NATIONAL BUREAU OF STANDARDS REPORT

10 149

A Preliminary Report

REDUCED-SIZE VENTS FOR ONE-STORY AND SPLIT-LEVEL RESIDENTIAL PLUMBING SYSTEMS

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A Preliminary Report

REDUCED-SIZE VENTS FOR ONE-STORY AND SPLIT-LEVEL RESIDENTIAL PLUMBING SYSTEMS

by
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A Preliminary Report
Reduced-size Vents
for One-story and Split-level Residential
Plumbing Systems

Abstract

This report presents a preliminary account of a laboratory study in which reduced-size vents for one-story and split-level residential plumbing systems were found to satisfy reasonable performance criteria. A detailed report is planned to be published as part of NBS' Building Science Series.

Vents smaller and less expensive than those required by plumbing codes performed favorably in laboratory testing at the National Bureau of Standards, signaling possible construction savings running in the millions of dollars yearly.

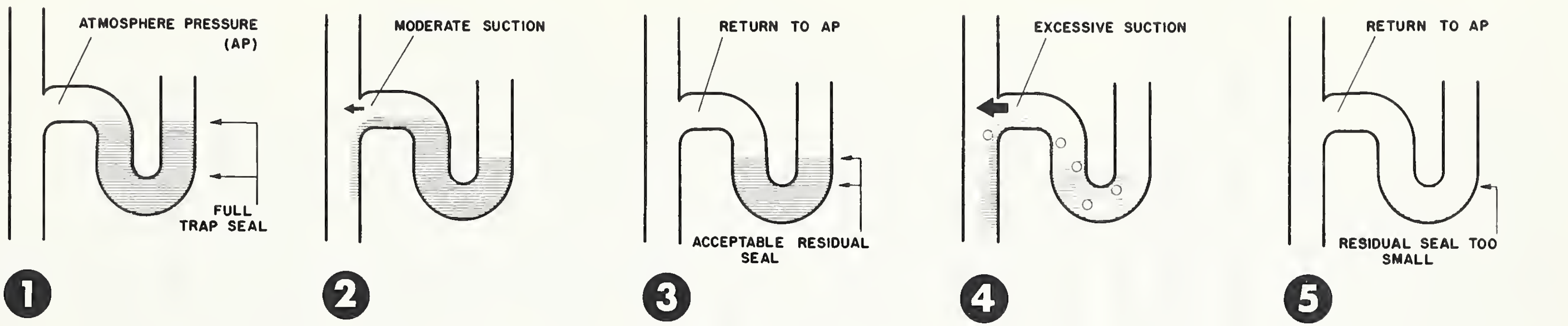
For one-story and split-level systems, air vents only one-sixth to one-half the diameters required by the codes were found to satisfy hydraulic and pneumatic performance criteria in most of the tests conducted by the Building Research Division of NBS' Institute for Applied Technology.

Venting protects water seals in the U-shaped traps of plumbing fixtures; the seals prevent the emission of sewer gases into the house. Without venting, the amplitudes of pneumatic fluctuations in the drainage system caused by the discharge of fixture contents are increased. Thus the seals are subject to vacuum siphonage or blowback into the fixture or even the room. Figure 1 illustrates these phenomena.

The study, requested by the National Association of Home Builders and financed jointly by NAHB and NBS, used two full-scale drain-waste-vent systems, one simulating that of a one-story, slab-on-grade or crawl-space house with plumbing fixtures on one elevation, and the other that of a split-level house with fixtures on three elevations.

Beyond economies in dimensional reduction alone, additional savings to homebuilders and buyers were suggested by the use of prefabricated manifold vent terminals such as used in the experimentation. The placement of such terminals

Trap Seal Reduction From Vacuum Or Suction



Trap Seal Reduction From Back Pressure

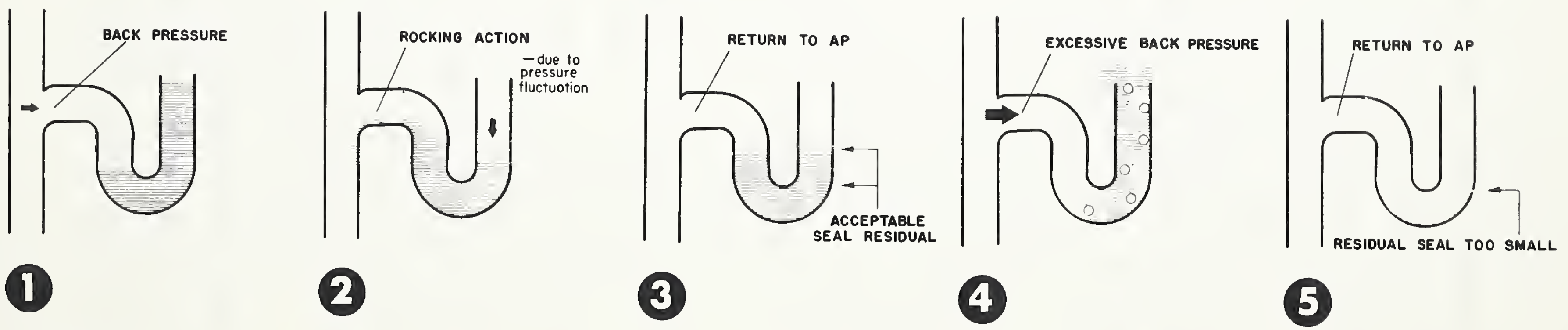


FIGURE I

horizontally through walls or gables obviates costly roof penetration and roof flashing.

However, the study was designed primarily to examine trap seal reaction to reduced venting. In the one-story system it found no trap blowback and seal reductions holding to less than 1 in with vents as small as 1/2-in diameter. The small vents were used with waste stacks normally having vents of 1 1/4- or 1 1/2-in diameter and with a soil stack usually having a vent of 3-in diameter.

In all, some 30 different combinations of fixtures and almost as many venting arrangements were used in testing the one-story system.

Undergoing similar testing, the split-level system performed with apparent adequacy with some reduction in vent sizes.

Results <u>suggest that plumbing codes are requiring vent sizes larger than necessary for split-level as well as one-story houses</u>. (Sample data acquired in these experiments will be cited later in this report.) As might have been expected, sharp diameter reductions resulted in questionable performance. For example, when all vents were sized at 1/2-in diameter, the reduction in some trap seals exceeded the customarily accepted limit of 1 in. (In a trap with a 2-in depth of seal, the shallowest generally allowed by the codes, a 1-in reduction leaves a 1-in residual seal to guard against pressure fluctuations and evaporation.) Even in these tests, however, no trap seals were broken.

Peak air demand rates in systems such as the ones tested tend to be substantially less than have been commonly assumed. Consideration of existing theory as well as experimental investigation revealed two explanations for this: 1. the vertical distances through which waste water falls in the stacks or vertical waste pipes of one-story and split-level systems frequently are insufficient to develop terminal velocity, and thus maximum vacuum, and 2. sizing vents so as to produce a momentary pressure drop in the vent (not exceeding the $\pm$ 1-in water column differential commonly allowed by the codes), in one-story and split-level systems tends to limit the peak air demand to values far below those determined from data on long stacks.

These findings explain the encouraging performance of the test systems under most of the loadings employed and indicate that the logical course in sizing vents, at least for one-story and split-level systems, is to allow for a reasonable pressure drop as is already customary, such as a 1-in water column, <u>and to compute the vent sizes based on a peak air demand rate corresponding to this design pressure drop</u>. Current theory does not recognize any reduction in air demand rate as a result of pressure drop in a vent.

NAHB has estimated reduced-size vent savings for one-story houses at between <u>$25 and $50 per system</u>, the figures depending on the kinds of materials being compared, the current degree of permissiveness in a given code jurisdiction, etc. Since possibly as many as 300,000 such houses are built in the United States each year, a nationwide saving of some $10 million can be projected. But if reduced-size vents can be adopted in split-level and two-story configurations, both per-house economies (in absolute terms) and nationwide savings would be even greater.

First tested at NBS was a system simulating that of a one-story house without basement, a simple, single-bath arrangement with minimal kitchen and laundry facilities. The tests included various fixture loadings and several different combinations of open and closed vents. Particular attention was paid to trap seal reductions, maximum water depths in the building drain and airflow rates in the vents.

Next, peak air demand rates for fixtures discharged individually were determined as a function of peak vent vacuum; the vacuum was varied manually by the partial closing of valves in the individual fixture vents provided for this purpose. The vents terminated in the atmosphere and were of sizes accepted by the plumbing codes.

One-half inch diameter tubing was then substituted for conventional-size vent piping throughout the system, beginning about 5 ft above floor level. While this was the experimental condition chosen, reduced vents could have been extended to perhaps 6 in above the flood-rim level of the fixtures.

Tests were run with various lengths of tubing connected to a manifold vent terminal (a 4-ft length of 2-in rigid tubing). The system was tested with both single- and multiple-fixture loadings. Of the latter loadings, discharges of the fixtures involved were initiated simultaneously in some cases; in other instances a time-sequence pattern was employed. Figure 2 shows the test system schematically.

The split-level system is shown schematically in Figure 3. It was put through similar runs, and again, with vents of several lengths and diameters, comparisons were made of trap seal reductions. All vents, code-size at first and then reduced-size, were either opened or closed. Reduced-size vents of 1/2-, 1- and 1 1/4-in tubing were used for the top-floor water closets while all other vents were of either 1/2- or 1 1/2-in diameter. As with the one-story system, more than 30 different combinations and sequences of fixture loadings were used.

The concurrent discharge of three fixtures in the split-level system or two fixtures in the one-story system was considered reasonable test loading in terms of both the theory of probability and the present state of the art in performance testing drain-waste-vent systems. Experimenters had to use some judgment in the selection of particular fixtures for either concurrent or sequential discharge; in general, the procedure was to seek combinations and sequences of two or three fixtures producing the worst results. Also, various tests involved a greater number of fixtures than seemed

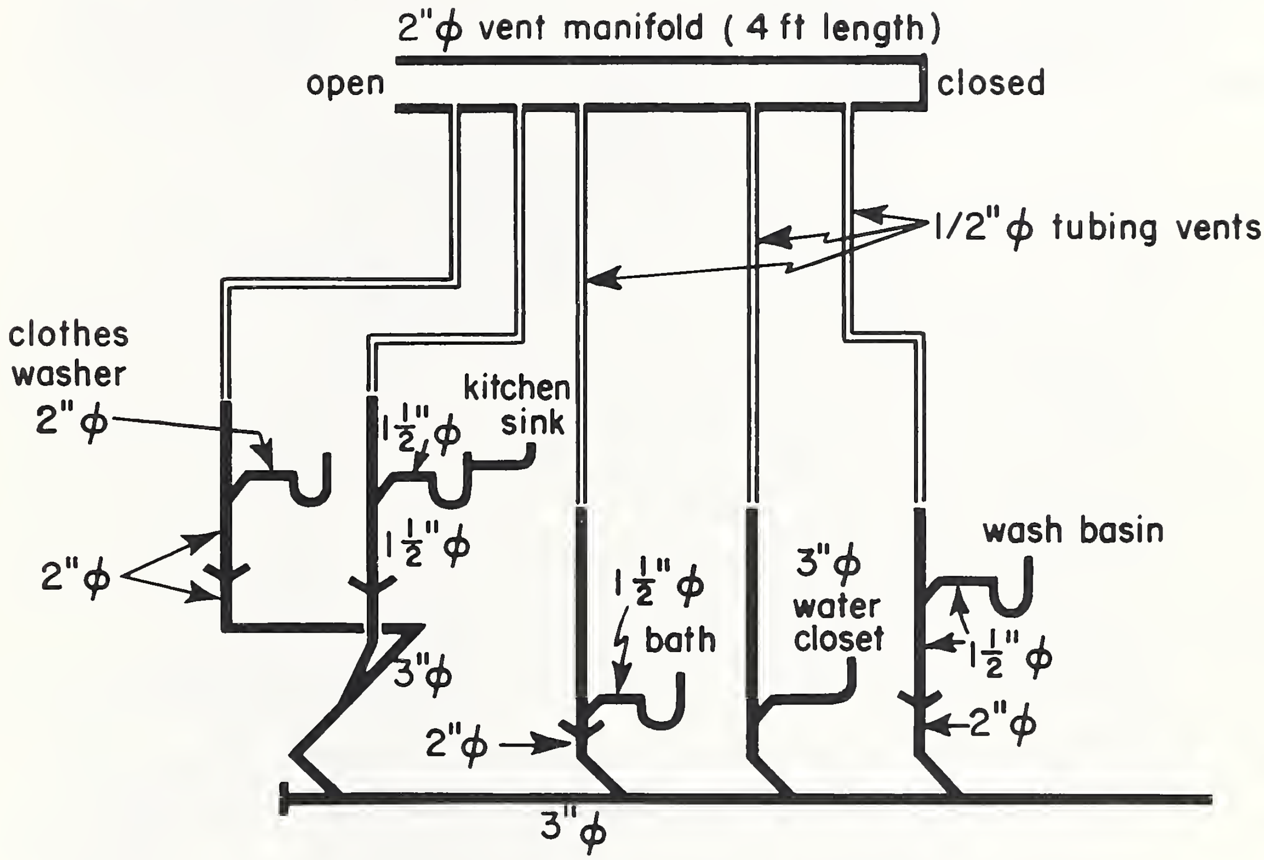


Figure 2- One-story test system schematic

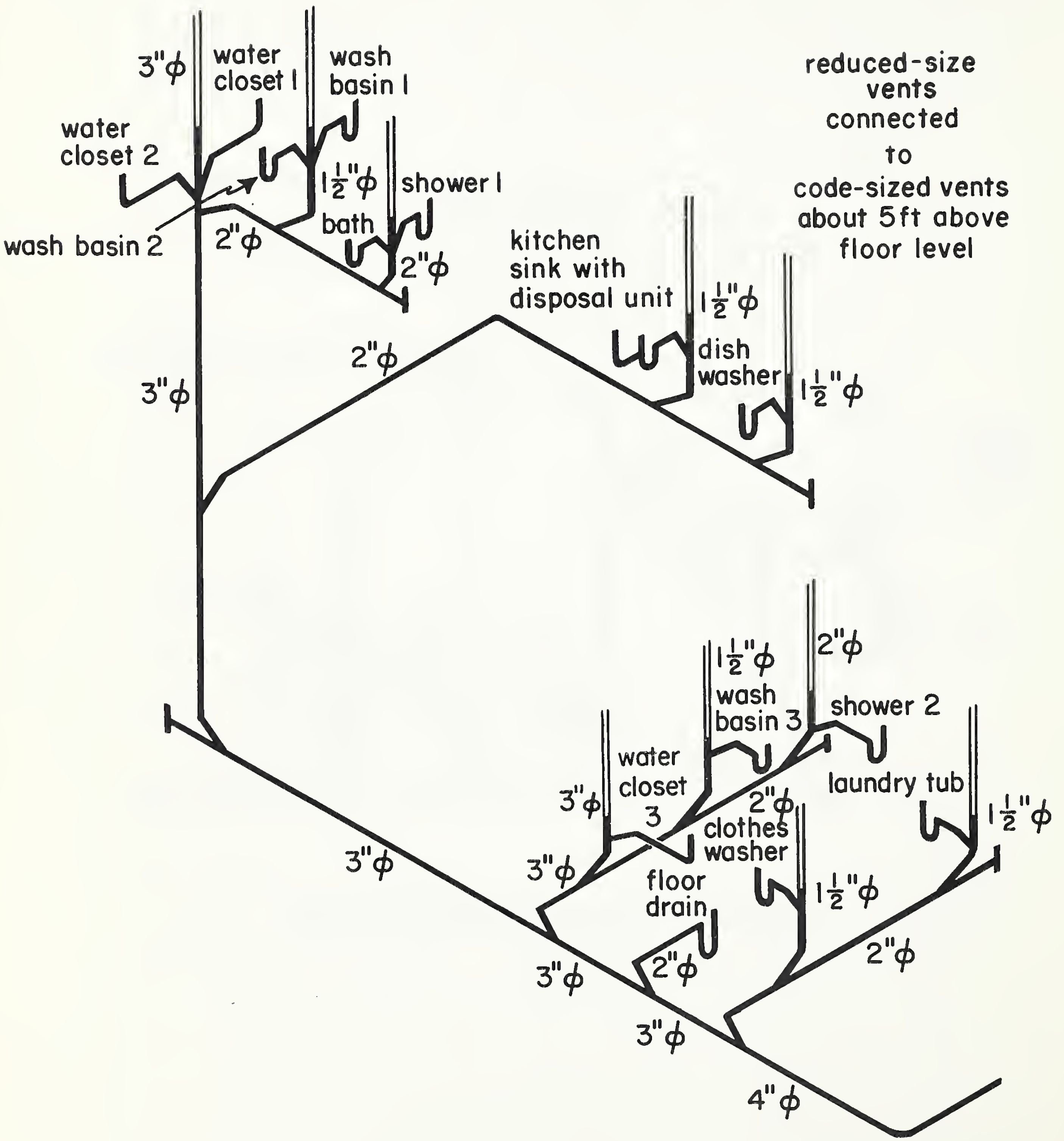


Figure 3—Split-level test system schematic

reasonable from considerations of probability alone.

Testing with the one-story system showed that trap seal loss is a function of vent length. Even with 1/2-in diameter vents 50 ft long, tested under many different loadings, seals of both idle and operating fixtures were satisfactorily maintained; that is, in none of the tests did any seal sustain a loss of as much as 1 in.

Data similar to Figure 4, which displays the results pertaining to induced siphonage of the idle traps of two fixtures, a water closet and a wash basin, were obtained for various loadings on the one-story system. The figure shows maximum cumulative trap seal reductions observed as a result of repeated discharges of all fixtures except the one indicated as idle without refilling traps between load applications.

In tests to determine the relationship between peak rate of airflow and peak vacuum generated in the vent by fixture discharge, experimenters found that as the vacuum was increased (by valve adjustment), the airflow rate dropped substantially. Air demands measured for the one-story system were markedly below those commonly assumed in computing sizes of vent pipes. Figure 5 shows the relationship between vacuum and airflow rate for the water closet. Data were obtained under similar conditions for the wash basin and the kitchen sink.

The measured air-demand values in Table 1 were read from curves similar to the one shown in Figure 5, obtained in

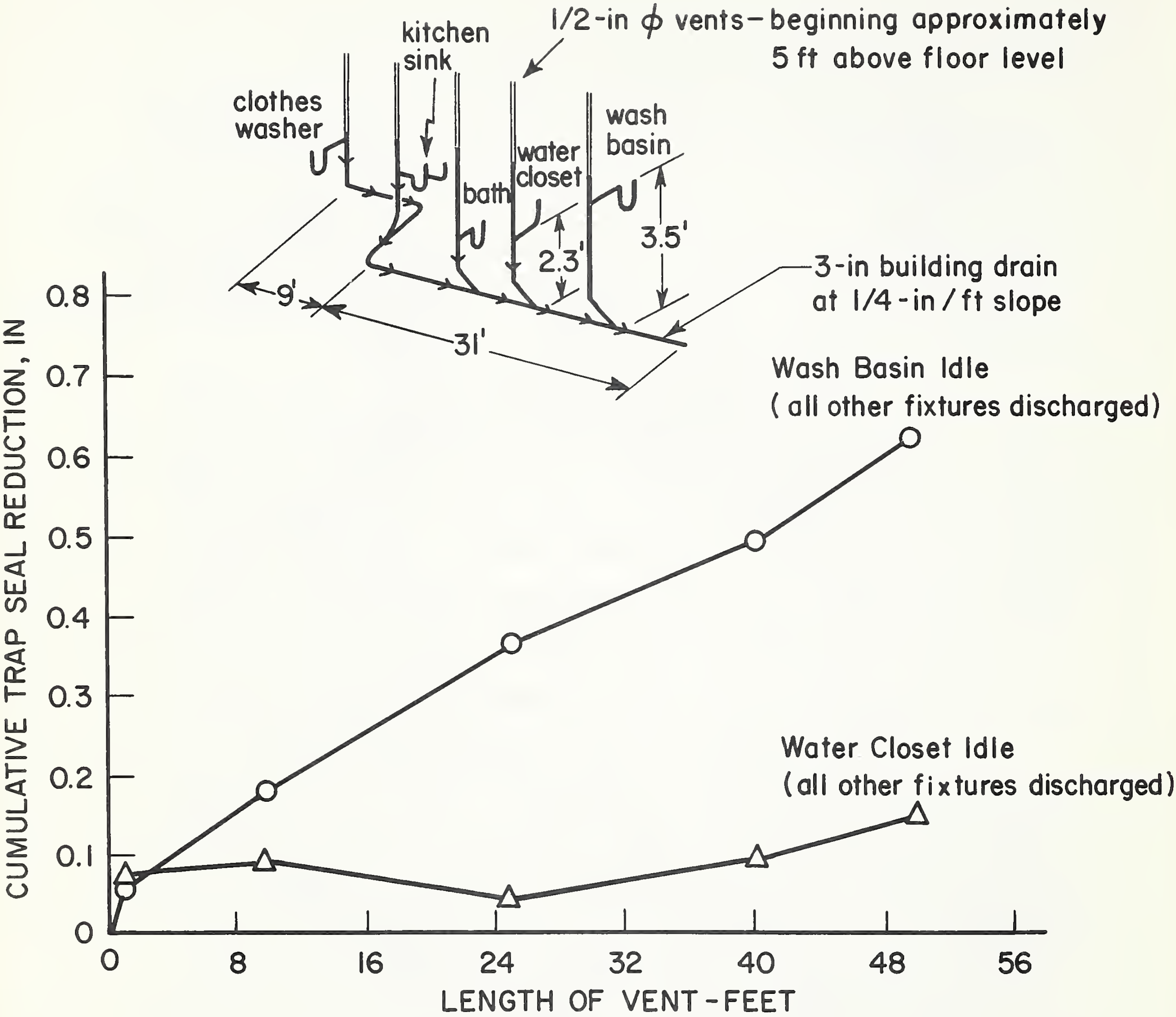


Figure 4 – Cumulative trap seal reduction data for lavatory and water closet traps as a function of vent length. All fixtures were repeatedly discharged simultaneously except the one indicated as idle, and without trap refill until maximum cumulative reductions were obtained

TABLE 1

COMPARISONS OF VENT SIZES FOR ONE-STORY, SLAB-ON-GRADE, DRAIN-WASTE-VENT SYSTEMS OBTAINED BY DIFFERENT METHODS

FIXTURE	PEAK PRESSURE DROP	PEAK AIR DEMAND RATE		MINIMUM VENT DIAMETER[3/] BASED ON--		
		measured[1/]	computed[2/] from Mono 31	usual code requirement	max. air demand computed from Mono 31	measured air demand rate[1/]
	in water col.	std gpm	std gpm	in	in	in
Reverse-trap W.C. 3-in stack	0.5	33	200	3	2	1
	1.0	5	200	3	2	1/2
Hydraulic-jet W.C., 1 1/2-in stack	0.5	2	35	1 1/4-1 1/2	1	1/2
	1.0	0	35	1 1/4-1 1/2	1	no vent required
Wash basin, 1 1/2-in stack	0.5	20	37	1 1/4-1 1/2	1	3/4
	1.0	5	37	1 1/4-1 1/2	1	1/2
Kitchen sink, 1 1/2-in stack	0.5	14	38	1 1/4-1 1/2	1	1/2
	1.0	13	38	1 1/4-1 1/2	1	1/2

1/ Measured in laboratory system shown in figs. 4 and 5

2/ Mono 31's Equation (56) was derived from experimentation with long stacks not vented within every branch interval and, in essential accord with the findings of that study, does not allow for any affect of vent pressure on air demand rates.

3/ Nominal, commercially designated sizes. In making these computations, the absolute roughness of pipes was taken as 0.0005 ft, schedule 40 steel-pipe diameters were assumed, and vent length was taken as 20 ft Diameters of less than 1/2 in were not selected, although they might be theoretically adequate in some instances.

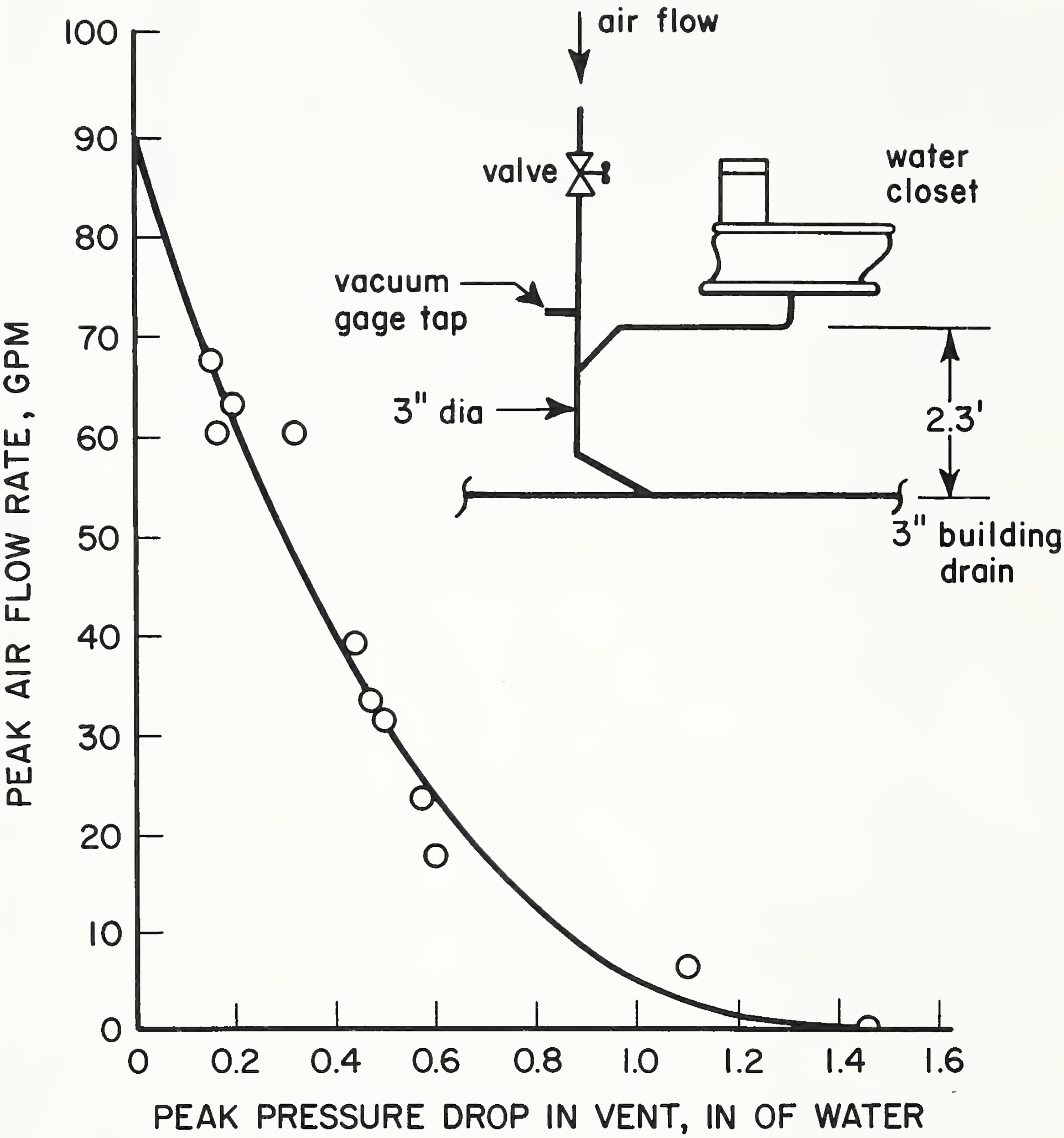


Figure 5 - Peak air flow rate in vent produced by discharge of conventional flush-tank water closet into 2.3 ft, 3-in dia, soil stack, shown as a function of minimum vent pressure (peak pressure drop). Curve computed from the equation

$$Q_a = 35.1\,(H_v - H_a)^{5/2}$$

where Q_a = peak air flow rate delivered by vent, gpm
H_s = peak pressure drop with closed vent (-1.46 in)
H_v = peak pressure drop with vent partially or fully open, in water column below atmospheric

the experimentation with the one-story, slab-on-grade system. For comparison, air demand rates are shown computed by the method of NBS Monograph 31, Capacities of Stacks in Sanitary Drainage Systems for Buildings. In recent times, many plumbing code writers have used methods similar to the one described in Mono 31 to estimate peak air demand rates. The experimentation reported in Mono 31 did not provide venting within each branch interval, and the stacks were of the order of 30 to 60 ft long. Under these conditions, it was determined that air demand rates were not affected appreciably by the magnitude of the vent pressure.

The vent sizes shown in Table 1 were derived in three ways: (1) based on the usual code requirement, (2) computed from an adaptation of the Darcy-Weisbach formula, essentially in accordance with the procedure given in Mono 31 and based on a pressure drop of 1 in. water column and on air demand rates and for the same pressure drops (1/2 in and 1 in. water column) that existed when the air demand rates were measured. Plumbing codes permit such pressure drops. The diameters given are the next larger nominal commercial size than the computed values.

It is significant that even with the application of the conservative approach to estimating air-demand rates given in Mono 31, vent sizes smaller than required by most codes were obtained. Still more striking are the diameter reductions from the use of experimentally-determined peak air demand rates from the slab-on-grade one-story system.

Trap seal reductions of more than 1 in were not found in tests of the split-level system with a 1 1/4-in diameter soil vent (18 ft. long) and all other vents 1/2-in diameter (25 ft long), except in those involving concurrent discharge of both top-floor water closets, a coincidence expected to exist no more than .01 to .1 percent of the time during "rush hour" periods. The following loads with the 1 1/4-in soil vent yielded trap seal reductions of less than 1 in in any trap, based on the worst result in three successive test runs with replenishment of trap seals after each run:

WC_1	
$S_1 + S_2$	discharged at the same time
$WC_1 + WB_1$	discharged at the same time
$WC_1 + B$	discharged at the same time
$WC_1 + WB_1 + B$	discharged at the same time
$WC_3 + WB_3 + CW + LT$	discharged at the same time

$WC_1 + WC_2$ discharged at the same time; WC_3 5 sec. later

$WC_1 + WB_1 + B$ discharged at the same time; WC_3 5 sec. later

$WC_1 + WB_1 + B$ discharged at the same time; $WC_3 + B$ 5 sec. later

(WC - water closet; S - kitchen sink; WB - wash basin; B - bath; CW - clothes washer; LT - laundry tub.)

In tests involving both top-floor water closets discharging concurrently with up to four additional fixtures using both clean-water and detergent loads, maximum trap seal reductions ranged up to 1 3/4-in--not enough to break the trap seals.

Figure 6 illustrates satisfactory results for the split-level system with 1/2-in and 1-in soil vents in a two-fixture loading. All other vents were 1/2-in diameter. In a test series with all vents completely closed (an unusually severe condition), maximum trap seal reductions of less than 1 in were observed with many single-fixture loads. As expected, however, excessive trap seal reductions were observed with some of the loadings.

The study indicates that most one-story and split-level plumbing systems probably can be designed to maintain residual seals of at least one-half the minimum trap seal depth with vent diameters of less than code size. Data were obtained that are useful in making estimates of peak pneumatic loads on the vents of systems similar to those tested. Such estimates are necessary in selecting minimum sizes of vents.

Additional studies could be undertaken to:

- Establish the performance limits of reduced-size venting for system configurations and use conditions differing substantially from those represented in this research.

- Investigate the performance potential of vent reservoirs, vacuum-relief valves and unvented vertical waste pipes, all of which received only limited attention within the scope of the study described here.

- Study the effects of detergents and solids on the performance of drain-waste-vent systems since the findings of this study cannot be considered conclusive with respect to these items.

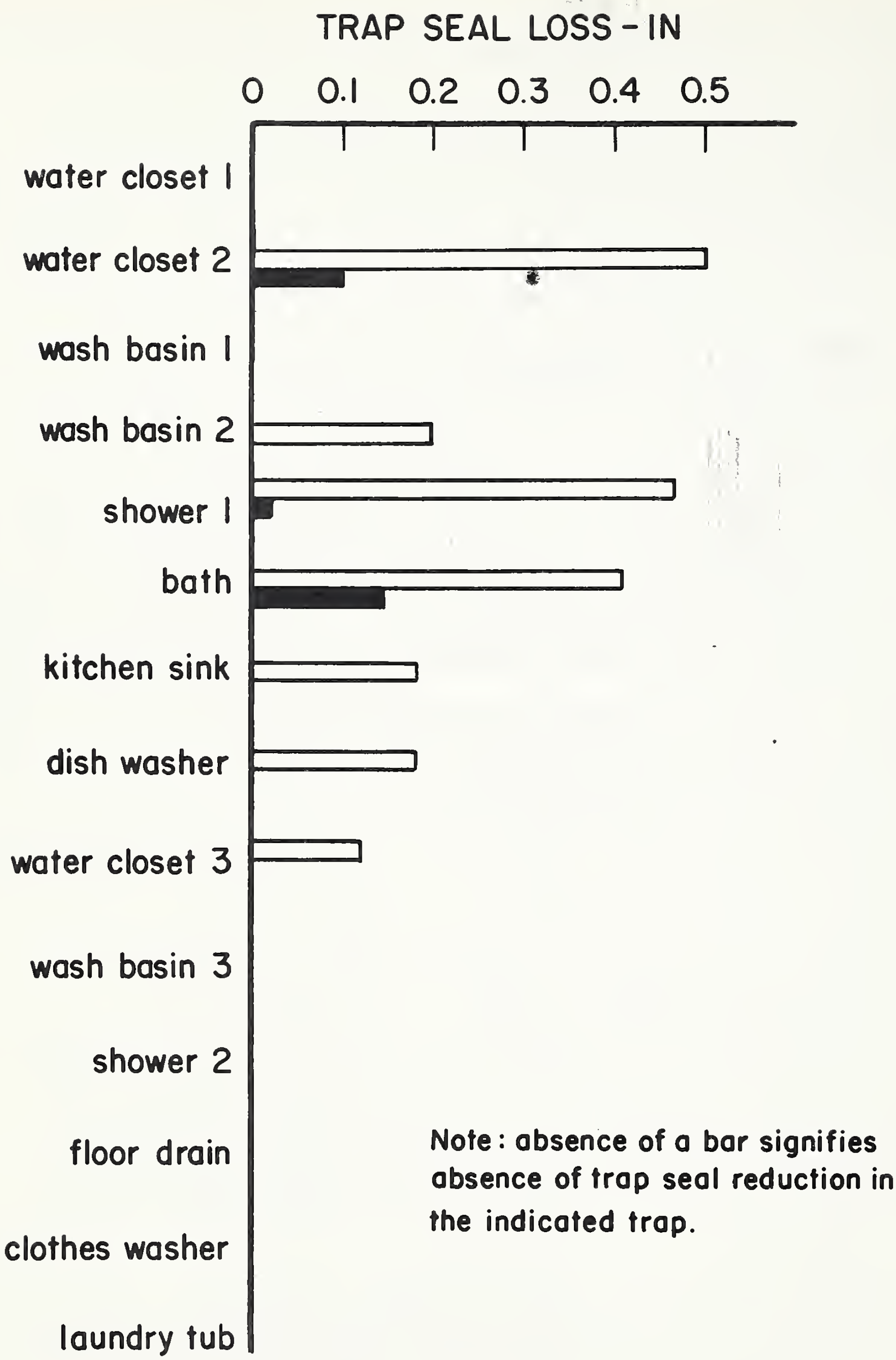


Figure 6 — Trap seal losses with two sizes of main vent (split-level system, Figure 3)

Loading: Clear water discharge of WC_1 wash basin, simultaneously.

Bargraph identification:

(open bar) 1-ft length of 1/2-in tubing on each vent standpipe.

(solid bar) Same as above, except 1-ft length of 1-in pipe on main vent standpipe.

- Develop a more comprehensive set of performance data on peak air demand rates and related vent pressure in individual and common vents for various pipe diameters, fitting shapes, fall distances, etc., in order to provide the important design criteria needed to calculate adequate but not excessive sizes.

- Sample field conditions and review existing data to establish the incidence of excessive wind-generated pneumatic pressure on the windward side of the house, and of excessive gas- or hydrodynamically-generated pressures in the public sewers. These factors are probably of limited significance but are sometimes cited by critics.

- Measure typical peak-load patterns in occupied houses and establish realistic load and diversity factors for the sizing of branch and main vents serving two or more individual or common vents. From such information it would be possible to prepare useful design aids in the form of graphs, tables or equations, and to improve procedures for selecting test loads.

It was not possible to satisfy the need for these additional data within the scope of the study described here.

Brief comment should be made on two matters referred to in the foregoing study area suggestions--the detergent problem and the ventilation of public sewers.

Many plumbing engineers and plumbing officials have indicated that detergent problems for the most part are associated with the lowest one or two branch intervals in tall buildings. Certain practical measures have been employed to reduce the risk of detergent effects in conventional systems: for example, avoiding the use of soil stacks to carry the waste water from detergent-using fixtures, and avoiding the installation of drain or vent connnections near the base of soil or waste stacks serving detergent-using fixtures. Probably similar measures would be helpful in small-vent systems. Trends in the detergent industry, meanwhile, appear to be headed toward reduced sudsing action and this, too, should be helpful.

As for the need of ventilating public sewers through the plumbing systems of buildings, it might be noted that this appears to be an academic matter in many communities. These are communities which require a water-sealed trap between the building and the sewer system. While some authorities fault this practice, their objections evidently are based on reasons other than poor sewer ventilation.

Code provisions would have to be modified to permit small-vent systems and to ensure their proper design and use under conditions which promise satisfactory performance. The study described here has provided encouraging basic performance data; field trials by the NAHB Research Foundation have yielded additional results under varied service conditions.

For the present, these general design rules are suggested for small-vent systems:

1. Reduced-size vents should not be installed below a point approximately 6 in above the flood rim of the fixtures served in order to minimize gradual fouling of small vents by occasional exposure to particulate matter in the waste water.

2. Reduced sizes should be permitted for only dry vents.

3. The cross-sectional area of a collector vent or manifold should not be less than the sum of the areas of the smaller vents connected to it. With further study this rule probably can be relaxed.

4. In areas where frost closure may occur, vent terminals should be sized according to local weather requirements. The use of materials that have low thermal conductivity will improve performance in respect to this characteristic. When roof terminals are used (instead of horizontal terminals), they should be extended upward no farther than necessary to avoid the entrance of roof water and its adverse hydraulic affects, and to avoid bridging by the gradual accumulation of ice on the roof surface. (Canadian experience suggests a limit between 2 and 4 in on the high side where the terminal pases through a pitched roof.) The development of a "frost closure map" or similar guide from offical weather records could remove some of the uncertainty in establishing realistic code requirements relating to frost closure.

5. Vent terminals serving reduced-size vents should be fitted with durable, corrosion-resistant screen caps having open areas exceeding the cross-sectional area of the vent terminal in order to reduce the possibilities of gradual blocking of the screen by lint, dust particles, etc. When such terminals extend horizontally to the outside they should have a down-turned fitting or preformed bend.

6. All vent piping should be arranged so that internal condensation or other moisture will drain by gravity to (a) a soil or waste pipe, or (b) to the outside, provided that this solution is not employed in frost closure-prone areas.

7. Reduced-size vents should be made of material that does not form loose scale deposits or suffer substantial reduction in diameter from scale formation or other causes under ordinary conditions of use.

Table 2 offers a tenative format for the sizing of small-bore vents. To accommodate reduced-size vents, it would be necessary to relax the usual code requirements that: 1. no vent be smaller than 1 1/4- or 1 1/2-in diameter, 2. at least one stack pass full-size through the roof, and 3. various types of vents be at least one-half the diameters of the drains they ventilate or of the vent stacks to which they connect.

One important need in connection with any work related to further research on code changes is a survey of code officials, contractors and engineers to better identify the

TABLE 2 TENTATIVE FORMAT FOR SPECIFYING SIZES OF SMALL VENTS

TYPE OF SYSTEM	TYPE OF VENT [a]	FIXTURE-UNIT LOAD SERVED BY VENT [b]	SIZE OF VENT [a] [d] (in)
One-story, slab-on-grade or crawl space (fixtures within one branch interval only)	Individual vent [e]	Up to 3 f u	1/2
		4-6 f u	3/4
	Common vent [e] or branch vent [e]	Up to 3 f u	3/4
		4-6 f u	1
	Stack (soil) vent [c]	Up to 6 f u	1
		7-15 f u	1 1/4
Two-story (fixtures in not more than 2 branch intervals), or split-level system (fixtures distributed between not more than 3 levels over a vertical span of not more than 15 ft)	Individual vent [e]	Up to 3 f u	1/2
		4-6 f u	3/4
	Common vent [e] or branch vent [e]	Up to 3 f u	3/4
		4-6 f u	1
	Stack (soil) vent [c] or vent stack	Up to 6 f u	1 1/4
		7-15 f u	1 1/2
		16-30 f u	2

a Dry vents only. Sizes estimated on the basis of research data on two full-scale laboratory systems.

b Load breakdown ranges are tentative only. Further research is needed to establish accurate load limits for reduced-size vents for systems with configurations differing significantly from those studied.

c Assumed size of soil stack 3 in

d The size of vent required for a given fixture load is affected by the diameter of the soil or waste stack, or vertical drain to which a trap arm or horizontal branch drain is connected, by the vertical distance that water falls in the vertical drain, and by the geometry of the fitting used to connect a trap arm to a vertical drain.

e For the purposes of this table, it is assumed that these vents do not extend through more than one branch interval, nor does the water have an unbroken fall of more than 5 ft in the stack or vertical waste pipe to which the trap-arm connects.

questions they need answered. It is hoped that this report will have helped to generate the kind of interest and discussion which will yield the most responsive and thoughtful comment in such a survey.

Robert Beausoliel, M.E., was project engineer for the experimentation described in this report; James Seay, engineering technician, assisted Mr. Beausoliel; Neil Gallagher, technical writer-editor, assisted with the preparation of this report. Liaison with the National Association of Home Builders was afforded through Mr. Ralph J. Johnson and his staff. The value of the work reported herein is due in no small measure to the valuable contributions of each of the named individuals.

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