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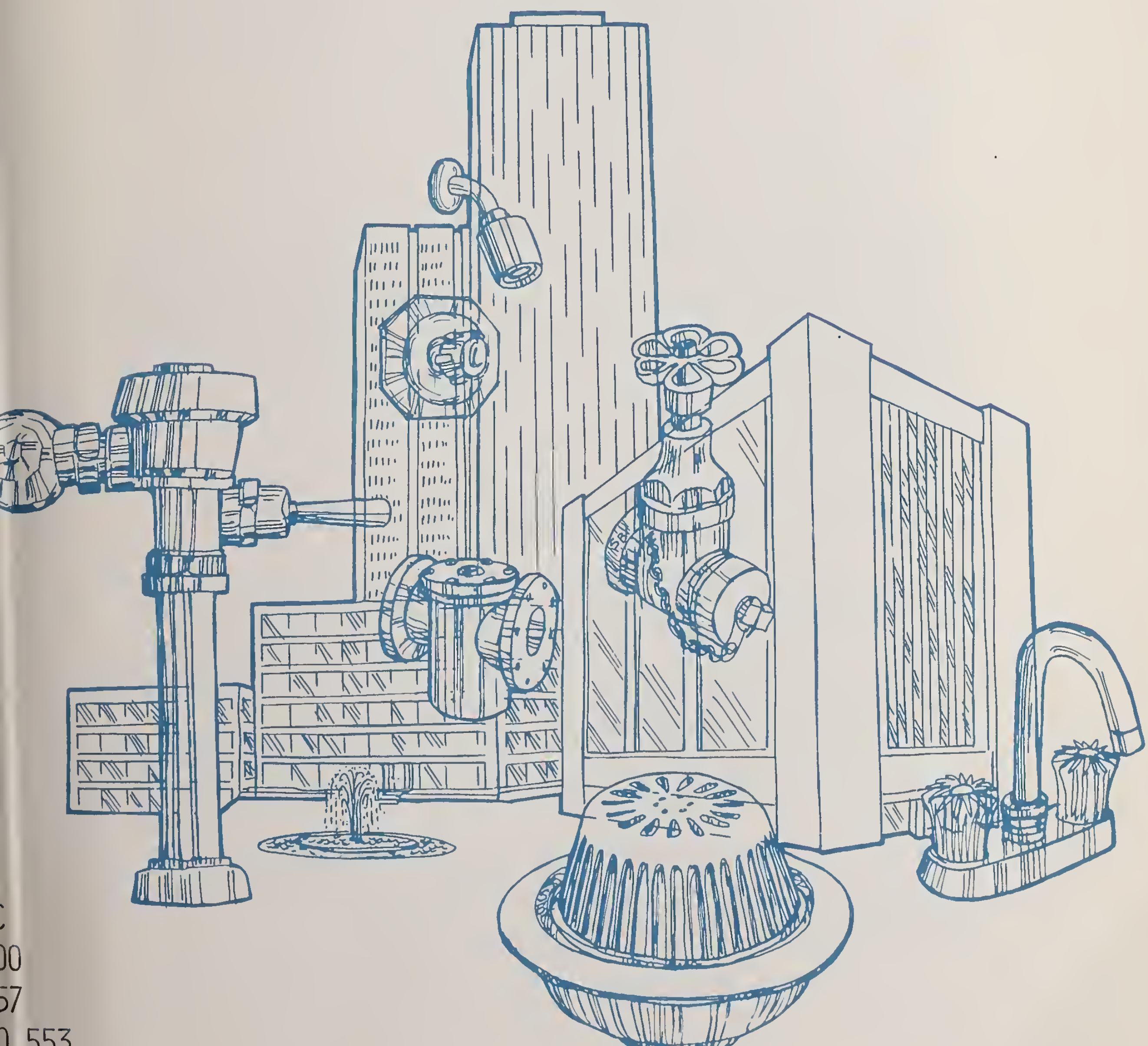
NBS Special Publication 553



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Water Supply and Drainage in Buildings

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Editors

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PREFACE

In the United States, the process by which plumbing systems are planned, designed, constructed, and operated is highly regulated by prescriptive (as contrasted with performance) codes and standards and largely comprises the specification, assembly, installation, and operation of materials and equipment offered by a diversity of manufacturers. Because the process revolves about products--fixtures, fittings, or trim (often referred to as brass), specialty items, and pipe--technological developments that have been and continue to be made are mainly product-oriented and the result of proprietary research and development activities of manufacturers. These proprietary activities benefit from and are constrained by research performed in furtherance of the development of plumbing codes and standards. The broader and more basic research has traditionally been centered at the National Bureau of Standards and augmented by programs at a limited number of universities such as the Stevens Institute of Technology, the University of Iowa, the University of Illinois, Pennsylvania State University, Massachusetts Institute of Technology, Johns Hopkins University and Virginia Polytechnic Institute.

With each new product or product-oriented advance or systems integration in a building there is growing awareness by those involved in plumbing (and by informed outsiders) that the current process of planning, designing, constructing, and operating plumbing systems does not (a) engage the expertise of all the scientific areas that, in actuality, comprise the basis of plumbing, (b) provide a valid basis for comparing objectives and economics of competitive development, (c) focus innovative efforts on potentially exploitable developments, and (d) facilitate exploitation of developments. This awareness is being heightened by recent drought experiences and broadened concerns of the availability of water and energy and the complexity and cost of waste water or by-product disposal.

Given this widening interest in, and national need not only for improving the state of the art of plumbing but also for improving the integration of considerations relating to plumbing with those relating to other building and utility concerns, the Counterpart Commission, in cooperation with the CIB W-62,decided that it would be useful to convene an international symposium. The meeting theme was directed at improving the description of plumbing research needs defined earlier by the Counterpart Commission,to place those needs in perspective vis-a-vis other building and utility research needs, and to suggest a general plan of action for research activity. In preparation for the symposium, the Counterpart Commission had a series of theme papers prepared by subcommittees of its members and other knowledgable specialists which could provide the framework for discussion at the symposium.

The topics of primary concern identified from the United States perspective were submitted in the following position papers:

1. <u>Water Requirements and the Procedures for Estimating the Demand for Water in Buildings</u>

   The most widely used procedure for estimating the demand for water within buildings is the probabilistic method developed by Dr. Roy Hunter while at the National Bureau of Standards. The Hunter method provides an estimate of the number of fixtures most likely to be operating simultaneously as a function of the total number of fixtures in the design. In developing this technique for real systems, Hunter departed from a rigorous probabilistic approach and substituted equivalency factors (fixture units). It is believed that the computational complexity of the true probabilistic approach was one of the reasons why Hunter developed the fixture unit concept. The advent of the modern digital computer removes this restraint.

   The Hunter technique and values assigned to the parameters have changed little since their establishment 35 years ago, and in view of their recent experiences in large-scale building projects, engineers have begun questioning the accuracy of this method. The results of several studies indicate that significant potential savings, in both initial costs and operating costs, can be achieved with an accurate knowledge of the demand for water within buildings.

   This position paper discusses alternative mathematical models, the nature and extent of a field data acquisition program, the human factor element, and the preparation of a design guide. Accurate knowledge of water usage patterns is required to establish a national policy in water related energy conservation.

2. <u>Water and Water-Related Energy Conservation in Buildings</u>

   In its final report, <u>Water Policies for the Future</u>, the National Water Commission concludes that the present water quantity situation is good except in the Rio Grande, Lower Colorado, and Great Basin regions, where consumption exceeds the man annual run-off. The shortage, as high as 36 percent in one area, is offset by mining groundwater or by bringing water in from other regions. Looking ahead, the Commission recommends future outlooks be based on several possible outcomes, in contrast to earlier studies which based projects on extensions of past trends. Our current concern for energy, for example, may influence water withdrawals and consumptions far beyond our expectations.

   It is against this background that water conservation in buildings must be evaluated. With existing technology, approximately 30 percent of the water consumed in residences can be saved; yet little progress is being made. Major research programs considering recycling of waste water are under way, and there may be areas where the implementation of these techniques should be accelerated. Needed are cost-benefit analysis at local, state, and federal levels and cost effectiveness analysis at the consumer level and particularly for large consumers. The impact of conservation practices on the health and welfare of residents also needs to be evaluated further.

This position paper examines water conservation practices and water-related energy conservation practices on a very broad scope. The interaction of water conservation with energy conservation and other savings (waste water treatment, regional and odd lot) may be far more important than the conservation of water itself.

3. <u>Protecting Water Quality in Buildings</u>

Much research has been done to provide a base for the setting of limits for organic and inorganic contaminants in our drinking water. Additional research has been undertaken to provide guidelines and technical manuals for health, engineering, and water supply associations so that treatment processes can be upgraded to meet the requirement of the Safe Drinking Water Act.

A determination of the extent to which contaminants enter the water within the building needs to be made. Inorganic materials have been known to come from the material used in the distribution network. Cross-connections with process equipment and sewer lines have been identified as sources of organic contaminants. The reuse of water will increase the potential for hazardous cross-connections and the buildup of heavy metals.

This position paper gives detailed consideration to the possible source of contamination within buildings and suggests a research program to produce answers to offset this health hazard.

4. <u>Hydraulics and Pneumatics of Gravity Drainage Systems</u>

Renewed interest in the hydraulics and pneumatics of gravity drainage systems has been stimulated in the United States by reports on the wide-spread acceptance of single-stack (self-vented) drainage systems in Britain and Europe and by the results of U.S. laboratory research and field trials with single-stack drainage, reduced-size venting, and other innovative designs. Some of the contemporary model codes are beginning to incorporate or at least to consider evaluation guidelines for innovative approaches to drainage system design. These innovative approaches probably offer significant potential savings in cost and materials, and some provide for simplified configurations that could be attractive from architectural and construction standpoints, particularly in manufactured modular construction.

This position paper assesses the status of current evaluation methodology, discusses the principal problems, and describes the potential impact of improved methodology, and includes a plan for stimulating needed research activity that should be useful both to researchers in the proposal of meaningful research and to potential funding organizations in evaluating the proposals and in allocating funds to selected programs showing significant potential.

5. Alternate Concepts for Transporting and Treating Wastes

Thirty to forty percent of the water consumed in the home is used by the water closet. The primary purpose of this waste water is to carry solids through the network of drainage pipes without clogging. The use of this highly processed clear potable water to carry away waste is questioned, and alternatives are sought. Interim solutions such as the separation of wastes, black water vs. grey water, must be examined and placed in perspective. Long-range solutions considering sewage treatment, energy, transport costs, etc., must be researched.

This position paper examines water supply and drainage for buildings in its broadest sense and suggests new concepts.

6. Performance Concepts for Water Supply and Drainage Systems

Difficulties have been encountered in the evaluation of innovative approaches in water supply and drainage under the provisions of contemporary American plumbing codes. These difficulties are largely attributable to the characteristics prescriptive nature of the codes and to the lack of an adequate evaluation methodology for predicting or testing the essential performance (i.e., those attributes that determine health, safety, and essential sanitary and physiological functions).

The philosophy of the performance approach in this field is that the traditional prescriptive standards, which are adequate for proven solutions, are not suited to the evaluation needs of innovative approaches. Thus, supplemental performance standards are needed to facilitate the acceptance of innovations.

This position paper describes the current status of performance evaluation methodology in relation to water supply and drainage for buildings, discuss the principal problems, and indicate the potential impact of improved methdology. A plan for stimulating needed research activity is included that will be useful to researchers in the proposal of meaningful research and to potential funding organizations in evaluating the proposals and in allocating funds to selected programs showing significant potential.

FOREWORD

This report contains the papers presented at the International Symposium on Water Supply and Drainage convened on September 28-30, 1976 at the National Academy of Sciences, Washington, D.C. conducted by the U.S. National Committee for the International Council for Building Research, Studies and Documentation (CIB) Counterpart Commission W-62. The meeting provided the opportunity to exchange information and identify general needs and common perspectives of plumbing in on-going research applications and practices in the United States and other countries.

The objective of the U.S. National Committee for the International Council for Building Research, Studies and Documentation (USNCCIB) Counterpart Commission W-62 is the enhancement of the efforts of those who seek to improve and apply the sciences and technologies used to provide potable water to, distribute the water within, and remove the liquid waste from buildings. To this end, the Counterpart Commission function is to:

1. Serve as a liaison between U.S. interests and the CIB and thereby provide a mechanism through which the ready exchange of plumbing research data generated by U.S. public and private organizations and other CIB members is encouraged.

2. Stimulate the generation of research studies and information on the state of the art and improvement in the field of plumbing research and technology.

3. Motivate organizations to take positive action in furthering plumbing research studies and documentation, and in improving practice.

This document was published by the National Bureau of Standards in collaboration with the National Academy of Sciences. The Counterpart Commission gratefully acknowledges the financial support provided by the National Science Foundation for the actual convening of the symposium,and the generosity of the National Bureau of Standards in publishing these proceedings; it sincerely appreciates the contribution of the participants at the symposium and of the authors of the papers incorporated in these proceedings.

The project which is the subject of this report was approved by the Governing Board of the National Research Council, acting in behalf of the National Academy of Sciences. Such approval reflects the Board's judgment that the project is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

The members of the Committee selected to undertake this project and prepare this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. Responsibility for the detailed aspects of this report rests with that committee.

Each report issuing from a study committee of the National Research Council is reviewed by an independent group of qualified individuals according to procedures established and monitored by the Report Review Committee of the National Academy of Sciences. Distribution of the report is approved by the President of the Academy, upon satisfactory completion of the review process.

The National Bureau of Standards assisted in the organization of the meeting and with staff participants in developing several of the contributed papers. The proceedings are published by the National Bureau of Standards to provide the document as a reference available to the public.

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Inquiries concerning this publication should be addressed to either 1) the Executive Director, Building Research Advisory Board, National Research Council, 2101 Constitution Avenue, NW, Washington, D.C. 20418, or 2) the National Bureau of Standards, Center for Building Technology, Washington, D.C. 20234.

The Editors

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ABSTRACT

This report contains the papers presented at the International Symposium n Water Supply and Drainage convened on September 28-30, 1976 at the National cademy of Sciences, Washington, D.C. and conducted by the U.S. National ommittee for the International Council for Building Research, Studies and ocumentation (CIB) Counterpart Commission W-62. The meeting provided the pportunity to exchange information and identify general needs and common erspectives of plumbing in on-going research applications and practices n the United States and other countries.

ey Words: Building water systems; CIB; international plumbing research; lumbing and drainage; U.S. research in plumbing.

WATER SUPPLY AND CONSERVATION

WATER REQUIREMENTS AND PROCEDURES FOR ESTIMATING THE DEMAND FOR WATER IN BUILDINGS

by

Robert V. Benazzi, Lawrence Guss,
Richard J. Orend, Robert S. Wyly, and Thomas P. Konen

The need to conserve all natural resources has led researchers to investigate methods for conserving both water and energy in today's plumbing systems, and one startling fact has become increasingly more evident; that is, within the plumbing industry very little is known about water requirements and the procedure for estimating the demand for water. Methods used today in the design and sizing of water supply systems are based upon guidelines that were established many years ago, and few changes have been made. On the basis of experience, engineers have tried to modify existing sizing techniques, but they have met with only limited success even though recent studies indicate that most supply systems are oversized by a large margin--a waste of valuable time, labor, and materials. Unfortunately, however, insufficient quantitative and qualitative data are available to permit development of the improved general computation procedures required if a meaningful policy on conservation of materials and water-related energy is to be established.

This paper seeks to describe current methodology, both domestic and foreign, and the problems associated with it. Also discussed are the merits and potential impact of improved methodology.

Background

The most widely used method for estimating the demand for the water supply system is that developed by Dr. Roy B. Hunter of the National Bureau of Standards.[1] Hunter realized that the most difficult task in determining the conditions of flow in a plumbing system is to predict the number of fixtures most likely to be operating simultaneously out of the total number of fixtures in the design. Knowing that the fixtures in a plumbing system are used intermittently, Hunter theorized that the actual loading effect of a single fixture was dependent upon the frequency of use of the fixture, the length of time that the fixture was in use, and the average flow rate of the fixture.

The method established by Hunter assumes that there are many fixtures and that the operation of each fixture is a random event. This method requires knowledge of the frequency of use (the time interval between fixture usage), the operating time, and the flow rate of each fixture. The values assumed by Hunter are given in Table 1.

TABLE 1 Characteristics of Selected Plumbing Fixture

Fixture	Frequency of Use T (sec.)	Operating Time t (sec.)	Flow Rate Q (l/sec.)	(gpm)
Water closet, valve	300	9	1.7	(27)
Water closet, tank	300	60	.25	(4)
Bathtub	900	60	.5	(8)

To determine the number of fixtures that could be in operation, Hunter made use of the binomial probability theory and developed the following general expression for a system consisting of the same type of fixture:

$$p_n^r = \binom{n}{r} (1-p)^{n-r} p^r$$

Where p_n^r = probability of r fixtures out of a total of n fixtures operating simultaneously, $\binom{n}{r}$ = the number of ways r fixtures can be selected from a collection of n fixtures, $(1-p)^{n-r}$ = probability of (n-r) fixtures operating at any given instant, and p^r = probability or r fixtures operating at any instant.

In converting this relationship into a useful tool, Dr. Hunter established the criterion that, for an adequate system, the demand should not exceed the design value more than 1 percent of the time. Thus, it can readily be seen that the demand load Q is equal to:

$$Q = q \cdot m,$$

Where q = the volume rate of consumption of a single fixture, and m = the maximum number of fixtures that probably will not operate simultaneously more than 1 percent of the time.

Because of the computation limits at the time Hunter developed his methodology, he did not generalize the expression given above to encompass several fixture types. Alternatively, Hunter developed the fixture unit concept which provided an empirical computation procedure for estimating the demand of mixed systems. This concept utilizes the assumption that the ratio of the design factor for different fixtures is independent of the demand. However, because no rigorous study has been made, this fixture unit approach has led to gross errors resulting in overdesign. Also, because of the paucity of field measurements of the input data for Hunter's technique, practicing engineers have used design guides generally based upon judgment of usage parameters. Many of these judgments were in gross error.

While the Hunter method has been in general use in both the United States and the United Kingdom since its presentation, Wise and Croft[2] recently obtained data for the frequency of use of water closets, lavatories, baths, and kitchen sinks in 108 British homes with average water needs. Using an analysis similar to Hunter's, but with their own field data, these investigators found they could nearly double their values for frequency of use without changing their design load calculations. If used in the design of a plumbing system, Wise and Croft's lower probabilities could result in smaller-diameter pipe sizes as compared to those determined from Hunter's values.

T. W. Maver[3] has investigated the frequency distribution method of demand in lieu of considering fixture types. The Maver approach requires the construction of frequency plots and the determination of distributional form. Upon acceptance of the hypothesis for a particular distribution, a demand may be specified that will be exceeded not more than a prespecified portion of time. Maver also considered the effects of various factors on maximum daily consumption through regression techniques.

Marchetti[4] has proposed a method that utilizes a radical formula equating a design factor to the square root of the number of homogeneous outlets. This approach utilizes one fixture type under limited circumstances of evaluation.

In 1972, Webster[5] challenged Hunter's basic assumption that each fixture has an equal probability of use. His theoretical treatment and analysis of the problem were based on a generalized Poisson distribution that assumes an equal probability of use of the various fixture types. Like Hunter, he assumed fixed flow rate requirements by fixture. By evaluation of the frequency of flow for all combinations of fixtures in a London apartment building study, Webster obtained a distribution of outlet fixture demand. He then compared this demand to the theoretical model. Webster found that his analysis yielded results which were in better agreement with his field data than the results predicted by Hunter's model.

With the advent of large, tall buildings, engineers began to take a serious look at the sizing techniques they employed. The advent of "tankless" pumping systems--systems utilizing either constant-speed or variable-speed pumps to maintain constant system pressure--also was instrumental in indicating overdesign. It was found that pumping plants seldom operated above 70 percent of their capacity. Heating plants for the production of domestic hot water also were found operating at substantially lower ratings than their capacities.

In 1959 a group of practicing engineers in Detroit brought this problem to the attention of the American Society of Sanitary Engineers (ASSE) at its national convention. A task force was organized and a test program was initiated on apartment buildings ranging in size from 20 to 292 units. The test results indicated that the overdesign of the cold water system ranged from 80 to 300 percent and the overdesign for the hot water ranged from 270 to 620 percent.[6]

A permanent group was formed under the auspices of the American Society of Mechanical Engineers (ASME) to undertake a national testing program to determine actual usage of hot and cold water in buildings of various types. In order to gain experience, a pilot program was undertaken by The Engineers Collaborative at a site owned and operated by the Chicago Housing Authority. Although data gathering was not the principal objective, sufficient information was collected to permit development of a curve (Figure 1.) that indicates demand predictions are in excess of 100 percent of those observed.[7]

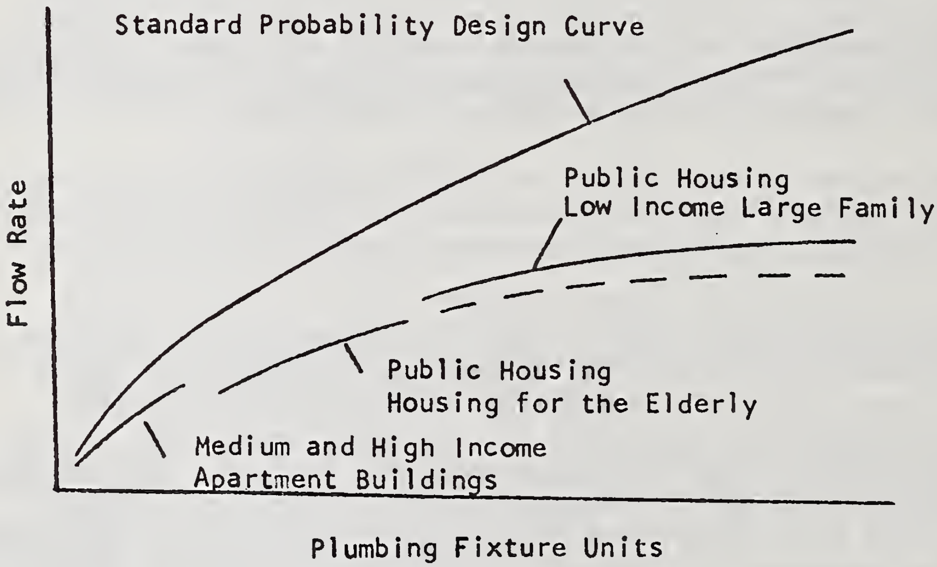

FIGURE 1. GENERAL COMPARISON BETWEEN TEST DATA AND THE STANDARD PROBABILITY CURVE FOR APARTMENT BUILDINGS TOTAL COLD WATER SUPPLY

In 1974, the impact of excessive demand estimates in piping networks was investigated by Monihan and Konen.[8] In cooperation with the consulting engineering firm of Jaros, Baum & Bolles, an existing 30-story apartment building was studied, and comparisons of demand estimate were made utilizing Hunter's method, the engineers' proprietary method, and a modified Hunter's curve. The parameters utilized by Hunter (i.e., frequency of use, operating time, and flow) were modified to new assumed values. This study indicated possible savings from the improved knowledge of demand as 15 to 20 percent in labor and 10 to 40 percent in material, depending upon the particular design and demand load.

For the most part, building codes in the United States recommend Hunter's method for estimating the demand of water in buildings, but engineers usually are allowed to vary from this method and substitute their own methods. For drainage systems, however, the codes differ slightly from one another. Data gathered from various research programs plus the experience of the members of the code committees are used to establish tables on drainage and vent systems. This has led to the establishment of several model plumbing codes which, while different from one another, all lead to overdesign.

In most cases, the need for newer research is indicated when one speaks of high-rise structures, because today's codes generally have been written for the smaller and lower-rise buildings. In almost all cases high-rise buildings fall outside the limits of the codes, and existing charts are just extrapolated. Thus, if a 50-story structure required 200-mm (8-inch) pipe, a 75-story structure would require a 250-mm (10-inch) pipe.

NEEDED RESEARCH AND ANTICIPATED BENEFITS

What is required today is a computation method that can be adopted both nationally and internationally and that would give the design engineers the ability to design a piping system for the needs of the structure, and the local officials the ability to check the design. Thus, all individuals on the building team would work from the same data base. Only then can economical design be realized. The establishment of a comprehensive computation method requires the following:

1. Development of a Mathematical Model

   The generation of a mathematical model or models describing the water supply distribution system in a building is essential to any program seeking to develop a new method for estimating demand. The development and confirmation of a mathematical model is the first step in the development of an analytical procedure. Since buildings vary in size, shape and function, it is anticipated that no one model will satisfy all applications. It is the responsibility of the research team not only to develop a useful model, but also to indicate the areas where the model will be applicable.

2. Establishment of User Needs

In line with the above research and possibly before final models have been established, much research is required into user needs. The primary prerequisite for determining the demand for water is to establish how the water will be used. Basically, user needs may be broken down into two categories: (1) biological needs, and (2) psychological needs.

Within each category three water usage characteristics may be defined. These correspond to Hunter's model and include: (1) frequency of usage; (2) duration of usage; and (3) flow rates. The characteristics overlap biological and psychological categories as do the specific functions such as flushing toilets, taking baths, washing dishes, cleaning, performed in using water. The principle objectives of research in this area must be: (1) to identify those water usage needs which are biological necessities (by category) and separate them from individually generated psychological demands; and (2) to determine how to conform to the biological needs and reduce the psychological (i.e., not "objectively" required) needs.

The biological needs for which water is used in buildings are easily identifiable (e.g., toilet, washing, cleaning, drinking and cooking) and (conceptually) are relatively easy to measure. The information required includes the absolute amount of water usage and the distribution of usage (by function) over time. From empirically derived models it will be possible to determine current need by function and across building types. Using available or new technology, it will be possible to reduce the need and demand for water by imposing rules or restrictions on water usage which fall within specified biological need limitations. Thus, if flush toilets are biological necessities, it is technically possible to design them so they consume less fresh water or use recycled water, thereby reducing demand and/or need. If we understand the usage of toilets over time it will be possible to design appropriate flow rates or to modify the usage pattern (frequencies).

The above discussion addresses the areas of identifying biological needs and current usage, and matching available technology to the needs in a manner which can reduce water usage and system demands. The resultant human factors difficulties arising from these efforts are what we shall define as psychological needs. The ability to meet a minimal biological requirement does not mean the solution achieved by technologists will be accepted by users.

As used here, psychological needs refer to individual requirements for water usage which are not biologically determined or which extend beyond the minimum biological requirements. Such needs are not less strongly felt, but it may be argued that they are "objectively" less necessary and are therefore subject to modification, i.e., reduction. In building this factor into design models or conservation efforts it is necessary to consider the establishment of minimum biological requirements and methods for gaining compliance (either voluntarily or by force) with those standards. For example, a shower nozzle may be designed which provides enough flow for adequate rinsing, but which restricts the water flow to considerably lower levels than are currently acceptable to most known users. The problem becomes one of imposing the new standard on a potentially non-receptive public. Similar problems exist with the amount of water needed to flush a toilet, the use of recycled water for certain functions, scheduling large scale water uses, etc.

In terms of information requirements the first step is to determine currently acceptable levels of change for each of the usage characteristics (flow, frequency, and duration) across all functional areas. It may then be possible to design down to these limits. If this does not reduce demand sufficiently it may be necessary to impose a more restrictive solution or change attitudes of users in the appropriate areas. Both of these activities require extensive future investigation.

The potential for change must be evaluated carefully since it is not practical to design fixtures or systems that never will be used. It must be determined how strong user habits are and whether water-saving fixtures will be accepted.

. Improvement of Fixture and Fitting Design

An obvious contributor to the demand of water in the building is the plumbing fixture itself. The conservationists have argued for water-saving fixtures, and from the point of view of saving gallons of water, this is important. However, it is even more important if the goal is to lower the demand rate for water in a building.

Brady and Konen have investigated the influence of changes in the frequency of use, the duration of use and the volume of discharge of a water closet. These influences are shown in Figures 2, 3, and 4. It is seen that the frequency of use factor is the most influential parameter. It is also seen that changes in the volume of water consumed by the water closet can reduce the demand where a large numder of fixtures are involved.

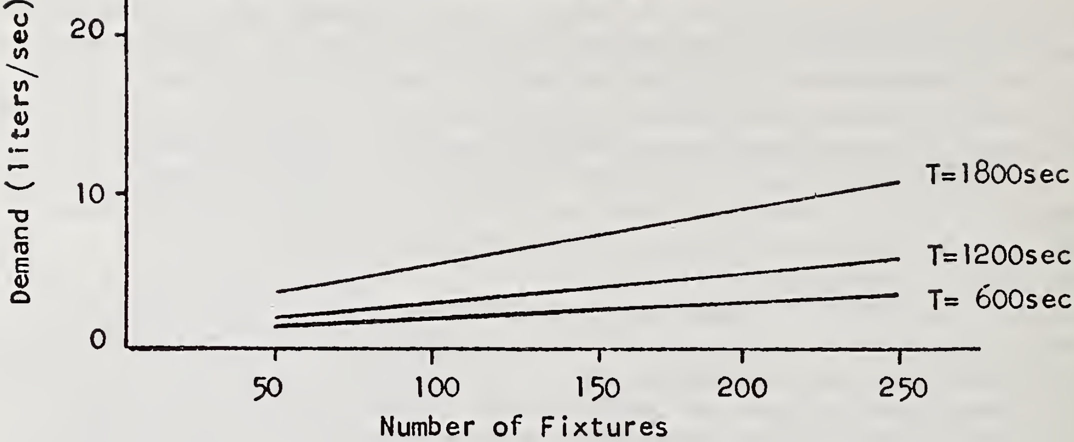

FIGURE 2. DEMAND VS NO. OF FIXTURES FOR SEVERAL VALUES OF FREQUENCY OF USE (T)

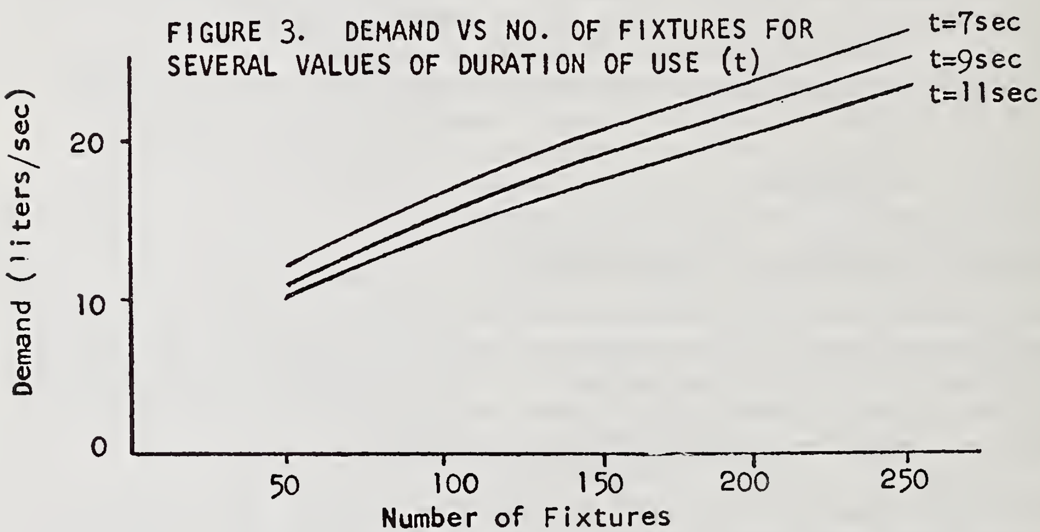

FIGURE 3. DEMAND VS NO. OF FIXTURES FOR SEVERAL VALUES OF DURATION OF USE (t)

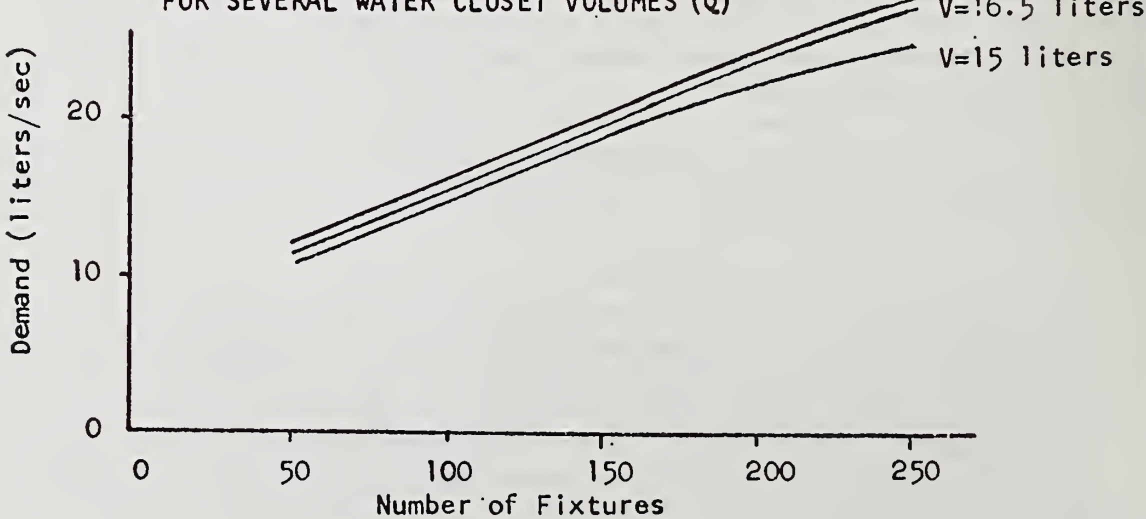

FIGURE 4. DEMAND VS NO. OF FIXTURES FOR SEVERAL WATER CLOSET VOLUMES (Q)

Thus, we can see the impact that fixture and fitting design have upon the demand curve for a building. Research must be continued on better methods of designing fixtures in the future.

4. Understanding the People/Fixture Ratio

Practicing engineers have observed a phenomenon about which very little is written--the people/fixture ratio. This term refers to the number of people a particular fixture is to handle during a given time span.

As mentioned earlier, one of the parameters that Hunter used in developing his method was the time between use of a fixture. It is obvious that if a fixture is to be used by 20 people, the time between uses will be considerably less than if a fixture is to be used by only one person. Practicing engineers have seen the effect of this ratio when designing stadiums or theaters, facilities in which the demand for water is increased greatly due to the increased usage of each fixture and the lessening of the time between usage. This phenomenon must occur, however, in all buildings. The effect that the time between use functions has on the demand curve can be seen in Figure 4. Thus, research is required into this area to determine, first, the proper number of people to be served by a fixture and, second, to provide a method that will allow the designer the opportunity to vary his demand formula based upon the variance in this ratio.

Anticipated Benefits

Billions of dollars are spent on the collection, storage, purification, and distribution of water in buildings; therefore, the benefits of the proposed research program are clear. Recent estimates of cost savings indicate the potential for:

1. A 25 percent reduction in residential water use through follow-up on programs based on reliable information establishing minimum and maximum flow rates for fixtures.

2. Savings in material costs of as much as 5 percent on the supply side and 20 percent on the drainage side through the use of smaller pipes, boilers, and pumps.[10]

3. Labor savings of 25 percent or more. The program would benefit consumers by lowering costs and bettering performance, manufacturers by permitting more effective use of materials and a more reliable basis for the standardization and improvements in quality of performance, contractors by improving their competitive position through the application of better design procedures that would permit more economical installation and more effective utilization of manpower and materials, engineers by providing a method with which they could design with confidence, eliminating the need for

large factors of safety, and the general public by conserving water (through the use of better-designed fixtures resulting from a better definition of use requirements).

4. Energy conservation through the use of better-designed systems based upon the establishment of more accurate water supply requirements.

To achieve these ends, it is believed that a new research program must be started and supported. The foregoing areas for research are those that can be envisioned now as areas requiring more and greater knowledge. As research continues, new areas requiring attention will very likely appear. The most important need in research today, however, is the exchange of ideas between the researchers. A concurrent and cooperating research effort both in this country and abroad is essential.

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PROTECTING WATER QUALITY IN BUILDINGS

by

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During the period 1971-1974 there were 99 reported outbreaks of disease associated with water used for drinking or domestic purposes, a significant increase over earlier periods. The reasons for this apparent increase are not known but it may be the result of an increase in surveillance. Approximately one-third of the waterborne disease outbreaks involved municipal water systems, these, however, were responsible for 67 percent of the 17,000 cases of illnesses. Thirty-two percent of the outbreaks were the result of deficiencies in the distribution systems. Other causes are inadequate treatment, 29 percent, and use of untreated surface water, 19 percent. These facts[1] indicate that disease caused by drinking contaminated water continues to occur.

The Safe Water Drinking Act of 1974 establishes as a national goal safe drinking water for all Americans. Faced with this enormous task, the Environmental Protection Agency (EPA) has developed a strategy that recognizes it is not possible to correct all problems in a year or two and that success will come in small increments. During the past year, the U.S. Environmental Protection Agency has promulgated National Interim Primary Drinking Water Regulations[2] which establish maximum contaminant levels for organic and inorganic chemicals, turbidity, and microbiological contaminants. These regulations apply to community and noncommunity water supply systems. The estimated annual costs to the 40,000 community water systems that provide water to 178 million Americans to conform to these regulations have been determined to be: $17 million to $36 million above the present expenditures for routine monitoring, $146 million to $247 million for capital expenditures for new treatment plants and $259 million for operating and maintenance expenditures.[3]

The major accomplishment by the EPA in promulgating interim drinking water standards and the review of the costs to achieve them mandates that the building industry examine its role in protecting the safe drinking water that will be delivered to the site.

Background

Traditionally the protection of water quality in buildings has been limited to a continuing program to monitor connections to the potable water system that could cause contamination from back pressure or back syphonage.

A cross connection is any actual or potential physical connection between a potable water supply and any waste pipe, soil pipe, sewer, drain, or any unapproved source through which it is possible for contaminated or polluted water to enter the potable system. Furthermore, it is any potable water supply outlet which is submerged or can be submerged in waste water or any other source of contamination. Cross connections may be regarded as direct or indirect. A direct connection is an arrangement whereby a safe water system is physically joined to a system containing unsafe water, sewage, or other waste. An indirect connection is an arrangement whereby unsafe water in a system may be blown, sucked, or otherwise diverted into a safe water system.

Concern for the protection of the water supply became evident with the introduction of pressure tanks. With the pressure tank system, more uses were found for water (e.g., fire protection, cooling, heating). Accompanying this increase in water usage was the need to prevent the backflow of water from the pressure tank into the water main.

At that time the house tank and most of the fixtures, such as water closets, bathtubs, laundry tubs, and sinks, had the fill pipes below the flood rim. The problem which arose from this design was that during times of low pressure in the public water system, water could syphon back into the system and cause contamination. In order to overcome this problem, New York City, in 1883, put into effect a regulation that all water supply connections made to fixtures below the flood rim had to be removed.[4] The most hazardous of these connections was the direct water supply valve for flushing water closets. Regulation of this particular connection was not enforced, and inevitably fell by the wayside. About 1903, the double check valve assembly came into use when it was found that a single check that had been in use would not give positive protection.

As more complex systems such as, industrial process piping and heating and cooling systems come into being, a more positive means of protection was needed to protect the potable water system. In 1942, the reduced pressure principle backflow preventer was introduced. This was designed to have a minimum of two independently acting, approved check valves, together with an automatically operated differential pressure relief valve located between the two check valves. During normal flow, and at the cessation of normal flow, the pressure between these two checks must be less than the upstream (supply) pressure. In case of leakage of either check valve, the differential pressure relief valve, by discharging to the atmosphere, must operate to maintain the pressure between the checks at less than the supply pressure. The unit must include tightly closing shutoff valves located at each end of the device and each device must be fitted with properly located test cocks.

Problems

Many effective products are commercially available to prevent contamination of the potable water system from back flow and back siphonage. Yet numerous cross connections occur each and every day. With all the technical knowledge and understanding of the hazards which can and do exist, there is still a long way to go in protecting the drinking water. Who knows what happened in Philadelphia just this year? Unconfirmed reports indicate 22 unprotected cross connections were found in an inspection of those facilities. Was it the water? In Aiken County, South Carolina, the town's water supply was contaminated by a chemical from an industrial building in 1975.[5] In Chattanooga, Tennessee, insecticide poison was found in water of 45 homes in March 1976.[6] There are many more such cases on record. Investigators estimate at least 1,000 cross connections are made per day in the United States alone. It is believed that cross connections continue because of lack of awareness on the part of the general public, the absence of specific detailed knowledge by plant maintenance workers and inadequate training of plumbing inspectors. Most manufacturers of protection devices will assist localities in initiating water protection programs and some manufacturers have held seminars.[7]

However, cross connections are not the only way in which water in the distribution systems within can become contaminated. The Danish Corrosion Center, following the lead of their Norwegian counterparts, have conducted laboratory experiments to determine if plumbing fittings manufactured in their country were subject to dissolution of metals in the water.[8] Their findings are shown and compared to the tolerance limits of the World Health Organization and the U.S. Environmental Protection Agency below.

Cadmium and Lead Concentrations Found in Fittings

Contaminant	Findings	Tolerance WHO and EPA
Cadmium	0.027 mg/ℓ*	0.01 mg/ℓ
Lead	0.1 mg/ℓ**	0.05 mg/ℓ

*one fitting others had concentrations of 0.01 mg/ℓ

**three fittings others had concentrations less than 0.05 mg/ℓ

These results are based on tests of 10 fittings that were exposed to synthetic water, soft and acidic, for a period of 10 days. Short-term experiments with exposures of less than 24 hours showed, with a one-hour exposure, metal pick-up was of the same order of magnitude as with an exposure of 12 or 24 hours. These findings suggest further study to ensure the safe drinking water remains safe as it travels through the water distribution system within the building.

Research Needs

Bacterial and chemical contamination of water has been known to occur in the distribution systems within buildings. The contamination of the water supplies has often been through cross connections. Recent research has suggested that contamination may result by the release of heavy metals from common materials used in these systems. These findings mandate that further studies and investigations be initiated to safeguard the public health.

1. A comprehensive study of the potential for the contamination of the water supply by cross connections within buildings should be undertaken. With a better definition of the cross connection problem, it is envisioned that improved regulations, which may consider the degree of the hazard for various types of interconnections, will evolve. The degree of the hazard should be determined after an evaluation of the potential for contamination is made considering the probability of failures and whether they are detected or undetected.

The concept of containment--isolation of the building from the community water system--should be considered. Investigation should study the concept for single-family dwellings, multifamily dwellings, and industrial buildings, separately and together.

2. The reporting of the contamination of water within buildings should be included as a part of regulations governing safe drinking water so that effective corrective action may be taken where required.

3. Unprotected cross connections in boilers and converters for providing domestic hot water should be investigated to determine the level of risk incurred. Solar energy systems have a similar problem.

4. A public awareness program should be considered as this may be the most effective method of reducing the multiplicity of cross connections that presently exist and aid in reducing the growth of potentially hazardous situations.

5. Consideration should be given to the extension of regulations that require protective devices on manufactured equipment that is connected to the water system. Many industrial, medical and home appliances tie into the distribution system as a matter of routine.

6. The contamination of the water supply system by heavy metals dissolving from conduits, joints and fittings must be investigated further. The corrosion engineer must now consider deterioration of the quality of the water in addition to the deterioration of the material carrying it.

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WATER AND WATER-RELATED CONSERVATION IN BUILDINGS

by

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Like other nations, the United States is dependent upon precipitation for its water supply. Although the United States is fortunate in having an annual overall precipitation of 30 inches, wide regional and seasonal variations have necessitated extensive measures to supply water where it is needed; for example, changing the course of rivers to bring water to arid regions; building dams to irrigate vast land areas; and constructing networks of aqueducts, canals, and pipelines to bring water over mountains to growing urban centers. The total expenditures for development of water resources over the years through 1971 are estimated to be $338 billion; current federal outlays for water resources and related developments are more than $4 billion per year.

In its 1973 report, Water Policies for the Future, the National Water Commission concluded that the present water quantity situation is good in all regions except the Rio Grande, Lower Colorado, and Great Basin (Nevada) regions, where consumption exceeds the mean annual runoff and the shortage is offset by mining groundwater or bringing in water from other regions. Streamflow* and 1970 withdrawals** and consumptions*** are compared in Table 1, and regions are identified. An average of 1400 million m^3 (370 billion gal) of water is utilized each day in the United States. The bulk of this water is used for irrigation (35 percent), in steam electric utilities (38 percent), and in industry (17 percent), with less than 10 percent being consumed in residential and commercial buildings through public water utilities.

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*The discharge in a surface stream course.

**The diversion and removal of water from a natural water course; this water often is returned with only minor change in quality.

***The water withdrawn from a supply and not directly returned to a surface or groundwater supply because of absorption, transpiration, evaporation, or incorporation in manufactured products; such water is not immediately available for reuse.

TABLE 1 - Streamflow Compared with Current Withdrawals and Consumption. (Billion gallons per day)

Region	Mean Annual Run-Off[2]	Annual Flow Available[2] 50% of the Years	90% of the Years	95% of the Years	Fresh Water Consumptive Use 1970[1]	Withdrawals 1970[1]
North Atlantic	163	163	123	112	1.8	55
South Atlantic-Gulf	197	188	131	116	3.3	35
Great Lakes	63.2	61.4	46.3	42.4	1.2	39
Ohio	125	125	80	67.5	.9	36
Tennessee	41.5	41.5	28.2	24.4	.24	7.9
Upper Mississippi	64.6	64.6	36.4	28.5	.8	16
Lower Mississippi	48.4	48.4	29.7	24.6	3.6	13
Souris-Red-Rainy	6.17	5.95	2.6	1.91	.07	.3
Missouri	54.1	53.7	29.9	23.9	12.0	24
Arkansas-White-Red	95.8	93.4	44.3	33.4	6.8	12
Texas-Gulf	39.1	37.5	15.8	11.4	6.2	21
Rio Grande	4.9	4.9	2.6	2.1	3.3	6.3
Upper Colorado	13.45	13.45	8.82	7.50	4.1	8.1
Lower Colorado	3.19	2.51	1.07	0.85	5.0	7.2
Great Basin	5.89	5.82	3.12	2.46	3.2	6.7
Columbia-North Pacific	210	210	154	138	11.0	30
California	65.1	64.1	33.8	25.6	22.0	48
Conterminous United States	1,201				87	365
Alaska	580				.02	.2
Hawaii	13.3				.8	2.7
Puerto Rico					.17	3.0
Total United States	1,794				88	371

[1]MURRAY, C Richard & REEVES, E Bodette (1972). Estimated Use of Water in the United States in 1970, Geological Survey Circular 676. U.S. Geological Survey, Washington, D.C. p. 17.

[2]U.S. WATER RESOURCES COUNCIL (1968). The Nation's Water Resources. U.S. Government Printing Office, Washington, D.C. p. 3-2-6.

WATER CONSERVATION AND MUNICIPAL SYSTEMS

Little effort has been expended to investigate ways to conserve water in municipal supplies except when regional or local shortages occur and, even then, conservation usually is promoted only during the crisis while the recommended solution is increasing the supply through construction of a major engineering project justified on single-valued projections of past trends. There are, nevertheless, four major reasons for being concerned about excessive use of treated water: First is the immense problem of pollution and the effort required to return water to nature in approximately the same condition it was withdrawn. Second is the enormous cost of processing water in both input and output phases. Third is the potential energy savings resulting from decreased water processing and use. Fourth is the occasional real water shortage, the probability of which can be decreased by more judicious use of available supplies.

The Water Pollution Control Act amendments of 1972 and the Safe Drinking Water Act of 1974 are reasons for change in attitudes toward processed water. Municipal sewer systems daily discharge 152 million m^3 (40 billion gal) of effluent into the nation's waterways. Much of this effluent receives only primary treatment and some receives no treatment at all. The Water Pollution Control Act requires publicly owned waste treatment plants to provide a minimum of secondary treatment by July 1, 1977. A needs survey, estimates the investment required to meet the 1977 objectives through the construction of secondary treatment facilities and interceptor sewers to be $36.6 billion.[1] The Environmental Protection Agency has identified the infiltration of groundwater into sewers as a major problem. As infiltration is reduced, the advantages of saving water in homes and commercial buildings will take on greater significance.

The continuing growth in U.S. water needs is shown in Figure 1. It is expected that as conformance to the Safe Drinking Water Act of 1974 is achieved, the cost of water will rise dramatically. For example, Jersey City, New Jersey, which supplies 265,000 m^3 (70 million gal) of water per day to several communities, has been advised that a filtration plant for its system will cost $42 million, and a rate increase of 300 percent has been suggested to cover the cost of this new plant. In California, pumping costs are expected to increase by a factor of 10 when the present contract with the power company expires. It is against this background that water conservation within buildings must be evaluated.

TECHNOLOGY VS. SOCIOECONOMIC IMPACT OF CONSERVATION

Water conservation research currently being conducted is centered on the introduction of new devices and techniques into the home or building. Three factors are particularly important: (1) the economics of water-conserving devices and techniques, (2) the politics of introducing them into current codes, and (3) their acceptance by individual users. These interrelated factors are known to have an impact upon the adoption of many technological changes, and water conservation in buildings is no exception.

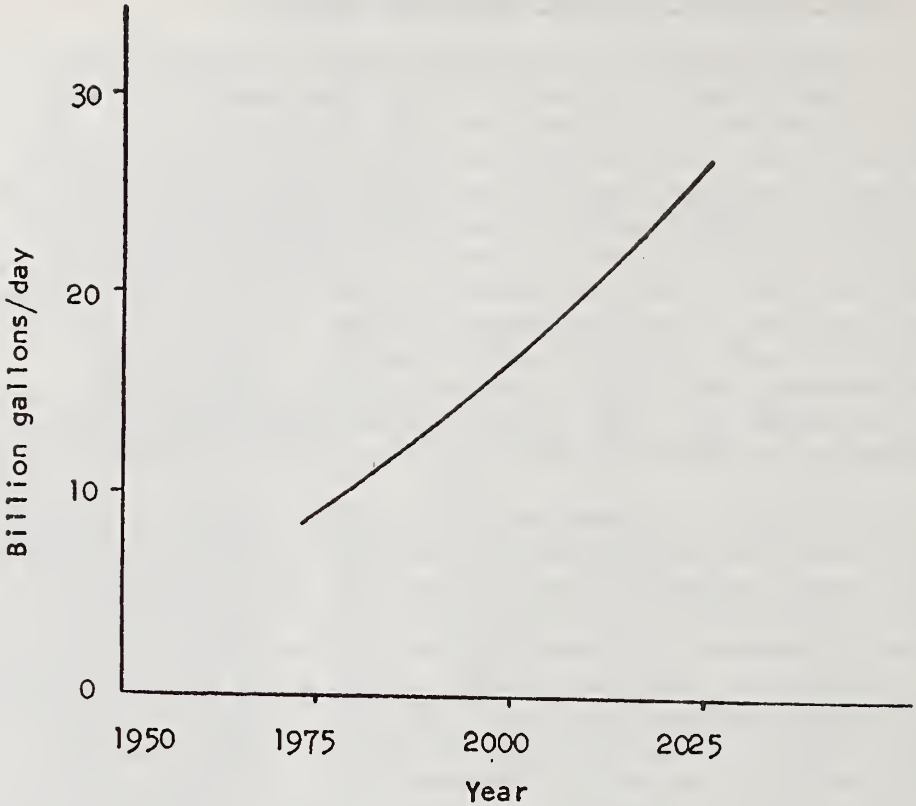

FIGURE 1. PROJECTED CONSUMPTION
MUNICIPAL WATER USE

Water conservation is in itself a challenge for efficient water management. Many outdated urban distribution systems lose as much as 50 percent of incoming water through leakage, while the overtaxed sewer systems often are required to carry out 40 percent more waste than needed due to infiltration of groundwater.

Considering the staggering costs for the supply and treatment of wastewater, it is imperative that water be used wisely. In the management of buildings, utilities conservation is one of the most significant programs carried out by a building manager. Considerable savings in both tax dollars and natural resources can be made when good management is applied to the use of electricity, heat, and water. The costs for water and sewage average approximately 4 percent of the total utility costs of normal building operations, but many indirect savings also result from careful water management. Reducing the amount of water used saves in the cost of heating water and lowers the electricity costs associated with the operation of pumps. Also, a reduction in the amount of water handled lowers the life-cycle costs for maintenance of pumps, fixtures, valves, motors, etc. Thus, an enterprising building manager who utilizes every means of water conservation at his command not only provides a service to his community but also can lower building operating costs without lowering the level of service.

Much is known about the direct impact of economics, but the interaction of economics with the other two "social" factors is less well defined and poses some interesting questions about the adoption of water-saving changes. The problems experienced with fluoridated water are an example of how a few people can cause enormous problems by the adoption of municipal policy changes despite the opinion of a majority of residents.[2] Changing water purity codes probably will be an equally difficult task. The economic and political issues related to this situation involve a determination of who stands to gain or lose because of such changes, as well as does the initial cost of converting individual systems. Finally, one must know what it will take to convince significant numbers of people that such changes are safe (assuming they are) and that they should be adopted. One early study on the possibility of reusing water for various household purposes revealed strong attitudinal barriers to some uses.[3] Those surveyed in this study found the use of recycled water for drinking to be most distasteful, and other uses progressively less distasteful as they moved futher from the body (i.e., bathing was indicated to be less distasteful than drinking, clothes washing less than bathing, etc.). Such results raise the question of how far water-saving techniques will be allowed to advance despite obvious conservation advantages. Thus, research is needed to assess the impact of conservation in conjunction with the technology of conservation.

RESIDENTIAL WATER USE AND THE POTENTIAL FOR CONSERVATION

Residential water consumption in the United States is approximately 82 percent higher than in Europe. Average daily consumption in Europe is 132 l/capita (35 gal/capita) while U.S. daily consumption is 240 l/capita (64 gal/capita). An analysis of water consumption for a family of four--two adults and two children in England--is given in Table 2.

TABLE 2 Daily Water Use by a Family of Four

	England[4]			United States[5]		
	Percent	Liters	(gal)	Percent	Liters	(gal)
Water closet flushing	37	196	(52)	39	378	(100)
Personal bathing	37	196	52	34	332	88
Laundry	11	56	15	14	133	35
Washing up (dishwashing)	11	56	15	6	57	15
Drinking & food preparation	4	24	6	5	45	12
Utility sink	*	*		2	19	5
Total	100	528	140	100	964	255

*Data not available for this category.

The most significant difference in water usage involves the water closet (WC) and is attributed to the higher volume used by U.S. water closets. In England, WCs that use 9 l/flush (2.4 gal/flush) or 14 l/flush (3.7 gal/flush) are available; in Europe, the typical WC uses 8 l/flush (2 gal/flush). Residential units in the United States consume approximately 19 l/flush (5 gal/flush). Most of the low-volume European WCs are of the washout type; a few have siphonic action. The typical U.S. WC is a vortex siphon unit that provides better scouring action in the inside surfaces of the bowl. In addition, the large water surface area in U.S. siphon bowl wells provides a cleaner and more hygienic receptacle for waste matter. Reduced-volume WCs manufactured in the United States using 13 l/flush (3.5 gal/flush) have attempted to maintain the vortex action to give the good performance the consumer is accustomed to, while reducing the volume of water. (A number of chemical [waterless] toilets are available in the United States, but these units are designed primarily for use in remote locations where water supply and drainage systems are not available.) The other differences in water consumption between the United States and Europe and Great Britain are attributed to differences in personal habits and the more widespread use in the United States of appliances such as dishwashers and automatic washing machines.

While fixture and fitting minimum flow rates based on function have not yet been researched, the British Code of Practice, CP 310[6], has established recommended rates of flow at various fittings. These values, along with information on typical U.S. and European values, are shown in Table 3.

TABLE 3 Typical Flow Rates for Plumbing Fittings (l[gal]/sec)

Fixture	England[7]	Europe[7]	United States: Early Code[8]	United States: Current Practice*
Washbasin	0.15 [2.4]	0.1 [1.6]	0.19 [3.0]	0.1 [1.6]
Sink	0.19 3.0	0.2 3.2	0.28 4.4	0.2 3.2
Bath	0.30 4.8	0.4 6.3	0.38 6.0	0.25 4.0
WC	0.12 1.9	0.1 1.6	0.19 3.0	0.2 3.2

*Estimated.

The potential for water saving in various appliances and fixtures may be estimated on the basis of the following criteria:

1. The amount of water that can be saved utilizing existing technology, feasible economic transition, and current standards of acceptance.

2. The amount that could ultimately be saved by utilizing future technology disregarding transition costs and research and development expenditures and assuming performance acceptance standards can be changed. Table 3 illustrates the potential for water saving using the foregoing criteria in a typical household of two adults and two children.

If the water consumption data presented in Table 3 were typical of all residential use, they would indicate that a complete nationwide replacement of plumbing fixtures and appliances by their currently available water-saving counterparts would result in a 34-percent saving in national residential water consumption. Similarly, this suggests an ultimate potential saving of about 78 percent. Assuming the presently estimated fraction of residential consumption to be 12 percent* of total U.S. water consumption[9], these savings would be 4 percent and 9 percent of total U.S. water consumption.

TABLE 4 Potential for Reduction of Daily Water Consumption by a Typical Family of Four

Use	Current, l (gal)	Criterion 1 l (gal)	Criterion 1 % Saved	Criterion 2 l (gal)	Criterion 2 % Saved
Dishwashing	57 (15)	41 (11)	27	19 (5)	66
Cooking/drinking	45 (12)	45 (12)	0	38 (10)	16
Utility sink	19 (5)	10 (25)	50	4 (1)	20
Laundry	133 (35)	91 (24)	32.5	38 (10)	71
Bathing	302 (80)	190 (50)	37.5	75 (20)	75
Bathroom sink	30 (8)	15 (4)	50	4 (1)	87
WC	378 (100)	242 (64)	35	38 (10)	90
Total	964 (255)	634 (190)	34	216 (57)	78

Although water, at least for the present, appears to be abundant in many parts of the United States, it has been estimated that residential water heating accounts for an energy consumption of 1.1 million barrels of oil per day. This represents 15 percent of residential energy consumption and 3 percent of total U.S. consumption.

Most studies relating to energy conservation recognize the saving that can result from improved efficiency of water heaters and from reduced consumption of hot water. In the latter category, which is of interest here, Muller estimates that 9 percent of energy used for residential water heating can be saved by the use of flow restrictors in showers and basin faucets.[10]

In addition to the energy saving resulting from conservation of domestic hot water, it should be noted that a reduction in the consumption of cold water also will save energy since most cold water supplies enter a building at temperatures below the ambient temperature within the building and leave the building at or new this ambient temperature. In many cases this represents an 11 °C (20 °F) temperature rise and the removal of 4180 kcal (16,600 Btu) per day from the heat in a typical house by the cold water used in the toilet alone. Obviously the use of reduced-volume water

*Includes individual water supplies.

closets will reduce this energy loss, but research is needed to prove the performance of such units under conditions simulating those in the field.

In any study of water-related energy conservation, both the energy used to heat domestic water and the total energy associated with supply--i.e., exploration, facility construction, pumping, purification, and sewage treatment--must be considered and this will involve the development of an energy balance sheet. Research is needed to prepare a comprehensive study of energy use in water supply and wastewater treatment systems.

NEEDED RESEARCH

The following specific research efforts are needed to assist the United States in meeting its future residential and commercial water supply needs while preserving energy resources:

1. A comprehensive study of the water source, supply, use, and wastewater treatment for residential and commercial buildings. The main thrust of this study should be an examination of the economic impact of conservation in contrast to the technology of conservation. Included should be a careful assessment of the problems of leakage from the water supply system and infiltration to the wastewater collection system. The main reason for such a study is to provide water managers and government officials with the basic economic information they need to make decisions regarding water supply and conservation measures.

2. The establishment of the interrelation between the water use by various fixtures and fittings and their functional performance. An 11 l/min (3 gal/min) shower and the 13 l (3.5 gal) water closet appear to have been arbitrarily selected as national goals. Studies are required to determine safe economic quantities of water required for acceptable performance of fixtures. Psychological factors (i.e., the public acceptance of such changes) must be considered in addition to the technical aspects of design.

3. A project to determine the comparative performance of fixtures in general and of water closets in particular under simulated conditions representative of typical installations in single-family and multi-family dwellings. Empirical test procedures and rating methods to determine the performance of water closets have been developed and are employed in quality assurance programs and general laboratory evaluations of new units. However, since performance may be influenced by installation and field conditions, a more complete evaluation can be obtained in a plumbing test facility where geometries and hydraulic conditions expected in a plumbing drainage system can be simulated. A comprehensive plan for evaluating water closet conformance to acceptable performance standards must consider each of the

following areas: (a) geometry of the drainage, waste, and vent system; (b) piping details immediately adjacent to the closet; (c) location of the closet in the system; and (d) hydraulic conditions in the stack. It should be noted that continuation of the sales and promotion of water-saving water closets and add-on devices without thorough evaluation could result in a health hazard as well as the more likely event of increased consumption through double flushing.

4. An assessment of the extent to which recycled water can be used and the practicality of using gray water for other than human consumption. The direct reuse of water for human consumption cannot be adopted until a major research program is completed to demonstrate that virological and other possible contamination does not present a significant health hazard.

5. Establishment of the energy impact of water conservation through a careful energy-benefit analysis of the energy associated with water consumption as well as a determination of the energy impact of various water-saving measures. For example, inhouse residential recycling systems may offer substantial net savings in water supply to the residence but also may result in a wasteful use of energy.

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HYDRAULIC ANALYSIS AND PERFORMANCE CONCEPTS FOR WATER SUPPLY AND DRAINAGE SYSTEMS

HYDRAULICS OF GRAVITY DRAINAGE SYSTEMS

by

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The function of a plumbing drainage system is to collect and transport wastewater from the fixtures to the building sewer. In achieving this function in a safe and efficient manner, water-sealed traps are used to protect the interior of the building from hazardous or obnoxious gases that may be produced in the drainage system or sewer. Traps are essentially water seals which permit the passage of water into the drainage system while blocking the flow of gas out of the system into the building. The normal depth of a trap seal is 50 mm (2 inches) for fixtures other than waterclosets, which generally have a seal depth ranging from 63 mm (2 1/2 inches) to 75 mm (3 inches). The flow of air and wastewater within the system is complex. It is three-phase, nonuniform, and unsteady. Over the years, laboratory and field data have been obtained to provide design loading tables for use in limiting the flow through the drainage piping to levels which will not threaten the integrity of the water seal in the traps. A full understanding of the fluid mechanics of the system has not been developed, due to the complexity of the hydraulic phenomena within the typical, interconnecting network of pipes. This has necessitated the use of cookbook designs, prescribed by codes. These prescriptive specifications encourage oversized systems, stifle innovation, and remove incentives for cost-effective approaches vitally needed in the building industry today.

This paper provides a historical perspective of gravity drainage systems in the U.S.A., discusses present design procedures, describes the hydraulics and pneumatics in some detail, and suggests research needed to achieve significant benefits.

Historical Perspective

The first plumbing drainage system in the United States were developed for use in buildings not over three stories in height, and generally consisted of a 50 mm (2-inch) diameter waste stack for sinks located in public hallways.[1] A similar system of 100 mm (4-inch) diameter collected the wastewater from hopper toilets located in closets with acess from public hallways. The criteria for the adequacy of the performance of these systems were rapid drainage of the wastewater and the absence of odors from sewer gas. These early single-stack drainage systems were prone to failure of the trap seal by siphonage and back pressure. About 1874, secondary ventilation through auxiliary, air pipes was proposed as a means of protecting the water seal in the trap by maintaining atmospheric pressure on both sides of the seal.

The theory was checked empirically and the principle of secondary venting was established. These continuous waste and vent systems, which were often modified on a local basis, led to a complex, non-uniform structure of regulations nationally.

The benefits that had been demonstrated through the development and utilitization of product standards in industrial production, together with the pressures of the housing needs following World War I, encouraged the standardization of building and plumbing regulations. A Building Code Committee was established in 1921 under the auspices of the U.S. Department of Commerce, and laboratory studies were conducted by the National Bureau of Standards under the committee's general supervision. Two significant reports[2,3] were issued, with the final product known as the "Hoover Code," which was widely utilized by state and local regulatory bodies, because it provided the first theoretical and experimental data that could be utilized in semirational design of plumbing drainage and venting systems. The first report contained experimental data on the hydraulic and pneumatic performance characteristics of one- and two-story drain, waste, and vent (DWV) systems, and presented a procedure for estimating peak hydraulic loads for design purposes involving the "fixture-unit" concept and the theory of probability. The 1932 report[3] benefited from further research stimulated by the 1924 report.[2] These activities produced additional scientific information on matters such as gas diffusion in drains, terminal velocities in tall drainage stacks and flow depths in building sewers. The Hoover Code was the forerunner of the widely accepted American Standard National Plumbing Code, ASA A40.8-1955.[4]

Studies [5,6,7,8,9] were made between 1932 and 1941 to provide additional scientific basis for DWV system design, in response to needs defined by the Federal Government agencies concerned with building construction, and by plumbing installation contractors and code administrators. Perhaps the most significant work[5] was that which produced the "Hunter Curve," a method proposed initially for estimating, for design purposes, momentary peak hydraulic loads on water-distributing systems. The method was soon adapted to the prediction of peak loads for sanitary drainage system, and was utilized to develop pipe-sizing tables for drainage and vent piping. This was reflected in design manuals and code recommendations of the late 1940's and the early 1950's, and has been carried over into most of the present model codes.[10]

In response to the increasing need for cost-effective design in building following World War II, renewed attention was turned to investigations of trap self-siphonage, [11] stack venting, [12] wet venting,[13] and capacities of stacks[14] and horizontal drains.[15] These investigations provided a basis for some design improvements and better definition of the performance capabilities and limitations of types of components and systems with which fairly widespread field experience had already been obtained. Some of this work is reflected in the present model codes.

More recently, starting about the mid-sixties, concern has turned to the need for effective evaluation methodology for innovative approaches, e.g. reduced-size venting, single-stack drainage, watersaving fixtures, etc.

The principal thrust of the present paper is the definition of the research needed to accomplish greater generalization and precision in the design of accepted systems, as well as to provide a suitable technical basis for performance evaluation of innovative systems (Figure 1). Some technical shortcomings of the existing methodology are described.

Present Practice

In actual design work, conformance to the loacl plumbing code within the appropriate jurisdiction is required. For a number of years the local codes have been patterned after the National Plumbing Code[4] or one of the other widely referenced and more recent model codes,[10] often with modifications based upon experience factors and special load conditions. The tables of allowable fixture loads on DWV systems and their components are, in most instances, traceable to early research on peak load prediction and on the hydraulics and pneumatics of DWV systems referred to above. These data, with their acknowledged limitations (as indicated below) have been processed conservatively to produce simple loading tables that specify pipe size directly, according to the numbers and types of plumbing fixtures and appliances served. This simple fixture procedure leads to prescriptive engineering methods that limit the value of the professional designer's contribution and many instances result in oversized, uneconomical systems.

The principal shortcomings and limitations of the present design and evaluation methodology can be summarized as follows:

1. Inadequate Data Base

   The data base is incomplete, both with respect to time and spatial distribution of hydraulic loads, and with respect to the hydraulic and pneumatic effects produced by these loads in representative systems. Factors contributing to this situation include the following:

   (a) Traditional instrumentation and data processing methods were not adequate for large masses of essentially dynamic data from complex systems.

   (b) The lack of established scale-modeling techniques and the high cost of full-scale testing in laboratory and field have led to experimentation in simplified laboratory systems not adequately representative of the systems actually installed in modern buildings, and to the use of very large safety factors in applying the data to design.

2. Imperfect Analytical Procedures

In large part because of the situation described in 1 above, the simple analytical procedures and mathematical models derived from the data and used to develop the design tables do not effectively take into account the inherent dynamic processes, some of the key parameters that determine service hydraulic load patterns, nor some of the important design and installation parameters (e.g. configuration, geometry) that affect hydraulic and pneumatic load-carrying capacity. Examples include (1) the relationship between water flow rate, air demand rate, pneumatic pressure fluctuation and trap-seal retention, and (2) the influence on air demand rate of length of stack, stack pressure gradient, air circulation in the piping network, slippage between air and water, and geometry and size of fittings used for connecting the drainage stack and the soil and waste branches.

3. Lack of Standard Hydraulic Test Methods

To some degree because of the situation described in 1 and 2 above, hydraulic test methods used for evaluating component assemblies and full-scale systems have not been standarized.

The lack of improved specific criteria and design procedures taking into account 1, 2, and 3 has not been widely recognized, until recently, as the main cause of overdesign in traditional systems and of difficulty and inordiante delay in determining acceptance of innovative designs.

Discussion of Research and Research Benefits

A major reason for renewed interest in the hydraulics and pneumatics of drainage systems in this country is the widespread acceptance in other countries of several types of single-stack, self-venting drainage systems. These systems are worthy of consideration for use in the United States for their potential for cost savings the simplified configuration of piping could lead to architectural benefits and simplification in modular construction.

A principal concern is the maintenance of a realistic balance between continued essential performance and the costs of construction and operation of the DWV system as modifications to the system are introduced without a methodology for definitive prediction of overall system. To date, success in implementing proposed innovative cost-saving devices, components and systems has varied from reasonably good to very poor. The present increased interest in water supply and drainage is attributable, inpart, to the growth in high-rise buildings with their more complex mechanical systems, to the rising costs of construction, and to the trend toward greater utilization of manufactured components in building construction requiring standardized plumbing systems. Whether the specific emphasis be the development of improved performance evaluation methodology, cost reduction, or simply improved precision in traditional design methodology, the hydraulics and pneumatics of drainage systems must be studied with modern research methods and facilities.

Monihan and Konen have suggested the feasibility of using existing technology, with appropriate modification of the values assigned to the various fixtures and fittings in the Hunter procedure, to achieve a 40-percent reduction in estimated momentary peak water demand rate. Baker, Bailey, and Sierka[16] have suggested a 60-percent reduction in consumption with flow limiters and recycling of gray water. Such reductions in water usage may reduce the transport velocities in horizontal drains below the generally accepted velocities of 0.6 m/s(2 ft/s) minimum in drainage piping and impair the effectiveness of the system. Clearly, the mass media advertisements of chemicals, aerosols, and other means for clearing of blocked drains indicates a problem exists in the continuing maintenance of flow of waste-water in drainage systems. DeYoung and Konen[17] have reported a 25-percent reduction in the velocity of the wastewater in the piping immediately adjacent to the water closet as the result of changing from a customary water closet using 19 liters (5 gallons) per operation (this includes water used to restore the trap seal as well as the excess that may be wasted by overfill of the trap seal) to a water-saving water closet using 11 liters (3 gallons). Cole[18] has reported concern about the use of very low-volume water closets, because they reduce the flow in sewers, and this might cause increased solids deposition and septicity in sewers under some circumstances, e.g. in new building projects during early stages of completion and occupancy. Studies in England[19,20] showed that in multifamily housing the frequency of fixture usage was significantly less than assumed in the development of the Hunter curve, and that peak water demand on the systems was significantly less than the estimates obtained from the traditional British procedure patterned after the Hunter model. Although the British data alone do not constitute significant evidence that the American procedure for determining design loads is deficient, similar American data do suggest strongly that there is a research need to improve the procedure for estimating peak drainage loads under service conditions.

The flow in plumbing drainage systems consists of solides, liquids, and gases. Researchers in the United States and the United Kingdom have generally believed that the "normal solids in "usual" amounts do not significantly influence the important hydraulic parameter, pressure, This has encouraged consideration of the flow as a two-phase system: water and air. Water enters a drainage system through a trap which provides a water seal to prevent sewer gases from entering the habitable area of the building. The wastewater does not generally fill the horizontal branch drains, with the occasional exception of the piping immediately adjacent to the trap and fixture. Main horizontal drainage lines are sized to run half-full at the expected peak flow rate, this safety factor being applied to account for multiple uncertainities in design methodology, service loads and installation detail. The principal driving force is the potential energy resulting from the slope of the drainage piping. Some kinetic energy contribution is made through the existence of "shooting" flow (super-critical velocity, Froude number greater than 1.0) in the immediate reach following the change in direction from vertical to horizontal. This energy is readily dissipated in most branch lines but may result in a troublesome hydraulic jump in the building drain at the base of a tall stack. Laboratory experimentation[15] has shown the occurrence of the jump a considerable distance downstream from the base of the stack (Figure 2). This is contrary to customary thinking that the jump ordinarily occurs within 10 stack diameters of the base of the stack. However, it has been observed in tests[21] with transparent pipe that a washing of the sides of the building drain with the wastewater occurs for a few feet downstream from the stack as a result of swirling, secondary flow generated in the vertical to horizontal bend. These washings can cause momentary blocking of vents taken off the building drain close to the base of the stack, and this contributes to adverse back pressures in the lower portion of some systems. Fittings for such vents rolled up to the customary minimum of 45° would be particularly susceptible to this phenomenon. The customary design rule of avoiding vent connections to the building drain within ten stack diameters of the base of the stack can be justified on the basis of this washing action rather than the hydraulic jump.

The generally accepted theory for the flow of wastewater in drainage stacks[1,8,9,14] depicts two-phase annular flow. The wastewater attaches itself to the walls of the pipe, forming an annulus. The falling water drags air with it inside a center core. The thickness of the annulus at the pipe wall increases with the rate of water discharge to a maximum allowable value corresponding to an area roughly between one-fourth and one-third of the cross-sectional area of the pipe. An increase in thickness beyond this range results in a breakdown of the characteristic annular flow, accompanied by excessive noise, turbulence and pressure fluctuations. The hydraulic capacity of drainage stacks with traditional venting has been defined as that flow rate for which the water occupies 7/24 of the cross-sectional area of the pipe at terminal velocity.

This theory depicts the falling water as acted upon by restraining shear forces occuring at the wall of the pipe (the restraint at the air-water interface is ignored) and indicates that these forces limit the water to a maximum (terminal) velocity ranging from about 3.2 m/s (10 ft/s) to 5.1 m/s (17 ft/s) for (cast-iron) stacks of 75 mm (3 inch) and 150 mm (6 inch) diameter, respectively. The corresponding terminal velocities are computed to develop in approximately 1.7 m (5.6 ft) to 4.4 m (14 ft), respectively, below the point at which water enters the stack. This theory does not take into account possible effects of inclusions in the flow, possible effects of inclusions in the flow, e.g. solids or detergents.

Recent investigations have challenged these concepts and the design criteria derived from them as too restrictive and not taking into account some of the important physical parameters that determine the ability of the systems to service the drainage from the connected load of fixtures, appliances, and other equipment (Figure 3). In any method for the direct computation of DWV system performance, the question of possible dynamic effects should be resolved. While continuous flow experimentation and static considerations have been emphasized in past research, recent evaluations of innovative systems using advanced measurement techniques have shown phenomena (both favorable and unfavorable) apparently due to the dynamic nature of wastewater discharge. Estimates of the critical frequency of the common waste fixture trap seal indicate it to be in the vicinity of the pulsation frequency one would expect in the drainage system of a high-rise building. If this is correct, resonance may contribute to excessive trap-seal depletion under some circumstances. On the other hand, preliminary efforts to correlate vent suction with trapseal reduction have indicated that some trap forms resist suction much better than had formerly been supposed. These considerations suggest a valid case for a study of the dynamic performance characteristics of flow in a range of representative DWV systems, using both analytical and experimental techniques with modern instruments and data acquisition facilities.

Research should take into account the needs for resource conservation and for associated cost reduction that might be realized in many situations by the proper sizing of piping to accommodate representative loads. Estimates of the cost savings from innovative designs such as single-stack or self-venting drainage, and reduced-size venting have been expressed in terms such as "up to 40 percent of the DWV piping cost," "potential savings of the order of $60 per bathroom," and "up to $150 per living unit." Estimates of the annual national reduction in construction costs from an across-the-board 10 percent savings in the cost of water supply and drainage systems, that might be possible from research of loads alone, have approximated $500 million. Perhaps at least 60 percent of this, or $300 million could be realized from improved methodology for DWV systems. It has been estimated that up to $15 million could be saved annually on the cost of thermoplastic pipe and fitting materials alone, merely from the widespread use of reduced-size venting.

Although labor savings are often thought not to be significant for a one-or two-pipe-size reduction, analysis of the National Association of Plumbing, Heating, Cooling Contractors' Labor Calculator[22] shows that installed costs that reflect labor costs are, in fact, appreciably affected by pipe size, even by a one-size reduction in some ranges.

Improved design and evaluation methodology would provide energy savings to the extent that significant reductions in quantities of material required for construction would provide corresponding savings of energy for raw materials, manufacture, transportation and handling. For example, even a one-size reduction in all the DWV thermoplastic pipe and fittings sold in the United States would produce a considerable energy savings in the manufacture of these products and a reduction in the use of petroleum feedstock for this purpose.

While less tangible than the obvious economic benefits suggested above, some additional significant and far-reaching benefits can be anticipated from research. The development of improved design and evaluation methodology which depends on research would contribute to uniformity of codes and to interstate acceptance reciprocity, and would facilitate realistic acceptance of innovative designs with their potential economic and resource-conserving benefits. This would hasten potential benefits in becoming real benefits, and would encourage beneficial innovation.

Improved precision, flexibility, and standardization of design and evaluation methodology would also provide a means to improve the service to clients by manufacturers, designers, and installers. The system or component providing adequate performance at an acceptable cost could be specified and its design, acceptance and installation could be completed more efficiently and effectively.

Needed Research

Research is needed in the following areas:

1. Measurement and Definition of Dynamic Flow Characteristics in Complex Systems.

   The limited studies, that have been made with simple test systems, have addressed isolated parts of this general problem, but these findings need to be brought together in a coordinated fashion and additional work done to complete the program. Some of the studies reported since 1972 in the CIB W62 Symposia provide a start in this direction. Generally accepted methods are needed for defining or predicting the hydraulic and pneumatic profiles of the flow from single fixtures and groups of fixtures distributed by time and space. Then this profile definition should be applied in a study of trap-seal reaction, a time-dependent energy transfer problem. This work would involve the establishment of adequate correlations between water flow rate, air flow rate, pneumatic pressure fluctuations, blow-back,cross-flow and water rise. System configurations, fitting geometry and representative additives to waste water (e.g. suds and solids) should be taken into account in this type of experimentation.

2. Carrying Capacities of Horizontal Drains.

   Closely related to 1. above, which is largely associated with phenomena in a vertical system, a need exists for better definition of carrying capacity of both simple and compound horizontal drains. Standing waves combined with hydraulic jumps may initiate undesirable oscillations within idle traps and may significantly alter hydraulic capacities of primary and secondary building drain branches from the values calculated from classical continuous-flow formulas. These studies would be concerned essentially with wave phenomena associated with the imposition of representative, transient loads.

3. Analytical Approaches in Predicting Performance.

Mathematical procedures or simulation techniques should be developed that will predict system performance as a function of input load. Possibly, the validity of the continuous-flow approach recommended by Lillywhite[23] and Wise[24] for research purposes will be confirmed by the suggested dynamic studies, but this will be dependent on the correlations to be defined and on the extention of the analytical relationships so as to be applicable to a range of designs that might be encountered in practice. Again, some of the work reported in the CIB W62 Symposia may provide needed guidance.

4. Scale Modeling Techniques.

For the purposes of predicting performance of designs not amenable to successful analytical treatment as in 3. above, scale modeling techniques need to be developed. Early attempts in this field were encouraging,[25] but later were abandoned in favor of full-scale testing. With the present high and rising cost of testing, it is prudent to reconsider the potential of scale-modeling in this field.

5. Standardization of Full-Scale System Performance Test Methods.

Until suitable scale-modeling techniques are developed and general computational capability is further advanced, a need will remain for full-scale system hydraulic performance tests (for evaluating innovative systems) that are reproducible and that can be economically carried out in the field. A number of different procedures have been tried for this purpose, but standardization has not been completed nor have all the technical uncertainties been resolved.

6. Definition and Modeling of Service Hydraulic Loads.

Hunter's model for momentary peak demand flow rates in large water service and distribution systems has been utilized also for the estimating of peak momentary discharge rates and for the sizing of piping in both small and large drain-waste-vent systems (Figure 4), for the sizing of water heaters, etc.

Some of these applications have required unwarranted extrapolations and probably unrealistic assumptions. Hunter had cautioned against unwarranted applications of the model and had pointed out some of its limitations.

The proper sizing of DWV system components depends on much-improved knowledge of service loads. This need is believed to be greater than any other single need indicated by 1-5 above. In fact, the full benefits of hydraulics research cannot be realized in practice until design loads definition is updated and expanded. This work should be a part of the research on better definition of design load for water service and distribution systems described in another paper in this symposium, to avoid duplication of effort. The needed load data for drainage and water supply systems are rather similar.

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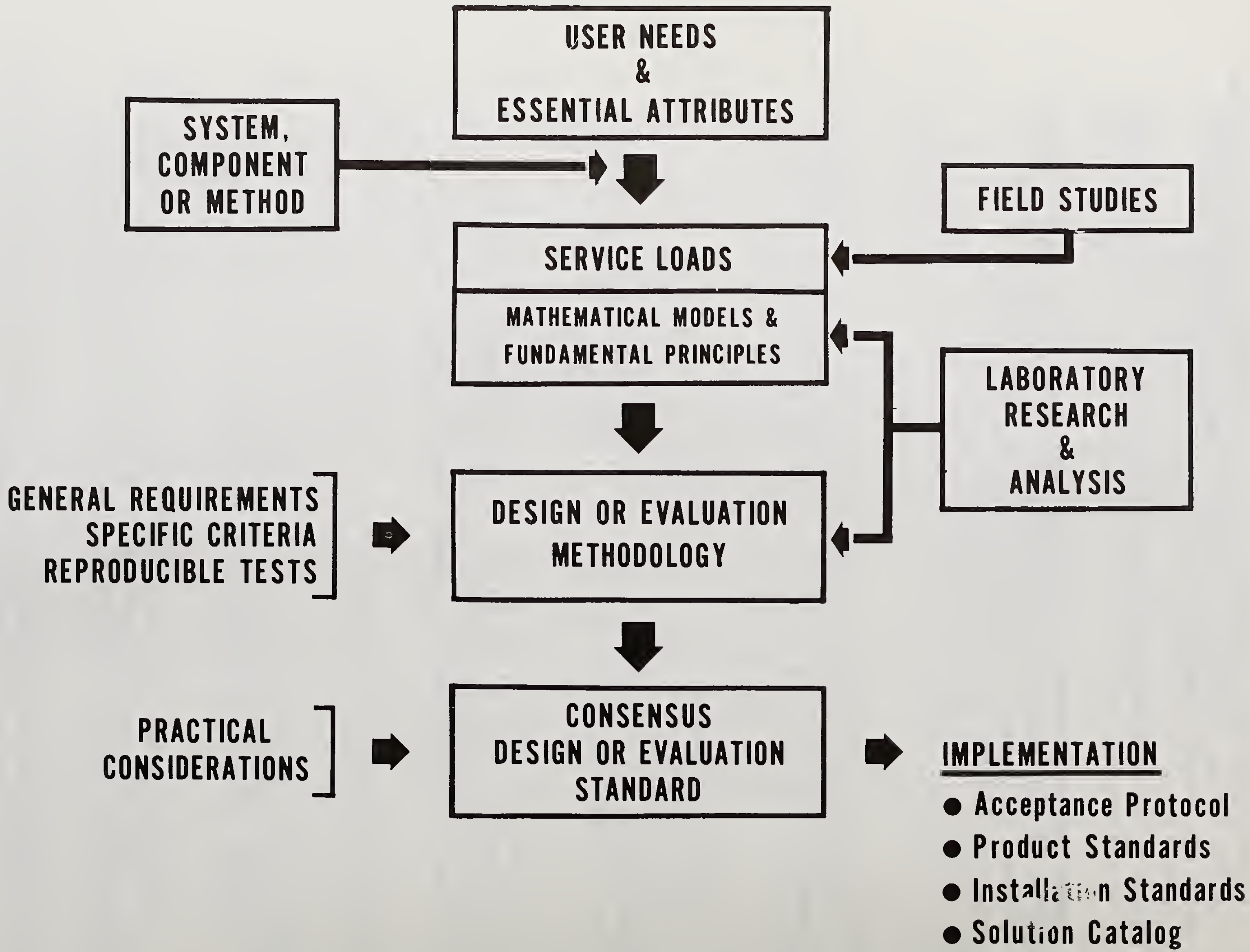

FIGURE 1. MODEL FOR DESIGN OR EVALUATION

FIGURE 2. HYDRAULIC JUMP WITH TRANSIENT FLOW IN EXPERIMENTAL BUILDING DRAIN, OCCURRING FAR FROM BASE OF STACK

- LACK OF DEFINITIVE CORRELATIONS FOR
  - TRAP-SEAL REACTION/AIR FLOW RATE /VENT PRESSURE FLUCTUATION
  - VELOCITY OF AIR FLOW/VELOCITY OF WATER FLOW IN STACKS (i.e. AIR/WATER SLIPPAGE)
- ABSENCE OF MODELS FOR
  - AIR CIRCULATION IN DWV NETWORKS
  - HYDRAULIC LOAD PROFILE EFFECT
  - SYSTEM CONFIGURATION AND HEIGHT EFFECTS
- INADEQUATE MODELS FOR
  - TRANSIENT FLOW CAPACITY OF HORIZONTAL DRAINS
  - SCALE EFFECT IN TESTING

FIGURE 3. DEFICIENCIES IN THE TRADITIONAL HYDRAULIC AND PNEUMATIC MODELS FOR DWV SYSTEMS

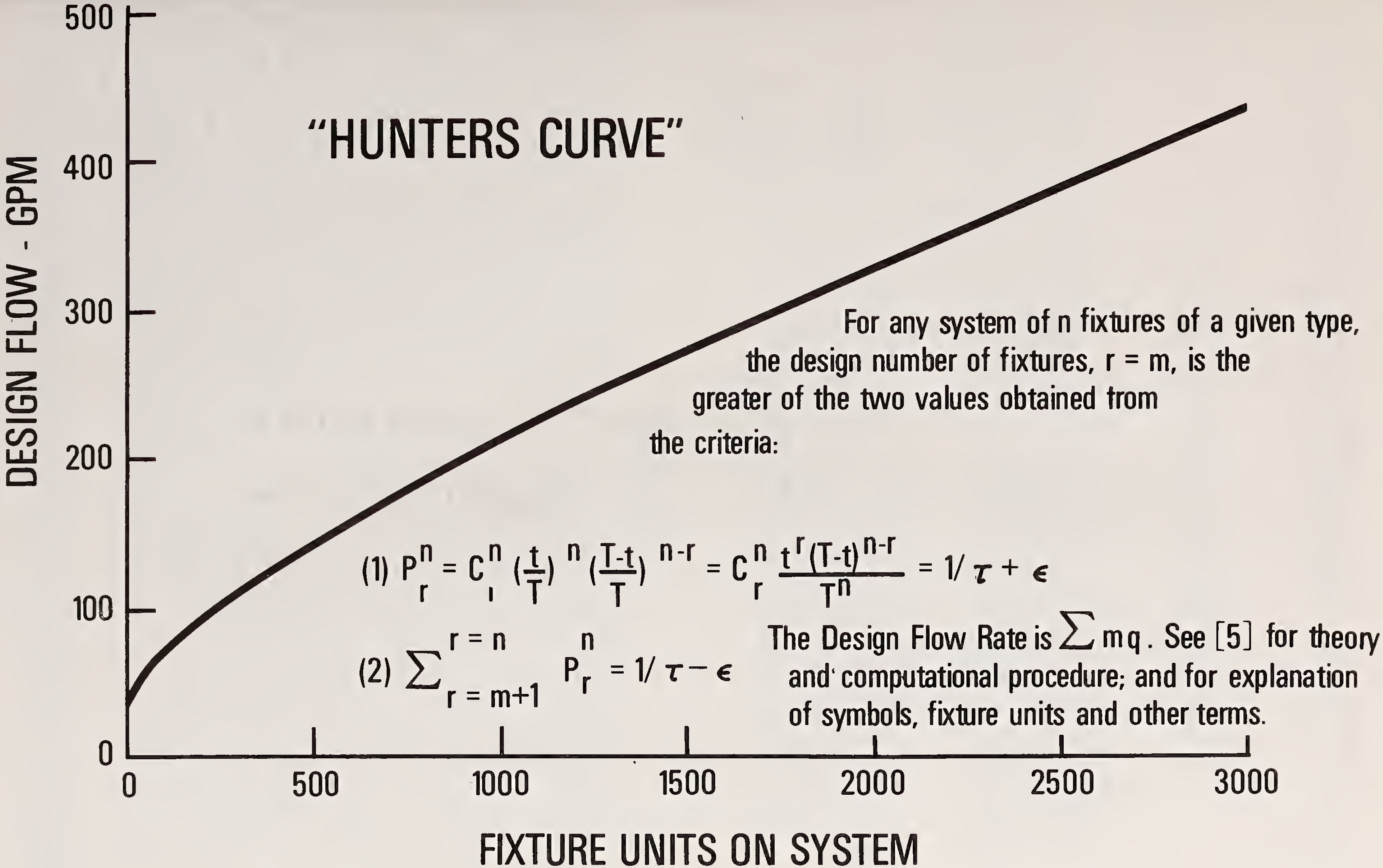

FIGURE 4. BASIC ELEMENTS OF THE HUNTER LOAD MODEL FOR DRAINAGE

PERFORMANCE CONCEPTS FOR WATER SUPPLY AND DRAINAGE SYSTEMS IN BUILDINGS

by

L. S. Galowin, W. J. Downing
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The performance concept is described in relation to water supply and drainage for buildings, its present status examined and the needs for research and implementation aids explored. Difficulties in determining acceptance of innovations under traditional plumbing codes and product standards are discussed, and the advantages offered by performance evaluation methodology are pointed out.

The paper describes some of the research needs and other impediments to early development and widespread implementation of viable performance evaluation methodology, and suggests means of overcome impediments. A current activity is described that is intended to develop a consensus performance standard for plumbing systems as a complement to the traditional prescriptive code.

INTRODUCTION

Difficulties have been encountered in the acceptance of innovative, performance-oriented to problems in water supply and drainage under the provisions of comtemporary American plumbing codes. These difficulties are due largely to the characteristic prescriptive nature of the existing codes and of the standards referenced by these codes, and to the absence of adequate methodologies for predicting or testing the essential performance, i.e., methodologies for determining the satisfaction of the requirements for health, safety and essential sanitary and physiological functions as deemed necessary to fulfill user needs and public welfare. The reliance upon traditional codes which specify allowable configurations and designs, pipe sizes and materials inhibits implementation of innovative solutions for water supply and drainage systems and for water conservation practices, and limits materials resource conservation and energy conservation opportunities. The consequences are overdesign of traditional systems and delay or difficulty in gaining acceptance of innovative approaches. The interest in the performance approach results from a recognition of the opportunities that it can provide for fulfilling the essential needs for building services in terms of user requirements through unencumbered engineering design to suit the particular circumstances.

In order to facilitate the development and utilization of performance standards, adequate performance evaluation methodology must be provided as a substitute for the slower service history evaluation approach of the prescriptive codes. The prescriptive specifications for materials, products and systems with which considerable service experience has been gained have usually served their purpose well. But with the development or proposal of new materials, components and systems, and of new uses for existing materials it is essential that performance evaluation techniques be developed which are applicable as systematic and organized procedures for predicting service performance.

Traditionally, specification writers attempted to identify and specify the materials and products that were known from service trials to provide satisfactory performance under normal usage conditions over a period of time. The concept of the performance approach, however, is based upon short-term measurements that signify the degree to which user requirements are fulfilled without imposing limitations on any particular combination of physical and chemical properties, on the design or on the method of manufacture or construction. For further background on the performance concept the reader is referred to bibliographies included in recent papers [1, 2].[1/]

It is necessary to distinguish between systems and materials in discussing the performance concept. System performance relates to the functional and safety adequacy; materials performance relates mainly to the durability aspect of sustaining the essential functions and safety of the system in which the materials are utilized. The problem of performance evaluation for a component made from an innovative material poses considerable difficulty because of uncertainty in the ability to simulate the effects of the service environment in tests for durability. (See Figure 1). This problem is also the predominant one in the traditional specification-type approach where the difficulty is the long period of service history required to permit a meaningful evaluation. Under either approach, findings may fall somewhere between the "clearly satisfactory" and "clearly intolerable" categories. In this area, the acceptance decision may require additional data and/or informed judgment based on a consideration of functional adequacy and realistic performance levels for the satisfaction of user requirements.

Considering the example of an innovative piping material, a number of the properties of materials may be involved in the development of performance evaluation methodology. In this approach, the particular requirements to be emphasized and the measures of performance that are critical will depend on conditions of the service application and on the physical and chemical properties of the material that determine the relevant performance characteristics. For example, fire spread might be a significant measure for an assembly of materials that are subject to burning or pyrolysis such as wood or thermoplastics, but probably not for an assembly of materials generally considered non-combustible such as masonry,

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1/ Numbers in brackets refer to the list of references at the end of this paper.

steel or cast iron. On the other hand, some of the important measures for metals, e.g., electrolytic corrosion, may be of little or no consequence for a non-metal.

The issues of current interest considered here are related primarily to problems in the development and implementation of performance standards for water supply and drainage for buildings. The key technical needs related to the identification of significant criteria to characterize the essential performance, and to the establishment of the methodologies and techniques for measurement on the basis of these criteria. Research and other actions should be directed to the resolution of technical problems associated with prediction of future service performance, and with the development of protocols for acceptance. The solution of these problems requires better definition of relevant physical and chemical processes and environments, and of the effects of installation detail on performance.

PRESENT STATUS OF PERFORMANCE EVALUATION METHODOLOGY

A. Existing, Stated or Implied Performance Statements

The present status of performance evaluation methodology in the USA is deficient. A few well developed elements of performance evaluation methods already exist as statements in codes or generally recognized standards. Other elements are implied in existing documents, but not actually stated in performance language. Still other elements have not been effectively defined or developed, and it is in these areas that the most important research needs can be identified.

In reviewing existing standards or other technical documents, one occasionally finds a complete or nearly complete performance statement, presented in a format approximately as follows:

Requirement (qualitative)
Criterion (quantitative)
Test (a definitive and reproducible measurement technique)
Commentary (rationale or explanation) -- optional

The familiar leak test requirements of the plumbing codes are usually presented in this format, approximately. But, unfortunately, not all statements in the present generally accepted standards and codes are complete or follow this logical arranagement.

Nevertheless, a number of existing implied performance statements can be identified and sometimes these can be restated in performance terms, wholly or in part. For example, a restatement can be made of the apparent performance intent of some of the familiar specifications in American plumbing codes relating to sanitary drain-waste-vent systems. The significant performance measures (criteria) may be expressed as follows, based on findings in recent research studies [3, 4]:

1. Adequate trap-seal retention with suction ($\geq$ 50%)

2. No emissions with back pressure (back pressure $\leq$ 38 mm WG[2/]

3. Minimum water rise or flow interference from hydrodynamic or hydrostatic effects (water rise $\leq$ 1.0 D; interfixture discharge retardation $\leq$ 10%)

While these criteria seem to be implied in qualitative terms by the codes, systematic definition and quantification is largely lacking. For standardization of the suggested performance statements, a consensus on quantification and test procedures is required.

The main problem with implied performance statements is that standard test procedures or other suitable evaluation techniques do not now exist in a number of instances. It appears, however, from a review of various recent documents describing test procedures for sanitary drainage system hydraulic performance evaluation, that early standardization of some of the procedures may be possible. Similarly, standard tests may be possible in other areas in the near future, such as tests for measuring the hydraulic and waste removal performance characteristics of plumbing fixtures and appliances.

B. Some Technical Impediments to Performance Evaluation

The principal technical impediments to a viable performance evaluation approach in the field of water supply and drainage in buildings can be categorized as follows:

1. Incomplete definition of the physical and chemical processes involved in the representative operation of the various components and systems that might be utilized in innovative approaches.

2. Inadequate information on the service environment, particularly with respect to load patterns involving:

   (a) hydraulic and pneumatic demands
   (b) forces, both transient and continuous
   (c) temperatures of fluids transported
   (d) chemical composition of fluids transported

3. Poor correlation between short-term test results and long-term performance in service.

For example, the mathematical models for gravity drainage systems

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2/ WG-water gage. A measure of pressure, with reference to atmospheric pressure, expressed in terms of equivalent height of water column.

are inadequately defined for the purposes of performance evaluation. Knowledge of the laws of air circulation, air-water "slippage", and air demand is incomplete and partly for this reason large "safety" factors are used in the design of traditional systems [5].

The inadequacy of existing information on the service environment is exemplified by recent reports on the deficiencies of the Hunter model for design hydraulic loads; yet the Hunter model remains the principal basis of the generally accepted U.S. practice. There is general, world-wide acknowledgement of the need for a comprehensive program to update or replace this mode [5, 6].

The problem of correlation between performance in short-term tests and that in the service environment has been exemplified by the difficulties and long period involved in establishing acceptance of thermoplastics piping in appropriate applications in the U.S.A. Significant elements of the problem have related to insufficient definition of temperature and chemical composition of fluids transported in service, and of the poor correlation between accelerated test results and long-term service performance [7].

C. ANSI A40 Performance Standard Program

It was against this background that initiation of the development of a complementary performance standard was recently authorized by the Sponsors and the Standards Committee of the A40 project Minimum Requirements for Plumbing, under the procedures of the American National Standards Institute (ANSI). The performance standard is expected to be complementary to the updated specification-type model code that is being developed, not in competition with it. In fact, the expectation is that a performance standard would be a useful aid in the administration of specification-type codes by establishing a methodology for acceptance of innovations, an area in which traditional codes are deficient. Conceivably, as familiarity and experience are gained in the concept and use of the performance standard, the specification-type code would gradually adopt more and more of the performance language and format.

The initial activity has been to begin the development of a consensus on the specific steps to be taken, on the sequence in which they are to be taken on the identification of feasible means for carrying the work to a suitable conclusion. This has been described in some detail in reference [1]. Once format, terminology and basic philosophy are agreed upon, the first major task is to index existing codes and standards for actual or implied performance statements in the agreed-upon format. It is expected this exercise will be quite informative in identifying several technical and administrative impediments to a current limited application of the performance approach, but at the same time will identify those areas in which early success is possible.

RESEARCH NEEDS AND ACTION REQUIREMENTS

A. General Needs

References [5, 6, 8, 9, 10] provide some detailed definition of a number of specific research needs in hydraulics and pneumatics of plumbing systems, alternative methods of waste disposal, water quality, water conservation and other technical areas. It is not the primary purpose of this paper to dwell on these details, but rather to suggest meaningful actions needed to facilitate broad implementation of performance evaluation methodology in the technical areas addressed by the referenced papers.

The performance approach can be beneficial because it enables us to think in a rational and systematic way about the entire building process, from the fabrication through the installation in buildings. However, it appears that the performance approach is going to be in a continuous state of development for some time because of the need for new information. There exists, then, the requirement for a deliberate and uniform process of development relying upon existing technical data and sound professional judgment for some time, but with the transition to improved quantitative evaluation methodologies as our knowledge expands. The gaps of technology require sufficient basic knowledge of the relevant physical and chemical phenomena, supplemented by analytical modeling methods or testing methods to provide definitive and meaningful bases for reproducible evaluative techniques. The simplest method of performance evaluation could comprise a mere visual inspection, possibly supplemented by the use of a ruler or a level. A higher-order method might take the form of a full scale test of a component or of the complete system, requiring the use of instruments suitable for measuring changing discharge rates, pressures, etc. The most sophisticated method is the utilization of a valid mathematical model that permits the computation of the performance, given the input values that represent the service conditions and the relevant properties or technical characteristics of the innovative system, component or material.

The broad topics of technical research and other activity which are identifiable can be categorized as follows:

1. Cataloging and analysis of the requirements of a variety of users, in a suitable performance format.

2. The identification of the essential measures (criteria) for performance and the establishment of realistic levels of performance of the installed system that will satisfy the users' essential requirements. These measures and performance levels must relate the functions and properties of the system and its components to the essential characteristics of the services delivered to the user.

3. The development of reproducible, reliabe test procedures, model laws and mathematical models involving the key

measures in (2) and including guidelines for interpretation of results to determine conformance with the requirements in (1).

4. The establishment of a consensus performance standard derived in accordance with the above steps and its acceptance by appropriate regulatory bodies. However, this should be supplemented by steps (5) - (8) for the desired impact.

5. The development of protocols for submission of supporting data to approval authorities and for its processing to determine acceptance.

6. The establishment of viable, accredited testing laboratories to fulfill the need for conducting tests called for in the performance standard.

7. The provision of inspection procedures and installation standards suitable for innovations.

8. The establishment of training and education programs to facilitate performance specifications interpretation and for examination of designs and installations represented as in accord with performance specification.

These general needs may be seen in perspective by considering Figure 2, which is a conceptual model for the evaluation of innovations.

B. Users and User Needs

The definition and satisfaction of user needs can be addressed in terms of qualitative requirements and quantitative measures that characterize the functions of water supply and drainage systems in terms of user awareness. It is necessary to establish the definition of the users in the framework of the building construction process through delivery to the ultimate occupant.

Perhaps the first user (of standards and evaluation methodology) in this chain is the plumbing or mechanical systems designer, who endeavors to specify safe, economic solutions whithin the multiple constraints established by the financier, by the regulatory authority, and sometimes by other members of the building team such as general contractor, architects and structural engineers. Barriers to optimum engineering design and cost effectiveness often occur at one or more of these links. A barrier frequently cited is the code or other regulatory document; yet the regulatory body is another important user, because public health, safety and occupant welfare are dependent on adequate standards and acceptance procedures administrated by the regulatory authority. Another important user is the installing contractor, who must preserve the essential attributes of the design to maintain adequacy of performance after installation. Standards must take into account the needs of the installer, particularly since installation can have very significant effects on costs and continuity of functional adequacy of the system.

Finally, the occupant, the ultimate consumer is the user of the final product, the building with its water supply and drainage services. This user is at the end of the chain, and has somewhat different needs from the previous users. His key needs are health/safety, functional adequacy sufficient to satisfy daily requirements for drinking water, culinary activities, bathing, cleaning, and removal of body wastes in a safe, sanitary and aesthetically acceptable manner. Other important needs of this user are cost effectiveness and durability (continuity of essential safety and functional capability). Thus, the performance standard must address parameters that can assure, with optimum cost and convenience, the satisfaction of this user's needs for adequate performance over a realistic time period such as the mortgage period or the period until planned retrofit or obsolescence occurs.

Research is needed to better define user requirements and user response to changes in the characteristics of familiar services. Data should be obtained, analyzed and indexed according to category of user and type of requirement. The analysis should endeavor to identify those user requirements that might be subject to quantification and measurement in terms of safety, function of some other attribute. The "measures" (criteria) involved in such quantification provide the cornerstones of definitive performance evaluation methods.

C. Measures of Performance and Performance Levels

If the users are first identified and their qualitative needs defined, as suggested in (B), then it becomes necessary to determine the parameters that can be utilized as quantitative measures (criteria) in procedures to measure the extent to which the qualitative user needs are satisfied.

In anticipation of the advent of new materials, new applications of traditional materials, hydraulic systems for innovative types of service and innovative hydraulic designs for traditional services, many questions arise concerning performance capability in terms of health/safety, functional adequacy and durability.

Examples include:

1. Corrosion resistance and leaching as related to the selection of new materials for potable water conforming to current regulations.

2. Backflow resistance of hydraulic systems comprising some components transporting potable and others nonpotable water.

3. Fouling and clogging resistance of hydraulic systems transporting water or other fluids having a high concentration of solid matter and a low rate of discharge.

4. Acoustic acceptability, pressure-shock resistance and erosion resistance of hydraulic systems utilizing innovative materials and designed for high velocity, intermittent flow.

5. Surface fouling, odor and sewer gas emission resistance, flushing effectiveness and water-use efficiency of water-saving fixtures and appliances.

6. Dimensional and strength stability of piping materials for solar heating systems utilizing different fluids.

7. Resistance to sewer emissions of drainage systems that violate the venting specifications of traditional codes of practice.

It is evident that these questions indicate the need for research to better define the physical or chemical parameters that can be used as reliable and meaningful measures of the adequacy of performance, as well as to determine the minimum levels of performance that should be provided by a performance standard.

D. Test Methods and Evaluation Techniques

Reasonably accurate and reproducible test methods or other systematic evaluation techniques are essential to the implementation of the performance approach. These procedures must be designed to employ definitive measures (criteria) as indicated in (C).

Perhaps the greatest need is for methodology suitable for predicting performance in service over a period of time.

Overdesign practices and prohibitions against innovative approaches tend to continue without suitable performance test methods that address user requirements and employ appropriate performance measures. Performance limits must be set, either in the performance standard or in the acceptance protocol.

In the utilization of performance test procedures, it will be helpful to include commentary or guidelines to aid in the interpretation and reporting of test results.

Certainly there is a need for considerable research in developing the systematic, reproducible evaluation methods that are needed. Recent experience gained in several exploratory performance studies has supported this view [3, 4, 11, 12, 13].

E. Consensus Performance Standard

The establishment of a consensus performance standard that includes the relevant performance statements is necessary for relating the provision of the services and the utility of such services to provide the attributes required by the user.

The performance statements must provide definitive guidance for evaluation of unqiue methods and materials, emphasizing systematic methodologies for determining satisfaction of an evaluation protocol for a generic class.

It is anticipated that the performance "standard" would actually comprise a number of parts, e.g., water supply and distribution, sanitary drainage, storm drainage, etc.; somewhat as is now the fashion in the prescriptive codes. Coordination in format, terminology and basic concept for the different parts would be essential, and should be so planned at the outset. The evaluation methods required to support the performance standard might be incorporated by reference if they themselves were promulgated by a recognized standards organization. Until this occurs, the evaluation methods should be included in the performance standard.

F. Implementation Aids

In order to achieve widespread implementation of a performance standard, approval protocols must be established. This requires the establishment of procedures and formats for submitting supporting data and interpreting test results to the end that a definitive acceptance decision can be obtained. For this purpose the important attributes and requirements must be clearly defined and related specifically to quantification by measurement through easily understood test methods. Guidelines are required to assist innovators in submitting the appropriate data in a suitable format.

Among the more important implementation aids are the following:

1. Laboratory Accreditation Program

There is a need for accreditation of testing laboratories to provide for the use of uniform methods of evaluation and for uniform capability for generating reliable, reproducible test results.

Testing laboratory accreditation fills a gap which is compatible with the American system of building code administration. In Europe acceptance protocols and certification testing are widely provided under centralized governmental direction. By contrast, in the U.S.A. this authority is vested in the fifty states or in the much larger number of smaller political divisions. This has contributed to delay in the development of a generally accepted laboratory accreditation program as well as to dealy in achieving uniformity among the various plumbing codes.

In order to fulfill the requirements for establishing test credibility for materials, elements and systems for water supply and drainage, a testing laboratory accreditation program on a national scale is required, but should not be unduly influenced by the national government. Advances in the utilization of the performance approach may be expected to increase through a comprehensive, generally accepted laboratory accreditation procedure. Possibly this need could be satisfied through the National Voluntary Laboratory Accreditation Program which was initiated by the promulgation of procedures published in the Federal Register on February 25, 1976, as part of part 7 of Title 15 in Commerce and Foreign Trade. There, it was stated that the goal of the program is to provide in cooperation with the private sector a national voluntary system. It has the stated purpose to examine upon request the professional and technical competence of private and public testing laboratories that serve regulatory and nonregulatory product and certification needs. The program also is intended to accredit those laboratories that meet the qualifications which will be established under these procedures. It is required that the participating laboratories that are accredited maintain their qualification status through suitable checks and examinations.

It is readily recognized that there is a close link established between the research necessary to formulate the required test methods and acceptance protocols and the determination of the adequacy of resources and expertise for suitable testing services. The detailed criteria for accreditation of laboratories in this field remains to be established. Not only are the technical expertise of staff and the quality of equipment important items, but also important are the methods for obtaining data, recording and keeping of records, as well as the ability to report results in a meaningful and useful manner.

The intent of the program is to serve in a timely manner the needs of industry, consumers, and the Government. The orientation of the program is such as to assure that accredited testing laboratories can render services of evaluation regarding a product or system to ascertain whether the requirements of applicable standards are satisfied. Requests to the Secretary of Commerce to determine if there is a need to accredit testing laboratories are required to include the text of an applicable standard and the text of a test method if not included in the standard. In setting forth the basis of a preliminary finding of need for accredited testing laboratories, consideration must be given to: the benefit to the public interest; whether it is necessary to extend beyond existing laboratory accreditation programs in the public or private sector; whether there is in existence a standard deemed as being of importance to commerce, consumer well being, or the public health and safety; whether there exists a valid testing methodology for ascertaining conformity to the standard for the specific product involved. At the present time, the vehicle for administering the laboratory accreditation program has not been effectively defined.

2. Plans Examination and Inspection of Installations

In demonstrating performance acceptability through function satisfaction in accordance with a standard and its test methodology, it is necessary to account for the possibility of degradation of the anticipated quality of performance as a consequence of the normal installation/construction process. Techniques must be developed and translated into practical application in the field which provide acceptance inspection procedures and installation standards for the purposes of the approval authorities. Inspection and field testing procedures are needed to detect and limit the occurrence and consequences of imperfect practices in the field. To implement the performance standard, there is a need for training and education of examiners who may review designs and inspect installations (in the factory or in the field). These tasks can be more difficult under a performance standard since more sophisticated expertise and interpretative capability may be required to establish compliance. The departure from reliance upon "cookbook" prescriptive specifications greatly modifies the procedures for plans review and installation inspection. Greater freedom to develop more truly engineered solutions becomes possible, but uniformity of acceptance requires trained, specialized staff to interpret and understand.

Reliance upon gradually obtained experience, on-the-job training, and formal engineering education appears to provide the current hope for growth toward acceptance of the performance approach in plans review and installation inspection. Continuing efforts will be required to promote professional educational orientation toward performance evaluation for water supply drainage systems. Also, installation standards should be initiated by the proponents of innovations working with the appropriate consensus standard body and regulatory authorities concerned with the performance standard. Conformance with these installation standards probably should be a part of the approval protocol.

3. Illustrated Manual of Acceptable Methods and Temporary Approvals

A useful guideline document would be a cumulative manual showing solutions that have been found acceptable under a performance standard. For situations where the evaluative art is not at hand for rigorous determination of conformance, a resource base (such as a technical council of a duly constitued evaluation group) with a laboratory arm established by the sponsors of a performance document under the auspices of a nationally recognized standards body, should be available to determine a consensus on the technological problems and to provide important guidance in the needed test development and data interpretation service. Such a Council might find it purposeful to administer a temporary approvals program for generally promising innovations for which generally recognized standards do not exist. In some ways, this might serve the function in the U.S. that the Agreement approvals system serves in Europe.

The Agreement System, used in several of the Western European countries, comprises explicit administrative and technical procedures for the evaluation of innovations, pending the development of generally recognized standards. Agreement certificates are valid for a stated period only, but often they provide a basis for interim acceptance by the regulatory authorities. This system has been described further by Trinkler [14].

Summary of Key Points

In the foregoing discussion of the performance approach, we have used the terminology: attribute, requirement, criterion and method of evaluation. These together with a commentary (optional), comprise a "performance statement." The universal attributes of function, health/safety and durability (continuity of essential functional capability and health/safety attributes) have been suggested. The term "requirement" is adopted to signify a meaningful, qualitative indicator of conscious user need related to the relevant universal attribute. The "criterion" is a quantitative measure that can be used as the basis of a "method of evaluation" (a test) to determine the extent to which the requirement has been satisfied. (See Figure 3.)

Since performance evaluation methodology does not address specific details of hardware nor is it concerned with just which particular engineering solution is employed, capability must be provided to predict or test for adequacy of any proposed solution through measurement. To satisfy such needs a systematic and reproducible methodology must be provided. That methodology may be either of a basic computational type, or of an empirical type utilizing a definitive reproducible test or sytematic inspection procedure. Due to the difficulties and high costs of field verification tests or demonstrations, suitable laboratory tests and computational procedures are needed. This need dictates efforts to develop suitable procedures for scale model testing and component assembly testing with non dimensional applicability to full-size systems. The utlimate evaluation technique is a mathematical model that predicts specific performance levels in terms of agreed upon physical or chemical criteria, provided the appropriate inputs are furnished with respect to representative loads, specific dimensions and configuration, and relevant properties of the materials. (See Figure 4.) This approach also leads to a recognition of the need to incorporate the principles of economic modeling and lifecycle concepts.

It is possible through a viable performance approach to reduce overdesign which has characterized prescriptive solutions. This is because the essential performance would be measured according to relevant criteria instead of inferred from a specification of the properties of particular solutions already found satisfactory (often actually much better than satisfactory) from a lengthy period of service experience. The prescriptive approach tends to produce over-design in traditional solutions and offers little help in attempting to evaluate innovative methods and materials in a reasonable time frame.

The performance approach requires a systematic methodology for evaluation especially applicable to innovative methods and materials, but yielding results compatible with service history when applied to traditional solutions. This requires the development of reproducible, reliable test procedures for measurement with guidelines for interpretation of test results to determine conformance. The formulation of standard test procedures accompanied by accepted interpretative techniques is essential to a viable, consensus performance standard. To be effective the research results must be supplemented by the development of an acceptance protocol through which regulatory bodies will recognize the basic evaluation methods derived from the research. This protocol would require also a means for accreditation of testing laboratories recognized for capability to conduct tests and evaluate the test results in accordance with a performance standard. (See Figure 4.)

CONCLUSIONS

A. Principal Technical Research and Standards Development Needs

From the foregoing it is concluded that many of the key technical needs can be satisfied by organized, aggressive research with a performance orientation. These needs can be categorized under the following headings.

1. Definition of user needs (requirements) and suitable measures (criteria) for determining the extent to which the requirements are satisfied.

2. Development of evaluative techniques through which systematic, reproducible quantitative determinations of adequacy of performance can be made using the criteria defined in (1). This will require new knowledge of the fundamental physical and chemical processes that determine adequacy of performance, better information on the service environment, the development of mathematical models, and the formulation and standardization of test methods with a performance orientation.

B. The Need for Acceptance Protocols and Laboratory Accreditation

A consensus of the building community and regulatory systems must be developed defining the elements of acceptance protocols, if the results of research are to be utilized optimally in the furtherance of the performance approach. A uniform approval methodology needs to be defined in some detail, and acceptable vehicles for promulgation of consensus performance standards need to be identified. Suitable mechanisms for laboratory accreditation and certification of new methods and materials must be defined that will be compatible with the objectives of performance evaluation.

C. Educational and Training Needs

Because of the new concepts, new terminology and special complexities of the performance approach for water supply and drainage, there is a significant need for education and special training, not only for potential users of performance evaluation methodology but also for the specialists who may participate in its development.

D. Recommendations on Activity Priorities and Establishment of Program

1. An important first step in the educational area has already been undertaken--i.e., authorization for initiating the drafting of an ANSI A40 performance standard for plumbing. This type of activity needs to be broadened to emcompass a greater range of building services so that familiarity with the performance approach can be obtained by workers in a different areas of expertise related to the design, standardization and regulation of building services.

2. A most important, second step is the consensus definition of research needs that can be obtained from the results of the pilot activity in (1). Encouraging developments in definition of various types of research needs are already occurring in the CIB W62 Commission program, particularly as reflected in the present symposium, and these data should be reviewed from the standpoint of performance evaluation needs. Because to date a considerable emphasis on empirical and prescriptive design criteria has characterized the research, it is anticipated that the suggested exercise will define special technical research needs for performance evaluation.

3. The third step requiring concentrated activity is the establishment of a consensus on the means for implementation of potentially valuable research findings. Planning for this program should be started before the work defined in step (2) is widely initiated. Suitable approaches relating to needs such as laboratory accreditation, regulatory acceptance protocol, accreditation of plans examiners and inspectors, installation standards and format for submittal of innovative proposals should be resolved. Only through successful implementation can the benefits of research be realized.

4. Following a reasonable consensus and the formulation of concrete recommendations from the studies indicated in (1) through (3) above, these recommendations should then be brought to the attention of potential funding agencies, regulatory agencies, the design and installation disciplines, and the manufacturers as an aid in the simulation and evaluation of proposals for specific, needed research.

E. Impact

A planned coordinated program along the general lines indicated above could provide the needed supplmentary and complementary methodology for viable performance evaluation of water supply and drainage for buildings. This could have important impact on cost reduction, on the conservation of resources and on stimulation of productive capacity through innovative methods and material. It could also provide benefits to the administrators of prescriptive codes in facilitating acceptance decisions in a uniform and organized fashion.

The present standard program within the ANSI A40 Project[3/] offers a significant opportunity to begin the systematic development and implementation of the performance approach in plumbing. The A40 Committee and its sponsors deserve widespread support in their program to emphasize this activity during the next several years.

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ALTERNATE CONCEPTS FOR TRANSPORTING AND

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by

T. P. Konen, R. S. Bevans, W.J. Boegly
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Twelve years after the first sanitary sewer system was constructed in 1844 in Hamburg, Germany, the United States began building public sewage facilities. In the early days, efforts were limited to the collection system; 100 years ago, only an occasional sewage treatment plant was built. Today 163 million people, 76 percent of our population, are served by sewers. Ninety-seven percent of these citizens are served by some type of treatment facility. It has been estimated that the gross investment in public sewage facilities during the period 1856-1971 has been $58.4 billion. The result of this seemingly huge effort has been a disappointment. The construction of treatment plants has just about offset the increase in BOD load resulting from the increases in sewered population. The BOD discharged to our waterways by treatment plants today is just slightly less than that discharged in 1957. See Table 1.

TABLE 1

EFFECT OF SANITARY SEWAGE TREATMENT[1]

Year	Collected by Sanitary Sewers	Reduced by Treatment	Discharged by Treatment Plants
	(millions of pounds of BOD per day)		
1957	16.4	7.7	8.7
1962	19.8	10.8	9.0
1968	23.3	15.0	8.3
1973	27.1	18.5	8.6

Of greater concern are the results of the 1973 Needs Survey prepared by the Environmental Protection Agency, wherein the estimated costs for constructing needed public sewage facilities for communities to meet the requirements set forth in the Federal Water Pollution Contract Act Amendments of 1972 are $60.1 billion, an amount equal to the total current investment. These costs were reported for five categories, as shown in Table 2.

TABLE 2

PROJECTED COSTS TO MEET REQUIREMENTS OF 1974 FWPCA[2]

(billions of dollars)

Category I	Secondary Treatment Facilities	$16.6
Category II	Treatment More Stringent than Secondary	5.6
Category III	Rehabilitation to Correct Infiltration and Inflow	0.7
Category IV	New Sewers	24.4
Category V	Correction of Overflows from Combined Sewers	12.7
		$60.1

Throughout the 1960's and early 1970's, the federal government encouraged th design and construction of larger and larger sewage treatment plants for the obvious lower unit costs. In communities where public officials favored growth, little time has been lost in applying for and receiving significant federal aid to build new sewer and treatment plants. In most cases, the federal government contributes 75 percent of the costs for these facilities. As a result, new sewers and sewage treatment plants have become the prime determinant in land use. The oversizing of interceptors to ensure adequate future capacity has accelerated growth. The regionalization of plants has hastened urban sprawl. Little attention was given to the cost of the collec- tion system as most of the engineering experience was in high density areas where the per capita costs for collection are generally low.

An example of the total cost of sewage collection and treatment is shown in Table 3. It is interesting to note that two-thirds of the total costs are for the amortization of capital expenditures with more than half of these costs attributed to the collection system. Not only is the collection syster expensive, it is also inefficient. Wastewater is comprised of the spent water from residences, industrial wastes, and ground water infiltration. A typical makeup is forty percent residential, forty percent industrial, and twenty percent infiltration. The actual pollutants are only a very small fraction of the total flow. It is a burden on the treatment plant to handle the high volume of water used to convey the small amount of waste matter to the plant.

There are additional disadvantages to large regional sewage treatment and collection systems. Among these are:

1) Point discharge - Enormous volumes of effluent and sludge are concentrated at one location which often poses additional environmental problems with the ultimate disposal of the waste.

2) Water where water is not required - Regional plants with advanced wastewater treatment produce an effluent whose quality is sufficiently high so as to permit its immediate reuse for purposes other than human consumption. Often the industrial and commercial uses are far from the treatment plant which results in high costs making reuse unattractive.

n additional concern that encourages change is the extensive building moraoriums that have been enacted in many locations as the result of overloaded reatment plants.

AN OPPORTUNITY FOR CHANGE

he 1972 Amendments to the Federal Water Pollution Control Act mandate that ll municipalities provide secondary treatment for their wastewater by 1977. n achieving this objective, municipalities and others may use a wide variety f secondary treatment methods and sludge disposal plans. The Environmental rotection Agency has gathered and distributed basic information for the reliminary evaluation of 11 alternative treatment technologies and 12 lternative sludge disposal methods. The treatment technologies include iological, chemical, and land treatment approaches. The sludge handling nd disposal methods include landfill, incineration, land spreading, and cean dumping. The study recognizes that conditions vary in different parts f the country and that optimum waste treatment systems are dependent on ocal and regional conditions.

he practicing engineer encounters numerous situations in designing buildings nd building complexes. At one time he may be involved in new construction n a rural area where sewers and treatment plants are nonexistent; at another ime he may be involved in the renovation of a major inner city complex where ewers are at their design capacity and the treatment plant overloaded. He ay be faced with any combination of the factors shown in Figure 1.

y treating water supply, drainage and waste disposal as a building system, he engineer can devise a design that will be cost effective and environmentally ound. There is often little incentive for innovation in the subsystems beause the improvements taken by themselves are often small.

n related papers at this symposium, the research needs and benefits of improved nowledge of the demand for water, the influence of water savings, and advanceents in the hydraulics of drainage have been given. Similar advances in astewater treatment should be possible.

here are at present several comprehensive reports on the collection, treatent, and disposal of liquid wastes. The first of these was prepared by the ederal Water Quality Administration,[4] now a part of the Environmental rotection Agency. This report examines in detail opportunities for reducing he effluent from individual homes, the present technology in treating these astes, and possible techniques for improving the treatment process. One undred and eight references are cited in the text. Fifty-five additional eferences are included. Nineteen manufacturers of waste treatment equipment re identified, fourteen of these were making home treatment units or contemplated aking them.

The second major report was prepared by the Oak Ridge National Laboratory for the Department of Housing and Urban Development in 1974.[3] A specific objective of this study mentioned earlier in this paper was an evaluation of the current and future technology of waste water collection and treatment so that it could be incorporated into Modular Integrated Utility Systems. One hundred and ninety references are cited. If a weakness exists in this report, it is its failure to suggest research needs.

It is evident from these studies that extensive research has been done in this field. It appears that many major corporations are actively pursuing this potential market.

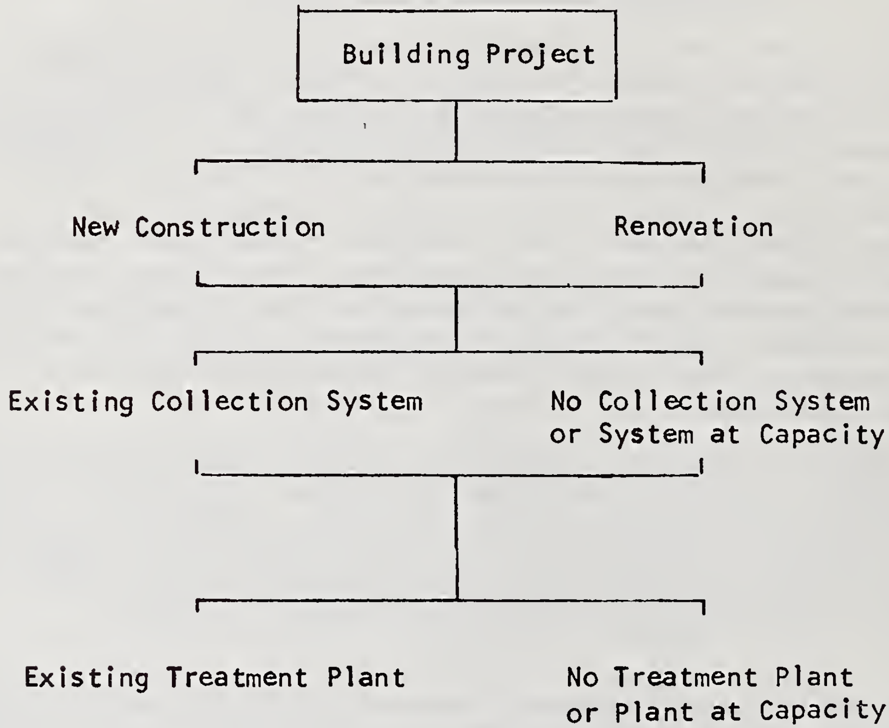


FIGURE 1

Looking Ahead

The percentage of the population living in the standard metropolitan statistical areas is continually increasing; it is expected to do so in the years to come, see Figure 2. In our central cities, urban renewal has resulted in a change in the use of the land, single-family homes, and small multifamily dwellings are being replaced by larger buildings. Some of these are apartment houses, some are office complexes, others are combinations. The growth of these multidwellin projects is shown in Figure 3. New types of residential projects such as condominiums and planned unit developments are coming into being. In a special edition, "Probing the Future," the editors of Engineering News-Record report the single-family detached housing's share of the market will fall from the 55 to 60 percent level of today to perhaps 30 percent by the end of this century. Apartments (five or more units) will account for 50 percent. The balance will be townhouses, duplexes and fourplexes. It is expected that by the year 2000, 80 percent of the population will live in or around our cities. Building complexes housing 20,000 people may be commonplace. We must prepare now to meet the needs of these new structures.

Research Needs

It is easy to state and comprehend that minimizing the water input requirements to a building is a good idea and that there is a ripple effect on the entire water cycle. What is difficult to judge is the significance of this idea. Where no collection or waste water treatment facilities exist, the impact of minimizing water consumption may be much more significant. The following programs are suggested to provide the building engineer with the tools to meet the requirements that are rapidly approaching our nation.

1. Earlier studies on waste treatment systems have not considered the relationship that exists between the building water supply and drainage systems and the treatment process. It is envisioned that the significant reduction in the waste water will influence the approach to on-site treatment. There have been many developments and a number of important field trials of new concepts. Detailed performance and operating experience data must be gathered on these developments and made available to the building engineer. Indications are that restraints, other than technical ones, are impeding the implementation of existing technology. Typical concerns to be explored are the reluctance of health authorities to grant approvals and the concern of building owners over the level of skills required and the adequacy of maintenance programs.

   Additional specific questions should be addressed to manufacturers. Among these are: What is the current annual production rate of package units? What is the manufacturer's estimate for these products in the years to come? The 1969 report prepared by the FWQA listed 19 firms in the package waste water treatment business. It will be interesting to determine how many are in this field today.

2. The design and installation of water supply and drainage systems are governed by plumbing codes developed on experimental data obtained in the 1930's. While numerous editions of these codes have been issued, the basic hydraulic information has not changed. A design and full scale laboratory model of a water supply and drainage system, based solely on the functional need, such that the demand rate and per capita consumption are a minimum, is a primary objective. European practices and field trials here in the U.S. have indicated that lavatory fitting flow rates of 1/2 gpm and less are acceptable. Water closets, compatible with gravity

FIGURE 2

Population

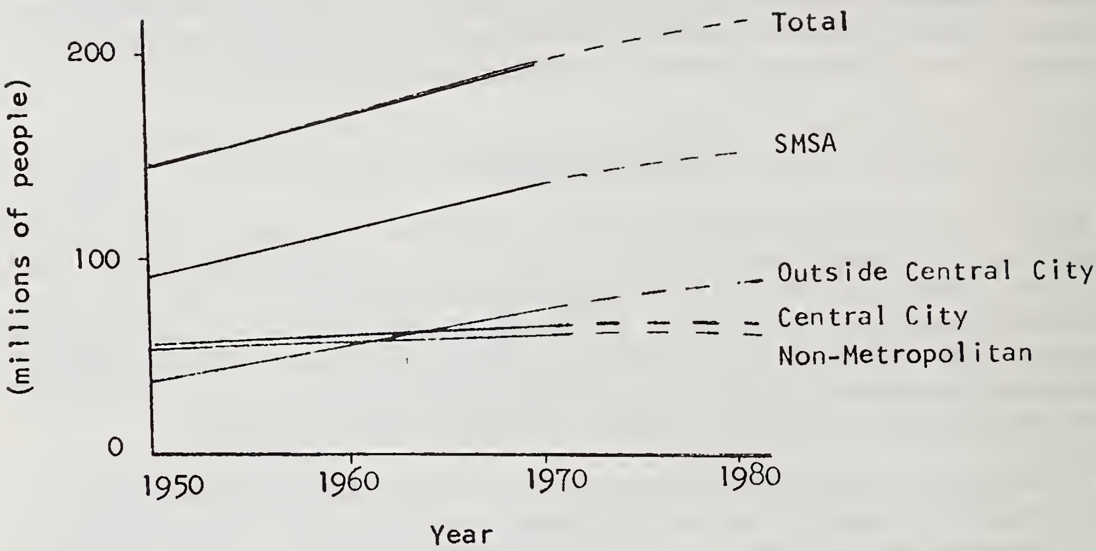
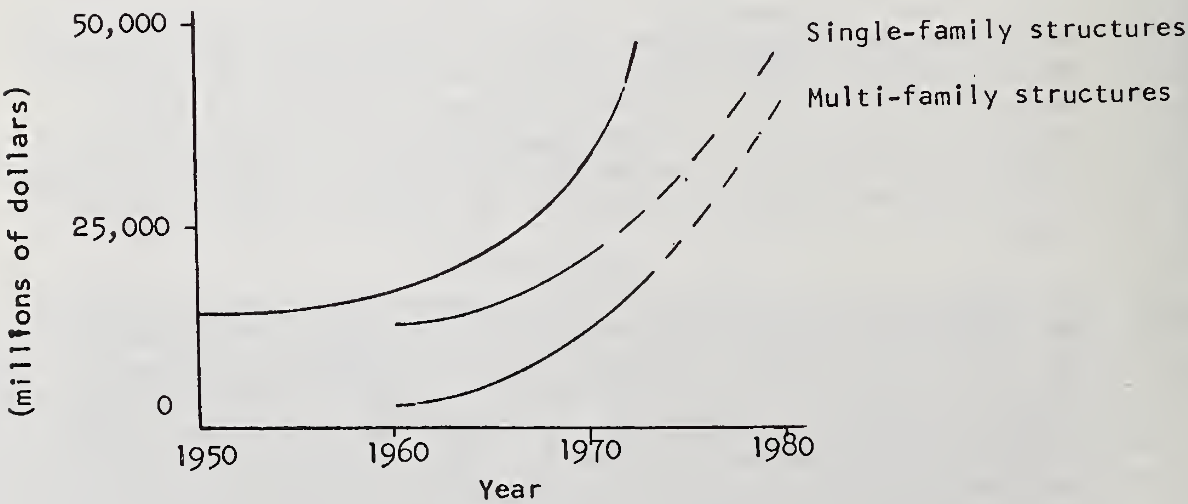


FIGURE 3

New Housing Units



drainage systems, are known to operate on volumes as low as 2 quarts. Additional studies indicate short duration of use factors for kitchens. Incorporating parameters applicable to the advanced system will reduce the expected peak flow approximately 40%. This, in turn, should yield a significant savings in material and labor.

The design of the supply piping will be based on the most advantageous use of materials and consider both energy cost and life-cycle cost. Gravity supply systems, fed from storage tanks, may regain favor over continuous pumping systems in view of energy considerations. Numerous changes in the vent system are expected.

3. An economic study of wastewater discharge, its treatment, and its influence on the environment for several combinations of conditions that have been known to occur in the field is required. Examples are: 1) installation where there is adequate water supply, no collection system, and good treatment facilities, 2) installation where there is an inadequate water supply, acceptable collection system, but an overtaxed treatment facility.

Following this overall view of the water supply, wastewater drainage and sewage treatment study, full scale demonstration programs reflecting improved systems and their advantages should be built on a regional basis so that the building water supply and output effluent have a minimum dependency on the surrounding environment.

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INTERNATIONAL PERSPECTIVES

CIB W-62 PURPOSE, METHODOLOGY AND FIELDS OF WORK

by

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CIB W-62 is one of the Working Commissions within CIB and furthermore it is one of the younger commissions. No. 70 has not yet been reached. Out of these numbers around 30 are in use.

W-62 has the working field: Water Supply and Drainage for Buildings, and for professionals within that field it must be surprising that our number is as high as 62. According to the importance of Water Supply and Drainage a much lower number--say 4 or 5--could be expected. We will try to find the reason for that later on, but first a few words about our mother organization.

CIB, The International Council for Building Research, Studies and Documentation

The International Council for Building Research, Studies and Documentation has the abbreviation CIB because of the French name: Conseil International du Batiment pour la recherche, l'etude et la documentation. CIB is a non-governmental organization having members in more than 50 countries throughout the world.

The Establishment of CIB

The first members--and the founders--of CIB were the large building research institutes. Today also other public and private institutes working with building research and information are members and so are a number of individual experts. The members fall in four categories, namely: Public Full Members, Industrial Full Members, Associate Members and Unattached Members. It may look a little complicated but in the daily work in the commission we never worry about that.

The idea of making such an organization goes back to the end of the second World War. During the war a large number of buildings were destroyed and it was necessary to increase the effort of building new houses by all possible means. In many countries building research institutes were established and for the new institutes international cooperation was a natural way of starting the work.

The first to take care of was the building information and documentation, and an organization covering this field--CIDB--was created in 1949. The present organization and the name CIB goes back to 1953. The international cooperation on buildings was started with the full support of the United Nations Organization.

Working Methods of CIB

CIB applies a number of different working methods. The most imposing one is the big public congress held every three years. The purpose of these congresses is first of all to inform of scientific progress. The last one took place in Budapest in Hungary in 1975 and treated the theme: The Impact of Research of the Built Environment. The next one will be in Edinburgh in 1977 and there for the first time we shall have contributions from most of the working commissions--including W-62. Furthermore several specialized conferences and symposia are to be arranged. As an example we had in 1972 a joint symposium on Performance Concept in Buildings in Philadelphia. It was arranged by RILEM, ASTM and CIB.

The Working Commissions

The research work is taking place in the working commissions among which the W-62 also is found. The commissions are quite different in their way of working. Some of them are concentrating on information of the research activities of their members. Some of them have coordinated research programs and others have integrated their work in order to produce common CIB publications.

W-62: Water Supply and Drainage for Buildings

W-62 was established as CIB commission in 1971 after some informal discussions between representatives of Great Britain, Czekoslovakia and the Scandinavian countries. All these countries had a wish and a need for international cooperation.

As terms of reference it was decided that the commission should:

report on research in progress in water supply and drainage systems,

encourage and coordinate further research aimed at providing information on the characteristics and performance of such systems and data for their design, and

arrange discussion meetings and conferences.

This program gave us members from 14 different countries who sent about 50 delegates to the first annual meeting and symposium in Garston at the British Building Research Establishment.

Since then we have increased the number of member countries up to about 25 representing almost all parts of the world. The very number of members is not the most important thing. It is far more interesting that most of our members are highly active within the research field of water supply and drainage. I suppose that the majority of laboratory facilities used for this purpose belong to our members. It is our duty to use these possibilities in the right way.

A great number of members will not necessarily result in many coordinated projects. Therefore we have never tried just to expand the number of members--but we have very often asked individual institutes or experts to join us.

The Past Work of W-62

I will try to summarize the work carried out in the commission from the beginning and until today.

Already at the first official meeting in 1972 we had a symposium. The theme of the symposium was "Water Demand in Buildings". We had the opportunity to present a number of new research reports from different countries and from different views. The symposium was a very fruitful one--especially for the research workers being active within this field.

The idea was to continue this way, that is to find a limited research field and a number of scientists being ready for presenting and discussing new papers. However, it proved to be difficult to structure the symposia in that way--our members were too active and had too many results, so at the symposium in Stockholm in 1973 we had papers from the whole field of drainage. This was a good meeting too and the greater variations in the subjects seemed to be popular among the members.

For the following year, 1974, we had decided not to have a symposium, but we had to change our minds. A large number of members asked for a possibility to present their work and to have a qualified discussion. Because of the change of decision this symposium--which took place in Copenhagen--was unstructured and covered drainage as well as water supply but in spite of that some good results were achieved.

During the first years we started working groups under the following headlines:

Experimental Techniques in Research on Drainage Systems

Performance Concept Related to Water Closets

Performance Criteria for Piping Materials as a Function of Use

Water Demand

Problems in International Cooperation on Water Supply and Drainage

At that time we felt in the commission that we had to decide whether we wanted to be just a forum of information or we rather should try to make planning for the future--to follow or to govern the development.

International cooperation is difficult because our goals--at least our short-term goals--are different. It is extremely difficult in an area as drainage and water supply because we have old and very strong traditions all of us--first of all the traditions called codes.

Codes must be based--at least partly--on the traditions. It is quite natural that we within the field of water supply and drainage have codes being very traditional and very restrictive. We will find the same pattern within all fields where a risk of life may occur, i.e., fire, combustion or electricity. In those cases you will find codes being based on detailed requirements for materials and design--non-performance requirements.

Non-performance requirements are used when it is too dangerous to make experiments--and water supply and drainage has been dangerous, indeed, and killed much more people than fires and explosions. This fear is reflected in today's code of practice, but we have forgotten the reason.

The way of making codes has changed, at least in some countries. The performance-based code will become a reality sooner or later, but we still have the existing installations which will be in use for many years and thereby influence the design of new systems. That's why our commission was number 62 instead of number 2, and that's why the international cooperation is extremely difficult.

The old traditions will also be a barrier for the cooperation in the future, but this barrier must in some way be perforated.

At one hand we have to face the fact that our member countries <u>are</u> different and in some way will maintain a difference. On the other hand, we must cooperate in such a way that all of us will benefit; it is difficult.

Building Up Guidelines for Future Work

In the planning group we saw the results of the differences among the member countries. The working groups mentioned earlier did not meet our expectations. The more remote from each other, the more different, the less the work.

At the same time we noticed an increasing interest in presenting papers at the symposia.

From these facts we draw the lesson that the research activity among our members was high but that it was hardly possible to change the direction of this activity. The only way was to avoid seeking for members being interested in a certain research problem, but rather take starting point in the actual work in the member institutes.

As a foundation for the planning we have to know what is going on in the member countries and member institutes. We must have data on projects and programs and we have to up-date these data regularly.

On this basis it must be possible to find ways of organized cooperation and information. On this basis we can find subjects for symposia, make contact among a small or a big number of persons, establish one-man groups for collection and combining data from other members and so forth.

We are at the beginning of this process. We have already pretty good information about the capacity of all member laboratories. We know the persons being involved and we have a broad view of the work going on.

At our last meeting in September 1975 in Scotland, we used our knowledge to structure the symposium. We called for papers on the following subjects:

Water Economy

Standards and Regulations

National Research Needs

Many of the papers were invited but the subjects were open to non-invited papers too.

We got papers of fairly good quality and most of the papers were valuable to a majority of members--and not only to the author and his national reputation.

With only four papers we got a fairly broad view of the problems of the water economy. Papers from England, Japan and India showed clearly three different categories: a country with rather small problems and good technology, a country with big problems and a good technology, and a country with big problems and a poor technology.

This year we have chosen subjects within the performance concept for our symposium, namely, Performance Requirements and Performance Testing. We have chosen this field for two main reasons. Firstly, many of our members are working very hard on this subject, so we have results as well as an audience being prepared for the discussion. Furthermore, we need the discussion because the use and the understanding of the performance concept seems to differ from one country to another.

The second reason for discussing the performance concept at this meeting is that we--especially on this subject--expect qualified contributions to the discussions from our American counterpart. We know that the U.S. has far the greatest experience in this field.

The Goals and the Future Work of W-62

I have been asked to tell about the goals of CIB W-62 and I should be glad to do that. We have not yet made an official long-range program but we have some ideas and wishes for the future. What I can give you now is my personal conception of the future of W-62, but other members present at this meeting are welcome to add, or to protest.

A few years ago I am sure that I could have given you a detailed and ambitious program. Today the answer will be a little different. Not less ambitious but the strict details have been replaced by the hope and the knowledge of the difficulties.

1. Mutual Understanding

The most important goal at the moment must be to bring the research workers together, to give them an opportunity to speak and, first of all, to teach them to listen to each other and to understand each other.

The understanding is important because differences in patterns and traditions have a heavy influence on the research--often we don't notice it.

In Scandinavia we normally use 6-8 litres of water to flush a water closet. Consequently, I find that our system is better than for instance the American system using about 20 litres per flush. We are working with water closets with reduced flush quantities down to 3 litres or less, but nevertheless I am fully convinced that our systems are much better than systems from abroad using no water at all.

How to make the best systems!

We have built up an understanding of the different functional requirements to be met.

The best tool for common, technical understanding is the performance concept. Using that, we can bridge the differences among our ways to make water supply and drainage. In that way we may understand that systems in other countries are not necessarily bad--but they are made to fulfill other performance requirements.

2. Research for Use in Practice

I am sure we could have a nice club for mathematical and physical games --we have had some of it now and then. We must never forget that science is not the purpose itself but one of our means. That is why we have to join the work with legislation, standardization, codes and the like, and bring the results of our scientific work into the rules of the society.

We must do that as well on the international stage as in the individual countries. We must prevent that national codes just are made as prolongation of old traditions because this will prevent research and development and exchange of products and ideas across the borders.

We must prevent that standardization is nothing but a fight among the biggest producers supported by their own countries. This can only be done on a basis of international research.

3. Making a World Model Code

From Scandinavia I can tell about our experience in making a supranational code covering five different countries. Eight years ago the hard work was finished and we had a performance-based model code covering drainage and water supply. Today all the countries have their national codes in function and the small differences among them are hardly to be noticed. When we started the work, some of the countries involved had nothing but a lot of different local rules.

New systems and components can be introduced by passing adequate approval tests. Test methods have been developed by the different Scandinavian building research institutes and related institutes. A component being approved in one of the Scandinavian countries will normally be approved in the other countries without difficulty and using the same test results. This is because all of the test methods have been worked out within the frame of a Scandinavian cooperation and because authorities, and test and research institutes from the different countries have regular meetings.

Work like that is difficult and the more different the countries are in geography and way of living, the more difficult it is. In the European Standard Organization--the CEN--they have established a group working with something like a European model code. Some of our members have joined the group and inform us regularly.

A worthy task for CIB W-62 would be to make a world model code, a code based on the fact that human beings all over the world are like each other--but also taking into account that needs, wishes and resources may vary from country to country.

4. To Give Priority to the Right Jobs

The W-62 should make a planning which could be a support for our members in giving priority to their research works.

We do that by inspiration--not by force (which anyhow is impossible).

We must try to prevent fighting against the details and forgetting the main issues. It must be wrong that some of the best laboratories are using their strength in making a perfect system a little better while other member countries are not able to bring clean water to the user.

Neither must we forget that water and water systems are just one of the possible solutions--except for the drinking water. I was a little afraid when we took the name "Water Supply and Drainage" as the name for our commission. However, it was too difficult to find a short name explaining that we want to handle all functions which today are carried out by means of water and waste water systems.

We may expect a change in systems. In many countries we have a lack of water for many different reasons. We find it in poor countries and rich countries. We have to consider this problem very careful. Do we need to use water for the same purposes and to the same extent as we do today? Could we improve the efficiency of our systems in order to save water?

5. <u>To Be a Link</u>

In the leaflet telling about USNC/CIB I found a little drawing representing this organization as a link between CIB and United States Building Community. I like that symbol and I want the W-62 to be a link too--in more than one respect.

We shall be a link from one member to another. From the rich member to the poor member--from the small member countries to the big ones. We shall link the developed technology and the undeveloped one, and as a non-governmental organization we should also be a link between authorities and the practice.

I hope that our commission will grow up to a good and a strong link.

STANDARDIZATION STRUCTURE IN EUROPE

by

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This document consists of three parts:

1. Review on the organization of European Committee for Standardization (CEN) and on its functioning rules.
2. Review on the organization of International Organization for Standardization (ISO) and on its functioning rules.
3. Summary on present works in CEN and ISO within the field of CIB W-62.
   - Questions studied,
   - Who studies them,
   - State of progress.

THE EUROPEAN COMMITTEE FOR STANDARDIZATION

1. Composition

The European Committee for Standardization (CEN), which has been created in Paris in May 1961, is an association of national standards bodies of European Community (EC) and European Free Trade Association (EFTA) countries.

The members of CEN are: Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Norway, Portugal, Sweden, Switzerland, and the United Kingdom, and the national standards bodies of any other European country which would accede to the Treaty of Rome or would become a member of EFTA. Further membership is open to any country of Western Europe whose economy is closely entwined with those of the EEC and EFTA countries, and whose ultimate adherence to one of these economic communities could be anticipated.

2. Scope of CEN

The aim of CEN is to promote the development of trade and exchange of services by eliminating obstacles caused by provisions of a technical nature and to free trade exchanges between all the member countries by the following means:

- Harmonization of members' standards to create European Standards, and the creation of European Standards "de novo" based on the requirements of the situation in any case where other appropriate and valid standards do not exist.
- Cooperation with political, economic and scientific European organizations in the field of standardization.
- Support of worldwide standardization, and particularly in the International Organization for Standards (ISO) and International Electrotechnical Commission (IEC).
- Ensuring an uniform implementation of ISO Standards and relevant IEC publications in Europe.
- Preparation of reports on the state of harmonization of standards of CEN members.
- Provision of certification services on the basis of European Standards.
- Making available to the Commission of the European Communities and other governmental organizations European Standards to which they can refer in their directives or other instruments.

Electrotechnical questions are not the concern of CEN.

3. Organization

The organizational structure of CEN consists of:

- a Steering Committee,
- a Central Secretariet,
- Working Groups (WG), with their secretariets,
- Such councils and committees as the Steering Committee may set up to further its aims.

Steering Committee

The Steering Committee consists of representatives of the members. Each member represented at meetings has one vote. The Chairman and the Vice-Chairman of the Steering Committee are elected by the members of CEN. (Present Chairman: Mr. Jan Ollner, Sweden.) The Steering Committee shall meet whenever necessary and at least once a year.

Central Secretariat

The CEN Central Secretariat is headed by a Secretary-General who is appointed by, and responsible to, the Steering Committee. The Secretary-General prepares the meetings of the Steering Committee. He is responsible for the implementation of the decisions of the Steering Committee.

Working Groups

The technical work of CEN is normally the responsibility of CEN working groups. The creation of a working group and allocation of its secretariat to a CEN member are decided by the Steering Committee. The Steering Committee also decides on the disbandment of a working group.

At the moment, there are 47 working groups.

The Chairman of the working group is elected by the members of the working group.

4. Technical Works

Choice of Subjects

Any member of CEN may take the initiative for asking for the study of a new question. Proposals for new work may also be received from international organizations.

A proposal will be considered as eligible if, in the field in question, differences between national standards or regulations cause obstacles to the exchange of knowledge, goods or services, or hamper mass production.

Subjects proposed by scientific or trade organizations will also be eligible, when the organizations are prepared to contribute to their study.

If work exists in ISO in the field selected, any CEN activity will be directed to complementing and implementing this ISO work.

Participation in the Work

Each member of CEN shall inform the Secretariat of the working group, as well as the CEN Central Secretariat, whether or not it wishes to be a member of the working group, or if it later modifies its participation.

Conduct of the Works

Working groups are expected to produce draft European Standards for CEN ballot by the agreed target date. For this purpose the scope of each project should be suitably restricted.

If it appears unlikely than an European Standard can be produced by the target date, the working group should aim at the issue of an Unification Report. The acceptance of an Unification Report, however, should not imply that further attempts to reach an agreement on an European Standard should be abandoned.

The working group is entirely free to conduct its work as it seems appropriate, establishing liaison with other organizations if necessary. It is responsible for the project up to, and including, the adoption of the working group's final draft.

Adoption

When a draft proposal has received substantial support from the members of a working group, it is sent to the Central Secretariat.

A. CEN member ballot

The final draft proposal is registered at the Central Secretariat and circulated as a Draft European Standard (pr EN) to all CEN members with the ballot form. This form should be returned within six months to the Central Secretariat.

B. Scruting of votes

At the end of the voting period, the Central Secretariat, in consultation with the working group secretariat, analyzes the results of the voting and prepare a ballot report for submission to the Steering Committee.

It also decides whether in the light of the voting criteria given in the CEN Constitution, a recommendation for acceptance should be made to the Steering Committee.

If the pr EN is not approved by the majority of the members voting, it cannot go forward, and the matter is referred back to the secretariat of the working group. A new draft may be prepared for submission to members.

C. Final ballot

The final text of the pr EN is submitted to the members of the Steering Committee. The voting period is two months. Following adoption by the CEN Steering Committee, the versions in English, French and German are forwarded to the Central Secretariat by the working group's secretariat. The Central Secretariat circulates them to all CEN members.

Publication

CEN members who have approved the European Standard are required to publish it as soon as possible and without change as a national Standard.

5. References

The above-mentioned indications are extracted from two documents of CEN:

- CEN/N 337 - CEN Constitution

- CEN/N 420 - Directives for the technical work of CEN.

THE INTERNATIONAL ORGANIZATION FOR STANDARDIZATION (ISO)

1. Composition

The International Organization for Standardization (ISO) has been created in 1947. It was a continuation of the International Federation of the National Standardizing Associations - ISA - created in 1926. The ISO includes:

- Member bodies: National Standards bodies (64 member bodies),
- Correspondent members: generally, governmental organizations (16 correspondent members)

on the whole, 80 countries.

2. Scope of ISO

The scope of ISO is aimed at worldwide agreement on International Standards with a view to the expansion of trade, the improvement of quality, the increase of productivity and the lowering of prices. ISO work covers virtually every area of technology, with the exception of electrotechnical questions which are the responsibility of ISO's affiliated organization the International Electrotechnical Commission (IEC).

3. Organization

The organizational structure of ISO consists of:

- a President (Mr. Ake T. Vrethem, Sweden)
- a Vice-President (Mr. Ralf Hennessy, Canada)
- a Secretary-General (Mr. Olle Sturen)
- a Council which consists of the President and 14 representatives of member bodies.
  - . an Executive Committee (EXCO)
  - . a Planning Committee (PLACO)
- Some Technicals Committees (TC)
  - . subcommittees (SC)
  - . working groups (WG).

The preparation and formulation of ISO International Standards is the responsibility of ISO technical committees.

4. Technical Works

Choice of Subjects

The initiative for the study of a new question belongs to:

- one of several member bodies,
- a Technical Committee,
- a Technical Division,
- a committee of Council,
- the Secretary-General,
- an external organization.

The demand is submitted at the Central Secretariat and circulated to all members committee. After the ballot (four months), the report established by the Central Secretariat is circulated to PLACO, and then to the Council which decide. (Creation of new Technical Committee.)

Participation in the Work

The technical committees consist of members committees which have expressed the wish to take part actively in works (P members) or want to know the state of progress (O members).

Conduct of the Works

The main work of each Technical Committee is to ensure the drawing up of International Standards. If no agreement can be obtained in order to submit a draft proposal, the Technical Committee can ask that the draft be published as a Technical Report. The works are carried out by members of the Technical Committee, which can also decide the creation of subcommittees and working groups. It can cooperate with other ISO technical committees or with other international organizations.

Adoption

When a draft proposal has obtained a large agreement from members of a Technical Committee or a subcommittee, it is dispatched to the secretartiat of the Committee or subcommittee.

The draft proposal is submitted for ballot to P members. When a large agreement is obtained, it is dispatched to the Central Secretariat.

The Central Secretariat records the draft proposal as a Draft International Standard (DIS) and circulates it to all the member-committees for approval.

Note: There is a procedure that said: "combined voting procedure" which allows just one ballot (P members and members committees together).

When a Draft International Standard has been adopted, it is dispatched to the Central Secretariat which submits it to the Council.

The Council decides if the DIS can be agreed or no, in order to be published as an International Standard.

Publication

After agreement by the Council, the Central Secretariat publishes the International Standard.

The members committees should circulate the International Standard in their respective countries.

5. References

The above-mentioned indications are extracted from the following documents of ISO:

- Directives for the technical work in ISO,
- ISO Memento,
- ISO Catalogue,
- Guide for the presentation of International Standards and Technical Reports.

EUROPEAN AND INTERNATIONAL STANDARDIZATION IN THE FIELD OF CIB W-62

1. Technical Committees - Subcommittees - Working Groups

The Figure 1 shows a simplified water supply and waste system, on which are given the questions studied now, either by CEN or ISO.

In a more detailed way, the works are carried out by the following institutes:

- Valves, taps and miscellaneous devices for water supply in buildings

  . CEN/WG 36: "Valves and taps for water supply in buildings"

    This working group studies particularly:

    - stop-valves,
    - draw-of taps,

- Water meters
  . ISO/TC 30: "Measurement of fluid flow in closed conduits"
  ....
      - SC 7: "Water meters".

- Pumps
  . ISO/TC 115: "Pumps".

- Pipes for water supply
  . Metallic: ISO/TC 5: "Metal pipes and fittings"
    - SC 1: "Steel tubes"
    - SC 3: "Non-ferrous metal pipes"
    - SC 5: "Fittings (other than cast iron)".
  . Plastics: ISO/TC 138: "Plastics pipes, fittings and valves for the transport of fluids"
    - WG 2: "Plastics pipes and fittings for water supplies".
    - WG 5: "Methods of test and general properties of pipes, fittings and valves in pastic materials".
    - WG 7: "Valves and auxiliary equipment of plastics materials".

- Taps and fittings for sanitary appliance
  . CEN/WG 34: "Water fittings and waste fittings for sanitary appliances" - Dimensions - Quality.

  This working group studies particularly:
    - Taps (single, mixing tap and mixers)
    - Waste fittings (emptying, siphon ...)
      . dimensional, mechanical, hydraulic, physical and chemical, acoustic characteristics.

- Sanitary appliance
  . CEN/WG 7: "Connecting dimensions of the sanitary appliances"

- Waste and soil pipes
  . metallic: ISO/TC 5: "Metal pipes and fittings"
    - SC 1: "Steel tubes"
    - SC 2: "Cast iron pipes, fittings and their joints"
    - SC 3: "Non-ferrous metal pipes"
    - SC 5: "Fittings (other than cast iron)".

. plastics: ISO/TC 138: "Plastics pipes, fittings and valves for the transport of fluids"

- WG 1: "Plastics pipes and fittings for soil, waste and drainage".
- WG 5: "Methods of test and gener properties of pipes, fittings and valves in plastic materials".
- WG 6: "Reinforced plastics pipes and fittings for all applications".

. mineral: ISO/TC 77: "Asbestos fibres and products in asbestos-cement"

- WG 20: Revision of ISO/R 391 and 392.

- Drainage equipment

  . CEN/WG 77: "Drainage equipment"

  (The scope of working of this working group is not yet completely defined).

Other technical committees interesting the CIB W-62:

- ISO/TC 21: "Equipment for fire protection and fire fighting".
- ISO/TC 59: "Building construction"

  /SC 7 - WG 2 - "Bathroom and toilets"

  - WG 4 - "Accomodation ducts".
- ISO/TC 92: "Fire tests on building materials and structures".
- ISO/TC 147: "Water quality".
- ISO/TC 156: "Corrosion of metals".

2. Results of Work

The different ISO technical committees mentioned have already established a number of International Standards (or specifications). These are given in ISO Catalogue (classified in technical committee order).

Concerning CEN, there is not yet European standards, but draft standards which are or which are going to be at inquiry.

- CEN/WG 34:

  . Pr EN 27 - Mixing taps with concealed body for mounting on horizontal surfaces - Part I - Dimensional characteristics.

  . Pr EN 28 - Mixing taps with combined visible body known as "single hole" for mounting on horizontal surfaces - Part I - Dimensional characteristics.

  . Pr EN 29 - Simple taps for mounting on a vertical surface - Part I - Dimensional characteristics.

. Pr EN .. - Mixing taps with visible cross-connected body for mounting on vertical surfaces - Part I - Dimensional characteristics.

- CEN/WG 36:

  . Pr EN 64 - Stop valves - Test for watertightness and mechanical strength.

  . Pr EN 64 - Stop valves - Mechanical endurance test for moving parts.

  . Pr EN 66 - Stop valves - Measurement of flow rate and head loss

  - Stop valves: dimensional characteristics:

    . Pr EN ..: Dimensions for the interchangeability of headwork on bodies of stop valves type Q_A

    . Pr EN ..: Dimensions for the interchangeability of headwork on bodies of stop valves type Q_B

    . Pr EN ..: Dimensions for the interchangeability of headwork on bodies of stap valves type Q_C

    . Pr EN ..: Dimensions of the different types of ends for connecting to pipework.

- CEN/GT 7:

  . Pr EN 31 - Pedestal wash basins - connecting dimensions.

  . Pr EN 32 - Wall hung wash basins - connecting dimensions.

  . Pr EN 33 - Pedestal washdown WC pan with close coupled cistern, visible or concealed trap with vertical outlet - Connecting dimensions.

  . Pr EN 34 - Pedestal washdown WC pan with close coupled cistern - connecting dimensions.

  . Pr EN 35 - Pedestal bidets over rim supply only - connecting dimensions.

  . Pr EN 36 - Wall hung bidets over rim supply only - connecting dimensions.

  . Pr EN 37 - Pedestal washdown WC pan with direct flush, visible or concealed traip with horizontal or vertical outlet - connecting dimensions.

  . Pr EN 38 - Wall hung WC pan with independent water supply - connecting dimensions.

- CEN/GT 77:

  This working group, lately set up, has not yet established European draft standards. Two experts' groups have been set up:

  GE 1: Drainage equipment for streets.

GE 2: Drainage equipment for houses.

At the moment, the GE 1 studies a document relating to "gully tops and manhole covers".

The GE 2 studies a document relating to floor gully.

CERTIFICATION AND AGREEMENT SYSTEM IN EUROPE

by

D. Trinkler

(Translated by Madison Brown)

Certification in Europe

Construction regulation in the U.S.A. is probably similar to that in Europe with the obvious difference that seven different languages are spoken in the European Community--Danish, Dutch, English, Flemish, French, German, and Italian. The American situation may also be comparable to what existed in Germany until some 30 years ago--namely, the decision as to whether or not a building material or a construction design was suitable for a specific intended use was made at the site itself and consequently these decisions frequently differed from site to site, region to region, or state to state, sometimes to the point that decisions contradicted each other. This state of affairs became more and more unsatisfactory as the exchange of goods and services grows more common and does so beyond the authority with which the decisions on suitability lie.

What seems generally true is that public authorities, namely the communities or states, consider it their responsibility to protect the public against all kinds of dangers. For example, because dangers for the individual or the general public can arise from the erection or use of buildings, various instruments were developed to protect against hazards in construction. Historically these instruments developed differently among the individual states and even within the states themselves.

According to the information collected by the Construction Engineering Institute (Institut für Bautechnik), the conditions in the European Community countries are as follows:

Belgium

Here we find technical certificates (agréments techniques) granted by the Belgian Association for Technical Certification in Construction (Union Belge pour l'Agrément Technique dans la Construction; UBAtc). This is a private association of the National Housing Institute (Institut National du Logement), the Scientific and Technical Construction Center (Centre Scientifique et Technique de la Construction), and the insurance companies (Bureau SECO). Such a certificate constitutes a qualitative, descriptive rating of building procedures, materials, elements, and facilities. The standardization is not very comprehensive. These ratings take into account safety, habitability, and durability; the rating furthermore contains economic aspects. Thus the granting of this technical certificate is not a matter of governmental authority.

In general, regulations issued under public law do not require a certificate. Such a certificate is, however, mandatory for construction commissioned by public authorities, under conditions of insurability (insurance is mandatory), and to some extent in building contracts.

Denmark

The Housing Ministry (Boligministeriet) through its department the State Construction Research Institute (Statens Byggeforskning Institut) grants certificates (Godkendelse). This is a confirmation under public law either that specific new building materials and construction designs comply with the requirements stipulated in the laws governing construction or that other new building materials and construction designs satisfy the requirements laid down by the Housing Ministry, if such are not covered by the construction laws or the standards.

Precondition for the granting of a building permit is the presentation of an approval certificate (Godkendelse) provided it is required, i.e. prescribed under public law.

Apart from this kind of certificate, there are others similar to the test certificates granted by special committees for sanitary equipment, gas appliances, electric household appliances, underground oil and fuel tanks, and elevators.

The Federal Republic of Germany

The Construction Engineering Institute (Institut für Bautechnik) in Berlin grants the general construction supervision certificate and the test certificates on behalf of the higher construction supervisory boards of the federal states (Länder).

These approval certificates attest to the intended serviceability of building materials not in common use, structural members, or construction designs from the standpoint of public safety with special emphasis on life and health.

An obligation exists under public law to apply for such a certificate unless evidence of serviceability has been produced in some other manner.

Test certificates are granted for specific manufactured building materials which have been designated in statuatory orders, structural members, and facilities, if, because of their special nature or intended use, their compliance with the safety requirements depends in considerable degree on their superior quality.

In the area of site drainage, testing is obligatory for:

- pipes for the discharge of sewage and storm water (with the exception of outside storm water drains and water supply pipes), their fittings and sealing materials (except the customary packings of white rope and lead);

- overhead drain pipes for storm water, urinals, air traps, basins, and drains with built-in air traps;

- flushing tanks and plug-type basin flushing devices;

- shut-off devices in sewage and storm water plants (with the exception of water supply pipes);

- waste water pumps and check valves and preventers;

- sewage treatment devices;

- gasoline separators; and

- fuel oil separators and fuel oil check valves.

As far as water supply is concerned, the German Gas and Hydraulic Engineers' Association (Deutscher Verin von Gas- und Wasserfachmännern; DVGW) regulates the approval of materials.

France

The situation in France is the most complicated. There is legally no binding approval system. Various governmental, semi-governmental, and private bodies grant so-called technical opinions (avis techniques) or approval certificates (agréments) upon request. These are technical recommendations regarding the suitability of construction procedures, materials, elements, or appliances whenever their newness or their use does not yet permit standardization. The most important office issuing such technical opinions is the Scientific and Technical Building Center (Centre Scientifique et Technique du Batiment; CSTB) in Paris. It issues technical opinions on the basis of the decisions of an inter-ministerial committee backed by experts from other organizations.

As a general principle, there is no obligation to apply for such a technical opinion. The regional (départmental) authorities are, however, entitled--as the lower echelon building authorities--to require information about the materials to be utilized in multi-storied buildings, special purpose buildings (e.g., those open to the public and places of work), as well as public housing apartment buildings; that is to say, demand proof of serviceability in the form of technical opinions. In this context, one should take into account that in France one half of all the apartments being built are public housing projects. As far as government buildings are concerned, the individual ministerial departments grant their own approval certificates within their spheres of competence--partly on the basis of their own tests--for new building materials, structural members, and designs.

Since all architects and building contractors are insured to meet a 10-year warranty obligation, the insurance companies, too, have a certain influence on construction activities. For this reason they also grant their own approvals for new building materials, structural members, and construction designs; and do this through a special organization, the Construction Risks Management Division (Groupement par la Gastion des Risques de la Construction; GECO). In these cases, however, the existing technical opinions of the Scientific and Technical Building Center or the approval certificates of the ministeries are not necessarily always accepted as they stand, since the insurance companies often increase or modify the requirements.

Thus, under certain circumstances the manufacturer of a certain non-standardized material will have to apply for a technical opinion at the Scientific and Technical Building Center, an approval certificate at one of the ministries, and an approval certificate at Construction Risks Management Division --all three at the same time.

Normally the Construction Risks Management Division is informed of the use of new products, since otherwise there is no insurance coverage.

Great Britain

In Great Britain there is no binding approval procedure for new building materials. At present every lower-echelon construction supervisory board, the District Council, can decide at its own descretion whether or not a new building material is suitable. An approval, however, can be applied for on a voluntary basis at the Approval Board--a private institution with government cooperation. In this case, we are dealing with the descriptive rating of suitability for conventional, standardized, or new building materials and designs, a rating that goes beyond safety. Even if these approvals--which have merely the effect of recommendations--are not binding on the construction supervisory authorities, they are nonetheless recognized by lower authorities as evidence of suitability.

In the future the ministry responsible for construction will be able to grant so-called type approvals itself or entrust other agencies with this responsibility. These type approvals are comparable to the general construction supervisory certificate in the Federal Republic of Germany. The lower authorities will be bound by the decision rendered in the type approval. Nonetheless, there will still be no obligation to apply for such an approval.

Ireland

In Ireland also there exists no binding approval procedure. The lower-echelon construction supervisory authorities, the Counties or the County Boroughs, can decide on their own whether a specific building material is suited or not.

However, for standardized building materials, structural members, and construction designs there is a mandatory quality control process, the Irish Standard Mark Licensing Scheme, enforced by the Institute for Industrial Research and Standards (IIRS), the Irish standardization organization.

Italy

Here as well the local authorities charged with the granting of building permits, the commune authorities or, in small communities, the mayor and the building committee, in granting building permits implicitly decide upon the admissibility of new building materials, structural members, and construction designs.

Every second year, however, a special governmental body does issue technical directives regarding the requirements for specific building materials, structural members, and construction designs. Manufacturers of reinforced concrete, prefabricated concrete, and metal components have to notify the responsible ministry about the manufacturing process, the results of their own in-plant monitoring, and the like. In addition, before the start of construction, they must submit to the state department of construction--independent of the usual procedure followed in securing a building permit--data regarding properties, quality, mixing ratios, etc.

In other cases the private Central Institute for Industrialization and Building Technology (Instituto Centrale per l'Industrializzazione e la Technologia Edifizia) in Milan grants approval for new building materials, structural members, and construction designs. The preponderance of certification is in the field of plastic products.

Luxemburg

The lower-echelon construction supervisory authorities decide upon the admissibility of new building materials during the granting of building permits.

The Netherlands

A central approval committee (CCA) which is composed of the Building Center (Bouwcentrum), which is the executive member, KOMO and KIWA, and other organizations issues certificates (atteste). These are descriptive suitability ratings for new building materials, structural members, and construction designs, a rating which extends beyond concerns for safety alone.

Basically there is no obligation under public law to apply for a certificate except in some instances of government (or government-financed) buildings; similarly, the 900-some communities are entitled, through their own building regulations, to demand the presentation of a certificate at the time application is made for a building permit.

UEAtc Procedure

The European Union for Technical Approval of Construction, the UEAtc (Union Européene pour l'Agrément technique dans la Construction) is composed of the responsible agencies in Austria, Belgium, Denmark, the Federal Republic of Germany, France, Great Britain, Italy, the Netherlands, Portugal, and Spain. These agencies are obliged to recognize by confirmation--with restrictions or amendments where necessary--an approval granted by a competent domestic authority.

The UEAtc approval certificate constitutes the positive assessment and description of a "non-traditional" building material, structural member, or building method. Two shortcomings of this certificate are that the term "non-traditional" is interpreted differently in these countries and that the certificate also covers building accessories and items used by the subcontracting trades. These items are not relevant as far as construction supervision in the Federal Republic of Germany is concerned.

The manufacturer of a product applies for an approval certificate at the UEAtc agency in his own country. On the basis of documentation and its own tests, this agency grants the approval. In the Federal Republic of Germany, this approval cannot substitute for the general approval granted by the construction supervisory authorities.

The approval certificate (agrément) is considered a "non-paper" only in the applicant's own country. Validity in other UEAtc countries does not follow automatically. Application for confirmation must be filed with the UEAtc agency of the country in which validity is sought. Confirmation results through the intermediary of the office which first granted the certificate. If there are no uniform UEAtc directives for the building material in question, confirmation is granted with consideration of any special national conditions which may possibly result from deviating technical or legal requirements or climatic conditions. In the Federal Republic of Germany, such confirmation can be granted for construction supervision only if the Construction Engineering Institute (Institut für Bautechnik) consents.

Conclusion

The preceding description of the situation in these individual countries reveals that different solutions are being employed. In this context, one has to consider that with the generally modest means available, optimal effectiveness is the goal, i.e., safety. For such studies many aspects must be taken into consideration, e.g., population density, number of training of supervisory staff, legal or non-legal means of enforcement.

In conclusion, I will describe how an approval or test certificate is granted in the Federal Republic.

A manufacturer or importer files an application for a test certificate with the Construction Engineering Institute (Institut für Bautechnik). In doing so, one must prove that the product satisfies the minimum requirements laid down by the generally recognized rules of architecture: for example, through measures which are comparable to those examples and principles stated in the standards; or, as an alternative measure, through accepting restrictions on utilization. In this case, comparative tests between a standardized and a new product under the same conditions constitute an objective method of assessment; unfortunately this is not always practicable, especially not in those cases in which durability is to be rated. The instrument of approval is not to be misused to by-pass inconvenient minimal requirements prescribed by the standards in order to sacrifice safety for economic advantages over competitors who comply with the standards.

In difficult cases the Construction Engineering Institute (Institut für Bautechnik) calls upon expert committees for assistance in handling applications. According to the bylaws of the Institute, such an expert committee is composed of at least seven, at most fifteen members. At least three of these are experts from the top-echelon construction supervisory authorities of the states (Länder) or of the Federal authorities having a technical interest in the matter.

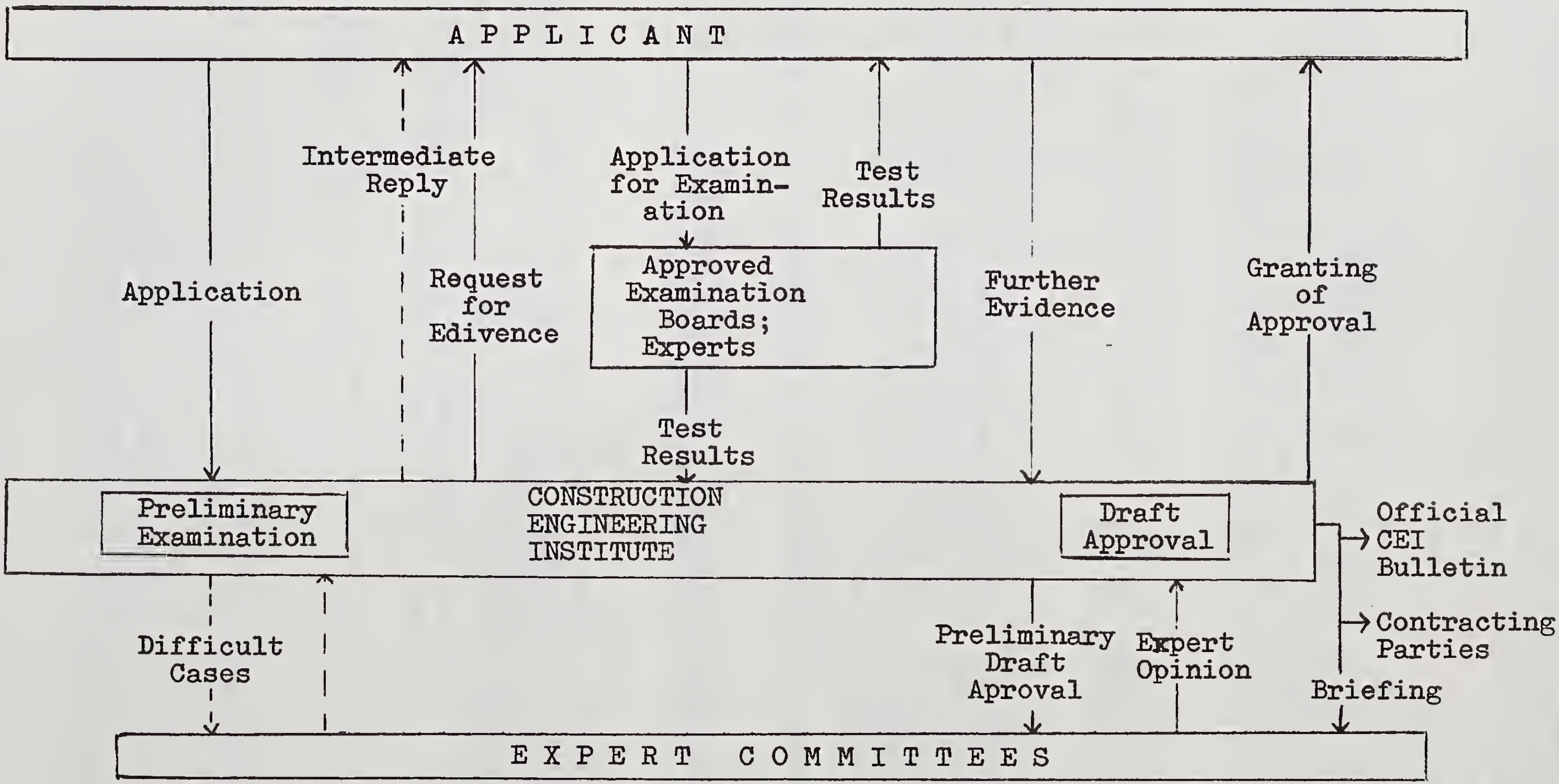
The expert committee may call upon further expert individuals to attend as guests. The experts work without fee.

The Board of Directors of the Construction Engineering Institute (Institut für Bautechnik) appoints the members, the chairman, and the deputy chairmen of the expert committees on the basis of recommendations from the Administrative Council. The expert committees may submit suggestions for appointments. The term of office is five years. It may otherwise expire at the end of the year in which the member becomes 68. Prior to the expiration of a term, an appointment can be revoked for cause.

The procedure for processing an application is represented in the attached diagram.

In the area of site drainage, five expert committees have been set up. They meet once or twice a year. These are the expert committees for:

- sewage pipes and fittings,
- sealing materials for sewage systems,
- sanitary equipment and fittings,
- waste water pumps and separators, and
- waste water treatment technology.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CONSTRUCTION ENGINEERING INSTITUTE
Draft Approval
Official CEI Bulletin
Contracting Parties
Difficult Cases
Preliminary Draft Aproval
Expert Opinion
Briefing
EXPERT COMMITTEES

RESEARCH LABORATORIES WITH CIB INTEREST

by

R. Hanslin, C. D. J. Webster and Viggo Nielsen

(A review of research activities and laboratories in Belgium, France, Switzerland [by R. Hanslin], the United Kingdom, South Africa, Australia, Japan [by C.D.J. Webster], Denmark, Finland, Norway and Sweden [by Viggo Nielsen].)

Belgium

Code Structure

Every water-undertaking community or city has its own regulations which can date back to the last century. In the field of water supply, there is only one statutory law of the Ministry of Health which regulates the quality of water. Only recently, the Centre Scientifique et Technique de la Construction (CSTC) proposed a uniform regulation (Règlement Sanitaire) for the design of supply and drainage systems. This regulation is the result of many years of research activities and analytical studies. The Règlement Sanitaire covers water supply, above- and below-ground drainage, and sewer lines.

To ensure the quality of plumbing materials and equipment, the Institut Belge de Normalisation (IBN) issues Belgian standards (NBN). Other quality standards are published by the Institut National du Logement (INL). These so-called "Specifications Techniques Unifices" (STS) are established by all organizations concerned with the specific field and replace the original "cahiers de charge".

Past Research Work

Some outstanding studies have been done by CSTC in the past years, especially with regard to the investigation of drainage systems. The results have been presented in many publications and papers.

This research work was started in 1963 in Liège and continued in 1965 partly at the CSTC Laboratory in a three-story house in Brussels with a 12m-high stack, in the high-rise building of the Cité Administrative in Brussels and at the CEBTP test tower in St. Rémy, France.

The studies included the investigation of flow patterns in stacks in function of inlet geometery, of the air flow function of stack length, diameter and flow rate, and of the pressure fluctuations throughout the whole system. With analytical methods, correlations of the various parameters were found.

Besides examining the hydraulic phenomena in stacks, the performance of traps and water-closets was determined. An interesting study dealt with the trap performance under back-pressure conditions together with suds.

Building component parts are also investigated with regard to noise propagation in an acoustical laboratory at the CSTC.

All tests at the CSTC are run highly systematically. The objects of the investigations are:

- improvement of plumbling technology and its performance;
- simplification of the installations; and
- introduction of prefabrication.

A joint study by the CSTC and the SIB Sweden of the performance of water-saving WCs and flush tanks has just been completed.

Present Research Activities

1. Water Supply

A two-year research program is under progress to investigate the internal corrosion in galvanized steel pipes for hot water distribution installations.

2. Drainage Systems

The research in the field of drainage is at present directed to a closer investigation of rain-water drainage. CSTC also participates in the CIB W-62 group studying the hydraulics of unvented branches.

France

Code Structure

The French Association for Standardization (AFNOR) is responsible for the preparation of standards when requested by initiators, the Centre Scientifique et Technique du Batiment (CSTB) or itself. The group that deals with the coordination of technical texts concerned with building materials is the Groupe Document Technique Unifié (DTU) which is in the hands of CSTB. The groupe DTU issues "Cahiers de charges", which set down the minimum standards of products of construction or application of materials. Although only in governmental contracts are French standard materials and DTU prescriptions compulsory, they are nevertheless followed quite widely in France today, because architects find it useful to specify these requirements as a safeguard against bad quality. Manufacturers too have formed their own standard group and issue the NF (Normes Francaises) standards and mark.

Non-standard materials and products which successfully pass the tests at the building. As an example: the air flow down the stack was found to be a function of various parameters such as the length of the stack. Not only the sizing and layout of single-stack systems were established and then published in the recommendations of 1966 but also a new single-stack system with special fittings for improved performance was developed.

Product Approval

Each official plumbing inspector has the competence to approve or reject a product. As his judgment was in general only based on common sense and experience, it was decided to establish a more scientific way of product approval. This led to the development of two new laboratories: one run by the SVGW for the supply and one by the Civil Engineering Department of the City of Zurich for the drainage side. Although both of these laboratories do not have federal status, they are recognized widely in Switzerland today. However, these labs are not geared for research work, but new findings especially in the field of performance characteristics of materials are often a by-product of this product testing.

Present Research Activities

1. Water Supply

A. Acoustics

In order to increase the quality of life and the standard of living stringent measures have been enforced by building standards and codes to limit the acoustical values. In conformity with the German code DIN 4109 the Federal Institute for Testing Materials (EMPA) and the Swiss Association of Gas and Water Works (SVGW) have built acoustical chambers in which mainly valves, faucets, WC tanks, hangers, etc., are tested regarding their noise propagation. Especially EMPA has done fundamental work in this respect, which serves as a guidance for manufacturers. On a private basis a manufacturer of plastics drainage material is examining at the moment the noise propagation of various drainage pipe materials, the effect of their layout and their interdependencies with other building components.

B. Water and Energy Conservation

Although water is no rare commodity in Switzerland, its yearly increase in use has to be taken under control as the capacities of many sewer treatment plants are exceeded with their polishing performance therefore deteriorating. Several means are today investigated, such as two-step WC tank flushing, pressure valves for apartments giving a set pressure, reduction in faucet flow rates, investigation of the actual needs of the public, etc.

In the field of energy conservation studies have been made for the Federal Government to evaluate district heating and the use of the thermal waste energy of atomic power plants. At the Vocational

CSTB receive an "Avis technique" which is recognized by the Bureaux de Contrôle.

- AFNOR centralizes and coordinates all work concerned with codes.
- Codes can be initiated by everybody.
- For buildings the technical code work is submitted to the Groupe de Coordination des Textes techniques intéressant le Bâtiment (Groupe DTU).
- When a code is requested by a member of the group DTU, it is published in a program and a commission is elected. The members are individuals from industry, trade, the bureaux de contrôle, the CSTB, etc. The draft of the code is submitted by DTU to AFNOR for approval.
- The group DTU has a second function: the issuance of the so-called "Cahiers des charges" which give details on methods of installation and calculations.
- Whenever a project is financed by public funds, the codes have to be followed. In the private sector they are optional. However, the DTUs are widely followed.
- The industries have no own code organization. However, they work intensively in the national organizations.
- The mark NF was established in 1938 by AFNOR. It certifies that a product is in conformity with the standard in question.
- For all materials and building techniques which are not traditional, an Avis Technique (requested by a governmental law in 1969) has to be achieved. The CSTB runs the secretariat of this commission and undertakes most of the tests.

Laboratories

The CSTB and the CEBTP (Centre Expérimental de recherches et d'études du Bâtiment et des Travaux Publics) are the two major laboratories in France for building research. But there exist a number of other technical centers which do research in the field of building technology.

As examples:

- Centre Technique du Bois (CTB): floors and walls of wood;
- Centre Technique des Tuiles & Briques (CTTB);
- Centre d'Etudes et de recherches de l'industrie des liants hydrauliques (CERILH): cement;
- Union Technique de l'Electricité (UTE): all electrical equipment;
- Centre Technique des Industries de la Construction Métallique (CTICM), and
- Centre d'Etude et de Recherche de l'Industrie du Béton (CERIB), etc.

1. Centre Scientifique et Technique du Bâtiment (CSTB)

A. Materials

The CSTB established its laboratories in Champs sur Marne near Paris in 1950. Here, besides other activities, plumbing products and materials are investigated and relevant research is made.

Fundamental work including extensive and long-duration experiments such as hot and cold water cycles, physical and chemical analysis, water absorption, mechanical stress and pressure tests with plastic pipes, joints and fittings, enable a better understanding and classification of this rather new material. With these tests, the wall thickness of various pipe materials and their layout and mounting techniques could be determined.

The work included both drainage and supply pipes. At present, a study of pipes and joints is under way investigating such topics as:

- suitability of different materials for supply and drainage pipes;
- protection of pipes against damage from outside;
- suitability of different glues to join pipes; and
- suitability of different elastic joints for pipe connections.

B. Water Supply

Presently the distribution of hot water in supply installations is being studied with special emphasis on:

- loss of energy in pipes and fittings; and
- investigation of the water consumption by statistical calculations and interviews.

C. Valves and Faucets

In several experiments such as endurance and tightness tests, various aspects of valves and faucets are being investigated. In view of energy conservation, the effectiveness of mixer taps is being studied. The products are also examined in an acoustic chamber.

At present, research includes stop valves, flow valves, check valves, pressure reduction valves, taps and equipment for water treatment.

D. Drainage

Single-stack drainage systems are examined in an eight-story test tower with ample space allowing two full bathroom layouts per floor to be joined to the stack. As all supply lines and fixtures are put in motion by electrical impulses, the tests are operated from a central command post. The pressures developed in the stack or branches are recorded on an UV-Recorder.

CSTB is also involved in the CIB W-62 examining the performance of unvented branches. In the field of drainage, CSTB is currently also investigating the hygienic demands and performance of sanitary appliances.

2. Centre d'Etudes du Bâtiment et des Travaux Publics (CEBTP)

The highest hydraulic test tower at present in the world is operated by the Union Nationale des Chambres Syndicales de Couverture et Plomberie and is situated in the grounds of the CEBTP laboratories in St. Rémy near Paris. In this 20-story test tower, supply and drainage systems are investigated. The pressures in stacks are monitored with electrical sensors placed into the various traps of the fixtures and recorded on an oscillograph which can be connected to a data processing machine.

At present, the CEBTP, which also operates an acoustic chamber, is studying with extensive tests roof water drainage, especially with regard to surface friction and stack-inlet configurations.

Switzerland

Code Structure

Due to the federalistic governmental system, each Swiss city or community has its autonomous building construction authority. More specifically, plumbing and drainage systems above and below ground are approved by local inspectors or community engineers. However, plumbing practice is quite uniform in Switzerland as the various bylaws are based on recommendations which were issued in 1960 for water supply installations and 1966 for drainage systems. Both standards are at present being revised and will receive when printed the status of a national code.

Early Research Work

In comparison to other countries, coordinated research started rather late, being originally the domain of companies and individuals. After World War II the Swiss Association of Gas and Water Works (SVGW) established a laboratory in Zurich. Besides running basic tests and investigating plumbing products, user patterns were established with large-scale inquiries. With these results, and based on the Poisson's probability distribution, a diagram to determine the design flow rates of supply systems was developed.

In 1959 the tallest test tower for drainage research at that time was built at the Vocational Training School in Berne. On this 10-story test set-up the hydraulic phenomena of the gravity-governed two-phase flow could be studied in all details. One of the major advantages of this test tower is its height which allows the simulation of an actual installation in a high-rise

Training School in Berne, the overall performance of water-heater systems are presently investigated.

2. Drainage

A. Sewer Pipes

At the Federal Institute of Technology in Zurich, large-scale experiments are carried out to investigate the hydraulic characteristics and to determine the capacity of steep sewer lines. Sewers with large gradients are fairly common in Switzerland. It is expected that these results will also give additional information for the design of drain pipes for terrace houses built on steep hillsides.

B. Drainage Systems

Although the hydraulics of drainage stacks and unvented branches have been thoroughly investigated in the past on the 10-story test tower in Berne, research activity is still going on. Especially further tests are run on unvented soil and waste branches serving several fixtures. This work is coordinated within CIB WG-62 and several laboratories such as the Centre Scientifique et Technique du Bâtiment (CSTB) in France, Centre Scientifique et Technique de la Construction (CSTC) in Belgium, National Swedish Institute for Building Research (SIB) and Institut für Bautechnik (IBT) in Germany are participating.

C. Roof Drainage

In conjunction with the Swiss Association of Master Plumbers and Sheet Metal Workers, the Vocational Training School in Berne is running an extensive study on the hydraulics of roof drainage, especially with regard to the capacity of gutters of various shapes, lengths and grades.

3. Standardization of Plumbing

Economy is not only a function of optimum performance, technical knowledge and skills of the trade, but also to a large extent of standardized plumbing products and layout techniques. With joint efforts between industry, trade and architects plumbing products, duct and room dimensions have been widely standardized. As a consequence, Swiss plumbing has reached a high level in prefabrication, which has not only increased productivity but also the technical quality of the system.

United Kingdom

Building Research Station

Prior to 1942 there was little organized work related to plumbing and drainage at BRS: the little work that was carried out was confined mainly to an examination of the properties of the materials used. In 1942 as part of national policy a series of committees was set up in the U.K. to study various aspects of post-war building, and one of these committees appointed by the Building Research Board was responsible for plumbing. During the preparation of the committee report, first on plumbing and subsequently on drainage, a considerable amount of experience of current problems was obtained and some of the early trials carried out in the period up to 1945 included:

- testing use of plastics for cold water supply in a full-size mock-up;
- appraisals of the labor times required for installation of plumbing equipment of different materials and the savings that could be achieved by partial prefabrications; and
- some consideration later of soil and underground drainage pipework.

By 1947, a more coordinated approach to research in this field was being adopted at BRE.

Soil and Waste Pipework

A major BRS research project on major above-ground drainage systems started in 1949 and further work on the same theme has been carried out intermittentl up to the present time. This project dealt with the possibilities of simplifying domestic systems currently in use--generally two pipe systems, one serving soil appliances and the other for waste water, and provided with extensive ventilation pipework in multi-story buildings--by carrying out tests in the laboratory and in inhibited blocks of flats. The aim was to provide design data on the Single Stack System, a form of drainage which had already been installed in a number of buildings in London in the 1930s. The data were primarily for dwellings up to five stories high with a compact bathroom and kitchen layout, but also covered performance requirements which were applicable to any above-ground drainage system. Designs were based on the use of British Standard pipes, fittings and appliances.

During the next few years field trials on multi-story domestic buildings enabled the use of the Single Stack System to be extended to 10-story building using a 100mm stack, and to 25-story buildings using a 150mm stack. Some work was also done on the application of Single Stack drainage to hospitals, offices and public buildings and a survey made on drainage systems installed in new hospital buildings.

Research was then concentrated on the development of a design method for the sizing of drainage and ventilation stacks for all types of multi-story build ings, based on information collected from laboratory tests on the flow of air and water in vertical pipes and the losses at branch inlets to stacks. The method used a simplified approach to the actual flow conditions and was published in 1969. This was further developed in the early 1970s and more data collected. All of this work has been consolidated in a new Code of Practice which ensures that all the results of past BRE work were fully and properly applied. This Code is due to be published.

Underground Drainage

BRE has also, in the past, been active on the structural design and construction of small-diameter rigid and non-rigid underground pipelines. In particular, research was on the relationship between pipe strength and the required bedding and cover for different traffic loadings. The work ceased in 1970. A project on the hydraulic design of small-diameter drains serving and close to domestic buildings is currently being carried out. One of the aims is to determine the cause of recurring blockages and relating them to size, gradient, type of pipework and fittings, and the hydraulic loading of the system. A statistical study of the relationship between drain gradient and frequency of blockage has been carried out. Access requirements are also being examined along with the possibility of using curved drains without additional access. Flow depths in installed drains are being measured, and laboratory tests on the attenuation of flow through near horizontal pipes have been completed, which will enable existing design-sizing methods to be assessed.

Water Economy

Meanwhile in the field of water supply interest had been focussed by 1955 on water economy. Studies were made of some of the causes of wastage of water. In dwellings one of the causes was thought to be leaky ball valves installed in flushing cisterns and storage cisterns and work was carried out to improve the durability of the seating surfaces for valves. Another cause of excessive water usage was the quantity of water used to flush WCs, and trials were carried out in a number of dwellings to determine the water saved if dual-flush cisterns were used, i.e., cisterns designed to give the user the choice of either a one-gallon or two-gallon flush. Studies were made of the water used for domestic purposes in office buildings resulting in the development of spray taps for ablutionary purpose which provided economies in the usage of water and in the use of energy and in some cases in installation costs.

In the last two years work has been revived in these fields and studies are being made of further economies; studies of ways of implementing early economies in the existing stock of buildings, and studies of the feasibility of some waterless appliances.

Protection of Water Supplies

The two main fields of protection involved in the water supply system are protection against backsiphonage and protection against explosion of the hot water system. Interest in problems of backsiphonage increased in 1948 after a visit by BRS staff to the U.S.A. where backsiphonage problems were currently being aired in a film entitled 'The Ominous Arms Case'. At the time work was devoted to modification of national standards for appliances. In more recent times, further work has been devoted to appraising and testing the various backsiphonage devices currently available with a view to possible future modifications of national regulations in this sphere.

With regard to protection against explosion, the U.K. has traditionally used cistern-fed, and vented, hot water supply systems. However, an appraisal is being made of the protective devices for mains pressure systems used elsewhere and also an appraisal of the economic assets of such alternatives.

Flow Rates and Flow Velocities

Estimation of demand flow rates from the water supply system and estimates of the flow load applied to drains are similar problems. The first work in this field at BRS was in 1961 and was inspired by the earlier pioneering work of Hunter at the NBS in the U.S.A. using fixture units. This work has been followed up at intervals by a series of different approaches to the same problem backed up by field studies of water use patterns in flats and University laboratories.

Where high pressures are available in the water pipework, the design flow velocities are limited because of noise considerations. For this reason studies have been made to determine practical limits that should be set to flow velocities.

Level of Provision of Appliances

BRS has recently conducted an investigation into pattern of use and demand levels for sanitary appliances in offices and schools and from this work revised scales of provision have been proposed.

Materials

A survey of the performance and maintenance costs of metals used in plumbing has been carried out. This study indicated most problems were already known. However, the use of stainless steel in plumbing has been studied and some aspects are still under consideration.

In the field of plastics, a study was made of the performance of available materials for hot water services.

Performance Testing

Work on the development of performance tests has been carried out primarily for taps and WCs, but also for various valves for protecting water supply systems.

South Africa

National Building Research Institute

1. History of Past Work

   From about 1960 to 1965 the work of the then Sanitation Unit was largely in the field of low-cost sanitation such as night soil systems and evaporation and oxidation ponds. Work was also begun on the development of design criteria for sewers based on large-scale flow gauging and sewer photography programmes.

Investigations were also carried out in the mid-1960s into the behavior of the then new materials for sewerage, namely pitch fibre and uPVC.

In the mid-1960s we also began to look at new drainage systems and materials, particularly single-stack and uPVC. The late 1960s saw a revolution towards the adoption of flexible construction for sewers with the consequent introduction of many new forms of joints for clay, concrete, and asbestos-cement pipes. NBRI played the major role in this revolutionary departure from traditional practice. During this time and right up to the present, we have continued our work on the field behavior of flexible pipes, air-testing of sewers, sewer flow data, sewer design criteria, various types of pipes and joints, maintenance practices and various aspects of plumbing systems.

2. Present Work

Until now we have not had adequate laboratory facilities to carry out much research on either drainage of water sypply systems for buildings. We only entered the water supply field two years ago, but staff shortages have held back the work. Most of our investigation work has thus been in the field with actual systems.

Our new plumbing test facility (tower) has however now been completed and we are beginning a test program of evaluating locally available appliances and fittings to determine discharge characteristics.

Australia

Housing Research Branch of Department of Housing and Construction

Due to Australia's Constitution, each of the Australian States have discrete autonomous plumbing and drainage authorities. Each State has developed its own codes and bylaws and these vary somewhat in content. Consequently, representatives from each State have come together and have formed a Standing Committee on Plumbing and Drainage, with the object of producing a National Plumbing Code for Australia.

In conjunction with the Melbourne and Metropolitan Board of Works, a test program has been commenced:

- Performance of sweep junctions,
- air entrainment at junctions in graded pipes,
- installation of uPVC floor-waste gullies in concrete floors,
- maximum lengths of waste fixture discharge pipes with respect to stranding of non-soluble/syspended matter,
- permissible discharge rates of fully ventilated stacks with respect to relief-vent sizes,
- minimum flushing capacities of WC cisterns, and

- minimum gradients of drains with guaranteed discharges.

Additional projects will be added pending further development of the National Plumbing Code.

Meanwhile the MMBW has done a series of tests on basin waste configurations, and the results of their tests have been included in a Draft National Plumbing Code. This document has been accepted in principle as the basis for future State regulations. We are now in the process of writing a Water Supply Code as a follow-on to the Draft National Plumbing Code.

Japan

Faculty of Engineering, Meiji University, Musashi Institute of Technology

1. Research Activity Developed Before World War II (1945)

   Only within a century, an interest in the field of plumbing has been increasingly paid by scientists as well as general people along with the remarkable progress in technology for this field.

   In Japan, many of the famous contractors and equipment manufacturers in this field had been established during the years between 1891 and 1920 when various legal regulations on water works, sewerage, disposal treatment, etc., relating to towns and buildings were promulgated. From such an age, the fundamental research on plumbing was initiated in Japan.

   In 1934, the Society of Domestic and Sanitary Engineering (which is presently called the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan) established a committee to propose regulations for plumbing based on the consideration that plumbing should no longer be left without any regulations in spite of the fact that no legal regulations have been proclaimed. In 1939, 'Plumbing Standards and its Explanation' was enacted by the committee and published. Thereafter, investigations and research started to be published in the same Journal.

2. Research Activity After World War II (1945)

   During the 20 years after the War, research on the equipment and material of plumbing was performed by related manufacturers. With repeated trial manufacturings and tests, new products were developed. Part of this resulted in the enactment of the Standards of the Society of Domestic and Sanitary Engineering (DSS) and the Society of Heating, Air-Conditioning and Sanitary Engineers of Japan (HASS). From these, many important standards have been transfered into the Japan Industrial Standard (JIS) after the establishment of the same by the Industrial Standardization Law enacted in 1949.

   On the other hand, public research organizations with university laboratories and research organizations for private enterprises are considered to have been engaged in obtaining the design data which comply with the actual conditions in Japan. The theme relating to water demand of a building belongs to the said category.

A. Water Supply

Regarding water demand, much research has been performed up until now, but although research on water demand was made in detail for apartment houses, in the past no satisfactory research was performed for other kinds of buildings. However, with the establishment of the Subcommittee on Water Supply in Building in the Plumbing Code Committee, systematic investigations have been performed on the buildings of the Telegraph and Telephone Corporation, the Municipally Owned Dwelling Houses, other office buildings, etc., based on the consideration that the water demand in application and the peak water demand in a building are important factors employing a new water supply system or a circulating use of water.

In the past, the fixture unit specified in NPC (National Plumbing Code) which permits easy application was adopted in Japan. By employing the NPC unit, however, only a rough estimate can be obtained without securing the precise usage factor or ways of usage. Therefore, with the cooperation of the Tokyo Institute of Technology, the Subcommittee on Water Supply in Buildings specified the unit flow rate for each fixture after analyzing various experiments and investigations on the characteristics of discharge quantity of each fixture, kinds and combinations of the fixture employed by various buildings and the way of usage of the fistures.

Referring to the Plumbing Code of the U.S., the value two times over that of the inside diameter of a water supply outlet was adopted in Japan for an air gap. Up until then, the necessity of not contaminating potable water had been stressed.

For the said purpose, the Branch Committee on the Prevention of Water Contamination was established in the Plumbing Code Committee in order to set up original standards taking various factors into consideration. Experiments and research proceeded with the cooperation of the Faculty of Engineering of Meiji University. With the maximum load of 400 mmHg, an experiment was performed to clarify the conditions of air gap in relation to the load in piping, the dimension, shape and structure of a water outlet, the thickness and shape of the top part of a water outlet, the angle of the top part against the water surface, the effects of accessed wall, and others. As a result of the study, the experimental results and the proposed values were both reported to the Branch Committee on the Prevention of Water Contamination in 1973.

Much research and many studies were performed on the required number of plumbing fixtures in the past. The Subcommittee on the Required Number of Fixtures in the Plumbing Standard Committee investigated the actual conditions in office buildings, schools and theatres, and in 1965 recommendations were made.

B. Hot Water Supply

Results of research into hot water supply were announed in 1961 by the Subcommittee on Water and Hot Water Supply Systems in Apartment Houses established in the Plumbing Code Committee.

C. Drainage

To decide a fixture unit for drainage system, the drain characteristics of a fixture should be obtained as in the case of a fixture unit for water supply systems and research work has been reported in the past. In connection with this program, the Branch Committee on Drainage established in the Plumbing Code Committee proceeded with experiments on the drain characteristics of a fixture, the allowable gradient of a drain branch pipe with the cooperation of the Engineering Research Institute of Tokyo University.

Since we had no standards for the capacity and structure of a gasoline interceptor for an auto garage or for a kitchen grease interceptor in the past, manufacturing of the same had been carried out by considering the examples in foreign countries. To improve this situation, the Branch Committee on Interceptors was established in the Plumbing Code Committee and succeeded in obtaining standards on the optimum capacity for the time being, backed by actual investigations and experiments carried out with the cooperation of the Faculty of Engineering of Meiji University.

Reports on treatments of special waste water were announced as early as 1959 in the form of a study or an article.

The materials for piping have been standardized by governmental, academic and civil organizations such as Japan Industrial Standards (JIS), the Standards of the Scoeity of Heating, Air-Conditioning and Sanitary Engineers of Japan (HASS), the Standards of the Japan Water Works Association (JWWA), etc. However, much attention has been paid to corrosion of piping materials in relation with contaminated water.

Merchandise which contains plumbing such as a kitchen unit, bathroom unit, sanitary unit, etc., have recently been marketed with a tendancy to increase both in variety and quantity and work has been done to standardize plumbing systems to facilitate their installation.

There are many problems to be solved in the future in the field of plumbing. In addition, a new problem of 'Water Saving' has appeared in front of us. This problem includes the decision of optimum flow rate for flushing and of optimum diameter of the drain pipe.

3. Organization and Research Activity of the Plumbing Code Committee

In 1951, the Committee on Revision of Standard Specifications, and in 1958, the Plumbing Code Committee were established in the Society of Domestic and Sanitary Engineering. The former Committee announced 'Plumbing Standard Specifications' from 1955 to 1965. The latter Committee aimed at establishing a Plumbing Code which would fit the Japanese circumstances by reviewing the fundamental items in the plumbing. At the initial stage, the following three branch committees were established, the activities of which succeeded in obtaining a result either through its own research or research submitted by other organizations:

A. First Branch Committee

Minimum requirements for the number of plumbing fixtures.

B. Second Branch Committee

(1) Conditions of drain at various vent systems and distribution of the air pressure variation in a drain pipe.

(2) Measurement on experimental values of unit flow rate from fixture drain.

C. Third Branch Committee

(1) Optimum flow rate and duration of water supply for important plumbing fixtures.

(2) Mounting method of an air cushion pipe and the effect of vacuum breakers for prevention of water hammer.

In 1959, this Committee was submitted the research theme of 'Plumbing System in an Apartment House' by Japan Housing Corporation. In 1961, the research with the theme of 'Rationalization of Plumbing System in Apartment Houses' was submitted, for which the Subcommittee on Water and Hot Water Supply System in an Apartment House was established to perform the following studies:

- study on idling of a water meter;
- study on local hot water supply system; and
- study on central hot water supply system in apartment houses.

The results of the above studies were reported to Japan Housing Corporation. In addition to the original studies of the Plumbing Code Committee and its established branch committees, submitted studies by other organizations were also performed as seen above. From these facts, it can be inferred that an attitude to solve the urgent problems in plumbing by gathering many experts together for advice in the form of a committee was established.

Thereafter, the organization of our Committee was anewed in 1964 by establishing the following subcommittees for research and study:

A. Subcommittee on Proposed Plumbing Code

To propose plumbing standards.

B. Subcommittee on Required Number of Fixtures

To investigate and study the required number of plumbing fixtures.

C. Subcommittee on Plumbing Literature

To investigate and classify domestic and overseas literature and data relating to plumbing.

The results of research activities by the Subcommittees were fully reported.

In one of the reports, 'Plumbing Standards', many of the items relating to numerical values were mentioned as 'to be specified separately'. This backs up our view that satisfactory experimentation and research should be made in order to obtain a final conclusion which is suitable to the actual situation in Japan. During the 10 years since that time, systematic research activities have been promoted with many branch committees established to provide fruitful results.

Denmark

Institutes and Organizations

Research within the field of water supply and drainage for buildings takes place on the Danish Building Research Institute (SBI) in Hoersholm.

Testing of components to water supply and drainage systems is carried out by SBI and JTI (Technological Institute of Jutland).

SBI is an independent institution under the management of a board appointed by the Ministry of Housing. The institution was established in 1947. The annual budget is around $3.5 million for the whole institute and about $2 million for work on water supply, drainage, heating and electrical installations.

SBI is financed 90 percent by the Ministry of Housing grants and 10 percent by research contracts and by sale of publications.

Laboratories and Facilities

About 270 m^2 of water supply and drainage laboratories with a ceiling height of 6 m. Gallery in three storeys for drainage experiments and a nine-storey tower for outdoor experiments.

A noise laboratory is permanently equipped with facilities for noise measurements according to the international standards ISO/DIS 3822/1 and DIN 52218.

The laboratory is made in two storeys with possibilities for other measurements, i.e., noise from stacks running through two storeys and heating systems.

Past Research Work

1. Water Supply

- Noise from water supply system (Project No. F-281).
- Performance requirements related to taps (Project No. F-392).

2. Drainage

- Unvented drainage stacks.
- Drain pipes with small slope.
- Measuring method for discharge characteristics of sanitary appliances.
- Design method for unvented parts of a drainage system.
- Method for designing, testing, and judgment of the trap (Project No. F-243).
- Performance requirements related to water closets (Project No. F-392).

Ongoing and Planned Research Work

1. Water Supply

- Performance requirements related to sanitary components and systems.
- Desposition of calcerous substances in taps and other components.
- Water supply systems designed for saving of water.

2. Drainage

- Performance requirements related to drainage components and systems.
- Performance of systems with water closets using less than eight litres per flushing--an investigation in laboratory and in building.

Technological Institute of Jutland

JTI is equipped with laboratories equipped for testing water closets, taps, check valves, vacuum valves, solenoid valves (water hammer), traps, floor gulleys, thermostatic valves, hoses for washing and dish washing machines. The testings are financed by the manufacturers and the sole agencies of the components. The testing reports are mainly used for getting the approval of the Ministry of Housing.

Finland

Institutes and Organizations

In the field of water supply and drainage for buildings, Finland has been without any official research activity until 1975.

Plastic pipe for underground drainage has been studied for sever years at the Technical Research Centre of Finland and the Finnish Plastic Industries Federation and a lot of results from research and testing are published.

In 1975 water supply and drainage was added to the activities of the Technical Research Centre of Finland (STF). STF is an independent institution under the management of the Ministry of Industry and Commerce.

Planned Work

The laboratories for water supply and drainage research are not finished yet. It is planned to start the activities with performance testing of sanitary components which have to be carried out in connection with the new Sanitary Code. The testing will be familiar to the testing carried out in other countries.

Norway

Institutes and Organizations

The Norwegian Building Research Institute is an independent institute under the management of a board appointed by the Norwegian Technical Scientific Council of Building Research. The budget is about $3.5 million for the whole Institute.

Laboratories and Facilities

The laboratories for water supply and drainage activities are located in a 15 m high building with a floor area of 100 m^2. The laboratories consist of a gallery with four storeys for performance test on drainage systems and noise laboratories for noise measurements according to ISO/DIS 3822/1.

Past Research Work

1. Water Supply

    - Frost prevention of buried pipelines.

2. Drainage

- Plastic pipes in buildings.
- Performance of sanitary installations.

Ongoing and Planned Research Work

1. Water Supply
   - Dimensioning of buried pipelines.
   - Performance requirements related to sanitary installations.

2. Drainage
   - Drainage systems in the buildings.
   - Rehabilitation of sanitary systems.
   - Development of WC drainage with WC using three litres per flush.

Testing Activities

The testing of sanitary components which have to be approved by the authorities at NBI. The testing carried out is very familiar to the testing carried out in the other Scandinavian countries, Denmark and Sweden. The test methods and the requirements for approval are made in collaboration within the group NBS-sanitary.

Sweden

Institutes and Organizations

The National Swedish Institute for Building Research (SIB) is independent with its own board of directors. The Ministry of Social Affairs grants SIB. The budget of about $4 million is mainly finance through the Governmental Council for Building Research.

Laboratories and Facilities

150 m^2 of indoor laboratories for experiments with water supply and drainage components.

Indoor tower facilities for a total height of 40 m and outdoor tower with a height of 120 m (about 45 storeys). Electronic system for monitoring and measuring the pressure and flow variations.

Research Work

The SIB laboratories work 50 percent with contract research, mainly concerning testing of new products.

Development of testing methods according to the Building Code which allow components and systems for which it can be proved in laboratory that they will work satisfactorily in the building. "Water economy" is a new project planned to be carried out. The project takes a total view at the water cycle system and analyzes the possibilities for savings from the borehole to the recipient.

CONTRIBUTED PAPERS

COST BENEFIT ON PLUMBING: LARGE FRINGE BENEFITS FOR SANITARY INSTALLATIONS BY THOROUGH ANALYSIS OF SYSTEM

by

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Some years ago the mechanical industry found a new tool called value analysis. The reason for this was that the production tools of this industry were very heavily engaged. Work study and production analysis had given very good results. But in spite of a well-organized production apparatus, the result was not satisfactory. Due to this, the industry began a value analysis of its products and after a short time the economic situation was, in many cases, considerably improved. How was this achieved?

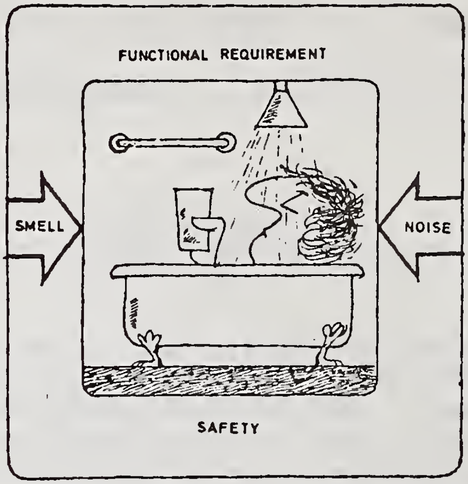
> Value is the lowest total cost for the maintenance of necessary functions at the right time and with desired quality
>
> $$\text{Value} = \frac{\text{Functional properties} \cdot \text{Attractiveness}}{\text{Cost (or price)}}$$
>
> In other words
>
> Value = Good return for money

The producers called together a group of specialists from the departments of production, buying and selling, in order to assess the properties or functions of the product and what it cost the firm to develop these functions in the product. The primary function was first decided upon. Then an attempt was made to find a new product at the lowest possible price which would fulfil the main function. This could often be a surprisingly cheap product, readily available. The products sometimes lacked the most important subsidiary functions. Perhaps also these could be obtained reasonably.

Examples: The same type of valve is used in a motor plant for emptying coolant as is used for draining hot water systems. The primary function is the stopping of water flow. A plug also does this. The price sank to about 10 percent of that of the value. The disadvantage is that the plug could be lost in inaccessible places. A chain was attached to the plug and, even though this doubled the cost, the producer had saved 80 percent of the original cost of the function of emptying coolant.

In other cases the cost may be the same but the functions have been improved so that the market and profits will increase.

Value analysis can also, in principle, be applied to sanitary installations. These are, however, more complicated than many industrial products and it has been necessary to develop a special procedure to separate the main functions from the secondary. The possibility of obtaining a better product for the same price is nevertheless present.

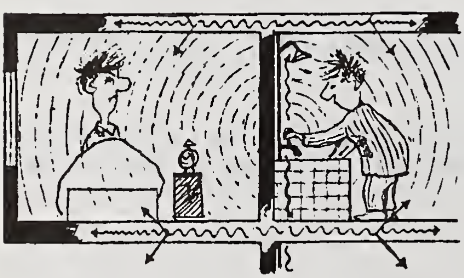


Up to the present we have lacked the functional analysis, which is the most important "tool" in the process. However, this "tool" is now being printed by the Norwegian Building Research Institute. This functional analysis has produced some remarkable results and led to new techniques and constructions. Nevertheless, most important is that the work on the developing of functional criteria has brought to light properties which increase the usefulness of sanitary installations and in which component manufacturers are very interested in cooperating. They have obtained a number of new sales possibilities and a clearer understanding of the improvements they can make, often at moderate expense.

Practical Examples

Previously the noise caused by WC cisterns was very troublesome, especially when the WC was used at night. It was found that the noise was the result of water at high pressure being forced through a small outlet into the cistern. Modification of the small outlet was difficult but the water pressure could be decreased by increasing friction in the system. This could be achieved by reducing the dimensions of the supply. The supply could thereby have a low noise level and, at the same time, the cost would be less. The manufacturers could market a more attractive product and profits be greater.

This procedure can be used for the whole plumbing system. Formerly large diameter copper pipe was used and flow was noisy, e.g. when a bath was filled.



Formerly large diameter copper pipe was used with resulting high noise level during running of bath

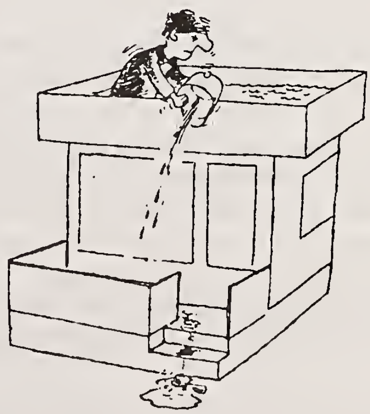
The noise function (low noise level), through the analysis, led to increased friction in the pipe in order to avoid the high water pressure when it was forced through the faucet.

The small diameters and high rates of flow in the pipe necessary to attain sufficient friction also resulted in other functional advantages: Hot water remains in the pipes and cools down between each tapping. The amount of water, however, is small in small diameters and the cost of water heating is thus less. At the same time water flows rapidly (8-10 metres per second) from the heater to the bathtub. Waiting time for hot water is thus reduced.

No waiting for hot water

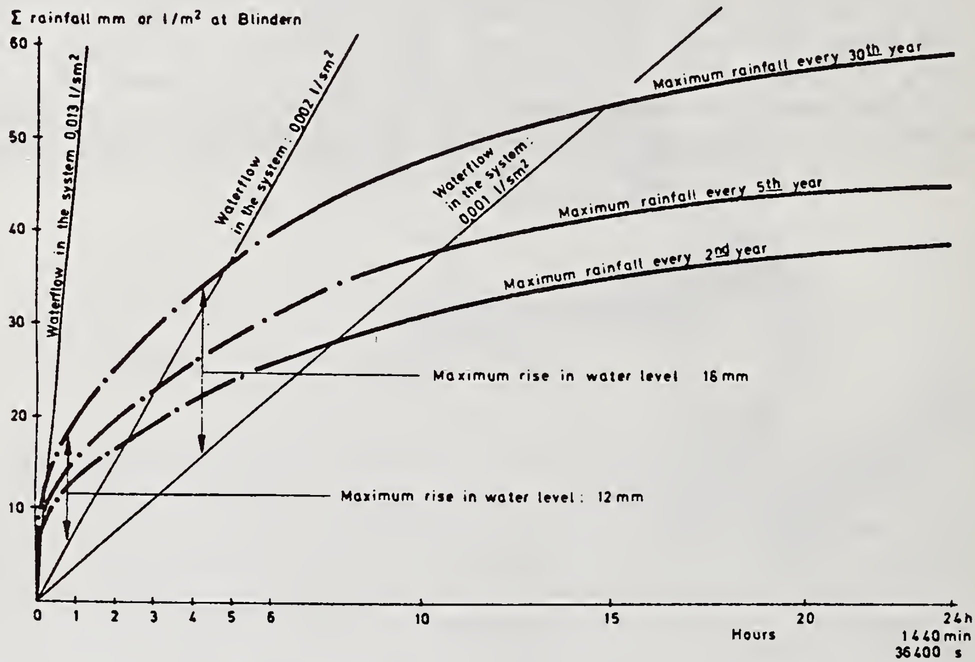
Another example is the function of leading away drainwater. Formerly, leaders were of large diameter in order to lead water quickly off flat roofs, to prevent leakage occurring during heavy rainfall.

Leakage should not occur during heavy rain



The dimensioning intensity of rainfall to avoid damage was assessed, based on the heaviest 10-minute rainfall measured during a 30-year period. This amounts to 200 litres per second per hectar. Analysis showed that heavy rainfall is of short duration and seldom occurs during continuous rain. Without any form for drainage, the roof would receive about 1 mm per minute, but this would only result in a water depth of 10 mm during 10 minutes heavy rain During winter the roof covering is subjected to far greater loading from wet snow.

DIAGRAM 1



The sum of rainfall in heavy rain compared with flow in the storm leader.

Maximum rise in water level is given as the differance between the curve for the rainfall and the waterflow in the system.

Experience has shown that a roof drain becomes blocked by leaves and other objects, with the result that the water will rise right to the top of the roof covering. Water will penetrate under the cornice joint and into the building. Two roof drains are often used to delay blockage by leaves. This, however, will postpone blockage by only about two weeks. The diameter of the leader from the roof drain has no influence on the blockage and therefore has no influence on the run-off rate of rainwater to avoid damage to the roof. The functional analysis showed that the roof must be fitted with a warning system to indicate that the roof drain is blocked. The simplest system is an overflow, which may with advantage lead the water on to the head of the caretaker.

The roof drain shall stop all solid matter which can become jammed in the leader. The roof drain may well allow leaves to pass through if the leader is of small diameter since the water velocity will be very great and self-cleaning good.

The overflow shall run on to the head of the caretaker

Large-diameter pipe, common today, is not only dear in purchase. The space it requires in a building is a considerable problem. Planning is often influenced by it, while at the same time it requires additional construction to obtain a tasteful concealment of the piping.

Functional analysis does not end here. Rainwater for heavy rainfall is very expensive for the community. Large-diameter main sewers are used to lead away the water, so that flooding of low-lying districts can be avoided.

Rainwater is led together with WC and kitchen waste water. Environmental authorities have plans involving the investment of millions for the transport and treatment of this water. Our functional analysis deals also with this aspect. What if we led the rainwater to the groundwater in the district?

A sinking groundwater level creates problems in some places. It results in settlement of building foundations. To counteract this we can lead rainwater from a roof into a rock-filled trench and allow it to permeate to the groundwater at convenient places.

The same procedure may be adopted for analysis of the entire sanitary installation and with success similar to the examples above. Similar work procedure has also been formed by the community for those who will use the aids and tools available. Building specifications and sanitary requirements determine functional requirements as criteria in order that the builder can ensure health and safety for the user. The requirements may be supplemented by the functional analysis which the Building Research Institute is now publishing. Thereby all links in the production process should be enabled to participate in the development of sanitary installations. Thereby they will be more valuable, i.e., the functions relative to the costs will be improved.

ECONOMIC WATER SUPPLY DESIGN BASED ON PERFORMANCE REQUIREMENTS

by

Eskil Olsson
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The increased attention being paid to the cost of water and the need for careful management of our natural resources are two good reasons which justify the development of new water supply and sewerage systems plus the necessary components for them.

Regulations and other steering instruments must, for a variety of reasons (energy, environment, economics, technology), be designed so as to limit unnecessary consumption of water and to stimulate technical progress. Water supply and sewerage systems for individual houses and for entire municipalities are designed and managed as separate entities. Studies of complete water supply and drainage systems, ignoring administrative boundaries, and relationships with the hydrological cycle, should provide new ideas as to possible approaches.

This paper presents three technical innovations developed in Sweden which are now in the process of being launched on the market. These are, the flow regulator, the duct system, and the BPA pipe system. They are all designed to comply with the Swedish building regulations and would together seem to engineer a not-inconsiderable decrease in water consumption. This, along with other trends in Sweden, may have a noticeable influence on the design of water supply and sewerage networks provided by local authorities. The systems have spotlighted certain deficiencies in the present range of pipe fittings and components, along with the need to discuss certain points contained in the regulations.

Flow Regulator

A tap--assuming that its flow pressure properties have been taken into account--is designed to produce a regulation flow at a given pressure. If the pressure is higher, the flow will be correspondingly greater.

However, the pressure in the pipe supplying a tap is often higher than that allowed for at design stage, one of the reasons being that the pressure in the municipal mains networks may vary. Water consumption throughout the day may differ, but the pumps at the waterworks are designed for constant operation. Variations in consumption are allowed for by providing for rises and falls in water levels in the reservoirs; the actual pressure may be 100-150 kPa higher than pressure guaranteed by the waterworks. Another reason is that the design flow in a branch pipe is, as a rule, an overall flow calculated on the basis of the probability of a number of taps being turned on at the same time. Since the design flow is always greater than the regulation flow from individual fittings--and sometimes even much greater--and since it is not usual to turn on more than one tap at a time, the actual pressure immediately preceding a tap will almost always be greater than that corresponding to the regulation flow. A third reason is that with the present range of pipes and fittings, it is difficult to design a stack which maintains a balance between differences in height and differences in flow resistance.

As we have plentiful supplies of water in Sweden and strict requirements regarding the performance of taps, taps in homes and offices almost always permit unnecessarily large flows of water. This can be eliminated by installing special valves in or immediately behind taps. Such valves, flow regulators, have been developed in Sweden in the past five years and are now being launched on the market. These help keep the flow more or less constant at all pressures up to 700 kPa (Figure 1).

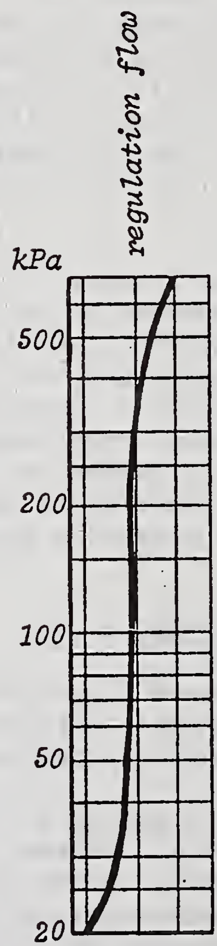


Figure 1 Optimization of flow to regulation flow

The flow regulator is a new product and is thus still open to improvement. We may expect to find them incorporated in actual tap fittings or combinations of the same in the future. The authorities responsible for issuing regulations and standards should make the following general requirements:

- Should a fault occur in the workings of the valve, the device automatically shut off the flow.
- The valve should be difficult to reach in order to prevent interference by laymen.
- The valve should be approved by the appropriate authority responsible for issuing regulations.
- The total pressure drop through valve and tap should not exceed 50 kPa.

Efforts should be made to achieve a better balance in the case of flows lower than the regulation flow. With the present range of tap fittings, the scope for adjustment is a rule too narrow. Difficulties encountered in trying to regulate flow increase with fluctuations in pressure. In general, the torsional angle is between 45° and 180°--in other words, far too short a moment to be able to balance the flow satisfactorily. This is an area in which improvements should be possible.

The next question is whether this technical detail is of any significance in Sweden. There is, for instance, plenty of water.

However, this is not entirely true for all part of the country and the Swedish plumbing industry exports a considerable amount to countries suffering from water shortage. Nevertheless, apart from this, useless consumption of water has a number of obvious disadvantages.

One of these is, of course, that treatment plants, for both supply and waste water, will be unnecessarily large to the corresponding degree. The economic effect of this varies greatly from one municipality to another. In places where there are extensive mains networks and where municipal expansion is taking place at a slower rate than forecast--something which is fairly common in Sweden--there is little to be gained from knowing whether water consumption is rapidly or gradually increasing, or decreasing. On the other hand, in municipalities where the authorities worry over the possibility of future deficiencies in capacity, a change of only 1 percent or so in annual consumption can have notable economic effects. The investments under consideration may concern sums corresponding to thousands of dollars per inhabitant. All local authorities will, for other reasons, be forced to raise their water rates, and in most casts by amounts in excess of those corresponding to the rate of inflation.

Another disadvantage, and this applies to all consumers in all Swedish municipalities, is that all water used by households almost always contains a certain amount of hot water. Hot water costs energy and in Sweden there is total unanimity in political circles as to the fact that unnecessary consumption of energy should be avoided. Measures to this end in other spheres receive substantial state aid. The Swedish Parliament has passed a resolution whereby all flats in Sweden are to be fitted with their own individual hot water meters.

There are also certain other tendencies in developments in Sweden which must be taken into account. Urbanization has at least for the time being entered a less hectic phase. Housing construction has undergone a marked decline and is expected to remain at a level corresponding to 75 percent of the volume constructed over the period 1955-65 in the years ahead. On the other hand, we have a large stock of "middle-aged housing" which we shall soon have to do something about systematically on a large scale. This modernization operation, which will among other things probably involve combining small flats to form larger ones, will often also mean the installation of entirely new plumbing systems and sanitary facilities.

As far as we can judge, water consumption per capita has stopped rising. Practically all homes in Sweden now have hot and cold water supply, WC and bath. Thus, even if improvement continues to be made in the standard of housing involving more such appliances per person, the total time during which they are in use will not necessarily increase.

WCs manufactured a few years ago consumed 9 litres every time when flushed. Those now on the market consume 6 litres and work is progressing on the development of WCs needing only 3 litres. There is also a type of closet known as Multrum in which latrine waste and household refuse are converted into compost and which consumes no water at all. At present, this type is used only in holiday chalets; there are also certain problems of odor. Various manufacturers are, however, considering the possibilities of developing variants on this theme, which would be approved for installation in permanent residential areas.

There are thus good reasons and ample scope for limiting water consumption. We would seem now to have reached a point at which the grown curve is leveling out. We may even find that water consumption falls. At all events, this puts many engineers in the municipal water and sewerage field in an entirely new situation.

In other words, the flow regulator has emerged at a point in time which renders it interesting news.

The Duct System

The duct system involves the installation of water and heating pipes according to the method long in use for electric wiring. Ducts and junction boxes are built into walls and floors. Soft piping of iron, copper or plastic is then inserted into the ducts and connected in the junction boxes. Ordinary metal coil piping with a minimum bore of 75 mm is used for ducting (Figure 2).

The duct system has three major advantages compared to conventional systems. Firstly, installation of plumbing need not be coordinated with erection of

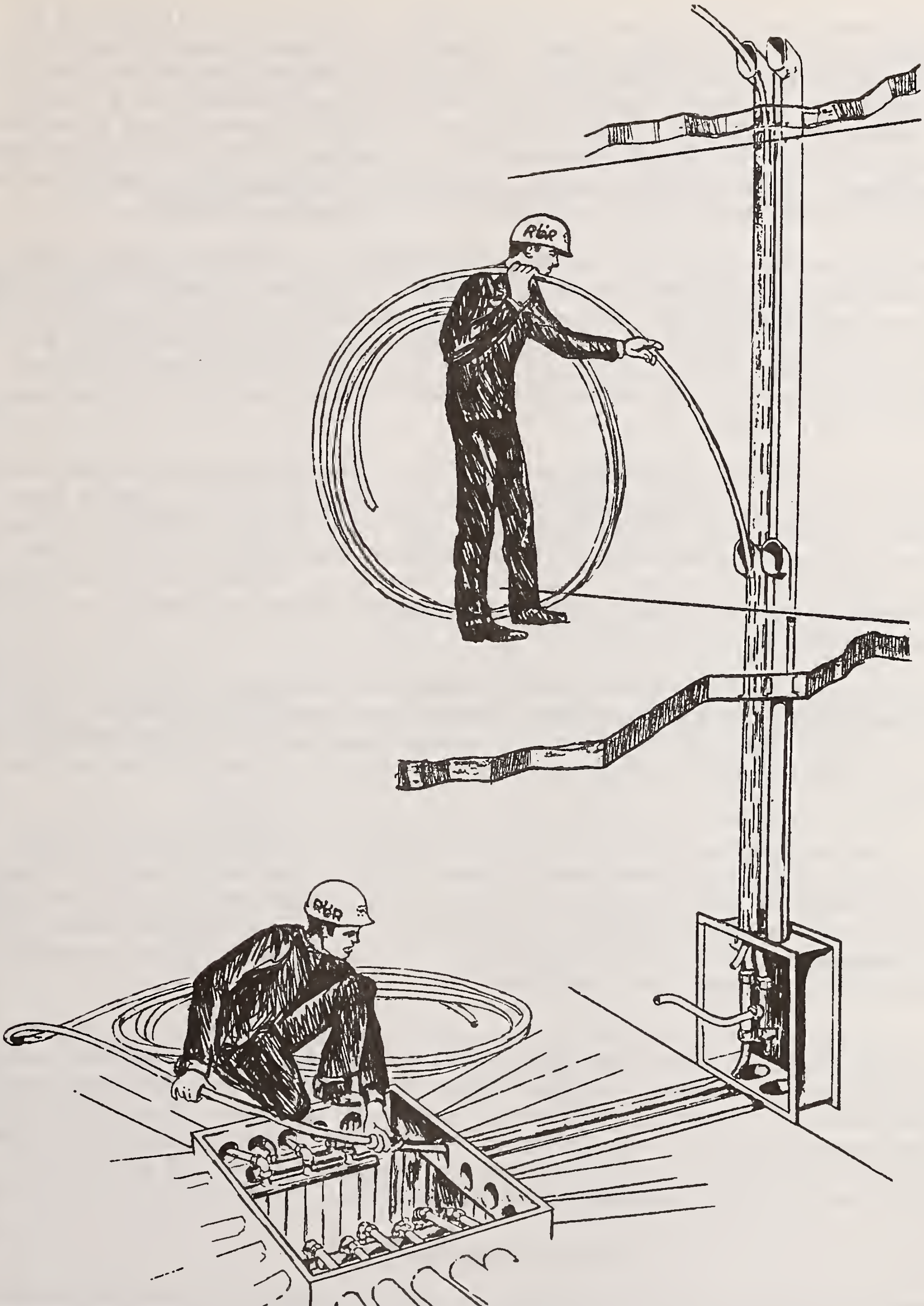


Figure 2 Duct system

the load-bearing structure and a clash between two trades as dissimilar as concreting and plumbing is avoided. Secondly, the piping used is easy to inspect and replace; this facilitates future alterations and may in some cases mean that greater stresses may be permitted on materials, e.g., higher water velocities in copper pipes. Thirdly, any water leaking from pipes is filtered off into the drainage system, thus reducing the risk of damage caused by overflow. In the past few years, the amount of damage caused by water has increased a great deal, and along with it the insurance premiums.

The duct system requires the use of soft piping. In addition, the diameter of inner pipe must be considerably less than that of a duct to permit insertion. There are many reasons for keeping diameters as small as possible--space, fire safety, acoustic insulation, materials consumption, handling expenses, etc. Since thick piping is also difficult to bend, it is natural that an effort should be made to produce the smallest possible bores and the thinnest possible walls for water pipes.

Experience gained from completed projects has shown that copper piping should not be of a size in excess of 22x1. When the pressure is low, such a pipe is capable of supplying a limited number of taps. It is also difficult to connect branch pipes inside ducts. It is therefore necessary to work with a large number of rising pipes, a situation from which advantage can be derived. Two systems connected in parallel involve smaller pressure losses than one system connected in series.

The smallest possible bore for pipes assumes that we avoid trying to transport unnecessarily large quantities of water and that the velocity of the water is high. The amounts of water flowing from taps should not exceed the standard flows. Also, the best possible use should be made of the pressure available.

This brings us back to the need to avoid unnecessary consumption of water. It is also obvious that it is best to have a high pressure in municipal mains. The duct system is one which favors pipes and couplings which will stand up to high pressures and velocities. Copper piping is less suitable than plastic. Development work is in progress with a view to reducing the pressure drops occurring in bends and coupling.

It will be fairly obvious from all this that some of the prerequisites for the duct system have little in common with the conventional systems of water supply, e.g., large numbers of small-bore rising pipes. Careful dimensioning is also essential to ensure that every chance may be taken of producing the smallest possible bores. The BPA Group, which has developed the duct system, have therefore also developed a system for standardization and simplified design of water supply in residential buildings.

The BPA Plumbing System

The BPA plumbing system offers scope for taking advantage of the consequences of the duct system. If properly exploited, it means lower water consumption and thus lower energy consumption for hot water supply. However, as long as there is no noticeable water shortage, it is two other factors which will decide whether the system is to be used or not. One is that it must be possible to use the system as a standard element of new construction. Development work has therefore had to take the following points into account:

- The system should comply with the regulations applying for the water and sanitary engineering field.
- It must be possible to assumble it using pipes and fittings already on the market and to connect it to existing appliances.
- It must provide scope for selecting the materials and components which offer the greatest advantages in each individual project.
- It must be applicable with all ordinary floor plans.

The second factor is that:

- The system must be competitive in economic terms.
- It must have a rationalizing effect on different phases of construction.

This goal is illustrated by the series of sketches in Figure 3.

However, standardized design inevitably means that certain means of making savings, which could be taken advantage of through meticulous planning of individual projects, will be bypassed. Further, if this saving potential is greater than the corresponding design costs, the general standard will not be applied. Standard designs must therefore have potential for adoption to individual projects.

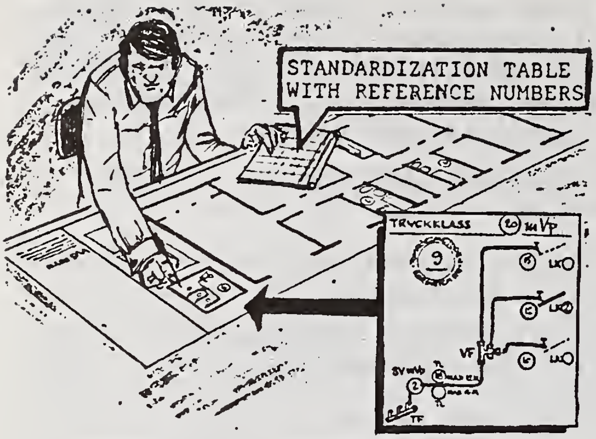
The difference in prerequisites are of course small in housing construction where there is large-scale production of similar units. It was therefore decided to develop the system initially for use in two- and three-storey blocks of flats, a category of building which represents a large share of the total construction volume. The unit in question is the stairwell, all such stairwells being similar in dimension regardless of where they are erected and by whom (Figure 4). But, even given this limitation, two other forms of variation in prerequisites remain, i.e., the pressure in the municipal mains and the floor plans applying for stairwell sections.

It was therefore considered best to begin by developing the system as a method requiring standard design of water supply pipes in two- and three-storey blocks of flats with the scope for variation required by pressure in municipal networks and different floor plans.

Principles of the System and Approach to Calculations

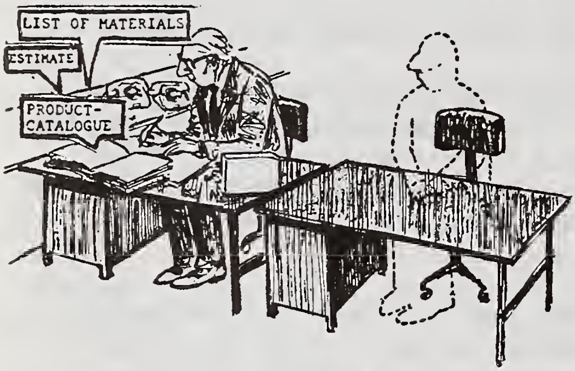
The system can be divided into two main parts--the basic structure and facilities served.

The basic structure can, in its turn, be divided into two parts. The first of these comprises installations from and including the point of connection



When the sanitary engineer receives the architects drawings, he looks up the reference number given by the architect in his standard table and notes down the data given in the table No drawings referring to water pipes in vertical parts of individual floors are needed.

BUYER = SPECIFIER OF MATERIALS



Since the system consists of standardized components specified in a product catalogue, no special specifications are necessary as regards materials.

ON SITE:

SIMPLIFIED CHECKING IN, CONTROL AND STOCKING OF MATERIALS

The question of stocks is simplified thanks to the limited range.

Figure 3 Example of rationalizing effects

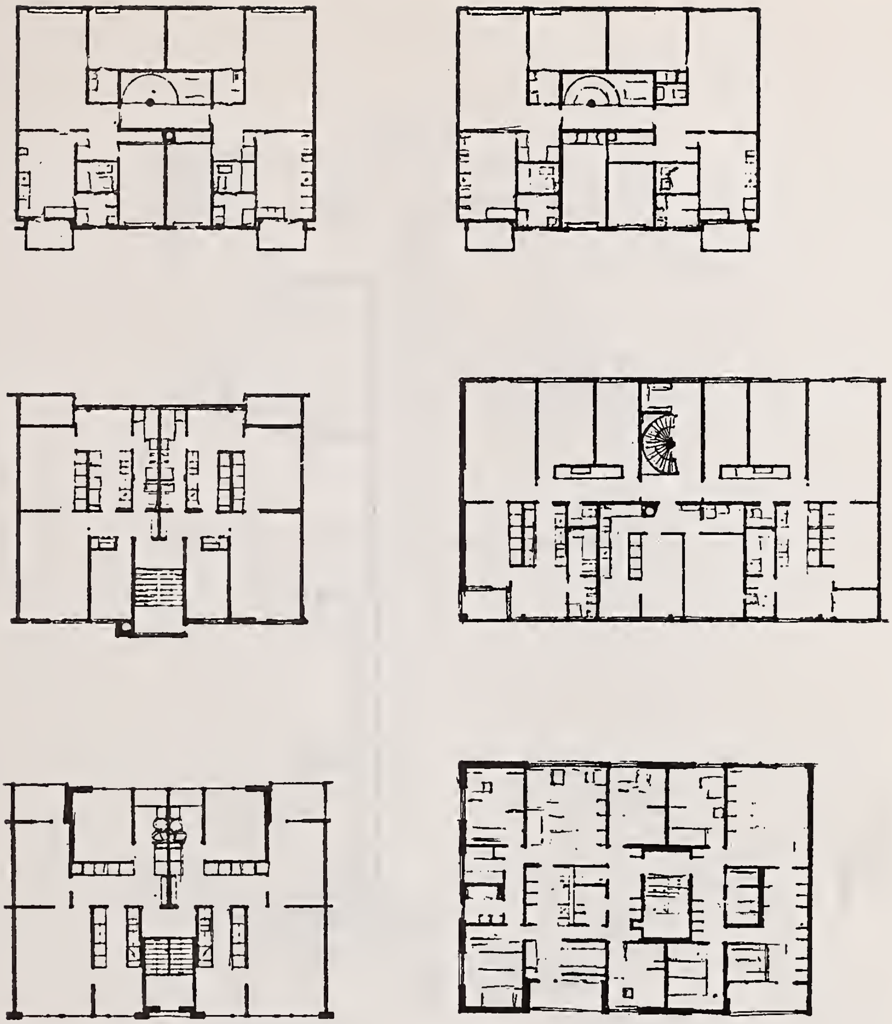


Figure 4 Floor plans in blocks of flats in the journal Arkitektur 7.1968. Scale 1:400

in the conventional plumbing system (ground floor in stairwell, TF) and up to the floor connection (Figure 5). The base slab of each stairwell contains a distributor device (Figure 6) which distributes water through pipes in the floor of the stiarwell (TL) to one or more individual floor distributors (VF) (Figure 6), from which a rising pipe supplies each floor. These rising pipes (VL) continue into the second part of the basic structure on the individual floors and are an extension with a maximum length of 2 m of the rising pipe (FR-VL, Figure 7). The purpose of this particular component is to make it easier to adapt the system to the prerequisites offered by floor plans. This extension of the rising pipe may lead to individual appliances or junctions of several pipes connecting a number of appliances; some examples are given in the figure. One of the major problems in

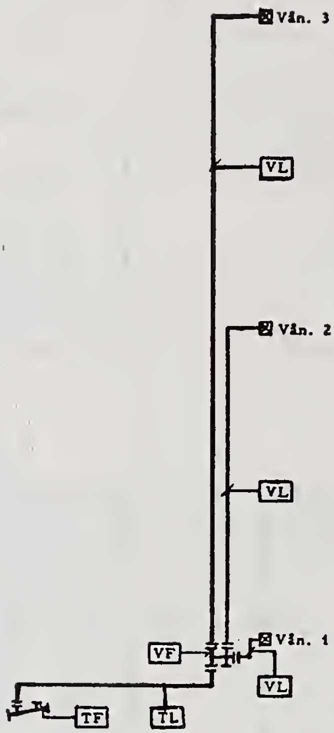


Figure 5 The BPA Plumbing System - Basic Structure Part 1.

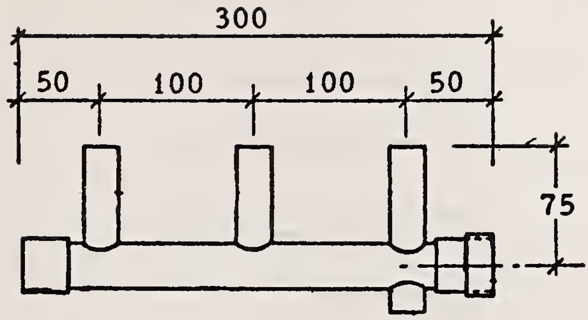
⊠ connection to the floor

TF central ground floor distributor

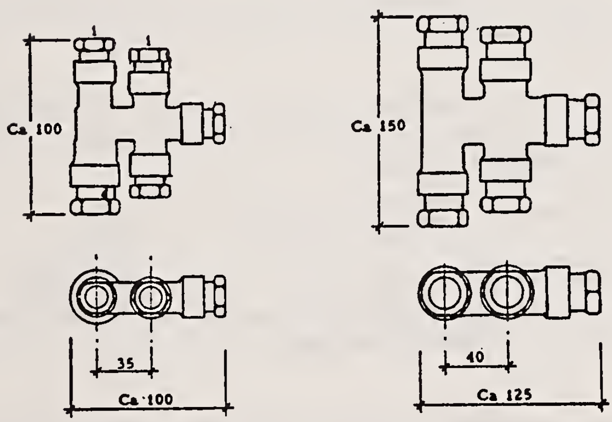
TL branch pipe

VF individual floor distributor

VL rising pipe



Central ground floor distributor (TF)



Individual floor distributors (VF)

Figure 6 The BPA Plumbing System

Central ground floor distributor (TF)
and individual floor distributor (VF)
Scale 1:5

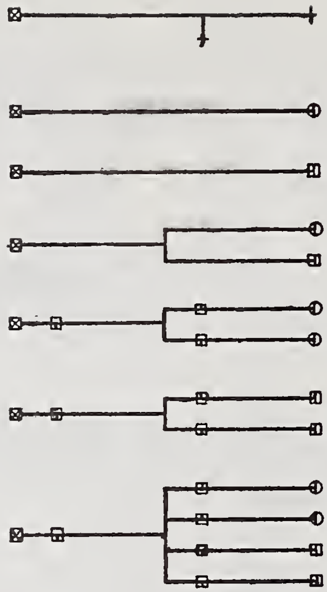


Figure 7 The BPA Plumbing System - Basic Structure Part 2 - extensions of rising pipes serving individual floors.

⊠ connection to the floor

⊥ individual tap

⊕ ⊞ junctions for connection of pipes to a number of taps

developing the system has been to establish how these different possibilities should be classed and described. However, lack of space prevents me from getting into the details of this dilemma.

Different combinations of tap fittings can be connected to the various connection points in Part 2 of the basic structure. These systems of pipes and fittings together constitute the facilities served and are steered by the appliances normally found in kitchens, bathrooms, WCs, etc. The systems used in each type of room can be standardized by definition of a "least favorable instance" and assignment of pipe dimensions accordingly. An example of this is given in Figure 8. However, the facilities (bathrooms, kitchens, etc.) may vary in number and location. Standardized systems for kitchens and bathrooms can therefore offer a large number of different combinations. Each of these (a total of 30 versions of the facilities in question have been studied) can, however, be reduced through calculation to two requirements

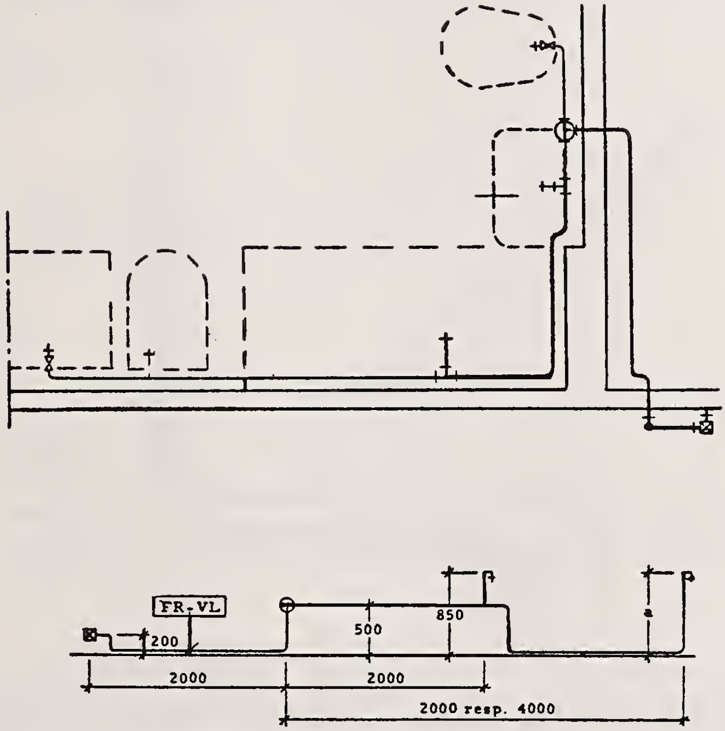


Figure 8 The BPA Plumbing System - Examples
of "the least favorable instance" for dimensioning of facilities served.
Plan and cross-section through length of pipe.

referring to pressure and flow at the end of the rising pipes. These two values have subsequently been used in making the calculations for the basic structure of the system.

The height of the basic structure is determined by the standard storey height (Figure 9).

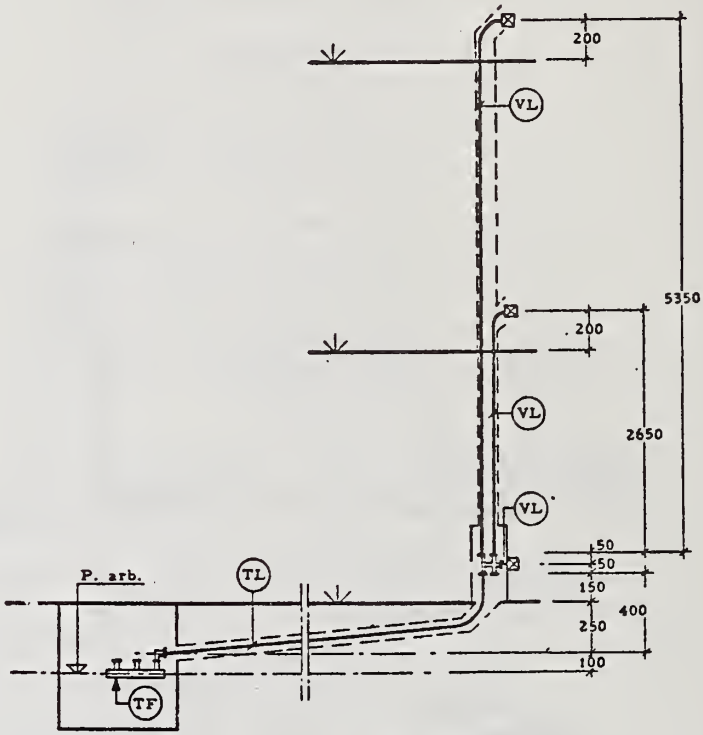


Figure 9
The BPA Plumbing System - Height in basic structure

It has been assumed that the maximum length of the pipe between the central ground floor distributor (TF) and the individual floor distributor (VF) will be 12 m, and the system has been designed to accommodate each two-metre interval.

The flows to be maintained in fittings in Sweden are governed by the regulations for water and sanitary engineering, which specify regulation flows of 0.4 l/s for hot and cold water in bath taps, 0.2 l/s for shower and sink fittings, and 0.1 l/s for taps supplying washbasins. The regulations also specify the design flows for pipes supplying two or more outlets. The probable flow is calculated on the basis of the probability of more than one tap being turned on at the same time.

The regulations for water and sanitary engineering also contain instructions regarding the greatest permissible velocity for water in copper pipes.

As such systems consist of a multitude of different components, it is also essential to know the pressure drops involved. When it was found that components of identical function exhibited different pressure drops, it became necessary to carry out systematic tests on all components which may be used. Five hundred components have been examined and some 3,000 measurements have been taken. Reference curves (pressure-flow) have since been constructed on the basis of this material for the different component types in question.

A special test rig was used to study pressure and flow in the components. The values obtained were then fed into a computer for processing and resulted in regression curves, regression coefficients and standard deviations (Figure 10).

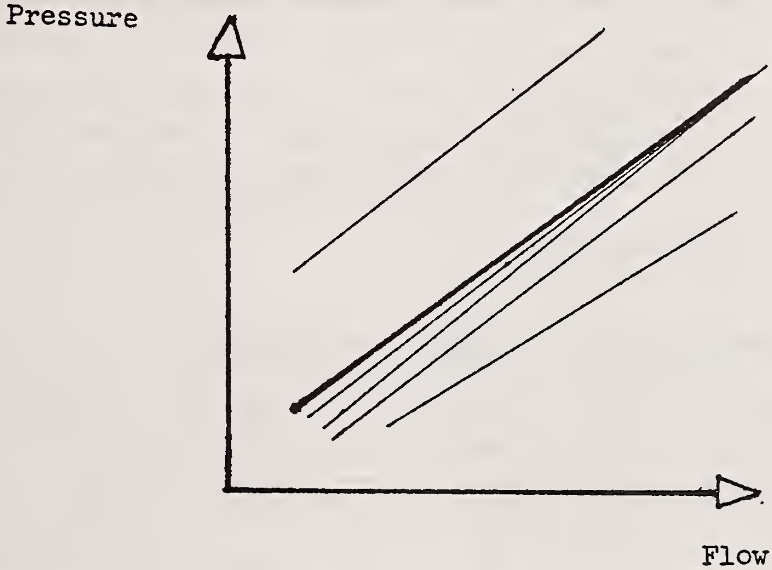


Figure 10
The BPA Plumbing System - Principle governing choice of reference curves for pipes and components

______ reference curve

______ regression curves for variants tested

Dimensioning

First, a summary of the prerequisites for dimensions.

The system consists of a basic structure plus facilities served, a large number of different arrangements being possible for the latter. A "least favorable instance" was established for 30 variants and dimensions were fixed on the basis of flow requirements set out in the water and sanitary engineering regulations and pressure drops recorded during tests carried out at our laboratory. In each case, dimensions were fixed in two different ways: a smaller bore requiring higher pressure (H) and a larger bore requiring lower (L). In two of the variants, H and L coincide.

Floors are assumed to be identical.

Table 1
The BPA Plumbing System
Table for dimensioning (low-pressure alternative) of the basic structure with facilities served consisting of one bathroom per floor

WORKING PRESSURE ZONES AND DIMENSIONS OF PIPES									
Working pressure P in TF inlets, excl. fittings	Branch pipe (TL) Limit markings: ——— Copper hot water pipes - - - - Copper cold water pipes Lengths in meters Min. bore D_i in mm						Rising pipe (VL) and extension (FR-VL) up to facilities served Min D_i in mm		
P	Meters/D_i		D=double pipe				Floor		
kPa	0-2	2-4	4-6	6-8	8-10	10-12	1	2	3
> 200	16	20	20	20	20	20D	16	16	20
> 210	16	16	20	20	20	20	16	16	20
> 250	16	16	20	20	20	20	13	16	16
> 260	16	16	16	20	20	20	13	16	16
> 280	16	16	16	16	20	20	13	16	16
> 290	13	16	16	16	16	20	13	16	16
> 400	13	16	16	16	16	20	13	13	13
> 410	13	16	16	16	16	16	13	13	13
> 430	13	13	16	16	16	16	13	13	13
> 460	13	13	13	16	16	16	13	13	13
> 500	13	13	13	13	16	16	13	13	13
> 530	10	13	13	13	16	16	13	13	13
> 540	10	13	13	13	13	16	13	13	13
< 700	10	13	13	13	13	16	13	13	13

Sum of regulation flows connected Q = 1.80 l/s in branch pipe

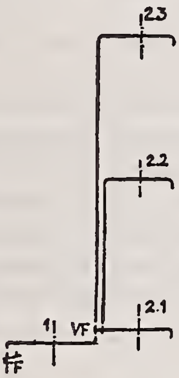
What then remains is to dimension the basic structure for each of the 58 cases (2x30-2). Pressure drops in pipes and fittings are those recorded in the course of tests at the plumbing laboratory. The lengths of rising pipes to individual floors are fixed. Branch pipes at ground-floor level, on the other hand, may be 2, 4, 6, 8, 10 or 12 m long.

It must be possible to vary the pressure in central ground-floor distributors depending upon the pressure in the municipal networks. Calculations have been made for every 10th kPa between 210 and 690 kPa, a total of 50 instances.

This leaves us with a total of 58x6x50 cases for which dimensions must be fixed. A computer is therefore necessary.

However, the prerequisites already mentioned offer no uniform solution to the problem of dimensions.

The following series of equations can be used:



Bernoulli's theorem for sections 1 and 2•3

Bernoulli's theorem for sections 1 and 2•2

Bernoulli's theorem for sections 1 and 2•1

Equation of continuity for floor distributor (VF)

The system allows for four unknown quantities, i.e., flows can be determined if the dimensions are known. However, our position is just the reverse; the flows are known and we need the pipe dimensions and these may vary. We must use five dimensions between 8 and 20 mm (bore). In choosing between these, the main consideration was that the total cost of piping should be as low as possible. An example of the results obtained is given in Table 1.

Separate calculations were made for each version of the facilities to be served. We began by making calculations based on a 6m-long branch pipe at ground-floor level. This gives us four unknown bores--for branch pipe and the three rising pipes. Each one may assume one of the following dimensions: 8, 10, 13, 16 or 20 mm. The computer calculates the necessary working pressure preceding the ground-floor distributor (TF) for all combinations (4x5 = 20). The combinations are then assembled on the basis of this pressure. Among those requiring a maximum of 200 kPa, the computer will chose the one involving the lowest total cost of piping and this is subsequently adopted for the 200-210 kPa interval. The computer then chooses from among all combinations the one which involves the lowest cost of piping at 210 kPa and which can be used in the 210-220 kPa interval. The computer thus draws up a table consisting of 50 lines, one for each interval of 10 kPa between 200 and 700 kPa in working pressure preceding the ground-floor distributor.

Data are later added to the table on the dimension of the branch pipe (TL) when this is 2, 4, 8, 10 or 12 m long. The dimension of rising pipes to individual floors is then for the sake of simplicity assumed to be the same as when there is a branch pipe (TL) 6 m in length.

In its printout, the computer reproduces only the lines in which changes occur.

The system can thus by and large be described as 58 such tables for two- and three-storey blocks of flats along with the accompanying rules and restrictions governing measurement. The most important of these rules is the restriction of the field of use permitted for copper pipes, shown by the full black lines and broken lines respectively in the table. Dimensions below these lines may not be used for copper pipes because the water velocities involved are too high.

Flow Regulators

A flow regulator is an essential ingredient of the BPA Plumbing System. Earlier in this paper, I mentioned three reasons why the actual flows often exceed those calculated for when deciding dimensions. The same course applies in the case of the BPA System. However, in this case, the important point to bear in mind is that dimensions are small. Larger safety margins would be necessary in the absence of flow regulators, which would have produced increases in dimensions that might represent a threat to the economy of the system.

Use

Methods have also been developed to simplify documentation routines and drawing operations. All data on dimensions and parts are given in a catalogue. All the designer has to do is check that installations included in his project fit into the frameworks sketched in the catalogue and to mark the locations of those installations on the architect's plans. This means that there is no need to provide separate drawings of hot and cold water systems, since they are identical. To make things still easier, BPA provides ready-printed transfers which can be stuck onto plans, the only thing required of the designer being to fill in the appropriate data referring to the basic layout of the system.

Thus, the main task of the designer will be to decide which of the 30 different combinations of kitchen and bathroom facilities are to be used on his project, i.e., to judge which of the solutions will prove least expensive. To do this, all that he needs in addition to details of cost of materials and labor are the data found in the catalogue and on the plans. The standardized design also makes it easy to establish unit prices for different parts of the system. These cost data can of course also be fed into the computer and be coordinated with the program used to produce the dimension tables. It would also be possible to correct these without delay, should changes occur in the cost relations between different components.

Admittedly, the system is based on the principle of a duct plus flexible internal pipework. However, the results obtained do not necessarily require this arrangement. Hard pipes can be used and installed in slots in walls or made replaceable by some other means. The general version of the system calls for the use of two special distributors. However, in two-storey buildings, it is better to use T pipes instead of individual floor distributors. In buildings with basements, the ground-floor distributors (TF) and branch pipes (TL) can be suspended from basement ceiling and the distributor can be replaced by a T pipe under certain conditions specified in the catalogue.

The system is thus to all intents and purposes a system for dimensioning and design. In other words, it is an open system unrestricted by the need to use special materials and components. Both the distributors can be purchased separately. As all appliances, with the exception of WCs and washing machines, are assumed to be fitted with flow regulators, it is also possible to use pipes and fittings offering less resistance to flow than that specified in the dimensioning tables. The same, of course, applies if facilities served on a given floor are fewer than the number assumed to permit the use of a particular dimensioning table.

The tables assume a maximum pressure drop in tap fittings and flow regulators of 50 kPa. Anyone requiring a fitting producing a greater pressure drop can make corrections for that difference by reducing the working pressure before the water reaches the ground-floor distributor by the same difference. Similar corrections may be made if the storey height is in excess of 2.7 m.

Comments

Tests of components carried out in conjunction with the development work have shown that there is ample scope of designing cheaper installations. A few examples are given in Figure 11.

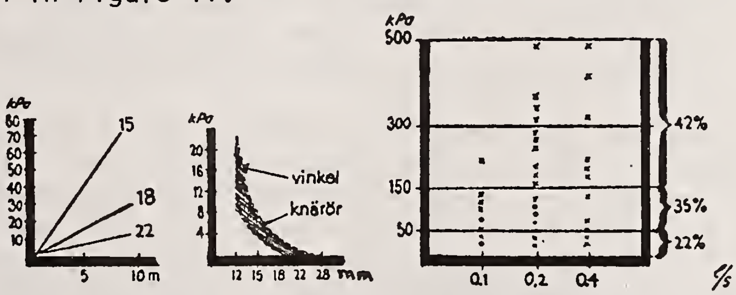


Figure 11 Pressure in pipes, components and fittings

The diagram illustrates systems of pipes represented by three pipe dimensions. They are given as equivalent lengths of pipe. The length of pipe can then be compared to the required pressure and the cost associated with it. Surplus pressure makes it possible to reduce the costs by decreasing the dimensions.

Secondly, we can see that components with the same function have different requirements regarding pressure and therefore affect costs to differing extents. Smaller pressure drops in components permit a reduction of dimensions.

Thirdly, the pressure requirements refer to fittings in use today. The diagram shows the scatter found at present. Pressures of less than 50 kPa (the value specified in the regulations) apply for only 22 percent of the fittings tested. The marked scatter makes it difficult to design installations satisfactorilly. Large gains stand to be made here.

Figure 12 illustrates the approach from the technical and economic points of view. Pressure and costs are parameters used on the x and y axes respectively.

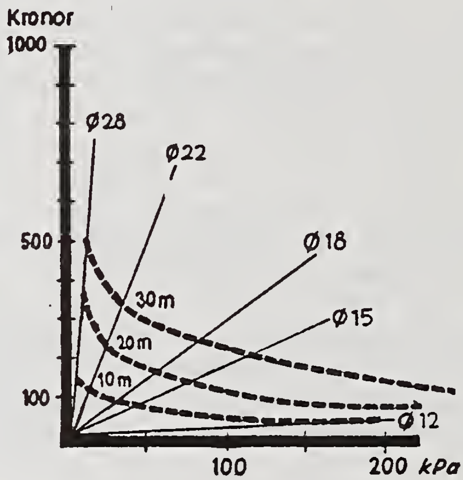


Figure 12
Principle governing solution from the technical and economic standpoint

The systems represent the dimensions 28, 22, 15, and so on. Cost curves are inserted into this diagram to represent different systems of pipes of equivalent worth. The diagram shows that higher pressures mean smaller dimensions and a saving of between 100 and 150 Swedish kronor per unit.

Work on the system has thus shown quite clearly that high pressure is of economic significance. A similar effect would be achieved if the regulation flows were to be reduced. In Sweden the regulations state that bath fittings should produce a flow of 0.4 l/s, while shower fittings need only produce half of that. The high figure specified for bath fittings can be questioned. As Table 2 shows, the regulations for bath fittings force the pressure requirements up by 200 kPa or more, something which has marked economic consequences.

The BPA system also gives us reason to question the suitability of fixing a regulation flow for each individual fitting. It is this which lies behind

Table 2
The BPA Plumbing System

Necessary working pressure (P) in part of pipe immediately preceding the central ground-floor distributor (TF) to permit the use of bores of less than 20 mm in the basic structure of the system installed in three-storey buildings (low-pressure alternative) when the branch pipe (TL) has a length of 12 m.

Combination of facilities	P
1 bathroom	410
1 bathroom + 1 separate shower	490
1 bathroom + 1 kitchen	460
1 bathroom + 1 separate WC	460
1 bathroom + 1 kitchen + 1 separate WC	500
1 bathroom + 2 kitchens	530
1 bathroom + 2 separate WCs	510
2 bathrooms	520
2 bathrooms + 2 separate showers	650
2 bathrooms + 2 kitchens	590
2 bathrooms + 2 separate WCs	590
2 bathrooms + 1 kitchen	570
2 bathrooms + 1 separate WC	570
1 shower	210
1 shower + 1 kitchen	240
1 shower + 1 separate WC	240
1 shower + 1 kitchen + 1 separate WC	260
2 showers	300
2 showers + 2 kitchens	350
2 showers + 2 separate WCs	350
1 kitchen	200
1 kitchen + 1 separate WC	210
2 kitchens	210
2 kitchens + 2 separate WCs	300
1 WC	200
2 WCs	200

the 58 variants found in Table 1. When flats are fitted with their own water meters for hot water, each home will as a rule also have its own connection to the rising main. It should be possible to fit this connection with a regulator, just as in the case of tap fittings, etc., to avoid unnecessarily large flows. It would then be reasonable to instead establish standard values for pressure and flow at junctions to individual flats. This would reduce the 58 variants to a single table.

These measures, and others, would together reduce water consumption and necessary investment. A development in this direction raises a large number of questions. Would a reduction of water consumption make it possible to treat waste water in the building itself or at least in the housing area? Will water volumes become so small that it will be possible to heat water locally in taps and thus eliminate the need for a separate hot water system? What will the consequences be in terms of alternations and repairs; are the existing pipes, if they can be used, too large from the economic standpoint or can the unnecessarily large flows be neutralized by flow regulators?

Finally, a few words about municipal water mains and sewerage systems. Figure 13 shows a cross-section through the water source and water tower and

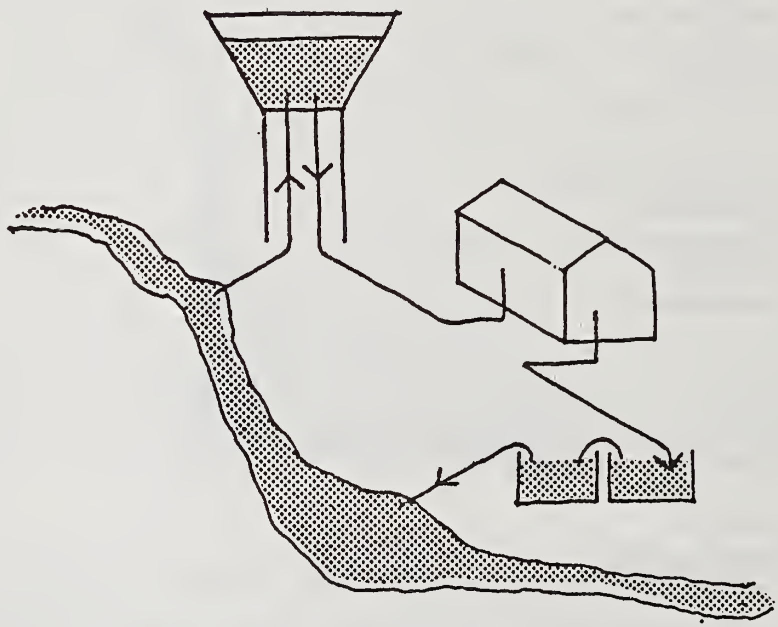


Figure 13 From water source to recipient

up to the sewerage treatment plant and recipient. I have included a building in which incoming water is used and converted into waste water. It is assumed that the volume of waste water will be identical to that of the fresh water used in the building; this is also probably true in general, although few field measurements are available on the subject. If the building consumes a smaller amount of fresh water, the level in the water tower should remain at a more stable and higher level, while the amount of water at the treatment plant should decrease--at least in principle. I have three remarks to make on this.

Within the systems of water supply found in Sweden today, the authorities are only in a position to limit the amount of water used by households in times of crisis. The means available are far too clumsy to permit application of such restrictions on a permanent basis.

Flow regulators fitted to all taps and water meters in all homes provide administrative and economic means--taxes, rationing, progressive tariffs--which can be adjusted according to the size and needs of individual households and given consumers the opportunity to decide for themselves how and when they want to save water. Flow regulators and water meters provide the community or the water authorities with scope for developing civilized means of influencing water consumptions, even when supplies are normal. It is even possible to say far in advance with the aid of forecasts and expansion plans when or in what situation the authorities expect that cuts will be necessary in water consumption and what such measures may involve.

The prospects of being able to control water consumption within certain limits make it worthwhile discussing how a reduction in consumption--at least in relation to forecasts--should be made use of. Should the waterworks maintain a higher and more even pressure and perhaps even install pumps for increasing pressure in situations where this is at present considered unnecessary? Since higher pressure reduces the cost of pipes in a building, the charge made for connection to the mains should perhaps be made dependent upon pressure. Or will studies and experience of measures to cut consumption produce entirely new solutions to those offered by available methods to guarantee domestic water supply?

Lower water consumption may entail a risk of blockages in waste water systems, while at the same time resulting in smaller volumes at treatment plants. The first of these two possible consequences is undesirable, while the second is advantageous. However, there is an element of uncertainty in both statements. We know very little about how much water, and what, runs through the municipal drainage systems. We do know, on the other hand, that much of the waste water leaks out of the pipes and that large quantities of groundwater find their way in. In collaboration with the National Environmental Protection Board, the plumbing laboratory is planning a series of flow measurements and analyses of contents of municipal sewage.

Acknowledgements

The work of preparing this review formed part of the Research Program of the plumbing laboratory belonging to the National Swedish Institute for Building Research. The systems and products described have been developed by Swedish construction companies and industrial concerns. Ingemar Wolff headed the team responsible for developing the BPA system. Tests carried out at the plumbing laboratory were directed by Lennart Lindvall.

Production, Transport and Use of Hot Water

by

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Introduction

The sudden rise of oil and other combustibles' prices which had taken place by the end of the year 1973 led to the so-called "energy crisis".

In order to cope with this crises, a lot of countries have been induced to undertake studies and research in order to find means of saving energy. As far as the building is concerned, projects have been waked ou. in three directions:

- thermal isolation;
- heating; and
- service hot water.

The reader will find in this report some indications about the research which is now proceding or foreseen in France in the field of service hot water.

Account of the Problem

Two main research lines have been foreseen:

- on about the present techniques, the purpose of which is starting from a better knowledge of these techniques to improve them, and to bring about, among other things, energy savings; and
- another one about new techniques, the purpose of which is starting from non- or little-used energy sources, to find new ways of producing service hot water.

For reach of these two research fields, studies have been worked out in three directions:

- production of service hot water;
- transport and distribution of service hot water; and
- use of service hot water.

The studies must be worked out always keeping in mind the user comfort. Indeed, it would be of no use to bring about highly satisfying solutions as far as energy savings are concerned, without being able to meet adequately the user needs in terms of service hot water.

Present Techniques

Energies

According to the presently used techniques, the energies to be taken into account are the "classical" energies such as:

- coal;
- oil (fuel);
- gas; and
- electricity.

Production

The study connected with hot water production includes two parts which are related to:

- production means
  - . individual or collective,
  - . with or without storage; and
- hot water production devices.

1. Production Means

A. Individual or collective production

In individual houses, the hot-water production is itself more often individual too, i.e., it is operated at a scale of a single-dwelling house.

In industrial or collective buildings (schools, hotels, barracks, hospitals, etc.) this production is central and collective.

On the other hand, both production ways (collective or individual) may be used for residence buildings or groups of buildings.

The problem which claims our attention in that last case is to know which are the advantages and drawbacks of each of these solutions, in order to determine if any one is better than the other and, in the affirmative, which one?

The choice of any of these solutions is difficult because each one has got its advantages and drawbacks.

First point to be taken into account is the energy source because, depending on its kind, the conclusions may be different.

From that point, the problem is to be regarded from three points of view:

- the financial aspect
  - . installations cost
  - . exploitation cost (consequently the idea of total cost [installation + exploitation])
- the energetical aspect (consumptions) which has itself its financial aspect; and
- the comfort aspect.

The installation cost depends on the chosen device. It will be therefore necessary to check whether, comfort being equal, the installation of a collective production is more or less expensive than the installation of a great number of individual installations. It will be necessary to consider the special case of common hot water and heating production.

The exploitation cost depends on the energy price, on the maintenance cost (including the cost of replacing material) on the flow-metering device, and so on. The determination of this cost is very important because it is probably nearly the same for both means of production with, maybe, a little bit less expensive for individual production.

The energetical cost depends on the kind of energy and also on the installation: the efficiency of a collective installation is probably somewhat lower than the efficiency of an individual installation.

The comfort aspect is the most difficult to take into account because, depending on each person, it is very subjective. Therefore, it will be necessary to make investigations on the satisfaction of the users in order to have a better knowledge of their needs. In fact, provided that they meet these needs, both kinds of installations (collective or individual) may be used.

Therefore, it can be seen that, depending on the considered aspect, a solution, or the other one will be the best one.

To make a choice between these two solutions, it is necessary to draw up the total balance. This study may be worked out in a certain number of existing installations, the conceptions of which are different: for each of these installations, the test solutions will be found out, and starting from these data some general rules will be defined.

B. With or Without Storage

Among the individual or collective production devices, two main types may be found:

- instantaneous heaters, and
- accumulation heaters.

The water heating in instantaneous heaters is supplied as water is drawn. The water heating in accumulation heaters does not depend on the drawing, for they hold a water reserve more or less important, which is heated at any moment by a heat-spring. Some other devices that could be called "semi-instantaneous heaters" are also used, mainly in case of almost unbroken drawing. Nevertheless, these heaters hold a small water reserve, the purpose of which is to regularize the hot-water temperature.

The problem that then claims our attention is to know what sort of device is the more convenient for a given installation.

As before, the first aspect to be considered is the kind of energy. Indeed, using some kinds of energy (gas, for example), the choice is possible, but not when using other kinds (electricity): an instantaneous electrical heater is rarely used except in the case of little flow rate and little power heaters.

Other aspects to be considered are, as has been said before, energetic, financial, and comfort.

The comfort aspect is here still very important. Indeed, the user is waiting that his heater give him water at the right temperature (at a reasonable rate) at the right moment and at a reasonable cost. This aspect will therefore be considered firstly for the choice of a heater. Nevertheless, the financial (total cost) and energetical aspects shall not be ignored.

Studies may be worked out in this field in order to point out--depending on the kind of installation--which type of device is the most adequate. For that reason, the type of hot-water production (individual or collective) as well as the user requirements--necessary quantities, instant flow rates, optimum frequency, etc. (see "Use")--must be taken into account.

2. Hot Water Production Devices

Depending on the production kinds--individual or collective, instantaneous or with storage--different sorts of devices are used.

In France, the following distinctions are made:

- Individual production:
  - . instananeous:

- water heater
  - gas (P = 125 mth/min)
  - electrical (P < 10 KW)
- bath heater
  - gas (125 < P < 400 mth/min)
- distributor
  - gas (P > 400 mth/min)

. with accumulation (gas, electricity...):

- accumulator (heating body is inside of the tank)
  - with free flow (not commonly used)
  - under pressure
- preheater (independent tank)

. double-purpose devices (heating + hot water).

- Collective production
  - boilers (coal, fuel, gas) coupled with hot-water vessels;
  - heat exchangers, the heating fluid of which is coming from outside: hot water, superheated water, steam; and
  - mixed generators (hot water + heating).

The relevant problem (without speaking of the type of device which choice results from what has been said above) is the problem of the fitness for employment of these devices, i.e.:

- mechanical and hydraulic characteristics, materials quality;
- consumptions, efficiency;
- behavior in service, and especially reliability, scale formation facility;
- characteristics of outlying security and regulation devices: safety unit, thermostate, temperature regulation, etc.

The knowledge of devices' performances will thus allow the setting up of standards for fitness for employment, and allow the user to choose the best device connected with a determined use.

ransport and Distribution - Installation

. Individual Production

At the level of individual production, few problems are set by the transport and distribution.

- The heaters providing a single drawing point must be settled as near as possible from this point; and

- The heaters providing more than one drawing point must be settled as near as possible from the point where small and numerous drawings are likely to occur (in order that the cold water volume which flows at the beginning of the drawing be as little as possible).

The choice of heater location must not therefore require any particular study.

The distribution pipes should therefore be as short as possible. Their diameters must be designed so that the hot water comes rapidly to the user.

The diameters of heating fluid supply canalizations (essentially gas) must be designed as well in sympathy with pipe lengths and heater kind (instantaneous or with accumulation).

Studies may be worked out in that direction to design the optimum dimension of pipes in sympathy with the parameters enumerated above.

As far as the installation is concerned, the object of the studies will be:

- installation security;
- premises ventilation (gas); and
- sizing of flue gases ducts.

2. <u>Collective Production</u>

The problems of transport, distribution and installation are here much more numerous.

A. Transport

The long-distance transport is required when the hot water or the heating fluid (case of exchangers) is coming from a central production supplying several buildings.

The problems then depend on the kind of ducted fluid--steam, overheated water, hot water (without speaking of tepid water, which will be studied later on).

The studies required by these problems concern:

- the kind of pipes materials, with account to the ducted fluid (corrosion, mecanic resistance);
- the pipes' diameter with account to their length, their rates or their speed;
- the dilation components;
- the pipes working up: overhead, underground, in gutters, etc.

- the canalizations' insulating: protection of external surfaces against corrosion;
- the pumping systems, etc.

B. Distribution

The first relevant problem is the trace of the distribution system. Two systems--arterial and ring--may be used:

(1) Arterial System

In this system, the water does not flow through pipes beyond the drawing periods. Generally, each system supplies a group of dwellings one above another. The advantages of this system are the following: the different distributions do not depend on each other, con cerning pression and rate. The hot water metering may be operated for each dwelling. The most important drawback is that the pipework must be cleared of a certain amount of cold water before the user may get some hot water.

(2) Ring System

In this system, the hot water flows continuously in the canalizations. This system enables the user to get hot water at the very moment of the drawing, which cust out the wastings.

On the other hand, greater lengths of pipes are needed (hence, some problems during the installation working up), and heat losses are more important since the pipes are warm constantly.

The second relevant problem is the distribution system's conception, and especially the cetermination, for each system (arterial or ring) of the number of drawing points to be supplied with hot water. This choice may depend on the building conception and especially on the opportunity of setting up systems. It may depend too on comfort. For example, an arterial system allows the use of two distribution systems for each dwelling--one which supplies the kitchen with 70°C water, and another one which supplies the bathroom with 40°C water; this water is coming from the same distribution, its temperature being pulled down using, for example, a "mixed thermostatic tap".

The third relevant problem is the hot water circulation type. Two solutions are used:

- the thermosiphon circulation which settles itself through the difference of density (depending themselves on the temperature drops) between the outward and back pipes; and
- the pump-driven circulation, which is a forced circulation.

These different problems put forward the pipe insulating problem, the importance of which depends on the chosen solution. Taking no account of the insulating stuff quality and efficiency, whose determination requires a purpose-made study, it is important to know whether the savings that result from the heat losses cut down, can make up for the insulating costs.

The pipe insulating is recommended for arterial systems. In thermosiphon-driven ring systems, the outward pipes may be insulated. On the other hand, it is not recommended to insulate the back pipes in order to let the heat losses happen and so embody the water to circulate. The pump-driven installations may have their whole pipes insulated.

The last point that must not be forgotten is the water itself (the kind of which requires a lot of special studies). Indeed, a lot of disturbances arising from corrosion or scaling, or both, have been recorded in pipes and devices. Therefore, the kind of ducted water must be taken in account when designing and working out an installation, especially as far as pipe materials kind, devices designing, water treatment installation and pipes blow off are concerned.

To sum up, the installation of hot-water distribution systems sets a lot of problems, some of them, badly known, are requiring studies. These studies are intricate because it does not exist a single worldwide solution, but many depending on:

- the building importance;
- its kind (one- or multi-storeyed); and
- the utilization: continuous, intermittent, etc.

In all the cases, the choice of the solution will depend, comfort being equal, on the balance between the cost of each installation kind and the connected hot water savings.

Use

In the present service hot water production and distribution installations, some inefficiencies are often reported by the user. These inefficiencies are depending on the above checked-off problems.

For instance, according to the distribution kind, an instantaneous production will induce an unsteadiness of the tapping temperature, a drop in the medium temperature during peak periods, pressure drops, etc. An accumulating production will induce an important drop in temperature after a tapping period and temperature fluctuations during daytime.

These drawbacks may be overcome by using overdesigned installations, which leads of course to higher exploitation and installation costs. This solution is nevertheless chosen often because of the lack of information about the inhabitants' consumption and the time repartition of these consumptions.

The problem that has to be solved, then, is to know precisely the amount of hot water required by the users. This may be known through a two-step study:

- Field measurement of hot-water consumption (instantaneous or average) on different levels: on device (sanitary or domestic), in apartment, in building and, on occasion, in group of buildings. In order to take into account the sanitary equipment, the family composition and the social classes, measurement has to be performed in different classes of apartments or buildings.

- Investigation about the satisfaction of the inhabitants in order to know their hot-water requirements.

Starting from these data, a statistical-type procedure taking into account the building characteristics and the foreseen way of living may be laid down so as to enable the designer to choose more accurately the hot-water production and distribution types. It will provide too the basis required for the installation calculation.

The hardness of such studies is due to the subjectivity with which the user requirements are defined. Indeed, a lot of them are satisfied with what they have, either because they had less before, either because they ignore they could have more. These investigations must therefore be carefully laid down and conducted; the resulting data must be cautiously read.

The investigation subject will be mainly threefold:

- the temperature, to point out which values are the most suitable to a defined purpose, and which variations may be allowed;

- the flow rate, in order to give information about the flow rates granted at teach tapping point (sink, wash basin, bath, shower, etc.); and

- the volume or mass, in order to make it possible to calculate the best-designed storage tank volume, particularly in accumulation installations.

Among these notions, the temperature at the drawing point must be especially taken into account for the installation design. The best value of the water temperature is, as it has been seen before, related to the utilization type: it may be, for example, 35°C for a shower or a bath, 40°C for a basin, 70°C or more for a sink.

Different solutions may therefore be considered:

- A single high-temperature system, the lower of the temperature is obtained through cold water addition or mixing. This solution may not be reasonable, for example, in the case of a thermosiphon-driven ring system, because it will give rise to important heat losses;

- A single low-temperature system; an independent heat production will be then required in the kitchen; and

- A low-temperature system and a high-temperature system, which will give rise either to a double heat production, or to a single one, the temperature being then lowered on one of the two systems.

On the other hand, the water temperature must be bounded to prevent scaling, heat losses, etc. This will make it necessary to study temperature controllers.

The last point to be taken into account is the hot-water metering problem. Thi problem has become recently very important, according to new regulations be prescribed in some countries (with some restraints which will reduce the numbe of solutions). This will lead to studies on the metering device itself and on its installation (mainly in the case of collective systems).

Till now the hot water was invoiced either as per contract, either in connection with the number of inhabitants, the housing area . . . or with position water meter readings (without any record of the temperature), etc.

In future, efforts should be directed towards other metering devices such as:

- "calorimetric" metering which, by taking into account both the flow rate and the temperature, makes it possible to know the heat amount delivered (These devices must be improved because they are presently much too intricate, expensive and unreliable.)

- "flow rate" metering, which allows the recording of the quantity of water used up, but requires, on the other hand, the steadiness of the hot water temperature (hence, a storage process and an improved regulation). A lot of researches must therefore be performed in that field in order to perfect accurate, reliable and unexpensive metering devices. The installation of these devices must be studied as well.

In arterial systems, the problems may be solved while equipping each dwelling with a flow meter; in the case of a double system, it comes then cheaper to settle the low-temperature system downstream of the metering device, thus saving a metering device. In ring systems, the solution depends on the system geometery. In some cases, however, there is nearly no solution. (For example, a flat where different supply pipes start from the same ring system.)

Comments

To sum up, a lot of problems (related to production, distribution and use of hot water) are still to be solved, even in the standing installations.

These problems are not new, and no care of them had been taken so long because energy was inexpensive. Now the main thing is to solve these problems because of the sudden rise in energy prices, and also becuase solving these problems may help to improve the design and the realization of the installations (in order to reach, all things considered, to an improvement in user comfort).

Ultimately, we must keep in mind that these studies are difficult because they require the use of a great number of parameters which are all depending one on another.

New Techniques

Energies

Because of the rise in energy prices, the use of unemployed energies till now has (or is going to) become worthwhile. These new energies are mainly the so-called "free energies", because they are issued from natural sources --sun, wind, underground, etc., or from an industrial by-product. Among these energies, the more interesting seem to be:

- solar energy;
- geothermal energy (not sources coming from Earth underground); and
- energy recovered from power stations and industries (residual waters).

Other energies may be mentioned too:

- energy recovered from building sewage waters, and
- wind energy (for some countries).

Solar Energy

Use of solar energy is advisable only in the districts where solar contribution is important during a great part of the year. The solar collectors' problem must be examined first. The influence of the collector position on its efficiency may be studied: orientation (horizontal, vertical, 45° angle), position referring to the sun, ground nature (more or less reflecting), etc.

The hot water production is the second study to be carried out.

These systems are usually connected with a heat exchanger; it will therefore be of no use to study anything else than the collector circuit and the accumulator (tank, etc.) since downstream of the accumulation we come back to classical solutions.

Because solar energy is not continuously available, it will be reasonable to plan either a storage mean or a contemporary (classical energies-derived) heat production. The balance between gross cost (installation and maintence) of such an equipment and the energy savings (in comparison with a classical system) will allow to calculate the cost of such an apparatus.

Geothermal Energy, Recovered Energy

Characteristics of such energies are mainly:

- the temperature of the heat ducting fluid (water, in most cases) is relatively low: 30°C to 70°C (geothermal energy) and about 30°C (power stations recovered energy); and

- the flow rates of this same fluid are very important (up to about 100, 200 m3/h).

Accordingly, the following problems, which are related to transport as well as to utilization, must be studied:

1. Production

The study of these two energies' production does not take place in this report. The geothermal energy production concerns mainly the two pits' (extracting and reinjecting pit) boring. The recovered energy concerns mainly the residual waters which otherwise would be thrown back to the rivers.

2. Transport

The problems to be solved are technical and economical:

- On a technical point of view, the transport of huge quantities of water over very long distances is the main problem; it requires study on the following points:

  . pipes: diameters (some meters) and kind of materials;

  . putting in practice: aerials, buried or in gutter pipes (and, should the occasion arise, insulating stuff);

  . expansion joints;

  . pumping devices, etc.

  It must not be forgotten, either, that most of the ducted waters are often most mineralized.

- On an economical point of view, the balance striking will help to fix the greatest economically speacking distance between the production and the utilization point.

3. Use

The problems connected to the use are mainly dependent on the water temperature:

- should the temperature be high enough, the hot water utilization is then directly possible;

- should it not be the case, the hot water utilization is possible after a reheating (provided by a heat pump, for instance); and

- in other cases, it will be necessary either to contrive both the previous solutions or (should the tepid water be unable to meet the whole requirements) to plan a complementary classical hot water production.

As noted elsewhere, the strong mineralization of the water must be taken into account. This will influence the choice of equipment and pipe materials, and will probably require a specific water treatment.

On an economical point of view, as it has already been said, the balance will be struck by comparison between the great cost of a "classical energy"-driven installation and a "free energy"-driven installation.

omments

he very kind of energies mentioned in this report prevents the extension of heir use to a whole country. Indeed, solar energy shall not be used in oorly sunshined districts. Likewise, geothermal and recovered energies may nly be utilized in places close to the production points (pits, power staions, plants).

ence, it follows that the studies will be the more often about peculiar cases. ccording to the great number of parameters to be taken into account, it will e difficult to set up general rules. However, such rules may be set up as far s some points are concerned. For instance, for geothermal waters, it should e possible, depending on the various temperatures of the water coming out of he pits, to set up the greatest distance between the pit and the utilization oint.

inally, the object of the present report is mainly the "service hot water" se; it must not, however, be forgotten that in most of the cases this water ill also be used for heating purposes.

Conclusion

he object of the present report was to point out some problems relevant to he use of classical and new energies.

t must not be regarded as a comprehensive study. For instance, some aspects ay have been studied in some countries and ignored in this report.

t is therefore necessary that all the research institutions should acquaint he CIB W-62 with the nature of these works, and the already obtained results.

n particular, it would be most important to know the conclusions of the inestigations performed about the user's requirements, since the choice of a olution is first dependent on a better satisfaction of these requirements.

PERFORMANCE REQUIREMENTS

FOR TAPS: A CONSENSUS FROM SCANDINAVIA

by

Viggo Nielsen

Definition and Field of Application

The present performance survey comprises water fittings being connected to a hot- and cold-water supply system which, by order of the consumer, can be made to attend to one or more of the following functions:

- to supply or to cut off the flow of water;
- to adjust the water flow to a desired rate;
- to supply water of a desired temperature; and/or
- to supply a water flow in a specified direction and with a specified jet characteristic.

Sanitary taps are a very big group of components with different functions, but also with many common features. This performance survey covers all different types of taps and, therefore, all requirements are not relevant for all taps. In the performance survey it is possible to find the characteristics that are relevant to a specific purpose.

This survey is preliminary, for use in connection with water-supply systems in dwellings, but it can, without essential alteration, be used in other building categories as well.

Properties

1. Tightness against static water pressure.
2. Tightness relating to maneuvering and closing operations.
3. Regulation of water flow.
4. Regulation of water temperature.
5. Suitability of the jet direction.
6. Suitability of the jet character.

7. Flow resistance.
8. Stability of flow and temperature.
9. Noise conditions.
10. Cleanability.
11. Simplicity in use.
12. Chemical and physical stability.
13. Susceptibility to bacterial growth.
14. Surface conditions.
15. Protection against scalding.
16. Heat insulation property.
17. Reliability.
18. Durability, inside resistance.
19. Durability, outside resistance.
20. Mechanical strength, inside.
21. Mechanical strength, outside.
22. Aging durability.
23. Compatibility.
24. Working characteristics.

Tightness Against Static Water Pressure

General Requirements

The top and the connection to the water supply system must be tight against the available water pressure. This should apply for normal use as well as for abnormal, but foreseen circumstances as strokes from outside and variations in the water pressure.

Proposed Degree of Fulfillment

The tap and the connection to the water supply system must be tight against a water pressure of 1600 kN/m^2, when it is closed by means of a force of 30 N and 1.5 Nm respectively at rotary motions. The water tightness must be maintained during, as well as after, the tests described in "Mechanical strength".

Testing

The water fitting is mounted as prescribed by the producer and/or according to normal practice on the test pipes being relevant to the water fitting in question. The water fitting is fully opened. The pressure in front of the water fitting is adjusted so that the water flow through the water fitting corresponds to the water flow adequate to the water fitting.

The operating device of the water fitting is closed by means of a force of 30 N and 1.5 Nm respectively at rotary motions. Through the water supply the water fitting is exposed to a pressure of 1600 kN/m^2.

The testing procedure is described in section 7.3.1 in paper (1) in the reference list.

Judgment

No leakage during or after the tests should be found.

Tightness Relating to Maneuvering and Closing Operations

General Requirements

The tap must not cause any unintended penetration of water when it is closed against the available water pressure with a closing force which is in accordance with the possibilities of the user. If the tap has more than one outlet, the flow of water must only occur through that outlet which is intended for use. If the tap is equipped with inlets from different water supply systems (normally cold and hot water), it must be constructed in such a way that water cannot overflow from one system to another--neither when the tap is in use nor when it is closed.

Proposed Degree of Fulfillment

The tap must close tight against a water pressure of 1600 kN/m^2 after having been exposed 100,000 times for opening/closing operations where the closing has been done by means of a force of 30 N and 1.5 Nm respectively.

If the tap has outlets through a multi-way valve, it must, when drawing off water from one of the outlets, close tight against a water pressure of 250 kN/m^2 for the outlets that are not in use.

Taps designed to be connected to two water supply systems must prevent overflow from the one system to the other with a pressure difference of 1000 kN/m^2 when the tap is closed and a pressure difference of 100 kN/m^2 the drawing off water takes place.

Testing

For the tests is used an apparatus being able to open and close the operating devices of the water fitting about 20 times per minute. The closing mechanism can be adjusted so that the tap is closed by means of a force of desired value. The method is described in section 7.4.1 in (1).

The tap is opened to draw off water from one of the outlets, and then this outlet is blocked by a plug or the like just at the outlet opening. After this, the tap is subjected to a water pressure of 250 kN/m^2, and it is recorded where there is any water flow from the other outlets. The same procedure is carried out for all the outlets.

Water taps designed to be connected to two water supply systems (hot and cold water) are mounted so that the hot water inlet is connected to a hot water supply system (75°C ± 2°C), and the cold water inlet is connected to a cold water supply system (5°C - 20°C).

At a pressure of 50 kN/m^2 on the cold as well as the hot water supply system, the water fitting is fully opened. The temperature of the cold water T_k and the temperature of the hot water T_v are recorded (within ± 1°C). The pressure of the cold water system is increased stepwise by 10 kN/m^2 until a pressure of 100 kN/m^2. The pressure as well as the temperatures, T_k and T_v, are recorded. The above procedure is repeated at a constant pressure of the cold water supply system and a pressure of the hot water supply system increasing from 50 kN/m^2 (0.5 kp/cm^2) to 100 kN/m^2 (1.0 kp/cm^2).

During both tests in question, it is examined by means of the temperatures recorded whether an overflow from one side to another is taking place.

Judgment

Unintended water penetration must not occur. 100,000 opening/closing operations correspond to 10-years use in a dwelling house.

A few drops are permitted.

No overflowing must occur when the tap is closed, and the pressure difference is less than 1000 kN/m^2.

No overflowing must occur when the tap is opened for water supply from both systems and the pressure difference is less than 100 kN/m^2.

Regulation of Water Flow

General Requirements

The tap must be constructed in such a way that the user can chose and, within reasonable periods of time, regulate the tap to supply just that flow of water which is desirable for the purpose with the draw off.

Proposed Degree of Fulfillment

Information which makes it possible to judge the taps' suitability to a certain purpose must be available. For taps with manual regulation of the flow of water, at least a graph showing the flow as a function of the maneuvering movement must be available.

Testing

The tap is mounted in a test set-up where a constant pressure can be maintained. The pressure is adjusted until the maximum flow through the tap is equal to the suitable flow for the tap. This flow depends on which purpose the tap is intended for. The suitable flow is indicated in (1) supplementary sheet D.

The flow through the tap is by means of the operation devices adjusted so that the flow is about 15, 30, 50, 70 and 100 percent of the suitable flow. The measured values of the flow are registered on a graph as function of the movement of the operation device. If the maneuvering is a circular movement as well, the angle as distance travelled by the device must be indicated.

Judgment

Subjective judgment.

At the moment no criteria exist on how a suitable regulation characteristic of a tap for a certain purpose must look alike. It is desireable that the relation between the value of the waterflow and the movement of the operation device shows linearity.

Taps which have a rotation movement on the operation device must give maximum 50 percent of the suitable flow of water when 50 percent of the movement of the operation device has been done.

Regulation of Water Temperature

General Requirements

The tap must be constructed in such a way that the user can choose and, within a reasonable period of time, adjust the tap to supply water with exactly the temperature that is desirable for the purpose with the draw off.

Proposed Degree of Fulfillment

The tap must, in a simple way and within a reasonable period of time, supply water with a temperature of deviced value. The accuracy of the temperature has to be ± 1°C.

Testing

The accordance between the temperature scale and the temperature of the water is checked while the tap is mounted in a test set-up where it is supplied with water as recommended by the manufacturer. If the tap is not equipped with a temperature scale, it is not possible to test the regulation characteristics of the tap in a simple way. The testing mentioned below can make a basis for a relative judgment of the possibilities for adjustment. Taps constructed for mixing of hot and cold water are mounted in a set-up and supplied with cold water (20°C) and hot water (60°C) with a pressure on both hot and cold water of 300 kN/m^2. The operation device on the tap is adjusted to a position where the flow of water is 15, 30, 50, 70° of 100 percent of the flow which is obtained when the hot water supply has maximum values in temperature and flow. At each of the above-mentioned flow of water the tap is adjusted to supply water with temperatures of 30°C, 40°C and 50°C.

All measurements are repeated with a pressure of 200 kN/m^2 and 100 kN/m^2 on the hot water system and 300 kN/m^2 on the cold water system. For each set of values for temperature and water flow, the position of the of the operation device is described as mentioned in the previous section. If the position of operation device can be described with two parameters, these are used as abscissa and ordinate in a graph where waterflow and temperature are described with level curves.

Judgment

Subjective judgment.

Remarks

If the temperature regulation is obtained in another way than mixing two water flows with different temperatures, other test methods are required.

If the tap is equipped with automatic control device for maintaining the temperature, it is desireable to know how fast a new temperature on the water is obtained when the operation device for temperature is moved.

Taps designed for mounting on gas- and electrical-heated water-heaters must work sufficiently also when the pressure difference between hot and cold water supply is 200 kN/m^2.

Suitability of the Jet Direction

General Requirements

The character of the jet direction must be appropriate as to the application of the tap.

Proposed Degree of Fulfillment

The character of the jet direction is not only dependent on the tap but also on the placing of the tap. The optimal jet direction depends partly on the function the tap shall fulfill and partly on the other components that are used during the fulfillment of the survey function. Information about the jet direction described as the angle between a vertical line and the outer line of the jet with that or those placings for which the tap is constructed.

Taps with adjustable jet direction are described as mentioned above in the whole range of variability. Taps with more than one jet are characterized with the angle between the perpendicular and the jet.

Testing

The tap is mounted as prescribed by the manufacturer. The angle between the jet and a vertical line is measured on photos of taps with flows on 70, 100 and 150 percent of the flow suitable for the tap.

Judgment

Subjective judgment.

Ninety-five percent of the water from the tap must hit a plate 300 mm from the tap within a circle with a diameter of 50 mm. None of the water must hit the plate outside a circle with a diameter of 150 mm.

Suitability of the Jet Character

General Requirements

The character of the jet must be appropriate as to the application of the tap.

Proposed Degree of Fulfillment

Criteria for the optimal character of the jet to a certain purpose are not available. The character of the most normal jets can roughly be described as: (a) heavy, coherent jet; (b) coherent, airy jet, and (c) many separated jets.

For each of the possibilities, the following information must be available:

(a) the areas of the cross section in the jet and the velocity just after the outlet.

(b) as (a). The mean velocity in the jet will, in this case, not characterize the velocity of the particles because of the airy water. The smaller the calculated velocity is, the more airy is the water.

(c) the number of jets, the area, and the mean velocity of the single jets.

Testing

The tap is mounted as mentioned in the previous section. The area of the cross section in right angle to the jet direction is determined by measuring on a photo of the tap and jet. The mean velocity is determined by measuring the flow. The flow is determined with the pressure adjusted so that the water flow through the tap is equal to the suitable flow for the tap in question.

Judgment

Subjective judgment.

Flow Resistance

General Requirements

The tap must have a flow resistance of such an extent that a water flow adequate to the purpose is obtained when the tap is fully opened.

Proposed Degree of Fulfillment

As the pressure of the supply system where the taps are used may vary within wide limits, the water flows do not depend on the tap only, and so it is not possible to prescribe definite numerical requirements to the hydraulic resistance of the tap.

To ensure that when dimensioning the hot and cold water supply systems, the tap can be chosen correctly as to the pressure of the supply system and the water flow desired, information must be available of the hydraulic resistance of the water fitting in fully opened position.

Testing

The tap is mounted in s set-up where special tubes for measuring the hydraulic resistance are the most important part. The method is described in (1) section 7.5.

Judgment

In documents from CEN WG-34, it is proposed that the water flow from a fully opened tap must fulfill requirements concerning the flow at a pressure drop of 300 kN/m^2.

Stability of Flow and Temperature

General Requirements

The tap must supply water with the flow and the temperature it is adjusted to by the user regardless of the temperature and pressure variations in the water supply to the tap.

Proposed Degree of Fulfillment

Taps with manual regulation devices: Nil.

Taps with automatic regulation devices: The maximum alteration in the adjusted temperature is 2°C with alteration of the pressure in the cold water supply of 30 kN/m^2.

Testing

The tap is connected to two pressure systems of cold and hot water respectively The pressure in the cold water system is changed in steps. The pressure and the temperature are recorded.

The method is described in (1) section 7.7.

Judgment

The numerical value of the ration $|\Delta t/\Delta P|$ where Δt is the alteration in the temperature (°C) of the outflowing water caused by the alteration in the pressure (kN/m^2) in the cold water supply system.

	very good		unacceptable
$\Delta t/\Delta P$	0,1		0,15

When the cold water pressure is reduced by 30 kN/m^2 (0,3 kp/cm^2) the temperature of the outflowing water must not exceed 43°C until a steady temperature has been obtained. Ten seconds after the stabilization of the pressure, the temperature of the outflowing water must not deviate more than ± 2°C from the value to which it has been adjusted.

Noise Conditions

General Requirements

The tap must not cause annoyance due to noise either in the surrounding rooms or in the room in which it is installed.

Proposed Degree of Fulfillment

In the room where the tap is installed, the noise level must not exceed 50 dB(A) and in the surrounding rooms it must not exceed 30 dB(A).

The noise level caused by the tap does not depend on the tap only, but also on the water pressure, the design of the piping systems and on the building design itself. To ensure that the tap can be used in a way which prevents exceeding the noise levels stated, the producer has to give relevant information of the tap's noise level. This information must consist of a statement of the tap's standard noise level, the so-called "Appliance sound level" measured according to the terms mentioned in "Testing". The method in question has only in view to judge the part of the noise transferred to the water supply system and further to the building components and other rooms. No test methods are developed for the noise caused by the tap in the room in which it is installed.

Testing

The test consists of a comparison between the noise level caused by the tap in a specified test set-up and the corresponding noise level originated in a standardized source of noise (installation noise-standard). The result of such a measuring is called the appliance sound level, L_{AP}, which is the difference between the noise level of the installation noise-standards and that of the tap plus a fixed reference value. At the definition of the appliance sound level a point is made of reaching values being close to the noise levels obtained in practice for rooms surrounding the one in which the tap is installed. However, it will only be a very rough approach, as the existing conditions of building and installation are of great importance. The method is described in DIN 52218 and ISO/DIS 3822/1.

Judgment

The tap's appliance sound level L_{AP} at a water pressure of 300 kN/m^2 can be used for gouping the taps in different classes of quality as to noise.

Class I: $L_{AP} \leqq 20$ dB(A)

Class II: $L_{AP} \leqq 30$ dB(A)

L_{AP} is calculated as:

$$L_{AP} = 45 - (L_S - L) \text{ dB(A)}$$

where L_S is the noise level caused by the noise standard and L is the noise caused by the tap in question. Taps in Class I will normally fulfill the requirement that the noise level in the surrounding rooms not exceed 30 dB(A).

Cleanability

General Requirements

The surfaces of the tap must be insusceptible to dirt and calcerous deposit. Alternatively, the tap must be easy to clean mainly by the detergent generally used.

The tap must be resistant to detergents generally used and to possible special detergents recommended by the manufacturer.

Proposed Degree of Fulfillment

The surface of the tap must be formed in such a way that any part is accessible to cleaning without special tools. The surface should not be damaged by detergents generally used for cleaning and for removing of calcerous deposit. If any of these detergents are deleterious to the tap, it must be stated by the manufacturer, in which case alternative detergent should be recommended.

Testing

Nil.

Judgment

Subjective judgment.

Chemical and Physical Stability

General Requirements

The tap must not cause any alteration of the outflowing water concerning taste and smell or detrimental substances.

Proposed Degree of Fulfillment

The tap must not cause any alteration in the chemical composition of the water.

Test

The water tap is mounted in a testing arrangement, and during one hour the fitting is subjected to a water flow being in accordance with the flow rate suitable for the tap in question. After having been demounted and replugged, the water fitting is flushed out by synthetic water, filled again with synthetic water, and plugged again. The synthetic water is analyzed by atomic absorption for Cd and Pb. The result is indicated in ug/l, and the total quantities of Cd and Pb dissolved from the tap are calculated.

The method is described in (2).

Information about the chemical, physical, and biological stability of the materials employed must be given by the producer.

Judgment

The maximum total quantity of Pb is 15 ug and of Cd is the maximum quantity 2 ug.

Susceptibility to Bacteria Growth

General Requirements

In the tap there must be no possibility of bacteria growth or other biological activities leading to cases of illness or poisoning.

Proposed Degree of Fulfillment

The tap must not contain any materials which may feed or form a basis for bacteria growth.

Normally the whole part of the tap must be flushed with water each time the tap is used.

Testing

Nil.

Judgment

Subjective judgment when other tests are carried out.

Remarks

Aerators, showers, etc., must be easy to demount and/or clean.

Surface Conditions

General Requirements

The surface of the tap must be formed in such a way that no nuisance or personal injury will occur at normal use, just as cleaning or unintentional touch must be safe.

Proposed Degree of Fulfillment

The closet must be without sharp edges and rough surfaces.

Testing

Nil.

Judgment

Subjective judgment.

Protection Against Scalding

General Requirements

The tap should be designed in a way which protects the user against scalding from outflowing water.

Proposed Degree of Fulfillment

The operation devices intended for draw off hot water must be marked carefully. Taps with automatic scalding protection must be designed in such a way that it is avoided that water of more than 38°C can be drawn off the tap at direct opening by a single operation. Blocking of the protection must not take place until the drawing off has been started.

Testing

The tap with automatic protection against scalding is subjected to a pressure of 300 kN/m^2 on the cold water side as well as on the hot water side. The temperature of the water being supplied to the water fitting should be 20°C and 93°C respectively. The temperature of the water pouring out from the tap is measured. The same measuring is carried at a pressure of 1000 kN/m^2 on the hot water side, and a pressure of 200 kN/m^2 on the cold water side.

Heat Insulation Property

General Requirements

The temperature of those parts of the tap which it is necessary to touch when operating the tap must not cause any damage to or inconvenience for the user.

Proposed Degree of Fulfillment

The temperature of those parts of the tap which it is necessary to touch when operating the tap must not cause that the temperature of the skin of the user increases 40°C for the hands and 35°C elsewhere.

Testing

The tap is connected to a hot-water supply system and a pressure of 300 kN/m^2 at a temperature of 75°C (± 2°C) is maintained. The tap is adjusted to the maximum of the water flow. Taps, the correct functions of which imply the connection of two or more water supply systems, should be mounted in such a way that the highest possible temperature of the drawn water can be obtained.

The tap should be run through by water during a period of 180 seconds, and after this the outer surface temperature is measured on those parts of the water fitting where touching is inevitable when operating the tap in a normal way. The surface temperature and the places of measuring are registered.

Judgment

The temperature must at no part of the surface in question exceed 41°C.

Reliability

General Requirements

The tap must keep its original properties without maintenance for a reasonable term of years.

The expected lifetime should be related to price, ease of replacement and maintenance of tap.

Proposed Degree of Fulfillment

The producer must give information about maintenance or repair which might be necessary in the life of the tap. The tap must be easily accessible for the above repairs (any replacement of components included) when the tap is mounted as prescribed. The producer must give information of replacement parts being supplied to the market and stocked.

Testing

Visual observations of the possibilities of repair.

Judgment

Subjective judgment.

Comments

It is required that the producer, on account of his own long-range tests, state the expected lifetime of the tap or the number of operations to which it might be exposed before it will be considered fit for renewal. At such information the tests in question have to be described in detail.

Durability, Inside Resistance

General Requirements

The tap must not be affected by the water from the water supply system.

Proposed Degree of Fulfillment

The tap must not be affected by the water from the water supply system classified as drinking water systems.

Testing

Nil.

Judgment

Subjective judgment based on information from producer.

Durability, Outside Resistance

General Requirements

The tap must be resistant to substances and chemicals which normally are available in a residential house.

Proposed Degree of Fulfillment

The producer must inform about substances and chemicals which can damage the surface of the tap.

Testing

Nil.

Judgment

Subjective judgment.

Mechanical Strength, Inside

General Requirements

The tap and its connections to the water supply system must be able to resist the highest normal water pressure which can occur.

Proposed Degree of Fulfillment

The tap must resist a pressure of 1600 kN/m^2 without damage. Taps constructed for higher working pressure than 1000 kN/m^2 must resist pressure + 50 percent.

Testing

The testing carried out under "Tightness Relating to Maneuvering and Closing Operations" will be sufficient also for the present property.

Judgment

The tap must be tight and without visible deformation.

Mechanical Strength, Outside

General Requirements

The tap and its connection to the water supply system must be able to resist the stresses due to normal use and occasional loads such as punches, kicks, and strokes.

Proposed Degree of Fulfillment

The tap must in mounted position be able to resist a force of 600 N on parts under pressure when the tap is closed and 100 N on other parts.

Testing

The tap is mounted according to the producer's instructions and/or according to common practice.

In a number of different places, chosen at random, the tap is subjected to the single forces mentioned above. The force is transferred to the water fitting by a plunger having a diameter of 25 mm and a plane and surface covered with rubber of a thickness of 3 mm and a Shore Durometer A Hardness of 55 ± 5.

Judgment

The above forces should not involve any permanent deformation or other breakages. No leakiness should be found when the tap is tested as described in "Tightness Relating to Maneuvering and Closing Operations".

Aging Durability

General Requirements

The materials forming part of the tap have to show a sufficient degree of chemical, physical, and biological stability to enable to tap to maintain the original look and other properties within the expected lifetime.

Proposed Degree of Fulfillment

Nil.

Testing

Nil.

Judgment

Subjective judgment.

Comments

No direct method to determine the durability is available. For some materials, certain methods can be used to judge the influence of some of the aging factors.

Compatibility

General Requirements

In a simple way, it should be possible to build the tap together with other relevant components and installation systems.

Proposed Degree of Fulfillment

The producer must give satisfactory information of the overall dimensions, measures relevant to the mounting, joint methods, fastening, and installation procedure of the tap.

Testing

Nil.

Judgment

Subjective judgment. The measures relevant to mounting must be in accordance with relevant standards.

Ease of Transport and Handling

General Requirements

Transport, storing and handling should be carried out without difficulties and in such a way that no risk of injury to health or breakage will occur.

Proposed Degree of Fulfillment

Nil.

Testing

Nil.

Judgment

Subjective judgment.

Comments

The producer ought to give information about the procedure of transport and handling, and furthermore describe the storage conditions.

REFERENCES

(1) The Approval Board of Sanitary Installations of the Danish Ministry of Housing. "Approval requirements and testing conditions of sanitary taps for water supply systems". VA 140/DK003 December 1974.

(2) Contamination of Drinking Water of Cadmium and Lead From Fittings. SBI-NOTAT 36. Report on two series of experiments carried out by Kate Nielsen.

CODE STRUCTURE AND STANDARDIZATION IN THE UNITED STATES

by

Milton Snyder

Introduction

The title for this Symposium is "Water Supply and Drainage for Building" and this title leads me to believe that, as a third-generation contracting plumber, I might be in the right place. What else is "plumbing" if it isn't water supply and drainage? As a practical matter, one of the difficult items when discussing plumbing, or plumbing codes, or any legislation or any standards involving plumbing, is to first agree on a definition of plumbing. This has been a serious situation for many years--that is, to decide what is and what is not plumbling--because plumbing is controlled and regulated differently than what is not plumbing. We will find as we procede further into our discussion today that the definition becomes difficult, complicated, and political and economic because of the many vested interests involved. Some of these interests want the definition of plumbing to be all-inclusive and believe that the definition of plumbing should include everything remotely connected with anything wet, and sometimes even with anything dry, and they believe the definition of plumbing should include anything that goes through a pipe, or is even slightly related to anything going through a pipe. On the other hand, there are interests that believe the definition of plumbing should be firmly restricted to water in and waste out, and further restricted to include these items only within the physical confines of a structure, and that if the water and waste items are outside of a building, they are not plumbing. Certainly somewhere in between these extremes is a sensible definition of plumbing that is objective and does not include or exclude items just because the interested parties are capable or incapable of performing the extraneous items, or providing the necessary materials.

For the purposes of our discussion today I submit the following definition of plumbing taken from one of our widely accepted model codes: "Plumbing is the practice, materials and fixtures used in the installation, maintenance, extension, alteration and removal of all piping, plumbing fixtures, plumbing appliances and plumbing appurtenances in connection with any of the following: sanitary drainage or storm facilities and venting system and the public or private water supply systems within or adjacent to any building, structure or conveyance; also the practice and materials used in the installation, maintenance, extension, alteration or removal of storm water, refrigeration and air conditioning drains, liquid waste or sewage, and water supply systems of any premises to their connection with the public water supply system or to any acceptable disposal facility. Except for the initial connection to a potable water supply and the final connection that discharges indirectly into a public or private disposal system the following are excluded from this definition: all piping, equipment or material used exclusively for environmental control, for incorporation of liquids or gases into any product or process for use in manufacturing or storage of any product, including product development, or for the installation, alteration, repair or removal of automatic sprinkler systems installed for fire protection only or their related appurtenances or standpipes connected to automatic sprinkler systems or overhead or underground fire lines beginning at a point where water is used exclusively for fire protection." (NAPHCC - National Standard Plumbing Code[1])

To describe this definition simply, it means that plumbing by definition means water in and waste out for directly connected fixtures intended for personal sanitation, and that all other uses of water in and waste out are plumbing only at the points where it is necessary to protect the water supply and to protect against problems in the drainage connections. We are now back where we started several minutes ago--that is, we are discussing water supply and drainage for buildings that we will now call 'plumbing'.

It is my intention to discuss with you today "Code Structure and Standardization" concerning the requirements for plumbing installations in the United States. To do this, I will briefly review the history of plumbing and plumbing codes and standards affecting plumbing, and then go into the present status of these items, and conclude with some personal reflections as to the status of the important items, and express some opinions.

Background

While the history of the United States tells us that our country is now 200 years old, the health and plumbing histories tell us that we had health and plumbing problems because of the disposal of human waste matter over 300 years ago. The magnitude of the problem was proportional to the density of the urban development of any specific area. When local councils were first formed in the effort to govern, they very quickly recognized the health problems involved with the habits of depositing human waste in the streets, or sometimes simply discarding them through an open window. Urban development did not permit many residents the luxury of open ground for the burying of wastes, or given them the availability of running water courses for the deposit of these wastes. The original health officers appointed by local councils did the best they could with what was available, and made sincere attempts to provide orderly and, to them, sanitary methods of waste disposal. It is interesting to note that it was the health officers who became involved in these matters because they were truly health matters, and because there was no one else who would or could become involved. Today, of course, the trend is away from health officer control over plumbing towards building inspection personnel control over plumbing, with the health officers being involved generally only on a peripheral basis, but still, as in all matters that could involve health, retaining the right to step in when they believe they should.

Plumbing as we know it today did not evolve until water under pressure became available. In this country, water under pressure first became available for fire fighting, and after the water was available, then water-borne wastes became the basis for modern plumbing. While all of this development has taken place in a comparatively short time--approximately 100 years--it took a lot of effort, planning, and work to provide the street sewerage systems, enlarge and improve the water supply systems, and design and build the plumbing fixtures and auxiliary equipment so that plumbing installations could be made. At the same time, small private installations with private water supplies under pressure and private disposal systems were being designed and installed.

Through all these early periods it was indeed health officers who were in control of the situation. Again, because proper disposal of human waste was a health matter, and equally important because these health officers were at the time the only ones with education and experience who were able to cope with the problems being generated.

In the last quarter of the 19th century, most of the large urban areas in this country realized that plumbing was here to stay, and that the proper installation was important, and they started to develop and implement plumbing codes. Even with the plumbing codes, the health officers remained in command.

The early plumbing codes placed the greatest part of their emphasis on the disposal of human wastes, and very little emphasis on the protection of the water being applied to make plumbing operative. In addition to controlling the various physical aspects of a plumbing installation such as ventilation, room locations, sizes, the fixtures themselves, and other such matters, they controlled the sizes and materials, and configurations of the piping through which the disposal of the waste matter took place. The early codes merely wrote into the laws and regulations what experience up to that time had taught them would work, and would work satisfactorily for a reasonable period of time.

It is interesting to note that this was the beginning of specification-type plumbing codes as far as waste matter was concerned, because they were very careful to detail the various sizes, and loadings, and geometry of the waste side of the plumbing system so that only what worked yesterday was approved for installation today. At the same time, there were very few codes that detailed any information about the water-supply piping, except to say that it must be there, and it must be adequate, and there was only one mention in a late 19th century plumbing code of protecting the water supply against contamination from the waste water, and even this was later ignored by the same code.

At the very beginning of water-borne wastes and plumbing codes controlling these wastes, there was knowledge that a liquid trap seal was the most appropriate method of protecting against the infiltration of filth and disease from the waste side of the system, and there was also the realization that protecting the integrity of this trap seal would become a major objective of a good plumbing code.

An interesting history of plumbing in this country, published some 25 years ago by our National Association of Plumbing Contractors,[1] points out that the concept of providing fresh air vents to assist in the protection of these trap seals was developed by one or more of the plumbing contractors of the time, and the first approach to the problem was to put small ventilation lines from the waste lines through to the outside wall. From this small beginning came all of our modern thinking and modern codes concerning venting. The past 100 years has created much thinking about this simple problem of protecting the integrity of the trap seal, and even our own National Bureau of Standards[2] has been involved with what is known as "Reduced-Size Venting" and it appears that after over 100 years we have come full circle and are right back where we started. It also appears that while the health officers of that time might have been in control of the situation, the plumbers of that time might have been more alert to the basic physical problems of plumbing installations and how to cope with them.

From the last quarter of the last century to the end of the first quarter of this century, progress in plumbing codes was continuous but not very meaningful. It was not very meaningful in the sense that there was no genuine new information being sought after by the people writing the plumbing codes, and plumbing coes were being written and rewritten after the fact, so to speak. Only the tried-and-true were kept in the code and purely on a specification basis, and purely on the basis of previously demonstrated practical satisfactory experiences. This approach applied mostly to the sizing, loading, and geometry of the waste piping systems. Fixtures, appurtenances, and appliances were receiving attention from the manufacturers of these items, and genuine changes and advances were being made in these items, and these changes were receiving code approvals. The manufacturers had, and still have, a large economic stake in advancing the cause of their equipment. There was no equivalent interest group willing to spend the money and the effort to advance the cause of investigating and modernizing the internal piping of a plumbing system, because no economic advantages could accrue to such a group.

Fortunately, in the early 1920s, our Commerce Department under the then Secretary of Commerce Herbert Hoover authorized the then-equivalent of our National Bureau of Standards to make a genuine investigation into the physics and hydraulics of plumbing installations, and to make such tests and examinations as they deemed necessary to accomplish this objective. This was done and after a few years and exhaustive report was issued on July 3, 1923, entitled "Recommended Minimum Requirements for Plumbing in Dwellings and Similar Buildings."[3] To my knowledge, this was the first authoritative work in this country that was based on more than yesterday's experience and in addition spent a great deal of time and effort on assembling the physical and hydraulic data applicable to plumbing, and then checked out the data and the theories in practical tests.

This report included a recommended plumbing code, a report of their investigations, and a discussion of the physics of plumbing systems, as well as other miscellaneous items such as standardization of materials. Every serious student of plumbing should not only read this report but study it very carefully. Most of it is still very valid today. Not only is most of it still valid today, but many of the plumbing codes we are still using are exact quotations from this document. This report on plumbing suggested a minimum plumbing code, then listed various legal reasons why communities and government were entitled to have plumbing codes, and as a matter of fact must have plumbing codes, and then went on to discuss the physics of plumbing systems so that their suggested codes could be understood and applied, and further listed certain materials for plumbing use.

While the recommended code was purely a specification-type code, there were general references to the results expected, and reference to the fact that some of the code provisions should be further studied, and as a matter of fact the inclusion in the report of the discussions concerning the physics of plumbing systems leads one to believe that the authors of this report felt that this was only a beginning and not a conclusive report or code. In spite of this, and because of the general lack of knowledge about what goes on inside of a plumbing system, and because there were no real efforts to get involved with a performance-type code, from that time on until almost the present time, the history of plumbing codes in the United States reflects only changes in the details of plumbing codes and little if any change in the approach to code writing or in the concept of what a plumbing code should really be.

This report and suggested plumbing code, frequently called the "Hoover Report"[3] or the "Hoover Code" after the then Secretary of Commerce, with its progress revisions through 1931 was often used as a textbook in the few schools that taught plumbing at a higher level than the how-to-do-it level, and was one of the textbooks at the very, very few college-level classes involved with plumbing.

In addition to the details of the plumbing installation, the Hoover Report discussed materials for use in plumbing installations. There is detailed reference in the report to the various piping materials then in common use for plumbing installations, and a listing of the specifications of the American Society for Testing Materials (ASTM)[4] for the various pipes and fittings. It should be pointed out that practically all of the information in the specivications or standards listed for the various pipe and fittings discussed was involved with the details of the manufacture and testing, as well as the base materials used in the construction, of the pipes and fittings and practically no listing or discussion of their use or adaptability, or need, in the installation of plumbing systems. This is today still the prevailing situation, with some changes that we will discuss later.

Current Activities

To continue with our history of plumbing codes, in November of 1940 our National Bureau of Standards published Report BMS 66 entitled "Plumbing Manual" which was the result of the work of a committee of only government people. This "Plumbing Manual" was intended for Federal plumbing work but it was hoped that it would also be helpful in bringing about greater uniformity and reduction of costs in all plumbing work. Very interesting sections on pressure and non-pressure drainage and listing different capacities for primary and secondary branches were never picked up by model or local codes. This aggressive forward step was never implemented. BMS 66 also contained the famous "Hunter's Curve" for estimating water-supply demands and pipe sizing information which were also discussed in BMS 65 and BMS 79. The fact that these 35-year-old reports are still in widespread use should indicate a lack of progress in plumbing information and code writing. American Standards Association, now known as the American National Standards Institute (ANSI)[5] appointed a committee, known as the A40 Committee, to prepare "Minimum Requirements for Plumbing and Standardization of Plumbing Equipment." This Committee was appointed in 1928 and frankly did little or no productive work, and was dischared in 1939. In 1941 the A40 Committee was reorganized with a broader-based membership and did do some real work with various reports to the extent that in 1949 they received approval for their work as an American Standard. Very shortly after the acceptance of the 1949 report, still another A40 Committee was formed with an extremely broad base of membership to again attempt to prepare an even better, more modern, more acceptable plumbing code to contain "Minimum Requirements for Plumbing." This Committee's work was completed and published in 1955 and is known as A40.8-1955,[6] and for many years in most places--and still in some places--was known as The National Plumbing Code. Again, because of the continuing need for better and more modern plumbing codes, and because of various political frictions in the field of code writing, A40.8-1955 was officially withdrawn as an American Standard on January 20, 1972. There is, at the present time, a current ANSI A40 Committee at work on a revision of this plumbing code.

The National Association of Master Plumbers published its "Standard Plumbing Code" in 1933, and revised it in 1942. When A40.8-1955 was a viable code, this national association (now known as the "National Association of Plumbing-Heating-Cooling Contractors"[1]) did not pursue the publication of its own code, and accepted the use of A40.8-1955, on which Committee representatives of the Association had served. When the publication of this code no longer had meaning, and when attempts at revision were so involved as to stymie any revision, this National Association published its own "National Standard Plumbing Code" beginning in the spring of 1971, with continuous revisions through the present time. Shortly after this publication date, the American Society of Plumbing Engineers[7] joined with the National Association in sponsorship of their code and in active participation as working members of the Code Committee.

Another group that served on the A40 Committee was the Western Plumbing Officials Association. At the same time they were serving on this Committee, they were also busy writing and publishing their own code, which they claim dates back to 1945. It is apparent that their greatest interest remained in their own code; originally used only on our West Coast, they seriously worked to expand their influence further inland. To assist in this expansion, they changed the name of their organization to the International Association of Plumbing and Mechanical Officials (IAPMO).[8] It must be noted that this organization, as well as two more that we will discuss, allow various types of people in the industry to have an input into their code writing, but only government officials involved in this type of work can vote.

Another group that served on the A40 Committee was the Building Officials and Code Administrators International, Inc.[9] This organization was one that did use and accept A40.8-1955 as the national plumbing code as long as it remained a viable code. In the last 1960s, BOCA, working as part of the Committee to revise the 1955 edition of A40.8, recognized that an impasse had been reached and that the code would not successfully be revised. In 1968 they published their own version of a plumbing code that they still continue to revise and to publish. Along with IAPMO, the BOCA organization gives voting powers only to government officials.

The Southern Building Congress,[10] an organization of building officials from the Southeastern States of the United States, never served on the A40 Committee. Starting in 1955, they have published a plumbing code and they are still revising and publishing this code. Along with IAPMO and BOCA, the Southern Building Congress gives voting powers only to government building officials.

Summary

To quickly review the recent history, the previously most popularly accepted code as being a truly national code was ANSI 40.8-1955; and after the withdrawal of this code, four organizations entered the competition in order to have their model codes accepted as a national code. These organizations are The National Association of Plumbing-Heating-Cooling Contractors jointly with The American Society of Plumbing Engineers, the International Association of Plumbing and Mechanical Officials, The Building Officials and Code Administrators International, Inc., and The Southern Building Code Congress. Every one of these organizations is well-meaning, and a plumbing installation made in accordance with any one of the plumbing codes will be a good installation. Obviously, they each have their own incentives that prompt them to pursue the use of their particular plumbing code in the various localities, and hopefully to be recognized as the number one national code.

Our local governments in this country are divided into villages, townships, cities, counties and states. At every level of these local governments, it is possible to have individual plumbing codes. In the very few instances where states have plumbing codes that are intended to be truly statewide, it is not really possible to prevent the smaller divisions of government from implementing their own changes in the plumbing code. Our national government has never undertaken to have a mandatory plumbing code at the national level, and it may not be legally possible for them to do so. However, through the use of their economic programs, the national government has from time to time attempted to control plumbing codes indirectly. Most of their efforts toward the economic control of plumbing work and plumbing codes were directed toward minimizing restrictions as to the use of materials and as to who is permitted to do plumbing work. Needless to say, these attempts met with great resistance from existing materials manufacturers and from the people presently licensed to do plumbing work.

We have said many times that while plumbing codes change as you cross city or county lines, there is no reason why they should, because the laws of physics, the basic pneumatic and hydraulic problems do not change. Obviously, it is the change in people, not the change in the problem, that creates the change in the plumbing code.

Now that we have reviewed the semi-chaotic history of plumbing codes, let us quickly review the equally semi-chaotic history of materials acceptance and approvals and standards, and also briefly discuss the slightly less chaotic story of who does what work and the licensing situation, all of which are an integral part of the code structure.

Starting with our 1923 Hoover Code, we found that there were standards and specifications for the manufacture of materials for use in plumbing systems. Just as with the plumbing codes, many different groups got into the act and started creating standards bodies and standards, some on a general basis, and some on a highly specialized basis, and all of them frequently creating standards specifications for the same items.

With all of these standards, many plumbing codes will and do accept materials manufactured under them, and in addition reserve the right to accept any additional materials they deam to be satisfactory for the intended use. Here again, every village, township, city, county or state can accept anything they choose to accept. "They" means the particular people in control of the situation at the time of such acceptance.

An important weakness in the total materials standards situation is that the standards are truly manufacturing standards, and are not necessarily good or proper standards for various plumbing uses in which the materials eventually will be used. Occasionally there is a brief mention in the standard of an intended plumbing use, and occasionally there is an appendix with some installation recommendations, but by and large the standards are purely manufacturing standards.

Other than Federal standards for use by our Federal Government in buildings constructed for their own account, all of the organizations involved in standards are voluntary organizations, and use of their standards is a voluntary act on the part of an individual manufacturer, and not compulsory. The only compulsion is economic, in the sense that unless the product conforms to a standard acceptable in the market intended for the product, sales of the product becomes more difficult.

To further indicate that these standards are not mandatory on the manufacturers, we quote below a statement issued by one of our prominent plumbing manufacturers at the start of every meeting at which a proposed standard is being discussed:

> "I request that the following written statement be recorded in this meeting to the effect that each representative in attendance is here solely for the purpose of assisting in the development of a voluntary standard through the drafting of language covering such standard; that no such representative has any authority to agree to accept such

standard or its language; that each representative only has authority to indicate by his vote whether or not he will recommend to his company the standard as drafted; and that the company of each representative shall have the exclusive right to determine for itself, independent of all others, whether or not it will accept such standards."

For assistance to those seeking further information and to demonstrate the large number of overlapping standards organizations, we list below the names of those commonly mentioned in our model codes:

- ANSI American National Standards Institute;[5]
- ASSE American Society of Sanitary Engineers;[11]
- ASTM American Society for Testing and Materials;[4]
- IAPMO International Association of Plumbing and Mechanical Officials;[8]
- AWWA American Water Works Association;[12]
- CS Commercial Standards;[13]
- FSS Federal Supply Services;[14]
- NSF National Sanitation Foundation;[15]
- PDI Plumbing and Drainage Institute;[16]
- UL Underwriters' Laboratories, Inc.;[17]
- ASME American Society of Mechanical Engineers;[6]
- MSS Manufacturers Standardization Society;[18] and
- SPR Simplified Practice Recommendations.[19]

The preparation of a plumbing code should involve the use of various groups of experts--those familiar with the piping details of a plumbing system including the hydraulic and pneumatic problems, those familiar with materials including ease of installation and life-expectancy problems, those familiar with consumer needs as to quantity and type of plumbing fixtures, those familiar with the administration of plumbing laws including permits, inspections, and the licensing of people authorized to do the actual installations, and such other experts as may be needed for specific situations. Most, if not all, code committees have experts on them--but these experts are only one or several in each of the required areas, and then jointly decide on all of the other areas. This does not lend itself to well-balanced plumbing codes with the interest of the general public and of the consumer coming first.

When you are discussing the licensing of people to do the plumbing work, there are many who feel that this is not a proper subject for a technical plumbing code, and certainly not a subject for a model or national code. Because of the many types of arrangements and histories in the various localities as to who does what, this certainly seems one part of a code that should be decided at the local level. This is not a part of the code that lends itself to the positive reasoning, tests, and calculations represented by the purely technical aspects of plumbing installations.

It might even be possible to also separate the materials approvals and acceptances from the technical parts of plumbing codes.

These statements about the possible separation of licensing and materials are made with the full knowledge that these two items--particularly the materials situation--were the principal causes of the failure of the Committee charged with revising A40.8-1955, and this failure promoted the current situation of four model codes vying for national recognition.

At the present time, all four of the organizations with model codes are making determined efforts towards having their particular code accepted on a wider basis, with the hope that eventually their particular code will be recognized as "the" national code.

Also at the present time, there is at work an A40 Committee making an heroic effort to revise and publish a current A40 code which, if accomplished, might again regain the status of being "the" national code. Strangely enough, there are representatives of several of the model code organizations working on this current A40 Committee. Hopefully, all concerned will pursue the A40 work at top speed and effort. This seems to be the only approach to a code that can be accepted by most of the interested parties on a national basis, and would have great influence on international thinking.

Discussion

At this time I would like to make some personal observations as to which way I believe codes will become structured in this country and also which way I believe they should be structured.

If the present A40 Committee succeeds in its work, there is an excellent chance that a revised A40 Code will take over the field that is now confused by the four model codes and will provide a basis for our many local areas to have a plumbing code based on the best possible plumbing code, including all of the latest and best information. If the A40 Committee does not succeed, it will be because of the diverse interests represented on this Committee, all which have equal say on matters in which they have little or no expertise, and frequently little or no interest, but use these matters in a political fashion to accomplish their own purposes. In all fairness, they are entitled to do this under the A40 set up, and further it is quite possible that this political maneuvering can conclude with a responsible result. Nevertheless, until a responsible result is accomplished, an objective look at the process seems to show that a successful revision of A40 cannot be positively predicted. In the absense of this revision, the present model code organizations will continue to scramble for localities to adopt their particular code--and again this might not be all bad, because the competitive spirit engendered by this keeps all of the model codes up-to-date and aggressive.

Another personal observation I want to make is that, concerning materials, the industry must make up its mind that new materials are being discovered and manufactured, and that these new materials must be given a chance.

As to licensing, I personally believe many of the local licensing structures are ancient and should be replaced. In this day of new techniques in the construction industry, various forms of limited licensing should be introduced to include semi-skilled specialists in various phases of the work to permit the equivalent of production-line work in construction work, while still reserving the present competency tests for those interested in the total picture of all plumbing work.

Finally, I must say that an in-depth review should take place concerning the possibility of performance requirements, and even more important in the direction of generating performance testing at the various levels of design and installation, so that expected results can be disproven before construction, or expected results can be guaranteed in advance.

To have and to implement performance-type codes will require better and more informed designers; much, much better and more informed plans examiners and inspectors; better installers; more responsive financial institutions who will recognize that innovations can be good; and a complete change of attitudes of manufacturers, installers, contractors and consumers.

Since most of the efforts on plumbing codes have been extended by people with vested interests, it appears that perhaps a government agency might be the only place where unbiased information and testing might be available on the technical details of pipe sizing, venting, and geometry that could provide better plumbing at lower costs.

Most of the efforts in the writing of plumbing codes have been spent on the design and installation of the drainage, waste, and venting system, which are of course extremely important. Now that most people are completely familiar with the need for the utmost care in the disposal of human waste, but mostly unfamiliar with the problems that can be created by contamination of the water supply from an improper installation, it appears that the major thrust should be along the lines of resolving technical problems involved with the protection of the water supply, and along the lines of an educational program to alert everybody, those within and those without of the industry, to the seriousness of the situation.

To paraphrase a recent advertisement, if we are still using codes that are substantially the same as they have been for 20 years or more, and if we are still using only the same materials, and still using the same construction techniques, then we must be wrong, because in this day and age there must be something better.

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1016 20th Street N.W.
Washington, DC 20036

[2] NBS — National Bureau of Standards
Washington, DC 20234

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BH 13 - July - 1923
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Washington, DC 20234

[4] ASTM — American Society for Testing and Materials
1916 Race Street
Philadelphia, PA 19103

[5] ANSI — American National Standards Institute
1430 Broadway
New York, NY 10018

[6] A40.8-1955 (ASME)
American Society of Mechanical Engineers
345 E 47th Street
New York, NY 10017

[7] ASPE — American Society of Plumbing Engineers
16161 Ventura Boulevard - Suite 105
Encino, CA 91316

[8] IAPMO — International Association of Plumbing and Mechanical Officials
5032 Alhambra Avenue
Los Angeles, CA 90032

[9] BOCA — Building Officials and Code Administrators International, Inc.
1313 E 60th Street
Chicago, IL 60637

[10] SBC — Southern Building Congress
1116 Brown Marx Building
Birmingham, AL 35203

[11] ASSE — American Society of Sanitary Engineering
228 Standard Building
Cleveland, OH 44113

[12] AWWA — American Water Works Association
521 Fifth Avenue
New York, NY 10017

[13] CS — Commercial Standards, Commodity Standards Division
Office of Industry and Commerce
U.S. Department of Commerce
Washington, DC 20230

[14] FSS — Federal Supply Service
Standards Division - General Services Administration
Washington, DC 20405

[15] NSF — National Sanitation Foundation
Ann Arbor, MI 48106

[16] PDS — Plumbing and Drainage Institute
1018 N Austin Boulevard
Oak Park, IL 60302

[17] UL — Underwriters' Laboratory, Inc.
207 E Ohio Street
Chicago, IL 15420

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420 Lexington Avenue
New York, NY 10017

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U.S. Department of Commerce
Washington, DC 20234

POTENTIAL SAVINGS FROM USING REDUCED-SIZE VENTING IN THE UNITED STATES[1]

by

Harold E. Marshall, Rosalie T. Ruegg, and Robert S. Wyly

Abstract

Venting is required for sanitary drain-waste-vent systems in buildings to protect trap seals of plumbing fixtures and thereby block entry of sewer gases, suds, sewage, and vermin into the buildings. Research has shown that reduced-size venting (RSV), an innovative type of venting which utilizes dry vent pipes substantially smaller in size than those permitted by existing U.S. plumbing codes, performs satisfactorily in one- and two-story houses. Builders, contractors, plumbers, consumers, and the research community are interested in the potential money savings from using RSV. Based on use of plastic pipe, and depending on other assumptions made, estimates of potential savings in the U.S. per single-family dwelling unit of one- and two-story type are from $46 to $125, and for the U.S. as a whole, from $58 million to $149 million over the next 11 years. Realization of these potential savings depends on how fast code authorities accept RSV in the plumbing codes and how fast builders and developers implement RSV technology once it is authorized in the codes. Although savings are likely to be greater in the U.S. than other countries due to the more elaborate venting requirements and the relatively large volume of housing starts, other countries may also find it cost effective to install RSV.

Key words: Cost savings; drain-waste-vent; economics; life-cycle; performance standards; pipe; plumbing; reduced-size vents; sanitary drainage systems; venting.

Introduction

In the United States venting is required for sanitary drain-waste-vent (DWV) systems in buildings to maintain the trap seals of plumbing fixtures. The venting provides protection by maintaining adequate water seals in the traps, thereby blocking the entry of sewer gases, suds, sewage and vermin into the buildings.

Traditional plumbing codes in the U.S. require that venting meet certain prescriptive standards. In the early 1960s, the National Association of Homebuilders (NAHB) proposed a laboratory investigation of Reduced-Size Venting (RSV) to test the hypothesis that RSV would be a viable approach to venting. RSV is an innovative type of venting which utilizes dry vent pipes substantially smaller in size than those permitted by existing plumbing codes. The hypothesis was based on an examination of two premises utilized historically in the derivation of the design criteria for standard venting. First, traditional criteria for sizing vent systems were derived from data obtained under hydraulic test conditions that were more severe than what would be expected in service, particularly for one- and two-story residential buildings. Preliminary analysis indicated that air requirements in the vents of the DWV systems of such buildings are substantially less than that assumed in the prescriptive requirements of the codes. Second, traditional criteria were based on the assumption that a substantial diameter reduction in vent pipes occurred in service from the accumulation of corrosion products. But with newer materials such as thermoplastics and some of the corrosion-resistant metals, this assumption seemed no longer valid.

Studies by the NAHB,[2] the National Bureau of Standards (NBS)[3,4,5] and the Steve Institute of Technology [6] have since shown that RSV can meet the implied essential requirements for performance (adequate trap-seal retention and absense of sewage and sewer gas emissions) imposed on conventional vent systems in one- and two-story houses by the prescriptive requirements of traditional U.S. codes NBS has published recommended design criteria for RSV[3] and has offered recommended code language for RSV in one of the model code organizations (i.e., the Building Officials and Code Administrators International) and to the American National Standards Institute (ANSI) Standards Committee A40 Minimum Requirements for Plumbing.

It is not the purpose of this paper to examine the performance characteristics nor the research details of RSV, because these have been presented elsewhere.[3,4,5] Rather, our purpose here is to examine the potential cost savings in the U.S. from substituting RSV for standard (conventional) venting in one- and two-story residences. Cost savings are expected from reduced materials costs, from reduced labor installation costs, and from reduced overhead and profit charges. No sacrifice in terms of higher maintenance costs, reduced performance, or reduced durability is expected for properly designed and installed systems. Savings from introducing RSV are estimated for one- and two-story single-family dwellings constructed nationwide over the next decade.

Such an analysis of potential savings is of interest to U.S. builders and contractors, both of whom are eager to reduce costs and thereby be more competitive, and to homebuyers, who are eager to minimize their costs for a home. It is of particular interest to those plumbing contractors who may benefit from increased aggregate profits due to their bids being more cost competitive. The analysis also provides useful information to members of the international research community (e.g., NBS) which are concerned about the returns on their investments in plumbing research.

We recognize that, in this early stage of the development of RSV, predictions of cost savings will be limited. Estimates of costs for the different plumbing system designs and some of the other information needed to make precise estimates of cost savings are without detailed empirical verification. However, we believe that the estimates of savings developed in this analysis give a reasonably accurate, preliminary indication of the economic viability of RSV, in that a conceptually logical model is used to evaluate cost savings, and the underlying assumptions are based on a sampling of expert industry opinion that appears realistic.

For prespective, we begin with a background discussion of the installation requirements and the performance attributes of RSV. We then calculate for one- and two-story residences the estimated cost savings per dwelling and the aggregate cost savings nationwide. We finish with a discussion of potential barriers to RSV adoption in the U.S.

RSV Performance Characteristics

The basic configuration of DWV systems utilizing RSV does not differ from standard DWV systems. However, the diameters of the dry vent pipes are smaller than the standard sizes--usually from one to four commercial pipe sizes smaller in the U.S. (Dry vents are pipes through which only air passes; wet vents, in addition to allowing air to pass, serve intermittently as drains.)

In order to ensure that RSV will meet the performance level now required by U.S. codes of conventional venting, the following design and installation requirements should be considered. Installation should limit RSV to elevations higher than 6 in. (15 cm) above the flood rim of the fixture(s) served or above any other points in dry vents which are likely to be intermittently submerged or subjected to wetting. Vent terminals should be covered with enlarged screen caps, and vent piping materials should be limited to those that are not subject to substantial scale formation under the prevailing site conditions. Manufacturers' recommendations should be used for any special fittings, for joining materials, and for installation procedures that may be required for size reductions. Finally, the design should be carried out in accordance with a tested and proven procedure.

Performance characteristics of RSV found in laboratory tests[3,4,5] show adequate hydraulic and pneumatic performance in one- and two-story residential type DWV systems. That is, during heavy hydraulic test loads, blow-back or ejection of sewer gases and suds was absent, and an adequate residual trap-seal was recorded for all traps.

Residential DWV systems are currently being evaluated by NBS in a field trial with RSV. Pre-occupancy tests using hydraulic loads similar to those described for the laboratory tests have been completed, and these show satisfactory hydraulic and pneumatic performance. Post-occupancy data are being obtained with special sensors and a 100-chanel automatic data acquisition system.

Cost Savings Per Dwelling

Cost savings per dwelling unit are estimated here in 1975 dollars as the difference in the costs of plastic RSV as compared with conventional plastic venting for one- and two-story single-family houses constructed from 1975 through 1985 in the U.S. It is assumed that the performance of RSV satisfies the minimum performance requirements implied by plumbing codes for venting, and that the durability and maintainability of RSV are equal to that of conventional systems. If then the costs of RSV are less than those of the conventional venting system called for by plumbing codes, we know that RSV is the more economically efficient technology for venting.

The cost savings per dwelling unit is calculated for plumbing systems using thermoplastic piping materials. It is assumed that the plumbing system in each new house contains two baths, one kitchen, and one laundry room.

Savings from using RSV are influenced by the kind of pipe material used, as well as by the particular venting design that is required by the code in force This is because pipe materials vary in cost (e.g., copper tube is currently more expensive than plastic pipe), and because venting designs vary in the amount of dry vent piping they require. Furthermore, some codes require larger sizes of vent piping in some applications than do other codes, resulting in potentially larger pipe size reductions and, therefore, greater cost savings. The cost savings that are anticipated from substituting RSV for conventional plastic venting, therefore, increase directly with the price of the convention al pipe and fitting, the number of units of dry vent pipe and fittings require and the size reductions made possible by substituting RSV.

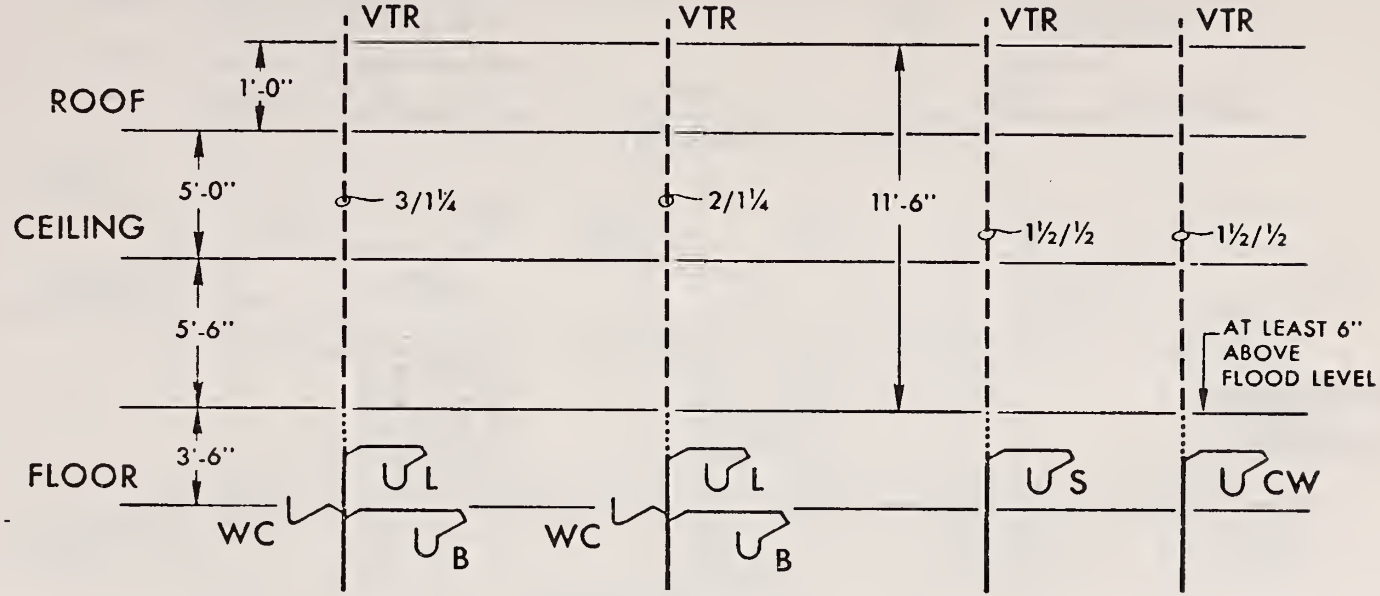
The analysis is based on the following three basic types of venting system designs: (1) a fully, individually vented system, referred to here as C1; (2) a wet vented system, referred to as C2; and (3) a stack vented system, referred to as C3. Figures 1 through 5 show schematically the details of these designs starting with the simplest (C3) and ending with the most complicated (C1) for one- and two-story houses. The diagrams are drawn to show the general differences in the designs and to show the measurements of pipe sizes, pipe lengths, and number and size of fittings used in calculating savings from substituting RSV. (The designs are not drawn to scale, and they are not intended to represent any professionally designed, as-built, DWV system.) Discussions indicating the importance of adequate piping schematics in the sizing procedure and materials take-off are given in BSS 60.[3]

The most elaborate venting system, C1, provides more dry venting that is eligible for RSV than the other two, and thereby provides the largest potential for RSV savings on a per dwelling unit basis. Because C2 has less eligible dr venting than C1, it results in somewhat smaller savings, while C3, the least elaborate of the systems, results in the smallest savings. Tables 1 and 2 sho the estimated savings in materials, labor, and overhead and profit that would result from introducing RSV in a house with each type of venting design. The estimated savings from using plastic RSV in place of conventional plastic venting in a one-story home with venting design of type C1, for example, are $95 in total, comprised of $19 (20 percent) in materials, $56 (59 percent) in labor, and $20 (21 percent) in overhead and profit. Tables 1 and 2 show that the cost savings per plumbing system from using RSV are greatest when it is applied in two-story homes with venting systems of type C1. The cost savings from RSV are least when applied in one-story residences with venting designs of type C3. The savings from using RSV range from $125 to $46.

To estimate the savings per system from RSV as shown in Table 1 and 2, the

Figure 1

BASIC DESIGN FEATURES FOR ONE-STORY, STACK-VENTED SYSTEM, C3



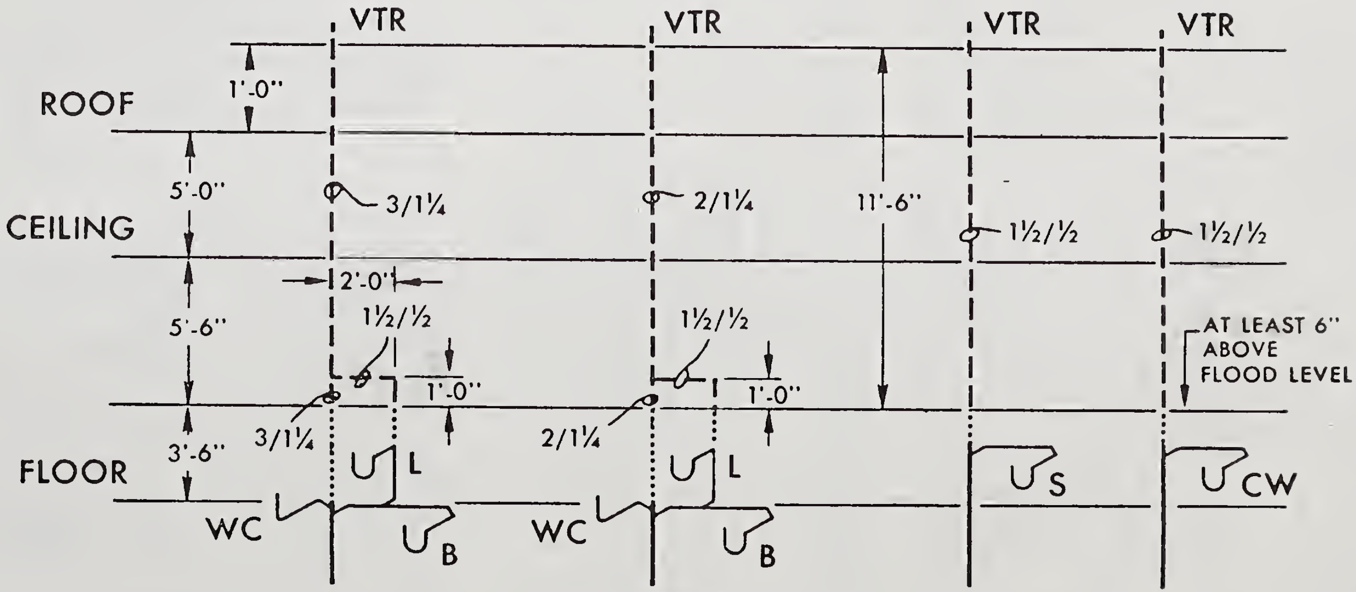
LEGEND:

———	DRAIN OR "WET" VENT
....	STANDARD SIZE DRY VENT
— — —	REDUCED-SIZE DRY VENT
3/1¼	MEANS DRY VENT REDUCTION IN SIZE FROM 3" TO 1¼"

VTR	VENT THROUGH ROOF
L	LAVATORY
WC	WATER CLOSET
B	BATH
S	SINK
CW	CLOTHES WASHER

Figure 2

BASIC DESIGN FEATURES FOR ONE-STORY, WET-VENTED SYSTEM, C2



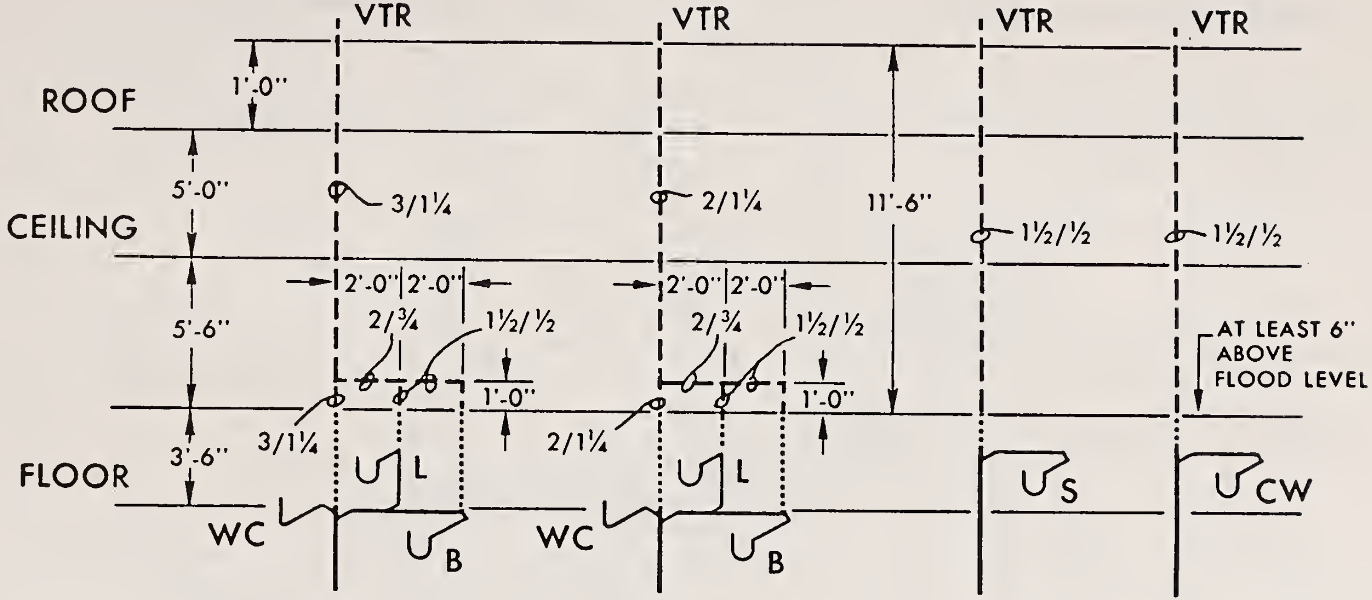
LEGEND:

———	DRAIN OR "WET" VENT
....	STANDARD SIZE DRY VENT
— — —	REDUCED-SIZE DRY VENT
3/1¼	MEANS DRY VENT REDUCTION IN SIZE FROM 3" TO 1¼"

VTR	VENT THROUGH ROOF
L	LAVATORY
WC	WATER CLOSET
B	BATH
S	SINK
CW	CLOTHES WASHER

Figure 3

BASIC DESIGN FEATURES FOR ONE-STORY, INDIVIDUALLY VENTED SYSTEM, C1



LEGEND:

———	DRAIN OR "WET" VENT
....	STANDARD SIZE DRY VENT
— — —	REDUCED-SIZE DRY VENT
3/1¼	MEANS DRY VENT REDUCTION IN SIZE FROM 3" TO 1¼"

VTR	VENT THROUGH ROOF
L	LAVATORY
WC	WATER CLOSET
B	BATH
S	SINK
CW	CLOTHES WASHER

Figure 4

BASIC DESIGN FEATURES FOR TWO-STORY, WET-VENTED SYSTEM, C2

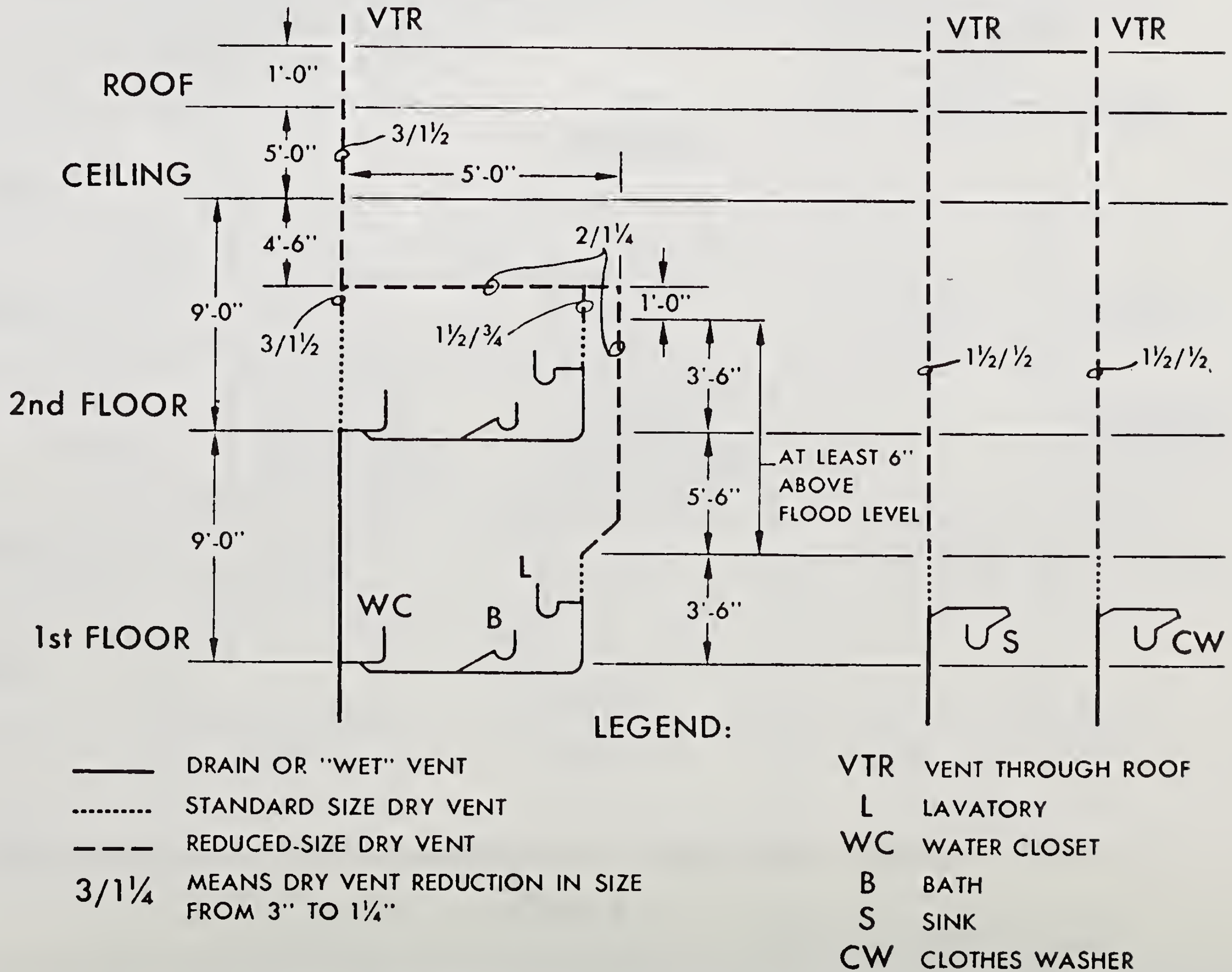
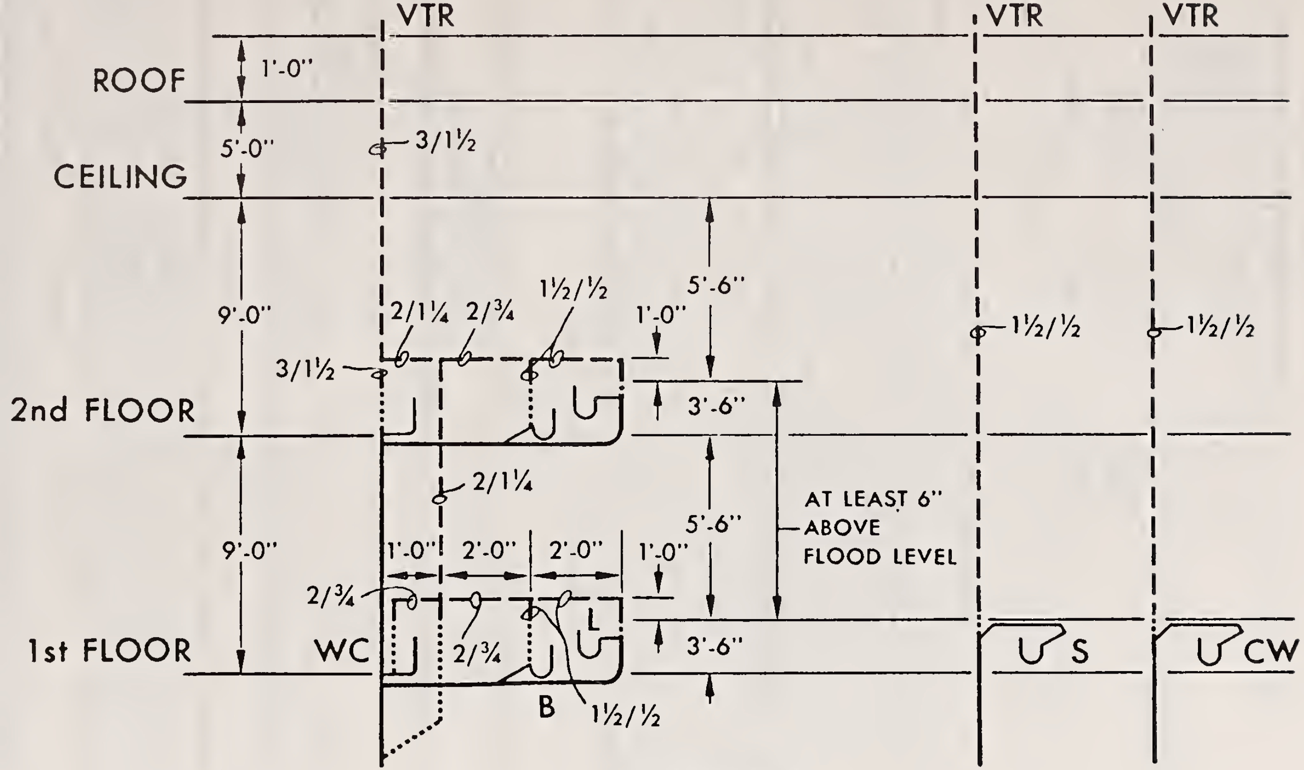


Figure 5

BASIC DESIGN FEATURES FOR TWO-STORY, INDIVIDUALLY VENTED SYSTEM, C1



LEGEND:

———	DRAIN OR "WET" VENT
....	STANDARD SIZE DRY VENT
— — —	REDUCED-SIZE DRY VENT
3/1¼	MEANS DRY VENT REDUCTION IN SIZE FROM 3" TO 1¼"

VTR	VENT THROUGH ROOF
L	LAVATORY
WC	WATER CLOSET
B	BATH
S	SINK
CW	CLOTHES WASHER

Table 1

Estimated Savings From RSV Per Plumbing System
In One-Story Residences

System Design	Dollar Savings (Percentage Distribution)			
	Materials	Labor	Overhead & Profit	Total
C1	18.65 (20)	56.26 (59)	19.85 (21)	94.76 (100)
C2	17.28 (22)	44.34 (57)	16.33 (21)	77.95 (100)
C3	16.01 (35)	20.22 (44)	9.60 (21)	45.83 (100)

Table 2

Estimated Savings From RSV Per Plumbing System
In Two-Story Residences

System Design	Dollar Savings (Percentage Distribution)			
	Materials	Labor	Overhead & Profit	Total
C1	22.73 (18)	76.14 (61)	26.20 (21)	125.07 (100)
C2	21.79 (31)	34.34 (48)	14.87 (21)	71.00 (100)
C3	N.A.†	N.A.†	N.A.†	N.A.†

† "N.A." means not applicable for purposes of this analysis.

costs of RSV were subtracted from the corresponding costs of a conventional venting system for each design. The total costs of installing RSV and conventional venting systems are calculated according to the following cost formula, which is based on a cost estimating guidebook[7] widely used in the U.S. by the plumbing industry.

$$C = (P + F + L)\ F_0\ F_P, \qquad (1)$$

where

- C = Total installed costs of a venting system,
- P = Cost of pipe materials,
- F = Cost of fitting materials,
- L = Cost of labor,
- F_0 = Contractor's overhead factor (e.g., if overhead charge = 15 percent, then $F_0 = 1.15$), and
- F_P = Contractor's profit factor (e.g., if profit = 10 percent, then $F_P = 1.10$).

The values for P and F were calculated on the basis of the measurements shown in the schematics in Figures 1 through 5 and on materials list prices. The system configurations, as well as the sizes and number of units for conventional-size pipe and fittings, were based on requirements of three prevalent plumbing codes in the U.S.: The 1975 Basic Plumbing Code (BOCA), 1975 Standard Plumbing Code (SBCC), and 1976 Uniform Plumbing Code (IAPMO).[8] Unit costs of pipe and fitting materials, shown in Tables 3 and 4 respectively, were obtained from plumbing materials and equipment suppliers in the Washington, D.C., area. These prices reflect a 30 percent reduction in manufacturers' national list prices to account for contractor discount. By multiplying the number of units times their respective unit prices, the materials costs for RSV and conventional venting were obtained for each of the venting designs for one- and two-story residences.

Table 3

Plastic (PVC) Pipe Costs by Size†

Size in Inches	3	2	1 1/2	1 1/4	1	3/4	1/2
Dollar Costs Per Foot	1.36	.66	.48	.41	.38	.26	.20

The values for labor costs, L, were derived by using the "pipe and fittings" method of the cost-estimating guidebook[7] and an average hourly labor rate of $20. Based on current practice in the U.S., as indicated by the cost-estimating guidebook and by consultations with industry authorities regarding

† Cost estimates are based on 1976 list prices of a leading brand of thermoplastic (PVC) pipe, reduced by 30 percent for contractor discount. Costs are for Schedule 40 DWV pipe in sizes 3, 2, 1 1/2 and 1 1/4 inches, and for Schedule 40 water pipe in sizes 1, 3/4, and 1/2 inches.

Table 4

Plastic Fitting Costs by Size†

SIZE	Dollar Costs						
	Coupling	Tee	Cross	90° Ell	45° Ell	Reducing Tee	Reducing Bushing
3	.74	2.59	4.53	N.A.*	N.A.	N.A.	N.A.
2	.38	.92	2.77	.58	.55	N.A.	N.A.
1 1/2	.25	.68	1.86	.47	.37	N.A.	N.A.
1 1/4	.25	.60	1.55	.42	.41	N.A.	N.A.
1	.35	.70	N.A.	.54	.70	N.A.	N.A.
3/4	.21	.36	N.A.	.30	.62	N.A.	N.A.
1/2	.15	.29	N.A.	.24	.37	N.A.	N.A.
3x2	N.A.	N.A.	N.A.	N.A.	N.A.	2.00	.78
3x1 1/2	N.A.	N.A.	N.A.	N.A.	N.A.	1.85	1.02
2x1 1/2	N.A.	N.A.	N.A.	N.A.	N.A.	.80	.26
2x1 1/4	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	.54
1 1/2x1 1/4	N.A.	N.A.	N.A.	N.A.	N.A.	.96	.30
1 1/2x3/4	N.A.	N.A.	N.A.	N.A.	N.A.	1.21	.56
1 1/2x1/2	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	.56
1 1/4x3/4	N.A.	N.A.	N.A.	N.A.	N.A.	.95	.52
1 1/4x1/2	N.A.	N.A.	N.A.	N.A.	N.A.	.95	.52
3/4x1/2	N.A.	N.A.	N.A.	N.A.	N.A.	.36	.20

its application, no labor charges were made for "flush" or short-pattern bushings and for couplings for either RSV or conventional venting.

To calculate overhead and profit, values of F_O = 1.15 and F_P = 1.10 were used, based on inverviews with contractors. These figures may vary in practice

† Cost estimates are based on 1976 list prices of a leading brand of Thermoplastic (PVC) fittings, reduced by 30 percent for contractor discount. Cost are for Schedule 40 DWV fittings in sizes 3, 2, 1 1/2 and 1 1/4 inches, and for Schedule 40 water pipe fittings in sizes 1, 3/4 and 1/2 inches.

* N.A. means not applicable for purposes of this project.

depending on the type and size of the project as well as on the size and business procedures of the plumbing contractor. (For further background calculations used in developing Tables 1 and 2, see Reference 9.)

Cost Savings Nationally

So far we have looked at the potential cost savings that would be generated by substituting RSV for conventional venting of a specific design in an individual one- and two-story house.

To determine the potential total impact of RSV on plumbing in the U.S., it would be necessary to look at the aggregated life-cycle cost savings over time for all types of buildings that might use RSV.

For the aggregate analysis undertaken here, the estimates of cost savings are limited to an 11-year period from 1975 through 1985, a period for which reasonably dependable projections of housing starts are available. The aggregate analysis is also confined to privately-owned, one-family houses projected for construction during this 11-year period. A lower-bound estimate results, both because of the limited time period and because the savings from the possible use of RSV in multi-family residences and commercial buildings, as well as in new plumbing units retrofitted in existing housing, are not estimated. The use of conservative projections for construction of new one- and two-story single-family housing units further lowers the estimates.

The first step in calculating aggregate RSV savings is to estimate the number of plumbing systems in which RSV will be used. It is assumed that each new house (one- or two-story) will contain one plumbing system as defined earlier. The estimated number of new privately-owned, single-family homes to be constructed yearly, which is assumed to indicate the number of new plumbing systems installed yearly, is based on U.S. Bureau of the Census population forecasts,[10] U.S. Bureau of the Census Construction Reports,[11] and U.S. Department of Agriculture housing forecasts.[12] (For a table of these housing estimates by region, see Reference 9.)

The estimated number of housing units and plumbing systems are approximate projections of possible housing demand (rather than actual construction), under the assumption of continued economic growth, moderate inflation, and no catestrophic events such as war. Cyclical variations are assumed to be offsetting in the long run, and are ignored in the projections.

A breakdown of estimated housing and plumbing systems was made by region because certain venting designs tend to be used more in some regions of the U.S. than in others, depending upon the codes in effect. It is also necessary to evaluate the relative incidence of codes in order to estimate cost savings.

Local jurisdictions generally adopt one of the widely recognized model plumbing codes which have been developed by various associations of plumbing and building officials, or pattern the local code after one of the models. The IAPMO Uniform Plumbing Code, one of the model codes, is usually interpreted to require venting systems of type C1 in most installations. The BOCA Basic

Plumbing Code and the SBCC Standard Plumbing Code, two other popular model codes, are similar to one another in terms of their venting requirements, both allowing all three types of venting for specified types of construction.

The Uniform Plumbing Code (IAPMO) is the predominant code for the western U.S. Thus most venting in the West is likely to be type C1. The basic Plumbing Code (BOCA) is probably the predominant model code for the northeastern U.S., but the Uniform Plumbing Code and the Standard Plumbing Code (SBCC) are also used as models in a number of localities in the Northeast. The Standard Plumbing Code seems to be the predominant model code in the southeastern U.S. A relatively higher proportion of venting installed in the Southeast is likely to be of the type C3 and a smaller proportion of the types C1 and C2 than in the Northeast, mainly because a greater percentage of houses in the Southeast are of an architectural design conducive to venting of type C3, the simplest type.

Figure 6 divides the U.S. into three main regions--western, northeastern, and southeastern--for the purpose of showing the approximate percentage of new homes which will have venting designs of each of the types C1, C2, and C3. The estimated percentages of new plumbing systems in each region that will have each type of venting design are shown in the legend at the bottom of the map. For example, it is estimated that 20 percent of the new plumbing systems in the Northeast will be of the venting design type C1; 20 percent, C2; and 60 percent, C3.

To estimate the future savings of RSV in the U.S., a final piece of information is needed. It is the "diffusion rate"--the rate at which RSV will be accepted by code authorities and applied in venting systems. It is unlikely that RSV will be widely adopted in the beginning, in that it generally takes time in the U.S. for any new building technology to be accepted both by the building regulatory system and by builders, plumbers, and homebuyers. But with demonstrated performance and cost savings, RSV is likely to become widely used.

As a rough proxy for the diffusion rate, we estimated by region the percentage of new, single-family houses each year in which RSV appears likely to be installed. (See Reference 9 for a listing of these estimates.) To derive these estimates, the percentage of new houses in which RSV will be used by 1985 was first forecasted in consultation with experts in the plumbing industry. The percentages of new houses in which RSV will be used in each year from 1975 through 1984 were then estimated on the basis of the 1985 forecast by the following formula:

$$F_j = \frac{\sum_{i=1}^{j} Y_i}{\sum_{i=1}^{n} Y_i} \cdot F_n, \qquad (2)$$

where

F_j = calculated percentage of new houses constructed in year j with RSV venting,

VENTING SYSTEM DESIGNS IN NEW HOUSES BY REGION

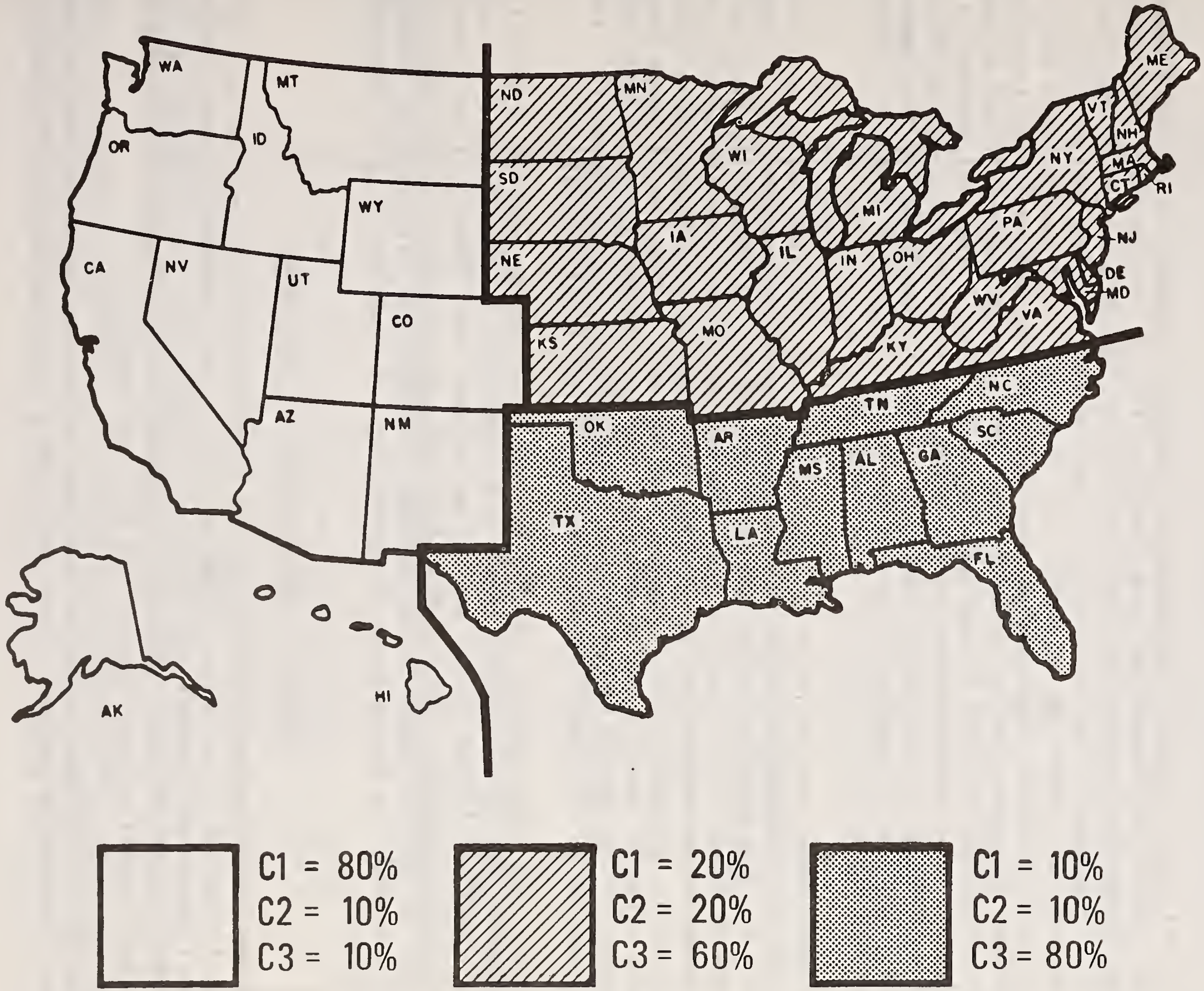


Figure 6

Y_i = years from 1975 through 1985 represented by consecutive numbers from 1 to 11, and

F_n = preducted percentage of new houses to be constructed in year n (i.e., 1985) utilizing RSV.

This formula was selected for estimating the percentages of new houses from 1975 through 1985 which will utilize RSV because it appeared reasonably descriptive of the patter of acceptance of an innovative building technology; that is, growing acceptance over time, but at a decreasing rate.

To derive the expected aggregate cost savings from RSV, first the savings for each region and house type were computed, taking into consideration the plumbing system cost savings from RSV for each of the three types of venting designs the percentages of houses likely to contain each type of venting design, and the expected percentage of houses utilizing RSV. The savings were then summed across all regions and house types. Table 5 shows the estimated total cost savings by region and for the U.S. as a whole, based on the stated assumptions. The projected estimate of aggregate present value savings, discounted with an interest rate of 10 percent, is $106.5 million, based on the use of RSV in an estimated 3.9 million single-family residences. The largest single part of these savings is expected to come from the use of RSV in one-story houses in the Southeast.

An additional cost factor that has not yet been discussed is the cost of research and development which is leading to the application of RSV. To ascertain the net benefits of RSV, we need to know the difference between the present value of cost savings from introducing RSV and the increased cost incurred in its implementation. Taking into account government and private laboratory research, field testing, and building trials, we estimate the present value of research and development costs to be approximately $900,000. Compared with the estimated savings (benefits), the costs are small. The present value of the resulting net benefits of RSV is $105.6 million.

Because the cost savings from RSV are sensitive to the assumed levels of acceptance, and because these levels are uncertain, we recalculated our estimates for lower and higher percentages of acceptance than those that were used in the original estimates. Savings from RSV (not shown in tables here) were still high--$58 million based on percentages of acceptance half as great, and $149 million based on percentages of acceptance 1.5 times as great as those used initially.[9]

Impact of RSV in the U.S. and Abroad

We have demonstrated that RSV has the potential for reducing the cost of housing in the U.S. Estimates of $46 to $125 in potential savings per single-family household, and of $58 million to $149 million for the nation as a whole over the next 11 years, show that the adoption of RSV could result in an important impact on the plumbing and building industry.

Realization of these potential cost savings in the U.S. depends on how fast code authorities accept RSV in the plumbing codes and how fast builders,

Table 5

Estimated Potential Cost Savings From Use of RSV, 1975 through 1985

Region	Type of House	Number of RSV Systems (1,000)	Present Value Savings ($1,000,000)
Northeast	1-Story	670	20.5
	2-Story	633	12.3
	Total	1,303	32.8
Southeast	1-Story	1,557	41.5
	2-Story	458	4.4
	Total	2,015	45.9
West	1-Story	429	18.7
	2-Story	172	9.1
	Total	601	27.8
All Regions	1-Story	2,656	80.7
	2-Story	1,263	25.8
	Total	3,919	106.5

developers, contractors, plumbers, and homebuyers implement RSV technology once it is authorized by the code. Greater use of RSV would be promoted in the U.S. by demonstrations that RSV meets the performance requirements of venting[3,4] and that RSV will save money. It should be recognized, however, that such factors as possible difficulties in obtaining the smaller-sized piping and the special transition fittings, initial lack of installation experience, lack of familiarity with research findings on the adequacy of performance of RSV, inappropriate code content to facilitate proper design and inspection, and resistance to change by labor may retard RSV acceptance and reduce the savings to be realized from RSV over the next decade. However, time will likely reduce many of these barriers to RSV, and one might expect that the combined thrust of greater familiarity, better documentation on field trials, and demonstrated cost savings will soon establish RSV in the U.S. as a viable venting technique applicable to any type of standard DWV system. The nation stands to benefit from the provision of plumbing systems with satisfactory performance at considerable dollar savings.

It is probably not justifiable to project the estimated U.S. savings potential to other countries. Because the U.S. has more elaborate venting requirements than most other countries, it may have more to gain on a per-housing-unit basis from adopting RSV than the other countries. However, in those countries where the government is a major builder, and where codes are centrally imposed, the transition to a new building innovation such as RSV would probably be much faster than in the U.S. To arrive at an accurate forecast of the cost savings impact from the use of RSV in other countries, it would be necessary to make country-specific analyses similar to this study for the U.S., taking into account current plumbing designs and venting requirements, as well as housing forecasts and RSV diffusion rates.

ACKNOWLEDGMENTS

This paper is based in part on a report by the Applied Economics Group of the National Bureau of Standards.[9] A more detailed treatment of these research findings and the methodology on which they are based appears in "Cost Savings from Reduced-Size Venting," an article published in Plumbing Engineer. The authors thank the many readers for their critical reviews of this paper, particularly Dr. John McConnaughey.

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This report contains the papers presented at the International Symposium on Water Supply and Drainage convened on September 28-30, 1976 at the National Academy of Sciences, Washington, D.C. and conducted by the U.S. National Committee for the International Council for Building Research, Studies and Documentation (CIB) Counterpart Commission W-62. The meeting provided the opportunity to exchange information and identify general needs and common perspectives of plumbing in on-going research applications and practices in the United States and other countries.

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