the process known variously as "white noise","the Wiener process", "the Gaussian process", or "Brownian motion". Its value at time t has a Normal distribution with mean 0 and variance t. Graph 2, which shows the variation over a year of the heat load on district heating schemes in Stockholm, looks remarkably similar to the Wiener process, especially if the annual trend is removed by division. It shows that the Wiener process might possibly have applications in sizing district heating plants. Graph 3 shows a realisation of another beautiful continuous-time stochastic process. called the Gamma process. It consists of an infinite number of jumps, most of them too tiny to see or to have much effect. Its value at time t has a Gamma distribution with mean t.

Stochastic processes cannot be completely represented in graphical form, in the way in which distributions can, by drawing their histogram or probability density function, but by plotting realisations - specific examples - of them against time, as with Graphs 1 and 3, we can gain a good impression of them.

SIMULATION

The term "simulation" means trying something out on a computer to see what results, but it can actually refer to two rather different things.

Physical simulation means feeding through demand data, such as water demand over a certain time period, while representing the rest of the system, such as the amount of water in a tank, by numbers, and seeing how these behave. This is exactly what Maver (1966) did in order to obtain the maximum draw-down in a tank for a variety of tank sizes and supply rates. Most research on solar energy is also done in this way, using a year or more's hourly radiation data to simulate different designs and determine the amount of energy collected, without having the expense of building each possible design (e.g., Courtney, 1977; Jørgensen, 1979). This behaviour of the system is deterministic, although there may be a random element in the input data.

Monte Carlo simulation means answering questions about stochastic models which could in principle be answered by mathematical analysis but are usually far too complicated. Random number generators are used to pick values from distributions, or even lots of values to simulate a whole stochastic process, and doing this lots of times to determine the mean or distribution of some calculated quantity. For example, Brinkworth (1977) developed a stochastic model for solar radiation sequences and used simulations of these instead of real data in physical simulations of solar heating systems.

It is possible to use both real and simulated input data by, for example, using measured radiation sequences together with simulated water demand data. This could be used for controlled investigations of the effect of introducing day-today variability into the water demands, or of introducing correllations between successive days.

The ease of doing computer simulations makes it possible to use much more realistic and complicat ed stochastic models than would have been the case if it had been necessary to rely on mathematical analysis for results. For example, Smalls (1977), modelling the duration of medical operations and their required flow rates of medical gasses, was able to use a model allowing not only for the different patterns on different days, but also the influence of surgeons' lunch breaks and tea breaks.

DATA SETS

The expense of collecting water demand measurements means that such data is still very scarce, despite the great need for it. So it is important that data which has been collected should be made as freely available as possible. The technological problems of doing this are being overcome by improved communication between computers. However, it is essential that the data files be clearly understandable and well documented. The difficulties which we have experienced in re-using some of our own data have impressed this upon us. Standardisation of the data collected would have obvious advantages, although there are different requirements for different needs. For example, hourly measurements of hot water demand might be adequate for assessing the economics of solar systems whereas almost continuous measurements might be required for pipe sizing.

CONCLUSION

We hope that this short paper may rouse some interest in the possibilities for using stochastic modelling and simulation, and may

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provoke some discussion on the practicalities of interchange of data.

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WM. CARSON.

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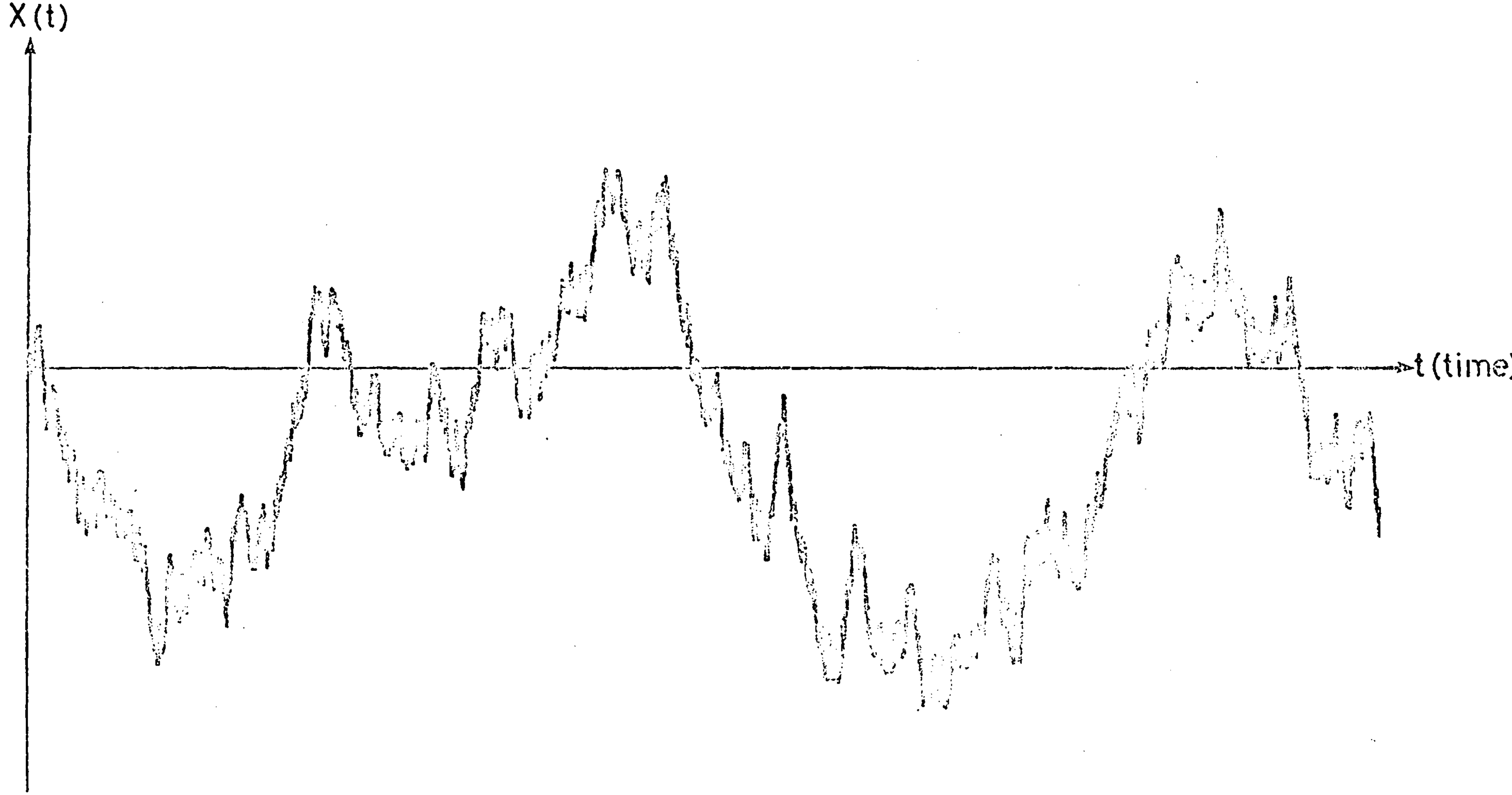
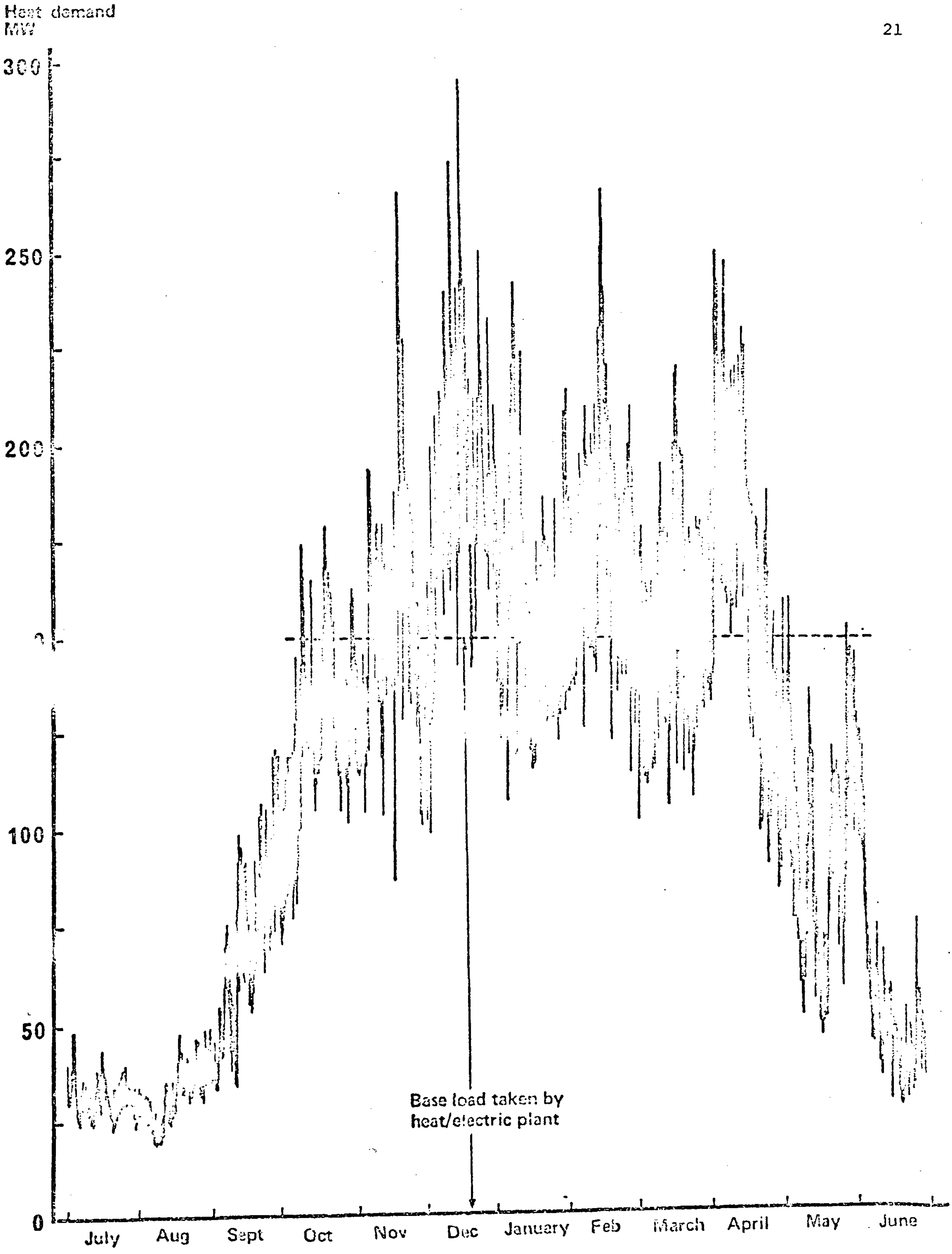
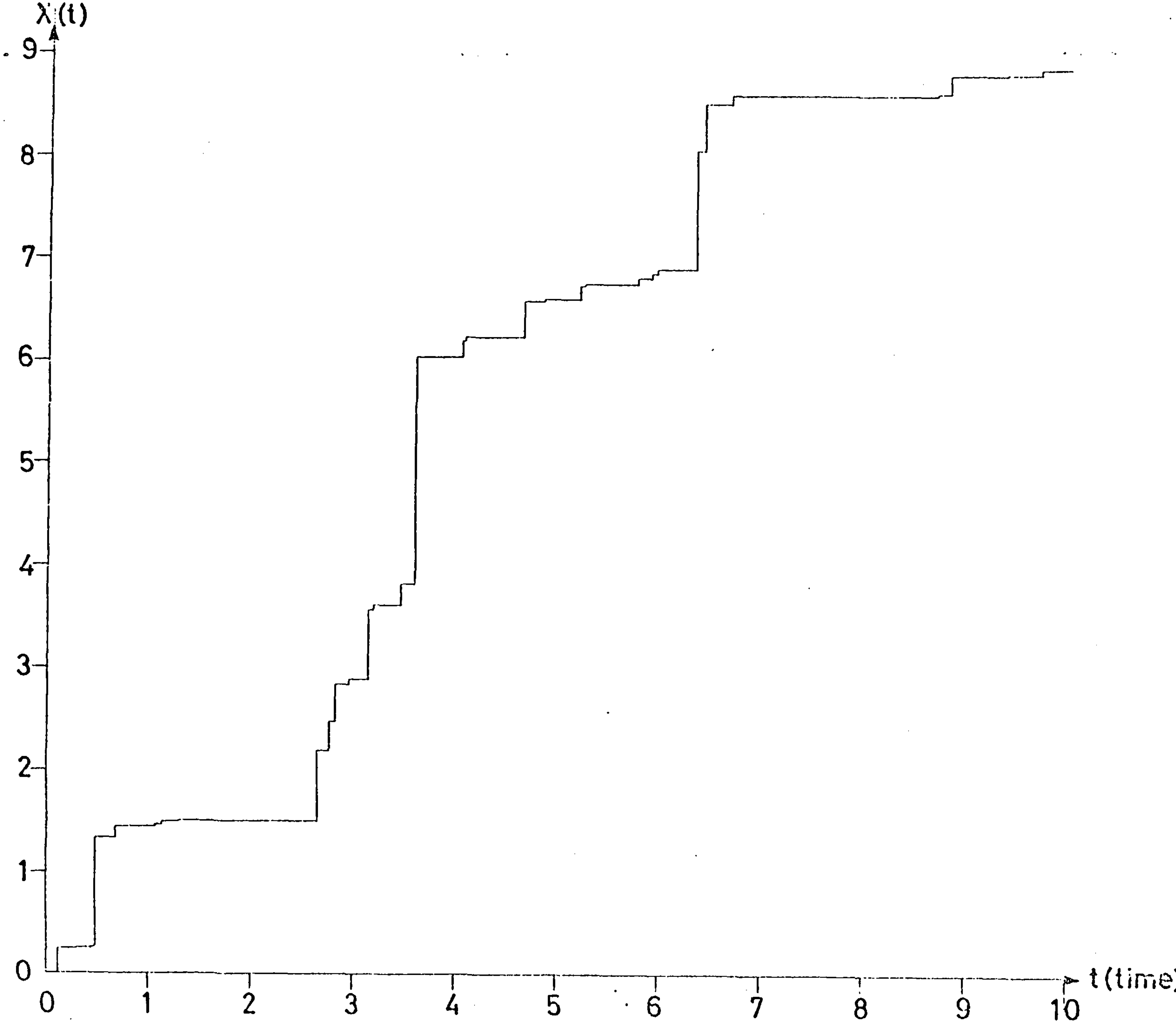


GRAPH 1: WIENER PROCESS



GRAPH 2 : Annual variation of heat requirements in Stockholm during 1975, mean value per hour.


λ(t)
t (time)
0
1
2
3
4
5
6
7
8
9
10

DRAINAGE AND WATER SUPPLY FOR BUILDINGS

A TWO-DAY SEMINAR ON CURRENT RESEARCH AND FUTURE NEEDS AND OBJECTIVES.

JUNE 3 AND 4 1980

PAPER NUMBER 2.

POSSIBILITIES FOR SAVING WATER IN THE HOME-

TECHNICAL ARRANGEMENTS AND THEIR CONSEQUENCES

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INTRODUCTION

During the past 7-8 years the importance of saving water has been more obviously for the consumer owing to the growing costs for the water supply. It is important to maintain this interest because it will initiate the development of water saving components and water saving drainage and water supply systems.

If small economies can be achieved in the domestic consumption without unacceptable reducing of the standards of hygiene or causing undue inconvenience to consumers the following economically and technically advantages will immediately appear.

a) present sources of water and existing treatment plant would remain adequate for several years,
b) existing pipesystems in the main supply would remain sufficiently in spite of a growing number of connected consumers,
c) new pipesystems for domestic buildings could probably be of smaller dimension than used to day,
d) all water saving entail energy savings since all water supplied need energy for pumping and/or treatment both as clean water and as waste water,
e) any reduction in the use of hot water represents a direct saving of energy for water heating.

The aim of this paper is to review a few components produced for water saving purposes. The review is combined with a survey concerning water consumption, rate of flow at the appliances and frequency of use.

An estimation of possible water saving and technical consequences when using "water saving components" finish the paper.

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CONSUMPTION

According to measurements in danish [1] and swedish [2] develling houses the following Figure 1 with values for water consumption can be set up.

Consumption / Appliance	litres (and %) per person and day cold water	hot water	total
Bath (tub shower)	27 (21%)	25 (31%)	52 (25%)
WC (8-9 l)	55 (42%)	- -	55 (26%)
Wash Basin	15 (11%)	15 (19%)	30 (14%)
Kitchensink	35 (26%)	40 (50%)	75 (35%)
Total	132 (100%)	80 (100%)	212 (100%)
Total	62%	38%	100%

Figure 1. Water consumption in litres cold and hot water per person and day. The consumption does not include water used for laundry (washing machine), car washing and gardenpurpose. The temperatures on the water are 10 °C and 65 °C. In brackets are indicated the procentuel value of the respective totale consumptions.

Figure 1 gives the approximated values for water consumption in dwelling houses with common facilities for clothswashing, car-washing and irrigation. Should those consumption be encluded the total comsumption will increase to approximately 250 litres per person and day.

A part of the consumption mentioned in figure 1 namely those used for fulfilling a purpose claiming a specified volume of water can not be influenced by reducing the rate of waterflow to an appliance.

Those two grups are started in Figure 2.

Consumption / Appliance purpose	Litres per person and day	
	"Volume demand"	"Flow demand"
Bath	13	39
WC (8-9 l)	55	-
Wash Basin	15	15
Kitchen Sink	45	30
Total 212	128	84
% of total	60	40

Figure 2. Estimated values for water consumption to appliances and purpose claiming either constant volume or constant flow.

The estimation is based on dishwashing by hand using 20 litres to each one of the demands. If dishwashing machine is used the "volume demand" for the kitchen sink decrease approximately 18 l/person and day.

In the "volume demand" for the wash basin and the kitchensink are included 12 l for house cleaning purposes.

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FLOW and FREQUENCY of USE

Components and appliances with "volume demand"

This group is important because as it appears from figure 2 the main part of the consumption is caused by demand to the volume of water. Earlier papers at CIB-seminars [3] and [4] and multiple others have focused on the investigation of this part of the matter and called the attention to several easily gained possibilities for saving water by using new bathtubs, WC's, washing and dishwashing machine etc. This paper does not handle this part of the consumption.

Components and appliances with "flow demand"

Bath

In figure 2 is given that 52 l/pd are used for bath. The exact figure for the consumption in a shower had to be calculated on basis of statistically information about bathing practice. Ongoing measurements [5] compare with results from [2] shows that 39 l/pd as indicated in figure 2 seems to be a relevant mean value for water comsumption to a bath with a hand-shower. The average duration of the shower is 2,5 minutes, and the average rate of flow

Flow, Handshower — $q_{mean} \sim 0{,}2$ l/s ($q_{max} \sim 0{,}45$ l/s)

through the shower fixture .

Older shower-head mounted in a fixed position has a bigger rate of flow which approximately increase to

Flow. Fixed shower — $q_{mean} \sim 0{,}4$ l/s ($q_{max} \sim 0{,}6$ l/s)

the shower is used approximately

Frequensey of use — 0,7 times per person and day.

(cold and hot water always together).

Wash Basin

Measurements on the supply pipes to the wash basin fixture shows that the average rate of flow through the outlet of the fixture is

Flow. Wash basin

$q_{mean} \sim 0,10$ l/s ($q_{max} \sim 0,3$ l/s)

(0,5 l/s cold water (10°C), and 0,5 l/shot water(65°)).

A logic conclusion is that the maximum values are obtained when the fixture are used for filling the basin or the toothmug.

The wash basin is used approximately (max values)

Frequency of use

4,8 (7,3) times per person and day.
(cold and hot water together)
1,4 (6,2) times per person and day.
(hot water alone).

Kitchen sink

The fixture at the sink is the most used fixture. The average flow through the outlet of the fixture is

Flow. Kitchen sink

$q_{mean} \sim 0,14$ l/s ($q_{max} \sim 0,37$ l/s)
(the flow of cold water is app 10% higher than the flow of hot water to the fixture).

It is assumed that when the rate of flow has a maximum value the purpose of the tapping is to fill a vessel of some kind with water.

The tap at the kitchen sink is used approximately (max value)

Frequency of use

9,7 (14,4) times per person and day
(cold and hot)
6,1 (12) times per person and day.
(hot alone).

SAVING POSSIBILITIES

Preconditions

All the above mentioned figures for water consumption, rate of flow and frequency of use are based on measurements in dwelling houses in use. All the devellings are of modern type equipped with two-hand mixer with aerator on the outlet. The flow-pressure characteristic for the tap at the kitchen sink appears as Figure 3.

(Figure 3)

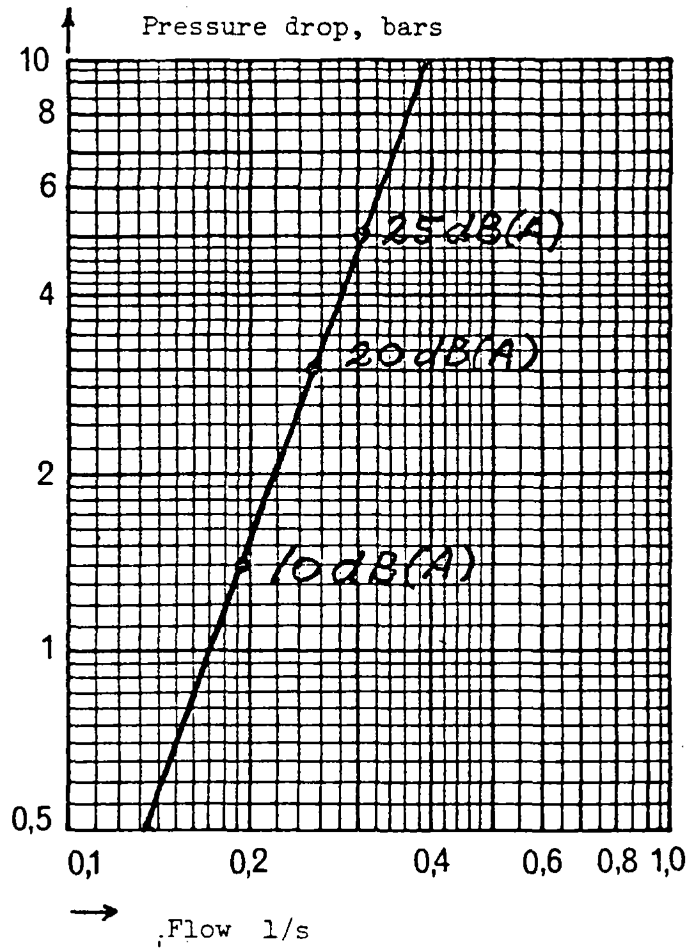

Figure 3. Flow-pressure charcateristic for the tap (kitchen) on which the measurements are done.

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The possibilities for saving water by reducing the rate of flow on the existing taps of modern type seems not to be good.

Developing

Development of new type of taps and shower units which fullfill the functional requirements to the purpose [6] with a lower rate of flow than mentioned above as q_{mean} is a possibility. It could initiate the developing if testing - and judgementmethod which allowed us to measure the performance of the outrunning water from the tap where created.

Hereby it would be possible to judge whether a certain function could be fullfilled with a minimized consumption of water.

Older taps

A majority of taps in danish dwelling houses are more than 10 years of age. The rate of flow from those taps seems to be considerably higher than nessesary for the purposes they are designed for. The reason is in most cases that the flow-resistence ind the valve and in the outlet are small, compared to modern taps.

If the costs allow it, the most recommendable solution is to exchange the older taps with modern ones.

Advertised for water saving purposes in the houses and available on the market are flow-restrictors, flow-controllers etcetera.

The effect of those restrictors depends of course of that the outlet of the tap at the same is equipped with an aerator, nozzle or shower head which can fulfill the functional requirement to the performance of the tap.

If the restrictor is installed on the inlet pipe of the tap it has to fit to the flow-pressure characteristic of the tap as described in Figure 4.

(Figure 4)

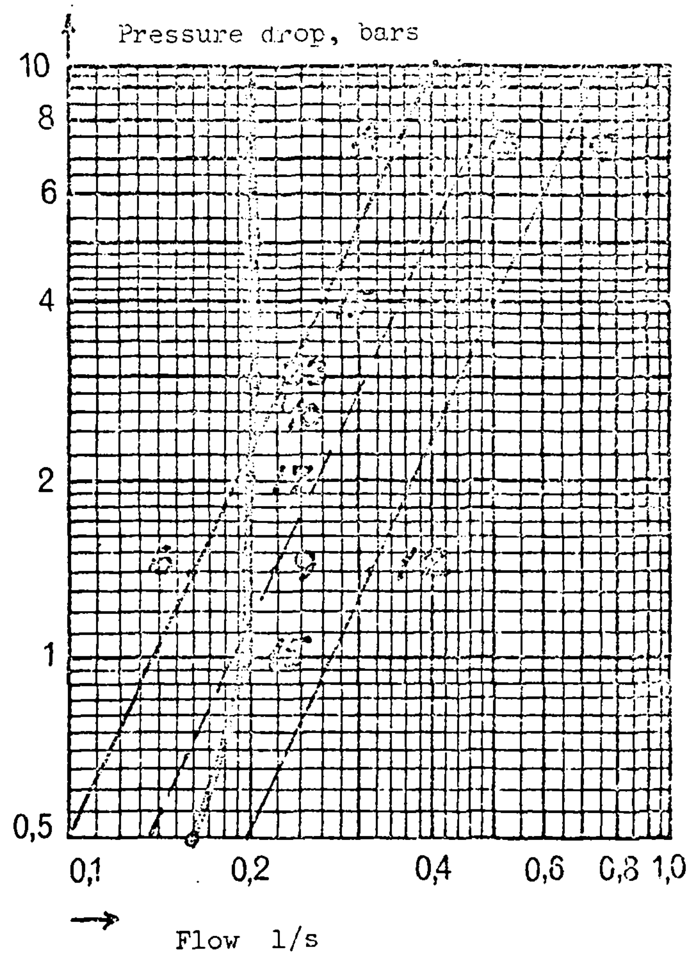

Figure 4. Flowrestrictor (0,2 l/s) mounted on the inlet pipes to 3 taps: A, B and C.

A: no considerable effect on the flow of water.

B: water saving effect a possibility.

C: the regulation effect of tap is lost.

In all 3 examples there is danger for an increased noise production from tap + restrictor.

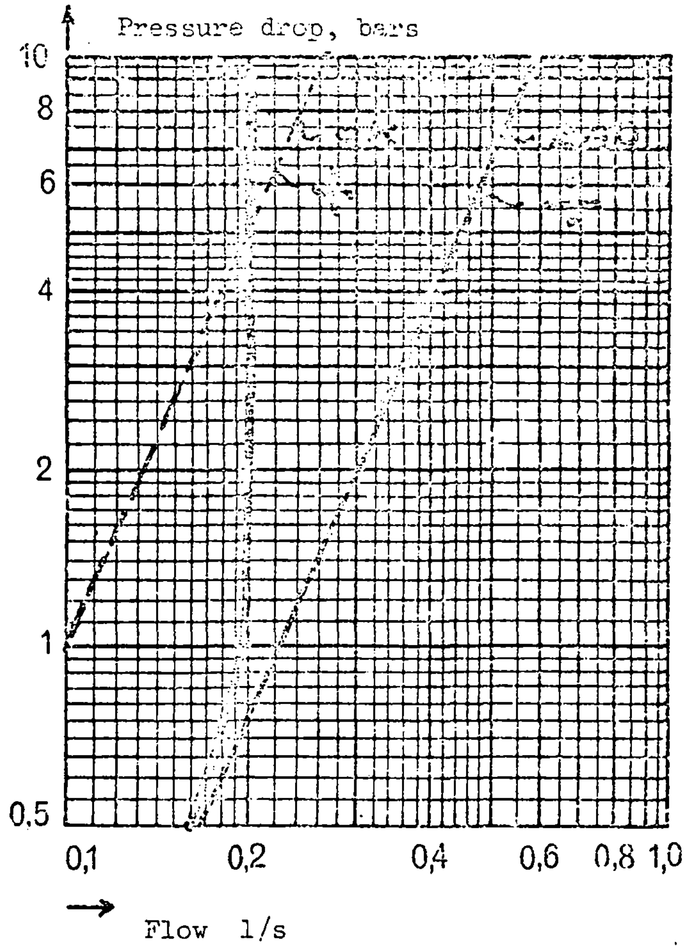

Figure 5. Flow-restrictor mounted on the outlet on a tap. If the pressure drop through the tap is as showed overflow fron hot to cold water supply system can occur.

(Figure 5)

If the restrictor is installed on the outlet it is also necessary to know the characteristic of the tap. If the restrictor and the tap has flow-pressure characteristic's as indicated on Figure 5 a dangerous situation can occur if the tap is a mixing tap without check valves. The hot water/cold water respectively can crossconnect to the other system and it would be possib to tap water with an unexpected temperature for instance on the storcy below the mixing valve with restrictor on the outlet.

CONCLUSION

The efforts concerning technical solutions for water saving purposes should be continnued with focus on reduction in the "Volume demand" as defined above. The group defined as "Flow demand" are still in a beginning developing periode for increasing the convenient flow for the purpose. Modern taps - especially one hand mixers - are evidently more water saving than older taps.

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[3] "Current measures for saving water in the home"
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E.F. Ball, BRE, England

[4] "Drainage system with WC's flushing 3 l of water"
CIB-Seminar, Paris 1979
Otto Iverkilde Nielsen and Viggo Nielsen, SBI, Denmark

[5] "Water Consumption in dwelling houses"
CIB-Seminar, Paris 1979

[6] "Performance requirements for taps - a consensus from Scandianvia"
CIB-Seminar, Washington DC 1976
NBS Special-Publication 553
Washington DC, 1979

DRAINAGE AND WATER SUPPLY FOR BUILDINGS

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SAVE WATER - SAVE ENERGY

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SAVE WATER - SAVE ENERGY

There is no shortage of water in Sweden. However, because of the energy situation we ought to use less water, in particular less hot water. In order to judge the effect of water-saving measures it is necessary to know how much water we use. This has been investigated in a high rise building in Norrköping, and the results are presented in this article. An account is also given of the Laboratory's study on flushing volumes for WC's, where the conclusion is drawn that a 3-litre WC is perfectly fearible and involves considerable cost savings.

The consumption of water in several different countries is shown in Table 1. It is difficult to give an explanation for the differences, though obviously living conditions and customs are important. The public water systems (dimensions) also have an effect on the water consumption. As can be seen from the table, the water consumption in Sweden is relatively high by comparison with other countries. Energy considerations make it desirable to tackle the consumption of water, in the first place hot water.

It is very difficult to estimate development trends as regards water consumption. However, in current prognoses it is generally assumed that there will be an increase in the per capita consumption up to the year 2000. Obviously there must be some correlation between resources and utilisation. In order to achieve this adjustment, it is necessary to have clear and comprehensive aims plus good planning. However, some control is also needed and this calls for regulations.

Survey

In order to estimate the effects of water-saving measures in the home, it is necessary to have an accurate picture of the water consumption in the houses concerned before any water-saving measures are adopted. The Water Laboratory of the

Swedish Building Research Institute has carried out a survey of water consumption in houses in the Swedish town of Norrköpir The aim was to first record the total water consumption in 20 flats. Five of these 20 flats were then studied in detail. In these five special cases, the water consumption was determined at each separate supply point by measuring the frequency and flow at each one.

The survey showed that the amount of water consumed in litres per person and day, l/pd, often varied considerably from one flat to another. The distribution of the total amount of water consumed also varied. In some flats more hot water was used in the kitchen than in the bathroom, while in other flats the situation was the reverse. This was observed over several measuring periods, and is probably chiefly due to the inhabitants' different habits. For example, people who are out at work can often wash or shower at their place of work, while people who stay at home consume only water in their own flat.

In addition, not everybody has the same hygienic requirements. In a study at a Swedish university, the washing habits of abou 200 persons were investigated. It was found that more than 50 of the men washed the whole of their bodies 1 - 2 times per week. Less than 50 % of the men washed all over more frequentl More than 50 % of the women washed the whole of their bodies 3 - 6 times per week. Less than 50 % of the women washed all over more frequently. Different habits also mean that some people use too much water when they bath (shower), while other use too much water when they wash up, or at worst that they ar wasting water both for bathing and for washing up.
In the five Norrköping flats which form the basis of the summa of water consumption shown in Figure 1, the amount of water consumed in the kitchen was relatively large by comparison wit measurements in other flats. The figure also shows the distribution between hot and cold water, and the total consumption in l/pd. By recording the consumption at each water outlet it is possible to estimate the significance of each separate poin in a saving programme, and the importance of undertaking such programme.

The importance of technical solutions

In blocks of flats, where the inhabitants are charged for the total amount of water consumed in the whole building, there is little inducement for the individual consumer to go in for systematic saving. In spite of information about the sharply rising costs of hot water, in particular, it is difficult to achieve the desired saving.

Thus we need technical solutions which will induce the consumers to save water and energy, promptly and conveniently. The Water Laboratory's measurements in Norrköping have shown, among other things, that hot-water costs can be reduced considerably by lowering the temperature of the hot water from 55°C to 45°C. In the same way, the costs increase if the temperature is raised to 65°C. The lower hot-water temperature was acceptable to the inhabitants, while on the other hand a temperature of 65°C was considered to be too hot.

The measurements in Norrköping also showed that people consumed different amounts of water depending upon the type of water tap installed in the flats. It was found that single-handle taps produced a saving by comparison with traditional taps with separate handles for hot and cold water.

An investigation carried out by the Swedish Consumer Institute has shown that washing up by hand. The same investigation, which bases its results on laboratory tests, has shown that washing clothes in a machine also uses less energy than washing them by hand. The Consumer Institute and the Water Laboratory at Studsvik have planned a joint survey to investigate these saving effects.

The importance of reducing running costs

In recent years more and more attention has been paid to the increasing running costs in both houses and flats, largely due to the rising oil prices.

The cost of heating water for hot-water taps is forming an ever larger proportion of these costs. The measurements in Norrköping have shown that a reduction in the temperature of the water supply reduces the energy costs for heating this water.

Other measures aimed at a reduction in the heating costs have been discussed, including the use of the hot water circulation as a direct source of heat at the water outlet point. In order to elucidate this aspect it will be necessary to have further surveys, new products and perhaps also new principles of dimensioning.

In a number of cases there has been talk of measuring individua hot-water consumption in apartment houses. Many people believe that this would be an effective way of reducing the ever-increa ing running costs for houses. Stig Nilsson and Thomas Lundgren have carried out an investigation, using funds donated by the Building Research Committee, to determine the saving effected by individual hot-water metering in four housing areas in Gothenburg. According to their investigation, it may be assumed that individual metering will reduce the consumption of hot water by between 20 and 30 %. A saving in hot water of 30 % means a saving in heating oil, besides the actual reduction in volume of water consumed. In our 20 test flats in Norrköping this would mean a saving of c. 2000 litres of heating oil per annum.

Some years ago there began to be an increase in the use of WC's with a flushing volume of 6 litres instead of 9 litres. At that time the main reason was one of dimensioning, although the water-saving aspect was also cited. Today the situation is quit the reverse. Now we are searching high and low for systems and components which can reduce water consumption. Several measures have already been taken; for example, there are some fittings with a limited flow, systems have been equipped with flow limiters, etc. In addition the consumers themselves, in paricul home owners, have been induced by various saving campaigns to alter their habits to a certain extent. For example, there is a tendency to shower instead of taking a bath, to rinse the dishes in a baisin instead of under running water as before etc

A 3-litre WC is possible

We know that a lot of water is used for flushing WC's. The problem with a low flushing volume is that the flushing out of horizontal pipes will probably be ineffective, and this creates a sanitary nuisance. Is is essential to have an adequate flushing out of the piping system, i.e. it must be flushed completely clear at least once every twenty four hours. In the Swedish sanitary installation regulations it is stated that this will be achieved if the force applied is at least 0.25 kp/cm^2, and the height to which the pipes are filled does not exceed 0.5 (h/D, where h = depth of water and D = pipe diameter), see Figure 2.
The Water Laboratory at Studsvik has for the last year been studying WC's with a flushing volume of 3 litres in combination with components whose principal function is based on an effective clear flushing of the piping network. These investigations are not quite complete, but the results hitherto obtained in connection with flow tests indicate that a good clear flushing effect is achieved in conventional sewage systems with a flushing volume of 3 litres.
What then are the advantages of a reduction in flushing volume from 6 to 3 lires, from both a technical and an economic point of view ?

Inside the building: Smaller pipe dimensions, thinner walls, a saving of space in openings and recesses, other savings in materials, new types of system.

Outside the building: Existing pipelines can be utilized for new housing projects, the risk of overloading at sewage works is reduced, smaller loadings on water pumps, etc.

The results of the measurements in Norrköping have shown clearly that the WC (6 litres) has the greatest water consumption, 55 l/pd, of all the water supply points, see Figure 1. On the basis of these results it is possible to estimate the economic effect of using WC's with a 3-litre flushing volume as opposed to 9 or 6 litres.

It is reasonable to assume that most of the flats build betweer 1960 and 1975 were equipped with WC's having a flushing volume of 9 litres. From 1975 it became increasingly common to have WC's with a flushing volume of 6 litres. Nevertheless, the 9-litre WC's were still markedly in the majority. For the sake oi comparison we can group the flushing volumes as follows:

1960 - 1975	9 litres
1975 - 1980	6 litres
1980 - 2000	3 litres

The average water rates in Sweden between 1960 and 1975 were 1.3 Skr/m^3, and between 1975 and 1980 they were 4 Skr/m^3. It may be assumed that they will be 8 Skr between 1980 and 2000. (10 Skr = appr. 1 pound sterling.) The water rates per cubic metre of used water have increased from 1960 to 1980 by c. 900 (from 0.6 to 5.2 Skr). On the basis of the figures obtained for water consumption in WC's, 55 l/pd, and assuming an averag of 2.5 inhabitants per flat, we obtain the water consumption and water rates shown in Table 2.
At present the number of flats containing WC's with a flushing volume of 9 litres is high. The same applies for flats contain-ing WC's with 6 litres. Considering current water rates (c. 5. Skr/m^3), and comparing them with the amount of water used in WC's per flat, the results shown in Table 3 are obtained. The table shows that a flat equipped with a WC having a flushing volume of 9 litres costs 250 Skr/year more than one where the WC contains 3 litres of water. This does not mean that the use saves this amount of money, since a large proportion of the water rates covers the water company's fixed charges, but from a management point of view it is interesting.

However, the results shown here cannot be applied either direc or generally, simply by, for example, cutting down the flushin volume in lavatories. A large-scale adoption of these measures would undoubtedly lead to sanitary nuisances, chiefly in the street sewers.
If the fittings supplied to the consumers are to be made more water-saving it is essential to know what effects this will have on the sewage system as a whole.

On the right road, but the way is long

Forecasts made by the Swedish Water Board indicate that water consumption will continue to increase, which will in turn affect operating costs. However, a number of measures have already been taken to reduce water consumption, both by changing consumer habits and by using water-saving components.

Nevertheless, much remains to be done. The water laboratory at Studsvik is not alone in conducting research in this field; the area to be covered is large, and we believe that a coordinated research effort can be extremely useful.

New ideas often meet with considerable suspicion, both from the consumer and from the authorities. We consider that it is important to have a positive attitude to new ideas, and not to reject them before their function and consequences have been demonstrated in practice.

Table 1. Mean household consumption in some different countries

Country	year	Consumption, litres per person and day
Denmark	1977	176
Luxemburg	1977	180
Netherlands	1977	137
France	1975	101
UK	1977	204
West Germany	1977	135
Switzerland	1977	255
Italy	1972	225
Austria	1974	149
USA	1976	432
Japan	1978	220
Sweden	1978	197
Kenya	1977	25-40

Table 2. Estimated water consumption in WC's and water rates.

Year	WC flushing volume, litres	litres/flat and year	cost in Skr/flat and year
1960-1975	9	75 000	97
1975-1980	6	50 000	197
1980-2000	3		198

Table 3. Estimated water consumption in WC's and costs accordir to current rates.

WC flushing volume	Water consumption in WC m^3/flat and year	Water rates Skr/flat and year, for WC
9	75	386
6	50	256
3	25	128

Figure 1. Water consumption in five test in flats in Norrköping.

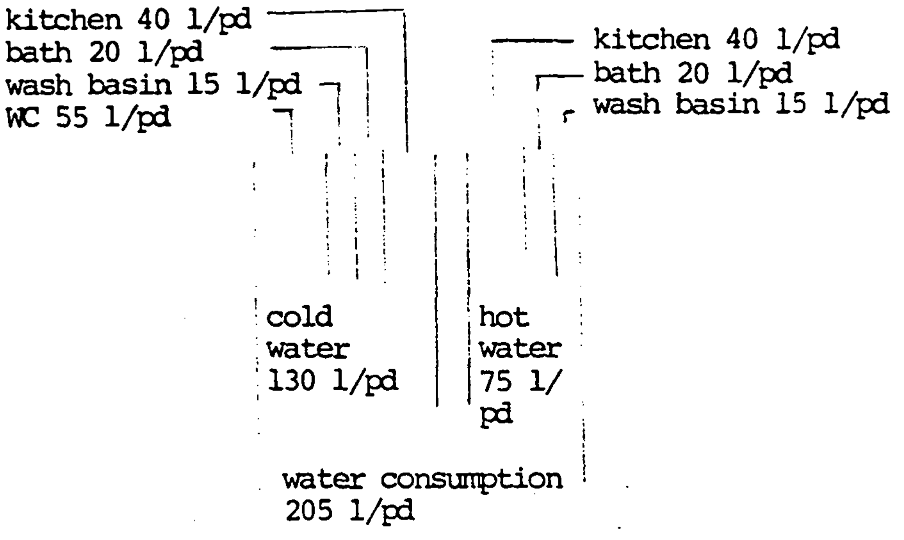
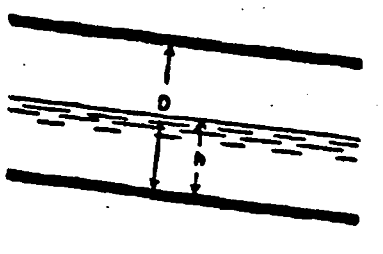


Figure 2. Sanitary installation requirements for clear flushing of piping.



DRAINAGE AND WATER SUPPLY FOR BUILDINGS

A two-day seminar on current research and future needs and objectives

Discussion session on Papers 1, 2 and 3, June 3rd, 11.15 - 12.30

Chairman : Dr. R. H. M. Wakelin, Drainage Research Group, Brunel University.

Dr. Wakelin : We've been discussing ways of saving water and also reducing hot water consumption. I would like to hear people's reactions to reclaiming heat from waste water. I know that the idea isn't new, but it hasn't been put into practice very significantly. This is the idea of collecting water from the bath, basin and kitchen sink, into a tank, extracting the heat from that water before it is discharged into the drainage system and incorporating also a facility to use that water to flush the W.C. with, because from the figures that we've seen on water usage, the W.C. is one of the major consumers of water. To my way of thinking we don't need to use potable water for flushing the W.C. and there seem to be possibilities of utilising waste water, which shouldn't be so soiled as to be unhygienic, to flush the W.C. I don't know whether any of the Scandinavian people are horrified at the idea of doing this, but it has not been mentioned this morning as a possibility, and I think we can kill two birds with one stone by using this concept to reclaim energy and also save water.

Mr. Ovesen : I know that in many test houses they are trying your idea, some with success and some without. I have seen in the United States that they use waste water for flushing W.C.'s and I know in some countries you will find reports - I remember a number from Sweden and Denmark - so I think you could study this idea, but my opinion right now is that it is possible but you will gain very little from this arrangement, and it is very expensive and difficult to make them and maintain them.

Dr. Wakelin : I think that is possibly true. I think we have an advantage in the U.K. because we don't have so many apartments as Europe in general - in other words we have more separated

Dr. Wakelin cont. houses. The investigation I've been carrying out over the last year isn't based on the heat pump system because I don't think this is the best way to do it at the moment because of costs. I'm looking at the method of conventional heat reclaim - straight forward heat exchange. The figures that I've worked out suggest that the price of the materials is about £150. Based on energy prices in this country you would save, if you had electric water heating, about £40 - £50 per annum which gives an internal rate of return of about 30% which I think is very viable. On the other hand if you have gas water heating the internal rate of return is only about 8% so that is only just economically viable. But energy costs are never going to come down relative to inflation and so I think it is still worth going ahead even at an 8% internal rate of return. I agree there are problems, but I am hopeful that it is possible and I hope to put a system in my own home to try it out, because I think there are a lot of teething problems that haven't been looked at in great depth. As you say there has been quite a lot of work done on this at a very advanced level with heat pumps but I think the whole principle of simplicity is essential. We have always had very simple drainage systems and I would like to keep it that way.

Dr. Swaffield : A question for Mr. Carson. It was suggested that data collection on water usage was something that could be interchanged between laboratories and also the problem that water usage is culture based with the usage of water depending a lot on the country of origin. I wonder if it would be sensible to suggest that several people got together after this meeting to discuss how to collect data - it could be agreed that data collected would fit into certain blocks. Then people collecting data in laboratories could have certain standards to work against. If we agreed a certain set of questions and a certain layout beforehand, that we all used, then data could all be collected in the same form. I don't know if this is a possibility or not.

Mr. Carson : I would be interested in a discussion like this but I would like to get a broader view of it before we start. I think that two points come to mind immediately. One is the relatively detailed technical aspects - of which computer code, and so on we should use? Personally I don't think this is very important because it is so easy to translate from one computer code to another as long as it's clearly defined and is some internationally recognised code. But I would be interested to hear what other people think about it.

Secondly on the content, I think there are two conflicting trends here. Mr. Nielsen and I were having a very short

Mr. Carson cont. word about this and he was pointing out that they have a data logging system which will record things in considerable detail and having got this system it doesn't cost any more to record stuff in detail than to record it in a very crude form. This is true with the advances in electronic data processing equipment and this is certainly the general trend - it is becoming cheaper to record data. At the same time, anyone who is starting data collection for their own particular reason has got to invest in that logging equipment and will find that the more detail they try to collect, the more expensive is their equipment and the more elaborate the data handling and collecting becomes. Now how far it is worth going towards fine detail in every case I just don't know. It would be a question of finance and resources. I would imagine that what we would come up with is a standard format of what should be collected in detail with everyone having the option of moving from that down to the various cruder stages. I would like to hear how other people see this; has it reached the stage where we can forget about the crude stuff and have the refined stuff every time because the extra cost is trivial.

I would like to organise something like this but I think an index must go with it and perhaps the CIB W62 secretariat could keep the index, listing who has what with a summary of their work. I think it would be an appropriate thing for them to do. We have in the past tried to establish a bibliography, an index to the literature, but we haven't yet found this very useful because they have just been lists and there has not been an index to go with them. So an index is an essential part of the operation.

Mr. Olsson : I like this idea very much. I think it is important for us who work in this field to know what we are all doing and for information research in the future for say 5 or 10 years ahead. So I think we should sit down and work out in detail what we intend to do. With this information, we could do lots of things we couldn't do before.

Dr. Wakelin : Has anyone any points on this subject or any other areas they would like to discuss?

Mr. Rosrud : I would like to ask the people present, how do you account for different types of families in the use of water? In Norway it is a trend in new areas of growth to build for families, starting with people with small children needing school etc., and in some 30 years it will be old-age pensioners in that same area. It has a different kind of use.

Mr. Rosrud cont. It is time now to put together different types of people - single people, families and pensioners in one area. Have you tried to take this into account?

Mr. Carson : We have certainly met this. It is another aspect of the data processing. It is easy to record flow rates, pressures etc. on instruments. What is much harder to record is the question of occupants, such as who is in the house and what are they doing? No doubt some of you will remember Ted Gibsons' story: in one of the flats he looked at they used virtually no water from Monday to Friday and non-stop all week-end, and this was because they were very unusual occupants. The father was a night-watchman and was out all night, and the daughter was a nurse and was out all day. She did all the housework at the weekend, using about 90% of their water then. Also, you need to take into account the apparatus in the house. We found a step function in one house we looked at where the family had a new baby and washing machine at the same time and the combined effect of the two was a step function in the water consumption. So this is a valid point and is probably one of the hardest parts of data collection and documentation.

Mr. Holmberg : We have studied, very carefully, five apartments where we know exactly what happens, where we can measure the water consumption. We know about the occupants, for example there are no children there. But now we are planning a new measuring system which is bigger. We are planning to monitor 20 - 25 flats and then we are going to just take aspects like washing machines, dish-washing machines etc., so I think we can answer this question in one or two years.

Mr. Carson : Just one more point. Although these differences occur, the question must be asked as to how significant they are from the point of view of the designs. I think Mr. Rosrud touched on it. During the life of a building, the occupants may alter and it may be that from a design point of view the things you are interested in are the critical situations that are likely to occur during the life of a building. You may get specific buildings that are designed for old people only, but the usual pattern in the U. K. is that it starts off with a young couple, then a time when there is a family, then the family move on and the couple is alone again. Then there are grandchildren so there is a whole range of possibilities here but how we cope with them, and how important they are, remains to be evaluated.

Dr. Wakelin : I think that's a very valid point. I think you are right, particularly in the U. K. as you couldn't say that a house is for old people, or for a young couple, but perhaps in Scandinavia you can predict more readily who the occupants will be. If not, you need to take a worst case analysis. That remains to be identified and I should imagine its the family with 'x' number of children - in this country I believe the average is 2. 3.

Mr. Rosrud : I have tried to think about how we should put into practice this kind of testing of a building during use. I have had some discussions about the same problem and when I wrote this up, I basically described the ordinary code of practice we have in the Scandinavian countries and I tried to figure out how much difference there was between our measurements of water consumption, and I couldn't find any case with more than 10% variation. I think that our ordinary calculations will be in that range anyway. For instance with regards pipe diameters, I don't think we are very far from the right system, but I agree that better calculations will provide better systems and that better data will be required. For the practical monitoring of water consumption I think you could rely on the experimental system.

Dr. Swaffield : It occurred to me, looking at the spread of water uses seen earlier on the slides, that the problem could be looked at in another way. Obviously we need to know the appliances used in certain buildings with regards the type of occupancy and so on. I wonder whether, in the data collection, we could use a broader set of parameters, the sort of thing that might be used in the sociological or economic type of survey of users. Perhaps we could identify people in European countries, by their likely patterns, based on their position in the economic structure of the country in terms of their jobs or earnings. Perhaps we could explain the figures that indicated that in France the average water consumption was 101 litres per person per day and in Scandinavia it was 250 litres per person per day and break those figures down and compare people in certain professional classes.

That might be a way of filling in the data which must exist already, within the countries, and then see if that might be a way to approach the problem. I know that in this country we have these classifications, but I don't know whether this has ever been used in this sort of context, as a way of bringing data closer together.

Dr. Wakelin : Another valid point. I think it is an area that needs to be investigated but again we have the problem of the varying use of dwellings.

Dr. Swaffield : We might well find that the pattern for a professional couple in the U. K. might be very similar to a professional couple in other European countries.

Mr. Read : Social and economic grouping must influence water consumption and therefore would presumably be useful to include in the data base. For instance, the marketing industry have such information on socio-economic groupings in this country, so we could decide how many washing machines etc. were used. But I would like to address a question to Mr. Nielsen and Mr. Olsson. One of the crucial things that comes out of your papers is the use of data and adapting some of these fittings to practical use to get some of the savings. What would be very useful would be rather more rigorous financial/economic analysis as to what you would get out of fittings that you look at, and why does one save water, and is it worth it economically? It sounds a nice idea but possibly the rate of return you get for the investment in a pressure fitting, or renovating a system may not be economically justifiable and it may be worth producing data on this. I know of one paper by the Building Research Establishment in the U.K. To me there appear to be three definite areas where these devices will be needed: one is in new installations and this is clearly one particular field which you could get into more easily with water saving devices; secondly there is retrofit, taking existing appliances and updating them; thirdly there is complete renovation. All three have rather different requirements and each will have a different economic viability. I don't know if in Scandinavia you've had a chance to look at internal rates of return on retrofitting or anything like that and I would be interested in your comments.

Mr. Nielsen : We haven't tried such overall evaluations of systems. I feel that it is mainly the technical design that is required. However, I think that you are right, in that it has influence on the whole system. I have no relevant figures for you though.

Mr. Olsson : I can add something to that. We are now looking at a building with 3 litre flush W. C. 's. We used three litre W. C. 's and we put in small pipes inside this building with economic advantage. In new developments we can therefore use smaller pipes. In retrofit situations we could retain the larger size pipework and discharge more W. C. 's into that pipework system. Therefore there are economic advantages either way.

Mr. Read : The crux of this must be that people like yourself must get the building regulations altered, because for instance in the U. K. you cannot legally install a low volume flush lavatory in your house. If I want to install a Swedish I. F. O. toilet I think I am outside Thames Water Authority building regulations, and I'm outside British Standards, so it seems to me that :-

(a) one needs to rigorously, economically and financially, analyse the outcomes of your thoughts.

(b) one needs to get some of these regulations changed if one is actually going to get any impact and get savings, because we can't get savings right now while the building regulations in this country are so specific.

Until that is done, we are still theorising.

Dr. Wakelin : I don't know whether we are the only country that is suffering from this, but I agree with the points that Mr. Read has made.

Dr. Swaffield : One of the things that concerned us about retrofitting of W . C. flush volume reducers which is being considered in the U. K. , is the shift of cost from water usage to maintenance. There are no figures, as far as I know, on the economic analysis of the effect you would get of saving water by retrofit of such things as user flush control devices and there are plenty of figures saying that they will save water (and there are those that say you will save 30% water) but the other side of the picture is blank. We don't know in large buildings, estates, etc. whether the maintenance rate has gone up or not , due to the build-up of excess deposition in the pipes, and due to the fact that you are retrofitting something that isn't changing the W. C. action. I think that if you take a W. C. that is designed to operate with 3 litres and installed as such, then you might not expect to get an increase in maintenance because it is designed as such. The point I am making is that if you change something on the existing system to reduce water discharge then in those cases I would expect to see the maintenance rise. I don't know whether anyone has these figures or whether anyone is collecting them.

Mr. Nielsen : I have no figures with me; but if you remember, I presented a paper in Paris. We had a test going on in a little town in Denmark in which we a equipped a 3-storey building with 36 apartments using 6 litre W. C. 's in one half and 3 litre

Mr. Nielsen cont. I.F.O. W.C.'s in the other half. That house is completely similar to another one built just 50 metres from it with the same drainage system and it is totally equipped with 6 litre W.C.'s and there haven't been any "inconveniences" due to blockage of the drainage system.

Dr. Swaffield : That perhaps is what you might expect because you are installing W.C.'s that have been designed for low volume flush operation. I think Mr. Read meant modification of existing installations.

Mr. Read : There is some information being accumulated at the moment by the Wessex Water Authority, because they have some retrofit of sewers and they have been doing sewer condition surveys for some time and keeping records of blockages and so forth, and this data will become available in the next year or so. To date, there is no evidence of any problems, but again they haven't been able to do a complete financial analys of all the implications. Obviously reducing water ends up changing the whole treatment process, because presumably your B.O.D. is higher and so forth. I think we are waiting to see how the Europeans feel, particularly the Swedes and Norwegians, because if one is looking to these sorts of things the long term impact is very substantial on the whole waste water industry, because one is looking to change quite a bit of the traditional Victorian technology.

Dr. Wakelin : I think another point that hasn't really been touched on, is levels of hygiene that we are maintaining or possibly changing with going for reduced volume flush, which is another aspect that I think might come up tomorrow with George Howarth and John Swaffield. Will a three-litre flush take a sanitary towel away or are we imposing changes on what users expect from a W.C.? I'm not saying necessarily that one should discharge sanitary towels via a W.C., but it is done, and that's something we've got to accept, in this country at least, and if you are going to impose 3 or 6 litre W.C.'s on the general population, you then might be lowering hygienic standards in the method of disposal of sanitary products and are we right in doing so? So again we've got to take a lot of other things into account. Are we going to start fitting incinerator units in houses to get rid of these products and if so we could be using more energy that way?

Dr. Swaffield : The point that Dr. Wakelin has just made comes back to the thing that I wanted to say: you can't really divorce what we are talking about in terms of water usage, from the social patterns of the people who are living in the

Dr. Swaffield cont. buildings, because the very point we are making now about the flushability of products such as sanitary towels is very much tied up with hygiene levels and what people come to expect with regards to quality, the sort of product people now expect to use, and this spreads into things like using disposable nappies for children, which is a very rapidly growing market. That is very much a function of what people expect in terms of being able to use products in their homes. We are now moving into a time when people are thinking more in terms of disposable items, rather than, for example, washing nappies as they used to do. We should look at these ideas and problems before we go ahead with plans for the future. It may be that we should look into involving people with an economic and sociological interest in this area and perhaps in the next meeting of the CIB W62, someone could be invited to present a paper in this area.

Mr. Holmberg : A little about the saving aspects. We observed that when we changed from a conventional system to a reduced water consumption system, we thought we were sure about this saving notion, but soon we observed more and more changes and we observed that this water consumption differs very much from winter to summer within a year. So now we are metering at exactly the same time in the year to get more accurate information.

They used, for example, 20% more water at Christmas and New Year time than in the summer when perhaps occupancy is zero for some of the time, so we have to choose carefully the place and time.

Mr. Carson : I was very interested to hear that last point on seasonal variations. It's something we've suspected over a long period of time but have never found sufficient evidence to convince us one way or the other. You seem to have found a seasonal variation. Is it simply a reflection of occupancy, which I think you suggested in your last sentence, that there was less consumption in the summer when no-one was there? If the occupancy remained constant, would the water consumption remain constant?

Mr. Holmberg : We have thought about this question. But the fact is that the consumption in our house would go down. We had a period of 102 days last summer when we were almost 20% down on normal consumption and because we were just changing the systems, everything went very badly.

Mr. Carson : So you don't really know yet.

Mr. Holmberg : On the temperature I would say that when we go from $65^{\circ}C$ to $45^{\circ}C$ we save about one per cent of the energy for each degree centigrade that the water temperature is lowered.

Mr. Olsson : We have also observed many great fluctuations. Therefore in the next investigation we will try to take a new building and use our existing information to build up a new system and put in instruments to monitor it, and after that I think we will have a very good chance of knowing what we have achieved in the building. After that I think we could have less fluctuations, even if we change little in the buildings.

Dr. Wakelin : I would like to ask Mr. Nielsen a question. You quoted on page 3 of your paper, some usage figures of bath/shower, because I think it was a combined shower in a bath. Did you have any data on the relative usage of the bath and the shower

Mr. Nielsen : I don't know if Mr. Olsson has some information but we have only the combined figures.

Mr. Olsson : No, our figures are also for the combined system.

Mr. Juple : We talk about water saving with the W. C. and we know also that most of the time they are used as a urinal. What do you think about a flushing system with selective volumes or old buildings with very low flush volumes? Have you done some research work in your country?

Mr. Olsson : We have not, but I think it is a very expensive system if we had to monitor it. Even to monitor the separate items of the kitchen, the bath, the wash basin, and the W. C., it is very expensive.

Mr. Ovesen : With reference to home urinals, as Mr. Juple mentioned, I don't think that I have seen them in any country so far, and I don't think it would be a good idea because it is space consuming and expensive, but I should like to hear whether anyone else has some experience of domestic urinals, and also of smaller W. C. flush volumes for discharge of urine from the W. C.

Mr. Juple : In Germany and Switzerland, the manufacturers try to sell home urinals; sometimes at exhibitions you see suites which include a W. C., a bath, a bidet, and a urinal, but you don't see the urinal much in housing, but they do exist.

Mr. Juple cont. They are very small urinals with two litre flush volumes. Your other question, in Switzerland we have no flush valves, but they do in Germany. In Switzerland we have the flush tank which is interruptable, to provide a lower volume flush, but I doubt if many people do bother to interrupt the flushing. Only those households which are individually monitored and who are conscious of the price of water generally bother to interrupt the flush for non-solid discharge.

Dr. Wakelin : Here we are probably somewhat different from Scandinavian countries because water metering in this country is very very rare. Only I would guess about 0.1% of domestic users are metered for water consumption and I think the advantage of using dual flush cisterns where you have a small flush for urine and a larger flush for solids is doubtful. As a user, because I don't have to pay for the water I use, I would always use the larger volume flush only to be sure of keeping my drainage system clear, because its going to be expensive for me to get someone in to clear my drains, and as I'm not paying for my water, I would always play safe. Whether I'm unique in this country I don't know, but I doubt it. I've also heard, and this is only a verbal quote, there are some experiments going on in this country with a user controlled device with which you hold the handle down for as long as it takes the solids to disappear from the W. C. bowl and then release the handle and the flush stops instantly. I believe that there are problems with children using this system because children cannot be bothered to wait long enough to clear the solids from the W.C. pan which is something which must be taken into account. Certainly with regard to dual flush cisterns they have tried these out in hospitals in this country and they turned out pretty badly, I think mainly due to the varied populations that the hospitals have to contend with. People didn't know how to use them correctly. I think they tried displaying instructions in several languages, telling people how to use the system, but if it takes a couple of minutes to read the instructions, I doubt whether people would bother, especially since they would not be aware that the cistern operates differently from the conventional type of siphon and cistern. All these things have got to be taken into account.

Dr. Swaffield : I'd be interested to hear what people thought of the idea of the waterless urinal, which is being considered in this country. This is a urinal with no water flushing at all, and depends on further usage to maintain the trap seal with undiluted urine.

With regards the user controlled W. C. flushing, you have the problem of contamination. With solids you can see that they have been cleared from the W. C. but there are

Dr. Swaffield cont. the problems of clearing fluid contamination, because you can't see if this has happened. It could be that the hygiene standard would be reduced to an unacceptable level.

Dr. Wakelin : With regards the waterless urinal, again another verbal quote: several of these devices are being used at the Building Research Station and when I enquired officially I was told that they were working well, but when I enquired of one particular person, he said that one urinal stank and they couldn't find any reason for it and they were putting the blame on one of the users. So there does seem to be a problem with the waterless urinal.

Mr. Eriksen : With regards the use of home urinals, for many years the trend was that people had smaller bathrooms and hence a larger kitchen or living room, but now we are tending to build larger bathrooms which could have space for a urinal. However I feel that the problem will be the smell. I don't know if anyone has any comments on how to prevent the smells from urinals.

Dr. Wakelin : Yes, I would agree with that. Does anyone else wish to comment on smell in relation to urinals? On the subject of space, are people making more space in bathrooms purely to obtain the feeling of spaciousness, in which case the fixed urinal is defeating the object of what people want, or are people creating more space for the purpose of fitting in more sanitary units. I suspect they just want more space generally rather than to get a bidet, urinal and anything else they can find to put in there. I certainly doubt whether the urinal will ever come in for domestic usage. First of all it needs to be male orientated, unless you are going for the male/female type of urinal which I believe is available. Also what about houses where you have two W. C. 's; do you then provide two urinals? So I personally can't really see the attraction of the home urinal.

Mr. Carson : A different point. This is a question for Mr. Nielsen. You displayed some graphs showing pressure drop across taps against flow rate, with the restrictor characteristic drawn on, and if I understood you rightly, you were saying that at the lower flow rate the restrictor had no effect. I don't think this is correct is it? Surely it would mean that you would have to open the tap further to get the same flow rate even though the restrictor is not the limiting device. The available pressure drop will be split between the restrictor and the tap.

Mr. Nielsen : This was almost what I said. I had three separate taps shown on that slide. One with a high pressure drop, one with a medium pressure drop and one with a low pressure drop, for the same flow. I said that if you had a tap with a very low pressure drop, the influence of the regulating device would be negligible because of the restrictor. If you had a tap with a high pressure drop, you would have a regulating possibility at the start, but if the pressure drop across the regulating restrictor is higher than that across the tap then you have no regulating possibility.

Mr. Carson : But fitting the restrictor would improve the amount of regulation that you had on the tap. You would have to open the tap further to obtain the same variation in flow.

Mr. Nielsen : You have to look at the existing system with the tap and then consider the whole system with the tap and restrictor. It is therefore essential to consider the whole system before fitting a restrictor to the tap.

Mr. Holmberg : One comment to Mr. Olsson and one question to Mr. Nielsen. Mr. Olsson showed figures indicating that women washed their whole body more often than men. I worked some seven years ago at a camping site where one had to put coins into a metering device to obtain hot water. The male and female bathing facilities were separate, and I found that there was always more money in the male coin box than in the female coin box.

I would like to ask Mr. Nielsen about some of his figures which indicated a high percentage of high flow rates. Do you know the time period of these flow rates? Do you know the minimum time period of each seperate tap opening?

Mr. Nielsen : We have not measured the time period for which each tap is open, but a time period of around 2 to 3 seconds is required before the tap opening is recorded as such.

Mr. Holmberg : I think that it is necessary to also know for design purposes the time period for which each tap was open.

Mr. Nielsen : The purpose of my paper was not to obtain values for the design or dimensioning of the pipework system, it was to obtain the relevant figures for the savings of water. I split it up into volume demand and flow demand. I think that one has to look at it differently if you are intending to save water than if you are intending to establish design criteria. I think that total consumption was sufficient for my purposes.

Mr. Uujamhan : I would like to ask Mr. Nielsen whether it is possible to monitor flow rates from measurements of sound levels? You quote sound level figures in your paper, and I wonder whether you could use these to establish the flow rate.

Mr. Nielsen : The data shown in Figure 3 of my paper were obtained in the laboratory, and these are readings that are required for all taps that are approved for the market in Denmark. The answer to your question, therefore, is no. These figures are only required for the establishment of specific noise standards.

End of first discussion session

DRAINAGE AND WATER SUPPLY FOR BUILDINGS

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FEATURES OF WATER SUPPLY AND SANITATION IN DEVELOPING COUNTRIES

A discussion paper

by

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INTRODUCTION

1. Meeting basic needs in water supply and waste disposal is the daily provision of between 20 and 50 litres per person of safe and convenient water for drinking, food preparation and personal hygiene, together with adequate and safe means of excreta and wastewater disposal. There are some 1 500 million people (the urban and rural poor) in developing countries (excluding China) whose basic needs are not met. The UN General Assembly has declared the 1980s as a decade during which a real and substantial effort should be made to meet these needs.

2. In 1976 the World Bank, aware that the benefits of its lending program in the water supply and sanitation sectors were not reaching the urban and rural poor, undertook a two year research program into appropriate technologies for low cost water supply and sanitation in developing countries. The results of this research program (Ref. 9) show that low cost technically viable alternative technologies to conventional water supply and sewerage do exist and that these technologies can have a public health impact similar to that of conventional approaches.

3. Following this research program, the United Nations Development Program (UNDP), as part of its preparations for the International Drinking Water Supply and Sanitation Decade (1981-1990), has sponsored a global project of demonstration programs in low cost water supply and sanitation in developing countries. Under this project, which the World Bank is executing, the Bank established a Technology Advisory Group (TAG) in late 1978 to facilitate the design, implementation and monitoring of these demonstration programs in selected parts of the developing world.

4. This paper summarizes the sector background, highlighting some of the current TAG sector thinking and highlights areas of further applied investigation which have been identified by TAG.

BACKGROUND

5. Sanitation and water supply planning and development work in developing countries is set in a range of social, economic, demographic and climatic situations, wide variation in some aspects is contrasted by remarkable similarities in other aspects. These are highlighted in Table I, which shows for example Sudan with an area of 2.5 million km^2 and a population density of 7 persons per km^2 contrasted with Lesotho with an area of 30 000 km^2 and a population density of 43 persons per km^2 (the U.K. has an area of 244 000 km^2 and a population density of some 246 persons per km^2). The countries have largely rural populations (generally over 85% rural) and a low per capita Gross National Product (GNP) of under US $ 500 per capita (the U.K. per capita GNP was US $ 5 000 in 1978).

6. Life expectancy is generally under 50 years with much of the population undernourished, and generally with poor curative and preventive medical facilities. The infant mortality rate is generally greater than 120 per thousand live births and in a few countries greater than 180 per 1 000. The human misery and sadness which this brings has a serious debilitating effect on society as well as on individual families. Between 40% and 50% of the population is under 14 years of age, with fewer than 5% at primary school; adult literacy is low (generally under 40% literate). The position is summarized in Table II.

7. Existing service levels of safe drinking water and adequate excreta disposal are variable but not particularly good as shown in Table III. Rural areas in particular have very poor water service levels and almost negligible excreta disposal facilities. In urban areas, service levels are highly skewed in favour of high income households who consume well above basic need levels and in many cases receive free, services for which the poor have either to pay or do not receive at all.

8. The countries are all low income countries. The outlook for improvement in per capita GNP, particularly when compared with the industrialised countries such as USA or the United Kingdom is poor, due to slow economic growth combined with high population growth; Figure I highlights this, showing the present and projected continued vast gap in GNP per capita between nations, while Figure II shows the considerabl past and projected growth in population. A major feature of this growth has been the trend towards increased urbanisation as shown in Figure III this trend is projected to continue such that typically in sub-Saharan Africa the estimated 1975 urban population of 80 million (about 21% of total population) is expected to grow to over 250 million (about 40% of total population) by 2000. The countries also have a variety of different religions, political, economic and socio-cultural environments which affect planning and implementation of water supply and sanitation programs.

DEVELOPMENT REQUIREMENTS

9. To overcome the existing very poor levels of water supply and sanitation services in the developing countries a range of technologies, and "service delivery models" have been identified by the two World Bank executed programs discussed previously (Ref. 9, 13, 14, 15) which have been fairly widely reviewed; the major findings of these reviews are that there is a wide range of affordable, appropriate and acceptable technologies available (but in many cases poorly developed) which can give adequate levels of service.

10. Water supply technologies include not only individual piped and metered house connections (costing typically $ 120 per capita) but also

- yard taps,
- communal stand posts (Figures IV & V)
- deep well and shallow well hand pumps (costing typically $ 25 per capita - Figures VI and VII) and
- wells.

11. Sanitation technologies (for excreta disposal) do not, as is still widely believed by the professions, consist of either waterborne sewerage, bucket latrines or nothing; a range of other sound systems is available including

- Ventilated Improved Pit Latrines (VIP latrines - See Figure VIII)
- Pour Flus (P.F.) latrines (See Figure IX)
- Sewered Pour Flush latrines
- Communal latrines
- Septic tanks ,
- Aquaprivies and
- Waterborne sewerage.

12. Figure X shows a generic classification of Sanitation Systems, and Table IV shows a detailed cost comparison of the technologies which highlights the high per-capita cost of waterborne sewerage compared with other options, and emphasizes the importance of affordability.

LIKELY SANITATION OPTIONS

13. Excreta disposal systems need to be technically appropriate, financially affordable and socially acceptable. From the work done on recent program development, there are two particularly attractive solutions to excreta disposal which meet this criteria: these are the VIP latrine and the PF latrine, both using alternative pit technology (see Figures VIII and IX). They are suitable for both urban and rural developments; when the first pit is filled, it is rested to allow for pathogen decay (see Ref. 9) while the second pit is used. When the latter is full, the first pit is emptied (after a period of at least 2 years) and the resulting humus (which has been formed by microbial action) can be safely removed and used for soil conditioning or agricultural fertilizer. The first pit is then used while the second pit rests and the contents biograde. The cycle continues. No further treatment of the humus is required; and the systems can be used in high density situations; pits are not continually excavated and re-excavated, which would be both expensive and cause household decommitment.

14. Both systems use the soil as a receiving body for liquids; P.F. are latrines which have twin leaching pits, are particularly suitable where personal ablution is with water as is done in Muslim and Hindu cultures (typically 4 to 6 l.c.d is generated) and VIP latrines where dry materials are used for cleansing. This implies (particularly for the PF latrine) that the soil must have leaching capacity.

15. In parallel with excreta disposal, provision must be made for sullage disposal; this would be to either a soakway disposed of in the yard, to a stormwater drain or onto gardens. (Sullage management is often overlooked in development projects; it can cause major health problems by providing insect vector breeding sites).

16. In situations of very high density, poor soil absorption capacity or once water consumtpion rises (with income level) to exceed soil absorption capacity an alternative system is the piped PF latrine; liquids (from excreta, ablutions, flushing and sullage) which would normally leach into the soil are carried to treatment in shallow flat sewers which have widely spaced manholes.

INVESTMENT IMPLICATIONS

17. The order of magnitude of investment required to meet the current broad service goals in developing countries is considerable; estimates vary widely and depend on the technical and institutional models adopted. The table below gives an indication of the required investment.

TABLE 17.1

1/&2/

Estimates of Investments Required to Meet Current Service Deficits of Water Supply and Sanitation in Developing Countries

		Unit Cost $/cap.	CASE 1 Pop. Served %	CASE 1 Pop. Served No. (millions)	CASE 1 Cost $US (billions)	CASE 2 Pop. Served %	CASE 2 Pop. Served No. (millions)	CASE 2 Cost $US (billion)
Urban Water Supply	hc	120	70	447	53.6	40	255	30.6
	stp	40	30	191	7.6	40	255	10.2
Sanitation	sew.	250	40	260	65.0	25	163	40.0
	sept.	100	40	260	26.0	15	98	9.8
	Lat.	30	20	131	3.9	40	260	7.8
Sub Total	Urban				156.1			98.4
Rural Water Supply	hc	150	20	313	46.9	10	157	23.6
	stp	40	40	628	25.1	30	471	18.8
	hc	25	40	628	15.7	40	628	15.7
Sanitation	sew.	250	20	335	83.8	10	167	39.2
	Lat.	20	80	1338	26.8	70	1171	23.4
Sub Total	Rural				198.3			120.7
TOTAL URBAN AND RURAL					354.4			219.1

1/ It should be noted that 100% urban coverage using water supply house connections and sewerage only (i.e. no appropriate technology) would cost $329.4 billion rather than the $156.1 billion calculated with a mix of technologies.

2/ Software costs are not included in these estimates.

3/ SOURCE: Ref. 16.

4/ hc. = house connection
sew. = sewered
lat. = Latrine
stp. = standpipe

18. It should be noted that these estimates exclude both sullage disposal and the "software" required to ensure sound program delivery and development together with long term maintenance; the investment implication of these inputs are considerable. They also exclude the capitalized value of operations and maintenance costs. Annex I shows details of these estimates.

19. Work undertaken in the water and sanitation sector over the past 18 months has raised a number of issues of note and identified areas in which further applied research is required.

ISSUES OF NOTE

Manpower development and training

20. Sound manpower development and training programs have long been recognized as crucial for economic growth and development in developing countries. Low cost sanitation developments are still in the formative stages; training and information dissemination is therefore essential at all levels. Decision makers, planners and engineers need orientation, technicians and operators need to be trained and householders need to be informed; the impact of this on project costs is substantial however and could often best be borne by central government.

Self-Help

21. "Self-help"[1/] which (together with "community participation") has tended to become the development planner's surrogate for sound programme design has a major role in sanitation programme development. The two major objectives of self-help are:

- to reduce system costs by having the householder undertake part of system construction, operation and maintenance; and

- to achieve householder commitment through involvement, thereby improving the chances of adequate system usage and maintenance, thereby realising investment benefits.

22. Numerous self-help orientated programmes have experienced implementation problems principally due to insufficient technical support thereby stretching householders beyond their capability. In these situations the waste of resources and squandering of householder goodwill will have a long term detrimental impact on sector development.

23. In many countries the traditional method of trying to improve low cost sanitation has been for the Health Ministry to verbally exhort householders to build latrines; in a few countries, sketches are provided (generally very poorly 'engineered' structures) after which the householder is left to his own devices with no access to technical backing, materials purchasing or financing. Latrines, when built, often collapse; in some cases children fall into the pits. What is needed

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1/ Self-help inputs to sanitation programs in the context of this paper are defined as inputs by beneficiaries in the form of householder labour and materials in the construction operation and maintenance phases.

in reality is sound, well-illustrated designs (bearing in mind adult literacy rates) preferably modelled in 3 dimensions, together with access to building materials, tools, low level technical assistance finance and supervision. The level of input required will clearly vary in each country and programme. It is crucial to successful program development that self-help is not stretched beyond its capability, and that the correct level of resource support is provided to assist participants.

Socio-cultural aspects of sanitation

24. A sound understanding of socio-cultural aspects of sanitation at community, household and individual level is essential to ensure effective program design and subsequent successful implementation; this implies working in multi-disciplinary teams, and program design must include socio-cultural inputs throughout project life to enable sound implementation.

Communal Sanitation Facilities

25. Consideration has been given in many countries over the years to the construction of communal or shared facilities. With the exceptio of the well documented and unique "Comfort Stations" program in Ibadan, Nigeria and a number of Indian programs, communal facilities have either been a failure or have been rejected by the community. However since community facilities are substantially more cost effective than individual household facilities, it is felt that their development should be explored further in African programs, such as programs in which each household has a private room which it maintains.

Beneficiary Oriented Information Systems

26. The development of beneficiary and community oriented information systems is crucial to program success. It is generally agreed that health education is an essential complementary input to water and sanitation investments; emphasis is now placed on the development of broad-based information systems which will include health education and will:

- introduce the program to the community
- stimulate interest and encourage participation
- provide technical information and identify benefits
- identify financing mechanisms and sources of materials
- promote continuing facility use by all the family

A range of communication media are available for this including radio, cassette tapes, pamphlets and posters. Urban authorities, and "hardware oriented authorities (Ministries of Works) have limited experience in this area; project design in future will need to strengthen these functions.

Cost Recovery

27. Policy and mechanisms for effective administration of water supply and sanitation cost recovery are in the formative stages in many countries. A common decision criteria has been that the monthly household financial cost of water supply and sanitation services should not exceed 5% of monthly household income. Low cost projects aim to deliver services to the rural and urban poor and by implication are aimed at households near or often below the poverty threshold; cost recovery policies for this population group are intrinsically difficult to develop and administer. There is little point in developing a cost recovery policy which requires effective institutions for implementation if these institutions do not exist; therefore, institution strengthening is considered a major project objective concurrent with the development of cost recovery policies.

Typical Program Components

28. From the work undertaken in the various countries, and experience to date in the sector it is concluded that a general structure for water supply and sanitation program development should include the following key elements:

- a central steering committee comprising the ministries of departments responsible for finance and planning, health, urban and rural development, water supply and sewerage;

- sound project management, technical assistance and site investigations;

- preinvestment assessment of socio-cultural factors, and beneficiary preference;

- information systems development and community dialogue;

- access to and delivery of building materials and mass produced components, combined with financing mechanisms;

- integration of designs with sanitation related physical infrastructure development (particularly water supply, storm water drainage, and housing layouts);

- integration of program management with existing administrative structures (such as village or town councils);

- a monitoring and evaluation program;

- a program for briefing central government personnel, and training engineers, technicians, artisans and extension workers.

AREAS OF APPLIED RESEARCH

29. Applied research is needed in a number of areas, in both water supply and sanitation; significantly less has been done in sanitation than water hence the need is greater in this area. Some of of the more significant areas which must be investigated if low cost sanitation programs are to proceed with confidence are discussed below:

Latrine Emptying

30. Latrine emptying is largely unresolved; there is no recent experience of emptying well engineered latrines and the recently develop twin pit latrines have yet to complete a life cycle. There is a marked reluctance in many cultures to handle excreta (fully decomposed or otherwise) and in investigations done by the IDRC Research Project 1/ into th acceptability of alternate sanitation systems, composting was rejected as being unacceptable due mainly to a reluctance to handle fresh or decomposed excreta.

31. In both urban and rural areas, latrines are currently moved when they are full; this is clearly uneconomic when they are well built and also unacceptable to householders who have put substantial effort and finance into latrine construction. As urban plot sizes reduce 2/ it becomes both technically difficult and expensive to re-excavate pits and move superstructures. The development of twin-pit latrines will overcome the problem. The BRE (UK) is planning to evaluate pit emptying methods in Botswana, and TAG is planning to investigate this elsewhere; this work is crucial to the development of low cost sanitation.

Environmental Pollution Hazards

32. Extensive improvements of service levels of water supply and sanitation in developing countries can only be undertaken if groundwater sources are substantially developed and low cost on-site systems of excreta disposal adopted. These two strategies are in conflict in that on-site excreta disposal will in many circumstances pollute groundwater sources. Insufficient is known at present about these potential hazards in developing countries, and consideration is being given in a number of countries to assessing the impact of on-site systems on the environment in general and groundwater in particular. The recent improvements in membrane filtration techniques (making them simple, inexpensive, reliabl and rugged) together with more reliable methods of sampling (such as the Water Research Centre UK in-situ sampling device) has meant that the rigorous monitoring programmes needed can be relatively easily undertaken. TAG is working with various governments in addressing this issue but much work still needs to be undertaken.

Small Bore Sewer Design

33. Small bore shallow flat sewers are a cost-effective solution to the removal of liquids from pour flush latrines and to carry sullage in areas with high water tables or impermeable soils. Little is known about their long term performance nor have firm design criteria been established and proven.

Ventilation of Pit Latrines

34. Ventilation dramatically reduces odour and insect problems usually associated with pit latrines, but the vent pipe is expensive. Field trials are required to optimize configuration, diameter, height and material and to test and verify theoretical models, establishing clear design criteria and confidence limits.

1/ The International Development and Research Centre of Canada undertoo a Research Project into low cost Sanitation in a number of countries in 1976 to 1978.

2/ Site and service plots sizes in low income urban Africa have reduced from over 1 000 sq m in the early 1970's to currently under 200 sq m

Pit Desluding Techniques

35. Double pit systems are preferable as they avoid the need to handle fresh excreta. However there may be many situations where single pits have to be used (in dense urban areas), where vault toilets have to be emptied frequently (in areas where on-site disposal of excreta is not possible) and where double pits need to be emptied mechanically (in areas of high groundwater). Many current pit desludging methods are unhygienic or damage the pit substructure. There is a need to test and evaluate a range of existing equipment and methods for pit emptying in a number of developing countries (cost-effective and acceptable technologies are likely to be highly country specific).

Evaluation of Pour Flush Latrines

36. Pour flush latrines with either twin or single soakage pits have been found to be a socially acceptable and financially affordable form of sanitation; it is expected that large scale sanitation projects using this technology will be developed over the next decade. Technical and sociological performance data as a basis for planning these investments is very limited; this data can be obtained however by rigorously evaluating a number of large scale sanitation projects in India which use pour flush/soakage pit technology.

Sanitation Entomology

37. Most of the technologies being proposed or implemented as appropriate low cost sanitation pose a definite risk of increased fly or mosquito breeding. Pit latrines of any kind (including VIP latrines) which have squat holes rather than a water seal are prone to massive fly breeding if the pit contents are dry and mosquito breeding if the pit contents are wet. Septic tanks and soakage pits are also major mosquito breeding sites. It is essential to know to what degree various designs of latrine (especially VIP and PF latrines) promote major fly or mosquito breeding and how such breeding may be controlled or eliminated at reasonable cost.

Septic Tanks

38. To permit lower cost solutions in higher density areas septic tanks should probably be multicompartmental, accept sullage and sewage in different compartments and possibly be used in conjunction with upflow anaerobic filters. There are no rigourously tested design criteria for multi compartmental tanks. Little is known about the long term absorbtion capacity of drainfields in different soil types, for accepting either sullage or septic tank effluent.

Nightsoil Treatment Ponds

39. Performance data on waste stabilization ponds used for the treatment of nightsoil is limited. Reliable design data is essential for areas where a vault toilet system is likely to be extensively used or where sludge from VIP, PF or other on-site system needs further treatment[1]

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1. Twin pit technology will obviate this need.

"Palafitic" Area Sanitation

40. Many developing countries have extensive low income housing areas built on stilts over waterlogged ground. Excreta disposal is a formidable problem, and there is a need to develop and evaluate workable cost effective services for these areas.

Water Demand Management

41. The range of low-water usage plumbing hardware and relevant information on it which is available to developing countries is very limited. Current designs and design methodologies are based on high-income and hence high usage needs. More effective water usage through improved hardware (with possibly user education) will both make water more affordable and service a far larger portion of the community. Rigourous analytical data is required on low volume flush cisterns and pans, drain performance problems, flow limiting devices, simple taps and stop cocks, P and Strap design optimisation together with data on appropriate manufacturing methods with appropriate quality control.

CONCLUSION

42. While the need for improved sanitation and water supply in the developing countries is substantial, many Governments have a commitment to develop programs to meet these needs. Although sanitation developmen are still in the formative stage, institutional structures and technical options are emerging which it is anticipated will prove successful. Crucial to success in this new area of development will be continued high government commitment combined with sound planning, sensitive implementation and considerable support by multilateral and bilateral agencies. These efforts will produce effective programmes only if sustained householder commitment to programme development is achieved by culturally responsive design and implementation.

43. Recent work has highlighted specific areas where further applied research is needed in order to build on existing experience. The water supply and sanitation industry in Europe, both public and private sector is in a unique position to be able to contribute to this having a wide range of skills and experience readily available. Undertaking this work would represent a major contribution to the massive effort being planned by developing countries to meet the basic water supply and sanitation needs of their low income population.

Acknowledgements

The author would like to express his thanks to the many Government and Agency officials and to his colleagues in TAG for much of the information and ideas contained in this paper. The views expressed however are those of the author alone, as are the ommissions.

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FIGURE I

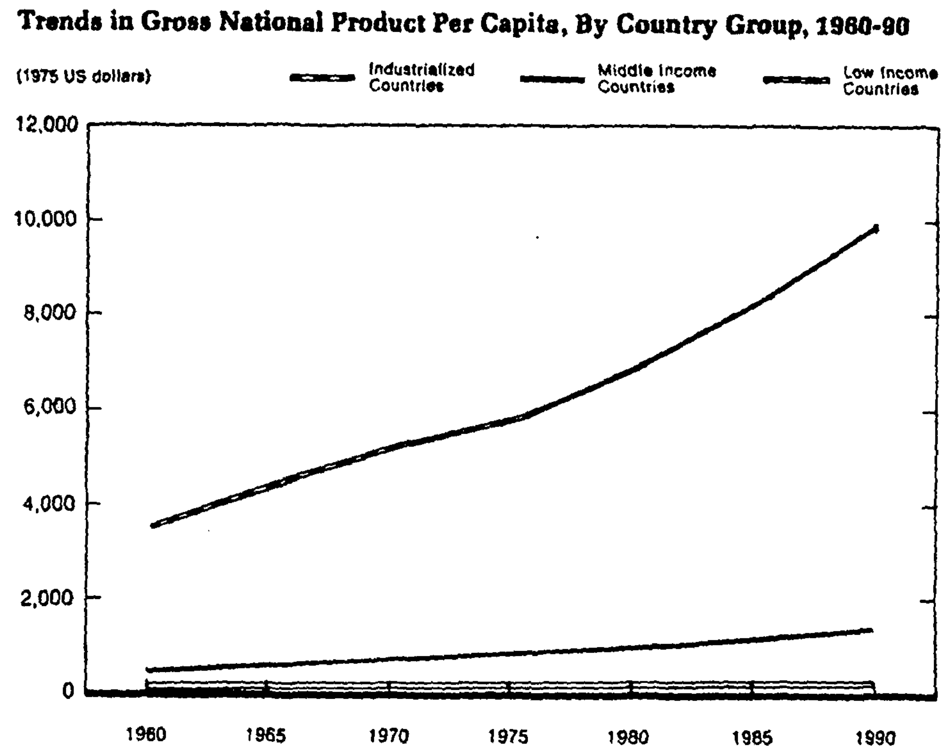
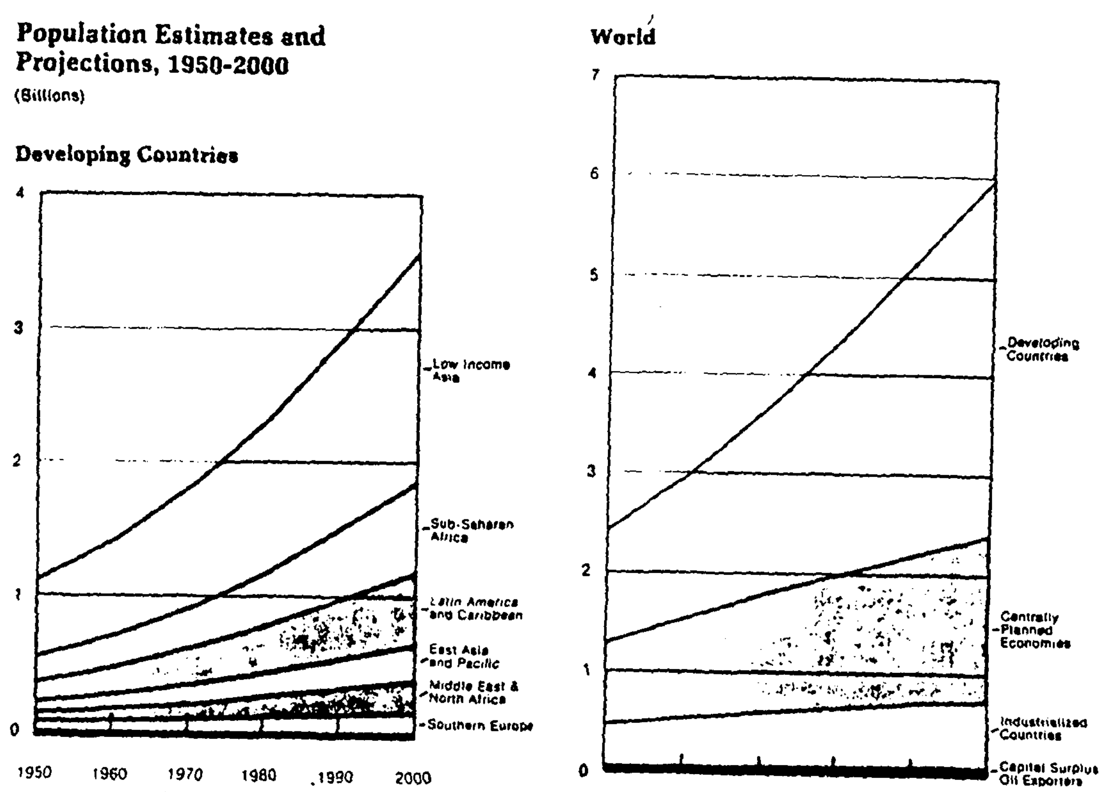


FIGURE II



SOURCE: Ref. 3

FIGURE III

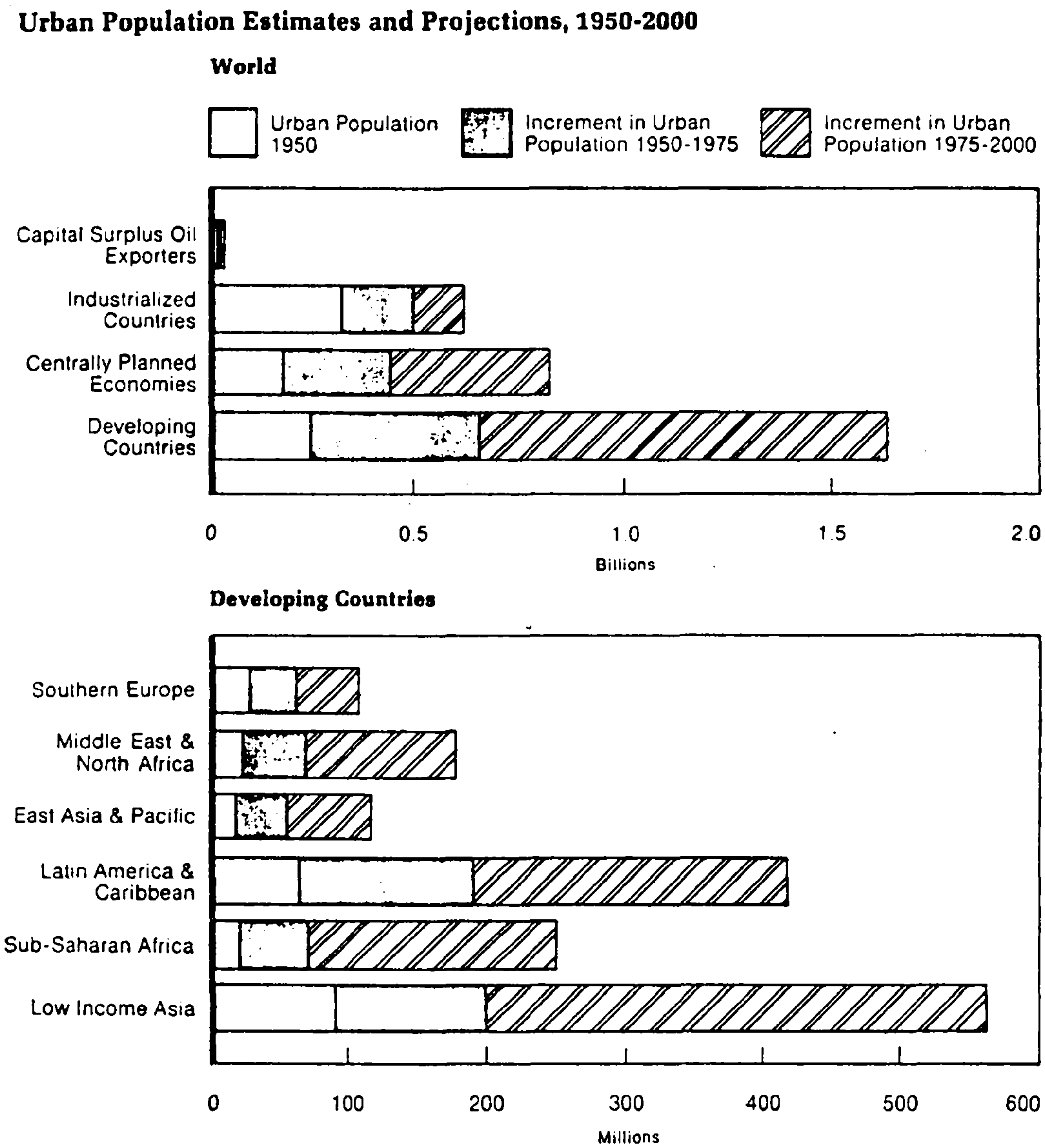


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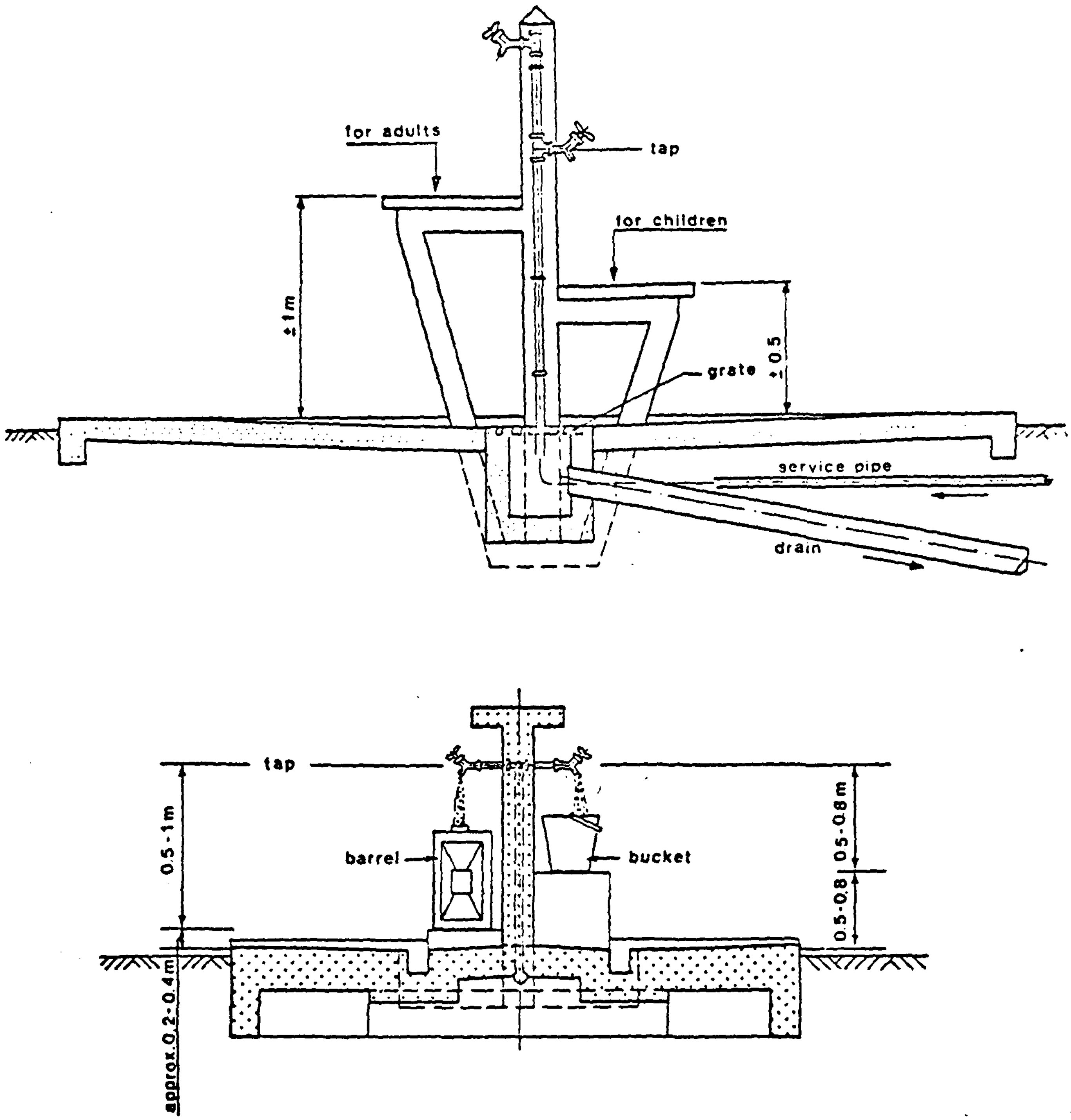
FIGURE IV

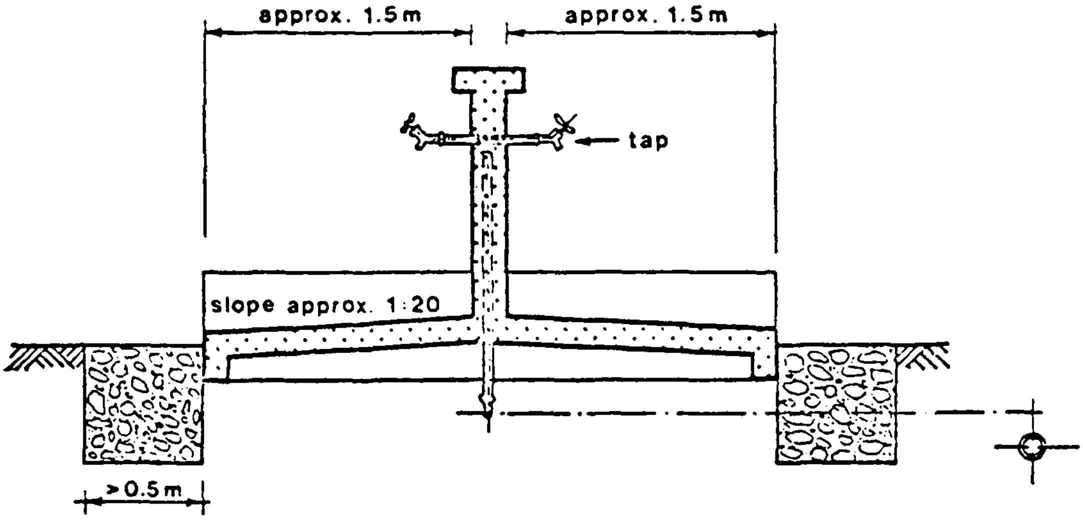


STANDPOSTS WITH RAISED PLATFORM

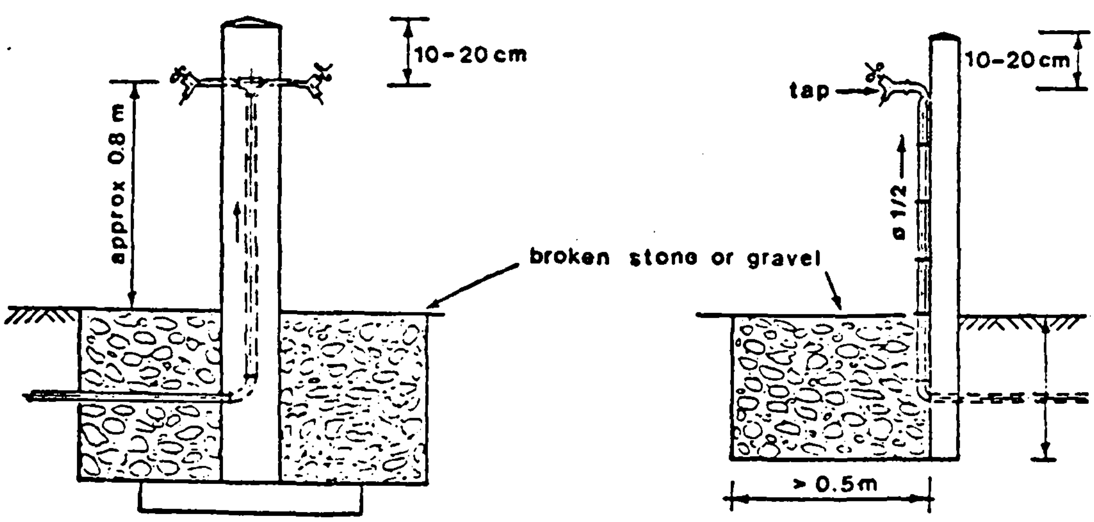
(a) to accommodate different categories of users

(b) to allow containers of different sizes to be used.

FIGURE V



A: CROSS-SECTION OF STANDPOST WITH TWO SCREW TAPS AND A CONCRETE PLATFORM



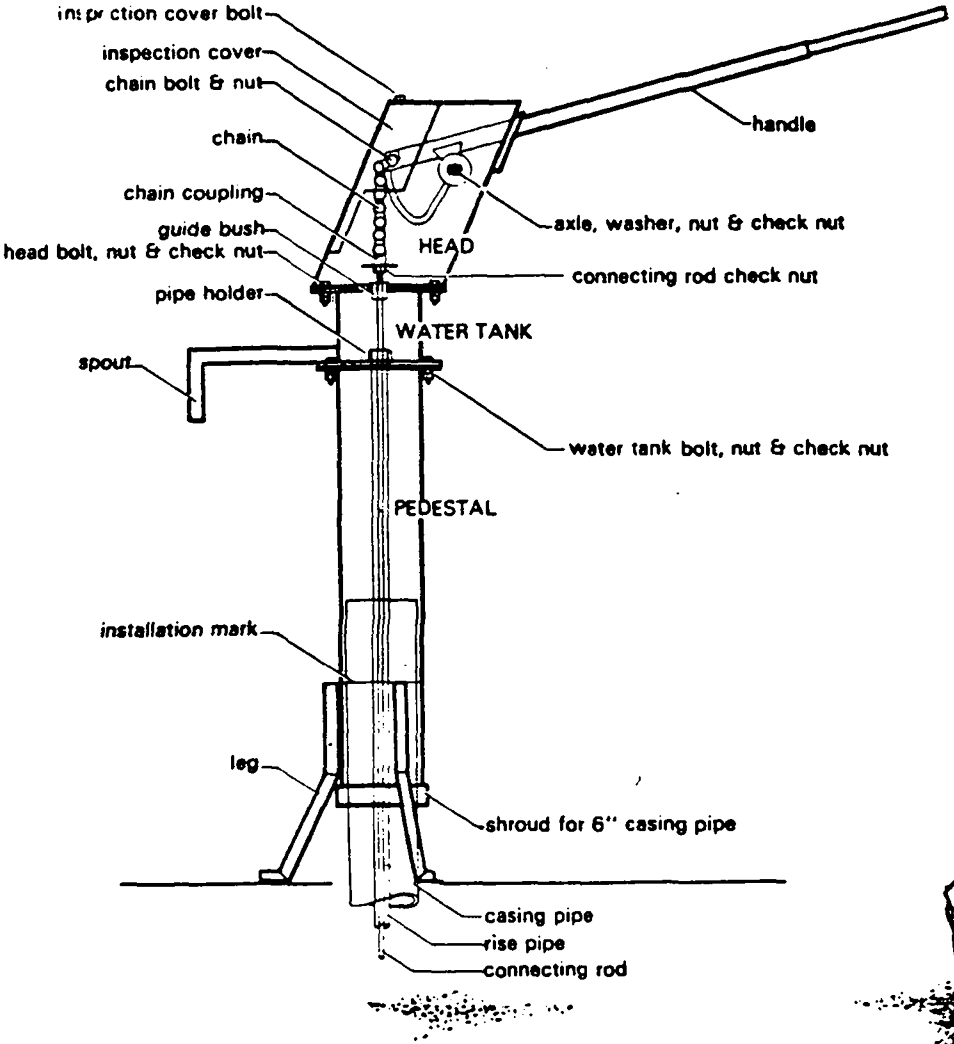
B: CROSS-SECTIONS OF SIMPLE STANDPOSTS TYPICAL OF RURAL WATER SUPPLIES

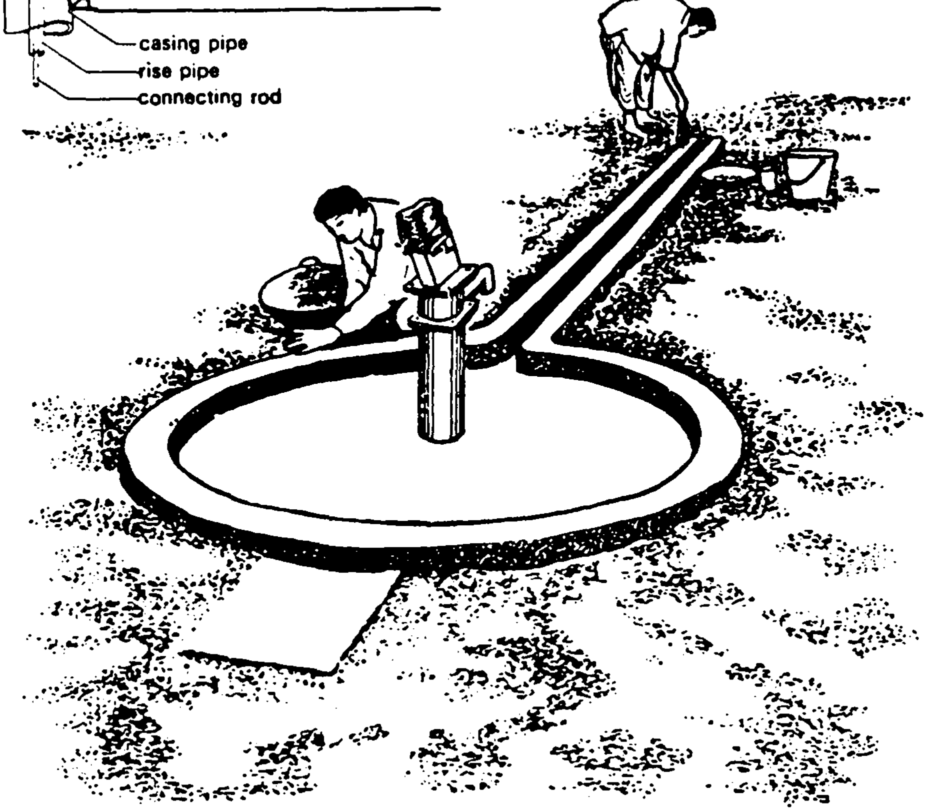
FIGURE VI

INDIA MARK-II HANDPUMP

TYPICAL DEEPWELL HANDPUMP

ELEVATION





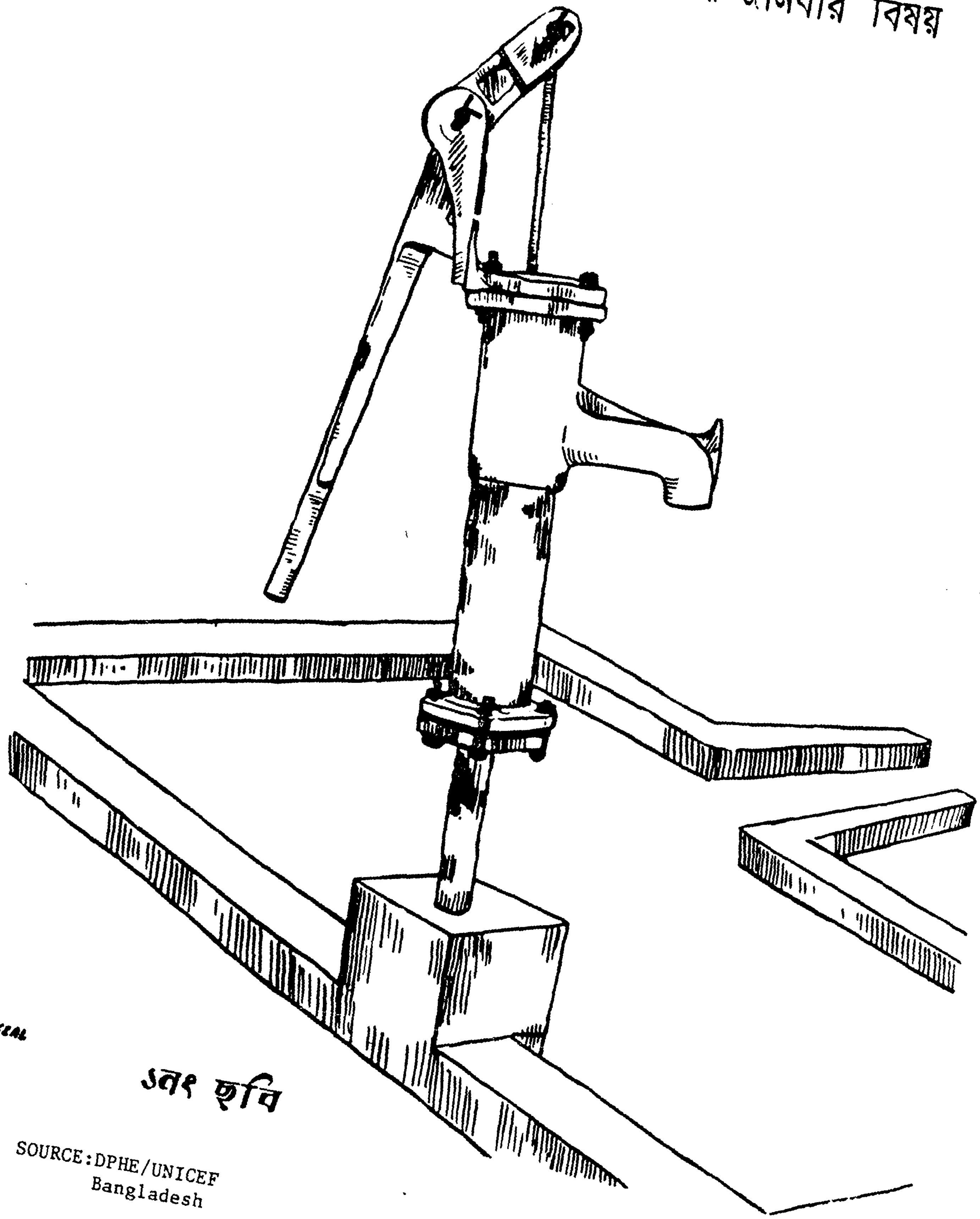
SOURCE: Unicef India

PLATFORM AND DRAIN

FIGURE VII

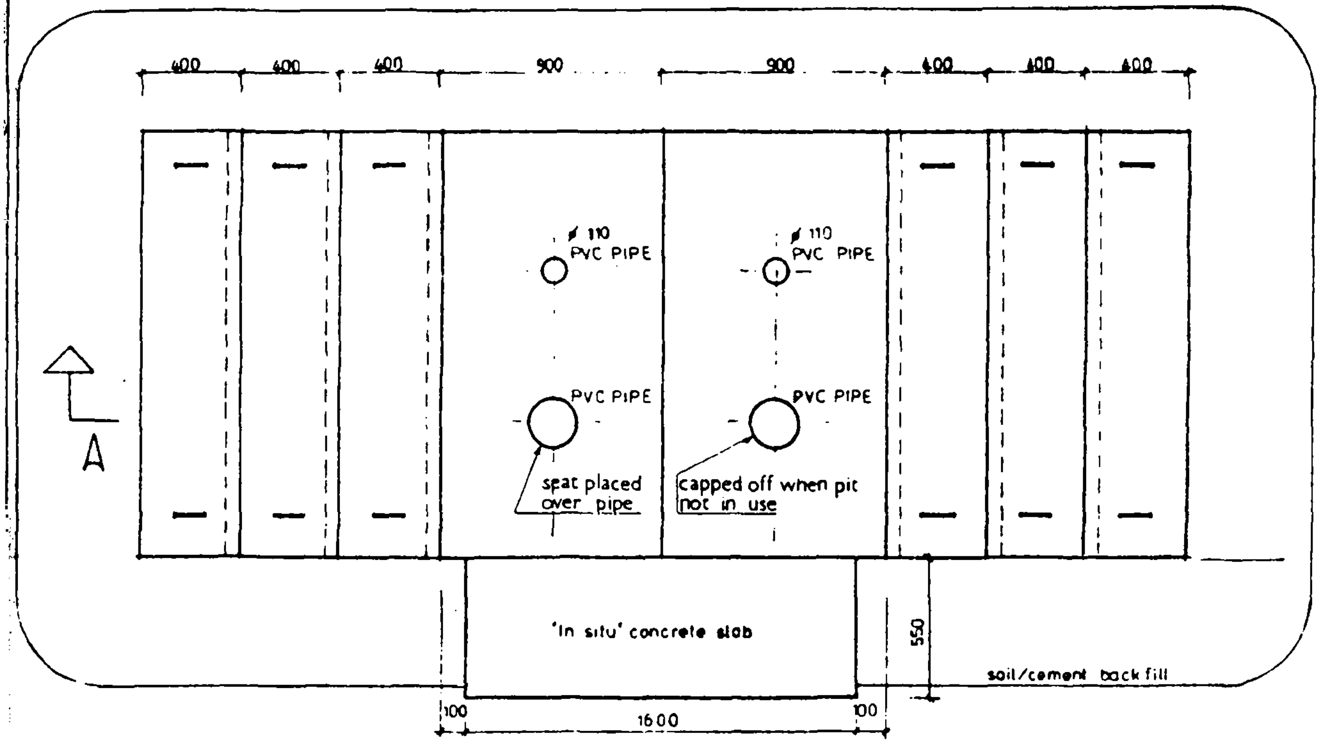
SHALLOW WELL HANDPUMP No.6

নলকূপের পাম্প মেরামত সম্বন্ধে জানবার বিষয়

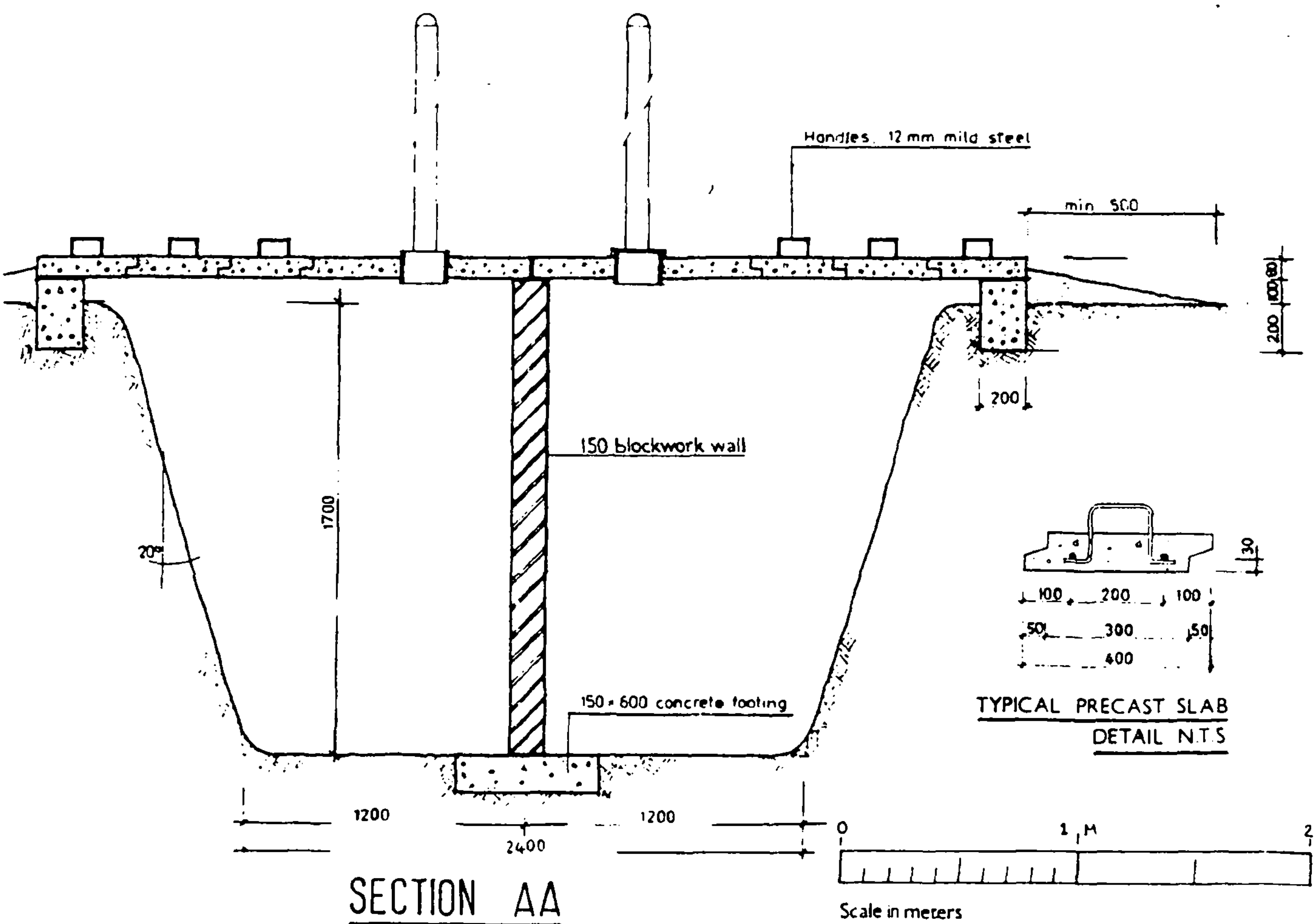


১নং ছবি

SOURCE:DPHE/UNICEF
Bangladesh

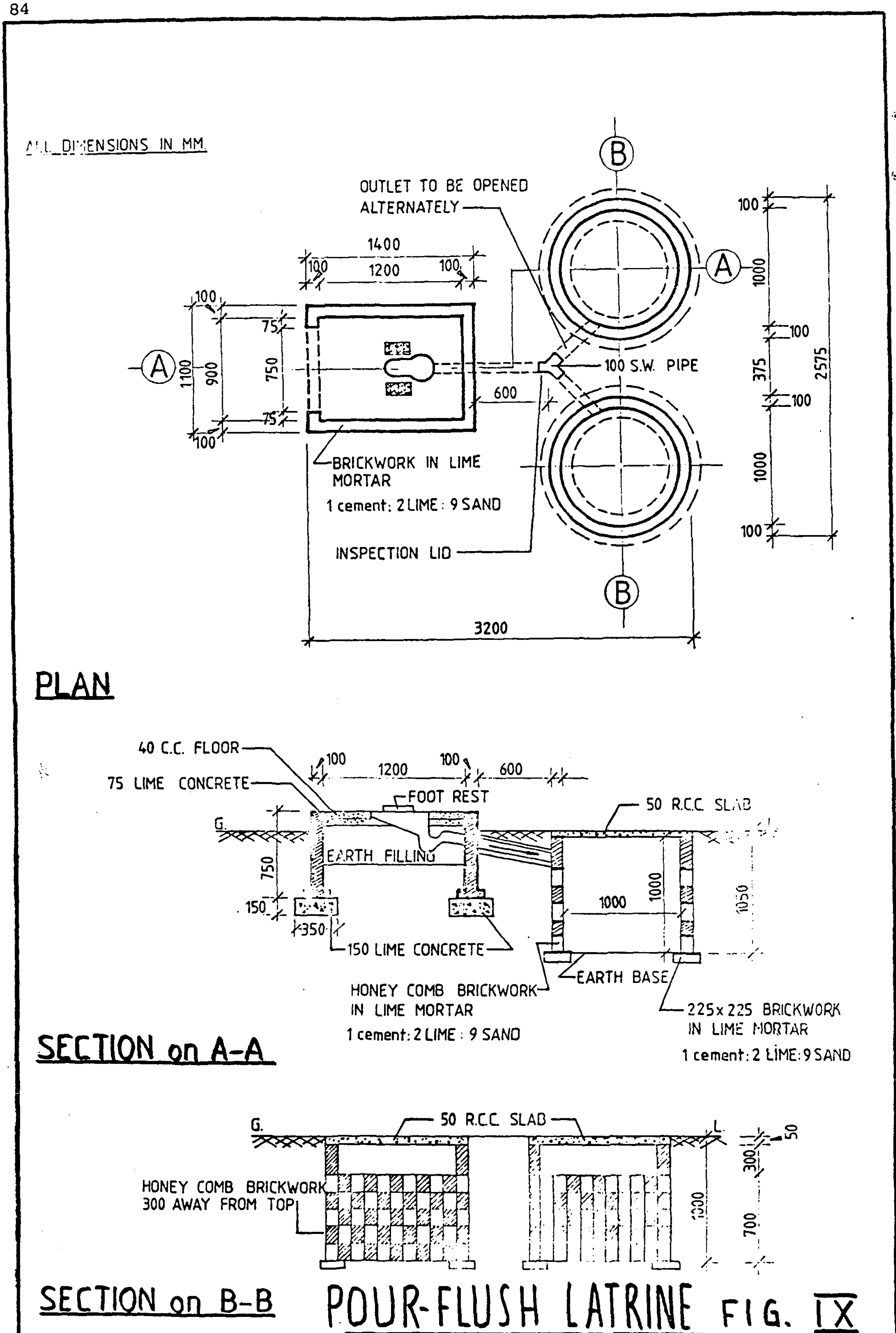


PLAN OF LATRINE



SECTION AA

REPUBLIC OF BOTSWANA	TWIN-PIT VIP LATRINE (REC II)	FIGURE VIII SHHA GABORONE JUNE 1979



POUR-FLUSH LATRINE FIG. IX

TAG / UNDP / INDIA FEB 1980

Generic Classification of Sanitation Systems

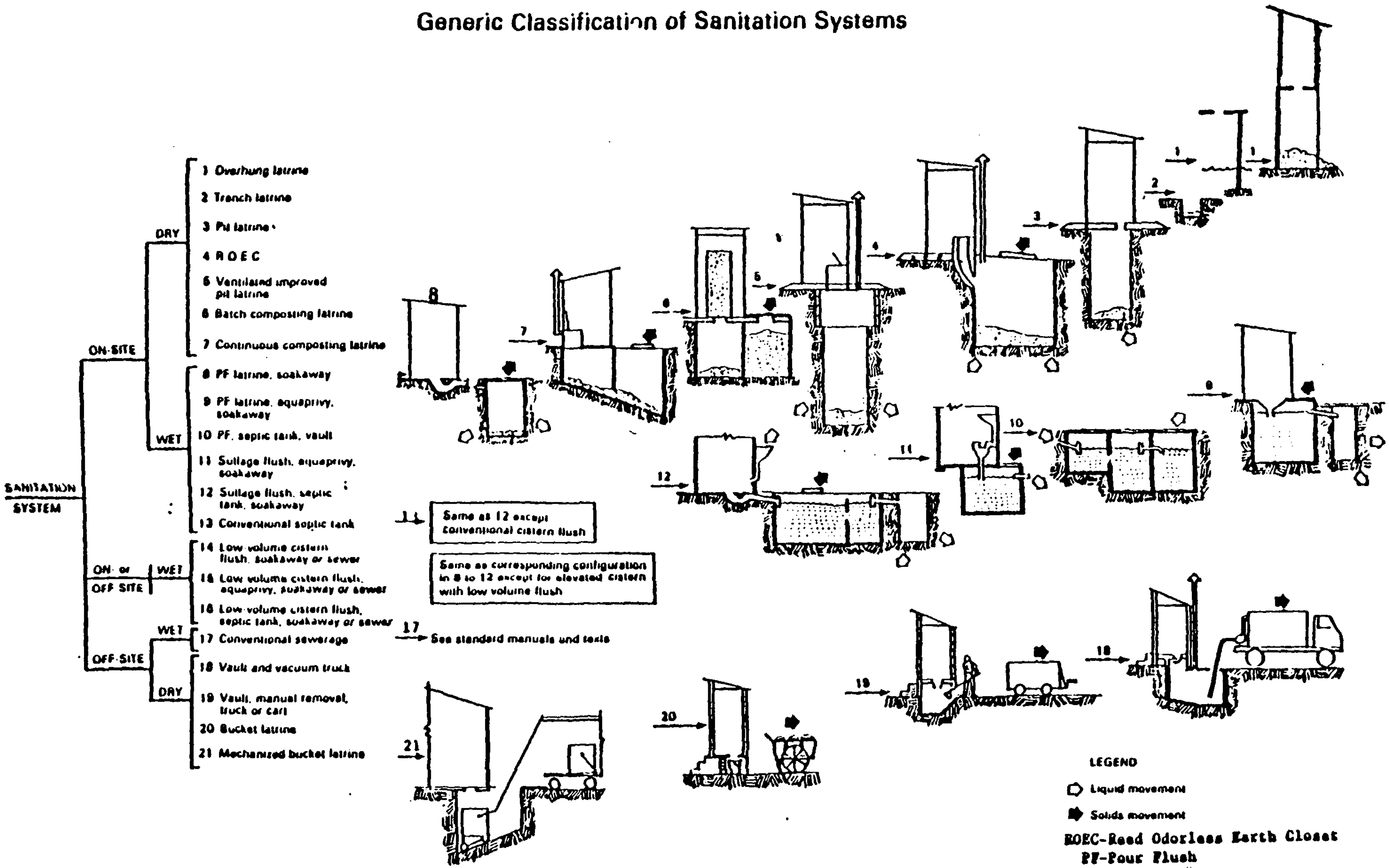


FIGURE X

Source Ref. 13

TABLE I

BACKGROUND DATA I

GEOGRAPHIC, DEMOGRAPHIC, AND ECONOMIC DATA

Country	Area square km	Population mid 1978	Population density Persons per sq km	% of Population that is rural	GNP per capita US $-1978
Botswana	570 000	0.7m	1.23	85%	620
Egypt	1 001 000	38.7m	38.7	58%	400
Lesotho	30 000	1.3m	43.3	90%	360
Nigeria	924 000	81.0m	87.7	77%	560
Ghana	239 000	11.0m	46.0	n.a.	390
Sudan	2 506 000	17.4m	6.9	85%	320
Tanzania	945 000	16.9m	17.9	88%	230
India	3 288 000	643.9m	195.8	80%	180
Bangladesh	144 000	83.6m	580.6	94%	90
USA	9 363 000	218.4m	23.3	-	9 700
United Kingdom	244 000	60.0m	245.9	-	5 030
China	9 597 000	914.0m	95.2	n.a.	460

SOURCE: REF. 1,2,3,4 and 7.

TABLE II

BACKGROUND DATA II

DEMOGRAPHIC, HEALTH AND SOCIOLOGICAL

Country	Life expectancy at birth-1977 (years)	Daily Per Capita Calorie Supply as % of Requirement 1974	Population per Nursing Person 1976 No.	% of children 0-14 years in total population 1975 %	2000 %	% of Age Group enrolled in Primary School 1976 %	Adult Literacy Rate 1975 %
Botswana	44 (1975)	n.a.	n.a.	46	44	n.a.	n.a.
Egypt	54	113	1 150	41	34	72	44
Lesotho	50	99	3 780	38	39	100	40
Nigeria	48	88	3 210	45	46	49	15 (1960)
Ghana	48	101	860	48	45	44	30
Sudan	46	88	1 260	46	42	39	20
Tanzania	51	86	3 300	47	46	70	66
India	51	89	6 320	47	35	79	36
Bangladesh	47	92	53 700	47	42	83	22
USA	73	133	150	25	22	100	99
UK	73	133	180	24	23	100	99
China	64	99	n.a.	34	25	n.a.	n.a.

SOURCE: Ref. 1,2,3 and 4.

TABLE III

LATEST ESTIMATES OF LEVELS OF SERVICE OF POTABLE WATER

SUPPLY AND SANITATION IN VARIOUS COUNTRIES

Country[1]	% of Population with Safe Potable Water		% of Population with[2] Adequate Sanitation	
	Urban	Rural	Urban	Rural
Botswana (Ref. 7)	90%	28%	30% to 50%	less than 25%
Egypt	80%	50%	n.a.	n.a.
Lesotho (Ref. 7)	65%	14%	51%	3% to 17%
Nigeria	n.a.	n.a.	n.a.	n.a.
Ghana (Ref. 6)	86%	14%	95%	40%
Sudan	49%	45%	less than 10% (Ref. 5)	less than 30% (Ref. 5)
Tanzania (Ref. 2)	68%	36%	n.a.	40%
India	83% (Ref.7)	20% (Ref. 7)	87%	2%
Bangladesh	15% (Ref. 7)	55% (Ref. 7)	40%	5%
USA	100%	100%	100%	less than 100%
United Kingdom	100%	100%	100%	100%
China	n.a.	n.a.	n.a.	n.a.

Note:

1) Unless indicated otherwise, source is Ref. 8.

2) "Adequate" is the definition used in compilation of official statistics. It does not imply that the sanitation facility is sufficient in terms of current TAG thinking.

TABLE IV

Alternative Sanitation Technologies
Financial Requirements for Investment and Recurrent Cost per Household
(1978 $)

	Total Investment Cost[a/] (1)	Monthly Investment Cost[b/] (2)	Monthly Recurrent Cost (3)	Monthly Water Cost (4)	Hypothetical Total Monthly Cost[b/] (5)	Percent of [c/] of Average Income House[hold] (6)
Low Cost						
Pour flush toilet	70	1.5	0.2	0.3	2.0	2
Pit latrine	125	2.6	-	-	2.6	3
Communal toilet[d/]	355	7.4	0.3	0.6	8.3	9
Vacuum truck cartage	105	2.2	1.6	-	3.8	4
Low cost septic tanks	205	4.3	0.4	0.5	5.2	6
Composting toilet	400	8.3	0.4	-	8.7	10
Bucket cartage[d/]	190	4.0	2.3	-	6.3	7
Medium Cost						
Sewered aquaprivy	570	7.1	2.0	0.9	10.0	11
Aquaprivy	1,100	13.7	0.3	0.2	14.2	16
Japanese vacuum truck cartage	710	8.8	5.0	-	13.8	15
High Cost						
Septic tanks	1,645	14.0	5.9	5.9	25.8	29
Sewerage	1,480	12.6	5.1	5.7	23.4	26

SOURCE: Ref. 13.

a/ Including household plumbing as well as all other on- and off-site system costs.

b/ Assuming investment cost is financed by loans at 8% over 5 years for the the Low Cost Systems, 10 years for the Medium Cost Systems and 20 years for the High Cost Systems.

c/ Assuming average annual income per capita of $180 and 6 persons per household.

d/ Based on per capita costs scaled up to household costs to account for multiple-household use in some of the case studies.

Investments Needed to Achieve Drinking Water and Sanitation Decade Targets

1. Assumptions

(a) Unit Costs

Water Supply,	Piped System with House Connections(hc)	120$/cap
	Piped System with Standpipes(stp)	40$/cap
	Rural Piped Water Supply with hc	150$/cap
	Rural Piped Water Supply with stp	40$/cap
	Rural Handpumps Water Supply hp	25$/cap
Sanitation,	Urban Waterborne Sewerage (sew) hc	250$/cap
	Urban onsite with (i) Septic Tanks(sept)	100$/cap
	(ii) Pourflush latrine or Communal Latrine(lat)	30$/cap
	Rural Waterborne with hc (sew)	250$/cap
	Rural Onsite with lat	20$/cap

(b) Service Levels

Case 1 (100% coverage using 1980 WHO Target Urban Service Standard Distribution)

Urban Water Supply
70% hc
30% stp

Sanitation
40% sew
40% sept. tanks
20% lat. & communal lat

Rural Water Supply
20% hc
40% stp
40% hp

Sanitation
80% sew
20% lat

Case 2 (80% coverage with service standard as suggested)

Urban Water Supply
40% hc
40% stp

Sanitation
25% sew
15% sept. tank
40% lat & communal lat

Rural Water Supply
10% hc
30% stp
40% hp

Sanitation
10% sew
70% lat

2. Population to be served[1/]

	Population Without Service (millions)			
	1975		1990	
	Water	Sanitation	Water	Sanitation
Urban	127	144	638	651
Rural	1 106	1 210	1 569	1 673
Total	1 223	1 354	2 207	2 334

3. Investments Required [2/]

		Unit Cost $/cap.	CASE 1 Pop. Served %	CASE 1 Pop. Served No. (millions)	CASE 1 Cost $US (billions)	CASE 2 Pop. Served %	CASE 2 Pop. Served No. (millions)	CASE 2 Cost $US (billion)
Urban Water Supply	hc	120	70	447	53.6	40	255	30.6
	stp	40	30	191	7.6	40	255	10.2
Sanitation	sew.	250	40	260	65.0	25	163	40.0
	sept.	100	40	260	26.0	15	98	9.8
	Lat.	30	20	131	3.9	40	260	7.8
Sub Total	Urban				156.1			98.4
Rural Water Supply	hc	150	20	313	46.9	10	157	23.6
	stp	40	40	628	25.1	30	471	18.8
	hc	25	40	628	15.7	40	628	15.7
Sanitation	sew.	250	20	335	83.8	10	167	39.2
	Lat.	20	80	1338	26.8	70	1171	23.4
Sub Total	Rural				198.3			120.7
TOTAL URBAN AND RURAL					354.4			219.1

1/ Calculated from information contained in UN Document E/CONF. 70/14 "Report on Community Water Supplies".

2/ It should be noted that 100% urban coverage using water supply house connections and sewerage only (i.e. no appropriate technology) would cost $329.4 billion rather than the $156.1 billion calculated with a mix of technologies.

BRUNEL UNIVERSITY

UXBRIDGE

ENGLAND

ASPECTS DE L'ALIMENTATION EN EAU ET DE L'ASSAINISSEMENT DANS LES PAYS EN VOIE DE DEVELOPPEMENT

par

GEOFFREY H. READ

DOCUMENT DISCUTABLE

Programme de Developpement des Nations Unies/Banque Mondiale

Groupe Consultatif sur la Technologie (TAG)

Projet GLO/78/006

Juin 1980

Ce document est un résumé du

texte anglais ci-joint.

INTRODUCTION

1. Afin de subvenir aux besoins essentiels dans le domaine de l'alimentation en eau et de l'assainissement, il faut faire amener quotidiennement à chaque personne entre 20 et 50 litres d'eau potable pure et facilement accessible, qui peut être utilisée pour faire la cuisine ainsi que pour maintenir le niveau d'hygiène personnelle. En meme temps il est nécessaire de prendre des mesures en vue de l'enlèvement des ordures ménagères et déchets et de l'excréta. Il y a à peu près 1 500 million de personnes (les gens pauvres de la population urbaine et rurale) qui habitent les pays en voie de développement (avec l'exception de la Chine) dont ces besoins essentiels ne sont pas observés. L'Assemblée Générale des Nations Unies a déclaré que la décénnie de 1980 devrait se consacrer à faire des efforts réels et intenses pour munir à ces besoins.

2. En 1976, la Banque Mondiale a entamé un programme de recherches, à durée de 2 ans, sur les technologies appropriées d'alimentation en eau et d'assainissement, de prix modeste, destinées aux pays en voie de developpement. A ce moment-la la Banque s'etait rendue compte que les bénéfices de son programme d'appui dans le domaine de l'alimentation en eau et de l'assainissement n'avaient pas encore atteint les pauvres urbaines et rurales. Les résultats de ce programme scientifique (Ref. 9) démontrent qu'il existe des technologies à prix bas qui fonctionnent bien, qui font concurrence aux systèmes d'alimentation en eau et d'assainissement qui sont en marche depuis un certain temps. Les résultats indiquent aussi que ces nouvelles technologies ont d'autant d'importanc du point de vue santé publique que celles dont on s'est servies jusqu'a présent.

3. Par suite de ce programme de recherches scientifiques le UNDP (Programme de Développement des Nations Unies) a lancé un projet global de programmes de démonstration dans les secteurs de l'alimentation en eau et de l'assainissement à bas prix dans les pays en voie de développement. Ces

activités font partie des préparatifs pour la Décénnie Internationale d'Alimentation en eau potable et d'Assainissement (1981-1990). Comme partie intégrale de ce projet exécuté par la Banque Mondiale, la Banque a etabli vers la fin de 1978 un groupe consultatif sur les aspects techniques (TAG). Le but en etait de faciliter la conception, l'exécution et l'évaluation de ces programmes de démonstration dans quelques pays du monde en voie de développement, qui avaient été sélectionnés d'avance.

4. Ce document résume l'histoire du travail dans ce secteur en mettant au point plusieurs idées sur la position actuelle prise par TAG, et en indiquant les études scientifiques appliquées à entreprendre.

DONNEES SUPPLEMENTAIRES

5. Il faut concevoir ces projets d'assainissement et d'alimentation en eau aux pays en voie de développement dans le cadre des facteurs socials, économiques, démographiques et climatologiques. On y remarque aussi bien de grandes variations que des similarités frappantes. Table numéro 1 par exemple montre le Soudan avec une superficie de 2.5 millions km^2 et dont la densité de la population est 7 personnes par km^2 par contraste avec le Lesotho avec une superficie de 30 000 km^2, dont la densité de la population est 43 personness par km^2 (le Royaume-Uni a une superficie de 244 000 km^2 et une densité de population de 246 personnes par km^2). Les pays en question ont des populations plutôt rurales (généralement au-dessus de 85% des gens habitent la campagne) de même qu'un Produit National Brut assez bas d'en dessous de 500 dollars par personne (en 1978 au Royaume-Uni le Produit National Brut fut 5 000 dollars par personne).

6. L'expectance de la vie est généralement en dessous de 50 années et une grande partie de la population est mal nourrie ayant acces à des services médicaux, curatifs et preventatifs, de qualité inférieure. Le taux de mortalité infantile est généralement au dessus de 120 par milles naissances, et dans quelques pays dépasse 180 par 1 000. La tristesse et la misère humaines qui en

résultent ne peuvent avoir qu'un effect débilitant sur la société, aussi bien que sur les familles individuelles. Entre 40% et 50% de la population a moins de 14 ans et moins de 5% va à l'ecole primaire. Le degré d'aptitude à lire et à écrire des adultes est très bas (moins de 40% des gens savent lire et ecrire). (Voir Table numéro 2 pour le résumé.)

7. Les services existants pour l'alimentation d'eau potable et pure et pour l'enlèvement et la destruction de l'excréta d'une manière efficace sont souvent variables mais de basse qualité (Table 3). En particulier, l'alimentation en eau dans les régions rurales est insuffisante et les facilités pour l'enlèvement de l'excréta n'existent presque pas. Dans les régions urbaines le niveau de fonctionnement de ces systèmes favorise exclusivement les familles à hauts revenus dont la consommation est bien au dessus du niveau des besoins essentiels. En plus, plusieurs d'entre eux profitent de services gratuits tandis que les pauvres doivent, ou bien payer, ou bien s'en passer complètement.

8. Tous les pays en question ont des revenus bas. Les prospectives d'amélioration du Produit National Brut mesuré par personne sont mauvaises si on les compare avec les pays industriels, comme par exemple le Royaume-Uni ou les Etat-Unis; et ceci parce que le développement economique est plutôt lent par comparaison avec la croissance rapide de la population. Figure numéro 1 explique cette tendance en montrant l'etat actuel et projeté du Produit National Brut et la grande différence qui existe entre les nations. Figure numéro 2 indique l'accroissement sensible de la population et compare la situation dans le passé avec les prédictions pour l'avenir. Figure numéro 3 souligne un aspect très important de cette augmentation - la tendance vers une urbanisation plus complète comme exemple citons la partie de l'Afrique en dessous du Sahara ou l'on constate que la population urbaine estimée à 80 million en 1975 (à peu pres 21% de la population totale) s'élargira à tel point qu'elle dépassera 250 million de gens en 2000 (à peu pres 40% de la population totale). Ces pays montrent des variations considérables en ce qui concerne la religion et la vie politique, economique, sociale et culturelle. Ces considérations exerceront

une influence sur les préparatifs des projets d'alimentation en eau et d'assainissement, de même que sur l'exécution de ces programmes.

CONDITIONS DE DEVELOPMENT

9. Les deux programmes initiés par la Banque Mondiale et discutés préalablement (Ref. 9, 13, 14, 15) ont établi toute une gamme de technologies et systèmes identifiés pour leur capacité de rendre un service efficace afin d'améliorer le niveau de fonctionnement des systèmes d'alimentation en eau et d'assainissement dans les pays en voie de développement. Les conclusions importantes ont été bien analysées: l'observation la plus frappante c'est qu'il existe toute une gamme de technologies convenables, et à prix raisonnable, qui fonctionnent assez bien et qui sont acceptées par la population (mais dans la plupart des cas elles n'ont pas été suffisamment développées).

10. Les technologies de services d'eau comprennent non seulement les alimentations tuyautées aux demeures individuelles et les installations a compteur d'eau (les frais moyens sont estimés a 120 dollars par personne); elles comprennent également:

- robinet dans la cour
- "communal stand posts" (Figures numéro 4 et 5)
- puits profonds et bas de fond à pompes à main (frais estimés a 25 dollars par personne (Figures numéro 6 et 7)
- puits

11. Les technologies conçues pour l'assainissement (à but d'enlever l'excréta) ne se limitent pas aux systèmes de "water-borne sewerage, bucket latrines" ou rien du tout, comme pensent beaucoup des gens professionels. Il existe toute une gamme de systèmes alternatifs, d'un fonctionnement sur, parmi lesquels:

- "Ventilated Improved Pit Latrines" (V.I.P. latrines - figure numéro 8)
- "Pour Flush (P.F.) latrines" (figure numéro 9)

- "Sewered Pour Flush latrines"
- Communal latrines"
- "Septic tanks"
- "Aquaprivies" et
- "Waterborne sewerage".

12. Figure numéro 10 nous donne une classification générique des systèmes sanitaires. Table numéro 4 étudie en détail la comparaison des technologies due point de vue ressources fiscales et démontre les frais excessifs du système d'égouts transporté par eau,calculés par personne, par comparaison avec des systèmes alternatifs et souligne l'importance des considérations financières.

RECHERCHES APPLIQUEES

29. Dans le domaine de l'alimentation en eau et de l'assainissement l'application pratique de ces recherches théoriques est essentielle vis-à-vis des différents systèmes. Moins de progres est évident dans le développpement de systèmes sanitaires que de systèmes d'alimentation en eau; donc les enquêtes scientifiques y sont plus pressantes. Quelques aspects à etudier pour que les programmes sanitaires développent bien sont mentionnés ci-dessous:

- "Latrine Emptying"
- Risques de la pollution de l'environnement
- "Small Bore Sewer Design"
- "Ventilation of Pit Latrines"
- "Pit Desludging Techniques"
- "Evaluation of Pour Flush Latrines"
- "Sanitation Entomology"
- "Septic Tanks"
- "Nightsoil Treatment Ponds"
- "'Palafitic' Area Sanitation"
- L'organisation de la demande pour l'alimentation en eau

TABLE 17.1

Frais estimés 1/ & 2/ des placements néc=ssaires à combler le déficit provenant des installations actuelles d'alimentation en eau et d'assainissement dans les pays en voie de développement

hc. = "house connection"
sew. = "sewered"
lat. = "Latrine"
stp. = "standpipe"

			EXEMPLE 1			EXEMPLE 2		
		Prix unitaire $ par personne	Pop. servie, numéro %	(millions)	Frais $ US (billions)	Pop. servie, numéro %	(millions)	Frais $ US (billions
Alimentation en eau urbaine	hc	120	70	447	53.6	40	255	30.6
	stp	40	30	191	7.6	40	255	10.2
assainissement	sew.	250	40	260	65.0	25	163	40.0
	sept.	100	40	260	26.0	15	98	9.8
	lat.	30	20	131	3.9	40	260	7.8
sous-total urbain					156.1			98.4
Alimentation en eau rurale	hc	150	20	313	46.9	10	157	23.6
	stp	40	40	628	25.1	30	471	18.8
	hc	25	40	628	15.7	40	628	15.7
assainissement	sew.	250	20	335	83.8	10	167	39.2
	lat.	20	80	1338	26.8	70	1171	23.4
sous-total rural					198.3			120.7
TOTAL URBAIN ET RURAL					354.4			219.1

1/ Il faut en conclure que l'alimentation en eau tuyautée au demeure même et en plus, seulement le système d'égouts (c'est a dire pas de technologie appropriée) coûteraient 329.4 billions de dollars. Le calcul pour des technologies mixtes serait 156.1 billions de dollars.

2/ Les frais estimés ci-dessus portent seulement sur la provision de facilités et non pas sur l'enseignement des gens du point de vue santé publique.

3/ SOURCE: Ref. 16.

CONCLUSIONS

42. Plusieurs d'entre les Gouvernements nationaux se sont engagés à développer des programmes afin de parer aux besoins urgents de systèmes d'assainissement et d'alimentation en eau plus efficaces dans les pays en voie de développement. Quoique les desseins de systèmes sanitaires ne sont pas encore tres avancés, le choix d'entre les systèmes du point de vue technique devient évident, de même que les institutions qui sont à même de diriger ces entreprises. Pour que ces tentatives soient couronnées de succès elles ont besoin de la coopération soutenue des gouvernements et de projets bien recherchés et faisables qui seront exécutés soigneusement. Elles ont également besoin de l'aide considérable offerte par les agences bilatérales et multilatères. Les programmes ne seront efficaces que si l'on obtient la coopération de chaque individu et de chaque famille par suite de l'installation de systèmes sensibles à la culture de la société.

43. Des études récentes ont démontré des lacunes dans le domaine des recherches appliquées ou il faut supplémenter les données deja acceptées. Les organisations européennes qui s'occupent des problèmes posés par l'alimentation en eau et l'assainissement dans les secteurs publiques et privés, ont dès maintenant l'occasion unique de faire une vraie contribution à la résolution de ces problèmes, par leur savoir et leur expertise. Si elles entreprennent ce travail elles contribueront aux initiatives importantes projetées par les pays en voie de développement pour apaiser les besoins essentiels de systèmes d'assainissement et d'alimentation en eau destinés à la population à bas revenu.

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A two-day seminar on current research and future needs and objectives

Discussion session on Paper 4, June 3rd, 15.00 - 15.30

Chairman : Mr. P. Juple, Geberit AG, Switzerland

Mr. Juple : I now open the discussion on Mr. Read's paper about sanitation problems for developing countries.

Mr. Olsson : Are you responsible for the development of the required technology within the developing countries themselves, or with manufacturers in the developed countries, in Europe for example?

Mr. Read : The things that I talked about in my paper have generally come out of this World Bank project. I don't say that they are exclusive World Bank ideas, but they are some of the ideas that have been generated, particularly on the sanitation. Many people have looked at water supply for some considerable time; for example in the U.K., the Building Research Establishment, the Intermediate Technology Development Group, Loughborough University, the Ross Institute where I physically sit, Imperial College. However, very few organisations have been looking at sanitation options. This is partly due to the fact that it is relatively unfashionable; it is not as glamorous as water supply, because engineers prefer projects like big dams and related water supply, whereas excreta disposal is not the glamorous end of the problem. Much of the excreta disposal work has been done by the Ross Institute and Leeds University and BRE. The second stage of the project is to develop and put into practice some of the ideas on a fairly large scale. For instance in India where this Bank Group have produced this working drawing of the pour flush system. The Bank is now at the stage, through UNDP, of producing drawings of this system to get them built on a very big scale. We think that the technology is sufficiently attractive and the costs sufficiently affordable to provide them on a big scale. The background of it is that in development work from the World Bank's point of view, there has not been any means of providing sanitation until some of these ideas were

Mr. Read cont. developed. A number of different people have been working on it, for instance in Norway, Sweden and Switzerland. However the backlog of work is so substantial that it probably needs someone with the muscle of the World Bank and probably the European Development Fund, which is now quite heavily involved in the sector development, to start developing the more feasible ideas.

Mr. Ovesen : You mentioned that you saw a role for the western research people to help. I would like you to elaborate a little more, as we in the CIB have had some meetings with the World Health Organisation (WHO) and we have tried to find a role for CIB within that context. What I got from these meetings was that we already have the technology and the people, and what we need is money for the projects. We do not have a need for western research potential. Could you tell us a little more about that, because I think many CIB countries are willing to carry out research within this field, but it is difficult to get definition of the work?

Mr. Read : I cannot speak for WHO, obviously, and I cannot speak for the World Bank, but I can speak for the project on which I work. Clearly we do not know all that we need to know. If you talk to anyone working on water and sanitation for developing countries, you will find that there are still large numbers of things that we do not know the answers to. For example, hand pumps; very little is known about the performance of hand pumps. The technology is simple, and the design has changed little since the 1930's, except for one or two, such as the Indian Mark II hand pump. The Consumers Association in this country are carrying out a hand pump testing programme to test the effectiveness of a whole range of hand pumps, so that the Agencies and the Governments concerned can say that we have rigorously tested these six hand pumps, these three we can just discount, these two we can redesign and this one looks very good for this particular situation. In the same way I've identified these dozen or so different areas on sanitation where we just do not know all the required information. For example, septic tanks; we design septic tanks with two compartments, but perhaps there should be three compartments; what is the pathogen performance and what is the optimisation of two versus three compartments? Should we put anaerobic upflow filters on the downstream end? What are the cost implications? What are the maintenance implications? Similarly with the shallow flat sewers, we are writing a working paper at the moment on the design of pour flush latrines, and clearly with a high water table and a soil which doesn't leach, they are still a very attractive proposition, and when you cost up shallow flat sewers, Mr. Read cont. making very dangerous assumptions, they are highly attractive. You can get 20,000 people served if you know the peak factors, if you know what 'n' values to assume on slime and effluent in the sewer, and if you confidently assume that you do not need manholes at more than 250 metre centres? These things we do not know. So this would be a typical area where CIB could assist. We've got to get the excreta off the streets. A major area that needs to be tackled is ground water polution.

Mr. Ovesen : Would you advise us to make closer contact with the World Bank rather than WHO?

Mr. Read : Speaking only in the context of the World Bank, we could formally approach CIB to discuss informally one or two areas which any one of you might be able to look at in detail. Perhaps we could discuss this and make some proposals later in the conference.

Dr. Swaffield : I think that this would be very valuable, and I feel that our proposals should be made known to the other members of CIB W62.

Mr. Read : One point that I would make is that we have rather emphasised the sanitation aspects of the problem, but a great deal of what we have discussed still involves water supply. There will be large urban areas which will have water-bourne sewerage or something, but to reduce the water consumption from 70, 90 or even 120 litres/person/day down to what is required which is something like 50 or 60 litres/person/day, means that you would serve twice as many people at the same investment. Therefore the whole water management aspect needs to be considered.

Mr. Carson : Would it perhaps be possible to add these additional items as a corollary to your paper for inclusion in the Proceedings of this seminar, or perhaps all the items will be included in the Proceedings anyway. This would then give us the opportunity to follow up some of the items.

Mr. Read : Yes certainly, but I will discuss the method of inclusion in the Proceedings with Dr. Wakelin.

Mr. Uujamhan : I come from one of these developing countries, namely Nigeria. I have myself used the pit latrines of the type that you described, and there are three technical points that I wish to ask about.

Mr. Uujamhan cont.

i) Seepage from the pit of the latrine into the ground water, which is likely to be used for drinking, is obviously a major risk. Has your group or any one else investigated this problem?

ii) What are your recommendations as far as development is concerned? Should the countries concerned develop along the lines you have suggested or should they accept the proven methods used in the western countries?

iii) Do you sponser research in the developing countries themselves?

Mr. Read : I will answer those questions in turn.

i) The whole nature of on-site disposal or on-site sanitation is that you will get leaching into the ground of the liquids, so it is a question of what is the relationship between time, temperature and quality, and the hydrogeology of the aquifer, and what you are using the aquifer for. If you look in the old books of the early 1900's, and even more recently, about pit latrines, there are rules of thumb saying don't locate your latrine near a well, for instance. This is obvious, but, what I'm saying is that we need a rather more vigorous analysis of the problem, so that we can say that there may be six different types of on-site situation related to hydrogeology and soil effective size. Under a soil effective size of so much you will get such good attenuation that you remove viruses and bacteria, the protozoa will certainly go out, but you will still get nitrates through. Over and above a certain soil effective size you will get viruses but no bacteria. And over and above a certain size, where you get fissure flow, you have to be extremely careful and you cannot go for an on-site solution if you are going to use the ground water. What we are saying is that with the whole nature of on-site disposal, you are putting pathogens and inorganics into the soil, and you are using the soil as a natural process. What we neec to do is plan water and sanitation together, and to kno enough about the movement and relationship between pathogens and on-site systems to ensure that the metho adopted does not make a technical mistake and cause more problems than it is actually solving. In the wors case we may have to go for shallow flat sewers to take away the effluent and seal all the latrines off. It all comes down to the site, the affordability, and the cost of the solution looked at. Each site has to be looked at on its own merits.

Mr. Read cont.

ii) There are no instructions as to what development should be. Each country should work out its own solution. What is said here is that the services of water supply and sanitation must be planned together, because one affects the other enormously. The country's solution, and the affordability solution and the cultural solution, is relatively specific to that situation. Certainly I would say that the Western technology is pretty inappropriate. It just so happened that Victorian engineers got quite into waterborne sewage to drive excreta down the pipes. It was a bit unfortunate in some ways. The BOD (Biochemical Oxygen Demand) is based on the average length of time it takes for rivers in the U.K. to travel to the sea. The average treatment works doesn't do any pathogen removal. Pathogen removal is a nonentity. It takes out the BOD.

As you probably know, Nigeria has many conventional sewage works that just don't operate at all, they are derelict, as does Egypt, as do many countries, even in Britain. Ponds work very well, and therefore for treatment, ponds are the answer if you have to go for waterborne sewage. However, each case is specific.

iii) Essentially our work is done in the developing countries, and most of our time is spent abroad, working with the governments, working with personnel in these countries. Many people are still thinking of high cost solutions, but they are coming round. People are becoming more interested in affordable solutions as something rather than waterborne sewage or nothing. That is the present option. The work is not being done in isolation here, much of the work is done in the field, also trying, where possible, to work with local research institutions. In many countries this is not a problem, but in some of the southern African countries, there aren't the necessary institutions.

Mr. Bokor : We were talking earlier about the Oxfam sanitation. Could you elaborate on where you see this fitting in?

Mr. Read : Oxfam are a British based disaster relief organisation. In disaster situations they help to provide nutrition, water supply, sanitation, housing, medical facilities and so forth. They have developed an interesting sewage treatment package, based on a communal latrine block, piped to huge butyl rubber tanks placed in series. They lie out in the sun and you get anaerobic digestion taking place in these sausage-like bags which stabilises the effluent. They are very good for

Mr. Read cont. what they are designed for. They are not designed to be a long term solution. They get all the excreta off the streets and get people using one place. There is not much pathogen removal. There is a tendency for them to become permanent as refugee camps tend to become permanent with resultant sludge problems. They are a very good short term solution and can be operational within two days and can provide short term sewage disposal for perhaps 25,000 people.

End of Tuesday's afternoon session

DRAINAGE AND WATER SUPPLY FOR BUILDINGS

A TWO-DAY SEMINAR ON CURRENT RESEARCH AND FUTURE NEEDS AND OBJECTIVES.

JUNE 3 AND 4 1980

PAPER NUMBER 5.

APPLICATION OF LABORATORY TEST TECHNIQUES TO BUILDING DRAINAGE DESIGN

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in conjunction with CIB W62.

APPLICATION OF LABORATORY TEST TECHNIQUES TO BUILDING DRAINAGE DESIGN

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SUMMARY

A comprehensive test programme undertaken at Brunel is described, aimed at providing a basis for the application of laboratory testing techniques, concerned with the transport of solids, to the design of internal building drainage systems.

The fundamental empirical relationship between solid velocity, pipe length, gradient and w.c. flush volume applying to branch systems is restated and shown to have wide application. The monitoring of installed drainage systems is described and the solid transport mechanisms are shown to be identical to those observed with model solids in the laboratory.

One of the major objectives of a drainage research programme must be to provide improved design guidelines that will lead to improvements in installed systems, judged in terms of economics of installation and usage or perhaps in terms of reduced visual intrusion. This link between research and design needs in the drainage area may be clearly seen in the past influences of research on the design and installation of in building systems. From the 1920's the impact of research on the problems associated with vertical stack flow and pressure oscillations can clearly be seen in present day designs; in particular the single stack system is totally dependent for its operation on a fundamental understanding of the mechanisms of fluid flow provided through planned research.

A parallel concept is the provision of laboratory test techniques that will enable designers to improve current systems to take into account new criteria imposed either by economics, changing building design practice or legislation. Current examples of this need may be found in the discussions relating to water conservation and its implications for drainage system design.

Although, as mentioned, research findings have been central in the development of current designs, the research has to a large extent been concerned with the effect of water flow through the drainage system. Obviously this is of prime importance due to the need to guarantee trap seal retention throughout a system, while system loading has always been regarded as a flow rate orientated topic.

The main reasons for the lack of fundamental work on the transport of solids in drainage systems may be identified as those problems inherent in any observation of system performance and the impossibility of defining solid parameters under equivalent laboratory conditions. Interest in the mechanisms of solid transport has grown in recent years, with a number of papers reporting work now being available. The importance of solid transport is now more widely recognised, possibly as a result of the introduction of water conservation criteria. Clearly the effects of reduced flush volume w.c. operation are not concentrated at the w.c., although this will undoubtedly lead to a reconsideration of w.c design, but affect the whole drainage system, particularly in terms of the probability of the formation of solid deposits along the drain, with consequent maintenance cost implications. These problems will of course be magnified in the long internal branch designs common in many large buildings, such as hospitals.

The purpose of this paper then will be to review the work available on solid transport and to outline the progress made towards providing laboratory based techniques to illustrate the effect on solid transport efficiency of any system design changes. From a review of the available research two main problems may be identified as having delayed progress in this area in the past, namely a sound basis for a choice of suitable solid model and the need to develop instrumentation suitable for measuring solid velocity in the drain.

Wyly (1) briefly considered the transport of waste solids, employing commercially available diapers, however the flush volumes employed were to U.S. standards, rather larger than U.K. practice. Similarly his choice of model was arbitrary and no attempt was made to either link the results to site observations or to measure solid velocity. Webster and Lillywhite (2) have recently reported work undertaken some 10 years ago involving the flushing of 25 mm cubes of s.g. 0.9 to 1.6 along clayware and pitchfibre pipes at 1/40 to 1/120 gradients. Unfortunately due to the lack of any instrumentation to record solid motion, and the arbitrary choice of solid that could not be related to any likely practical waste material, this work failed to recognise the governing relationships of solid transport that link velocity to pipe gradient, material and water flow conditions outlined in this paper and previous reports based on the Brunel research programme (3).

Matsuo and Tsukagoshi (4) also reported work on solid transport, utilizing PVA (polyvinyl alcohol) sponge models, however no velocity measurements were undertaken and the pipe system employed, in 100 mm glass, was too complex to allow any generalized conclusions to be made.

Against this background the current drainage research programme within the Department of Building Technology at Brunel was initiated in 1974 following a request from DHSS to investigate problems caused by solid deposition in the long horizontal drainage systems then becoming more common in the large new hospitals.

It was decided to attempt to tackle the two main problems identified, namely instrumentation development and the derivation of a basis for model solid choice. The velocity measurement instrumentation proved rather the easier of the two problems to solve. By initially utilizing transparent UPVC pipe it was possible to develop a family of photoelectric cell/light source systems that have been the subject of development and refinement at Brunel over the past few years and which have provided the data-base for the relationships identified. The initial concept was that the solid in passing over the light source reduced the voltage output of the photocell mounted diametrically opposite, thus producing a voltage change that could be displayed as a continuous trace on a penrecorder or used to trigger an electronic counter, subsequent photocell units being used to terminate the timing sequence. Development of use with opaque pipes led to the mounting of each photocell and light source in one unit on the crown of the pipe. Changing light reflections received by the photocell as solids passed beneath a "window" cut into the crown of the pipe again provided the voltage changes required to utilize either the pen recorder or timer options above.

A development of this system is currently in use in the site observations described later in this paper. In this application full use is made of the penrecorder option to provide data on multiple solid tansport. The most recent development in this instrumentation family is the introduction of a small computer acting as both a data logger and a data handling device that will accept signals from a series of photocells and will allow rapid presentation of test results as solid velocity versus length profiles on a VDU or printer output.

Solid choice was a more complex problem. Initially it was decided to utilize a single maternity pad as a model solid having dimensions 300 mm by 60 mm x 20 mm with a water saturated weight in the 250 to 280 g range. Obviously the solid model choosen had to be cheap, repeatable in size and readily available in bulk. Quite obviously the problems inherent in the use of fecal material were insoluble on the scale of testing and the open laboratory environment envisaged for this research.

The early results of this programme, that was funded by DHSS, have been published (3). Figure 1 illustrates the solid velocity for a single maternity pad flushed into 14 m long UPVC and Cast Iron 100 mm diameter pipes at a range of gradients from 1/40 to 1/200 via a single w.c. operating on a 9 litre flush volume. The data is presented in terms velocity versus the $\sqrt{L/G}$ group, where L is the distance travelled by the solid in a pipe at gradient G.

The zones referred to in Figure 1 refer to observations of solid motion previously published (3), the central zone 2 is linear, the data following onto a curve

$$V = C_1 - C_2 \sqrt{\frac{L}{G}} \qquad - (1)$$

and representing sufficient pipe length to cover the majority of branch drainage systems met in large buildings. The form of equation 1 may be predicted from a dimensional analysis of the variables involved in the solid transport mechanisms.

These results for the first time indicated the presence of a relationship linking solid velocity, and hence the probability of solid depositions, to the system design parameters, such as pipe gradient, material, flush volumes etc. and obviously presented a possible design tool that could link laboratory testing to installed system observations.

As a result of this initial programme further research was initiated in 1977 based on what has become three main lines of investigation:-

1) Development of a more representative solid model for laboratory use, drawing on previously published work and experience with alternative material such as PVA sponge. In parallel to this laboratory programme, observation of installed system performance was initiated at a large London hospital, these site tests to include compatible measurements to those

taken in the laboratory. This work was funded by DHSS as a continuation of the original research.

2) Investigation of the limits of application of the $\sqrt{L/G}$ dependence, of Figure 1, in terms of reduced flush volume proposals and including the influence of pipe cross section size and shape on the transport efficiency at any flush volume. This thread in the programme was funded by Brunel through BSc and MSc project work and the results have been published (5).

3) Investigation of the limits of application of equation 1 in terms of the influence of solid size and shape. Initially this was to have been an element in 2 above, however through the interest of the Association of Sanitary Protection Manufacturers in developing a flushability criterion for sanitary towels and other sanitary products, such as tampons and diapers, it was possible to carry out an extensive test programme utilizing a wide range of products geometrically similar to the maternity pad but exhibiting a wide range of dimensions and saturated weights.

Figure 1 has illustrated the velocity versus $\sqrt{L/G}$ dependence for one solid at one flush volume in various pipe materials. Figures 2 and 3 illustrate the application of this dependence to both a wide range of solids, Figure 2, and to a range of flush volumes and "pipe" cross sectional areas and shapes, Figure 3. It will be noted from Figure 3 that the form of equation 1 has been modified to include flush volume, F, as described in (5),

$$V = \frac{C_3 - F}{C_5} - \frac{C_4 - F}{C_6}\sqrt{\frac{L}{G}} \qquad (2)$$

where C_3 to C_6 are empirical constants.

It may be seen that reducing the pipe cross section area improves solid transport at low flush volumes as the depth of water available behind the solid is maintained as the flush volume is reduced. This effect is more pronounced in non circular ducts. The results of this particular study would seem to strongly support the proposal by Rosrud (6) that 75 mm pipe be considered, as it is in Scandinavian practice, for isolated w.c's operating on reduced flush volumes.

As mentioned previously PVA sponge had been investigated as a model material by Matsuo and Tsukagoshi. It was decided to utilize this material as a basis for a model solid. A survey of the available literature on the physical properties and likely weights of fecal material highlighted the lack of data available in this area. Following the work of Feachem (7), Goldblith and Wick (8) and Kira (9), it was decided to model a 150 g solid by means of a PVA model of 140 mm length by 38 mm diameter.

Considerable problems were encountered in this stage of the work due to the total lack of data on fecal properties such as flexibility and surface friction factor. In terms of modelling the control of specific gravity was also a problem. In parallel with the work at Brunel a research project at the Berlin Technical University had produced an alternative model solid material (10), designated Fakazell 95 or 105 depending on desired specific gravity and intended primarily for w.c. discharge performance investigations and not for transport tests. Both the PVA and Fakazell, which appears to be based on powdered paper, a PVA adhesive and an additive to delay hardening for up to 4 days, produced cylindrical models with diameters in the 25 to 40 mm range. The recommended Fakazell load is 200 g, which is high when compared to Feachem's findings for the culture groups likely to benefit from this test programme.

It was possible to test both the PVA sponge and Fakazell models in the Brunel laboratory by flushing into 14m of 100 mm diameter UPVC transparent piping. Observations and video tapes were made of these comparative tests in addition to velocity profile measurements via the photocell and light source instrumentation.

Figure 4 illustrates a comparison between the maternity pad, typical sanitary towel,and PVA,and Fakazell models. It may be clearly seen that all the solids conform to the form of equation 1. The deceleration rates, C_2, vary considerably between these available models and highlights the need to link these tests results to measurements taken under controlled conditions in installed systems.

In much the same way that there was no available literature on solid transport in 1974, the published work on installed system monitoring is almost non existent. Recently interest in this topic has grown and Nielsen (11) recently reported observations at the Danish Building Research Institute, however the work did not include any solid velocity data and as such added little to the tests already underway at Brunel. The work reported as part of the programme at Brunel has therefore established the validity of equation 1 for an extensive range of conditions, however without cross correlation to the transport of waste materials in installed systems this would be of limited value to the designer. Given cross linking coefficients the techniques developed for laboratory testing will allow designers the ability to investigate quickly the effect of system changes on solid transport. In order to provide such a correlation the current work in this area at Brunel is concentrated on the monitoring of installed system operation, employing all the techniques developed for laboratory use and thus providing results directly compatible to those presented above.

In order to be able to link theoretical analysis of forces acting on a model solid and laboratory experiments to the performance of the range of waste solids found in practice, site testing of a 'live' installation was considered essential. Some difficulty was experienced in finding a suitable internal building drainage system which would meet the essential requirements; a sufficient level of usage; the accommodation to replace existing pipework with sufficiently long runs of clear UPVC soil pipe prior to connection with any other live pipe or vertical main; the accommodation to allow accurate adjustment of gradient; a building layout suitable to allow all such adjustments to the system and all consequent monitoring activities to remain undetected by the facility user. A suitable installation was selected in a large London hospital and monitoring activities have been in progress for approximately one year. Figures 5, 6, 7 and 8 illustrate the original and current installations involving a 4 w.c. female unit and an adjacent 2 w.c. male unit. Monitoring was initiated on the female suite and all figures available to date refer only to this installation. Compilation of data from the male facility is continuing. Both male and female installations serve a large cafeteria adjacent to the hospital's main entrance, which is used mainly by the general public but also by members of staff and mobile patients. It was considered important not to monitor an installation used only by patients as this would not reflect an average system load.

The installed w.c's are un-vented Armitage Shanks 'S' trap, and the cisterns are of the water saving short/long flush type which have been adapted prior to this survey to deliver full flush only. The cisterns deliver via 1½" internal diameter flush pipes, and are mounted 1.140 m above f.f.l. A bin is provided in each facility for hand towels, but in addition in the female lavatory each cubicle is provided with sanitary towel bags and a pedal bin. The toilet tissue paper provided throughout is of the greaseproof type.

After adapting the installations to the required layout monitoring equipment was installed. Float switches were placed one in each cistern which were connected to counters via indicator lights in the floor void. This allowed for readings to be taken at regular intervals of the number of cistern operations to each w.c. Although considerable data has been collected in this way a full usage analysis is as yet incomplete, but a basic figure based on readings taken over several months indicates approximately 2,134 operations per week in total of the four w.c's in the female facility, there being no peak day, but slightly reduced usage at weekends and daily peaks at about 10 a.m and 3 p.m. The number of operations is not quite equally split between the four w.c's, the centre two being monitored also for velocity readings receiving slightly more usage than the other two w.c's. This variation in w.c. usage is thought to be due to a combination of room layout, ease of access to the cubicles, the general level of hygiene in any cubicle at any particular time, and personal behaviour. The float switches also operate a panel of indicator lights in the floor void to allow time for the operator to engage the velocity measuring equipment in readiness for the imminent discharge. All wiring to float switches above the floor void has been concealed inside overflow pipework to avoid attention from the system user. The cisterns were initially set to discharge 9 litres, but it has proved necessary to reset the volumes at regular intervals due to a tendency of the particular cisterns being used to readjust themselves. This problem occurs because the vertical stand, inside the cistern, of the water supply to the valve is not sufficiently rigid, and tends to warp or bend thus altering the ball adjustment.

The velocity measuring equipment employed consists of a series of photoelectric/light source units connected to a pen recorder. This system was set up to provide velocity readings at nine points at 1 m intervals along the drain. In order to interpret such pen recorder output correctly, and also to build up data describing overall system loading, a full visual description of each solid in every monitored flush was recorded. A solid identification numbering system was employed to allow the operator to classify solids quickly and easily. Each solid number describes one solid only and consists of six separate numbers, an example of which is:

2 / 9 /16 / 0 / 3 / 0

(tissue paper/8" long/very thick/not app./Flat Profile/Not app.)

At gradients of 1/150 and 1/200, 2163 flushes were monitored for solid velocity. Of these 7.6% were involved in simultaneous discharge of the two w.c's and it is on the single flush data remaining (1,004 @ 1/150 and 995 at 1/200) that figures presented here are based. Obviously velocities of solids in simultaneous discharge flushes were considerably greater than would otherwise be the case. Figures 9 and 10 give details of the numbers of solids per flush as compared to the number of flushes, the number of flushes leaving stoppages in the monitored pipework, and other related data, for gradients of 1/150 and 1/200 respectively. As expected these figures show that a greater proportion of flushes leave a stoppage behind in the monitored pipework as the gradient is flattened. The figures also indicate that at both gradients more flushes left a stoppage behind than encountered one already in the pipe. These two figures must of necessity be the same over any one sample period, the explanation for the difference seen here is that monitoring was carried out on many separate occasions and it was considered necessary to allow any stoppage in the pipe at the beginning of a test period to clear before monitoring began, as no details of how any such stoppage arrived at that position would have been recorded.

An interesting point can be seen from the fact that at a gradient of 1/150, 4.6% of all single flushes left at least one stoppage behind in the monitored pipework, whereas 0.2% of all single flushes both encountered at least one previous stoppage already in the pipe and left at least one stoppage in the pipe. Considering the fact that only 2.3% of all single flushes encountered any previous stoppage in the pipe, this means that 8.7% $(^{0.2}/_{2.3})$ of flushes meeting at least one stoppage also left at least one stoppage, as compared with only 4.6% of all single flushes leaving any stoppage. Similarly for a gradient of 1/200 we see that 25% $(^{1.8}/_{7.2})$ of flushes encountering a stoppage already in the pipe also left a stoppage, whereas only 9.2% of all single flushes left a stoppage. Clearly this indicates that the occurrence of one stoppage increases the probability of another stoppage, and thus the probability of escalation to a blockage. This fact justifies one of the assumptions made earlier during laboratory experiments, that above ground drainage should be designed to prevent the occurrence of stoppages above an agreed safe limit which must be determined.

Figures 9 and 10 also show that in total only 9.3% of flushes at 1/150 and 9.7% of flushes at 1/200 contained any fecal material, in fact the greatest proportion of the system load is toilet tissue paper. Figures 11 and 12 give more detailed information on the material content of one and two solid flushes.

The results presented thus far concerning the monitoring of the female installation provide quite a clear picture of the system load. By far the largest proportion of flushes either carry no solid or one solid only, and of the flushes containing one solid only that solid is of toilet tissue paper in the large majority of cases. Figure 13 shows the solid velocity of all single solid flushes containing toilet tissue paper observed to be of approximately 150 mm length, plotted against $\sqrt{L/G}$ for w.c's 2 and 3 at gradients of 1/150 and 1/200. This figure shows that the solids concerned exhibit extremely good travel characteristics, and this is the case for other solid groupings monitored. Figure 13 also indicates that solids originating from w.c. 2 which enter the straight length of monitored pipework via a 135° junction have slightly reduced velocities as compared to similar solids originating from w.c. 3, and this also is reflected in other data recorded. However, the most important observation to be drawn from Figure 13 is that the velocity against $\sqrt{L/G}$ relationship holds extremely well, the results gained at different gradients being drawn very closely to a line.

Figure 14 shows the velocity against $\sqrt{L/G}$ relationship for fecal solids, each being the first solid of a two solid flush, the second solid of each flush being toilet tissue paper. It can be seen here that travel characteristics are again very good, the solids from w.c.2 at gradients of 1/150 and 1/200 being drawn very closely to a line. Data have not been plotted here of results from w.c.3 at gradient 1/200, due to an insufficient number of occurrences of this group of solid content for results to be statistically valid. The velocity data presented in Figures 13 and 14 are based on solid groupings which regularly occurred during monitoring, and of which a sufficient number of such occurrences were recorded to be considered worthy of statistical analysis, that is as opposed to being isolated and unrepresentative. It is due to the fact that the possible load of any multi-solid flush can vary to such a large extent, as regards number of solids, material type of solids, and order of arrival of solids, along with the fact that only a minority of flushes were multi-solid flushes, that such data analysis is considerably complicated and is not yet complete.

Velocity against $\sqrt{L/G}$ profiles are illustrated in Figure 15 which were established in laboratory experiments using a range of sanitary towels. These are only a few examples of test results from an extensive range of sanitary towels, baby diapers and tampon products, as mentioned previously as regards the investigation of the limits of application of Equation 1, which have been compiled by the Drainage Research Group at Brunel. These results are made available by the U.K. Association of Sanitary Protection Manufacturers, (ASPM), for whom the testing was undertaken on a consultancy basis. It can be seen in Figure 15 that the profiles vary considerably, but also that they span the range of possible profiles. Using such data as this it is possible to match results gained in the labotatory using one or other sanitary protection product to results gained on site for some other type of solid, such as fecal material or toilet tissue paper. It is intended that on completion of this study it will be possible in such a way to define on site system loads, or sections or classifications of system loads, so that a particular sanitary protection product can be used in future laboratory experiments to simulate the load or part load to which it has been matched. It will be necessary that this matching procedure also take account of the standard deviations from the velocity profiles of the solids being compared, to ensure a truly significant comparison.

Data collections are currently underway in the study of the male facility, and initial observations indicate that loads are generally heavier than was the case in the study of the female facility. It is also expected that the proportion of water only flushes will be considerably reduced. If this should prove to be the case the possibility may have to be considered that male and female sanitation services require distinct and separate design criteria.

CONCLUSIONS

Clearly the full results of the test programme have yet to be published, however the results presented in this paper show that the laboratory derived empirical relationships apply equally to the transport of fecal and other waste in building drainage systems. The implications of this result as an aid to design decisions have been outlined and are felt to be particularly important in view of the current discussions on reduced flush volume and water conservation system design.

The result that fecal material can be easily represented by readily available models based on commercially available sanitary products will allow system performance to be predicted from laboratory tests. The usage data and the spread of waste materials monitored in installed systems will be modelled by means of a range of model solids whose deceleration characteristics will be known from laboratory evaluation.

This stage of the programme at Brunel is scheduled for completion in 1980 and it is hoped to publish further data on completion of the project.

ACKNOWLEDGMENTS

The programme reported has been supported by DHSS commissions; this support is gratefully acknowledged.

The Drainage Research Group would also like to acknowledge the contribution of many firms in the drainage area and in particular the Association of Sanitary Protection Manufacturers for allowing publication of tests undertaken by DReG as consultancy studies.

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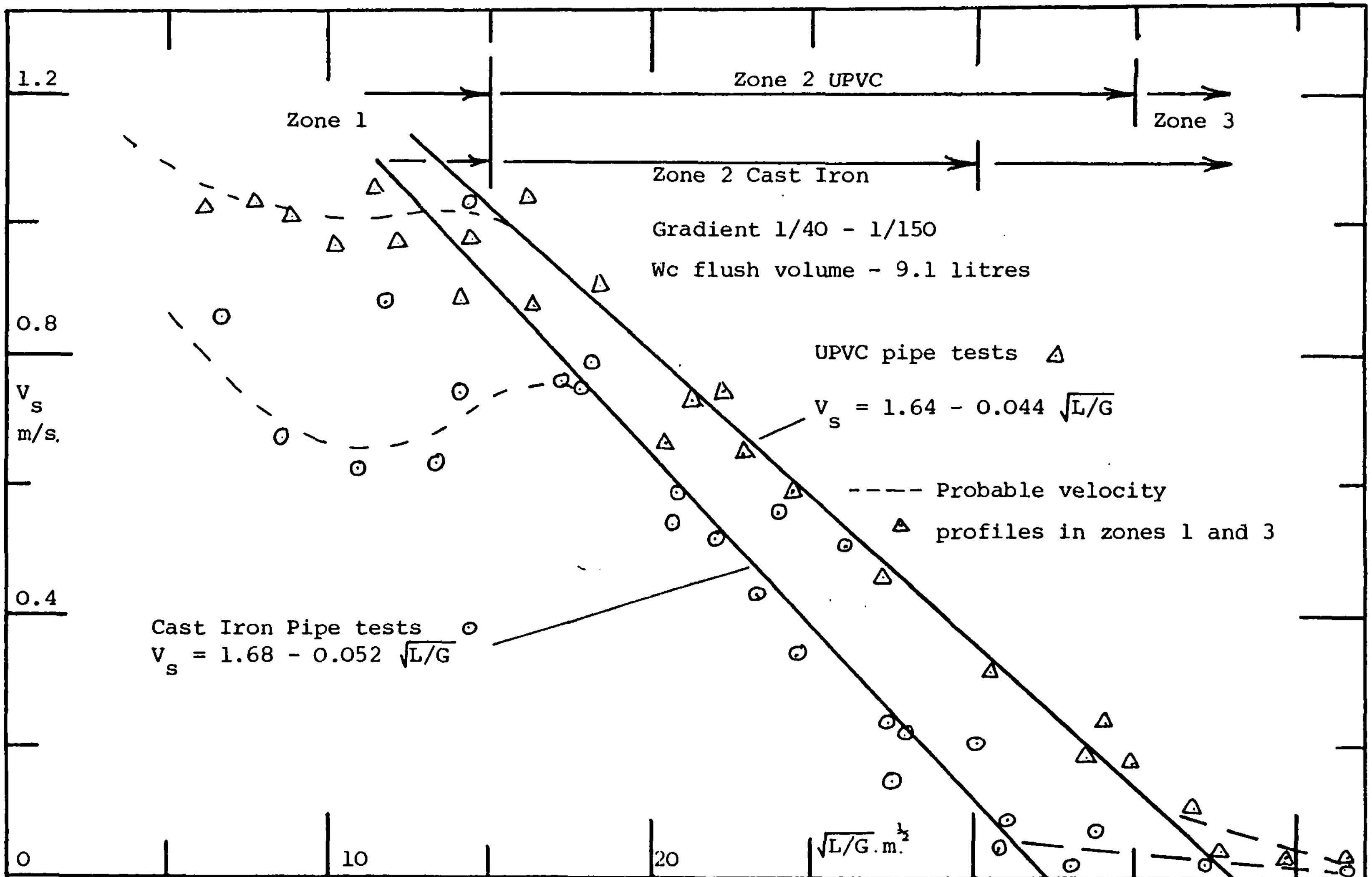

FIGURE 1. Comparison of maternity pad transport in UPVC or Cast Iron 100 mm diameter pipe.

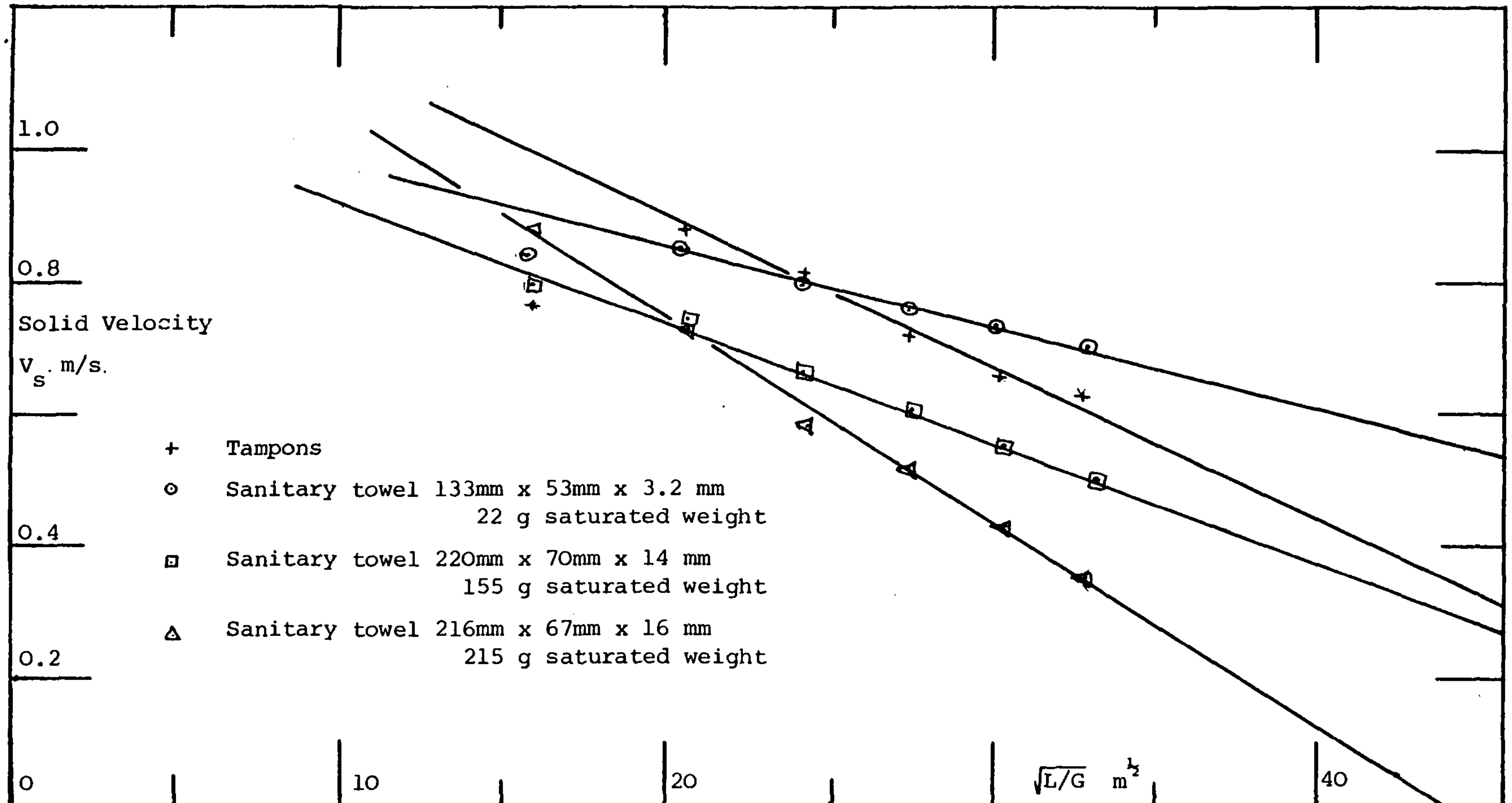

FIGURE 2. Confirmation of $\sqrt{L/G}$ dependence for a range of sanitary products taken from ASPM test series.

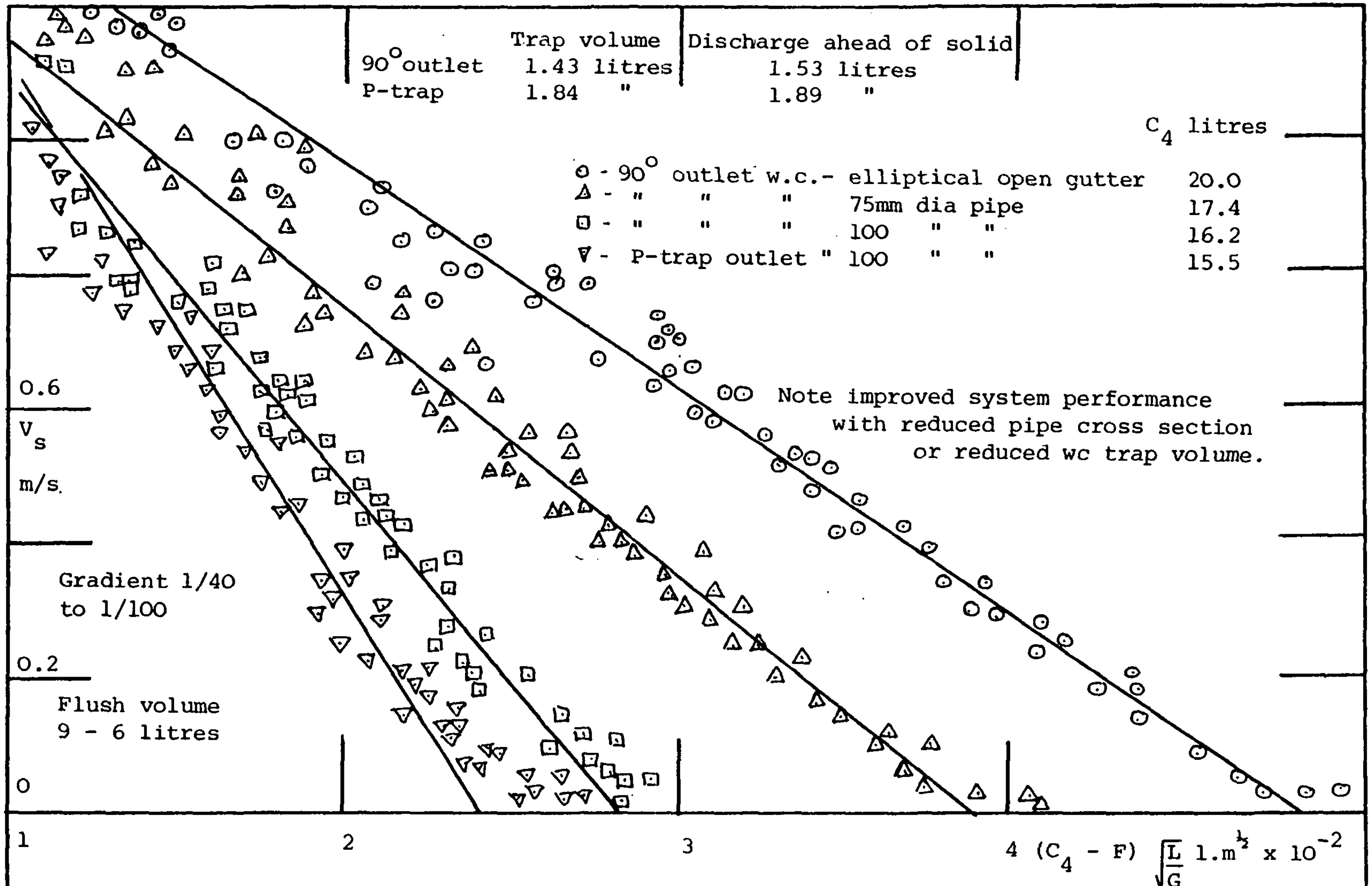

Figure 3. Effect of a reduction in wc flush volume and "pipe" cross section on maternity pad transport.

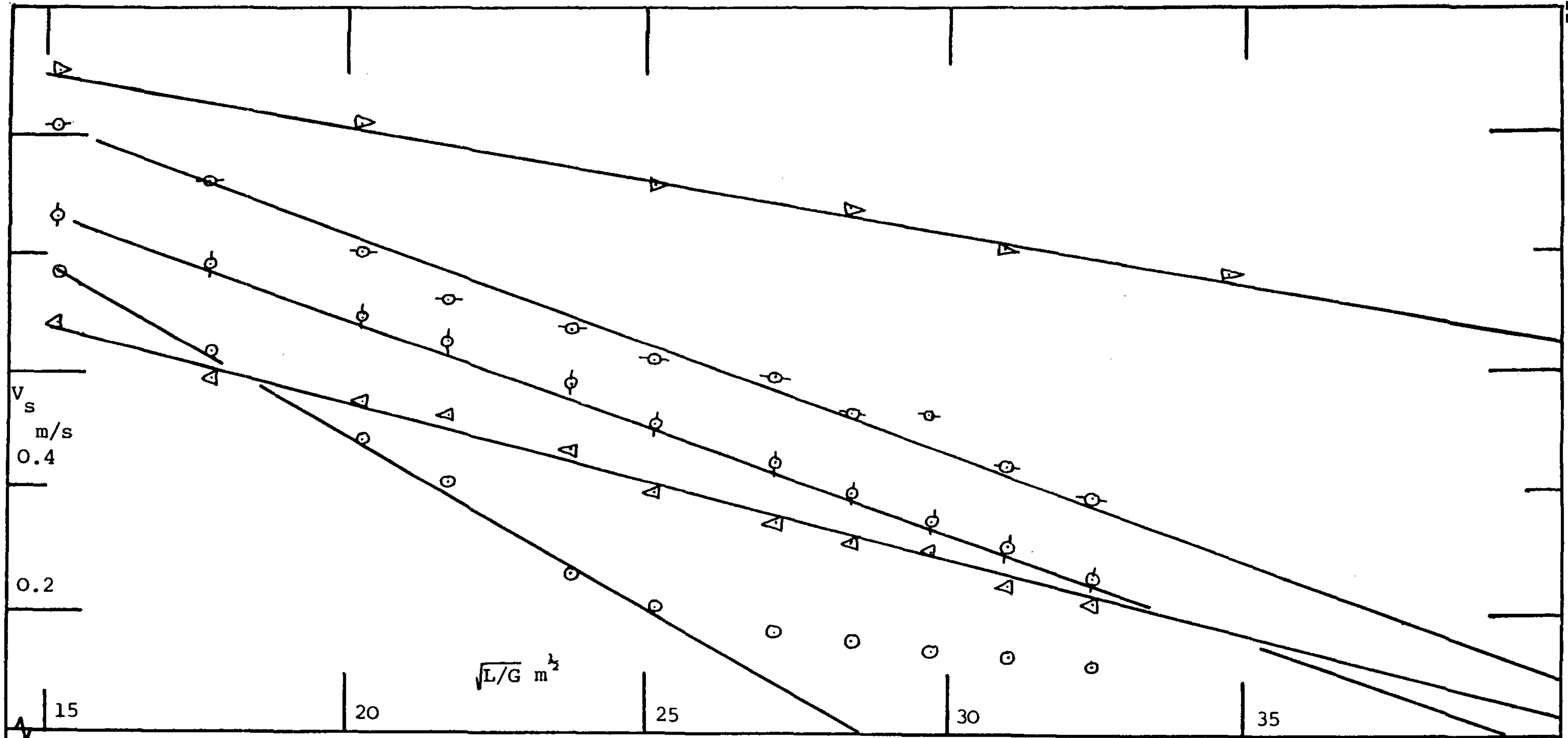

FIGURE 4. Comparative solid velocity profiles for PVA model solid, sanitary towels and Fakazell 95 and 105 plotted against $\sqrt{(\text{Distance travelled from w.c., L/pipe gradient, G})}$. Note zone 3 clearly shown for PVA solid transport.

Δ Sanitary towel (155 mm x 7 mm x 45 mm)

∇ Maternity pad (300mm x 20mm x 60mm) plus 2 x 6 sheets toilet tissue

-⊙- Fakazell 95 (3 x 100mm lengths) plus 2 x 6 sheets toilet tissue

ϕ Fakazell 105 (3 x 100 mm lengths) plus 2 x 6 sheets toilet tissue

⊙ PVA model solid (140mm x 38mm diameter) plus 2 x 6 sheets toilet tissue.

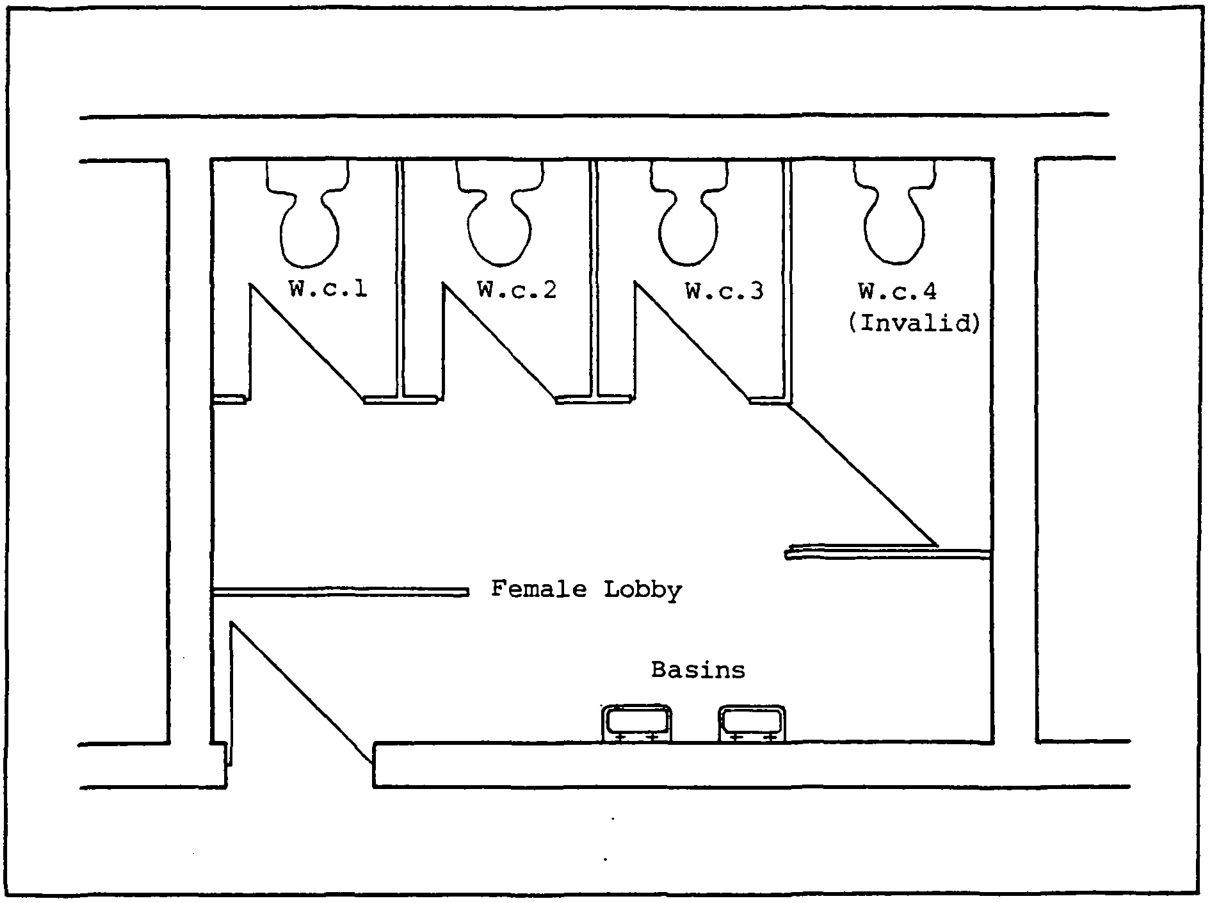

FIGURE 5. Female Lavatory - floor plan.

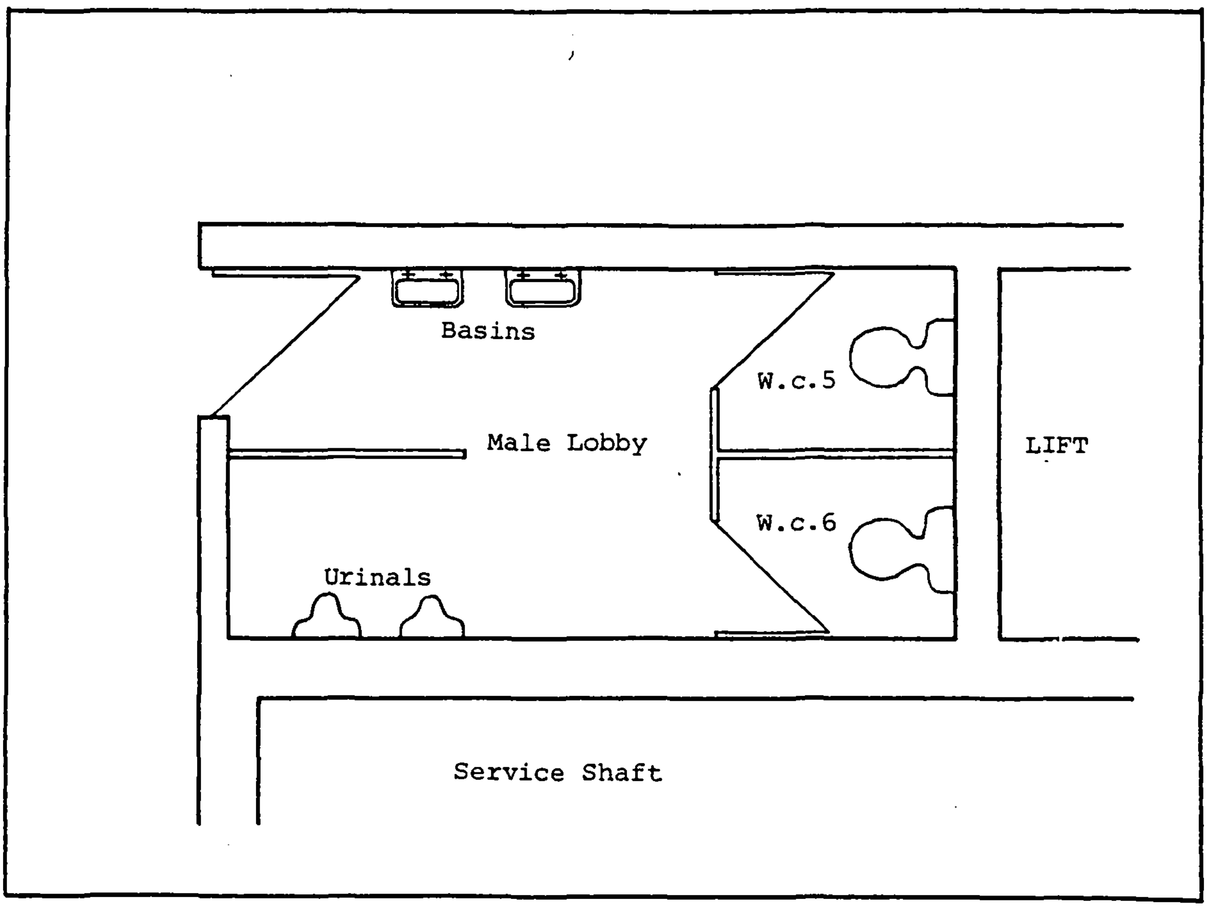

FIGURE 6. Male Lavatory - floor plan.

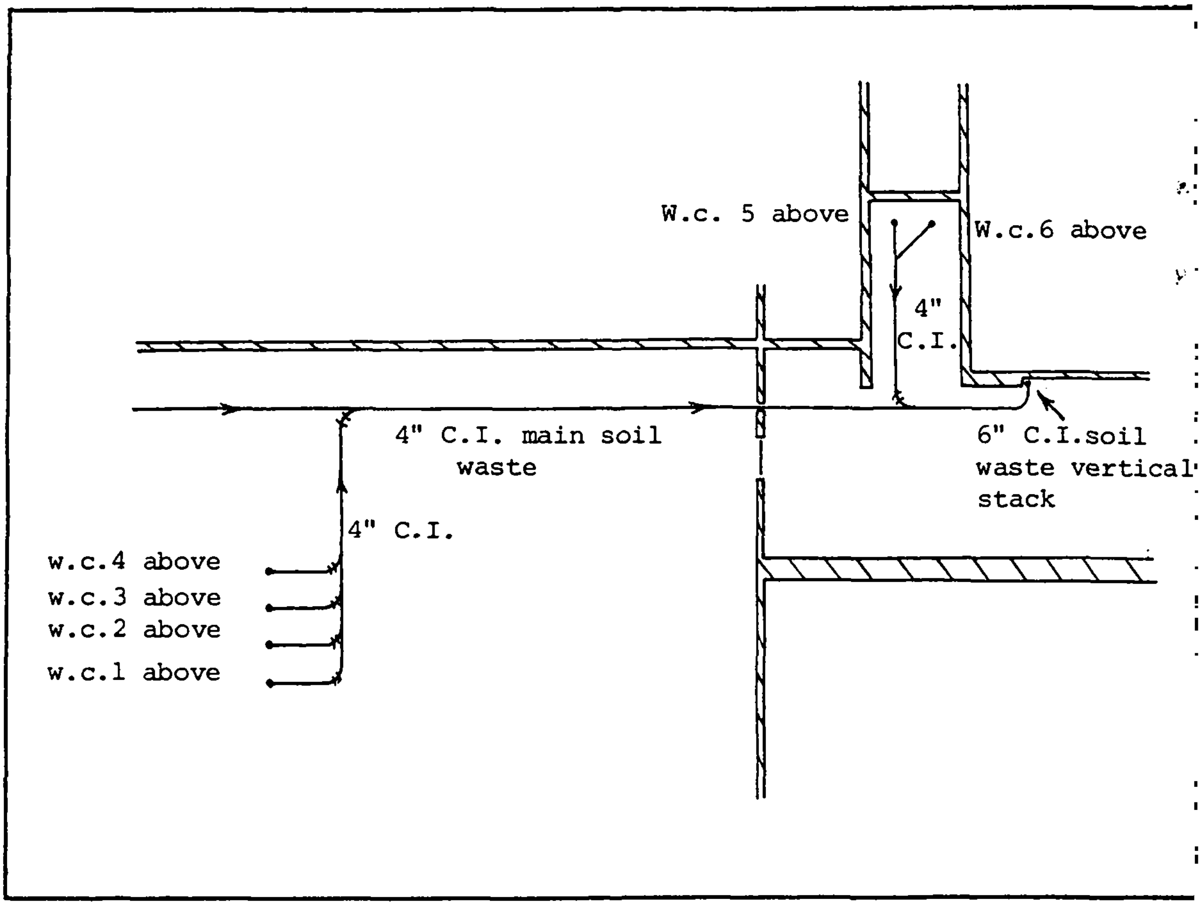

FIGURE 7. Previously existing sanitation service in hospital floor void to two suites of w.c's above

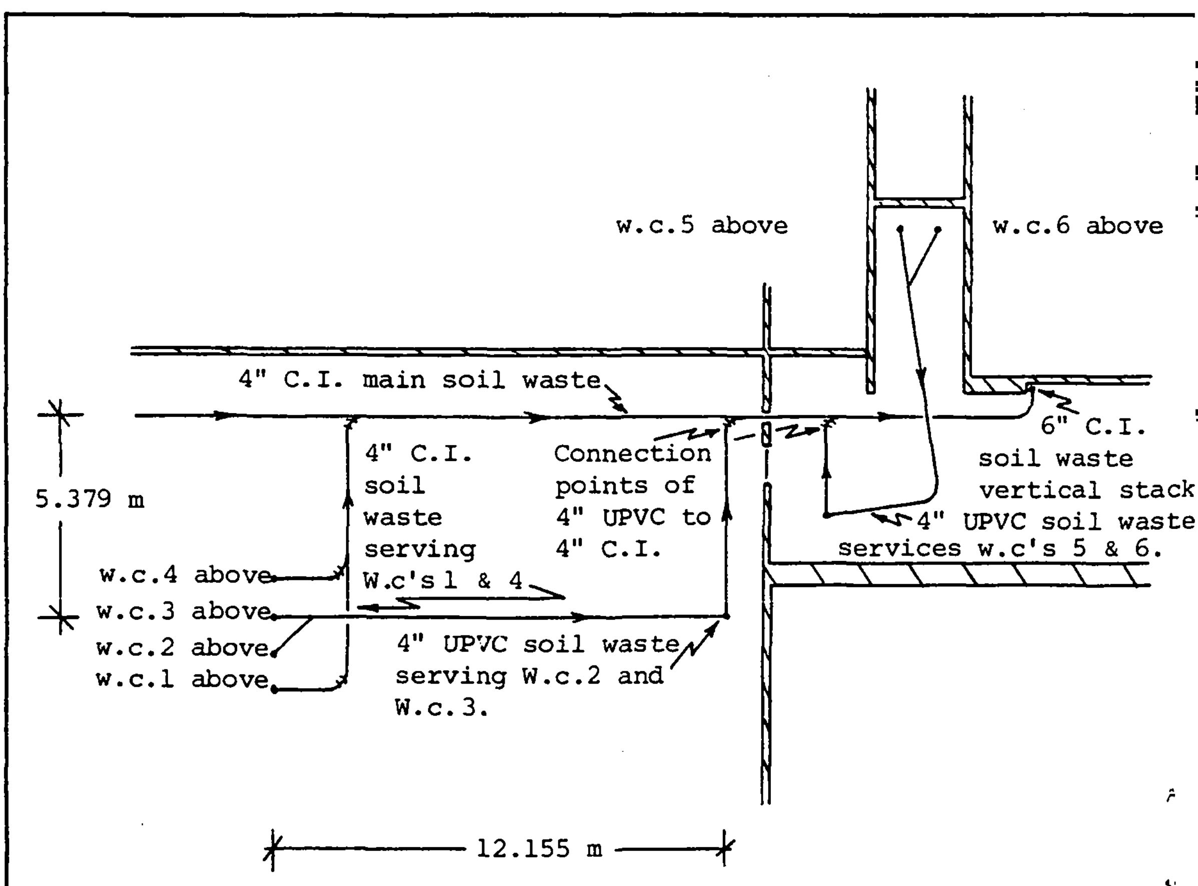

FIGURE 8. Current sanitation service in hospital floor void, as monitored, to two suites of w.c's above.

No. of solids in flush including solids already in pipe.	0	1	2	3	4	5	6	7	8	TOTAL
No. of Flushes	31.6%	48.1%	12.1%	4.5%	2.3%	0.9%	0.4%	0.1%	-	100%
No. of flushes leaving at least one stoppage in pipe	-	1.4%	1.2%	0.9%	0.7%	0.2%	0.1%	0.1%		4.6%
No. of flushes encountering at least one stoppage already in pipe	-	0.7%	1.0%	0.6%	-	-	-	-		2.3%
No.of flushes both encountering at least one solid already in pipe and leaving at least one stoppage in pipe.	-	-	0.1%	0.1%	-	-	-	-		0.2%
No. of flushes containing at least one fecal solid	-	0.6%	2.7%	2.8%	1.9%	0.8%	0.4%	0.1%		9.3%

FIGURE 9. Female Suite, Gradient of 1/150, flush content and solid deposition data.

Note: All percentages relate to the total number of single flushes successfully monitored at this gradient (i.e. not including simultaneous discharge flushes).

No. of solids in flush including solids already in pipe	0	1	2	3	4	5	6	7	8	9	TOTAL
No. of flushes	31.1%	45.4%	13.1%	3.6%	2.8%	2.4%	0.5%	0.6%	0.3%	0.2%	100%
No. of flushes leaving at least one solid in pipe	-	3.7%	1.8%	1.0%	0.8%	1.1%	0.1%	0.4%	0.2%	0.1%	9.2%
No. of flushes encountering at least one stoppage already in pipe	-	1.0%	2.7%	0.9%	1.1%	0.7%	-	0.5%	0.1%	0.2%	7.2%
No. of flushes both, encountering at least one solid already in pipe and leaving at least one stoppage in pipe	-	0.2%	0.3%	0.1%	0.2%	0.4%	-	0.4%	0.1%	0.1%	1.8%
No. of flushes containing at least one fecal solid	-	0.4%	1.0%	2.1%	2.4%	2.3%	0.5%	0.5%	0.3%	0.2%	9.7%

FIGURE 10. Female suite, gradient of 1/200, flush content and solid deposition data.

Note: All percentage relate to the total number of single flushes successfully monitored at this gradient (i.e. not including simultaneous discharge flushes).

MATERIAL TYPE OF SOLID	1/150	1/200
Fecal Material	1.2%	0.9%
Toilet Tissue Paper	92.4%	98.5%
Sanitary Towel	2.9%	0.2%
Tampon	0.6%	-
Toilet Tissue Paper and Fecal Material as one solid	1.2%	-
Some other solid	1.7%	0.4%
Total	100%	100%

FIGURE 11. Female suite, material content of single solid flushes

MATERIAL TYPE AND ORDER OF SOLID 1st Solid/2nd Solid	1/150	1/200
Toilet tissue paper/toilet tissue paper	66.1%	87.7%
Fecal material/toilet tissue paper	16.5%	6.9%
Toilet tissue paper/Fecal material	3.3%	0.8%
Fecal material/Fecal material	0.8%	-
Some other combination	13.3%	4.6%
Total	100%	100%

FIGURE 12. Female Suite, material content of two solid flushes.

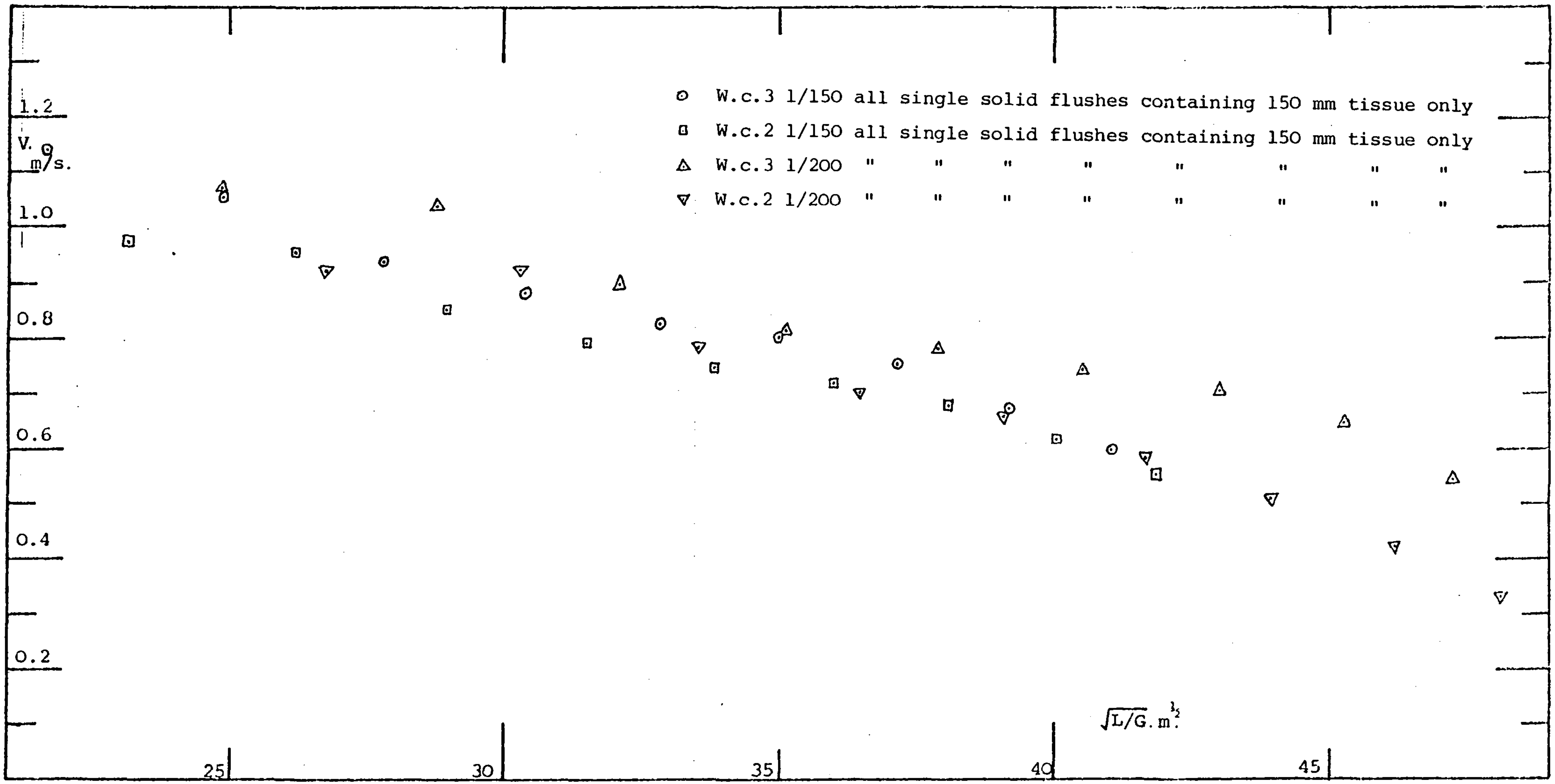

FIGURE 13. Waste solid velocity along the 100 mm diameter UPVC pipe plotted against the square root of (distance from WC/pipe gradient). Results shown are for single solid flushes where the solids involved were observed to be toilet tissue paper of approximately 150 mm length.

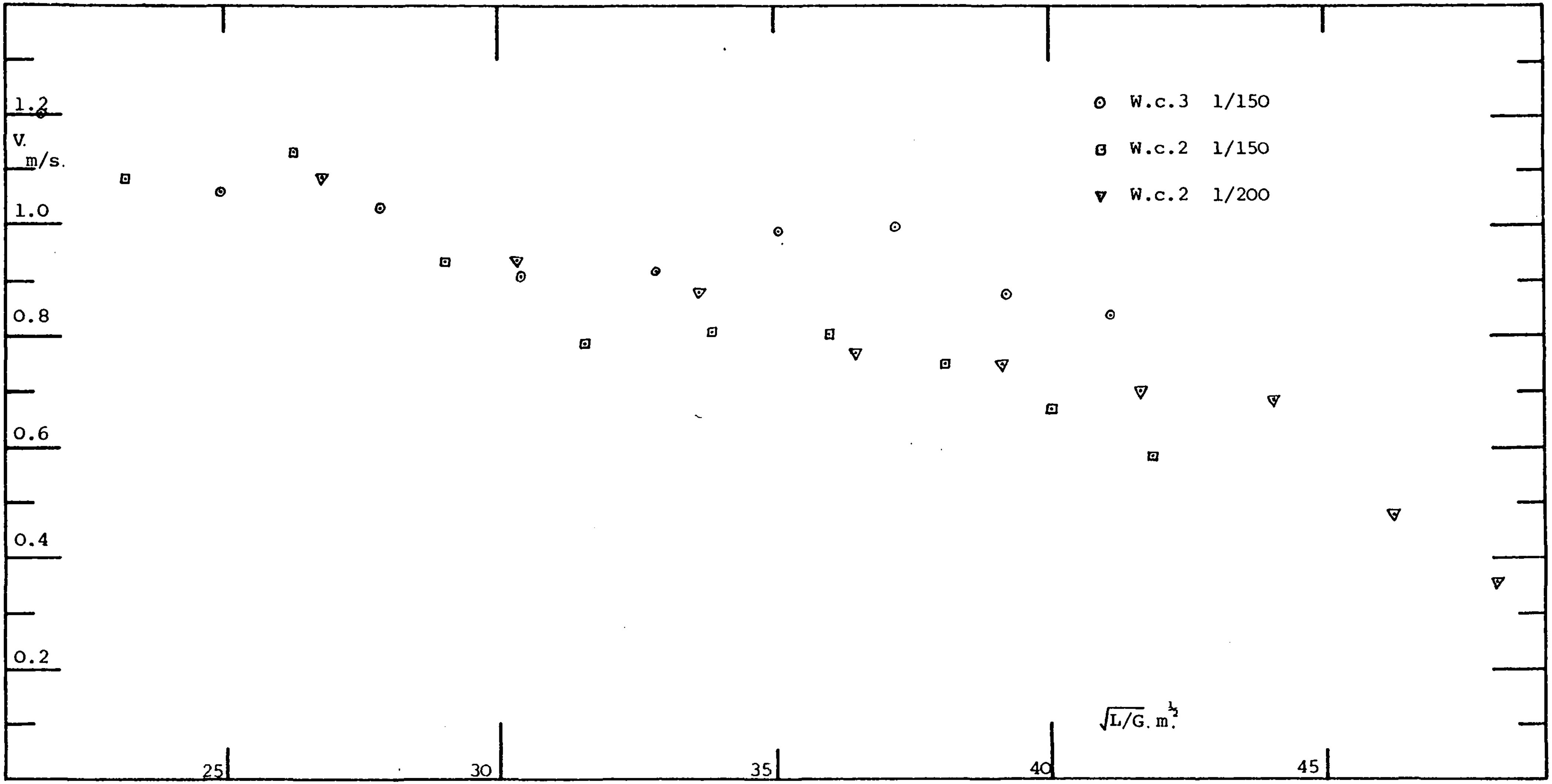

FIGURE 14. Waste solid velocity along the 100 mm diameter UPVC pipe plotted against the square root of (distance from WC/pipe gradient). Solids compared are of fecal material, each being the first solid of a two solid flush, the second solid of each flush being toilet tissue paper.

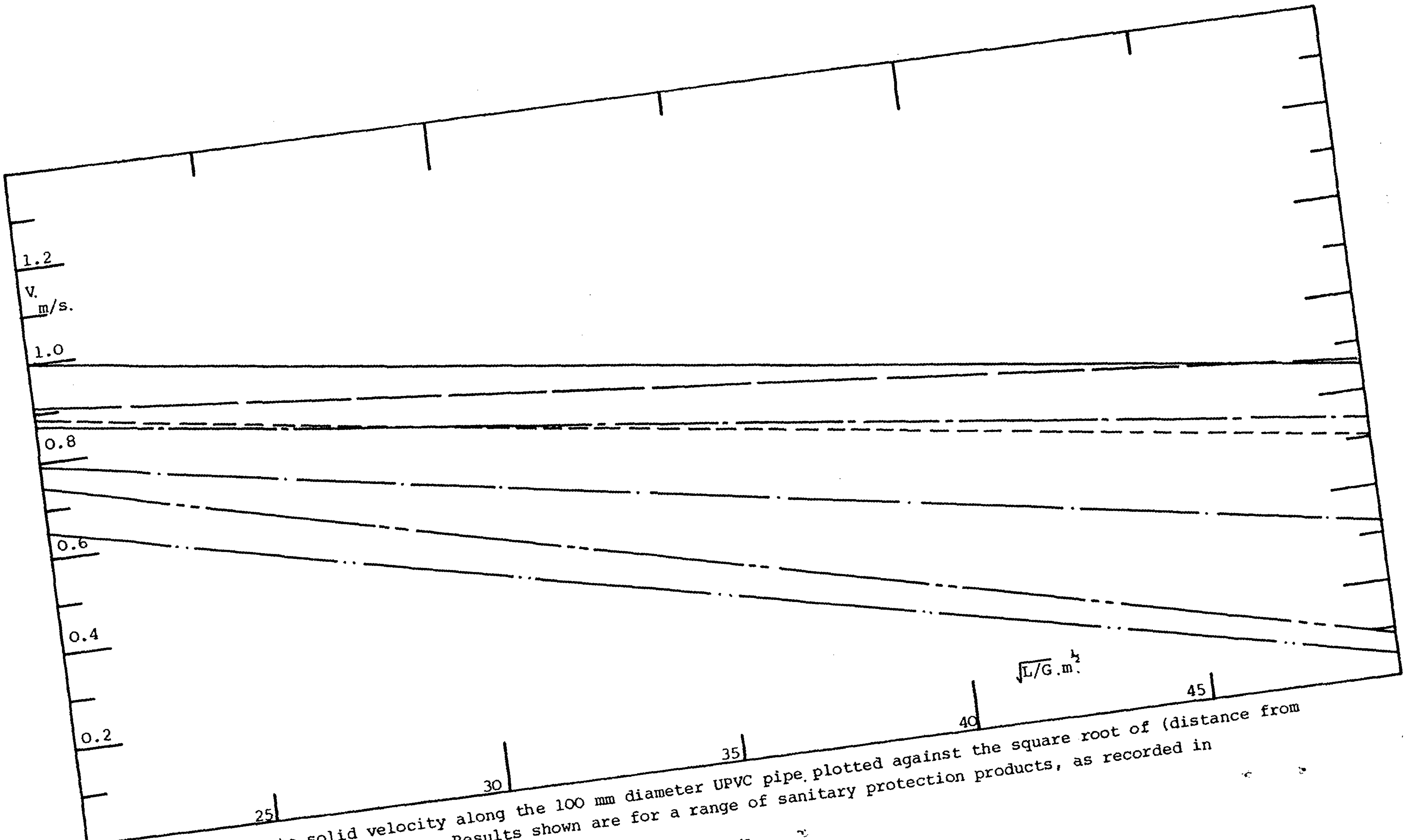

FIGURE 15. Waste solid velocity along the 100 mm diameter UPVC pipe plotted against the square root of (distance from WC/pipe gradient). Results shown are for a range of sanitary protection products, as recorded in laboratory tests.

DRAINAGE AND WATER SUPPLY FOR BUILDINGS

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DEVELOPMENT OF A FLUSHABILITY CRITERION FOR SANITARY PRODUCTS

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DEVELOPMENT OF A FLUSHABILITY CRITERION FOR SANITARY PRODUCTS

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SUMMARY

The development of a set of flushability criteria for sanitary protection products is described. The need for a criterion is stated and the initial test work undertaken to establish the required pass levels is fully described.

The results show that the form of earlier empirical relations developed at Brunel to link waste solid velocity to pipe length and gradient apply to a wide range of solid size and shape parameters.

Finally the agreed test specification is presented together with a view of future development work in this area. The results collected over the test period are to be analysed further to identify any correlation between transport characteristics and size and shape parameters.

INTRODUCTION

The Association of Sanitary Protection Manufacturers (ASPM) is a body formed to represent the views of, and set agreed standards amongst, all members of the industry. One of these standards to be examined was the term "flushable" which is printed on nearly all the packages of sanitary protection products.

These sanitary protection products can vary widely in size, construction and weight, as follows:-

(a)	Tampons	-		2 to 5 grammes and	5 cms long
(b)	Towels (Napkins)	-	Mini	4 to 8 grammes	15 cms long
			Towels	6 to 20 grammes	20 cms long
(c)	Panty Shields	-		2 to 4 grammes	15 cms long

The towel raw materials are basically "cellulose" - fillings of tissue, fluffing pulp with a non-woven cover. There is sometimes a plastic film inside the towel as a fluid barrier. Plastic can also be used as a release tape to cover the pressure sensitive adhesive on the back of the towel. The non-woven cover can be very specialised - either completely non-absorbent polyesters or a "flushable" cover which disperses after some time in water. Rayon or a rayon/cotton mixture is the usual fibre for tampons.

The actual number of products used per day is estimated as follows:-

PRODUCT		NO. OF PADS MILLIONS/DAY
TAMPONS		2.49
TOWELS	Mini	0.62
	Looped	1.06
	Self Adhesive	2.28

Our own surveys have shown that approximately 80% of the ladies dispose of these products by flushing down the toilet i.e. five million products per day. There are various flushability instructions given on the packs.

"Simply flush it away - all in one piece"

"Just remove the cover and flush away separately"

"Completely flushable (no need to pull apart), just flush the whole towel away"

"Remove outer covering, empty contents and flush away. Then flush cover separately"

"Do not flush"

These instructions support the general public's view that "flushable" means it will disappear down the toilet. However the ASPM wanted to be more specific in its definition of "flushable".

Flushability Definition

The Technical Committe of the ASPM considered that the definition was really in two parts - the product should flush from the pan but also cause no problems in the subsequent drainage system. Various Research Establishments were contacted, with the following general conclusions:

(a) Drain blockages were in fact due in the main to a drain fault i.e. poor joints or faulty pipework.

(b) Although the BSI minimum flush volume is 9 litres, in the majority of WC systems the volume is 12 litres. However there are moves to reduce this minimum standard and in addition dual flush and controlled flush systems could be introduced.

(c) If the towels managed to get into the main sewage pipe trunking system no problems should occur.

(d) The amount of plastic in the products is unlikely to cause a problem at the sewage farm.

Therefore it seemed reasonable to concentrate on a method of measuring the failure of the product to leave the WC and also the "state" of the product after travelling some distance in the pipe-work. ASPM member companies had already simple WC systems plus a collection device for evaluating flushability. Unfortunately these were non-standard methods with no scientific measurements.

However it was possible using the test rig developed by the Drainage Research Group at Brunel University to define both a test method and specification. In summary they have:

(a) A test rig available consisting of a WC pan, connected to a short vertical section and then 14 metres of horizontal pipe. The velocity of the solid can be measured at various points along the pipe length and the volume of water ahead of the solid measured.

(b) Developed a theory of solid transport which will allow them to predict the drainage performance of a solid at any gradient of pipe and various types of pipe.

Flushability Specification

A 100 samples should be tested on the BRUNEL rig and the following criteria must be satisfied.

(a) WC failures: A maximum of six WC failures plus pipe stoppages below 10 metres are allowed i.e. 3 WC failures + 3 stoppages below 10 metres.

(b) If a WC failure occurs then the product must flush greater than 10 metres along the pipework on the second flush.

Flushability Rig and Method

TEST EQUIPMENT

A. The test pipe consisted of 7 x 2 m lengths of 100 mm bore UPVC discharge pipe connected at its upstream end to a vented discharge Twyfords P-trap WC via a Terrain UPVC 104^{o} junction and 92½^{o} UPVC bend. The centre line of the UPVC pipe was 300mm below simulated floor level at this connection.

The pipe is supported over its whole length by means of two 7 m long lightweight aluminium ladders. Initial level setting by use of a surveyor's level ensured later gradient adjustments to an accuracy of 0.5 mm. A gradient of 1/80 was used for all the reported tests. The performance of the test pipe was monitored by recording the velocity of the waste solids at six points along the pipe length. Table 1 indicated the positions chosen. The discharge was collected at the downstream end of the test pipe by a tank equipped with a depth recording linear displacement transducer linked to a pen recorder. From the volume vs time output of this system the quantity of water entering the collection tank ahead of the solid could be accurately measured.

Table 1 SUMMARY OF VELOCITY MEASURING POSITIONS

Test Code

B.

Velocity Position	1	2	3	4	5	6
Distance from WC (m)	3.05	5.08	7.11	9.15	11.18	13.21
Separation photocells		-0.3m				

C. Velocity Position

Velocity Position	1	2	3	4	5	6
Distance from WC (m)	3.05	5.08	7.11	9.15	11.18	13.21
Velocity measuring length		-1.0m				

SAMPLE PREPARATION

D. (a) If an adhesive backed towel is tested, the release strip must be taken off and towel placed on a clean, fresh section of "pantie" cloth. (The cloth to be defined and sample at Brunel). A 2 kilogramme weight (3cm wide x 20cm long) is placed on towel for 90 seconds. The towel to be then peeled longitudinally from the cloth. If however on dropping the towel into the pan it sticks to the side of pan due to the adhesive then these results should be ignored.

E. (b) The product should be pre-soaked with water

Tampons	-	no pre-soak
Panty shields	-	2cc
Mini towel	-	6cc
Towel	-	20cc

The water should be applied over the middle third of the product and to avoid excess running off the surface it should take 1 minute to apply the fluid.

F. (c) The product must be torn, if necessary, as defined on the package.

SAMPLE PLACEMENT

G. (a) The product should be held vertically and the bottom of the pad (not loops) should be level with the rim of the toilet and in the centre of the basin.

H. (b) The product is dropped into the pan and 20 seconds later the toilet is flushed.

MEASUREMENT

I (a) WC FAILURE: If the product fails to leave the toilet, this is noted plus the number of flushes required to remove the product.

J. (b) VELOCITY: The velocity is recorded at various points along the pipework system as defined in the test equipment. It may be necessary to change the method of measuring the velocity if the solid disperses.

K. (c) STOPPAGE DISTANCE: If the product stops in the pipework the distance from the WC is recorded.

L. (d) % VOLUME OF FLUID AHEAD: This is recorded as it should confirm a satisfactory flush. It is measured by a signal from the depth recorder in the collection tank at the end of the pipework.

NUMBER OF TESTS:

A minimum of a 100 tests should be completed.

FLUSHABILITY REPORT

DRAINAGE RESEARCH GROUP,
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The attached test specification details the test rig and methods used to determine the acceptance of the towel for disposal by WC flushing. The operative paragraphs of the specification are listed where appropriate:-

Towel type	Dr. White's Panty Pads Super Plus
Test equipment	A
Velocity measurement positions	C
Sample preparation	D,E,F
Sample placement	G,H
Measurements	I,J,K,L
Number of WC flushes	100
WC flush failures	-
WC 2nd flush failures	

Theoretical zero velocity pipelength based on $V = C_1 - C_2 \sqrt{L/G}$ $\sqrt{L/G} = 62.44$
$L = 48.7$m at 1/80

Stoppage distances recorded Mean = - Max = - Min = - STD = -

Number of stoppages in pipe 0

Volume discharged ahead of solid Mean = 1.96 Max = 3.94 Min = 0.98 STD = 0.59 1
21.6% 43.2% 10.8% 6.43%

Comments on test performance No problems encountered during WC tests.

This product passes the test specification

FLUSHABILITY ASSUMPTIONS

In carrying out this investigation to determine a flushability method various assumptions have been made and certain facts found:-

(1) WC Pan: A BSI P-trap WC was used as the majority of U.K. houses would have this type of toilet. At this stage siphonic systems have not been investigated.

(2) Flush Volume: The current British Standard stipulates a minimum flushing volume of 9 litres, and this was used in the test method. However it is more likely that the volume is 11/12 litres in the home. There are available reduced volume flush systems and controlled flush systems, none of these have been investigated.

(3) Cover Flushing: In the past it has been recommended on those towels which have the cover torn that the cover is flushed separately. It was found better to flush cover and contents together.

(4) Air Entrapment: One of the major factors in poor performance was air entrapment in the product which forced the product to float.

(5) Product Placement: It was decided to specify the position from which the product is dropped so as to try to eliminate any product falling onto the sides of the pan, and prevent any bridging effect on long products.

(6) Pre-soak: It was found that the product performance in general deteriorated if water was added to the product before flushing. Various level's of pre-soaking have been defined.

Tampons	-	0
Panty shield	-	2cc
Mini	-	6cc
Towels	-	20cc

(7) Product Shape: At this stage it was felt better to ignore the fact the product could be shaped after use. This was due to the difficulty of reproducing a standard shape, and some evidence that it did not affect the performance.

(8) Sample size: A 100 samples were tested as typical of 6 months usage and it was felt that a 1 in 15 first failure would be acceptable. Care should be taken not to refer the specification as "6% of towels can fail to leave the WC".

(9) Stoppage Distance 10 metres: There are no British Standards for pipework distances, but it was considered by Brunel that the majority of systems would be less than 10 metres even taking into consideration the twists and turns that sometimes occur.

In conclusion we do have an industry agreed specification and test method of flushability of sanitary protection products, and hopefully the number of complaints we have from our customers due to flushability problems will reduce from the present one complaint in 100 million products used!

Background to the flushability test work at Brunel

The Drainage Research Group at Brunel have been involved in a fundamental study of the mechanisms of solid transport in above ground drainage systems for a number of years. The initial research, funded by the U.K. Department of Health and Social Security, had led to the establishment for the first time in 1976 of an empirical relationship linking solid velocity to both pipe length travelled and to pipe gradient. Initially (1) this was limited in its application to tests involving maternity pad model solids w.c. flushed under laboratory conditions into a 14 m length of drainage pipework set at gradients from 1/40 to 1/200. Pipe material was initially transparent UPVC although glass and cast iron pipes were also tested. In 1977 further funding from DHSS allowed this programme to continue and to include, in its current stage, the monitoring of installed systems as a means of demonstrating the application of the empirical relationship mentioned above to the wide range of waste transported along a typical drainage system.

The initial relationship linking solid velocity, and hence the probability of deposition, to pipe length and gradient was found to have a form -

$$V = C_1 - C_2 \sqrt{\frac{L}{G}} \qquad - (1)$$

where L is the distance travelled along the pipe set at a gradient G, over the main length section of w.c. fed branch drain pipe runs. This basic equation was found to apply in the same format to pipes of various materials, e.g. glass, UPVC or cast iron, or to pipes of various cross sectional dimensions and shapes, e.g. 100 mm and 75 mm diameter and elliptical. Similarly the relationship for various flush volumes with the standard maternity pad solids was found to have a form -

$$V = \frac{C_4 - F}{C_5} - \frac{C_6 - F}{C_7} \sqrt{\frac{L}{G}} \qquad - (2)$$

where C_{4-7} are empirical constants.

Thus when the group was approached by ASPM to aid in the development of a set of flushability criteria for sanitary products that would include solid transport as well as w.c. discharge targets it was clear that the test work envisaged would fit conveniently into the research programme. The Association of Sanitary Protection

Manufacturers are to be thanked both for entering fully into this co-operation with Brunel and for allowing the test results to be published in an anonymous form.

Development of the test rig

As the proposed work fitted so closely into the group's programme it was possible to modify one of the existing test pipe runs to form the basis of a flushability test rig. A P-trap w.c. was chosen as the standard input device based on enquiries on market penetration of various w.c. types. The pipe chosen was 14 m of 100 mm diameter transparent UPVC to facilitate the use of standard photo-electric cell and light source instrumentation developed at Brunel to record solid passage along the pipe and hence velocity. Choice of pipe length and gradient were more difficult. After much discussion a gradient of 1/80 and a successful transport length of 10 m was chosen as reasonable to represent both the more convoluted pipe networks to be found in domestic installation and also the possible worst case formed by an isolated branch w.c., possible in a large building toilet area or a downstairs second w.c. in the domestic sector.

Test programme and results

The initial objective in 1978 was the confirmation of the application of a relationship of the form of equation 1 to the range of products to be tested, not only in the complete form compatible with the single maternity pad test but also in the torn state compatible with the manufacturer's instructions.

Figures 1 and 2 illustrate typical test results from this initial test series where dry untorn and torn towels were flushed from the w.c. In all cases the form of equation 1 is confirmed. Under the normal untorn towel test condition the photo-electric cell/light source pair separation was 0.3 m. However, due to the interaction between multiple solids transported along the pipe, the setting employed for the torn towel tests was increased to 1 m. Although this yields average rather than point velocities the $\sqrt{L/G}$ dependence holds, although the gradient of the data equation is much reduced, indicating an improved travel capability.

Figure 3 illustrates the mechanism of multiple solid transport in the drainage pipe, the successive accelerations, both positive and negative, being referred to as the "push me - pull you" effect. At this stage it is perhaps useful to introduce two other measurement terms, namely the flush volume ahead of the solid and the theoretical zero solid velocity value of $\sqrt{L/G}$.

Throughout the tests, and the earlier DHSS work, values of the quantity of water collected at the drain discharge ahead of the solid were recorded by a simple float driven level sensing device in the collection tank. It had been observed that the transport characteristics of a solid depend largely on its position in the flush and this is borne out by the ASPM results. Solids that fail the test specification on w.c. failure rate may be shown to have a wide spread of volume ahead results; indeed a w.c. failure may be regarded as a limiting value to these results. In the test rig described values of volume ahead above 30% of the 9 litre flush volume generally lead to problems in satisfying the test specification.

The theoretical zero velocity point from equation 1 is of course given by -

$$C_3 = \left(\sqrt{\frac{L}{G}}\right)_{V=0} = C_1/C_2 \qquad (3)$$

In practice deposition may occur from any velocity below about 0.2 m/s. At these low solid velocities the continuing transport is entirely dependent on the retention of a water volume behind the solid. Any irregularity in the pipe can then retard the solid sufficiently to allow excessive water leakage past and deposition will then occur.

At this stage in the testing programme it was decided to investigate the effect of pre-soaking the towel prior to placing in the w.c. bowl. Available literature would suggest (2) that the volume range of menstrual fluid, consisting of blood, mucin and epithelial cells, should be 8 - 20 g. It was decided to employ pre-soak water volumes in this range. Figure 4 and Table 2 illustrate the results of these tests. It is apparent that the addition of pre-soak water to the pad resulted in a deterioration in both the w.c. discharge and solid transport properties of the five pads investigated initially. This result at first seemed to be contradictory to the expected mechanism. However, a series of films taken of the pad sinking action in the w.c. bowl prior to flushing led to an acceptable explanation of these results. With an initially dry towel dropped into the bowl the saturation of the towel material occurs by capillary action so that the level of the water in the saturated towel is always above the bowl water level. This results in a force which draws the towel down into the bowl water.

If the central area of the towel is pre-soaked then two effects are noticeable, firstly the saturated towel tends to cling to the ceramic side of the bowl, and this prevents its immersion in the bowl water, and secondly the presence of a saturated strip across the towel seems to prevent the capillary action and bowl water does not move up inside the towel past this area.

Both these effects lead to a later discharge from the w.c. and hence to deterioration of the transport performance in the drainage system. Any tendency to retain air within the towel cover is naturally exacerbated by this failure to totally sink, again leading to late w.c. discharge.

The final simulation considered was a controlled degradation of the adhesive now used on many towels due to the lessening popularity of looped towels. Although this was not a major problem in terms of the number of towel types affected it is obviously necessary to simulate the loss of adhesive if for no other reason than to be able to state that any failures to pass the test specification were not due to uncharacteristic towel adhesion to the w.c. bowl or to the pipe invert.

After much discussion, and some tests involving preheating of towels to degrade the adhesive, a test procedure involving compressing the towel onto representative commercially available female underwear material was developed.

In parallel to the work reported, similar tests were undertaken on tampons and disposable diaper materials. Figure 5 illustrates these investigations and again confirms the $\sqrt{L}/G$ group predominance. One effect that was noticeable with all torn products but more pronounced with diapers was the random discharge from the w.c. In some cases the material was discharged as a continuous, well spread out stream of pulp with no deposition problems. However in some cases the w.c. action resulted in the diaper pulp being discharged in a concentrated mass with rapid deceleration and deposition in the waste pipe.

CONCLUSIONS

The tests reported involving sanitary towel products have contributed to the development of the flushability specification presented earlier in this paper. This specification has now been approved by ASPM as the basis for future product testing.

In developing the specification, the decisions taken were based on the widest possible application of the test findings, hence the choice of a relatively cheap and common domestic w.c. type. It may be necessary to investigate further the effects of other w.c. types on the flushability of sanitary products, in particular siphonic w.c. designs may well be a topic for future investigation.

The test results will be analysed further to investigate whether there is a correlation between values of C_1, C_2, and C_3 and the geometry of the solids and their position in the w.c. flush, as represented by the volume ahead of solid data.

ACKNOWLEDGMENTS

The Association of Sanitary Protection Manufacturers are to be thanked for making available test results from a programme of work carried out by the Drainage Research Group at Brunel on a consultancy basis.

REFERENCES

1. Swaffield J.A. and Wakelin R.H.M. "Observation and analysis of the parameters affecting the transport of waste solids in internal drainage systems". Journal IPHE 1976.

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Table 2 : COMPARISON OF THE W.C. PERFORMANCE AND TRANSPORT CHARACTERISTICS OF THE TOWELS TESTED WITH AND WITHOUT ADDITION OF PRESOAK WATER PRIOR TO PLACING IN THE W.C. (Note value of C_3 represents $\sqrt{L/G}$ at V=0, a theoretical stoppage position.

Material	A		B		C		D		E	
Condition	Dry	+8ml H_2O	Dry	+8ml H_2O	Dry	+8ml H_2O	Dry	+20ml H_2O	Dry	+20ml H_2O
No. wc failures/ No. tests	0/5	6/30	0/5	4/34	1/6	6/30	0/15	0/20	0/15	0/20
% flush ahead solid	18.75	33.96	25.5	38.4	18.0	29.4	8.2	21.9	14.3	21.9
No. stoppages	0	4	0	5	0	0	0	0	0	0
Mean stoppage position, m	-	10.3	-	9.8	-	-	-	-	-	-
V(L=3.0m)m/s	0.84	0.78	0.75	0.72	0.86	0.86	1.17	0.83	1.06	0.75
V(L=13.2m)m/s	0.58	0.37	0.51	0.34	0.64	0.52	0.61	0.47	0.60	0.45
C_3	62.4	46.3	51.0	44	67.0	57.6	55.3	54	54	56.47
Towel characteristics	l = 190 mm		225 mm		196 mm		226 mm		220 mm	
	w = 70 mm		65 mm		65 mm		70 mm		70 mm	
	t = 14 mm		17 mm		10 mm		16 mm		14 mm	
Saturated wt.	195 g		210 g		140 g		210 g		155 g	

Note that the presoaked towels have worse transport characteristics under each of the measurement criteria of w.c. failures, stoppage positions, volume ahead of solid and velocity at any point along the waste pipe.

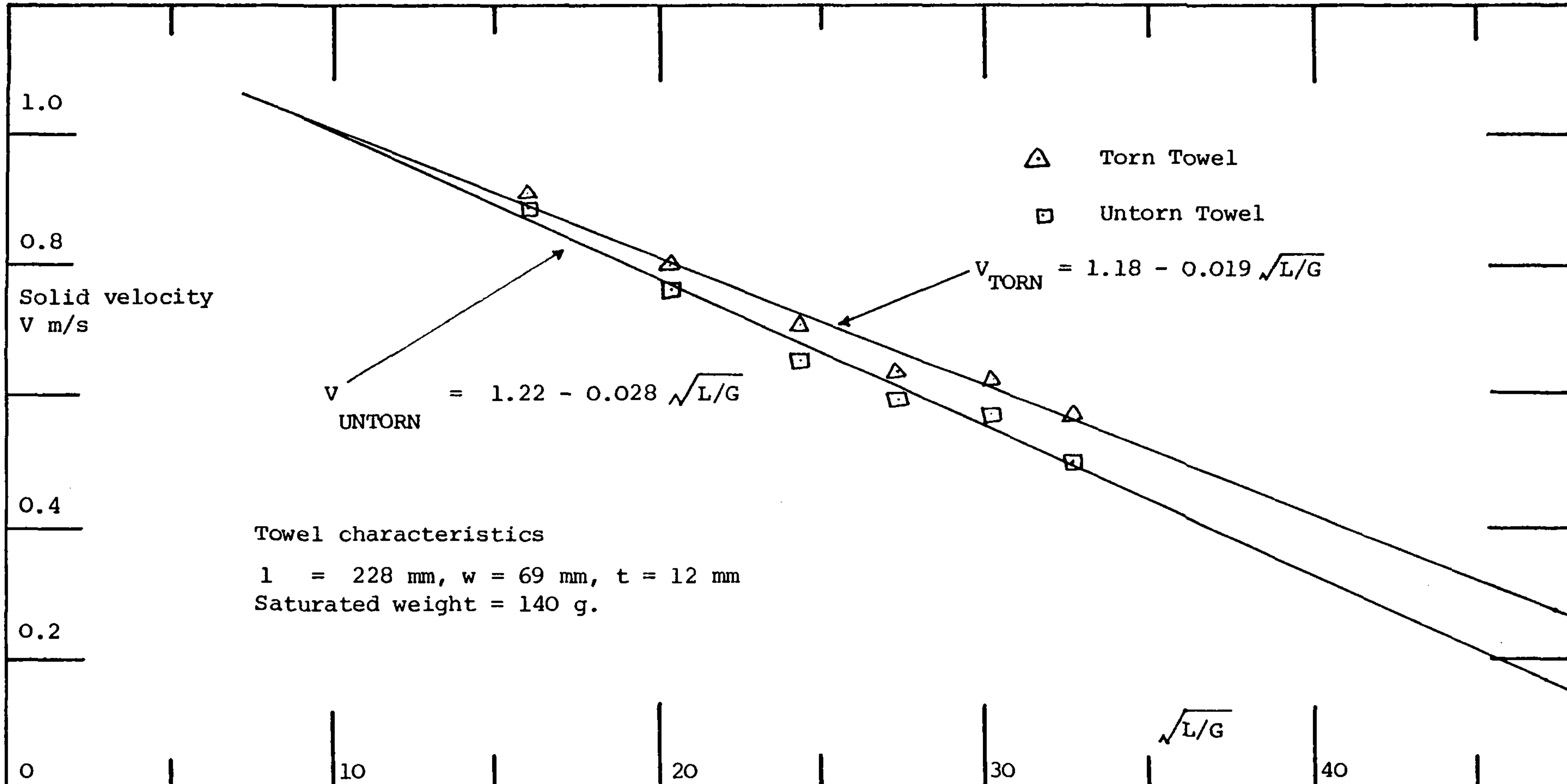

FIGURE 1. Initial test example illustrating velocity dependence on $\sqrt{L/G}$ group for both torn and untorn towels flushed into 14 m of 100 mm diameter UPVC piping via a 9 litre flush P-trap w.c. Note L denotes distance travelled along a pipe set at a gradient G.

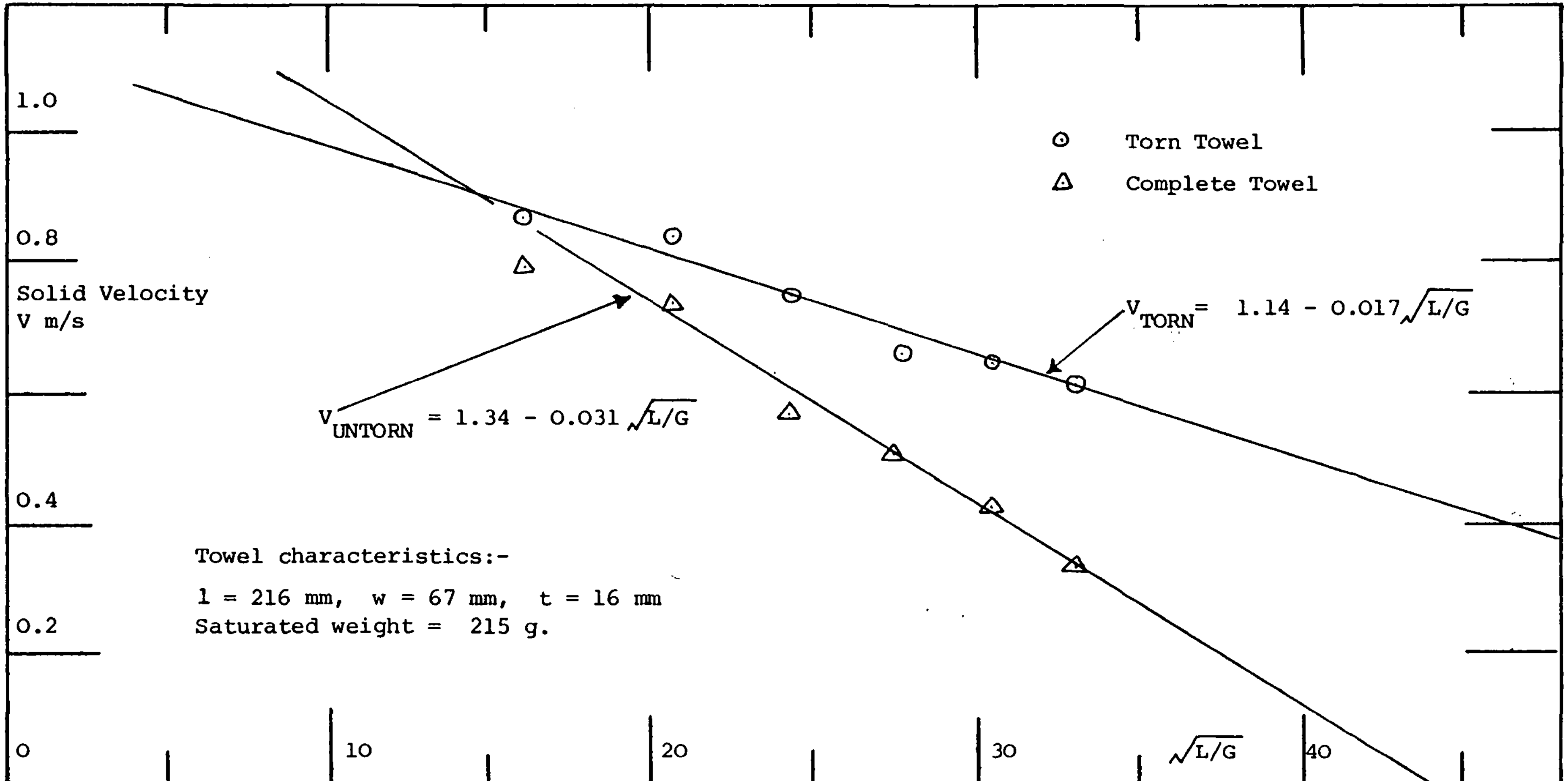

FIGURE 2. Initial test example illustrating velocity dependence on $\sqrt{L/G}$ for both complete and torn sanitary towel transported along 14 m of 100 mm diameter UPVC drainage piping.

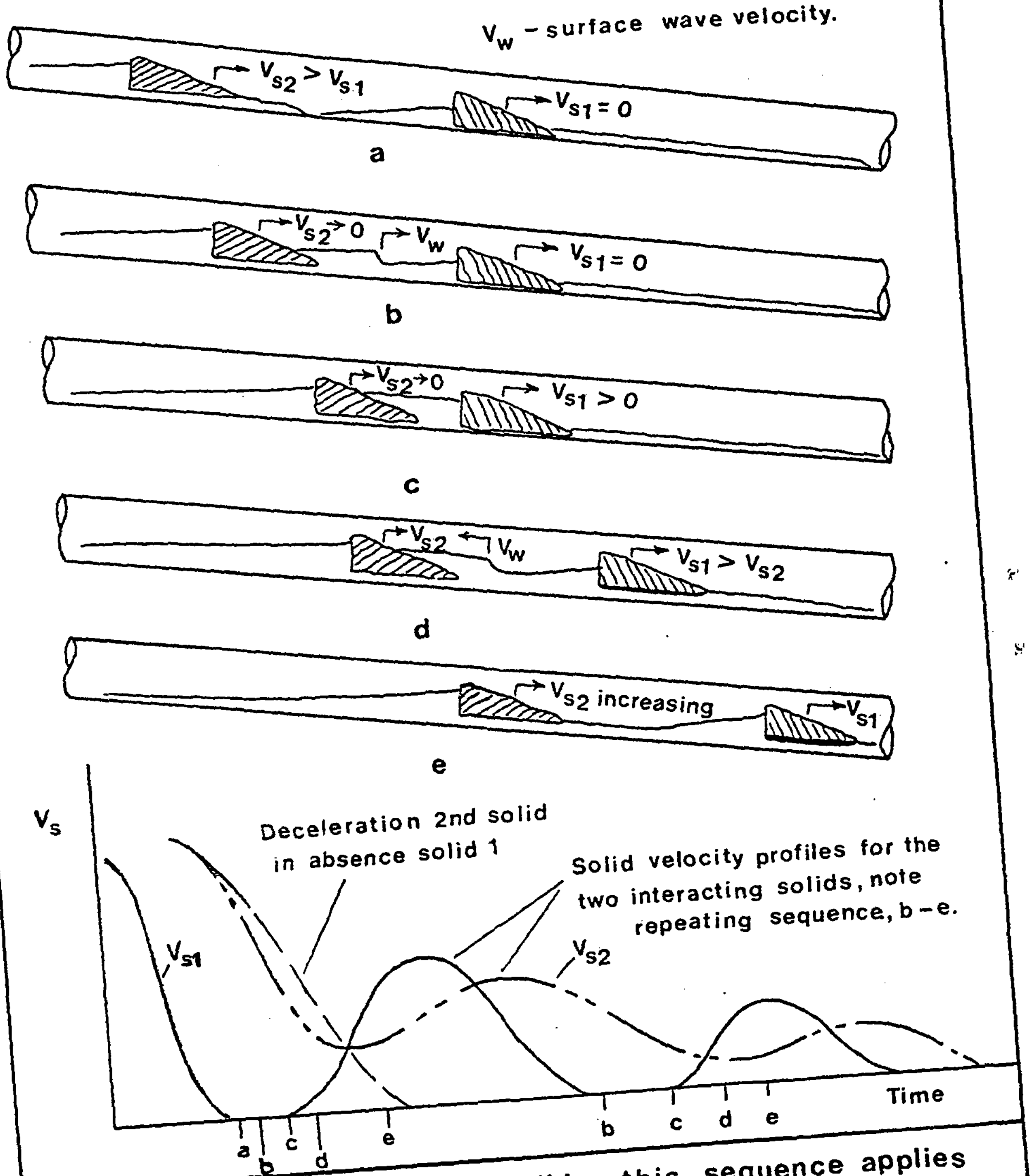

Figure 3 . Interaction of two solids, this sequence applies to separated solids in a single flush and to solids in consecutive flushes.

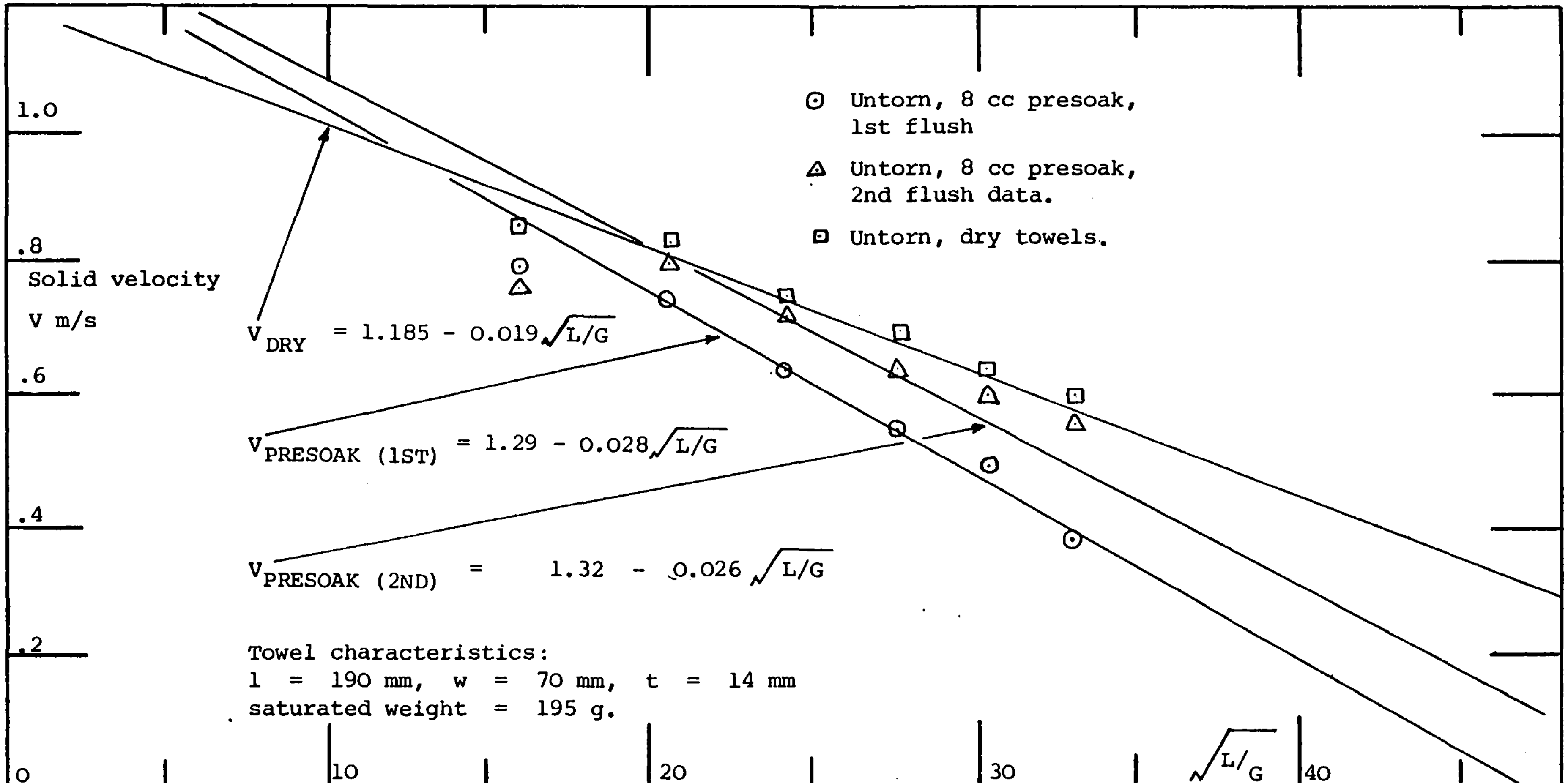

Figure 4. Effect of a 8 cc presoak on the transport characteristic of an untorn sanitary towel. Note improvement in travel characteristics on 2nd flush. This was due to the towel leaving the pan relatively earlier in the flush on the second attempt; in this case mean volume ahead on 1st flush was 34% and 30% on 2nd flush.

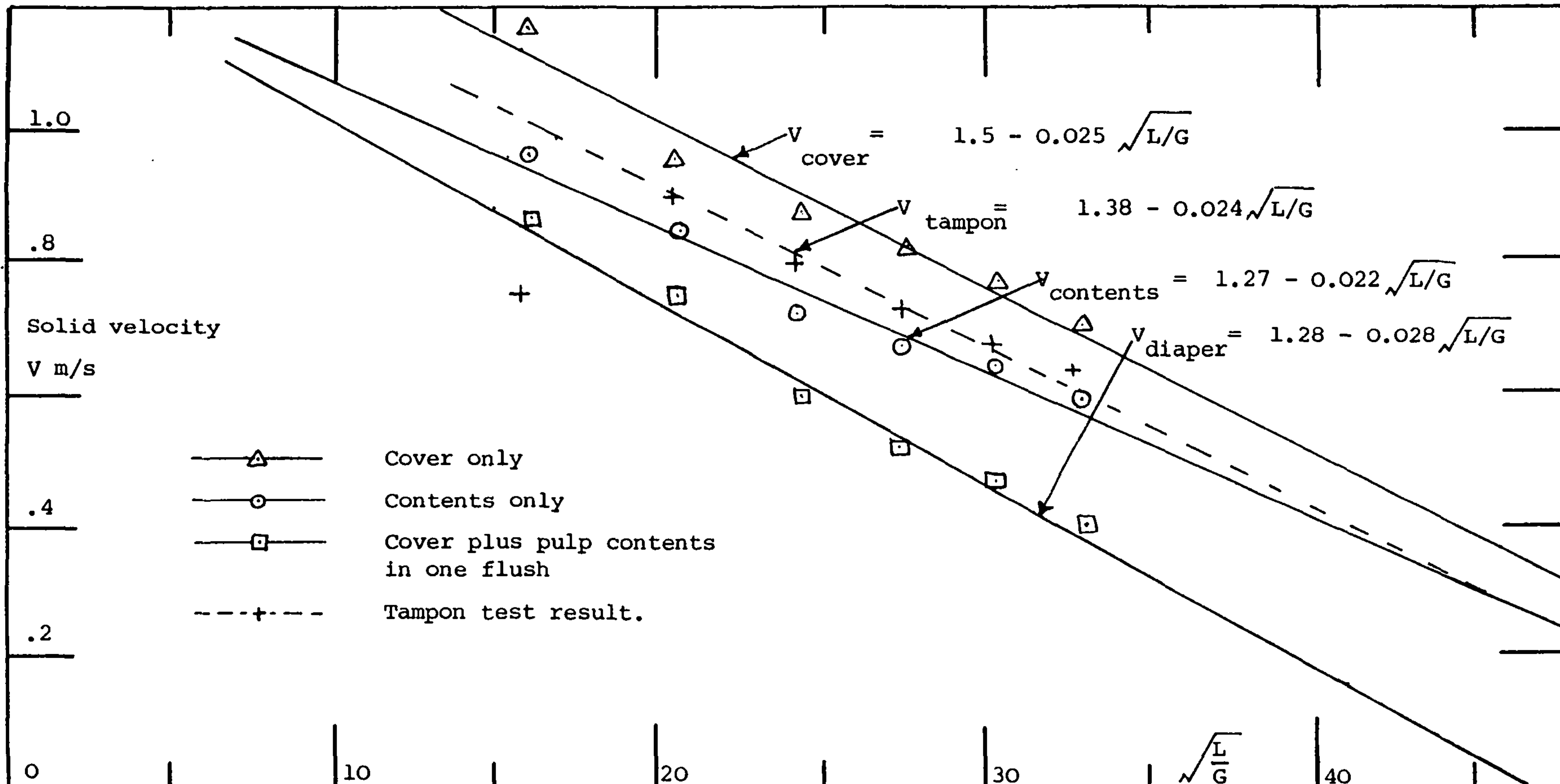

Figure 5. Velocity vs $\sqrt{L/G}$ profiles for tampons and a disposable diaper. Note diaper transport investigated for both cover and pulp contents flushed together and separately in two consecutive w.c. operations.

DRAINAGE AND WATER SUPPLY FOR BUILDINGS

A TWO-DAY SEMINAR ON CURRENT RESEARCH AND FUTURE NEEDS AND OBJECTIVES.

JUNE 3 AND 4 1980

PAPER NUMBER 7.

FAKAZELL, A NEW TEST MEDIUM TO SIMULATE REALITY IN W.C. SYSTEM PERFORMANCE EVALUATION

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TFH BERLIN

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Hans-Joachim Knoblauch

FÄKAZELL, a new test medium to simulate reality in W.C. system performance evaluation

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FAKAZELL, a new test medium to simulate reality in W.C. system performance evaluation

C o n t e n t s

Report on current research as well as future requirements and goals given during a two-day seminar on June 3 and 4, 1980 arranged by
BRUNEL UNIVERSITY, Uxbridge, England
Department of Building Technology

Summary

The methods used up to now to evaluate the flushing performance of closet bowls are based on laboratory tests by observing, if solid or sponge-like testing objects and paper can be flushed out with separate flushings and a specified flushing water volume. Consequently, only a positive or negative evaluation is possible.

The development of a paste-like material similar to faecal matter with adaptable density and consistency and which can be placed into closet bowls in the desired way, makes it possible to simulate the flushing of natural faecal matter together with paper.

With special measuring instruments it is possible to record at the same time the water volume, the flow rate out of the closet bowl as well as the exit of the flushing matter, namely the faecal matter substitute and paper separately. Subsequently, the separate phases of the discharge operation can be distinctly evaluated and the influence of various factors can be analyzed.

1. Characteristics of Faecal Matter Substitutes

The evaluation of simulated discharge operations in closet bowls and drainage pipes is decisively influenced by the quality of the faecal matter substitute used. For testing and research purposes the following materials have been used up to now:

a) Solid Objects: For example, balls made of synthetic materials in different sizes and densities.

b) Resilient Objects in the form of sponges, which, after being deformed by squeezing together, resume their original shape after getting wet. Several cylinderical shapes are used.

c) Resilient Objects made of textile cotton which have sponge-like features when wet, known as the so-called sanitary napkin, used in one piece.

d) Paste-like Matter which does not resume a preceding shape after it is deformed. One or more parts are used as a faecal matter substitute.

With regard to deformation, paste-like matter corresponds to natural faecal matter.

Closet bowls should be thoroughly rinsed after each test with faecal matter and there should be no remainders in the bowl or trap. Connected paste-like forms on the one hand and several irregular shaped pieces on the other hand are flushed down in different ways. Large parts can fall apart into several pieces during discharge. This indicates that only paste-like matter can be used to simulate the variable conditions of natural faecal matter.

The way the faecal matter substitute can be deformed has a decisive influence on the changes of the flow pattern in the trap during the flushing process and consequently on the flow rate which is responsible for transporting the solids. With the majority of all well-known closet bowl models the cross-sectional area of the trap changes from cm to cm. Here unyielding objects (solid matter), resilient matter (flexible by loading and unloading) and paste-like matter (flexible by loading) very differently influence the discharge. The water volume which follows the solids, the so-called afterflow depends on the amount of water which can pass by the solids. The afterflow has an important influence on the transportation of flushing solids in branches and stacks during a flushing operation.

Closet bowl flushings can only be simulated authentically, if faecal matter substitutes and paper are flushed together. Several solid and resilient objects are often wrapped in paper and are caught in the trap. This results in unrealistic situations.

2. Measuring Instruments to Record the Evacuation Process of Solids

In the first part of a research project in the laboratory for plumbing technique at the "Technische Fachhochschule" in Berlin, 19 closet bowl types produced in Germany were tested to determine, if flushing performances could be distinctly evaluated by experimental recordings. Criteria resulted, as shown in picture 1:

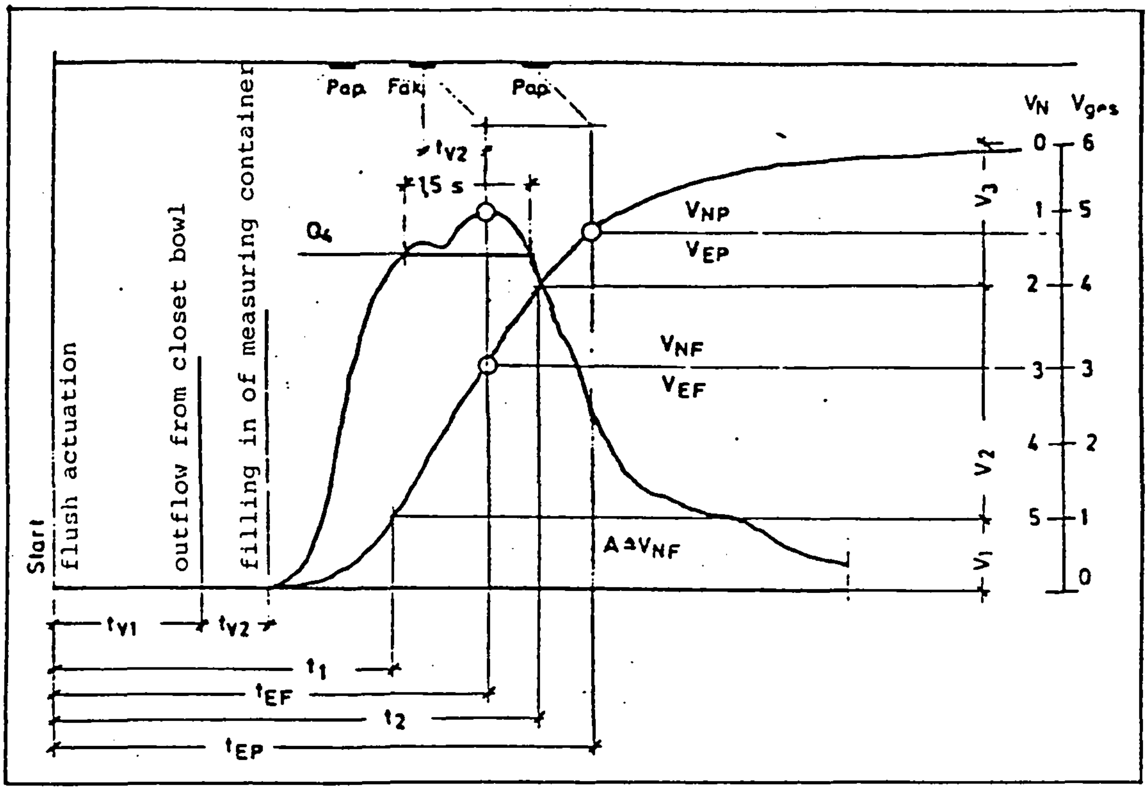
a) The flow rate Q_4 defined as the discharge rate out of the closet bowl of which the maximum value corresponds to a deviation of 1,5 sec (This value is at this time being internationally discussed as standard), and

b) the afterflow V_N, defined as V_{NF} when referring to the faecal matter substitute and V_{NP} when referring to paper.

A water flow measuring instrument developed by the Swiss firm GEBERIT AG allows a synchronized recording of ΣV (flow volume - time diagram) and $Q = dV/dt$ (flow rate - time diagram).

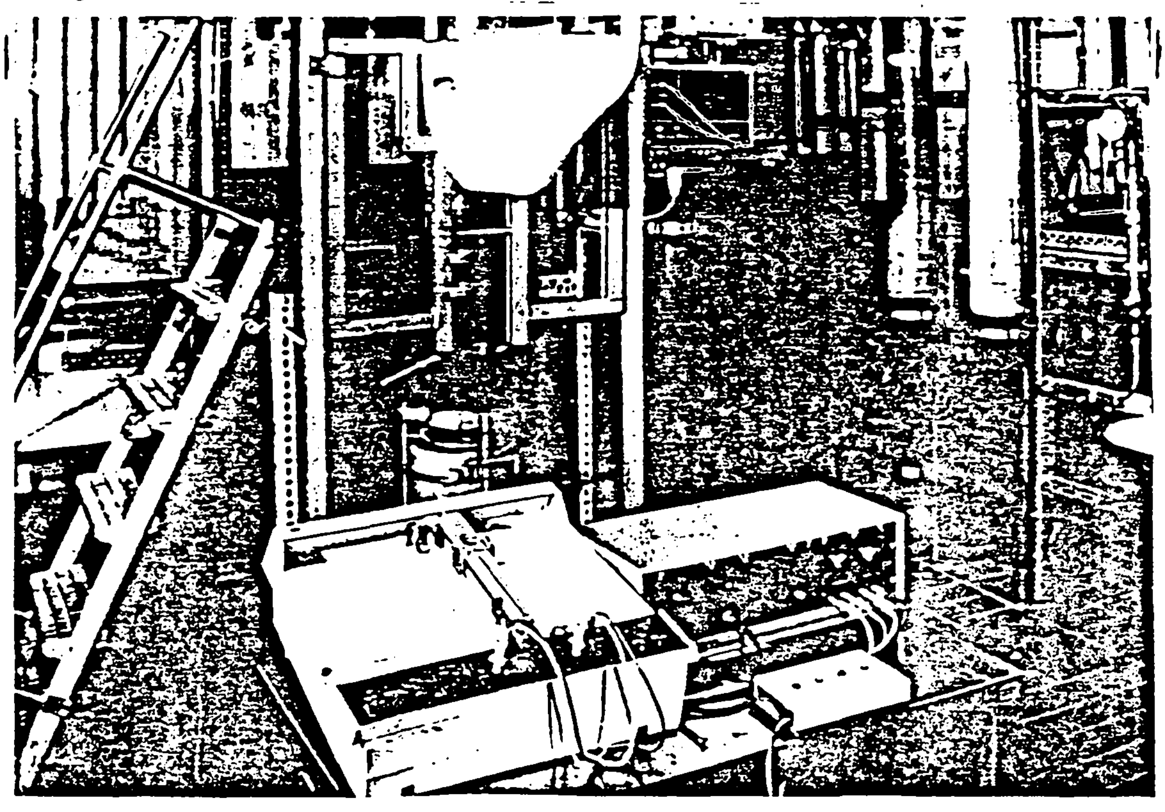
The presence of flushing solids changes the course of both characteristic curves, due to the cross-sectional narrowing in the trap. In the combined diagram also the third criteria, the moment the flushing solid leaves the bowl, can be registered. After considering the delay values depending on the flow rate (the time difference between the exit of the solids and the recording of the flow rate), the afterflow criteria V_{NF} and V_{NP} can be projected on the flow rate- time and flow volume - time curves by registering the moment of evacuation of the solid matter.

Picture 2 shows the measuring instruments.



Picture 1: Illustration of the measurement value recordings and the analysis to determine Q_4, V_E and V_N

Picture 2: Place of measuring with container (under the WC), monitoring amplifier (right), signal transmitter (front right) and line recorder (left).



When solid, resilient and paste-like faecal matter substitutes were used, varying dispersed characteristic curves resulted. Therefore, the development of a faecal matter substitute with the same ductility as natural faecal matter appeared to be necessary. However, also the density and consistency of the solid substitute must be extensively adaptable to natural faecal matter.

3. FAKAZELL - a paste-like faecal matter substitute - How it is Processed and its Rheological Characteristics

Faecal matter substitutes must meet the following requirements:

- mushy, consistency and surface similar to faecal matter
- variable and adaptable density
- does not decompose
- no unpleasant odour
- disperses in water
- does not irritate the skin
- harmless to drainage systems
- can be uniformly coloured

FAKAZELL consists of up to 20 % solid substances (mainly cellulose) and up to 80 % water.

It is prepared from two components (filling and binding material) with different colourings, which are mixed together and uniformly kneaded, thus resulting in a colour mixture.

Important rheological adaptation values are the density and the consistency. These two values decisively influence the evacuation out of the closet bowl and the floating behaviour in the drainage pipes. Before using, the density can be adapted to the desired value at will with additional matter.

Since natural faecal matter from a bowel movement consists of remainders of different foods, it has variable densities (not only $\rho \geq 1.0$ kg/l, but also $\rho < 1.0$ kg/l). Therefore, when testing closet bowls, faecal matter substitutes with different densities should be used. For the tests within the scope of this project, two different densities appear to be sufficient.

ρ = 1.03 . . . 1.05 kg/l (FAKAZELL 105)

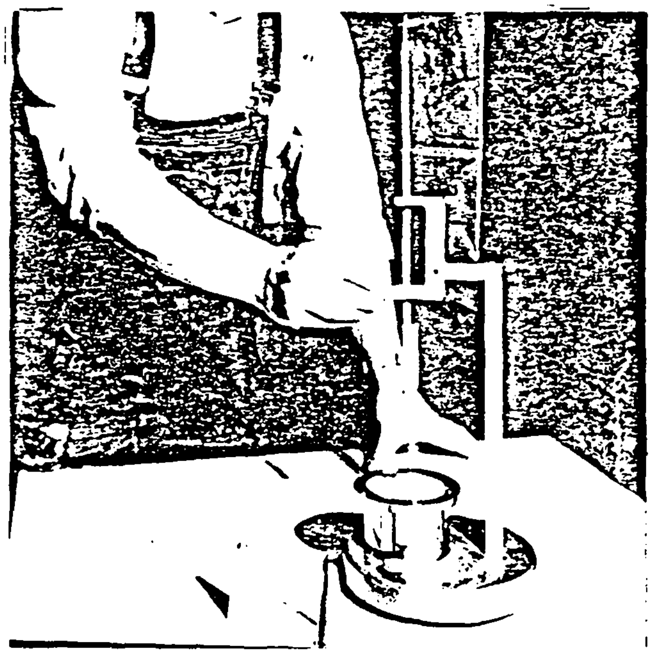
ρ = 0.95 . . . 0.97 kg/l (FAKAZELL 95)

The consistency is not a clear-cut concept. Determining the consistency is purely a method which comparatively expresses the rigidity of paste-like solids with a measured value. In reality penetremeters (for example as cone penetremeters) are used. To measure the consistency of FAKAZELL, the easy to use rigidity measuring device according to DIN 4211, which is shown in picture 3 is sufficient. This device is usually used to measure the rigidity of plaster and wall binding stones in construction engineering. With this device the penetration depth of a defined falling object (according to DIN a cylinder in PVC shaped like a ball on one end) with a determined weight is measured in mm in a mush test.

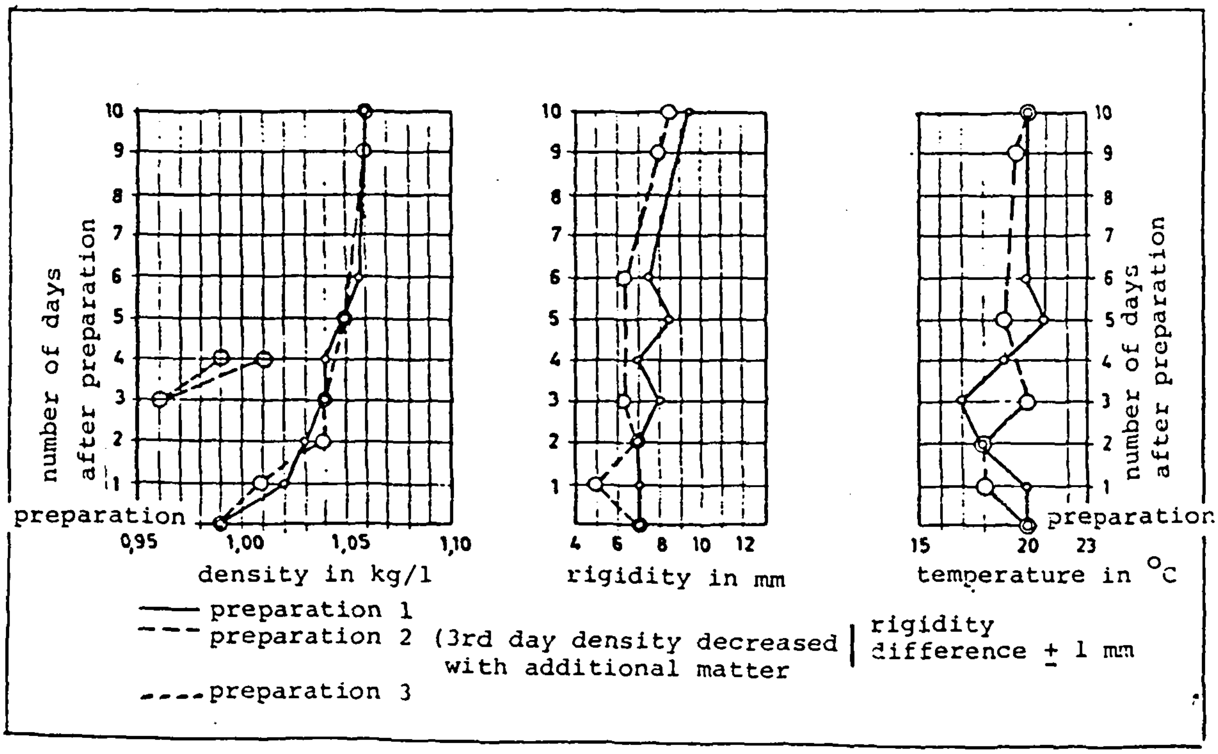
Not only the density and rigidity test, but also the consistency control should be immediately carried out after the preparation of the mush, if it must be kept for a longer period of time. Picture 4 shows the change of the rheological values in the course of 10 days. If the density is adapted with additional matter, the rheological behaviour, which is dependent on time, changes.

Because of the influences of density and consistency on the test results, the FAKAZELL mush was only used once during the research project. All substances which are dispersible in water change the rheological values already after the first use and renewed kneading.

<u>Picture 3:</u> Rigidity measuring instrument according to DIN 4211 in operation.



<u>Picture 4:</u> Rheological behaviour of FAKAZELL in the course of 10 days. The mush can be used from the 3rd day on.



A reutilization from one day to the next, even without additional matter to adapt the density, is basically possible. After the first use, the mush is immediately separated from the paper and hung up in a sieve or net to drain. In picture 4 the change of the density and consistency after rekneading is shown.

For the closet bowl test, this variation can be justified. When testing the floating behaviour in drainage pipes, adherence to the rheological values must be carefully observed. If there is a difference in the density of 0.01 kg/l and different floating distances result, then it is hard to determine if these differences are caused by the density or other influences.

Special instruments were developed to process FAKAZELL. The following pictures illustrate the instruments and their application.

A mush press is used to place equal portions of FAKAZELL in the closet bowls. Its function is represented in picture 5. It is largely made of commercial PE drainage pipes and fittings as shown in picture 6. Corresponding to the required amount of mush, the cartridge can be cut to size from a PE pipe with an inside diameter of 50 mm.

When it is placed into the flat wash down WC bowls the mush lays similar to natural paste-like faecal matter as shown in picture 7. In flush-down type WC bowls the faecal matter substitute drops in very irregular shapes.

For the first part of the project 200 g of FAKAZELL in the form of a sausage as shown in picture 8 was placed into the bowl of the test specimen. The centre point of the press was marked on the support grating to guarantee the same direction and height for the drop.

Since without preliminary tests approx. 1'000 portions were processed for the first part of the research project, it is conceivable that a special cartridge filling instrument is necessary.

<u>Picture 5:</u>

FAKAZELL press

1 body

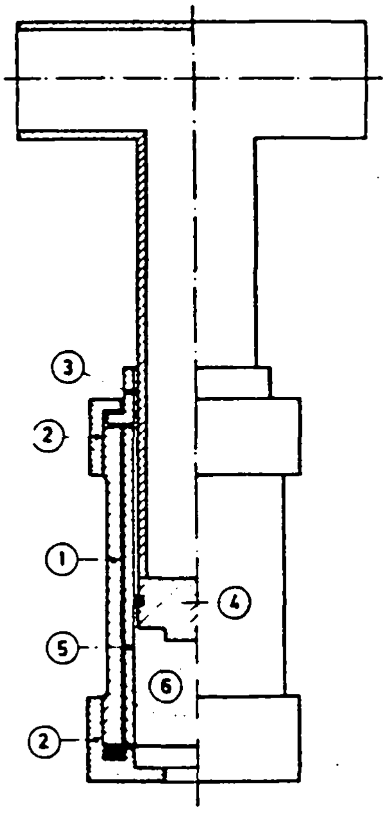
2 screw cap

3 flange bushing

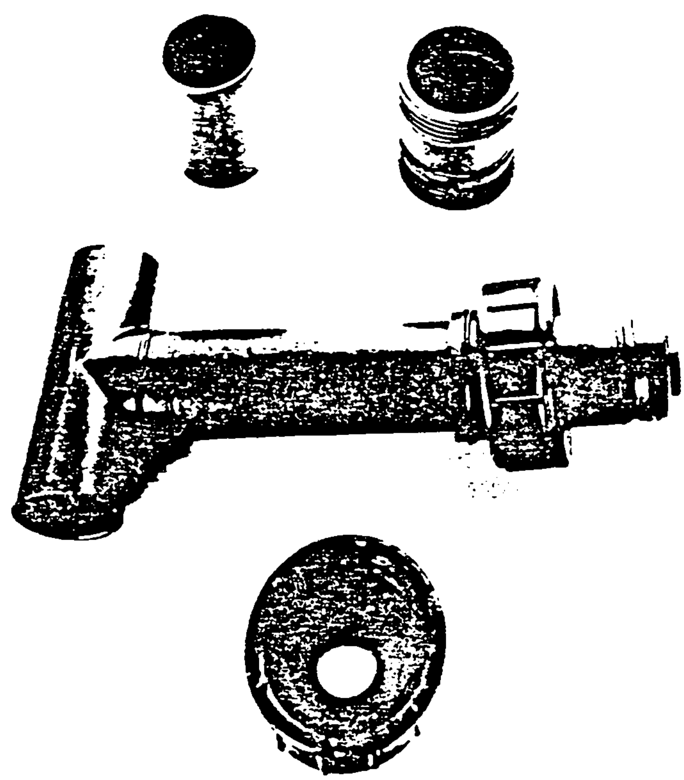
4 piston with O-ring

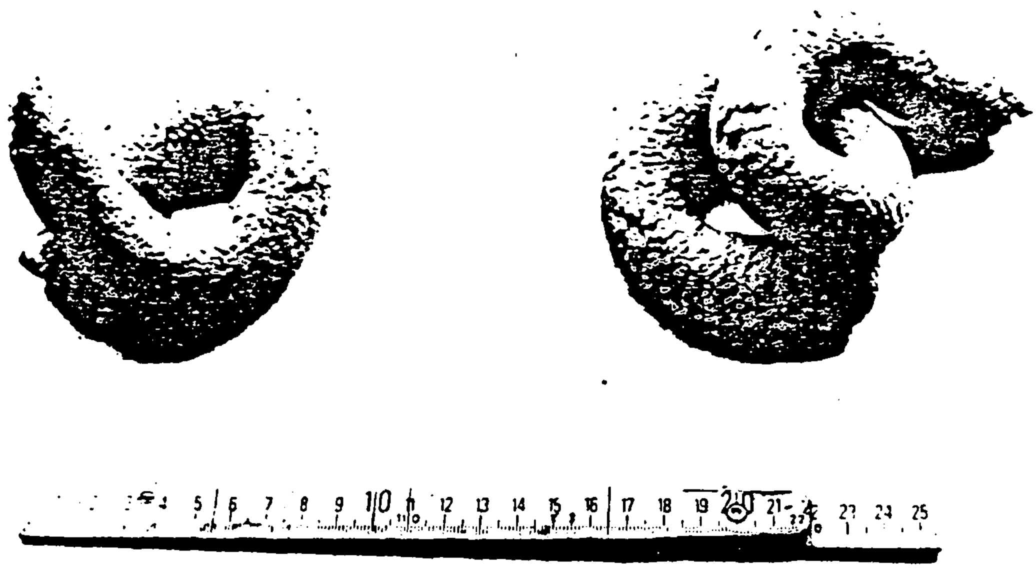
5 cartridge

6 FAKAZELL mush



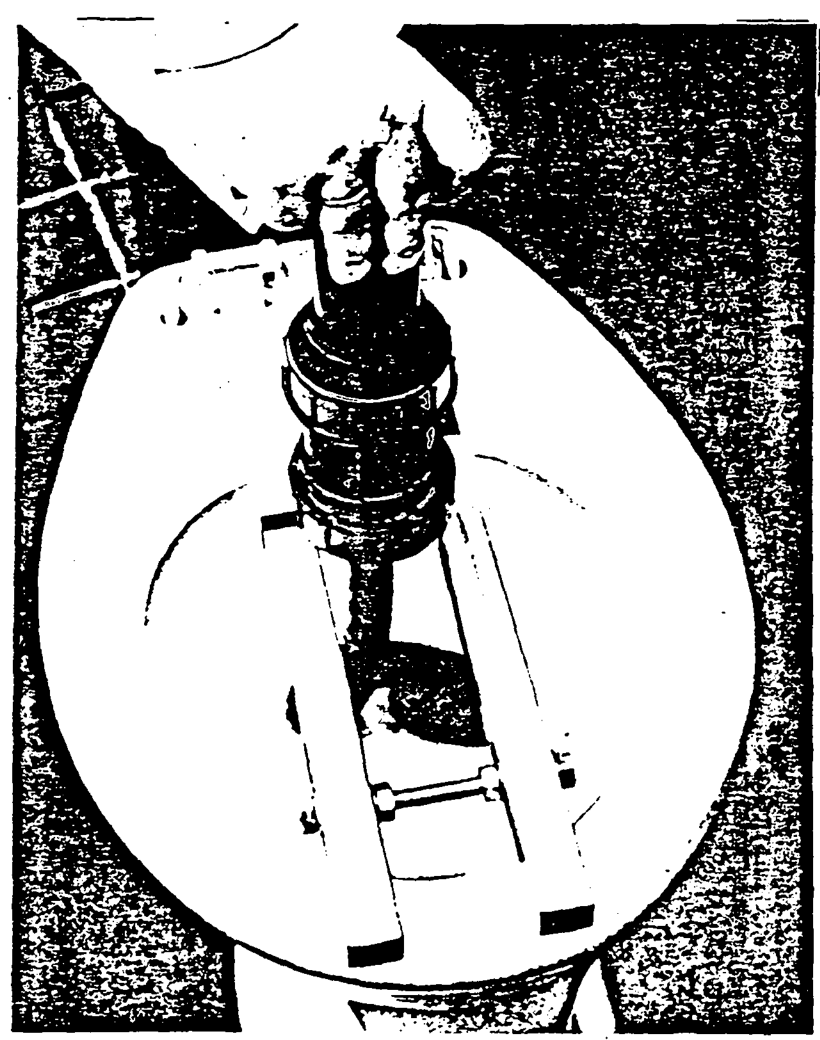
<u>Picture 6:</u> Parts of the FAKAZELL press





Picture 7: FAKAZELL portions 150 g (left and 200 g (right)

Picture 8:
Placing FAKAZELL
in the closet
bowl.



Picture 9: FAKAZELL filling instrument

1 container

2 pair of flanges

3 piston with pull out string

4 filling nozzle

5 cartridge

6 compressed air connection

7 ball tap "fill up"

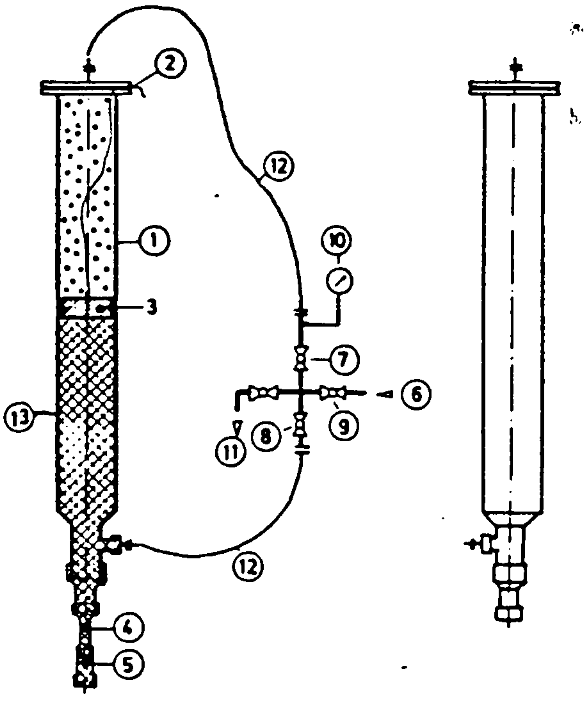
8 ball tap "clean"

9 ball tap "portioning"

10 manometer

11 ball tap "discharge"

12 pressure hoses



Picture 10: FAKAZELL filling station - filling the cartridges

The function of this instrument is illustrated in picture 9. The FAKAZELL mush (13) is pressed out of the container with compressed air above the piston (3) under 0,5 ... 1.0 bar through the filling nozzle (4). The outside diameter of the filling nozzle corresponds to the inside diameter of the cartridge (5). If the cartridges, which are closed at the lower end with a cap, are pushed completely against the filling nozzle, the mush will fill in regularly resp. cross-sectionally from below to above to prevent air gaps. The filling velocity is adjustable with the air pressure on the portioning tap (9) and/or the discharge tap (11).

To clean the container (1) the filling nozzle is closed and the container is filled with water. After compressed air is filled in, which causes the water to whirl around. With this instrument all FAKAZELL remainders loosen from the inside of the container.

After the container is emptied, the container walls can be dried quickly with blowing air. In order to comply with the rheological values, the container and the cartridges should be dry before they are filled.

The filling instrument is made of commercial PE drainage pipes and fittings.

As already mentioned, FAKAZELL should be processed with a steady temperature. This can be done with the evaporation of water on the outer surface of terry towels, which are sewn around the container and lightly sprinkled from above with water.

Picture 10 shows the application of the filling instruments

The amount of time and accuracy necessary to process FAKAZELL was evaluated as disadvantageous in discussions concerning this testing model. Without doubt, testing with FAKAZELL compared with rigid and resilient matter requires as much extra time as it takes to process it. If the reasons for the required amount of time are listed, it might be easier to decide, if this method can be justified.

For processing 20 kg of FAKAZELL the following amounts of time are necessary for an assistant:

a) Preparation of the components and mixing	40 min
b) Determination of the density and consistency	10 min
c) Feeding the filling instrument	30 min
d) Filling 100 cartridges at 200 g each	30 min
e) Cleaning the cartridges	10 min
Total time required for processing 100 portions of FAKAZELL at 200 g each or 130 portions at 150 g each	120 min

The reutilization of FAKAZELL hardly saves time. It can be considered for a series of measurings. In this case it is not necessary to add new mush to smaller amounts and to wait till it is ready for use.

The distribution of FAKAZELL mush for example in 5 or 10 kg containers would eliminate weighing the component parts (except water) at the place of use. Furthermore, the central control of the rheological characeristics related to this procedure would benefit uniform test results. Up to now the costs could not be calculated. However, this much can be said: The drastic increase of the testing costs, due to the cost of FAKAZELL could hardly be justified.

4. Analysis of the Flushing Performance from Measurement Recordings of FAKAZELL Evacuation

The application of the described instruments makes measurement recordings possible, which are informative with regard to the flushing behaviour of WC's.

- Undoubtedly the foremost construction goal will be a possible early evacuation of the flushing solids, if the water consumption has to be decreased. Of course, generally, the total flushing water volume is specified in the test regulations, but the afterflow is not. If an early evacuation results during the testing of WC models for approvals leaving a larger share of water for the afterflow, this has the same meaning as the confirmation of a good hydraulical quality.
- If the evacuation occurs in the final stage of the discharge (in the flat area of the t-v-characteristic curve) the probability of an incomplete faeces and paper evacuation must be taken into consideration.
- Such a test method would be good for the consumer. Of course, it is conceivable that manufacturers of WC's with the above mentioned good hydraulical quality are prepared to also express this in measurement recordings.
- With such measurement recordings the technical designer is offered the possibility to recognize comparative development progress. It can also be determined in which way forms specified exclusively from the design affect the hydraulical function.

The following pictures illustrate essential differences in the flushing behaviour of WC's.

<u>Picture 11:</u> The characteristic curve representing clean water of a flush-down WC with a mounted cistern with Vges = 6.0 l results in a discharge of Q_4 = 1.6 l/s.

<u>Picture 12:</u> A flushing of 200 g with a density of ρ = 1.03 kg/l and 9 mm rigidity according to DIN 4211 (this is an average value which refers to the range of application of FAKAZELL) results in a very early and reliable evacuation. The final value of ΣV compared to the first value Vges is a considerably smaller recording, because of the displacement volume of the solids.

The more similar the characteristic curves from a set of flushings, the more steady and reliable the flushing behaviour.

Picture 13: The characteristic curve representing the clean water of a German universal closet bowl, which can be used as desired with cisterns and flushing valves shows a discharge of Q_4 = 1.2 l/s. For the flushing a device developed by the TFH Berlin was used, which in connection with a conventional flushing valve makes reliable, but differentiated flow rates and flushing water volumes possible.

Picture 14: The flushing solid was caught in the trap. The discharge was decreased down to 0.5 l/s. Then with two flushings the break-through of the flushing solid resulted. With the third flushing the solid was still not evacuated.

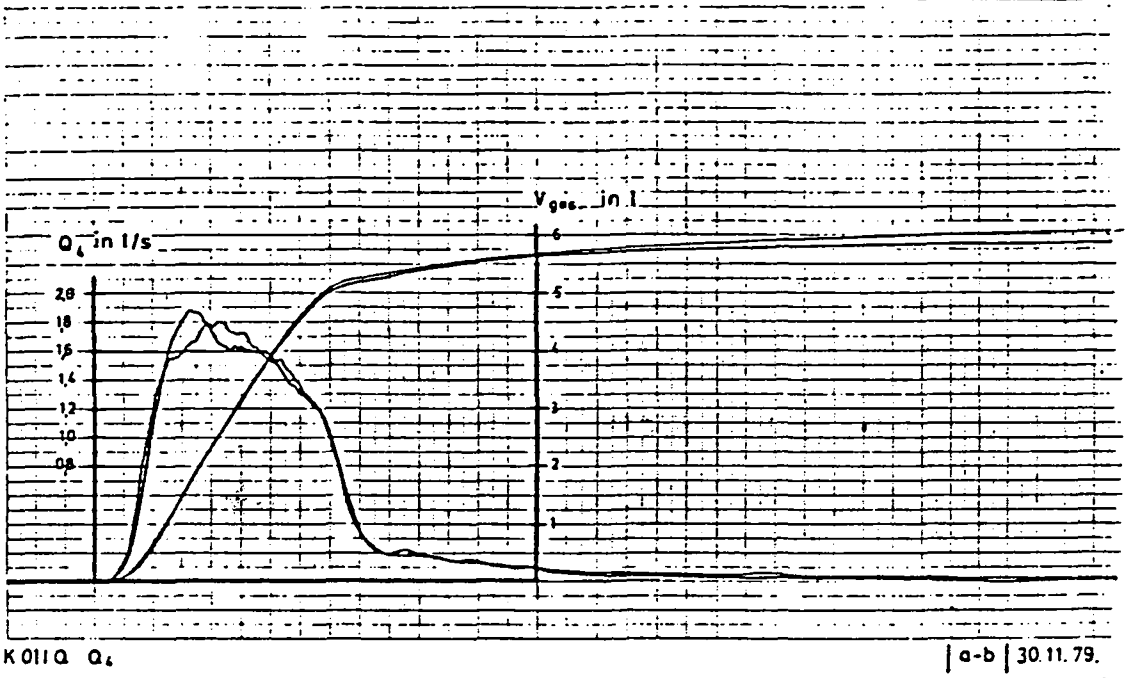
Picture 15: With the same setting as in the previous diagram the flushing once again did not result in the evacuation of the FAKAZELL. However, in this case, the paper was flushed down.

Picture 16: This diagram comparatively shows measurement recordings of flushings above a cistern with an installation height of 120 mm. The black and red characteristic curves from flushing operations without flushing solids result in a discharge of Q_4 = 1.2 l/s. The flushing behaviour represented by the blue curve shows a similar course as in the diagrams 14 and 15, when the flushing valve installation was used with the same discharge.

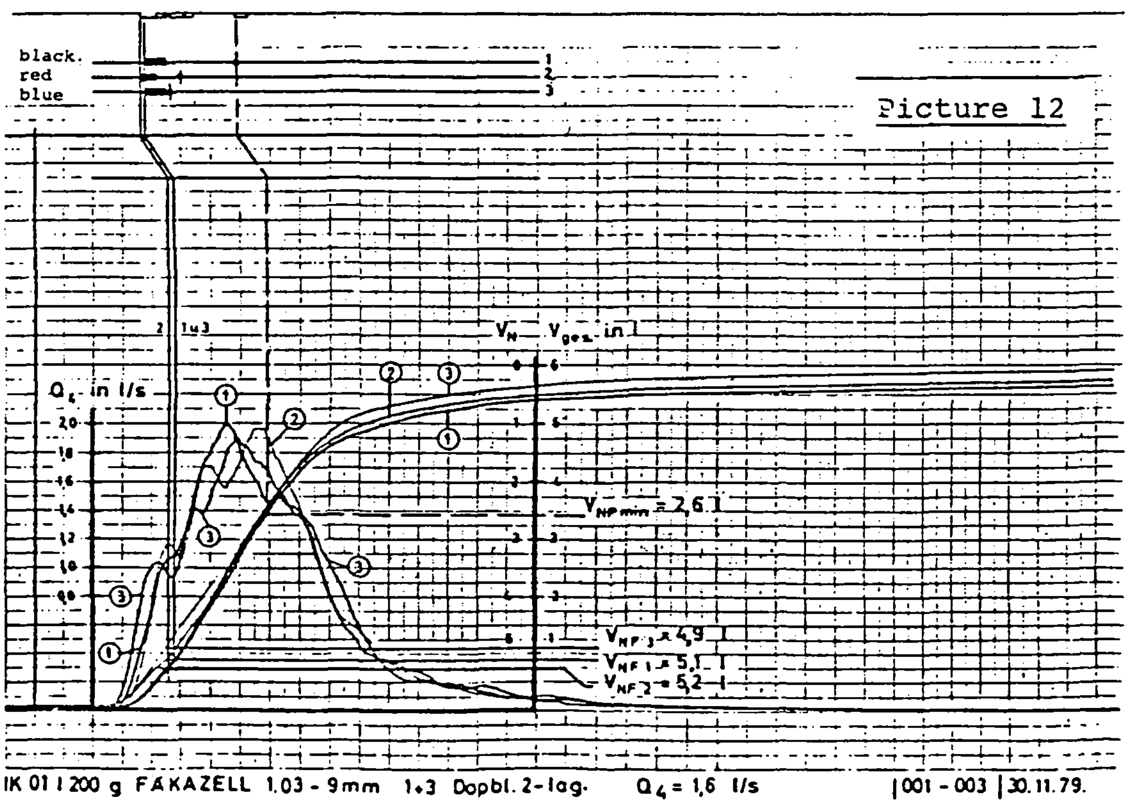
To summarize, the following evaluation with regard to the rinsing of the trap is possible from the measurement recordings shown:

- The closet bowl which was evaluated in the first two measurement recordings (diagram 11 and 12) produces reliable results with a large afterflow. A flushing with Vges = 6.0 l guarantees a reliable function.

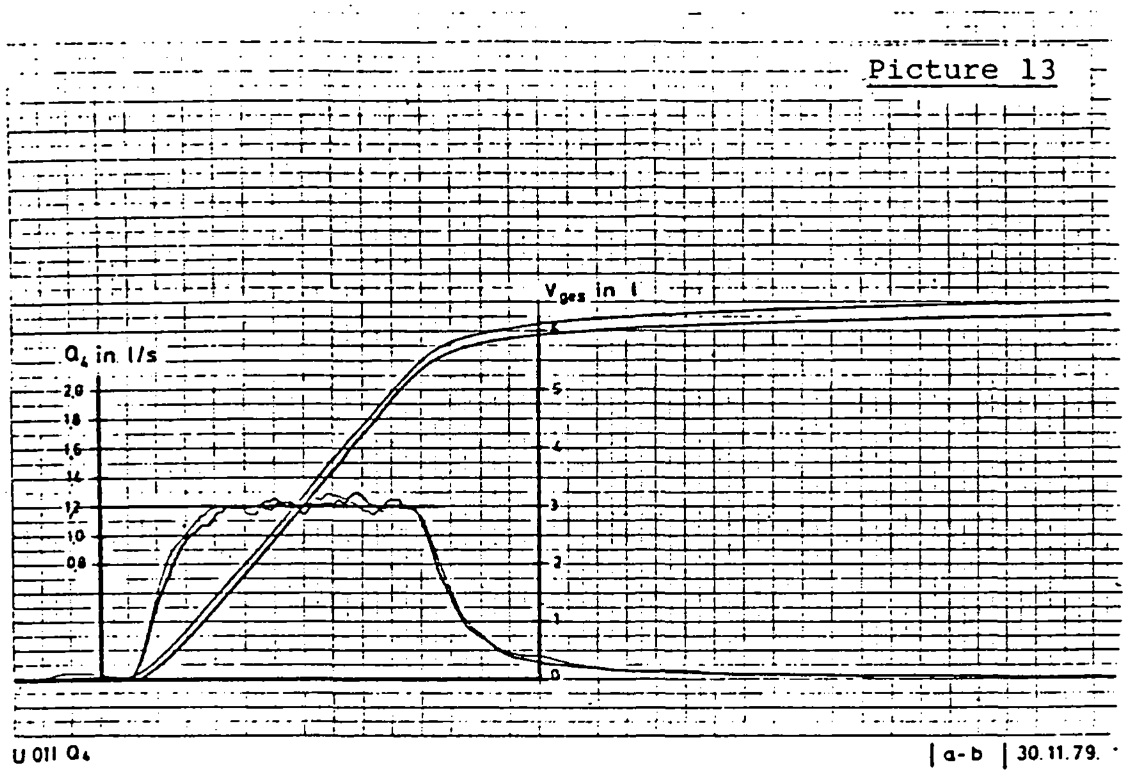
Picture 11



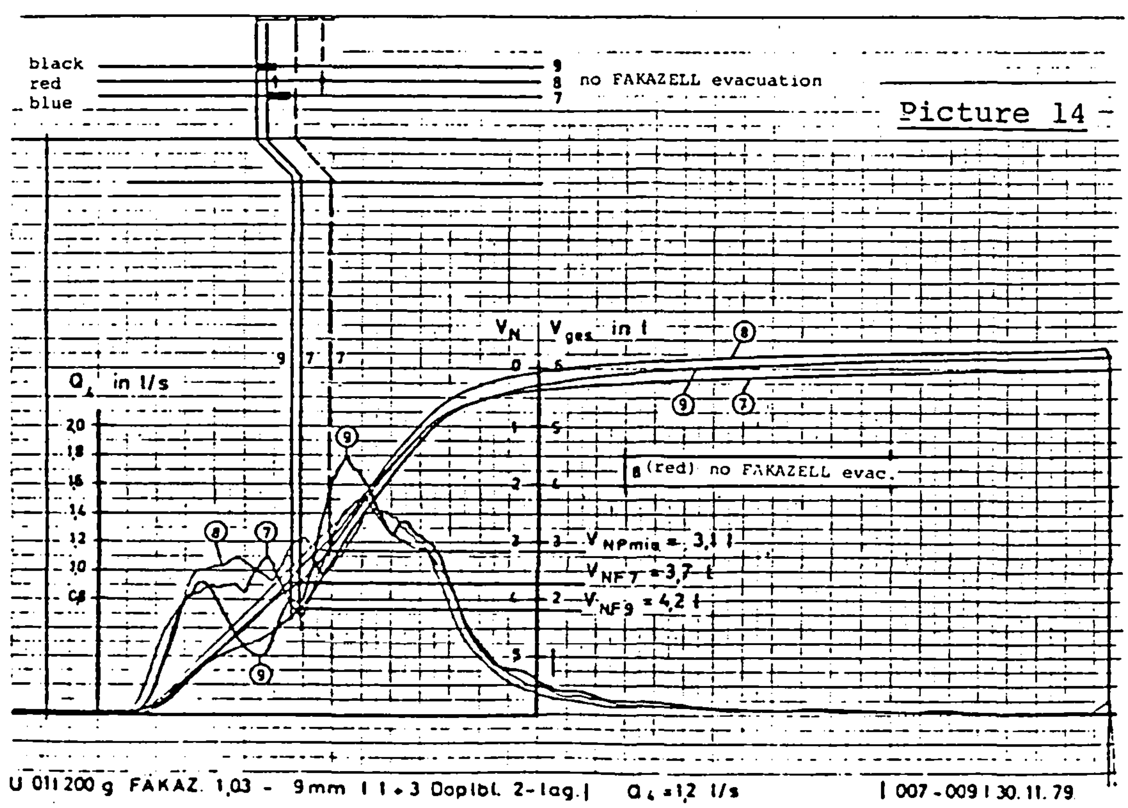
Picture 12

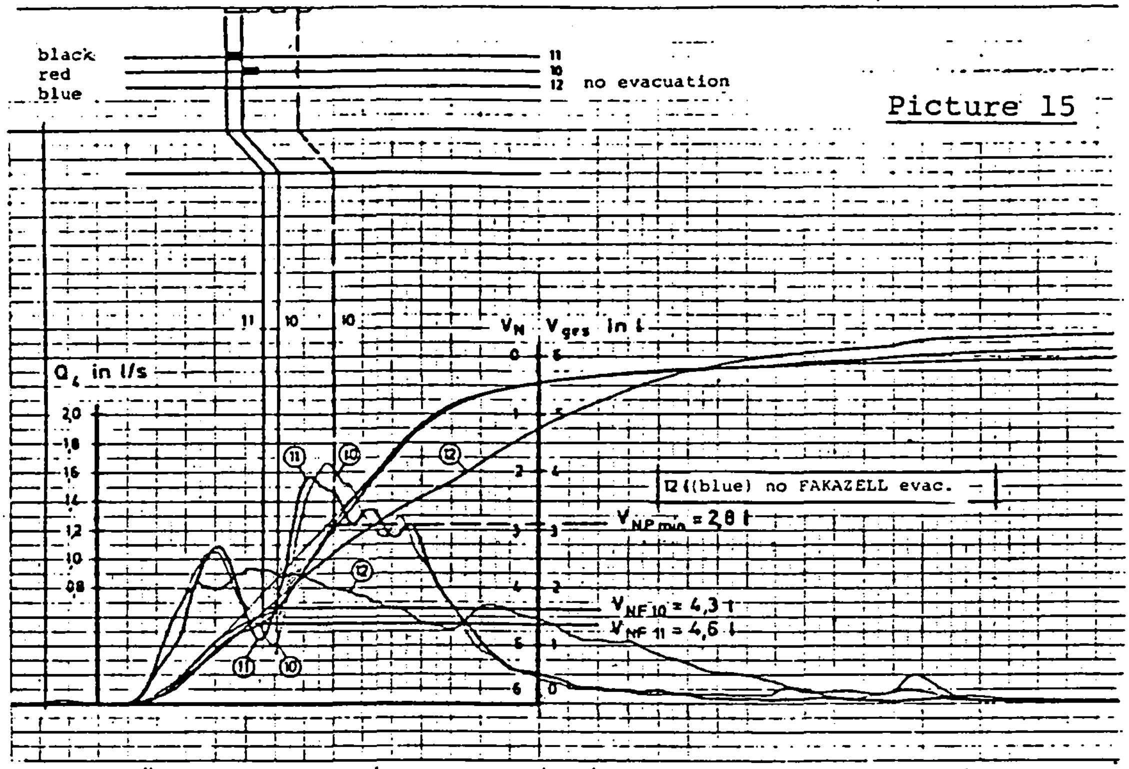


Picture 13

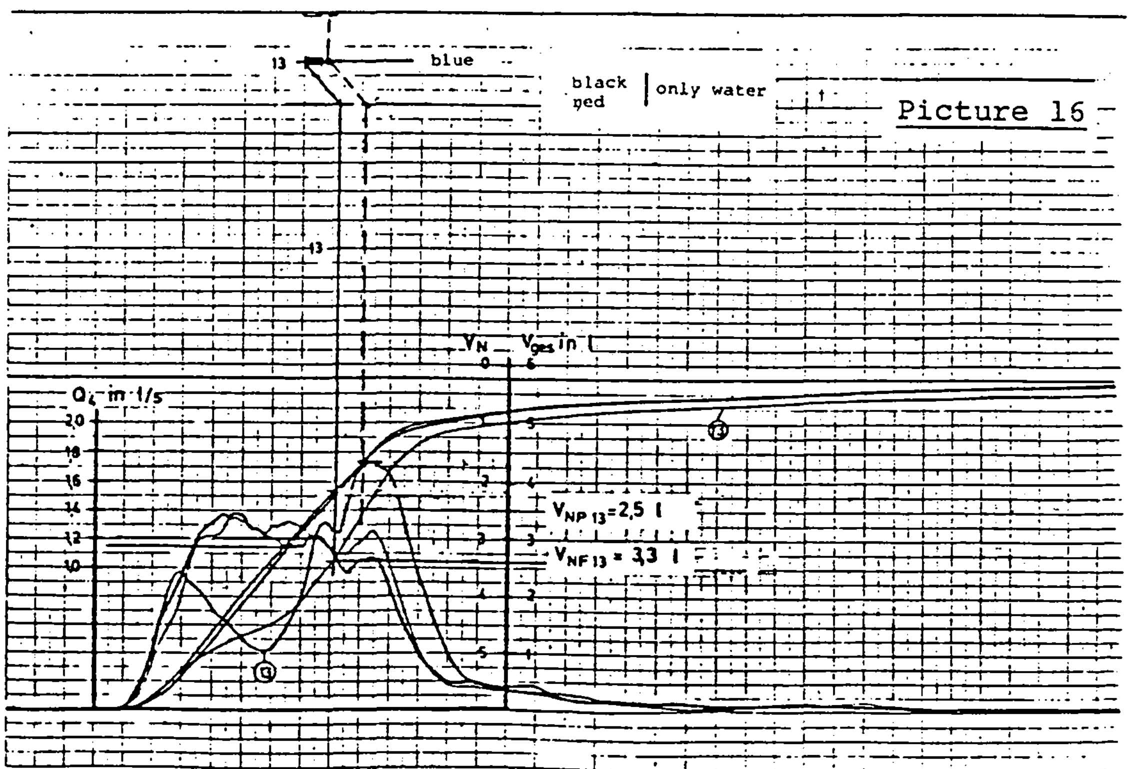


Picture 14





U 011 200 g FÄKAZELL 1,03 - 9mm | 1+3 Doplbl. 2-lag. | Q_L = 1,2 l/s | 010 - 012 | 30.11.79.



U 01| 200 g FÄKAZELL 1,03 - 9 mm | 1+3 Dplbl. 2-lag. | Spülkast. 120 mm | | 013

- The measurement recordings of the second series of diagrams (13 ... 16) clearly show an unreliable characteristic of the tested bowl. A flushing with Vges = 6.0 l is not justified. With variated flushing water volumes or if necessary flow rates, the application requirements should have been determined by way of this technique.

For the purpose of a reliable evaluation with reference to application, similar measurement recordings should be carried out using FAKAZELL with a density of $\rho \approx 1.0$ kg/l.

A deduction, if suitable or not suitable, can only be made from an analysis of an accumulation of a determined curve characteristic or from unsuccessful evacuations. This does not only pertain to the measuring instruments illustrated in this report. Even with other instruments the evaluation from a few flushings is extremely questionable. Testimonies which are fair to the consumer and the manufacturer can only be formulated after about 20 flushings.

5. Conclusion

Now that paste-like matter has been introduced as a faecal matter substitute in combination with paper during the flushing of WC's, realistic flow operations can be simulated. The paste-like faecal matter substitute FAKAZELL not only can be formed as desired and, to a great extent, uniformly shaped, but also the density and consistency can be adapted to that of natural faecal matter.

With the described measuring instruments, the transportation of FAKAZELL through the trap can be recorded and registered in every stage. These measuring instruments show, if the flushing solid is flushed earlier or later and indicates the amount of afterflow which contributes to flushing it out to the drainage pipe. Experimental evidence, if the flushing solid efficiently or unreliably evacuates after getting caught in the trap and after the flushing water accumulates, reveal flushing characteristics which have not been recorded in tests done up to now.

This type of information with experimental evidence can however only be obtained with more time and precision in the tests.

The reduction of the flushing water volume almost until the function limit hardly justifies more conventional positive/negative tests of different types, but requires a testing method which corresponds to the natural use of WC's. The consumer should be guaranteed a reliable function and the technical engineer should be given free play for further development.

DRAINAGE AND WATER SUPPLY FOR BUILDINGS

A TWO-DAY SEMINAR ON CURRENT RESEARCH AND FUTURE NEEDS AND OBJECTIVES.

JUNE 3 AND 4 1980

PAPER NUMBER 8.

SANITARY INSTALLATIONS - PROPERTIES THEY OUGHT TO HAVE.

PERFORMANCE REQUIREMENTS AND QUALITY TESTING OF SANITARY INSTALLATIONS

TORE ROSRUD

Norwegian Building Research Institute, Oslo.

Only the first 19 pages of this 236 page document (Instruction 13) are included.

Organised by

DRAINAGE RESEARCH GROUP
DEPT OF BUILDING TECHNOLOGY
BRUNEL UNIVERSITY
UXBRIDGE
MIDDLESEX

in conjunction with CIB W62.

Tore Røsrud

SANITARY INSTALLATIONS
Properties they ought to have

Performance requirements and quality testing of sanitary installations

Instruction 13

Norwegian
Building Reseach Institute
Oslo 1979

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FOREWORD

This publication describes functions and criteria for Sanitary installations. It is part of the criteria project prepared by the Norwegian Building Research Institute. An attempt has been made to find out what prestation an installation shall have when in use (what will be attained), so that it is possible to choose constructions and materials which are most suitable in each case. The work is based on the activities and needs of the user. The result - the criterion obtained - can for example serve as a guide for planning work, as a basis for tenders or for product development, standardizing and specifications.
Work on this publication was the first to be commenced on the performance project. It was found to be very difficult, not least because a scientific approach has first been made in recent years. Amongst other things the majority of testing procedures for measurement of criteria was lacking. However we have here attempted to give procedures. It is underlined that the majority of these are proposals which require intensive laboratory research before they can be regarded as final.
As far the NBI is able to work will be continued on testing methods. International cooperation will here be of great assistance.
In spite of uncertainties about testing procedures the NBI hopes that this method of looking at them - first and foremost to be clear over what one will attain - will serve to advance the development of the whole field.
This description of prestations is more comprehensive than those previously published and the approach is somewhat different.
The work has been carried out by Tore Røsrud. He was educated of Oslo Technical School (1945) and at dr. philos. Almar Næss' Teknisk Akademi (1965). Røsrud became a Master Plumber in 1947 is a member of the Norwegian Engineers Association and has been engaged as a research worker at the NBI since 1956.
Besides Røsrud several other of the institute's members have taken part in discussions concerning the work and its scope, especially the chief project leader of these works, Øivind Birkeland, was an active member. In addition Røsrud has had thorough discussions with and obtain the views of manufactures, master plumbers and representatives of the authorities and other specialists from this and other countries.
The NBI would like to thank all those who have made this work possible.

Blindern, September 1979

Sven Erik Lundby

CONTENTS

INTRODUCTION

This publication gives a general view of the requirements you might wish to demand in a good sanitary installation and the test methods which should be used to control if the requirements are fulfilled. The book deals with building installations, especially pointed to dwellings.

It might serve as the design base for:

- traditional project work
- development of new products
- contracting layout (where desired performance is given, not the construction and the material)
- control of the performance in a delivered installation
- development of prescriptions, regulations, byelaws, standards and similar documents.

The usual owner will also be able to use the publication so that he can be orientated when choosing quality for his installation. We will emphasize that we are here talking about quality compared with the price.

Relatively many properties are dealt with. You will have to decide yourself which of them are the most important. Even if many properties are described, you may surely find things which are omitted, and they might even be of importance when dealing with special areas of use. Performance requirements will hardly be used when formulating esthetical requirements. Such requirements are, therefore, practically not discussed here.

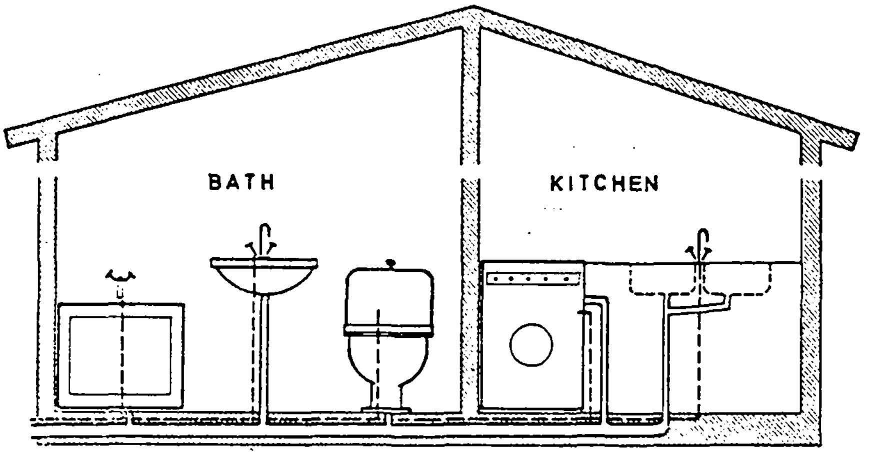
Requirements are in usual language orders from the authorities. Functional and performance requirements must be considered as demands or expression of needs. You might also bear in mind that in practice it is not possible to fulfill all the highest performance levels simultaneously. The question is, therefore, to find a sensible compromise.

The publication and its use

DEFINITIONS

A sanitary installation is that part of a building which
- provides water to the place of use
- provides the possiblility of using water
- leads away used water with accompanying waste matter.

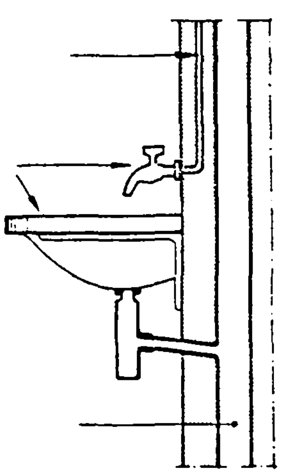
This paper is based on a conventional installation.



It consists of:
- Water supply - the pipework conveying the water to the places of use
- Sanitary equipment - the fixed items using work for various purposes (food preparation, personal hygiene etc.)
- Drainage system - the pipework leading the water away.

Water supply

Sanitary equipment



Drainage system

Any equipment for water treatment is included in all three parts of the installation.

CONSUMER REQUIREMENTS - FROM ACTIVITIES

TO PERFORMANCE REQUIREMENTS

The nature of the building's consumers (persons, groups of people, things,machines etc.) and the activities which take place in the building form a basis for the performance requirements. [1] [3]

Use of water

Activities vary for buildings for domestic animals, industrial buildings etc. and are totally dependent on the nature of production. Many activities in private houses can however also be relevant for such buildings.

Activities connected with the sanitary equipment in a house

Food preparation

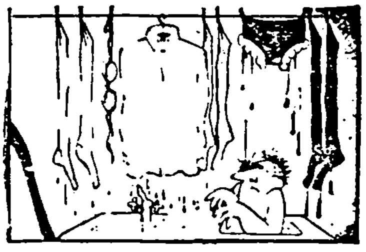
- run drinking-water
- run water for food preparation
- clean foodstuff
- soak dried foodstuff
- soak salted foodstuff
- thaw frozen foodstuff
- cool and temper food items
- pour off waste fluid after cooking, coffee grounds, tea-leave
- remove other food remains and kitchen waste
- clean cultery, dishes and equipment mechanically and bacteriologically.

Personal hygiene

- wash face, hands and other parts of body
- wash and rinse hair
- colour and bleach hair
- beauty treatment
- skin treatment
- shaving
- other hair removal
- clean teath
- drink water
- gargle
- eye - bath
- footbath and foot-care
- manicure
- baby washing
- baby care
- sauna, turkish bath etc.
- shower, massage or motion with special water jets (certain groups of consumer have special requirements regarding equipment, e.g. old people, handicapped persons with foot-rot or skin diseases etc.)
- bath in bathtub, relax body (certain groups of users have special requirements regarding equipment, e.g. small childre long persons, fat persons, pregnant women, old people,disabl rheumatics)
- remove fecal matter, urine, vomit, sanitary towels,paper dia
- wash seat
- enema, rinsing, intestine rinsing
- care of artificial links

Care of clothing and household articles

- soak washing
- white wash and coloured wash
- rinse washing
- wring washing
- wash heavy, thick woollen clothing
- wash light, fine woollen clothing
- wash silk stockings and fine underwear
- wash non-iron shirts and other non-iron wear
- rinse and wring such special items
- moisten clean clothing
- press clothing
- moisten flannel
- colour clothing and materials
- bleach textiles
- impregnate clothing
- clean clothes
- remove stains from textiles
- wash light curtains
- wash floor runners



Care or house and contents

- wash ceilings, walls, floors, lists, doors
- wash furniture, furnishing items and sanitary equipment
- scour unpainted woodwork
- clean coated furniture with ammonia-water or cleaning fluid
- clean windows
- clean or polish metals
- clean candlesticks
- care of potted plants and cut flowers

Hobby and leisure-time

- clean paintbrushes and other equipment used for decoration and maintenance of house
- develop and copy film
- clean drawing-ink equipment, water and oil-colour equipment
- make wine
- soak stamps
- bath dolls and other plastic toys
- care of aquarium
- bathe and wash dogs and other household animals
- mend puncture
- wash car or other transport means (private)
- water garden

Other activities

- extinguish fires
- lead away rain water
- lead away groundwater
- maintain sanitary installations
- change sanitary installations

Formulation of performance requirements which apply to use

The function during use of sanitary installations is first and foremost dependent on the actual "equipment's" properties.

Sanitary equipment has had a natural development from olden days, without special thought for that it shall be used for the varieties of activities listed about. Sanitary equipment having divergent properties and fixed at divergent locations in the house could be desirable if we were not so bound traditionally. In this paper we will make ourselves independent of the traditional sanitary equipment and find out the connection between activities requireing use of water and the performance requirements which may be expected |2|. We set the performance requirements of the sanitary installation as a whole and not for each individual item of equipment.

The sanitary installation shall:

Provide water of desired quality
Provide sufficient flow of water
Provide water at the right time
Supply water in a convenient manner
Have variable flow
Provide water of suitable temperature
Have sufficient sanitary equipment
Provide good space for use of water
Be flexible
Accomodate desired quantity of water in the equipment
Have suitable height
Have desired shape and colour
Have storage space for aids near equipment
Provide support for body during use
Lead away excrement and other waste matter
Give access to body washing after using W.C.
Be suitable for clothes washing
Be suitable for dish-washing
Collect surplus water
Prevent large items entering waste system
Lead away groundwater
Lead away rainwater

Supply water in a convenient manner

The connection between activities, performance requirements and the sanitary equipment which may be used to satisfy performance requirements is shown under items 1-18 in the main part of the book.

Formulation of performance requirements taking external action into account

The sanitary installation is subject to influences and stresses. These occur when the installation is in use. In addition the surroundings will cause stresses. These can arise due to the climate or they can be caused by the construction [2]. The connection between these stresses and which performance requirements are necessary to resist then is shown on p. [19]. If the installation is to resist these stresses it must satisfy the performance requirements in the following list.

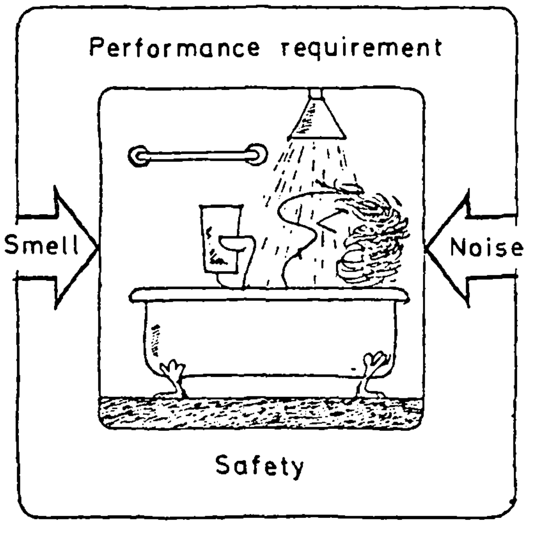
The sanitary installation shall:

Dampen all types of noise
Prevent damaging vibration and water-hammer
Prevent irritating smell
Prevent irritating heat transfer and resist temperature changes
Have sufficient strength and rigidity
Be suited to the building construction as well as possible
Have stable water-level
Resist wear and corrosion
Provide resistance to damage during use
Resist formation of damp
Resist frost
Protect the water against light and resist UV-rays
Prevent damage from biological sources
Be explosion-resistant
Preserve nature
Maintain appearance
Have easy surface cleaning
Have easy clean of drainage
Have easy replacement and maintenance

The above list gives the performance requirements in a concentrated manner. They vary greatly in scope and importance for the user. Performance requirements are dealt with in more detail under items 1-32 in the main part of the book. They are also made concrete in the form of "criteria".

Criteria are as far as possible expressed in cyphers which the materials and constructions must satisfy for the performance requirements to be attained.

Performance requirements "describe" in general terms what one wishes to attain based on what the water is to be used for and the quality of the installation which an average user will require. In some cases we have described the performance requirements for users with special needs. We have attempted to formulate the performance requirements in the manner in which the user wishes them to be, without regard as to whether it is thus possible to judge this in a previously known manner. This has resulted in that in some cases we have met performance requirements which still lack knowledge in order to assess. In these cases we have simply given our comments and advice which will make it easier for the user himself to judge his needs.



Literature

1 Cronberg, T. Performance requirements for buildings. A study based on user activities. Stockholm, Statens råd för byggnadsforskning, 1975. (Byggforskningen. Document, 1975, 3.)

2 Røsrud, T. Performance requirements for plumbing systems. National Bureau of Standards Special Publication 361, Volume 1: Performance Concept in Buildings; Proceedings of the Joint RILEM-ASTM-CIB Symposium, held May 2-5, 1972 Philadelphia, Pennsylvania (Issued March 1972).

3 Bjørneboe, J. Ytelsestankegangen - Planlegging basert på brukerkrav. Oslo 1976. (Norges byggforskningsinstitutt. Arbeidsrapport 8.)

GIVEN CONDITIONS

External conditions

A number of conditions are normally given due to the building location being fixed and its details mainly planned. Requirements of an installation must be assessed with this in mind

Natural conditions

- Climate. Precipitation and especially its intensity are of importance.

External equipment

- Ground conditions.

External equipment

The nature and performance of the installation will be affected by other installations to which it is connected. Of special importance is the location and nature of existing water and sewerage mains and whether the drainage system is connected to a treatment plant or not. The quality of water supplies, neighbouring buildings and pollution from these can also affect the sanitary installation.

Conditions imposed by the building

Planning, cooperation

Choice of planning, main construction of the remaining part of the building and production methods "bind" a sanitary installation. There is however a reciprocal dependence between the sanitary installation and the building. Cooperation is necessary during planning in order to find the properties which a building and the installation in cooperation must have in order to satisfy the given conditions.

The construction of the building must be so that the fitter together with others engaged, in building can satisfy the given conditions. For example the bearing strength of a wall must be sufficient to support a wash stand having the properties the client desires.

Legal conditions

Laws, specifications and regulations in addition to legally binding agreements between firms and persons affected form a framework for the nature of a house installation |1| .

Other conditions

Tradition, regard to the environment, available installation material etc. may naturally also influence the installation.

Literature

1 VVS Årbok 1980. Oslo, Skarland Press A/S, 1980, s. 102 - 103.

CRITERIA

Criteria are requirements which the installation must satisfy in order to satisfy the performance requirements under given conditions. They are citeria to show that the performance is fulfilled. They are given both as qualitative requirements (expressed in words) and as quantitative requirements (expressed by a number).

They are as far as possible divided into six quality gradings in order to make it simple to give suitable, realistic requirements.

Table 0.01. Division into quality gradings

Quality grading	Number for prestation measured according to given method
0 No requirement	< 0
1 Low desire and requirement	⟨0-2]
2 Moderate desire and requirement	⟨2-4]
3 Normal desire and requirement	⟨4-6]
4 Large desire and requirement	⟨6-8]
5 Especially great requirement	>8

The sign ⟨ means "from", but not including the following numbers.
The sign] means "up to and including".

These six quality gradings are intended as a guide to those using this paper, so that one can choose a suitable quality in each individual case.

The use of quality gradings is difficult to make applicable for all the various properties. That which is the best quality grading can also vary according to usage and the needs of the user. Normally the quality grading is chosen so that grade 3 corresponds to any official requirement that may exist.

Many of the criteria are interdependent on one another. Sometimes therefore several criteria must be satisfied at the same time in order to satisfy the performance requirement.

Testing

Existing and recognized methods of measuring the criteria are used where this is possible. Most of these methods are linked to components and materials and not to the completed construction. However, the result of such testing can in certain cases make it possible also to draw conclusions about the "function of the construction" |1|. There where measuring methods for the relevant criteria do not exist, in some cases a measuring method is suggested which may possibly be developed.

Comments

Comments often discuss the desirability of further work on criteria and methods of their measurement. Occasionally guidance is given as to how one can arrive at a design which satisfies the criteria using suitable materials and constructions.

Sections on the individual criteria is often concluded with a summary of relevant literature.

Literature

1 Hansen, H. Bedømmelse av prøvemetoder. Oslo, Norges byggforskningsinstitutt, 1973. Internt notat.

ECONOMY

The cost of the sanitary installation comprises usually abt. 10-15% of the total cost of the building. Acquirement of fittings, pipes etc. amounts to abt. 2/3 of this whilst the remaining 1/3 is labour costs. It pays to spend time in considering the purchases, both because one can then obtain an installation suiting one's own taste and because high prices do not always give the most suitable installations. On the contrary a favourable price can often be arrived at by considering the relevant requirements and then buying equipment and piping which combines these in a favourable manner.

Value = Good value for money

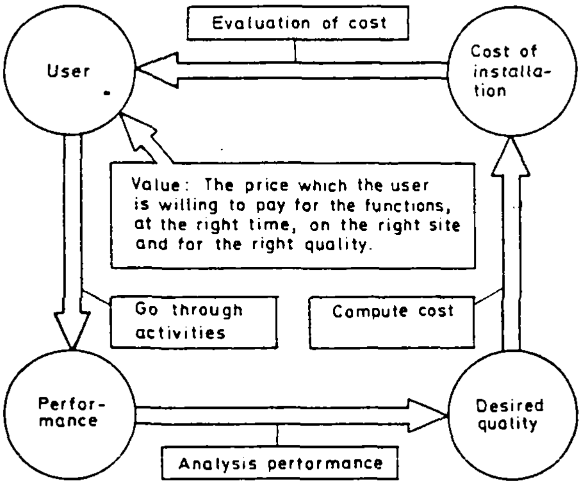
A combined assessment of the performance (and criteria) in relation to the cost is called a value analysis |1|. A consideration of the most relevant items on the check-list will be sufficient (see p. 20) for many. For large buildings however a deeper assessment of the cost relative to the quality desired is needed. It must include calculations to find the optimal economic framework. A complete analysis can only be carried out by large contractors and for large projects having many units of the same kind.

Value analysis

Each item of equipment has normally a main function. A wash basin shall collect and lead water away when one washes hands and face. A WC shall lead away the body's waste products. A bath-tub shall accomodate water which surrounds the body and so on.

The analysis is commenced by finding out the lowest cost in order to fulfil the main function in question.

Value analysis:



The equipment shall also have subsidiary functions which make it good to use, long-lasting and attractive. We must assess these functions (and prestations) in relation to what each individual prestation costs in addition. By these means we obtain a combined cost of the equipment and we know what we are paying for. Finally we arrive at the value of the whole installation from the following equation:

$$\text{Value} = \frac{\text{properties in use; attractiveness}}{\text{cost (or price)}}$$

As we can see a comprehensive calculation is necessary just to find the purchase price.

Equally important is that we have included other costs such as operation and maintenance when this is of importance for choice of prestation. We have therefore described the combined cost below:

Purchase price:
All costs necessary to get the installation in desired working order are included in the purchase price. All aspects of the purchase price must be considered, including conditions of payment, adjustments due to price fluctuations, time of delivery, guarantee, dealing with disputes etc.

Running expenses:
All necessary annual expenses, as for example running expenses, depreciation, interest, insurance etc. are included in the annual expenses.

Future expenses:
Here are included the cost of modifying the installation due to a change in usage. The work it can be necessary to carry out is usually not known. The cost of individual modifications may nevertheless be estimated based on how great the constructional changes are. It is of economic importance that components can be reused and what it will cost to get rid of unusable items.

Literature

1 Eidsvig, B. Verdianalyse; Kreativ problemløsning på alle plan. Oslo, Tanum, 1971. 330 s.

PLANNING AND PRODUCTION

The production of a sanitary installation consists mainly of assembling equipment, piping and fittings. These are delivered to the building site as far as possibly complete. The items must therefore in advance have the properties which make it possible for the fitter to fulfil the derived criteria. Manufacturers of sanitary equipment have shown great interest in giving their products the qualities required for the fitter to be able to fulfil the requirements with a high quality grading.

Cooperation in planning

Planning

Preparatory meeting are important. Lack of coordination in building plans is one of the most important reasons for expensive buildings. Architects, consultants, contractors and the client are here at a meeting. Master plumbers will wish to repeat constructional details using the same dimensions in many parts of the building. They will also arrive at a simplification of the pipework. Both things help make the building cheaper. In addition the work is fixed in a definite manner so that changes are avoided and a basis formed for a rational product.

Choice of criteria

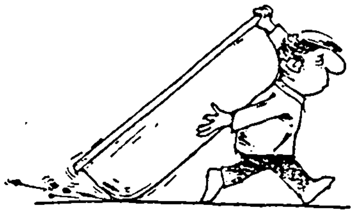
The planner uses the given conditions and economic considerations as a starting point. He goes through check-lists, selects and examines the criteria which mainly cover his need. He notes the items where it is not relevant to set requirements and which may be omitted without a lessening of quality. The other requirements are assumed normal quality (as a rule quality grading 3).

Bonus and fine according to quality

The planner may agree with the fitter the importance he attacks to the fulfilling of various quality gradings. He can give a bonus for a higher quality than agreed, when this is of benefit to him. A fine for a lower quality grading may also be considered.

Assembly work

Sanitary equipment and pipework shall be assembled and fitted in such a manner that the favourable qualities of components are maintained and so that the quality grading is fulfilled.



Assembly work

How easy it is to carry out installation is dependent on the working process used for:

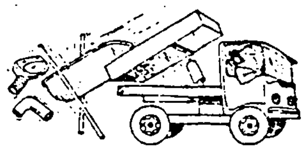
- fitting the components together
- joining them
- attaching them

In addition it is dependent on how the installation is planned and situated in the building.

Stresses

Materials and constructions are subjected to stress during transport, storage and assembly. In addition mechanical loading impact etc. often occur during the building process.

Transport stresses



Delivered at the building site in a condition as ready for use as possible.

Equipment, pipework and components must withstand the stresses they are subjected to when they are transported from the manufacturer via wholesaler and retailer to the building site. In addition handling on the building site may often be rough. Packing and other protection may be used to resist such treatment arising before the installation is handed over to the user.

Storage

Storage of materials and constructions can lead to a reduction in quality due to dampness and UV rays in open air and by loading and impact in piles of piping etc. Lengthy storage on the building site sometimes leads to moving and large stresses. An agreement should therefore be made for delivery as the components are required.

Protection during construction period

Ready assembled sections of the installation must be protected during the construction period if they cannot withstand stresses caused by the construction process. Visible parts of the installation such as fittings, taps etc. are often protected by various types of covering, paper, plastic etc. Requirements may also be made as to when during the construction period the installation must be carried out to avoid damage.

Clearance

Visible materials may in the period of clearance be subjected to heavy-handed cleaning. They may be subjected to loading from persons sitting or standing on the side of equipment, support themselves by pipework etc. Stresses are sometimes greater during clearance than when the building is taken into use.

Cleaning is dealt with under 35.31. Stain resistance. Loading is included under 23.11. Strength of handles and supports.

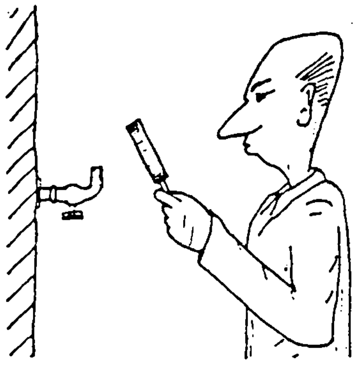
Time for delivery

The time from the first investment until the installation is complete may be reduced by determining criteria as a basis for planning. Assembly can thereby be commenced whilst planning of subsequent installations takes place |1|.

Taking over

The building passes to owner and user to the agreed time. The user must on behalf of the owner ensure that the installation functions as it shall and that performance requirements are satisfied. He must also ensure that stresses are not greater than those required by the criteria.

The user is scrutiniseing the installation



The earlier the user can point out faults and omissions which conflict with the criteria, the easier it is to determine whether the responsibility is the installer's. If doubt arises as to whether criteria are satisfied, it is the responsibility of the installer to show that he has supplied the agreed items. On the other hand the user shall bear the cost of the assessment he has asked for if it is shown that the agreed criteria were satisfied. The installer will be able to agree with his supplies and partners the responsibility they have to him, but he shall not be able to transfer responsibility or refer the user to a third party |2|.

Literature

1 Lindgren, O-. Pap, I og Örn, L. Tidig upphandling av rörledningsanläggningar enligt arvodesmetoden, TUA. Stockholm 1975. 89 s. Byggforskningen. Rapport, 19, 1975.

2 Norske Rørleggerbedrifters Landsforening, NRL. Alminnelige kjøpsvilkår ved levering av VVS-materialer til norske rørleggerbedrifter tilsluttet NRL. Oslo 1976.

Table 1. Relationships between the activities, performance relasted to use and the sanitary fictures

Activities		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
Personal hygiene	Use of WC for disposal of feces and urines		⊠	⊠		⊠	⊠				⊠	⊠	⊠			⊠	⊠	⊠	⊠			⊠				⊠
	Washing of the body	⊘	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠		⊠		⊠	⊠			⊠				⊠
	Washing of sick and elderly people and invalids	⊘	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠		⊠		⊠	⊠			⊠				⊠
Food preparation	Tapping or drawing of drinking water	⊠	⊠	⊠			⊠	⊠	⊠		⊠		⊘	⊠	⊠	⊘						⊠				⊠
	Washing and cleaning for food preparation	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	□					⊠				⊠
	Washing dishes and cooking utensils	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	□				⊠	⊠				⊠
	Disposing of waste water and food waste										⊠	⊠		⊠	⊠	⊠						⊠				⊠
Cleaning the inside of the house	Washing floors, walls and ceilings	⊘	□	⊠	□		⊠		⊠		□	□	⊠	⊘	⊠	⊠	□		⊠			⊘				⊘
	Cleaning windows, stairs and furniture	⊘	□	⊠			⊠		⊠		□	□	⊠	⊘	⊠	⊠			□			⊘				⊘
	Cleaning technical equipment etc.	⊘	□	⊠	□		⊠	□	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠						⊠				⊘
Washing clothes and household textiles	Soaking, washing and rinsing clothes	□		⊠		⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠				⊠		⊠				⊠
	Dampen clothes for ironing		□				⊠		⊠																	⊘
	Drying clothes													⊠	⊠							⊠				⊘
Spare time activities	Cleaning painting implements		⊠	⊠		⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	□					⊠				⊠
	Developing films	□	⊠	⊠	□	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	□					⊠				⊠
	Washing the car		⊠	⊠	⊠	□	⊠	⊠			⊘		⊠	□	⊠	□						⊘				⊠
	Watering the garden		⊠	⊠	⊠		⊠	□			⊘		□									⊘				⊠
Factors influenced by nature	Put out fire		⊠	⊠	⊠		⊠							□	□							⊘			⊠	⊠
	Carry off rain and ground water										□			⊠	⊠	⊠							⊠	⊠		⊠

Fixtures	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
faucets	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠		⊠	□							□	□	□	⊠			□	⊠
waste water sink	□	⊠	⊠		⊠	⊠	⊠	⊠		⊠	⊠	⊠	⊠	⊠	⊠	□		⊠		□	⊠				⊠
food waste grinder										⊠						□									⊠
floor drain	□	⊠	⊠	⊠	□	⊠	⊠	⊠		⊠	□	⊠	⊠	⊠	⊠			□			⊠				⊠
lavatory	□	⊠	⊠	□	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠			⊘			⊠				⊠
kitchen sink	⊠	⊠	⊠	□	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠			⊘		⊠	⊠				⊠
water closet		⊠	⊠		⊠	⊠				⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠			⊠				⊠
laundry tub	□	⊠	⊠		⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠			⊠	□		⊠				⊠
clothes washing machine	□	□	⊠		⊠	⊠		□	⊠	⊠	⊠	⊠	⊠	⊠	⊠			⊠	⊠		⊠				⊠
dishwasher	⊠	□	⊠		⊠	⊠		⊠		⊠	⊠	⊠	⊠	⊠	⊠			⊠		⊠	⊠				⊠
shower-bath	⊘	⊠	⊠	⊠	⊠	⊠	⊠	⊠	□	⊠	⊠	⊠	⊠	⊠	⊠		□	⊠			⊠				⊠
bath tub	⊘	⊠	⊠	⊠	⊠	⊠	⊘	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠			⊠			⊠				⊠
drinking fountain	⊠	⊠	⊠		⊠	⊠		□		⊠	⊠		⊠	⊠	⊠			⊠			⊠				⊠
bidet	⊘	⊠	⊠		⊠	⊠	□	⊠	□	⊠	⊠	⊠	⊠	⊠	⊠		⊠	⊠			⊠				⊠
hose bib or sill cock		⊠	⊠	⊠		□		□		⊘		⊠		□				□			⊠			□	⊠
car washing facility		⊠	⊠	⊠	□	⊠	⊠	⊠		⊠	□	⊠	⊠	⊠	⊠			□			⊠			□	⊠
wash basin for photographic dark room and other hobby activities	□	⊠	⊠	⊘	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠	⊠			⊠			⊠				⊠
roof or area drain					□					⊠	⊠		⊠	⊠	⊠			□				⊠			⊠
subsoil drain										□			⊠	⊠									⊠		⊠
fire sprinklers, nozzles and hose connections		⊠	⊠	⊠						⊠											⊘			⊠	⊠

PERFORMANCE REQUIREMENTS DIRECTLY RELATED TO USE

1. provide water of desired quality
2. supply water in an acceptable way
3. provide adequate flow of water (quantitative)
4. provide water at various places
5. supply water inside the sanitary appliances
6. provide water at the desired time
7. provide adjustable flow of water
8. provide water of a suitable temperature
9. maintain a desired quantity of water
10. have a suitable height
11. have a suitable shape
12. have arrangements for equipment desired near the appliance
13. collect excess water
14. carry off excess water
15. keep objects away from the drain
16. carry off fecals and other waste materials
17. provide suitable cleaning of the body after using W.C.
18. provide support for the body during use
19. washing clothes
20. washing up
21. provide space for activities by the sanitary fixture

Performance requirements related to other needs

22. carry off rain water
23. carry off ground water
24. put out fire
25. ease of replacement, maintenance and alteration

The importance of the performance

essential = ⊠
some importance = ⊘
particular importance under special circumstances = □

Table 2 Connection between influencing factors and performance requirements

INFLUENCING FACTORS			REQUIREMENTS
On the installation as a result of use	On the installation as a result of its environment (climate, constructions etc.)	From the installation to the environment	Performances required by the influencing factors
1. explosion hazard			1. provide safety against explosion
2.		noise caused by tapping and use	2. reduce noises from the use of water
3.		noise from the flow of water	3. reduce noise from water current
4.		noise because unsmoothly working	4. avoid noise because unsmoothly working due to thermal expansion etc.
5.		noise from airbubbles in traps, vibration	5. avoid bubble noises
6.	vibration - water hammer	vibration	6. reduce vibrations and water hammer
7. damage by wrong use, impact, scratches etc.		damage by water	7. provide safety against damage caused by wrong use and wrong equipment
8. soiling-static electric attraction of dust	dust (air/ventilation)		8. facilitate the cleaning of external surfaces and surroundings
9.		blocking-up of pipes with waste materials	9. reduce need for cleaning waste pipes and facilitate internal cleaning
10. effects of heat transfer	temperature changes	heat emmission	10. reduce heat transfer and withstand temperature changes
11.	frost		11. withstand the effect of frost
12.	influence of light		12. withstand the effect of light
13. condensation	condensation	dampness	13. withstand the effect of moisture
14. water pressure		water leakage	14. withstand leakage
15. weight- and pressure-loading	weight- and pressure-loading, settlements	weight- and pressure-loading	15. provide safety against weight- and pressure loading
16. wear and tear through age and use	external and internal corrosion, damage during maintenance	damage during maintenance	16. reduce damage from maintenance and corrosion
17.		weakening of the construction through passages for piping	17. reduce need for space and the weakening of the structure by passages for piping
18.		pollution of nature	18. conserve the nature
19. discolouring	discolouring	discolouring	19. keep up the appearance
20.	growth of bacteria and vermin	growth of bacteria and vermin	20. control growth of bacteria and entry of vermin
21.		smell	21. prevent irritating smells from sewer gases
22.	effect of fire	spreading of fire	22. avoid spreading of fire and reduce its hazards

DRAINAGE AND WATER SUPPLY FOR BUILDINGS

A two-day seminar on current research and future needs and objectives

Discussion session on Papers 6, 7 and 8, June 4th, 11.45 - 12.45

Chairman : Mr. Nielsen, Danish Building Research Institute

Mr. Nielsen : In France and Sweden, and possibly Denmark, there are sanitary towels which break up before reaching the bottom of the vertical stack. Transportation of these sanitary towels does not, therefore, create any problems. Do you have any of these products in Great Britain?

Dr. Howarth : No. There is only one Scandinavian product on the market here, but that does not break up.

Mr. Olsson : We carried out some investigations into the transportation of sanitary towels. We considered many different points. These investigations were carried out in a multi-storey building. We first of all talked to the occupants of the building who told us that there had been many drain blockages. We also knew that several manufacturers printed on the sanitary towel packets that the sanitary towels are flushable. There was disagreement amongst the manufacturers as to whether the towels were flushable or not. Then we started to look at what happened in the vertical stack and the whole drainage system. We had a vertical stack, vented at the top, a "horizontal" branch for the W. C. to the stack, and a below ground "horizontal" drain at the base of the stack. We tested six different types of W. C., each having different discharge flow rates, and from these six we took the worst for the remaining tests. We then investigated the stack, to find at which floor level we got the worst value. We investigated floor one to twelve, and we found the sixth floor was the worst. We also tested stacks of 90 and 100 mm diameter and different length branches. We found that a branch length of 5 to 10 metres was sufficient for testing and we adopted 7 metres. We only used six litre W. C. flush volume. We were monitoring the amount of trap seal loss, particularly from the lavatory trap. We found that we got positive pressure and negative pressure. We investigated different types of towel, and defined the performance relative

Mr. Olsson cont. to the pressures created in the stack, with a certain limit to define acceptability. We found a significant problem of solid retardation at the base of the vertical stack.

Mr. Nielsen : The results of your investigations are presented in a Swedish report and it is available to the public.

Mr. Olsson : We found some types were acceptable, but one type tended to blow up, and the best one was one that had a net cover.

Dr. Howarth : We've found that the net covered type are generally worse.

Dr. Wakelin : Presumably you found that the 90 mm diameter stack was worse than the 100 mm diameter stack? Was there very much difference between them?

Mr. Olsson : Yes, the 90 mm was worse, the extent depending on the type of towel.

Dr. Swaffield : Comparing the Swedish approach to our own, the Swedish approach was obviously more detailed. Our approach was to only consider the problem as far as the stack, as having reached the stack, the towel transportation will be aided by discharges from other appliances connected to that stack. I still feel that the worst case is the long branch with a single W. C. connected to it.

Mr. Olsson : Whilst I agree with Dr. Swaffield that the branch is one of the most important parts of the system, the problem at the base of the stack is important, as also is a consideration of the positive and negative pressures created in the system.

Dr. Swaffield : Perhaps a significant reason for the difference in our two approaches is the difference in the proportion of high rise to low rise dwellings in our two countries. The vast majority of domestic accommodation in this country is low rise, with a stack length of perhaps 6 metres, and therefore the positive and negative pressure does not create a problem.

Mr. Olsson : The positive and negative pressure is not a problem up to three storeys.

Mr. Ovesen : You mentioned that with tampons there might be problems with tupe applicators and the cellophane wrappers. Could you define the problems and any possible solutions.

Dr. Howarth : In one case, the digital tampon has a cellophane wrapper which tends to float, but if you design it to sink, it will not keep the tampon dry, which is its purpose. We, as manufacturers, have a problem as we must keep the product dry and compact, and yet the cellophane wrapper is not readily flushable i. e. it remains floating in the pan after the W. C. is flushed. It can require three or four flushes to discharge the cellophane wrapper. There is no simple solution to the problem.

In the case of the applicator tampon, the main problem is the tube. The tube has a tendency to float. The tampon is no problem with regards flushability. The tube can be designed to spring open, but more work needs to be done to ascertain whether this is advantageous. I believe it is better to design the tubes to become rapidly soft and soggy. I do not think it needs to unwind, and in fact this could be detrimental to its flushability performance. One recent event that worries me is the introduction in this country of a tampon with a plastic applicator, which people will probably flush down the W. C.

Could I please make one further point. You seem to be using sanitary towels in two ways. One of these is as a model, and I'd like to give a word of warning. We do change our products, in other words, items available now could be different in a year or two's time. Be careful when you choose a product that its specification remains the same. The covers are going to change, new raw materials are coming in. What is known as super-absorbers, which soak up and "lock in" the fluid and water, and will pick up about one hundred times more water than at present, and you will not get the water out, are a possible future development.

Your other way of using towels is to investigate what actually happens when these products are flushed. Again a word of warning. People do not necessarily read instructions. People use umpteen different ways of placing the product into the W. C. pan and this can be very important.

Mr. Carson : Either Dr. Howarth or Dr. Swaffield mentioned that presoaking the towel prevented the capillary action soaking the whole towel. Have you any explanation as to why this happens?

Mr. Howarth : Because the towel fibres have already swelled due to presoaking with water and this prevents any further capillary action.

Dr. Swaffield : We have actually filmed this phenomenon. An additional reason is that the wet part of the towel tends to adhere to the side of the pan above the water level, and this tends to prevent the towel slipping further into the water. Other causes of the poor discharge performance of the presoaked towel are the tendency to trap air at one end of the towel causing unbalanced and excessive buoyancy, and also the tendency for the towel to fold over at the presoaked centre section resulting in too thick a solid for discharge via the trap of the W.C. pan.

Mr. Thompson : I would like to ask Dr. Howarth if he feels that the 20 seconds stated in Mr. Stensrud's paper for soaking of the towel in the W.C. bowl is realistic of normal practice?

Dr. Howarth : We had long discussions on this point and we decided that 20 seconds is realistic. In addition, 20 seconds is the British Standard adopted time period for soaking of toilet paper in the W.C. pan. Mr. Stensrud's figure therefore independently agrees with our own view. We feel that this time period is representative of normal practice.

Mr. Carson : With regards the use of sanitary towels and also Fakazell as models, have these models been calibrated against conventional solids i.e. excreta?

Dr. Swaffield : The answer to your question, from the Drainage Research Group, is yes. We have done a considerable amount of work with maternity pads on our Department of Health work and also sanitary towels on our ASPM work, and in addition as an extension of our DHSS work, we are monitoring the travel of excreta and associated materials in a large London hospital. We can therefore compare the travel performance of faecal material and a large range of sanitary products. We can do this on a graph of solid velocity against the square rout of (distance along the drainage pipe divided by the pipe gradient) i.e. $\sqrt{L/G}$. You can see that there is a similarity between faecal material and a sanitary towel that you could choose. Therefore knowing the travel characteristics of the faecal material, we can go to our data bank of characteristics of sanitary towels and adopt a suitable sanitary towel for use as a model in laboratory work.

I would like to express my sincere gratitude to Professor Knoblauch for providing and allowing us to use, some of Fakazell material, which we have tested outselves. The Fakazell 95 and Fakazell 105, in relation to the faecal material, and various sanitary towels and also the PVA sponge solids which the Japanese adopted, shows that the

Dr. Swaffield cont. PVA model is a very poor model, the sanitary towels are very good, and the Fakazell is between the two. The Fakazell gives a greater deceleration characteristic than the faecal material.

I would like to ask Professor Knoblauch whether he has calibrated his Fakazell model against faecal material independently from the work that we have done, and also if he could comment on the load of 200 grams which we felt was excessive? Work carried out recently by Dr. Feachem at the Ross Institute, suggests that a load of 140 grams would be closer to the sort of load you would expect in the cultural areas that we are considering in Western Europe.

Prof. Knoblauch : (as translated by Mr. Juple)

In answer to the first question, Professor Knoblauch has not carried out comparison tests between faecal material and Fakazell, and has therefore not calibrated the Fakazell against faecal material. However, Fakazell was not developed to study transportation of solids in drainage systems. It was developed only to test the flushing of W.C. pans.

Dr. Swaffield : I would like to point out that we have used Fakazell to test the flushing performance of W.C. pans and for this purpose it is very good. The presently accepted W.C. flushing tests are : the multiple ball test and the large single ball British Standard test. Has Professor Knoblauch calibrated Fakazell against these two tests, and does he feel that they all give similar results?

Mr. Thompson : I would also ask if Professor Knoblauch has calibrated Fakazell against any other test methods?

Prof. Knoblauch : (as translated by Mr. Juple)

Professor Knoblauch has carried out calibration tests between Fakazell and the DIN tests. These were the paper sheets and the sponges, and the multiple (50) balls of specific gravity o.85 (polypropolene). Professor Knoblauch does not feel that significant conclusions can be drawn from comparison of these test results, since the addition of paper to any of these test methods gives very variable results.

Dr. Wakelin : Does Professor Knoblauch generally test the Fakazell with toilet paper?

Prof. Knoblauch : (as translated by Mr. Juple)

Yes. First some sheets of toilet paper on the water surface, then the Fakazell and then more toilet paper.

Mr. Olsson : I would like to ask Dr. Swaffield a question. What we have found when we compare these various test methods with each other is that different W. C. 's give different comparative results. Some are better for ping-pong balls, others for paper. I would ask whether your sanitary towel tests give the same results for different W. C. 's.

Dr. Swaffield : With the sanitary towel tests, we adopted a W. C. which we felt would be commonly found in domestic situations. We chose a relatively cheap British Standard W. C. which is available generally. I agree that different types of W. C. would give different results. We have done work with different types of W. C., varying from Department of Health type pans, P-trap and S-trap W. C. 's, and 90^o and 114^o outlet pans, and we did get different characteristics obviously. However with the limited time scale and finance from the ASPM work we felt it was better to adopt a pan that was in common domestic use.

Mr. Olsson : From your paper you are recommending a sanitary towel for testing.

Dr. Swaffield : What we are saying is that you could use a sanitary towel to represent the loading that occurs in the real faecal material situation, because you would know the transport characteristics of faecal material which was similar to a certain size sanitary towel. What we are trying to do is to find a model which is relatively cheap, relatively repeatable, available in large quantities, and which can be used, preferably, without preparation or mess. Obviously the sanitary towel fits that specification perfectly.

The discussion of Paper 6, 7 and 8 continues during the next discussion session at 14.00 on June 4th.

DRAINAGE AND WATER SUPPLY FOR BUILDINGS

A two-day seminar on current research and future needs and objectives

Continuing discussion session on Papers 6, 7 and 8, June 4th, 14.00 - 15.30.

Chairman : Mr. Ovesen, Danish Building Research Institute

Mr. Rosrud : I would like to ask Dr. Swaffield about the possibility of sanitary towels being flushed with toilet paper and possibly other matter, resulting in a very heavy discharge load.

I would also like to suggest that we try to agree on a standard sanitary towel model. Have you thought of proposing some form of standard, to enable us to compare results?

Dr. Swaffield : We have not tested sanitary towels in the laboratory with other matter. However, some of the discharges at the hospital include sanitary towels with paper and faecal material, so we might get some relevant data from that.

I would agree that a standard model solid would be beneficial for comparison purposes, and for standard testing. It would be useful to speculate as to a suitable size model to use, bearing in mind that these results on faecal material are only the initial results, and that we are processing and collecting more data at present. A suitable towel might be one that fitted into the middle of our V versus $\sqrt{L/G}$ graphical results which might be a sanitary towel of 160 - 200 mm length with a water saturation value of perhaps 160 millilitres. The important point is the one made by Mr. Carson, that it must be calibrated against faecal material.

Mr. Ovesen : You are suggesting that a similar characteristic as displayed on the V versus $\sqrt{L/G}$ graph between faecal material and a particular sanitary towel defines a good model. Do you feel that this graphical method is sufficient to distinguish between good and bad models?

Dr. Swaffield : The results which we have shown for faecal material are not yet conclusive. The female toilet area from which these were obtained, displayed a considerable variety of discharges: faecal material without paper, to large quantities of tissue paper without faecal material and also faecal material with tissue paper. From this range of discharges we can build up a picture of the loading on that system in terms of a family of curves on the V versus $\sqrt{L/G}$ graphs. A typical usage might have been 4 or 5 tissues with faecal material. We could then choose a sanitary towel with a similar V versus $\sqrt{L/G}$ characteristic as a model. Variations, or original drainage system designs, could be investigated in the laboratory using the calibrated model. I would emphasise the difficulty that Mr. Bokor has experienced in obtaining and analysing all these data. These included social, access, secrecy, user unawareness, instrumentation, solid identification and differentiation, difficulties.

Mr. Olsson : That line on the V versus $\sqrt{L/G}$ graph representing a certain type of faecal discharge, is it one result or the mean of several results, and in which case how many?

Dr. Swaffield : That line represents a monitoring period of about nine months. As I said before, the discharges exhibit a considerable variation. You can get faecal material alone, faecal material followed by toilet paper, paper followed by faecal material, separate pieces of faecal material with paper before or after or both, etc. Mr. Bokor has, therefore, had to categorise all the discharges, which are in excess of 1,000 for the female W.C., with the discharge pipe at a particular gradient (1/150 or 1/200), into sets (about 40 sets) of similar discharges, before taking the mean for each set.

Mr. Bokor : The actual number, for a particular line as shown, is considerable, but varies from line to line, as the proportions will not be the same.

Dr. Swaffield : We are now monitoring on the male toilet area which will display a mugh higher percentage of faecal material compared to the female toilet area.

Mr. Ovesen : Can you be sure of the type of towel being discharged?

Dr. Swaffield : No, those lines are for faecal material which we can see as we are using transparent pipe. The results are not obtained by an automatic process and each and every one is observed

Dr. Swaffield cont. and noted at the time of the discharge. Due to the multiple solid situation that we have in this system, we have had to revert to our original velocity measuring system based on photo-electric cells and a pen recorder.

Mr. Olsson : I am surprised at the relative positioning of the paper only discharges. I would have expected the results to be the other way round. I wonder, therefore, what influence does the pipe roughness have with respect to time?

Dr. Swaffield : There is a lot of speculation as to the influence of roughness building up in the above ground pipework systems. The cast iron discharge pipes that we removed, and replaced with our transparent UPVC system, had been in for approximately 10 years and there was no noticeable build up of slime or surface deposit. We have had no evidence of slime build up on the UPVC system to date.

Chairman : Could we now turn our discussion to Professor Knoblauch's paper.

Mr. Nielsen : I would like to ask how you measure what you term "afterflow", and would your values be comparable to those that Dr. Swaffield quotes? Does the solid discharge occur at the maximum discharge rate?

Prof. Knoblauch : (as translated by Mr. Juple)

The point of discharge of the Fakazell from the W. C. is noted by an observer who makes a mark on the trace.

Dr. Swaffield : There is a difference in our method of recording the afterflow. We monitor the volume or percentage flush ahead of solid (from which can be obtained the volume or percentage afterflow) at the end of the discharge pipe run which is about 14 metres long. There will have been some water migration past the solid in travelling along the discharge pipe. The amount of migration is not very significant since if the solid is small it will travel at virtually water velocity, and hence the amount of water migration past the solid will be small. In the case of a large sanitary towel which travels at a slower velocity along the discharge pipe, the damming effect of that solid results in a relatively deep flow behind the sanitary towel and again the water migration past the solid will be small. We chose to monitor the volume ahead in that way because we could then monitor both that and solid velocity at the same time. Our values for volume ahead of the solid cannot be compared directly to the readings taken by Professor Knoblauch. All our results have been measured consistently at the end of the 14 metres long discharge pipe, so our own results can be compared relatively.

Dr. Swaffield cont. To add an answer to Mr. Nielsen's question on the discharge point of the solid on the flow profile, I do not see that this has to be at the maximum flow rate out of the pan. In the case of a large solid which fills the trap passage, this would reduce the initial flow rate out of the p an, but once the solid itself is discharged you could get suction/piston action which should result in a higher flow rate from the pan after the solid has been discharged, rather than at the same time as the solid is discharged.

Mr. Nielsen : To conclude what you have said. Is it your opinion that the influence of the afterflow measured as Professor Knoblauch has done is not so important for the transportation in the discharge pipe?

Dr. Swaffield : No, the volume of water leaving the W. C. pan after the solid is vital to the transportation, and in fact governs the transport in the discharge pipe. A good W. C. discharges the solid as early as possible in the flush. Our experience with the sanitary towel suggests that any solid that leaves the W. C. after 30 - 40% of the water has been discharged is relatively likely to result in solid deposition. Less than 25% flush ahead of solid is generally alright. This is based on a 9 litre flush.

Mr. Olsson : I would like to ask Professor Knoblauch what is the correlation between the afterflow and the transport length?

Prof. Knoblauch : (as translated by Mr. Juple)

The afterflow is the most important parameter with regards the transport length. The latest tests have shown that with a 3 litre afterflow you can clear a 10 metre discharge pipe length with 200 grams of Fakazell and toilet paper. When the W. C. discharges into a main drain with the drain extending upstream, you get considerable back flow up the main drain, and you get 80% successful discharge from a 10 metre discharge pipe length, at a gradient of 1/50.

Mr. Nielsen : I would like to ask Professor Knoblauch for an exact description of the Fakazell?

Prof. Knoblauch : (as translated by Mr. Juple)

The Fakazell is 80% water and 20% other material. There is a patent or trademark on the material, and it will be produced commercially.

Dr. Swaffield : I feel that 1/50 is a relatively steep discharge pipe gradient, and explains why Professor Knoblauch was surprised at our results, taken at a much flatter gradient. We would expect from our V versus $\sqrt{L/G}$ characteristic for Fakazell that at 1/50 the solids would travel at least 15 metres. There is not a major divergence, therefore, between our results and these of Professor Knoblauch.

Mr. Thomson : I would like to ask Dr. Swaffield and Professor Knoblauch a question. I understand that Professor Knoblauch's results are for European type cisterns and flushing valves whereas Dr. Swaffield's results generally relate to U.K. type siphon cisterns. Both authors state that water volume after the solid is very important. Could either of the authors comment on any differences between U.K. siphon cisterns and European flush valves?

Dr. Swaffield : I would confirm that all our work has been done with U.K. siphon cisterns, but with different type W.C.'s and cisterns. The water volume behind the solid is very important. If you look at variations between 1 litre/sec and 1.8 litre/sec discharge flow rate from the W.C. with large solids, which we are talking about in the case of Fakazell, then the initial entry to the discharge pipe has a dramatic damping effect. This is the Zone 1 region that we explained at the CIB W62 conference in Oslo, where the retardation of the solid allows the water to build up behind the solid and push it down the pipe. Therefore differences that might appear large in the initial flow rate are very quickly attenuated, so that once into the discharge pipe, the difference in flow rate does not make as much difference to the solid transport as you might assume. There could be a major difference, however, in the ability to clear the solids from the pan, where the criteria are very different.

Prof. Knoblauch : (as translated by Mr. Juple)

The rate of flow out of the W.C. pan has some effect on the transport of the solids in the discharge pipe. Professor Knoblauch has found that the non-siphon cistern has a peak discharge flow rate of over 2.5 litres/second without the W.C. pan, but due to rim resistance etc., the flow rate from the W.C. pan is in the order of 1.8 litres/second to 2.1 litres/second. W.C. pans that are designed for the flush valve can reduce the flow rate with a non-siphon cistern to 1.0 litres/second, or 0.9 litres/second, but these W.C.'s are not very good with regards solid transportation in the discharge pipe.

Mr. Read : I would like to make two observations. One is that if, as you seem to agree, the afterflow volume is particularly important, then shouldn't attention be focused on the

Mr. Read cont. detailed geometrics of the W.C. trap. That is, how you get the solid from the pan, through the trap and into the discharge pipe, as early as possible. My second observation is that it would surely be worth developing a joint methodology on testing W.C.'s.

Mr. Eriksen : Dr. Swaffield indicated that the rate of flow from the W.C. was not of major significance. Won't that depend on the flush volume, i.e. whether it is 3 litre or 6 litre? From Mr. Stensrud's paper it would appear that you should not put certain cisterns on certain W.C. pans.

Dr. Swaffield : The comments that I made were based on a 9 litre flush volume and were broadly based on the work that we did for the Department of Health a few years ago, when we tested both P-trap and S-trap W.C.'s. Although there were differences in discharge characteristics, by the time the solid had travelled a few metres down the pipe, the differences had attenuated out.

Mr. Thomson : Could you say, as a corollary to that, that as you reduce the total flush volume, the volume of water discharged after the solid does not reduce by the same ratio?

Dr. Swaffield : I can answer that, but perhaps Mr. Marriott, who carried out some of the work on this aspect, and which we published in a paper at the Brussels conference, is better qualified to answer it.

Mr. Marriott : I carried out some tests with flush volumes of 9, 7.5, 6, and 4.5 litres with British Standard W.C. pans and cisterns, and one of the most interesting points that was evident from those tests was that the volume of water discharged ahead of the solid remained relatively constant and was very approximately equal to the volume of water in the W.C. trap. Therefore with a W.C. trap volume of, say, 1.5 litres, 7.5 litres of a 9 litre flush was discharged behind the solid, but only 3 litres of 4.5 litre flush was discharged behind the solid. Therefore although the flush volume has been halved, the effective volume of water behind the solid has been reduced to two fifths. Therefore to reduce the flush volume significantly, it is necessary to re-design the W.C. and reduce the trap volume, as Mr. Stensrud's paper shows, as the 3 litre flush volume W.C. has a very much reduced trap volume.

Mr. Ovesen : I understand from Professor Knoblauch that he considered it to be necessary that for a W.C. to discharge the Fakazell

Mr. Ovesen cont. 10 metres along the discharge pipe for an average of 80% of the discharges, then 3 litres of water needed to be discharged after the solids, and that this was a test that should be passed. However, Mr. Stensrud's paper and presentation indicated that his tests with a total flush volume of 3 litres were successful, but he cannot have had 3 litres of water discharged behind the solid. I would ask if either Mr. Stensrud, or Professor Knoblauch or anyone else, has any explanation of this difference of opinion?

Mr. Stensrud : I believe that the difference is due to the reduced diameter discharge pipe that we used. One should not regard the volume of water behind the solid in isolation from other parameters such as pipework size, since this will affect the depth of water behind the solid.

Dr. Swaffield : I agree entirely with what Mr. Stensrud has just said. This again comes back to the paper that Mr. Marriott and I presented in Brussels. We published results of tests on 100 mm and 75 mm diameter discharge pipes, and also elliptical section pipes, with flush volumes varying from 9 down to 4.5 litres. What Mr. Stensrud said with regard reducing pipe diameter is even more true if you change the shape of the pipe as well. We showed that by reducing from 100 mm to 75 mm diameter you could get better discharge performances even with reduced flush volume, and better still if you went for parabolic or elliptical section invert. We therefore suggested that consideration of water conservation by reduced flush volume should be carried out in conjunction with a consideration of the appropriate pipe size or shape. In addition, venting of the system should also be considered, but if the pipe sizing is considered in sufficient detail, additional vent pipework should not be necessary as long as the flush volume is reduced correctly.

Mr. Olsson : I feel that Professor Knoblauch and Mr. Stensrud have used two different systems. Mr. Stensrud's system was vented but Professor Knoblauch's was a conventional unvented system. In addition the volume of water behind the solid in Mr. Stensrud's system would not have been very much below 3 litres, as most of the flush volume was discharged behind the solid, and taking account of the reduced pipe diameter, I would think that the transport performance would be similar to Professor Knoblauch's system.

Prof. Knoblauch : (as translated by Mr. Juple)

I agree that it is necessary to consider the pipe work size in relation to the flush volume, and that since the two pipework systems were not the same, one should not compare

Prof. Knoblauch cont. the results in isolation from the differences in the systems. In additon, the effect of branch connections to the main drain and the angle of entry of these connections requires very careful consideration, as does the standard of workmanship in pipework cutting etc.

Mr. Read : I would like to ask Mr. Stensrud two questions :-

i) From your paper I did not get a clear conclusion or recommendation as to what you now think will work with regards discharge pipe diameters and lengths. Are you in a position to do this?

ii) Having found, in the laboratory, that these 3 litre W. C. 's work satisfactorily, are you now going to do some field trials to verify their efficiency in practice?

Mr. Stensrud : In answer to your second question, these W. C. 's have been in use at some camping sites in Norway, and they are planning to install some more this summer. So they have been used in practice without any problems so far.

Mr. Eriksen : This research has just been completed, and it is now necessary to decide if we are to go any further with it. These W. C. 's are best suited to camping sites and camps etc., where there is no main sewer system. We anticipate that we will continue with field trials.

Mr. Stensrud : In answer to your first question, a gradient of 1 in 40 is suitable, but possibly 1 in 60 if the conditions prevent steeper gradient drains. A pipe diameter of 63 mm is required.

Mr. Read : Is it possible to rod a 63 mm diameter, 15 meter long, pipe?

Mr. Stensrud : We have not tried to rod this size pipe system, but there are already rodding systems to clear this size of drain.

Mr. Olsson : I would like to ask two questions :-

i) What velocity do you have when the discharge pipe flows full bore?

ii) In Sweden we have a similar 3 litre W. C. system but with 75 mm diameter pipes, but we found it

Mr. Olsson cont. necessary to increase from 75 mm to 90 mm, due to blockage formations. The pipe length is 50 metres from the house to the septic tank. Do you have any comments?

Mr. Stensrud : For a 20 metre long pipe we had an average velocity of 1 m/s based on the fact that the solid took 20 seconds to clear the 20 metre long pipe. The pipe ran full bore initially, for several metres, and then flowed non-full bore.

In reply to your second question, we did not get any blockages.

Mr. Ovesen : You state in the conclusion to your paper, that you did not have any blockages, but on some of your diagrams you showed a 'B' marked for blockage.

Mr. Stensrud : There were no blockages with the 63 mm diameter discharge pipe. However we did have blockages with the 50 mm and 40 mm diameter pipes. We did not test 90 mm or 100 mm diameter pipes with the 3 litre flush. We did get blockages with the 110 diameter pipe with 9 litre flush volume W. C. 's

Mr. Rosrud : I would like to make some comments on the practical use. This system was shown to some of the delegates who are present here, at the Oslo CIB W62 conference, and it has been in practical use since 1975. I would emphasise the importance of the whole system approach, since the system has been developed with both the W. C. and discharge pipe in conjunction. I feel that the system could be improved with a smaller W. C. trap and this should now be investigated.

Mr. Read : I am a simple designer and I want to know what to do. If I have a 3 litre flush volume latrine or W. C. pan, do I have a 63 mm diameter pipe? You say that I should. Do I lay it at 1/30, 1/40 or 1/50? How do I clear any blockages?

Mr. Stensrud : We have only been testing this particular system for approximately 6 months so I do not feel that we are ready to make such definite conclusions. I feel that the answer would be 1/40, but a lot depends on the W. C. itself, and how far you wish to transport the solids on the first flush. We did loose some of the trap seal after the W. C. was discharged, but this was never more than 10 mm.

Dr. Swaffield : We are discussing the relationship between length and gradient, and we should remember Mr. Rosrud's opening

Dr. Swaffield cont. question this afternoon about a standard testing method. One of the important things that the Drainage Research Group has been developing is the relationship $\sqrt{L/G}$ i.e. the square root of (length travelled divided by the pipe gradient). Now if we are willing to accept that $\sqrt{L/G}$ is sufficiently well documented and therefore true, then that answers Mr. Read's question. From this relationship you can decide the allowable pipe length relative to a particular gradient, or the required gradient relative to a particular pipe length. I would emphasise that there is now independent corroberation of the $\sqrt{L/G}$ relationship from Mr. Galowin's group at N.B.S. in Washington, using completely different solids and a completely different flushing system, which is independant of a W.C. I therefore feel that in our standard test method we should include some form of velocity measurement as opposed to just observation, and people could then use the $\sqrt{L/G}$ technique.

Mr. Nielsen : I would like to ask Mr. Stensrud whether the extra flushes that were required to clear deposited sanitary towels from the previous flush, contained sanitary towels or were water only?

Mr. Stensrud : The extra flushes were water only.

Mr. Rosrud : In answer to the querry about clearing and cleaning the discharge pipe, there are a lot of different types of tools available. I do not feel that there would be any problems. We had 3 litre flush volume Swedish W.C.'s, similar to this more recent pan, in the older houses in Oslo for 50 years, with no problems at all.

Mr. Read : I will be very interested to hear about the practical field trials of this 3 litre W.C. system. I would have thought that one of the criteria that you would be looking for in your excellent "yellow book" is dearer maintenance. I feel that maintenance is a very major problem, and even if the hardware is available, the problem is often to find someone to actually clear the blockage, and this is generally very expensive.

End of the discussion session on Papers 6, 7 and 8.

DRAINAGE AND WATER SUPPLY FOR BUILDINGS

A two-day seminar on current research
and future needs and objectives,
organised by the Drainage Research Group,
at Brunel University, on 3rd and 4th June, 1980.

Final discussion period to formulate proposals and to conclude the seminar, 16.00 - 17.00 hours on June 4th, 1980.

Chairman : Mr. Ovesen, Danish Building Research Institute

Mr. Ovesen : The aim of this final discussion session is to reach some conclusions. I would propose that we turn our discussions to the question asked by Mr. Read, that we should create a working group or nucleus of interested people to deal with sanitation and water supply for developing countries. I think that it is a very convenient time to raise this question, because a month ago we had a CIB W62 planning group meeting at which we discussed whether we should start again with having working groups and ad hoc groups, and in fact, we decided to make that proposal at the next meeting in Pretoria. Our co-ordinator, Mr. Perrier, will make the proposal that we should start a working group on tests for W.C.'s. I therefore feel that there is opportunity to follow up this discussion and put our efforts together for work in the future on sanitation and water supply for developing countries. However, I feel that we should agree on some form of manifestation to be included in the Proceedings of this seminar, and that the Proceedings should be sent to the next meeting of the Commission. Perhaps delegates here could let it be known whether they would wish to join a working group.

Mr. Rosrud : I think it is essential that we decide on the area of work to be covered by this working group. Whether it should be the W.C. or the discharge pipe work.

Mr. Ovesen : I want to emphasise that we cannot make final decisions here, but we can make proposals to be considered by the

Mr. Ovesen cont. next meeting. This proposal could be for W.C.'s and flushing tests. We must first decide whether delegates here feel that such a working group is required. I presume that the Drainage Research Group at Brunel University would be willing to be involved.

Dr. Swaffield : We would certainly support a working party on W.C. performance, but we would like to see the terms of reference of that working party to include the transport beyond the W.C., as has already been shown to be necessary. We would also like to see included, water conservation, in terms of W.C. testing. Therefore these three points ought to be included :-

i) Test procedures for W.C.'s

ii) Transport of the solid material beyond the W.C.

iii) Reduced flush volumes.

Mr. Olsson : I feel that the work should also include requirements for the future. The first point that must be investigated and settled is the solid material to be used for testing. After that the work would involve W.C. testing and consideration of the discharge performance in the discharge pipework system. The work must be split up. Everyone must agree on a standard solid model so that all results can be compared.

Mr. Read : I wonder if the terms of reference could include the bulk water supply requirements and hence peak factors of your reduced volume flush systems, and the reticulation factors, as your system could change the whole design of reticulation, and also the design of treatment plants. All this information would be required by the Civil Engineers, rather than the Building Services Engineers. Of course these items might broaden the scope of the group too much.

Mr. Ovesen : I agree that there is a real danger of broadening the scope too much.

Dr. Swaffield : One of the things that I would like to see us take more seriously, as an organisation involved in laboratory work, to some extent is the monitoring and instrumentation of solid velocity in the discharge pipework. We, in the Drainage Research Group, are very willing to share our experience of solid velocity measurement with other laboratories, as we have already done with Mr. Galowin of N.B.S. in Washington.

Mr. Ovesen : If there are no further points to be raised on this item, I feel that we should move on to consider an item raised earlier in the seminar involving water consumption flow rate measurements and the standardisation required. Do you feel that a working group is required for this topic?

Mr. Olsson : I feel that we need to get together and decide on the most important parameters for monitoring and how it should be done. After that we will need to consider the way to define the probability of flow.

Mr. Carson : My ideas which I mentioned earlier in the seminar, were not to achieve standardisation of the measurements made, but to build up an index of what measurements had been made, and to give the ability to exchange information with each other. Collecting data on usage, on site, is an expensive operation. We could move on to standardisation later, but the danger of standardisation is that it will fossilise the measurement techniques, and the way instrumentation is advancing at present, the last thing we want is to get stuck with something that may be good now, but would be out of date in a short time. I've been giving the idea of an index a little thought since I first raised it, and I wonder whether we should build up several indices. One index could be for water consumption and flow rate data, and another index could be for fixture usage data. Another set or other sets could involve drainage data. Several, relatively small indices on specific items, are easier to use than one major index. The sort of information that could be included in a water consumption index is : whether it was hot water, cold water, total water, chilled water etc; what measurements were made (i.e. litres/second; instantaneous measurement and if so, how frequently; litres consumed, and if so, over what time period; any temperature references; etc.) dates and times of the measurements; building/instalation/equipment details; occupancy details. In the index this would only be a very brief summary to indicate the nature of what was available. It would then be necessary to consider the data record itself, for instance; who owns it; how to contact someone responsible for it; the format of the data (i.e. IBM coding, magnetic tape, tables etc.): availability and if so, any price involved; references to publications. This is just an example and would probably be similar for any other index. We would obviously have to bear in mind when using the indices that the information would possibly be based on different social and cultural backgrounds.

Mr. Ovesen : That is what I meant by standardisation. Your ideas are very interesting. That could be an excellent way to obtain better corroboration. Has anyone any other views on this topic?

<u>Dr. Wakelin</u> : I feel that there should be a representative from each country to involve any similar work being undertaken by other organisations or firms in that representative's country. For instance Mr. G.J.W. Marsh of Marley Extrusions Limited in this country has been carrying out self financed research on water consumption. This additional work should at least be referenced.

<u>Mr. Olsson</u> : Do you feel that it is feasible to compare information gathered from different sources? There are so many factors that could influence the data and which cannot necessarily be defined. I feel that it is better to look into the future and consider new ways of providing information.

<u>Mr. Ovesen</u> : We ought to get some rules and perhaps forms that need to be filled in before new measurements are taken, then you would know what is necessary before you start, so that you would not be taking incomplete measurements.

<u>Mr. Olsson</u> : We do not know exactly what the consumer really requires. We could decide on a standard demand model, and everyone could compare their own readings with this.

<u>Dr. Swaffield</u> : The other point that I raised earlier on this topic is the identification of different groups across geographical boundaries, based on social grouping. I wonder whether before the next meeting of CIB W62, which I believe is to be in Berlin, it would be possible to approach organisations that have experience of classification of people by socio-economic groups. Dr. Howarth mentioned briefly this morning, that manufacturers of things like sanitary towels have a very good idea of the sort of people, and their relative group, who buy certain products. Other manufacturers must have similar information. An involvement of people with that background might help us to compare like with like, without reference to nationality etc.

<u>Mr. Olsson</u> : We are finding that our research is often made following the changes made by industries to save water and save energy. I feel that we should consider what we ought to do in such circumstances. I feel that the index should include future proposals.

<u>Mr. Carson</u> : The index that I had anticipated was purely a research workers tool equivalent to a bibliography in a library. At

Mr. Carson cont. that level I think it is still valid. I think that some of Mr. Olsson's ideas are slightly different. Whether the two approaches can be combined, I'm not certain.

Mr. Ovesen : To wind up this item of the discussion, I would like to make a proposal :-

"THAT MR. CARSON SHOULD DRAFT OUT THE IDEAS FOR AN INDEX OR SEVERAL INDICES ON SUITABLE RESEARCH TOPICS AND TO CIRCULATE THIS DRAFT TO SOME OF THE OTHER MEMBERS OF CIB W62 TO ENABLE PRE-DISCUSSION BEFORE THE CIB W62 MEETING IN BERLIN. I WOULD SUGGEST CORROBORATION WITH MR. NIELSEN, MR. OLSSON AND MR. HOLMBURG WHO HAVE BEEN INVOLVED IN SUCH MONITORING."

Mr. Nielsen : I would be pleased to participate in a working group.

Mr. Olsson : We in Sweden would like to be involved in such a working group.

Mr. Ovesen : I think that we should use the remaining time to consider the item of sanitation and water supply for the developing countries which was introduced by Mr. Read. I feel that we, in CIB should take up this topic again. I feel that Mr. Read has provided us with a fresh insight and opening into this topic, and could provide a better corroboration on many technical matters. I think that we should try to convey to the other members of CIB W62 that we want this co-operation to develop as soon as possible.

Dr. Swaffield : I would whole-heartedly support what you have just said. Mr. Perrier suggested this meeting for the people who were unable to go to South Africa and it therefore seems right that we should have involved ourselves in this topic, and I'm very grateful to Mr. Read for his excellent paper and presentation. I think that Mr. Read's paper should be sent to Mr. Perrier to be distributed to the other members of CIB W62 with an expression of our views that we should form closer links with Mr. Read's organisation, and to do all that we can to help.

Dr. Wakelin : I would like to address a question to Mr. Read. You represent an organistion that seems to be fairly international, Dr. Wakelin cont. but there are other organisations who are doing similar work. How would each individual developing country approach the problem of sanitation and water supply? To one central body or to the representative of whichever organisation is available in their country? Is there close co-operation between all the organisations involved and would the research information be freely and readily disseminated amongst all the people who might benefit from it?

Mr. Read : What we have done in the paper is to identify for people like yourselves, areas of particular need for research. All these areas of need are recognised by all concerned, working in this sector. So certainly, the fact that I work for the World Bank doesn't mean that others, say WHO, don't agree with what we say. As far as the international co-ordination of water and sanitation, this is obviously very difficult. The World Health Organisation is seen to be one of the leading agencies, and the U. N. is launching the decade for sanitation on, I think, the 20th of November this year. I don't think there is any conflict of interest or purpose. With regards dissemination of information between agencies, there is a great deal of discussion and contact between all the agencies. We work with the WHO, UNICEF and all the various funding agencies. I feel that we need to speculate as to the ways the people in CIB could help. It may be hard to put together a large CIB package. The answer might be for you to make some form of reference to the clear need to corroborate at a Western European level with the developing countries. The actual work could be developed through the various aid agencies with the research groups in each country. CIB could possibly co-ordinate the research. I hope that the issue will be raised at your next full meeting, but whether the delegates here feel that you can do anything more at this stage is up to you. The World Bank could possibly approach CIB and state the areas that need urgent investigation.

Mr. Rosrud : Are there any French copies of your paper?

Mr. Read : The paper could be translated into French if you felt it would be useful to do so. Perhaps the summary and key conclusions and recommendations would be sufficient.

Mr. Ovesen : That would be sufficient, I think.

Mr. Rosrud : After a lengthy and very worthwhile discussion, this meeting seems to agree about the urgency that should be attached to the problems of sanitation and water supply in the developing

Mr. Rosrud cont. countries, as outlined by Mr. Read. As a result of this meeting I think that Mr. Perrier should circulate a report of the meeting (i.e. the proceedings) to the CIB W62 members, and make known our views and concern that CIB W62 should assist as much, and as quickly, as possible.

Dr. Wakelin : All the papers presented at this meeting, together with an edited transcription of the discussion, will be bound into a Proceedings of this meeting and I will send a copy to Mr. Perrier in the hope that he will circulate it in whatever form he wishes to the other members of CIB W62.

Dr. Swaffield : We feel that that would discharge our responsibility to Mr. Perrier, as given to us and minuted at the Paris meeting.

Mr. Ovesen : At the Paris meeting, Mr. Perrier asked me to find someone who could report on our meeting, to the proposed meeting in Pretoria. I thought that Cyril Webster of B.R.E. would attend both meetings, but he has not been present here. So I am unable to fulfill this duty, and I think your report or Proceedings would be the best way to solve this problem.

Let us return to the topic which we were discussing with Mr. Read. Normally we do not have a very heavy co-ordination of the work within the group here, so I do not think that we could even attempt to make a strongly co-ordinated programme of research for the developing countries. On the other hand, we have had some very positive discussions here, so even if we cannot co-ordinate the work, we could perhaps define some goals for it. I feel that further discussion will be required within CIB before individuals go to their respective national aid agency, or possibly at the same time.

Mr. Read : Would you like this UNDP World Bank Project to formally write to CIB W62, saying that following the meeting today, we were reminded of these following needs, in the hope that CIB W62 might be able to assist with some of the areas that we are investigating. That could then open a forum for CIB members, with their respective funding agencies, for financing specific projects. I could give a list of about a dozen topics that could make major contributions to our programme. Clearly finance for the research would probably come from the aid organisations.

Mr. Ovesen : That could be a good opening, but I think it might be better, and easier, if we make the contact and ask you for information.

Mr. Ovesen cont. I think that Mr. Perrier could invite you to our next planning group meeting in order to discuss it at the next full meeting. I think that that could be the best for both parties.

Dr. Wakelin : What is the timescale for what you have just suggested? When is the next planning group meeting, and when would be the next full meeting?

Mr. Ovesen : The next planning group meeting would be with the next full meeting and therefore the main discussion would be at the next full meeting following that one. The planning group meeting is in January, I think.

Dr. Wakelin : I've got the impression that the problems require more immediate attention. Perhaps Mr. Read can confirm whether that is correct.

Mr. Read : Perhaps the best thing might be for me to discuss it with The Bank and see what they feel, and then perhaps I should write to you informally.

Mr. Ovesen : I should be glad to have such a letter from you, and then try to find some way of having a meeting as soon as possible, with CIB.

Mr. Read : It would be useful to have something formalised by the beginning of The Decade, say 20th November 1980.

Mr. Carson : I agree that the problems do require immediate attention. The thing that struck me more than all else in Mr. Read's paper was the list of practical problems which we could get our teeth into. Previously the problem, as illustrated to us, has been a big requirement for more water, which wasn't our area, but now we've got something worthwhile to tackle. What I would do myself, is to get in touch directly, so that if I am interested in a certain topic, I would ask for further details and then quote a price for doing the work.

Mr. Ovesen : That is a solution that is open to anyone of course, and could be a good solution.

Dr. Wakelin : Could I suggest then that Mr. Read is given a full list with addresses of all the members of CIB, and that any general letters that he sends to CIB, should also be sent to all individual members, for quicker reaction.

Mr. Ovesen : Perhaps it could be split up, so that Mr. Read sends the invitation letter to me, with additional information for all the members.

Dr. Wakelin : Would you circulate that additional information?

Mr. Ovesen : No. I will try to find the proper way to make the contact, because I'm afraid of being too informal.

Dr. Wakelin : Perhaps Mr. Read should write to delegates present here on an informal level.

Mr. Ovesen : I think that the first thing is to send the paper to all the CIB W62 members who are not here, as the paper lists the problems.

Mr. Read : Would there therefore be two distinct approaches, a formal one and an informal? There are, of course other items, such as water supply, hand pumps, stand post design, peak factor of reticulation etc. We do have more details than appear in the paper.

Mr. Ovesen : Yes, I think that will be the best way. If there is no further discussion, I would now like to close this discussion session, but first I would like to thank, on behalf of all the delegates here, the Drainage Research Group at Brunel University for the excellent arrangements and for an excellent meeting. Thank you.

Dr. Wakelin : I do not feel that there is anything formal that I have to say to close the meeting, other than to return the thanks to all the delegates who have attended this seminar. I feel that we have covered a lot of ground and formed some proposals that hopefully will bear fruit in the near future.

Thank you all.

AUTHORS AND CONTRIBUTORS INDEX

DRAINAGE AND WATER SUPPLY FOR BUILDINGS

A two-day seminar on current research
and future needs and objectives.

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Mr. Bahl Anderson	:	Teknologisk Institut, Denmark
Mr. S.D. Bokor	:	DReG Brunel University
Mr. W. Carson	:	Building Services Research Unit, Glasgow Unit
Mr. Davidson	:	BRE U.K. (2nd day only)
Mr. T.E. Eriksen	:	Porsgrunds Porselaensfabrik, Norway
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