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NATIONAL BUREAU OF STANDARDS REPORT

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REPORT

ON

REVIEW OF INFORMATION ON PERFORMANCE

OF SINGLE-STACK, SANITARY DWV SYSTEMS FOR BUILDINGS

by

Robert S. Wyly
Environmental Engineering Section
Building Research Division
Institute for Applied Technology

Sponsored by
The Technical Studies Program
Federal Housing Administration
Department of Housing and Urban Development

NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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CONTENTS

ABSTRACT

This report presents a generalized summary of the essential features of two European systems of "single-stack" sanitary drainage for multistory housing, and gives recommendations for activities considered essential to an orderly evaluation of the potential of such systems under American conditions. Perhaps the most significant distinguishing feature of single-stack systems is the absence of the sub-system of secondary ventilation piping that has long been considered essential to acceptable performance in multistory buildings by plumbing officials and by designers and installers of plumbing systems in America. Obviously, considerable savings in construction costs would result from the elimination of secondary ventilation. A number of European research studies on the subject of single-stack drainage are described, and standard codes of practice identified that recognize this method of drainage. The need for certain further performance data from single-stack systems is discussed.

1. INTRODUCTION

This study is intended (a) to evaluate existing European data on the performance of single-stack DWV systems for tall buildings, (b) to identify conditions which might require further studies in order to establish the feasibility of single-stack drainage in America, (c) to identify significant performance criteria, and (d) to describe, in a general way, new tests that may be needed to complete the evaluation of the feasibility of single-stack drainage under American conditions.

This report presents a summary of findings to date on two European single-stack drainage systems - the Sovent System (from Switzerland), and the British System. Conclusions and recommendations are given, based on available information. A further report is planned, including more detail and some analytical work with existing data, to supplement and support the recommendations given herein. While other variations of single-stack systems exist in Europe, and a vacuum-drainage system has been developed in Sweden, these are not specifically treated herein.

In Europe, the ventilation of the sanitary drainage system provided by the extension of the soil or waste stack through the roof as a vent to the atmosphere is referred to as "primary" ventilation. This feature is retained in most versions of European single-stack drainage. The usual American practice of providing a separate vent stack and its associated individual, group, and branch vents is referred to in Europe as "secondary" ventilation, and is virtually eliminated in the single-stack systems described in this report.

It seems important to recognize at the outset that the development of the British System started in the early 1950's, while the development of the Sovent System dates from the early 1960's. Thus, the Sovent System is a relatively recent version of single-stack drainage. Thus, while the Sovent System is presented first in the present report, this definitely does not signify any preference for, or superiority of, either system.

The high and increasing costs of construction of modern buildings are causing concern. This concern is intensified when statistics and predictions are reviewed that indicate the size of the enormous building program that now faces the nation. Not only is the problem an economic one, in terms of cost of materials and labor, but it is also a problem in conservation of resources. Yet at the same time, reasonable minimum standards of performance for buildings and the systems comprising them must be met so that the occupants of these buildings will be guaranteed a safe, healthful, and aesthetically pleasant environment insofar as feasible.

Plumbing in modern, multistory buildings represents a respectable proportion of the total cost, and the sanitary drainage system without doubt accounts for a major part of the plumbing cost. For example, it has been estimated that in Britain, the cost of sanitary services and underground drainage account for 5 to 10% of the total cost of modern buildings [1] [1/]. It is not surprising, then, that European experience in recent times with greatly simplified DWV systems has been viewed with interest on this side of the Atlantic, particularly when the reports are accompanied with claims of savings of the order of 30 to 50% of the cost of conventional DWV systems [2]. Thus, there seems to be good reason to undertake an evaluation of the performance of single-stack systems currently being used in Europe, based on on-site inspections, discussions with European groups, and a review of the literature. From this, it is reasonable to expect that some useful recommendations can be developed regarding possible application of

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1/ Figures in brackets refer to the list of literature references at the end of this report.

single-stack drainage systems in American plumbing practice, and regarding any further research that may be necessary to establish the feasibility and limits of this type of drainage under American conditions.

2. SOVENT SINGLE-STACK SYSTEM

2.1. General Description

The Sovent System makes use of a special fitting at each floor level, shaped as an upright shunt around a vertical branch inlet to the stack (see Figure 1). Near the base of the stack, a deaerator fitting is employed, together with a relatively short vent. The originators of the system state that this construction relieves the excess pneumatic pressure generated near the bottom of the stack. This vent connects the deaerator fitting to the building drain by bypassing the stack-base fitting (see Figure 2).

The principle of operation is that introduction of the branch flow vertically into the stack avoids interference of the flows in the stack and the branches, and prevents restriction of the air passageway in the stack by discharge from a branch, thus reducing the tendency to pneumatic pressure fluctuations. The shunt not only reduces flow interference and prevents temporary "plugging" of the stack, but also reduces effective density, velocity, and air demand, according to the information reveiwed. This information indicates that the bottom deaerator fitting and its associated vent are used to equalize pressure imbalance at the base of the stack, or at an offset in the stack (see Figure 3).

The venting of individual fixtures and groups of fixtures, as commonly practiced in America, is not considered necessary by the originators of the Sovent System, and was not employed in a number of Swiss multistory housing installations observed. The elimination of this practice is based on the use of horizontal branches of adequate size, and on the use of adequate diameters for fixture drains used to connect traps to a common horizontal branch. As further safeguards against loss of trap seal from interaction between fixtures connected to the same horizontal branch, the fixtures are ordinarily grouped in relatively close proximity to the soil or waste stack, and some form of siphonage-resistant trap is used, such as a deep-seal p-trap, or a bottle trap. Because of its particular geometry, the water-closet trap is less resistant to siphonage by a static vacuum than a tubular p-trap; but because of its greater mass, it may resist rapidly fluctuating pressure differentials more successfully than a p-trap of the same seal depth. Figure 4 shows the arrangements of drainage piping used in one apartment building, utilizing the Sovent design.

2.2. Possible Advantages

Obviously, the virtual elimination of the conventional American secondary venting system in a tall building points to an attractive saving in labor and materials. It has been claimed, apparently for good reason, that in quite tall buildings load on a 4-in. stack can be greater with the Sovent System than with other types of contemporary European single-stack gravity drainage systems. These advantages and savings must be weighed against the cost of the Sovent fittings and the relatively large spaces that evidently must be provided for them during building construction.

2.3. Research

2.3.1 Research Completed

Considerable experimentation on Sovent systems has been conducted in Switzerland in the laboratories of the Lehrwerkstatten der Stadt Bern, where comparisons have been made with other single-stack systems of types currently used on the European continent. Tests have been made under laboratory conditions for stacks up to about 10 stories in height. Various hydraulic loads have been applied and the maximum excursions in pneumatic pressures within the junction fittings and within the horizontal branches have been determined. In selected tests, the amount of air entering the top of the stack has been measured, pneumatic pressures at certain levels have been recorded continuously, and from these records the velocity of flow in the stack inferred. Some tests have been carried out using toilet paper, paper diapers, and detergent loadings.

In order to study the performance under service conditions, a number of tall buildings have been instrumented, and pressure measurements made over a period of time, both with manual loadings and with normal service loads. One building nearing completion was visited, in which a manual test was made by flushing a number of fixtures at an intermediate level, and the condition of the trap seals at lower floors was observed. No adverse results were noted in this test.

The data [3, 4, 5, 6, 7, 8] that have been made available in the present review indicate superior pneumatic performance of the Sovent system as compared with at least one other form of Continental single-stack plumbing having the same stack length and diameter, and this suggests that for quite tall buildings the Sovent system may have an economic advantage as compared with the other single-stack systems since the latter would need to be of a larger diameter to maintain satisfactory pneumatic conditions. However, in fairness to other single-stack systems, it must be recognized that for light loadings, the special performance features of the Sovent system may be unnecessary under European conditions, and that in a building of perhaps 10 stories or less the cost of the Sovent fittings and the cost of the deaerator vent may make the Sovent system less attractive than other European systems of single-stack drainage.

2.3.2. Further Information Needed

Probably the greatest need for information in America regarding the Sovent system is a comparison of performance with a typical American vented system, applying the same loadings. Although it may be that useful information can be obtained in a properly equipped laboratory, perhaps a field test should be considered as well for its practical value. Measurements and observations should be taken over a period of time under service conditions in at least one high-rise apartment building in which some typical stacks are of the Sovent type and others of the usual American design. The essential measurements would be peak values of pressure and vacuum, and residual trap seal depths. User reactions should be sampled.

Also needed are data on the performance of trap seals of American-style fixtures connected to horizontal branches when subjected to interactions between different fixtures on the branch, the connections being made in the most satisfactory fashion consistent with the Sovent design. Tests should be made to establish minimum fixture drain sizes for American off-the-floor fixtures, such as sinks and wash-basins, when connected to a horizontal branch without secondary ventilation, in the Sovent fashion. If applications are anticipated in buildings other than housing, some work should be done to study the performance of long horizontal branches serving batteries of fixtures without conventional vents, such as might be the case if the Sovent system were used in office buildings and some types of commercial and institutional buildings. Evidently the Swiss applications have been limited to multistory housing, with only a few exceptions of quite recent date. Possibilities can be visualized for unconventional, limited venting with small-bore tubing in Sovent systems in non-housing installations; however, data are needed on the performance of such systems.

Questions have been raised about the effects of fouling, corrosion, detergents, and wind currents on performance of single-stack systems relative to that of conventionally vented systems [9]. The literature should be examined further for information on these factors. Meaningful laboratory tests for some of these properties may be difficult to devise, however. In addition, the data forming the basis of the present report do not firmly establish the limits of the Sovent system for American-style plumbing fixtures. It may be that useful loadings will be less than for a fully-vented system [9] ; however this may not necessarily be of great practical significance in installations involving relatively light loadings in comparison to those allowed by many plumbing codes in the U. S. A. In other words, stacks in moderate-height apartment buildings may not be required to carry more than a small part of the load allowed for a conventionally vented 4-in. stack by many American plumbing codes; in such instances it has been claimed that the actual load may be within the capacity of a Sovent stack which permits elimination of the entire secondary ventilation system with the exception of the short deaerator vent.

The European data on the Sovent system should be examined in some detail to relate the magnitude of the test loads used to connected fixture loads that might yield equivalent hydraulic service loads, assuming applicability of the mathematical theory utilized in ASA A40.8-1955 for predicting peak loads.

From the literature reviewed, it seems that some further research on the basic mechanisms of flow in the Sovent system is needed, to provide continuity between theory and practical application equivalent to what has been established for the British System. Among such information would be measurement-type data supporting explanations or theories regarding the fluid mechanics of the special fittings employed in the Sovent design. Specific needs exist for an evaluation of any tendency to fouling or clogging that might be introduced by the presence of the projecting nib in the deaerator fitting, and for an evaluation of the effectiveness of the deaerator fitting in reducing pressure at the foot of the stack and in reducing hydraulic jump in the building drain. Experience in the development of the British System has led British designers to the conclusion that suitable pressures may be maintained near the foot of a stack by the use of a simple, standardized long-radius bend and, if necessary, by the use of a building drain of slightly larger diameter than the stack. It would also be informative to compare the pressure-control effectiveness of the Sovent junction fitting with the 2-in. radius sweep W.C. fitting used in the British design. It may be that research has been carried out to answer some of these questions on the Sovent design, but the data so far reviewed do not appear to provide all the desired information.

2.4. Use In Buildings

According to a 1966 release by a well-known manufacturer of plumbing goods in Switzerland [10], approximately 9,000 apartment living units are now served by Sovent systems (8327 in Switzerland and 744 in other countries). This release also indicates that since its introduction in 1961, use of the Sovent system has increased each year, with the sharpest increases in 1965 and 1966, due at least in part to its use in the Lignon high-rise complex under construction in Geneva (buildings up to 30 stories, development planned for about 30,000 people). At this site, prefabrication of the plumbing-pipe assemblies is practiced, so that on-site labor is greatly reduced.

Only a relatively few connections must be made at each branch interval in completing the rough plumbing.

2.5. Materials

Sovent systems are available in Switzerland in several materials, including copper, cast iron, steel, PVC plastic, and asbestos cement. The cost ratios between the different materials at any particular time evidently influence the choice of a material to a considerable degree. In the buildings up to 30 stories high observed under construction in the Lignon development, asbestos cement Sovent drainage fittings and main stacks with a resilient joint system were used, but other materials are reported to have been used in other buildings in Switzerland. In a number of instances, plastic piping was being used for small fixture drains and horizontal branches of 2-in. diameter and less, and in some instances was used for 4-in. soil branches.

3. BRITISH SINGLE-STACK SYSTEM

3.1. General Description

The British System utilizes short-pattern T-Y or straight T fittings made according to the applicable British Standards, to connect the fixtures individually to a drainage stack without secondary ventilation piping. Induced siphonage is limited by appropriate sizing of the stack according to height and load, and, it is claimed, by the favorable geometry of the British Standard fitting used to connect the water closet to the stack. Self siphonage is limited by following certain recommendations on fixture drain lengths, sizes, and slopes, by the use of deep-seal traps, and by trap refill from the favorable geometry of certain fixtures. Offsets in the wet portion of the stack are prohibited, large-radius bends must be used at the stack base, and at least under some conditions the building drain must be one size larger than the stack. To reduce pneumatic pressures at the stack base and prevent detergent foam backup, ground-floor fixtures are connected to the building drain, and in the case of very tall buildings, the next higher floor is also connected to the building drain.

The basic principle of operation of the British system is that by somewhat over-sizing the stack, and by providing favorable fitting geometry at critical points, pneumatic pressure disturbances are reduced. Detailed rules for design and sizing must be followed as specified in the literature. Figures 5 through 7, and Table 1, are examples of these rules. In 1967, The Building Research Station issued recommendations on single-stack systems permitting up to 5 stories of back-to-back flats or up to 10 stories of single flats on a 4-in. stack, up to 12 stories of back-to-back flats or up to 15 stories of single flats on a 5-in. stack, and up to 25 stories of back-to-back or single flats on a 6-in. stack [11].

3.2. Possible Advantages

As in the case of the Sovent System, the elimination of virtually all secondary venting in tall buildings is an attractive feature. While for quite tall buildings the stack sizes for the British System will usually be larger than for the Sovent System (5 in. or 6 in. instead of 4 in.), this disadvantage may be offset in some cases by the lower cost of the simpler British fittings and by the fact that a deaereator fitting and vent are not used in the British design. It seems likely that the British System would have the greatest attraction for use in multistory housing of moderate height, perhaps for apartment buildings of 10 stories or less.

3.3. Research

3.3.1. Research Completed

Considerable research on single-stack systems has been conducted in Britain by the Building Research Station, Ministry of Building and Public Works [1, 2, 12, 13, 14, 15, 16]. In addition to laboratory studies the Station has made field measurements and observation on a number of single-stack drainage installations, and has been instrumental in the promulgation of recommendations on correct design of such systems [11, 17, 18, 19, 20, 21]. Work of this nature is still proceeding in tall buildings. A summary article entitled, "Britain's Single-Stack Drainage System", by A. F. E. Wise, appearing in the April, 1967, issue of Air Conditioning Heating and Ventilating [16] gives a short, informative description of essential features.

3.3.2. Further Information Needed

As in the case of the Sovent System, probably the greatest need for information in America regarding the British System is a comparison of performance with a typical American vented system, applying the same loadings. Both laboratory and field comparisons would be desirable, but the great practical value of a field test in a real building should not be overlooked. Peak pressures and vacua, and residual trap seal depths should be measured, and user reactions sampled.

Also, as stated in Sec. 2.3.2. for the Sovent system, information may be desired about the performance of American-type fixtures in batteries associated with possible non-housing applications of the British System.

As indicated in Sec. 2.3.2. for the Sovent System, some consideration should be given to the relative dangers of fouling and corrosion, wind pressures, and detergent effects in the British System without secondary ventilation, as compared to the American practice in which secondary ventilation is employed.

The British data on their single-stack system should be examined in some detail in an effort to estimate the magnitude of connected fixture load that might be expected to yield hydraulic loads comparable to the test loads used, assuming applicability of the mathematical theory utilized in A40.8-1955 for predicting peak loads.

3.4 Use in Buildings

Single-stack drainage systems for two-story houses have evidently been in use in Britain for some 15 years. In 1954, the Building Research Station recommended 4-in. single-stack systems in buildings up to 5 stories high. Research and experience over the next few years provided needed information on performance of these systems. In 1962 and 1963, the recommendations were extended to cover stacks of 4, 5, and 6 in. diameter up to certain height limits. In 1966 and 1967

[1, 11] these recommendations were further extended as follows:

4 inch stacks - - - - up to 10 stories

5 inch stacks - - - - up to 15 stories

6 inch stacks - - - - up to 25 stories

A number of builders and designers of plumbing systems report that in contemporary British multistory housing the single-stack or a modified single stack system is almost always installed. The Station has monitored the performance of a number of such buildings and has reported generally satisfactory service, providing the rules for design are strictly adhered to. Some have questioned the quality of performance of single-stack systems but it is not clear whether this question is raised because of possible insufficient investigation, or because of questionable performance of systems which violated the BRS design rules, or for some other reason.

3.5. Materials

In Britain, the single-stack systems seen utilized either cast-iron soil pipe or PVC plastic pipe in the stack, and either copper tube or PVC plastic for the small fixture drains. Plastic stacks employed one form or another of a joint system providing for the accommodation of thermal movements.

4. OTHER EUROPEAN SYSTEMS

In Holland, Switzerland, France, Germany, and Sweden single-stack sanitary drainage systems were observed which did not utilize special junction fittings, but which were designed in accordance with sizing rules which had been worked out. For example, Figure 8 shows some of the Swedish rules. Thus, in some ways these systems resemble the British system, with some differences in the sizing and connection of fixture drains to the stack or horizontal branch. Information was obtained indicating that a form of single-stack drainage has been used in Austria for about 10 years. Single-stack drainage is allowed by DIN 1986, the West German code of practice for sanitary drainage, issued in 1962 [28] . It was reported that 80 mm (3 1/8 in.) stacks without secondary ventilation have been used in 17-story apartment buildings in Berlin. Foreign-language literature obtained on this subject indicates that research has been conducted on the European Continent to establish rules for sizing and configuration, and that in some instances these rules have been incorporated in standard codes of practice [22, 23, 24, 25, 26, 27, 28, 29].

Some reservations about the performance of single-stack systems have been expressed by plumbing contractors and installation experts in Germany, but to date no specific data have been offered in support of this position. Perhaps the most widely known code of practice on the Continent recognizing single-stack drainage is DIN 1986, as indicated above.

A special form of sanitary drainage has been introduced in Sweden, involving the separation of the DWV system into soil and waste sub-systems, along with the elimination of all secondary ventilation piping [30]. By means of a specially constructed water closet and a vacuum source operating at approximately one-half atmosphere and connected to the soil sub-system, it has been shown that only about 3 pints of water are required for a single operation of the water closet. Actually, it may be possible to design the system to combine the separate soil and waste stacks in a single stack connected to a vacuum source; however, at the present this is not considered essential or economical by the proponents of the vacuum system. The waste sub-system is provided with diaphragm traps beneath the fixtures to increase resistance to pneumatic pressure excursions in the waste stack which operates by gravity. The vacuum system has been used in multi-story buildings utilizing soil and waste piping no larger than 2-in. diameter. This system obviously contributes to water conservation as well as to the reduction of vent piping, requiring only about 10 percent of the quantity of water for flushing a water closet as is customary in America. A further attractive feature of the design is the reduction of liquid load on the sewage treatment plant; this might reduce the cost of operation and construction of such plants while at the same time reducing the tendency to stream pollution.

5. ESSENTIAL HYDRAULIC AND PNEUMATIC PERFORMANCE CRITERIA

Broadly speaking, the following performance criteria or guide lines seem pertinent to systems using water-seal traps:

(a) Sufficient air relief should be provided at critical points in the system to prevent excessive depletion of trap seals through self siphonage or aspiration (induced siphonage), or to prevent objectionable forcing of trap seals from positive pneumatic pressures (important to reduce noise, to avoid sewer gases entering premises, and to avoid backflow of waste matter into fixtures).

(b) Drain piping should be of optimum size to carry all expected loadings except the most unlikely ones without causing undesirable retardation to flow as indicated by extended period of drainage from fixtures or by backup or cross-flow (due to excessive hydrostatic head), and without reducing flow velocity to the extent that fouling and deposition is likely to present a problem.

(c) Test loads should be selected so they are reasonable: both from a consideration of the probability of concurrent operation of fixtures and other water-using equipment, and from a consideration of the likely effects of an occasional overload (important to the standardization of test loadings and to avoid the selection of unnecessarily heavy test loads, while at the same time avoiding the selection of loads too light to be representative).

(d) Tendency to foul throughout the drainage system should be minimized through adequate flow velocity, reasonably smooth water passageways, freedom from "pooling" in drain lines, and other reasonable measures (particularly important to avoid fouling and clogging in fittings where changes in direction occur, and in long trap arms, horizontal branches, and building drains).

(e) Waste water or water-borne waste matter discharged through any trap arm or horizontal branch should not back up or flow into the trap arm of another horizontal branch in such a manner or to such an extent that trap seals are adversely affected or excessive deposition of solids occurs in traps, trap arms, or horizontal branches (important to avoid fouling and clogging of trap arms, traps, and horizontal branches not frequently used, and to avoid backflow of waste material into fixtures).

(f) Hydrostatic heads should not be developed in any portion of the drainage system downstream of the points of connection of individual fixture drains to horizontal branches or stacks. That is, in general, the drains are not to flow full.

Test loads for evaluating performance of sanitary drainage systems present some problems, but in any event should be selected from a consideration of probable concurrent operation of fixtures and appliances and of the consequences of an occasional overload.

It has been customary in the USA to limit pneumatic pressure excursions to ±1 inch of water column. Somewhat greater limits are recognized by some groups in Europe. If deep-seal or siphonage-resistant traps are used for fixtures most subject to seal loss, or if peak values of pressure or vacuum exist for periods of time generally less than the response time of the trap seals it may be reasonable to set an allowable pressure range greater than ±1 inch. Thus, information is needed on the relationships between trap-seal loss, trap-seal depth, amplitude and frequency of pressure excursions, and response characteristics of instruments used for making measurements.

6. CONCLUSIONS

Based on study of European literature and on interviews and on-site observations, the following statements appear warranted. Any further findings having substantial significance will be reported at a later time. The statements follow:

(a) There is widespread and, apparently, increasing use of single-stack drainage in Europe, for housing. The proportions of installations of this type were not determined in the present study. Systems of this type have been recognized in standard codes of practice in several countries.

(b) The potential savings in the cost of sanitary drainage systems by the use of the single-stack design have been variously estimated at 30 to 50%.

(c) Laboratory and field data available in the present study indicate probable satisfactory hydraulic and pneumatic service from two or more basic designs of single-stack systems, under European conditions, provided all design specifications are faithfully followed.

(d) Because of the facts (1) that European water closets discharge much smaller quanties of water than American closets, and (2) that European fixtures have been used in the laboratory studies reported, the numbers of fixtures allowed in Europe on a stack of a given size might have to be reduced if American type fixtures were to be used. Current studies using American-size loadings may throw some additional light on the limits of the Sovent system under these conditions. Results of these tests should be studied carefully.

(e) User habits in Europe and in America may be different, and this could conceivably affect peak loads under service conditions. Thus the extrapolation of the European data directly to American design is rendered difficult.

(f) The data reviewed relating to load limits for European single-stack systems are not considered to be of a nature that would permit a conclusive determination of permissible loadings on single-stack systems under American conditions, for comparison with loads allowed by plumbing codes for conventional American systems with secondary ventilation. This may retard the acceptance of multi-story single-stack drainage in America. However, it is pointed out here that for multi-story housing of moderate heights the maximum loadings allowed by many American plumbing codes frequently are not encountered because of the limited numbers of plumbing fixtures to be installed.

(g) Some reservations about general use of single-stack systems have been expressed by inspectors, installers, and contractors.

in several countries; but the bases of these reservations are not altogether clear. Further inquiries on this question are planned.

(h) In view of the savings that European experience suggests may be inherent in the use of single-stack drainage, questions about its applicability in America should be answered. Field trials with suitable, practicable, measurements should be undertaken in this country, and tests conducted relating to problems that can be studied in the laboratory

(i) A field program is strongly recommended, to comprise an evaluation of performance of selected stacks of two or more different single-stack designs in comparison with the performance of typical American-type stacks with secondary ventilation. Stacks to be compared would need to be in the same building and subject to the same loadings, and provisions for simple instrumentation provided during construction; for example, access to horizontal branch lines and stack-branch junctions would have to be provided, and pressure taps and electrical receptacles would have to be provided in convenient locations. Simple instrumentation comprising pressure switches, a time-pulse circuit, and dial counters could be provided to yield a record of the amount of time that the pneumatic pressure in the system is above or below specified limits. This type of measurement should be made both for manual flushing loads before occupancy, and for the in-use loads over a period of time after occupancy. Of course, more sophisticated instrumentation could be employed, but this is probably not essential as a general procedure. It would be desirable to also make detailed measurements of residual trap seal depths after manual flushing tests, and to make spot-checks of trap seal depths on a logical sampling basis during the in-use tests after occupancy. This would be desirable in view of the current lack of basic data correlating response rates of trap seals and instruments with frequency and amplitude of pressure fluctuations in drainage systems. These field tests should be made initially in one building, and depending on the results, extended to one or more additional buildings of the multistory housing type. Effects of detergents and paper could be explored in the manual flushing tests.

(j) Practical laboratory tests are recommended, as follows:

1. Taking European standard requirements on design and sizing of horizontal branches and fixture drains (without secondary ventilation) for use with single-stack systems as a guide, construct several one-story test systems to check hydraulic and pneumatic performance as it relates to induced siphonage and self-siphonage of fixture traps as affected by discharge of fixtures within the same branch interval. Piping, fittings, and fixtures commercially available in the U. S. A. would

be utilized in the test systems. Identify sizes and designs of horizontal-branch and fixture-drain systems that perform satisfactorily in tests. Explore effects of use of detergents, paper, and greasy waste matter on performance, as applicable.

2. Make a test to compare rates of corrosion in branch drains without secondary ventilation in comparison with rates in branch drains provided with secondary ventilation. The corrosive agent used for test purposes should possess the essential properties of hydrogen sulphide gas insofar as they relate to corrosion in sanitary drainage systems.

3. Devise suitable models of conventional and single-stack systems, and expose to air drafts that, preferably, are of controlled speed and direction. The purpose of this test would be to shed some light on the proposition that wind currents acting on vent terminals have a greater adverse effect on trap seals in a single-stack system than in a typical system with secondary ventilation.

4. In case of negative results in test No. 1, explore advantages that may be inherent in the use of small-bore loop vents without a vent stack.

5. Utilizing a 4- or 5-story laboratory test facility, check pneumatic performance of an American vented

system, and of British and Sovent single-stack systems, with selected test loads. Check pneumatic performance of water closet junction fittings, and of fittings used at the foot of the stack, as affected by shape or radius.

6. In some of the tests listed in 4 and 5 above, explore improvements in performance that may be realized by utilizing available water closets designed to conserve water.

(k) Cost estimates should be prepared for some typical high-rise sanitary drainage systems, in which costs are compared for the Sovent design and at least one other European design, and for typical American design, for say 5, 10, 15, and 20-story heights. These should be prepared by organizations familiar with current materials and labor costs, and experienced in estimating.

(l) If, from the foregoing, satisfactory performance is established utilizing certain designs of single-stack systems, it is essential that a set of detailed, illustrated construction specifications and essential design requirements be prepared so as to accurately identify acceptable designs and important performance-related features.

(m) While the Swedish vacuum drainage system differs dramatically from the single-stack systems referred to as the "British System" and the "Sovent System", it should be studied further in America. The information obtained on the vacuum system indicates potential savings in vent piping and water consumption, and a reduction in liquid loading on sewerage works which might aid in stream-pollution abatement.

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Table 1 Minimum stack sizes and vents required for various loading conditions--recommendations by the British Building Research Station, 1967.

Type	Stack diameter in.	Requirements	Requirements
House			
(Single-family dwellings up to 3 storeys)	3½		
Flats			
		Stack serving one group on each floor*	*Stack serving two groups* on each floor*
Up to 5 storeys	4	Single-stack	Single-stack
6 to 10	4	Single-stack	2 in. vent stack with one connection on alternate floors
11 to 15	4	2 in. vent stack with one connection on alternate floors	2 in. vent stack with one connection on each floor
16 to 20	4	2½ in. vent stack with one connection on alternate floors	2½ in. vent stack with one connection on each floor
Up to 12 storeys	5	Single-stack	Single-stack
12 to 15	5	Single-stack	2 in. vent stack with one connection on alternate floors
Up to 25 storeys	6	Single-stack	Single-stack
Maisonettes			
		Stack serving one group on alternate floors	*Stacking serving two groups on alternate floors*
Up to 10 storeys	4	Single stack	Single stack
11 to 15	4	Single stack	2 in. vent stack with one connection on alternate (bathroom floors)
16 to 20	4	2 in. vent stack with one connection on alternate (bathroom) floors	2½ in. vent stack with one connection on alternate (bathroom floors)

*Each group consists of a W.C., bath, basin and sink. Where dwellings contain more appliances, it may be necessary to provide more vents.

N.B.
The above recommendations apply to systems with swept-inlet W.C. branches. With straight-inlet branches, a 4 in. stack with no vents has been found satisfactory for up to 4 storeys; a 6 in. stack with no vents has been found satisfactory for up to 15 storeys.

Table 2 Dimensioning of fixture drainage connections, with and without secondary ventilation ----- recommendations by the Swiss Sewage System Association, 1966.

Apparat S-Wort Gruppe a–	Zulässige Abflußmenge in l/min b–	c– Dimensionierung des Apparate-Ablaufanschlusses 1	e–	2	3	4	5	Sekundäre Lüftung d– 6
		mm	Anschlußgewinde	mm Ø	mm Ø	mm Ø	mm Ø	mm Ø
1	15	25	1"	25	32	32	40	25
2	30	32	6/4"	32	40	40	50	25
4	60	40	1 1/2"	32	50	50	60	32
6	90	50	2"	40	60	60	80	32
8	120			65	80	80	100	40
10	150			65—80	80	80—100	100	40

Details:
1. Apparatus outlet
2. Odor lock (siphon)
3. Odor lock-outlet
4. Connecting line horizontal (up to 87°)
5. Connecting line diagonal and vertical
6. Secondary ventilation

Legend: a - apparatus S-value group; b - permissible outflow quantity in l/min; c - dimensioning of apparatus outlet connection; d - secondary ventilation; e - connecting piece thread.

The horizontal connection line under column 4 is to be preferred to the larger-dimensioned diagonal or vertical connecting line under column 5.

In case of secondary ventilation, the dimensions in column 5 can be reduced to those in column 4.

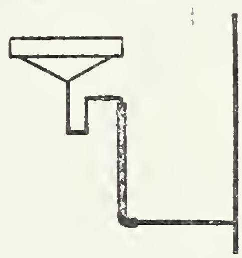
Table 3 Sizing table for soil and waste stacks without secondary ventilation---recommendations by the Swiss Sewage System Association, 1966.

a– Falleitung		b– Höchstzulässige Anzahl		c– Nach den S-Werten entsprechend zu erwartende Wassermenge	
d– Dimension LW in mm nach Ziffer 4.1	e– Größter zulässiger S-Wert	WC f–	g– S-Wert	in l/s	in l/min
50	2	—	4	0,75	45
60	4	—	12	1,50	90
70	4	—	24	2,00	120
80	6	—	72	3,00	180
100	10	16	320	4,50	270
125	—	36	720	6,00	360
150	—	90	1800	10,00	600

Legend: a – dropline; b – maximum permissible number; c – water volume to be expected according to S-values; d – dimension, LW in mm according to item 4.1, above; e – maximum permissible S-value; f – flush toilet; g – S-value.

Dropline segments

Perpendicular segments to a maximum of 1.5 m in height.



Dropline (drop section)

Outlet /evacuation/ line running perpendicularly from the basic /ground/ line (house sewage system) through the various floors until a point above the roof (1).

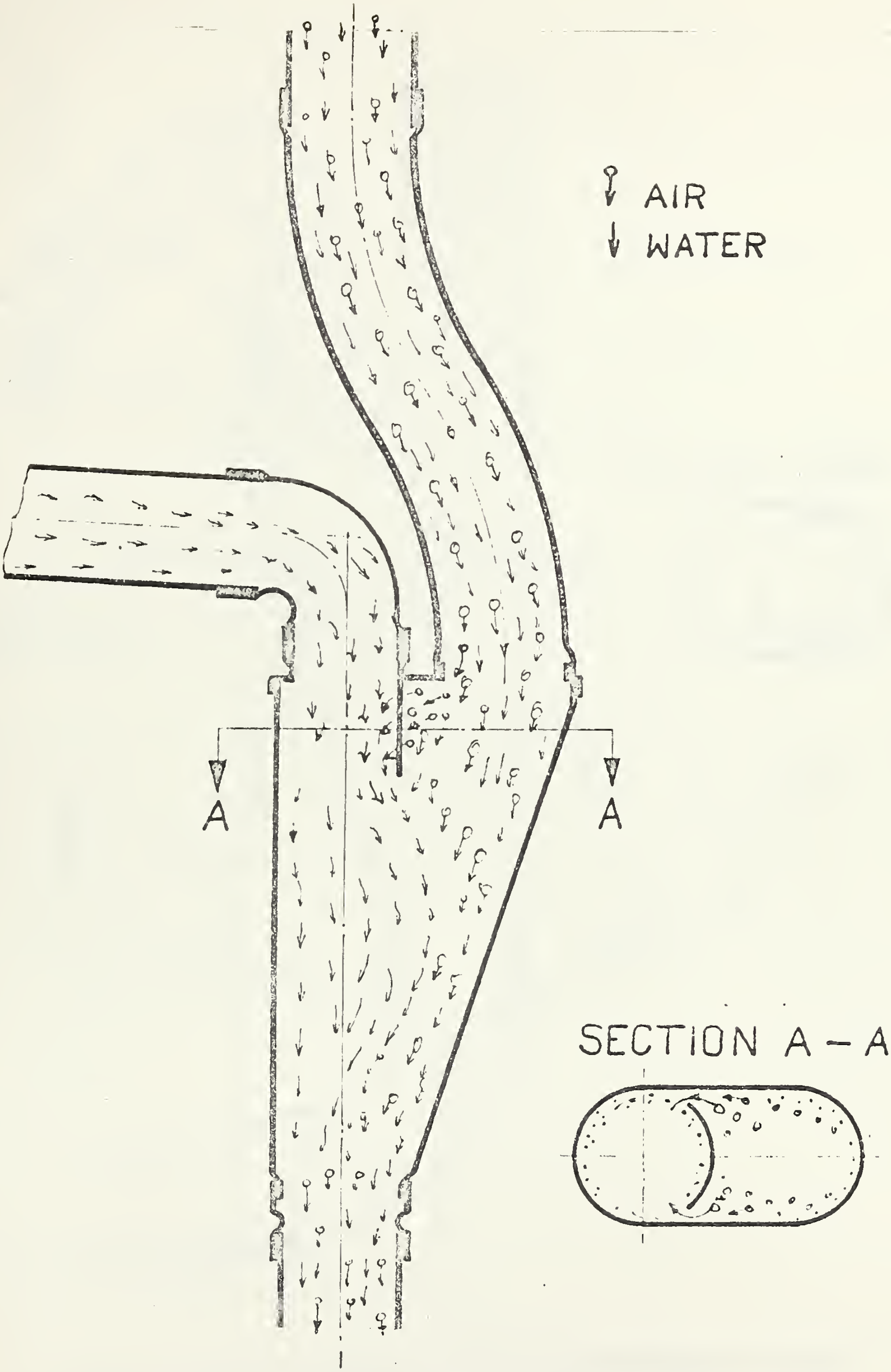


Figure 1 Sovent junction mixer fitting comprises an upright shunt section in stack, and a vertical branch inlet; this reduces mutual interference between the two streams.

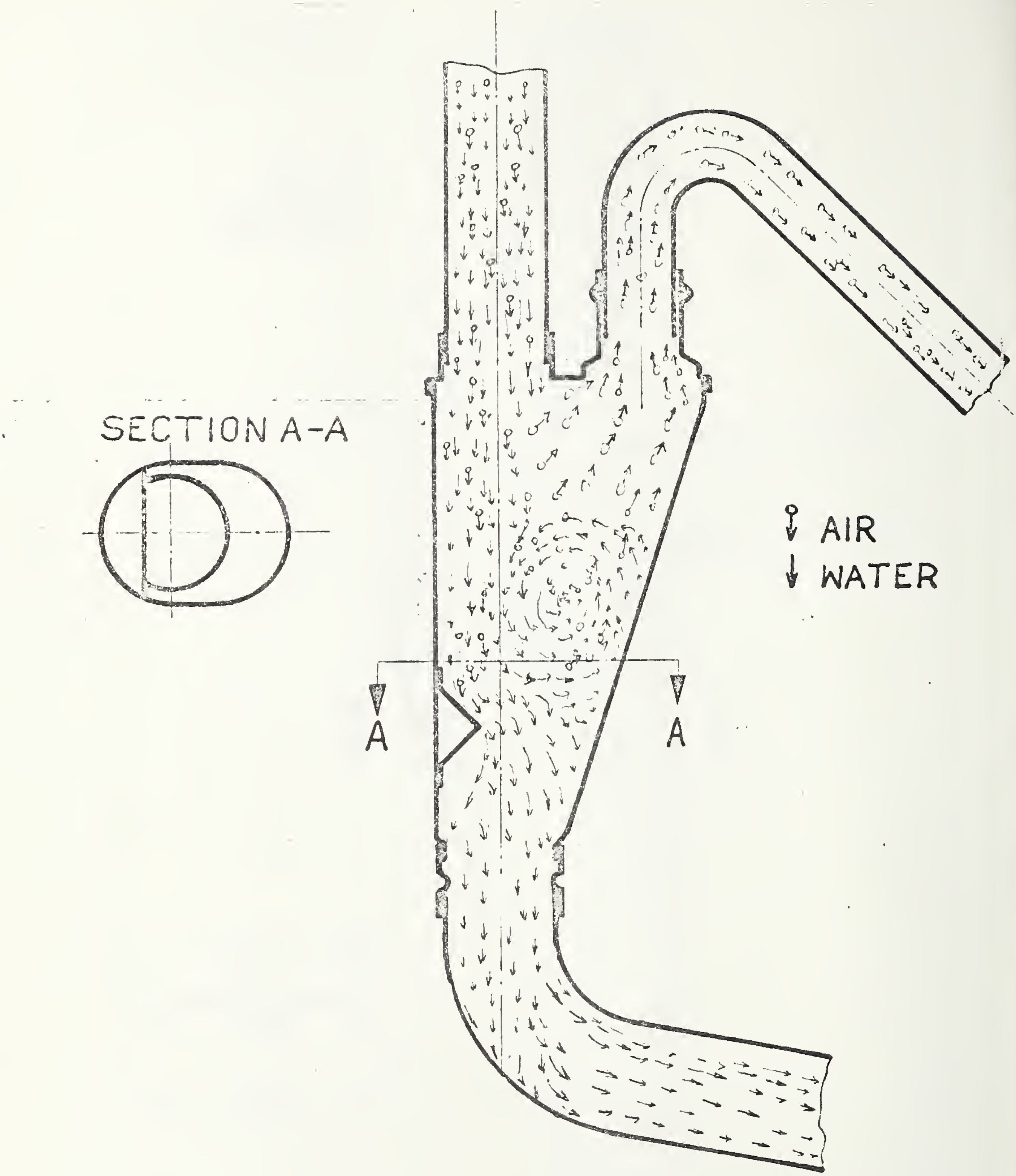


Figure 2 Sovent deaerator fitting employs baffle and vent to relieve excess pneumatic pressure in lower part of stack, and to reduce tendency to hydraulic jump in building drain.

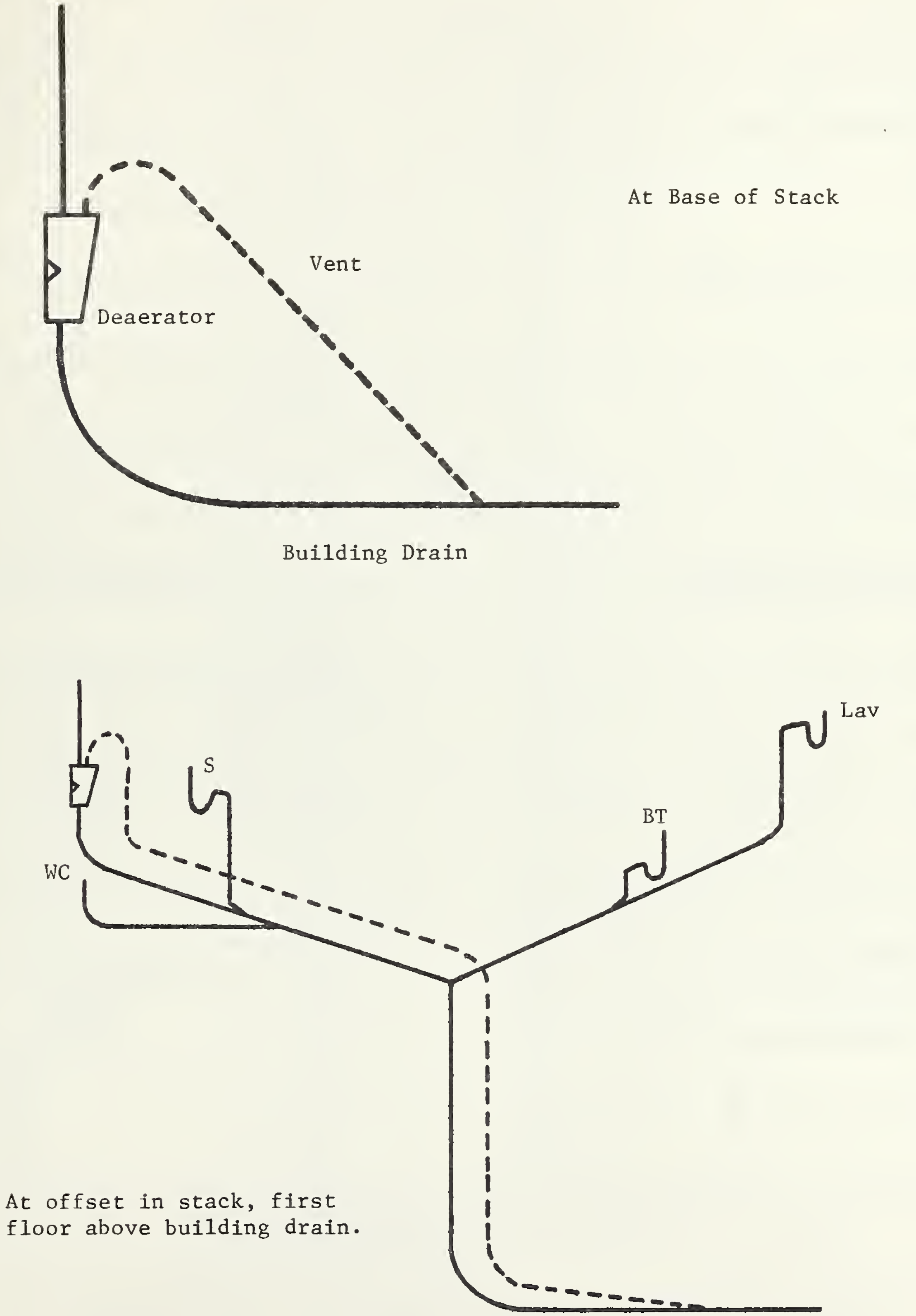


Figure 3 Typical arrangement of deaerator fitting and vent in lower part of stack to relieve excess pneumatic pressure.

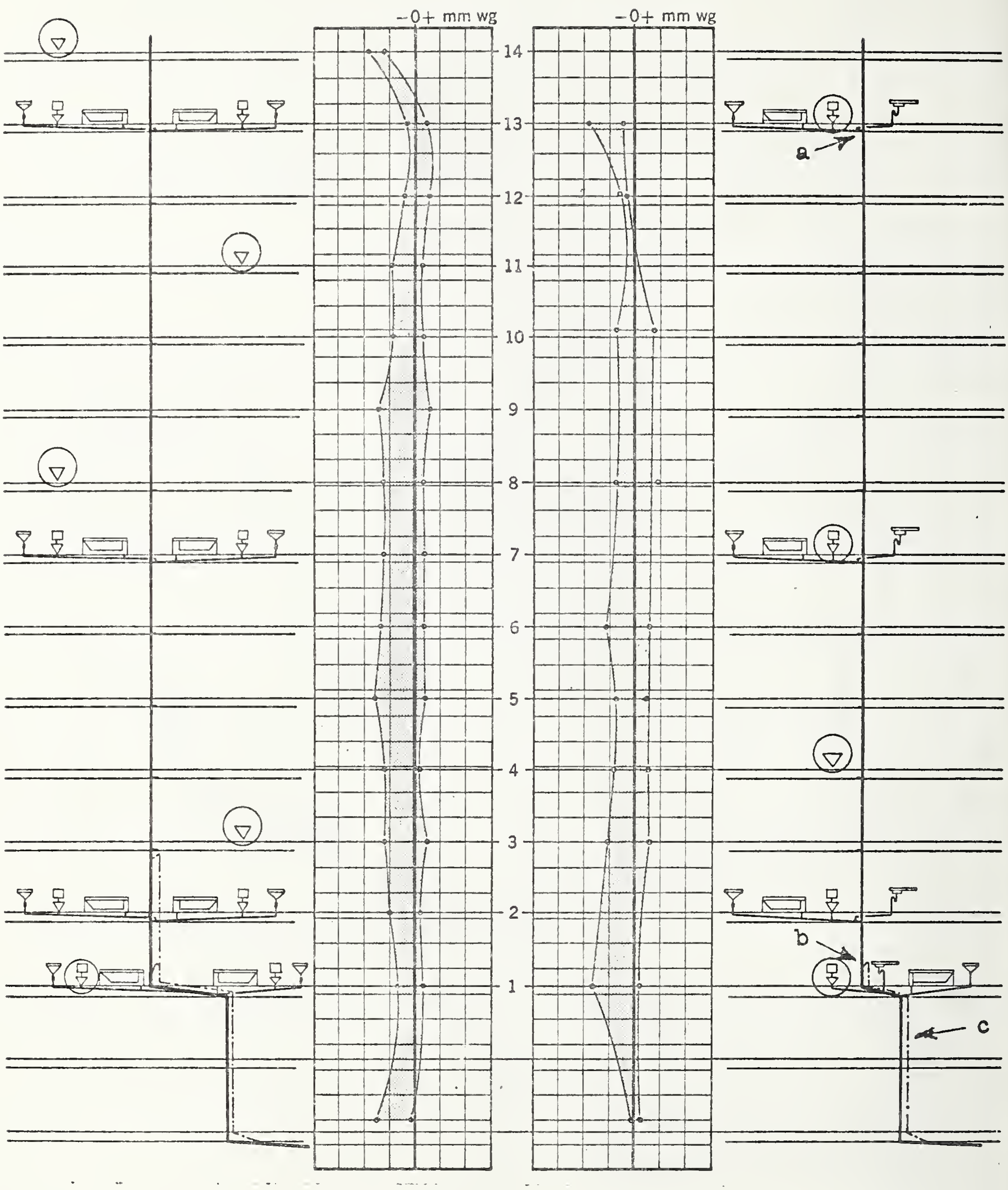


Figure 4 Sovent drainage stacks in 13-story apartment in Bern, Switzerland; pneumatic performance in manual flushing test shown on graphs.

a. Junction mixer fitting
b. Deaerator fitting
c. Deaerator vent

Notes:

1. Circled fixtures discharged simultaneously to produce test load
2. Each horizontal division on graph represents 10 mm of pressure water gage (w.g.). Pressures above atmospheric = +, below = -.

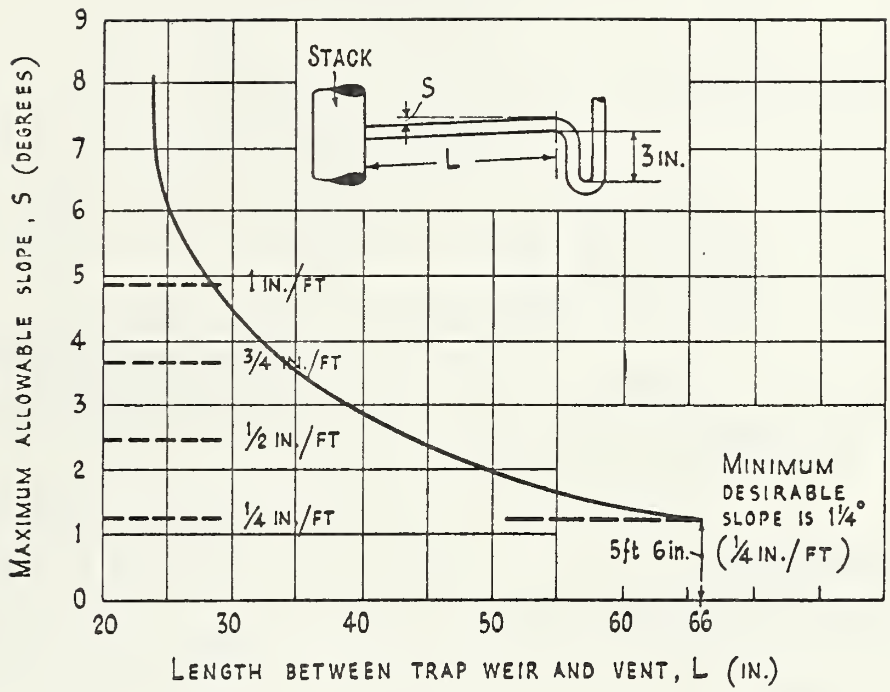


Figure 5 Maximum lengths and slopes of unvented 1 1/4-in. lavatory drain using tee inlet to stack and 3-in. deep-seal P trap--recommendations by the British Building Research Station, 1967.

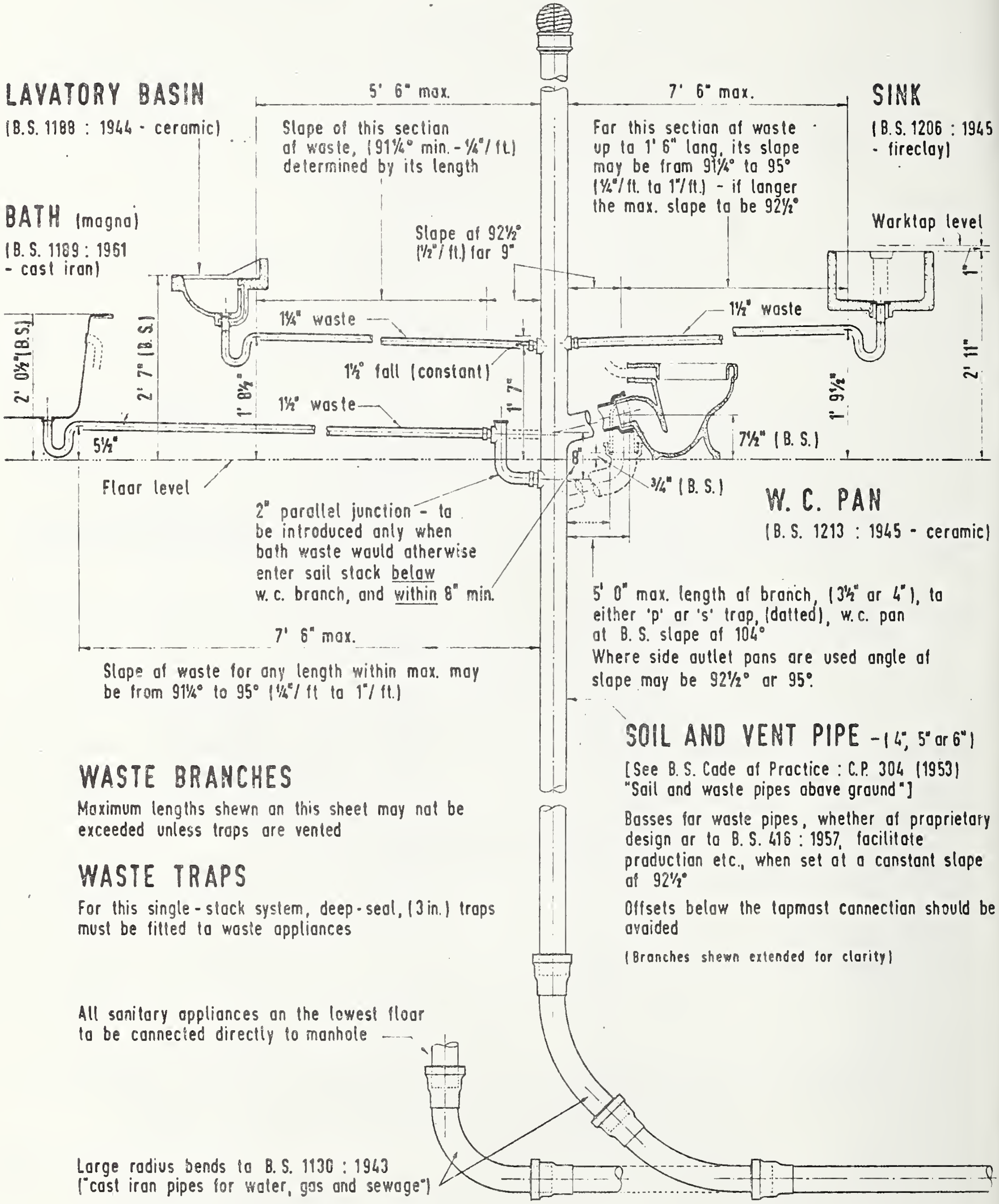


Figure 6 Basic principles of design of unvented soil and waste branches--recommendations by the British Ministry of Housing and Local Government, 1962.

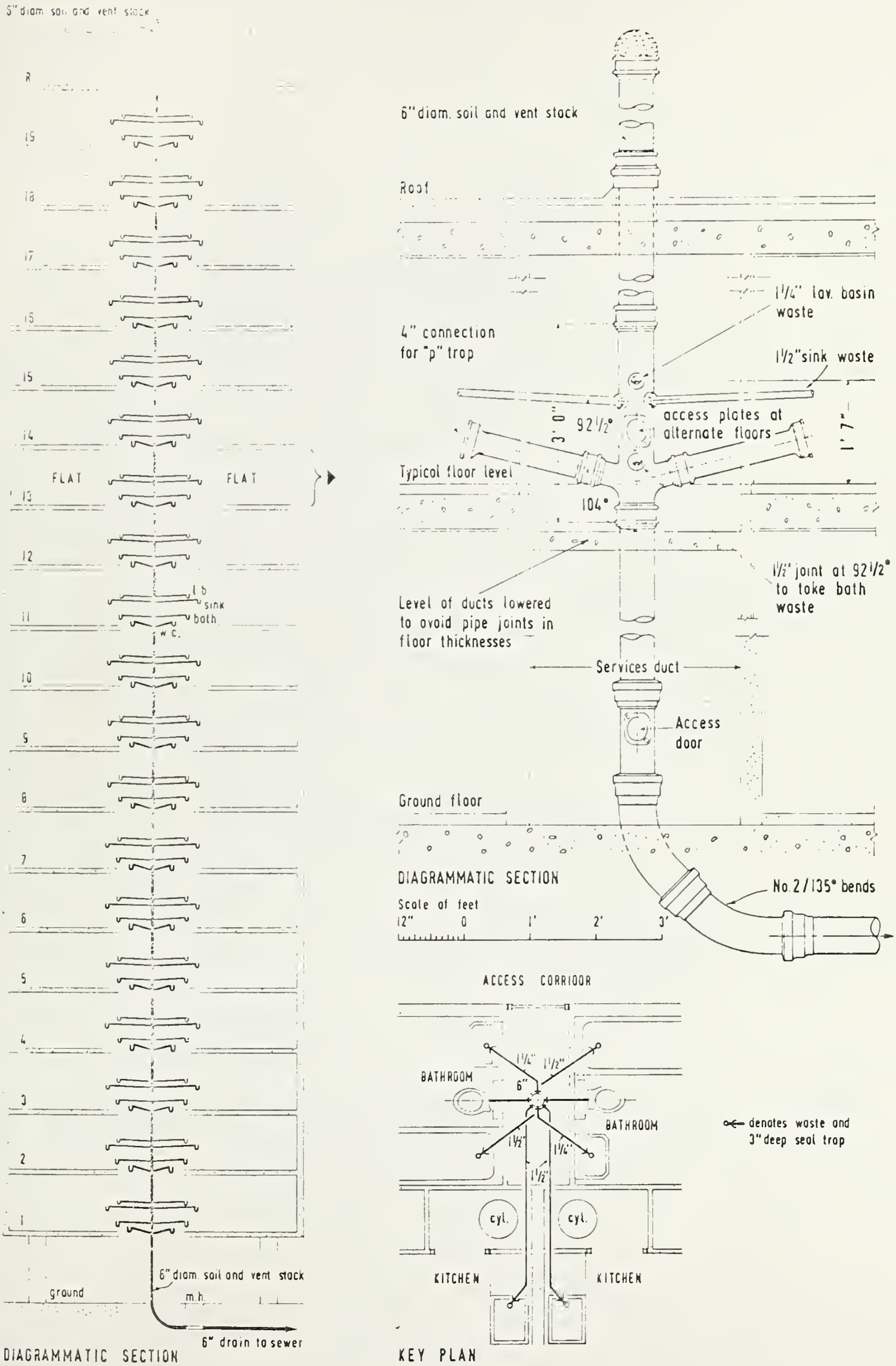
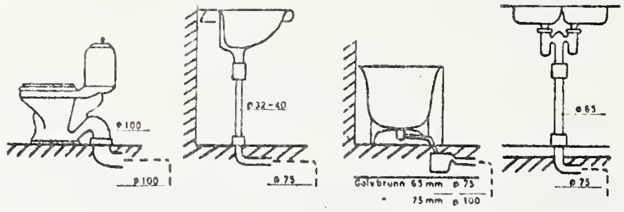
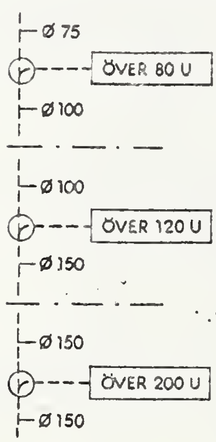
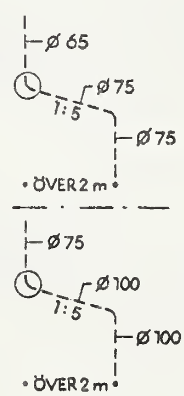


Figure 7 A plan for single stack drainage in 20-story apartment building-- recommendations by the British Ministry of Housing and Local Government, 1962.



a) *Minimimått* bestämda av den enskilda apparaten gällande såväl gren- som stamledning.





b) *Dimensionsökning* på stamledning bestämd av antalet utslagsenheter (U), där wc = 5 U, disklåda = 4 U, tvättställ = 1 U och badkar = 4 U. När antalet U från ett grenrör överstiger på fig. angivna skall stamledningen utökas till angivna dimension.

c) *Dimensionsökning* på stamledning vid dragning i sidled.

Figure 8 Dimensioning of drainage piping systems without secondary ventilation--recommendations of the National Swedish Institute for Building Research, 1963.

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