# NATIONAL BUREAU OF STANDARDS REPORT

9346

## PROGRESS REPORT NO. 6
## ON
## FLUID DYNAMICS OF PLUMBING

by
R. W. Beausoliel
and
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U. S. DEPARTMENT OF COMMERCE
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by
R. W. Beausoliel
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for

The National Association of Home Builders

NBS

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# ABSTRACT

This progress report, the sixth and last in a series, gives results of various selected hydraulic loadings on a three-bath, three-level test plumbing system. Trap-seal losses were measured with several venting arrangements. A limited number of tests were made with detergents or solids included in the loads.

The results show that the three-level system required more air for adequate venting than the one-level, slab-on-grade system previously tested. Also, the inclusion of detergents in some of the test loads resulted in adverse trap seal performance.

Further experimental work is needed to adequately evaluate the performance of test systems with vents smaller than customary, using various loadings. Standardization of test loads is also needed.

# CONTENTS

# 1. INTRODUCTION

A 3 bath, 3 level experimental plumbing system was utilized for the tests made during this reporting period. Plans called for work to establish minimum diameters and maximum lengths of vents which would allow proper trap seal performance under practical loading conditions. Previous work with a 1 bath, slab on grade system showed satisfactory pneumatic performance of the test system with considerable reduction in vent diameter below customary sizes with clear water loadings [1]*. In the 3 level system detergents or solids were used in some of the loadings for comparison with clear water loadings.

The work plan also called for some further investigation of air demand on vents as affected by soil or waste stack length, fitting geometry, and vertical distribution of load in multiple-fixture loads. However, because of complexities in evaluating the performance of the 3-level test system, and because a portion of the project funds were applied to a deficit incurred in the previous fiscal year, no work on air demand was carried out during this reporting period.

It was not expected nor intended that the laboratory work alone would set a precedent for the use of small-diameter vents. Obviously, some factors could not be investigated in the laboratory. For example, possible effects of aging, weathering, corrosion, fouling, and frost closure are difficult or impracticable to simulate in the laboratory. These aspects relating to use of unconventional small-size vents can best

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* Numbers in brackets refer to the corresponding number in the Bibliography at the end of this report

be investigated by a field study. The sponsor has expressed interest in such a study, and it is understood that at the present time plans for such installations in various parts of the country are being developed so that climatic conditions can be included in the long-time field evaluations.

The project was approved by the National Bureau of Standards under the Grants-in-Aid Program as outlined in NBS Report No. 7736. [2]

## 2. APPARATUS

The test system is shown in figure 1. For test purposes, the vents were not interconnected as would normally be done in the field, but terminated separately. This modification was considered necessary to simplify the experimental program. It was considered a conservative approach, since the relief of pneumatic pressure fluctuations from recirculation between vents which sometimes occurs in interconnected systems was not available in the test system used here.

All piping which would normally be below grade was fabricated of cast-iron service-weight pipe. Above grade, 3 in. soil stacks and 3 in. vents were of cast iron. The cast-iron soil piping and fittings were of hub type joined with neoprene gaskets instead of lead-oakum-pitch joints. In some instances where special fitting types were not available, oakum-pitch joints were made. All of the 1-1/2 and 2 in. vents and the branches to the main building drain and soil stack that were installed in an above-grade location were fabricated of Schedule 40, galvanized steel pipe joined by appropriate recessed, screwed, cast-iron drainage fittings. To meet plumbing code requirements, the building drain was intended to be fabricated of 3 in. cast-iron soil pipe as far downstream as the point of connection to the basement bathroom group. Beyond this point, the building drain was to be enlarged to 4 in. size. The reason for this enlargement is dependent on code practice not to discharge over two water closets into a 3 in. building drain. Due to an inadvertent error during construction, the 4 in. portion of the building drain was not extended upstream beyond the laundry group of fixtures; therefore, a portion of the 3 in. building drain actually served three water closets. Since the error was not discovered until the installation was ready for testing, it seemed reasonable first to investigate system performance with the undersized drain for later comparison with the larger drain. This section of drain has recently been enlarged to 4 in. diameter. The system has been designed to discharge into the laboratory building drain; however, the end of the experimental system is not tied directly into the laboratory drain but is separated by an air gap. This separation will assure that the pneumatic pressure at the end of the experimental drain will be atmospheric.

The two showers were simulated by means of 2 in. cast-iron soil pipe "P" traps. The floor drain is represented by a 3 in. cast iron soil pipe "P" trap. Means for introducing water to replenish trap seal loss in these traps have been provided.

The two back-to-back water closets were joined to the 3 in. soil stack by 4" x 6" x 16" closet bends and 3" x 4" double Washington combination Y and 1/8 bends. The water closet on the lower level was joined to the 3 in. soil stack by a 4" x 3" reducing closet bend and a 3 in. combination Y and 1/8th bend. No attempt was made to cut these closet bends as done earlier for the one-story test system, since this should not significantly affect results. As shown in figure 1, the rest of the fixtures included a bathtub installed back-to-back with a shower; two back-to-back lavatories on the upper level and one on the basement level; and a two-compartment kitchen sink with food-waste disposal unit and a dishwasher on the intermediate level. The dishwasher was installed with its own trap and vent. It could have been installed by means of the hole-in the-head food-waste disposal unit, but the installation with separate vent was thought to be more severe from the standpoint of load contribution to the drainage system. Obviously, the hole-in-the -head arrangement would be the more economical arrangement. The laundry fixtures consisted of a concrete laundry tub and automatic clothes washer, each installed with a separate trap, stack, and vent. The clothes washer discharged into its stack by way of a 2 in. standpipe and recessed, screwed, cast-iron drainage "P" trap. The water supply for the test system consisted of runs of 1/2 in. I.D. rubber garden hose terminating at the fixtures at one end and at a pressure-reducing station manifold at the other end. Because of the lack of sufficient personnel to expeditiously fill and discharge fixtures, and to observe trap seal losses, it was considered necessary to automate the experimental system so that all fixtures could be operated from a central control station. In past experimentation, persons have often been used for trap seal reading, fixture filling and discharging. However, contemporary personnel costs and the complexity of testing the 3 level experimental system suggested that the automation approach be used. As automated, all fixtures could be filled and discharged remotely from the central station by one person and the trap seal losses for all fixtures could be read from this station. The main advantage of the automation approach, over and above economics, is that no coordination problem existed during the discharge of the fixtures in accordance with some predetermined loading sequence. Of course, the main disadvantage was the considerable amount of time consumed in the design, construction, and debugging of the innovations required.

The fact that this system was connected indirectly with the laboratory building drain permitted the use of soap and artificial solids representing human fecal matter in test loadings. As a general rule, previous laboratory investigations of the hydraulics and pneumatics of plumbing have been carried out at NBS with clean water. In one investigation of the hydraulics and pneumatics of 2 in. drainage stacks with 2- and 3-in. building drains, artificial solids loadings were employed in some of the tests [3]. In that investigation, simulated faeces were made from a mixture of plastic asbestos and fine wood shavings molded into cylinders 1-1/2 to 2 in. in diameter and approximately 4-1/2 in. long. In other tests, paper towels and toilet paper were used. The solids loadings contributed to clogging in horizontal lines of 2-in. diameter in some cases, although in most instances the obstructions could be cleared by repeated discharge of fixtures without additional solids. See reference [1] for a discussion of the characteristics of cellulose sponge bricks 4-1/2 in. long and 1-1/4 in. in cross section which were used in the present work. See reference [4] for typical fixture fill depths and discharge rates for all except the laundry tub. This fixture was filled to 7-1/2 in. above the discharge orifice, giving a volume of 11.2 gal. and an average discharge rate of 14.0 gpm.

## 3. PROCEDURE

The test procedure was designed to yield data on trap-seal performance of the system for various load applications and sizes and lengths of vents. Most of the work was carried out with the 3-in. building drain extending beyond the point of connection to the basement bathroom group, as described in Section 2. The fact that a section of the building drain was incorrectly, 3-in. instead of 4-in. diameter during most of the testing does not appear important since (a) such tests as have been made with both 3 and 4 in. diameters for this short section of drain showed no significant difference in performance, and (b) most of the test loads involved the discharge of not over two water closets, which is the maximum number of water closets allowed for a 3-in. building drain by the National Plumbing Code. Initially 50 ft. coils of 1/2-in. I.D. polyethylene tubing having a 1/16 in. wall were installed on each vent. Each coil assumed the same diameter (see figures 2 and 3). With these lengths of tubing attached to the full-size vent standpipes as shown in figures 2 and 3, and with the atmospheric terminals of the small I.D. tubing sealed, an air test was applied to the system such that a positive pressure of 2-in. of water gage was maintained for at least 1 hr. The pressure loss that occurred during this time was not more than 0.1 in. of water gage. This may have resulted from cooling effects in the drain. In any case, a leak of such small proportions would have negligible effect on the over all venting performance. Upon satisfactory completion of the air test, electric probes were inserted through the crown of the building drain extending nearly to the invert at the positions along the drain as shown in figure 1. These probes were connected to a power supply, a sensitive microammeter, and a hand-operated rotary switch. By using a stop watch in conjunction with this apparatus, the times required for the discharge from various combinations of fixtures to arrive at the probe positions in the drain were recorded, as shown in table 1. This was done so that all of the water from any particular sequence of fixture discharges could be concentrated approximately at one position in the building drain, if desired. This load concentration tended to give the most severe condition. Various loading patterns were applied to the test system with 50-ft., 1/2-in. I.D. vents closed and also open. Some of these loadings were repreated with 25-ft. and 1-ft. le lengths of 1/2-in. I.D. tubing. Loadings were applied in a similar manner after the installation of a 1-ft. length of schedule 40, galvanized 1-in. I.D. steel pipe for the main vent, as well as an 18-ft. length of 1-1/4-in. I.D. pipe of the same material for the main vent, while in both cases using 25-ft. lengths of 1/2-in. I.D. tubing for all other vents (see figures 4 and 5). Trap seal losses were determined for a number of the lo loadings listed in table 2. Some of these loadings were applied with artificial solids or detergent inclusions.

The artificial solids were of the type indicated in reference [1]. The detergent loadings consisted of 200 ml of TIDE in the automatic clothes washing machine, and SWAN in the discharge of the lavatories, bath tub, and kitchen sink in the loadings involving detergent in these fixtures. The SWAN was measured in caps full (container cap), a cap full being 8 ml.

## 4. RESULTS AND DISCUSSION

The work on the 3-level system has progressed through the first stage of the investigation as originally planned. This stage was concerned primarily with the determination of an appropriate set of loadings and a minimum vent diameter or combination of minimum diameters to use in the second stage. The second stage had been intended as the final and more thorough aspect of the work upon which this report would have been based, and was intended as an evaluation of performance as a function of vent length. Since it became apparent that stage two could not be completed within the limitations of the investigation, most of the tests were made with arbitrary vent diameters, the lengths being either limiting extremes or somewhat representative of lengths required in field installations.

In the various bar-graph figures showing trap-seal losses, all data are based on averages from test runs in triplicate, with the 3-in. building drain extending downstream to the basement laundry group of fixtures, where it was enlarged to 4-in. diameter. The lack of a bar and numeral above a fixture designation on the horizontal scale signifies no trap seal loss for that fixture following application of the indicated load.

Figure 6 shows trap seal loss for various fixtures with 1/2-in. I.D. tubing vents 1-ft. long on each vent standpipe. This information is compared with results from the substitution of a 1-ft. length of 1-in. Sch. 40 galvanized steel pipe for the main vent. A test load was applied consisting of the simultaneous discharge of clear water from closet No. 1 and lavatory No. 1. None of the trap seal losses exceed 1/2-in. The substitutiin of the 1-ft. length of 1-in. galvanized steel pipe for the main vent showed a marked improvement. Except for water closet No. 3, which had 0.12 in. loss with the 1/2-in. main vent and none after the enlargement of the main vent, the lower level fixtures did not have any seal losses. As a general rule, even with the vents sealed, the discharge of clear water from upstairs fixtures produced negligible loss of trap seal at the basement level.

Figure 7 shows trap seal loss for various fixtures with 1/2-in. I. D. tubing vents 25-ft. long on each vent standpipe. This information is compared with results from the substitution of 1/2-in. I. D. tubing vents 1-ft. long on each standpipe. The test load was the clear water discharge of both compartments of the two compartment kitchen sink. Also the effects of substituting for the main vent first a 1-ft. length of 1-in. galvanized steel pipe and next an 18-ft. length of 1-1/4in. galvanized steel pipe are compared on the same plot. The worst loss occurred in the bathtub trap with the 25-ft. tubing vents (0.76-in. of water). Considerable improvement was observed with enlargement of the main vent. The lower fixtures did not have any trap seal losses with either venting arrangement.

Figure 8 gives similar information to figure 7 except that 1-ft. lengths of individual vents were not used, and the load was different. The test load was the clear water discharge of water closet No. 1. It is seen that with the 1/2-in. vents throughout, four trap seal losses were 1 in. or more and lavatory No. 2 lost almost 2 in. of trap seal. An increase in main vent size showed a remarkable improvement in trap seal performance for this particular loading. The magnitude of the seal losses where 1/2-in. I. D. venting was used throughout suggests the unsuitability of using this size on all individual vents of this system. Again attention is focused on the fact that very little trap seal loss was encountered on the lower level (maximum loss 0.18 in. of water from shower trap).

Figure 9 shows trap seal loss from the simultaneous discharge of all lower level fixtures. This is shown for 25-ft. lengths and 1-ft. lengths 1/2-in. I. D. tubing vents. Also, the effects of installing the two larger diameters of main vent are shown. The trap seal losses seem exceptionally low for such a heavy loading. Again, improvement of considerable amount is noted after substituting a larger diameter on the main vent. It is also interesting to note that relatively little trap seal loss occurred in the upper level fixture group. This further confirms the finding from several of the tests described above that clear water loadings at one end of the system rarely affected trap seals at the other end.

Figure 10 shows the effect of open and closed vents on the kitchen group during the discharge of water closet No. 1. The venting consisted of 1-ft. lengths of 1/2-in. I. D. tubing. It was desired to find out if the air introduced through short lengths of 1/2-in. tubing vents to the kitchen group of fixtures would result in an improvement similar to that resulting from enlargement of the main vent. It is obvious that some improvement resulted from the additional venting provided by the kitchen sink vent and dishwasher vent, but in most instances this improvement was only marginal.

Figure 11 compares the trap seal performance with the three lengths of 1/2-in. I. D. tubing used during this work. The 50-ft. lengths are compared in both the open and closed condition. These comparisons are made only for the discharge of water closet No. 1. Several of the losses for lengths of 25 and 50 ft. are well beyond 1 in. of water. The system certainly should be expected to perform well with only the discharge of one water closet.

Figure 12 shows trap seal losses with clean water and detergent solution loadings from the two-compartment kitchen sink. The effect of operating the garbage grinder while discharging a detergent solution was also investigated. These comparisons are made with 1-ft. lengths of 1/2-in. I. D. tubing in place on all vents. The effect of purging the system with clean water in an attempt to wash out all of the residual suds from the drain is also shown. The water temperature was 50° C and 16 ml. of SWAN detergent was added to each sink compartment which contained 1500 ml. of water. The discharge of clean water caused little or no loss of trap seal in most instances. The addition of detergent solution to the test load substantially increased some of the trap seal losses, particularly for water closet No. 3, and the operating of the garbage grinder in conjunction with the detergent loading substantially increased the trap seal loss of water closet No. 3. The effect of purging suds from the system between runs appears to have resulted in an improvement in the trap seal performance downstream from the sink, and a worsening upstream.

Figure 13 shows the effect of artificial solids inclusion in the discharge of water closet No. 1. The comparison is made between a clear water discharge and discharges including one, two, or three solids [1]. The venting consisted of 1/2-in. I. D. tubing 1-ft. long on each individual fixture vent standpipe. Little or no practical difference can be seen between the results of loadings with and without solids nor can much effect be detected due to the number of solids introduced.

Figure 14 presents data on trap seal losses for the various fixtures for the following discharge pattern: Water closet No. 1, Lavatory No. 1, and bathtub simultaneously; followed 5 sec. later by water closet No. 3, and automatic clothes washing machine simultaneously. This is shown for a clear water discharge in comparison with a discharge in which 200 ml of

TIDE was included in the automatic washing machine. Addition of detergent to the test load increased the trap seal losses of three fixtures on the lowest level of the system, but none of these exceeded 5/8-in. Losses for the fixtures on the upper and intermediate levels were not increased by the detergent loading. The location of the clothes washing machine on the most downstream branch of the system near the building sewer may account for the relatively slight effect of detergent load on fixture trap seals upstream from the washing machine. Individual vents consisted of 25-ft. lengths of 1/2-in. I.D. tubing and the main vent was an 18-ft. length of 1-1/4-in. galvanized steel pipe.

Figure 15 shows the effect of discharging lavatory No. 1 and lavatory No. 2 with clear water and with 8 ml of SWAN in each. Little or no trap seal loss occurred from the clear water load except for water closet No. 3, which lost a little over 1/2-in. of seal. The addition of the detergent increased the losses in some fixtures, but resulted in a smaller loss for water closet No. 3. As a general rule, in other tests, water closet No. 3 received the worst seal loss from detergent loadings.

Figure 16 shows the effect of discharging water closet No. 1 and bath tub simultaneously. This was done with clear water and with SWAN detergent in the tub. The effects from clear water loadings are compared to those from 16 ml and 48 ml detergent added to the bathtub. The venting consisted of 25-ft. lengths of 1/2-in. I. D. tubing for all except the main vent. The main vent was an 18-ft. length of 1-1/4-in. galvanized steel schedule 40 pipe. Again, all trap seal losses were less than 1-in. with the clear water loading. The detergent loading yielded worse results only in the case of water closet No. 3, but here the effect was drastic. The temperature of the water in the bath tub was approximately 50° C, probably somewhat hotter than would normally be discharged in service. This may have contributed to excessive suds generation.

All of the above work was done with the 3-in. building drain extending down to its junction with the basement laundry group, where it was enlarged to 4-in. diameter. The section of 3-in. drain between the basement bath group and the laundry group has recently been replaced by a 4-in. diameter section, as required by the National Plumbing Code [5].

Since this modification to the drain, results from the detergent loading of figure 16 have been observed closely to acquire some understanding of the phenomenon involved in the complete failure of W.C. No. 3 trap. By inspection it was found that this failure occurred several minutes after the passage of all water from the system. A 4-ft. length of 2-in. clear plastic vent pipe extending above W.C. No. 3 permitted observation of the detergent flowing up into the vent. The pressure generated was such as to cause the suds to over-flow the vent, and to cause a noticeable rise in W.C. No. 3 trap seal. This occurred in a clean system which had been completely purged of residue detergent from preceding tests. Approx. 16 ml of detergent was used in the test loads. The vent sizes were 1-1/2 in. for individual fixtures, 1-1/4 in. for the main vent, and 2 in. for W.C. No. 3. It was found that it took many purges with clear water in order to eliminate all of the detergent from the system, and that the detergent suds remained in the drain for many hours. For example, these suds were found to remain in W.C. No. 3 vent for as long as 40 hrs. after the initial discharge. This suds persistence has been seen by other researchers. See page 70 of reference [6]. A measurement showed that 2000 ml of detergent foam placed in a large beaker with a diameter of about 10-in. persisted for only about 3 hrs. The residue consisted of about 100 ml of liquid. This seems to indicate that the evaporation rate, or decomposition rate, as you please, may be dependent on the diameter of the container, and possibly also on contact of suds with the atmosphere and with water. Some experimentation would be required to adequately describe and explain this phenomenon.

The only further data taken on the system after drain modification concerned the clear water discharge of water closet No. 1 and water closet No. 2 simultaneously, followed by water closet No. 3 five seconds later. This was performed with full diameter vents on all fixtures except the water closets. Vent standpipes 1-1/2-in. I.D. and 5-ft. long were used on the various fixtures and an 18-ft. length of 1-1/4 in. pipe on the main vent (water closet No. 1 & No. 2 vent). Water closet No. 3 was vented through a length of 3-in. cast iron reduced to 2-in. During the first three runs, water closet No. 3 lost 3/4 in. of seal with seal replenishment between runs. This was somewhat surprising; so more runs were taken. It was found that after the third run, this loss in water closet No. 3 did not occur. It was found that no trap seal losses took place with an additional seven runs, either in W.C. No. 3 or in any other fixture. The occurrence of the initial three losses of seal in water closet No. 3 may have been caused by residue detergent suds generated during earlier testing with detergents, although efforts had been made to assure that the system was cleared of detergent before commencing the latter test. In any case, the result of the final seven runs indicated that the system was adequately vented for the three water closet loading. Preliminary loadings with this combination with the 3-in., non-code section of building drain between the basement bath and laundry groups had previously shown no trap seal losses with this venting arrangement. Thus, the performance of the system with vents, as described above, was satisfactory with a clear water loading comprising the 3 water closets, both with and without the "non-code" 3-in. section of building drain.

For comparison, figure 17 shows data for the 3-water closet, clear water load with 1/2 in. I.D. tubing 25-ft. long for each of the individual vents, and a 1-1/4 in. steel pipe 18-ft. long for the main vent. The building drain was 3-in. diameter extending downstream to the basement laundry group branch, and 4-in. beyond this point. Water closets No. 1 and No. 2 were discharged simultaneously, followed by W.C. No. 3 either 3, 5, or 7 seconds later. The results show that a time delay of five seconds in discharging W.C. No. 3 produced, on the average, a little more severe load than either 3 or 7 seconds. However, the difference was not striking. In addition, figure 17 shows that the use of 1/2-in. I. D. tubing for the individual vents yielded questionable, "borderline" performance with this load. Thus, additional venting is probably essential for this load which, however, seems rather unlikely to occur in field service.

Experience over a period of time with full scale experimental plumbing systems has shown that the discharge of all fixtures simultaneously does not necessarily yield the greatest trap seal losses. The data of figure 18 show one example of this. The data were taken under the worst possible pneumatic condition---all vents sealed. Therefore, it should not be inferred that the performance obtained was typical of the system with venting. As shown in the figure, the discharge of one water closet resulted in more trap seal loss than all fixtures discharged simultaneously. One possible explanation for this is the self trap-seal-loss replenishing characteristic of the discharging fixtures. Also, it is possible that the interference of colliding streams in some of the horizontal drains may have prevented the creation of sub-atmospheric pressures adjacent to the trap seals. It should not be inferred from the above that the discharge of one fixture was the most severe load that could have been applied, since no data are shown with intermediate numbers of fixtures between the two extremes. Possibly some sequence of discharge of all except one or two fixtures would have yielded the greatest seal losses.

## 5. CONCLUSIONS

1. It can be concluded from this work that 1/2-in. I.D. polyethylene vents used throughout the test system did not yield satisfactory pneumatic performance. Further work might show that, at least for clear water loads, 1/2-in. or 3/4-in. I.D. vents could be used on certain fixtures in combination with larger size vents elsewhere in the system. This possibility was suggested from the results of tests made on the 3-level system with a 1-1/4 in. main vent in combination with 1/2-in. individual vents.
2. In the limited amount of work done with solids loading, little effect of artificial solids inclusions was detected. However, from this alone it cannot be said that solids loadings do not affect trap seal performance. While the artificial solids used were believed to represent one type of a heavy load, it might be desirable to vary the type of solid material used and include some paper in the W.C. loads. For instance, toilet paper and baby diapers of the disposable type

might be tried. British and Swiss investigators have detected substantial effects from the use of newspaper and paper diapers.

3. The adverse effects due to detergents in some of the tests, particularly in relation to trap seals of some of the lowest fixtures, indicates either (a) the detergent test loads used may have been unreasonably heavy, or (b) the physical arrangement of the test pipework was not such as to yield the most favorable performance with detergent loads. It is understood that builders, plumbing inspectors, and engineers have generally reported little or no detergent foam problems in one and two family houses. Thus, it seems clear that further study of the properties of detergent foam and of the detergent phenomenon under conditions representative of a typical house plumbing drainage system should be carried out. The following might be studied: (a) attenuation of sudsing action with dishwashing or laundering, (b) effect of temperature on extent of suds generation, (c) effects of detergent concentration and composition on suds pressure and rate of suds generation, (d) effect of pipe diameter and rate of suds generation on suds pressure, (e) persistence of suds as related to size of container (or pipe) and proximity to liquid or atmosphere, (f) effect of pipe diameter on ease of entry of suds into a branch drain or vent, and (g) the mechanism by which negative pressures occur in a suds-choked system subsequent to cessation of water flow.

4. From a consideration of experience-based practices and the data obtained in this study, it seems likely that it would be advantageous to separate the discharge from detergent using fixtures in houses, such as the kitchen sink, automatic clothes washing machine, laundry tub, etc.,

from the discharge of other fixtures connecting the waste branch serving detergent fixtures to the building drain as close as possible to the building sewer, instead of connecting it to the main stack or to the building drain near or ahead of other branch drains. This aspect of piping arrangement should be further investigated. In some instances, separate drainage of detergent-using fixtures in high-rise buildings, has been found effective in alleviating detergent "back-up".

5. It would be informative to load field systems with detergent and observe whether or not there is a tendency for the suds to back up into certain fixtures, or to cause trap-seal losses. Observation on "back-up" would be facilitated by removing the water from the idle fixture traps. For instance, basement water closet seal removal would allow easy access to the trap way for suds generated in the drain. Without seal removal, it would be difficult to detect a field system choked with detergent suds.
6. Further study is needed to establish "reasonable"test loads in small systems such as installed in one and two-family houses. Standardization of test loads would be of great value in achieving uniformity of results between different tests and different laboratories, and would permit the evaluation of system performance under loadings similar to service loadings.

## 6. BIBLIOGRAPHY

[1] Progress Report No. 5 on Fluid Dynamics of Plumbing, NBS Report No. 9013.

[2] Progress Report No. 1 on Fluid Dynamics of Plumbing, NBS Report No. 7736.

[3] Hydraulics and Pneumatics of 2-inch Drainage Stacks, NBS Report No. 2521.

[4] Progress Report No. 3 on Fluid Dynamics of Plumbing, NBS Report No. 8354.

[5] National Plumbing Code, ASA A40.8-1955, American Society of Mechanical Engineers and American Public Health Association.

[6] Drainage Pipework in Dwellings: Hydraulic Design and Performance, A.F.E. Wise, Her Majesty's Stationary Office, London, 1957

Table 1. Fixture discharge arrival time at selected positions in building drain

| Fixture Discharge Pattern [1] | Run no. | Time to Station No. 1 | Time to Station No. 2 | Time to Station No. 3 | Time to Station No. 4 |
|---|---|---|---|---|---|
| | | sec. | sec. | sec. | sec. |
| A | 1 | 5 | 10 | 13 | 18 |
| A | 2 | 5 | 10 | 12 | 17 |
| A | 2 | 5 | 10 | 12 | 17 |
| B [3] | 1 | 5 | 10 | 12 | 17 |
| C | 1 | 5 | 11 | 14 | 21 |
| C | 2 | 5 | 9 | 12 | 26 |
| C | 3 | 4 | 8 | 11 | 18 |
| D [4] | | | | | |
| E | 1 | 5 | 11 | 14 | 23 |
| E | 2 | 5 | 11 | 14 | 22 |
| E | 3 | 4 | 11 | 14 | 22 |
| F | 1 | 5 | 12 | 16 | 24 |
| F | 2 | 6 | 11 | 16 | 24 |
| F | 3 | 5 | 11 | 16 | 23 |
| F [2] | 1 | 7 | 9 | 14 | 28 |
| F [2] | 2 | 7 | 14 | 18 | 26 |
| F [2] | 3 | 7 | 14 | 19 | 27 |
| G | 1 | 5 | 11 | 14 | 23 |
| G | 2 | 5 | 11 | 14 | 23 |
| G | 3 | 5 | 11 | 14 | 23 |
| G [2] | 1 | 5 | 11 | 14 | 23 |
| G [2] | 2 | 5 | 11 | 14 | 23 |
| G [2] | 3 | 5 | 11 | 14 | 23 |

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[1] See Table 2 for explanation of symbols

[2] With garbage grinder running

[3] Only one run made. Assumed equivalent to pattern "A".

[4] No data taken. Assumed equivalent to "C".

Table 1. (Continued)
Fixture discharge arrival time at selected positions in building drain

| Fixture Discharge Pattern 1/ | Run no. | Time to Station No. 1 | Time to Station No. 2 | Time to Station No. 3 | Time to Station No. 4 |
|---|---|---|---|---|---|
| | | sec. | sec. | sec. | sec. |
| H | 1 | 9 | 18 | - | 32 |
| H | 2 | 9 | 18 | - | 31 |
| H | 3 | 9 | 17 | - | 32 |
| I | 1 | - | - | 5 | 13.5 |
| I | 2 | - | - | 5.5 | 13.5 |
| I | 3 | - | - | 5 | 13.6 |
| J | 1 | - | - | 4.5 | 13 |
| J | 2 | - | - | 4.5 | 13 |
| J | 3 | - | - | 4.5 | 13 |
| K | 1 | - | - | - | 10 |
| K | 2 | - | - | - | 10 |
| K | 3 | - | - | - | 10 |
| L | 1 | - | - | - | 14 |
| L | 2 | - | - | - | 12 |
| L | 3 | - | - | - | 11 |
| M | 1 | 5 | 8 | 10 | 13 |
| M | 2 | 5 | 8 | 10 | 13 |
| M | 3 | 5 | 8 | 10 | 12.5 |
| N | 1 | 3 | 6.5 | 8.5 | 16.5 |
| N | 2 | 2.5 | 7.0 | 9.0 | 15.0 |
| N | 3 | 2.5 | 7.0 | 9.5 | 17.2 |
| O | 1 | 4 | 8 | 10 | 17 |
| O | 2 | 4 | 8 | 10 | 15 |
| O | 3 | 3.5 | 7.5 | 9.5 | 15.4 |
| P | 1 | 4 | 8 | 10 | 18 |
| P | 2 | 4 | 8.5 | 9.5 | 18.2 |
| P | 3 | 4.5 | 8.0 | 10 | 14.6 |

Table 1. (Continued)
Fixture discharge arrival time at selected positions in building drain

| Fixture Discharge Pattern 1/ | Run no. | Time to Station No. 1 | Time to Station No. 2 | Time to Station No. 3 | Time to Station No. 4 |
|---|---|---|---|---|---|
| | | sec. | sec. | sec. | sec. |
| Q 5/ | | | | | |
| R 5/ | | | | | |
| S 5/ | | | | | |
| T | 1 | 2.5 | 6.0 | 8.0 | 14.0 |
| T | 2 | 2.5 | 6.5 | 7.0 | 11.5 |
| T | 3 | 2.8 | 6.5 | 7.5 | 12.0 |
| U | 1 | 4.5 | 9.0 | 12.0 | 18.0 |
| U | 2 | 4.5 | 9.0 | 11.0 | 18.0 |
| U | 3 | 4.0 | 8.8 | 11.0 | 18.5 |
| U 2/ | 1 | 4 | 9.5 | 12.0 | 22.0 |
| U 2/ | 2 | 4 | 9.5 | 12.5 | 21.0 |
| U 2/ | 3 | - | — | — | |
| V 5/ | | | | | |
| W 5/ | | | | | |
| X 5/ | | | | | |
| Y 5/ | | | | | |
| Z | 1 | - | - | | 9.5 |
| Z | 2 | - | - | | 7.5 |
| Z | 3 | - | - | | 7.5 |
| $A_1$ | 1 | 3 | 6 | 7.5 | 14.2 |
| $A_1$ | 2 | 3 | 5.5 | 8.0 | 14.5 |
| $A_1$ | 3 | 3 | 5.0 | 8.0 | 13.5 |

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5/ No data taken for these patterns

## Table 2. Fixture Discharge Pattern Code
(An Explanation of Table 1 Symbols)

| SYMBOL | PATTERN |
|---|---|
| A | Water closet No. 1 |
| B | Water closet No. 2 |
| C | Lavatory No. 1 |
| D | Lavatory No. 2 |
| E | Bathtub |
| F | Kitchen sink compartment No. 1 |
| G | Kitchen sink compartment No. 2 |
| H | Dish washer |
| I | Water closet No. 3 |
| J | Lavatory No. 3 |
| K | Wash tub (laundry tub) |
| L | Automatic clothes washer |
| M | Water closet No. 1 & Water closet No. 2 simultaneously |
| N | Lavatory No. 1 & Lavatory No. 2 simultaneously |
| O | Water closet No. 1 & Lavatory No. 1 simultaneously |
| P | Water closet No. 2 & Bath tub simultaneously |
| Q | Water Closet No. 1, Lavatory No. 1 & Bath tub simultaneously |
| R | Water closet No. 1, Water closet No. 2 & Lavatory No. 1 simultaneously |
| S | Water closet No. 1, Water closet No. 2, Lavatory No. 1 & Lavatory No. 2 simultaneously |
| T | Water closets No. 1 & No. 2, Lavatories No. 1 & No. 2, and Bath tub simultaneously |
| U | Sink compartments No. 1 & No. 2 (Kitchen sink) simultaneously |
| V | Kitchen sink compartment No. 1 & Dish washer simultaneously |

Table 2. (Continued) Fixture Discharge Pattern Code

| SYMBOL | PATTERN |
|---|---|
| W | Kitchen sink compartment No. 2 & Dish washer simultaneously |
| X | Kitchen sink compartments No. 1 & No. 2 & Dish washer simultaneously |
| Y | Water closet No. 3 & Lavatory No. 3 simultaneously |
| Z | Laundry tub & Automatic clothes washer simultaneously |
| $A_1$ | Kitchen sink compartments & Dish washer simultaneously, followed 2 seconds later by top floor group simultaneously |
| $B_1$ | All fixtures discharged simultaneously |
| $C_1$ | All basement level fixtures discharged simultaneously |
| $D_1$ | Two compartment kitchen sink and dishwasher simultaneously, followed 2 seconds later by basement fixtures simultaneously |

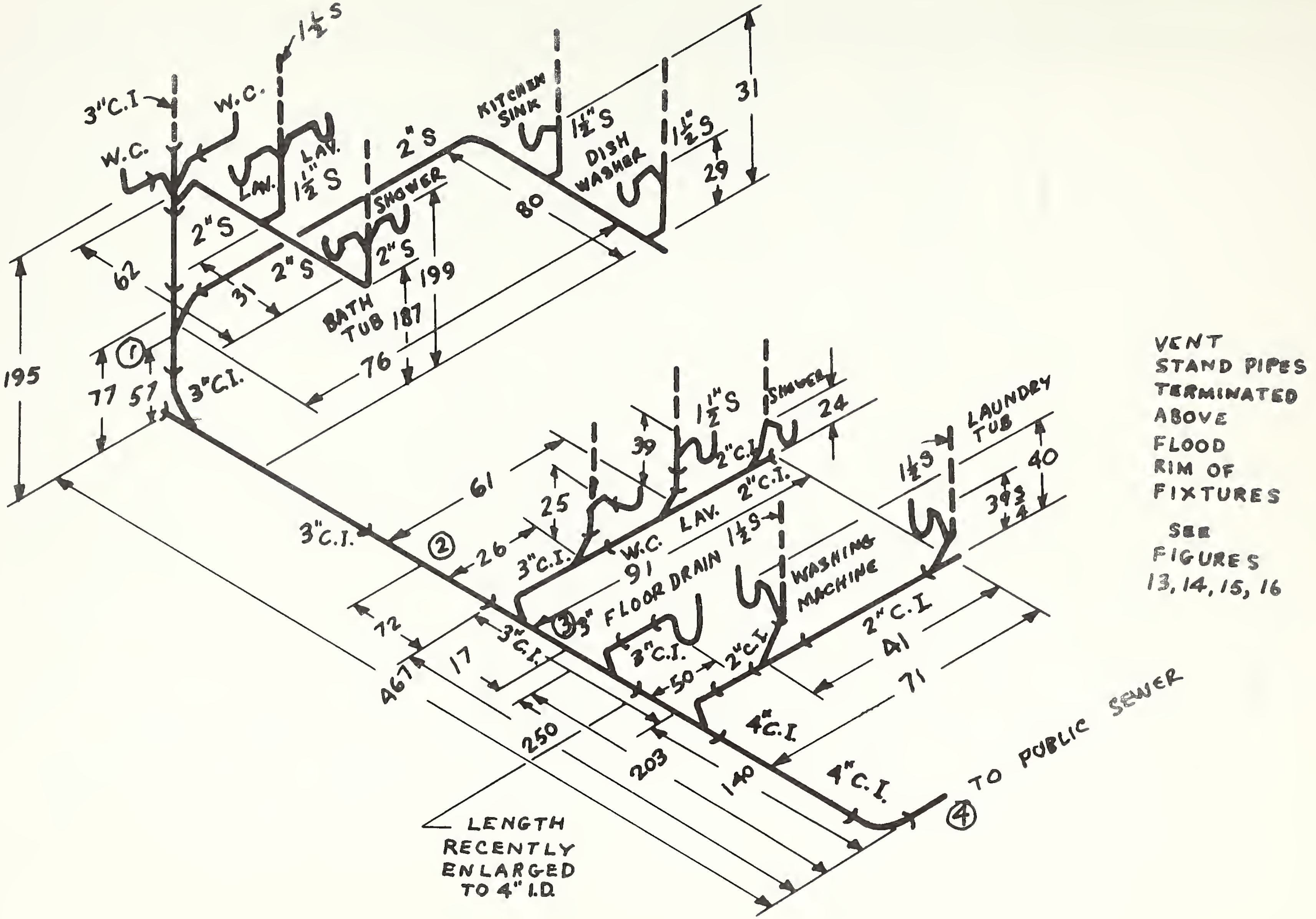

Figure 1. Full-scale, three-bath test system representing a type that might be used in a two story house with a basement (Dimensions in inches. Circled numbers refer to the measuring stations for the data shown in Table 1  Small size vents were extended upward from the standpipes).

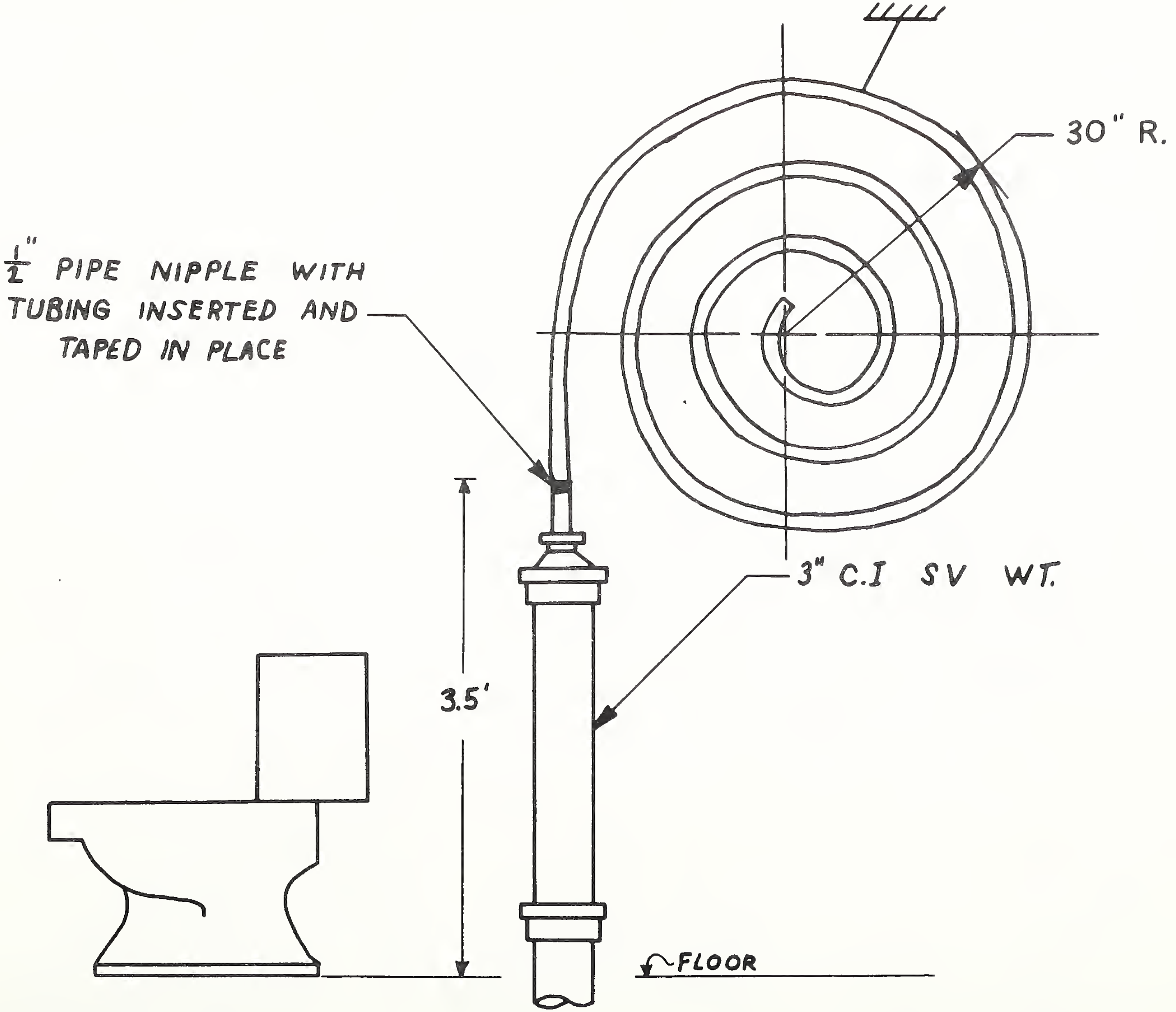

Figure 2. Test vent installation details for water closets using 1/2-in. I.D. tubing 50-ft. long (The 25-ft. coil had approximately the same radius, and the 1-ft. length was installed without coiling.

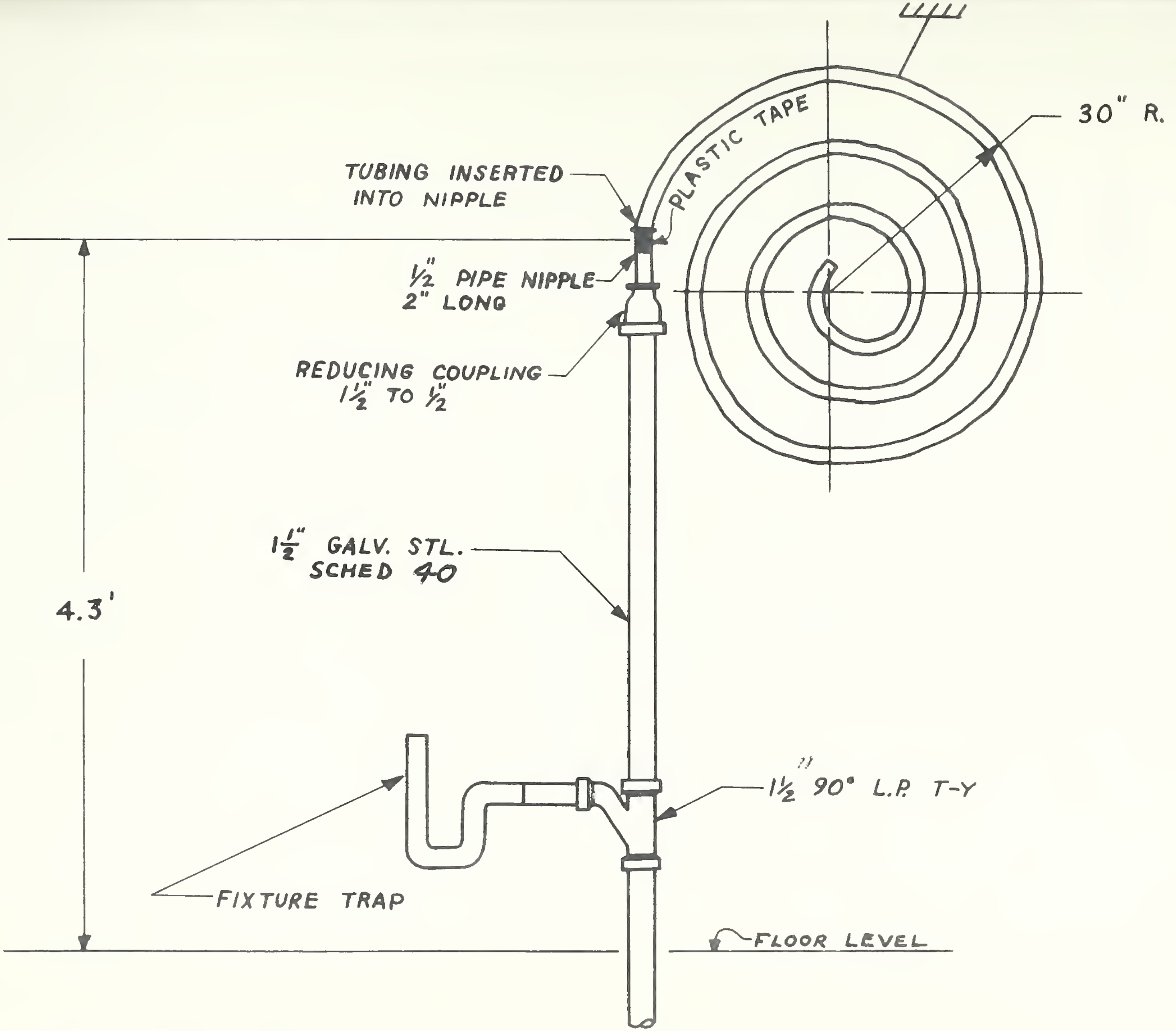

Figure 3. Test vent installation details for fixtures other than water closets using 1/2-in. I.D. tubing 50-ft. long. (The 25-ft. coil had approximately the same radius, and the 1-ft. length was installed without coiling).

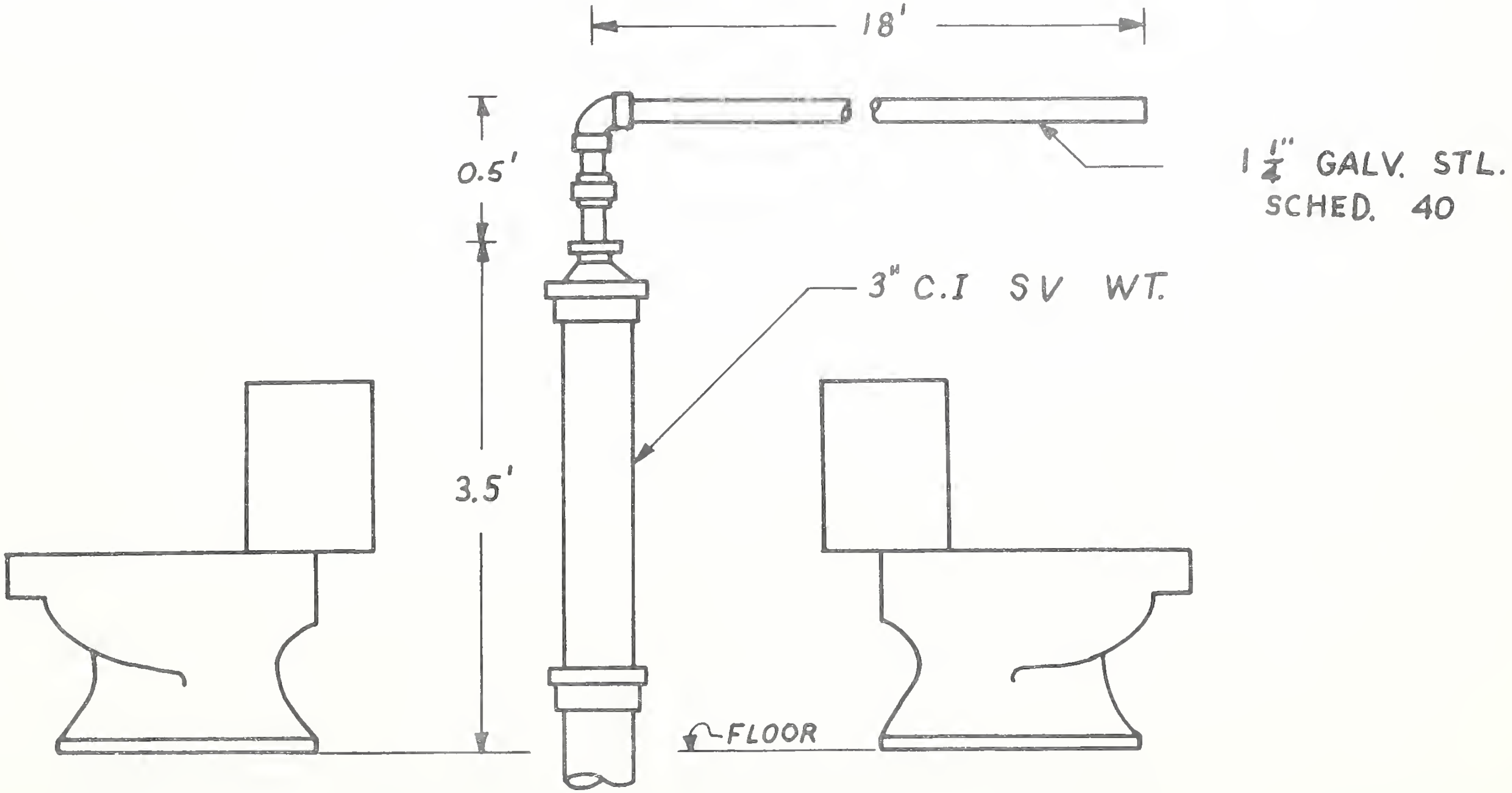

Figure 4. Test installation details for main vent using a 18-ft. length of 1-1/4-in. steel pipe

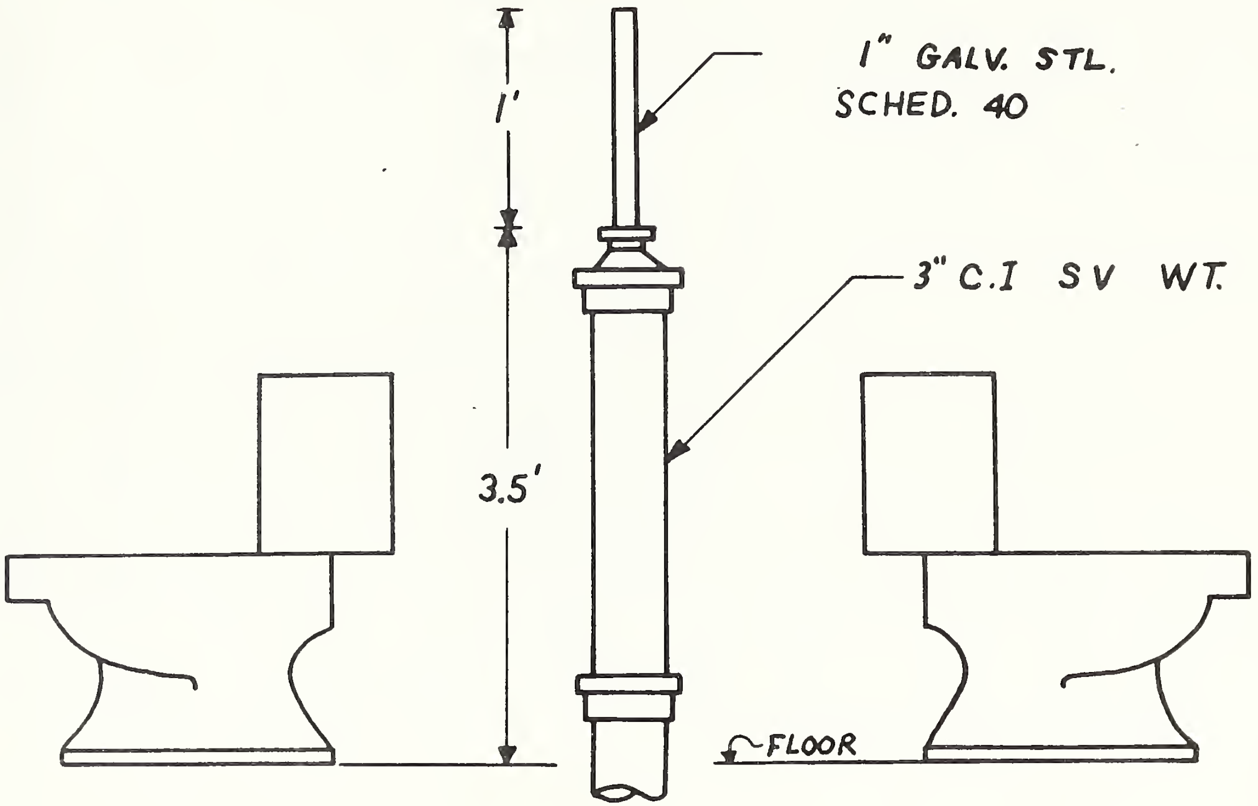

Figure 5. Test installation details for main vent using a 1-ft. length of 1-in. steel pipe.

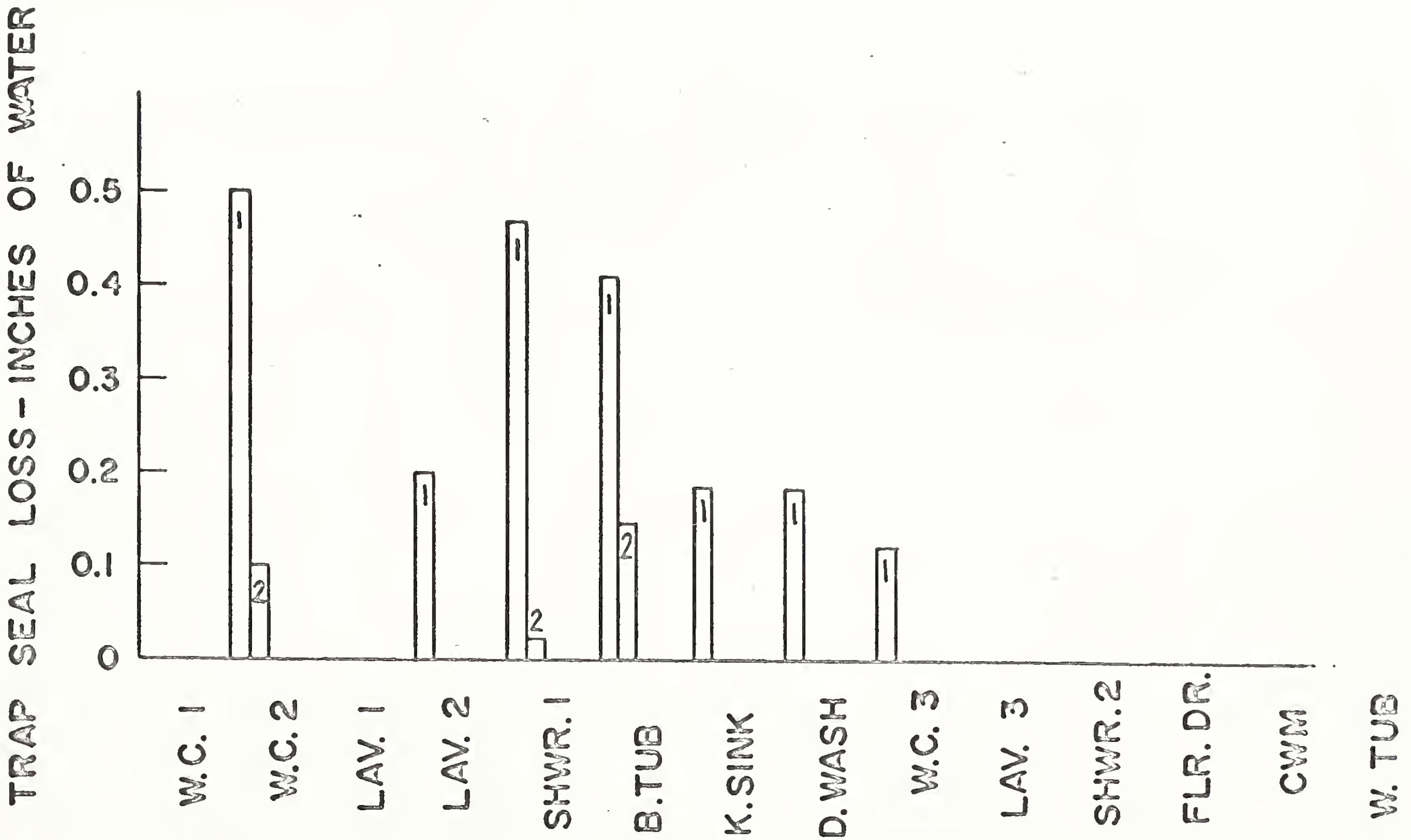

Figure 6. Trap seal losses as affected by enlarging main vent.
Loading: Clear water discharge of $W.C._1$ & $Lavatory_1$ simultaneously
Bargraph Identification:
1. 1-ft. length of 1/2-in. I.D. tubing on each vent standpipe.
2. Same as 1. except 1-in. dia., 1-ft. length of steel pipe installed on main vent.

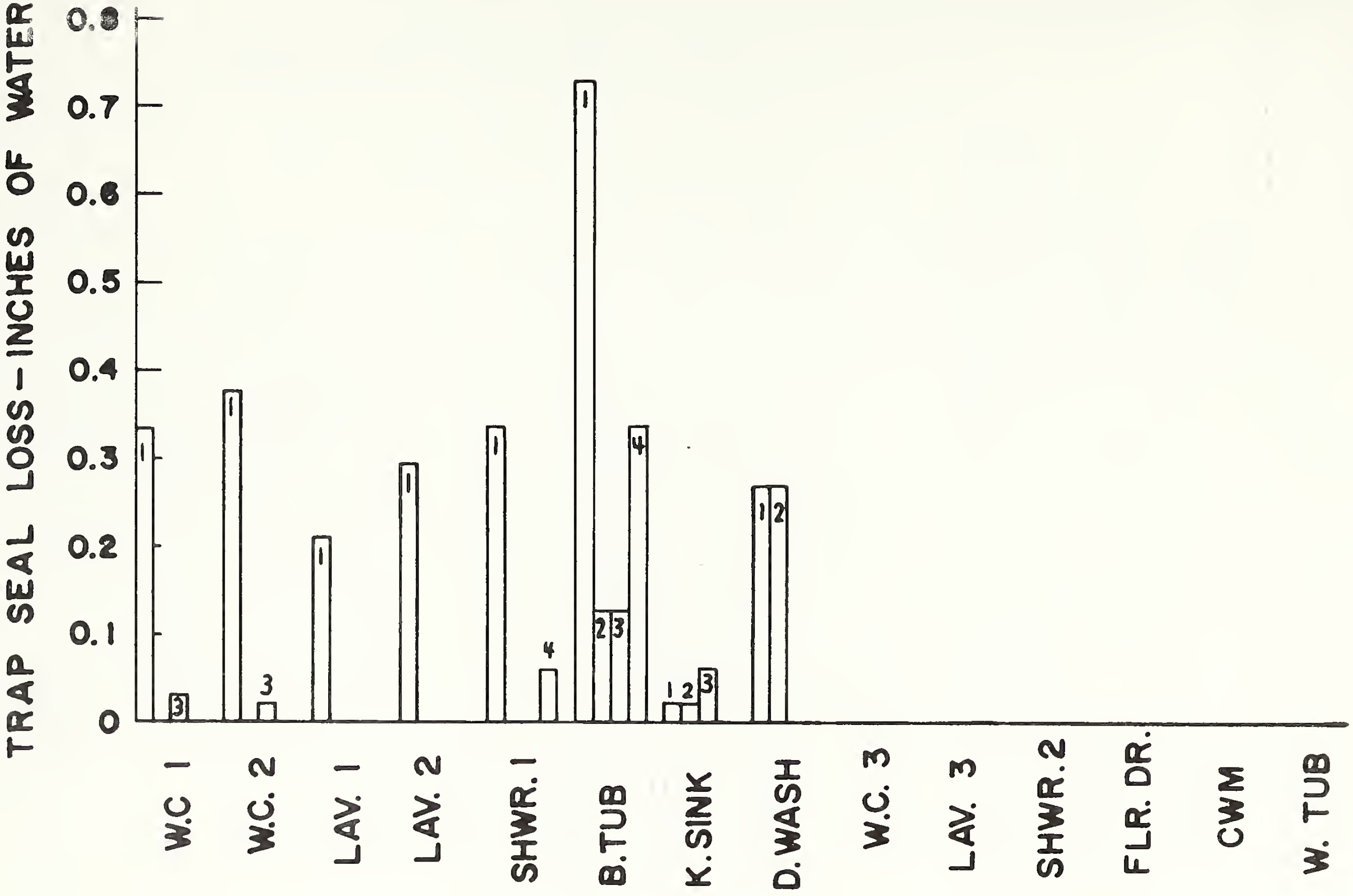

Figure 7. Trap seal losses as affected by shortening or enlarging vents.
Loading: Clear water discharge of $S_1$ & $S_2$.
Bargraph Identification:

1. 25-ft. length of 1/2-in. I.D. tubing installed on each vent standpipe.
2. Same as 1. except that a 1-ft. length of 1-in. steel pipe was used on the main vent.
3. Same as 2. except that an 18-ft. length of 1-1/4-in. steel pipe was used.
4. Same as 1. except 1-ft. lengths were used.

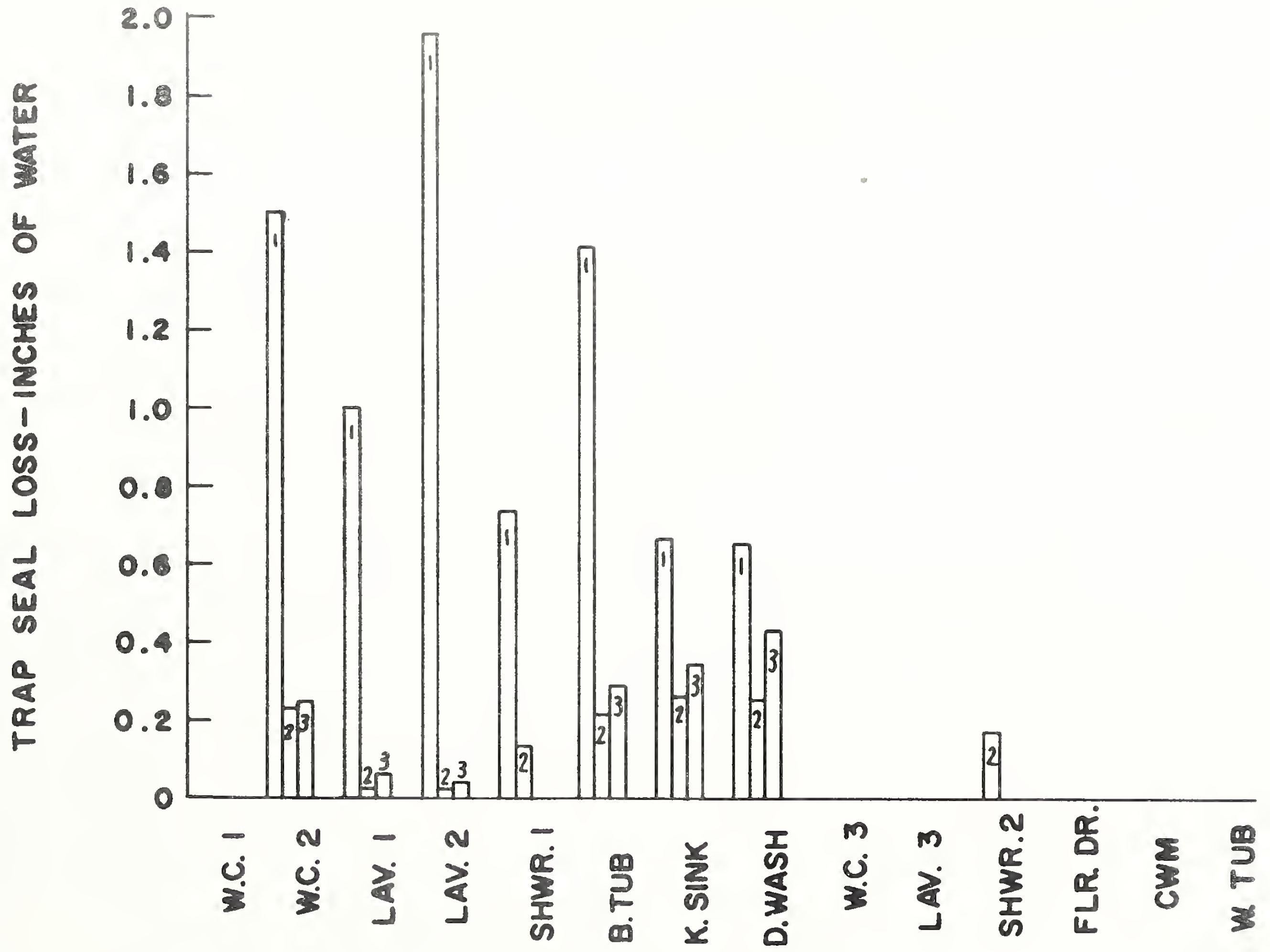

Figure 8. Trap seal losses as affected by shortening or enlarging vents.
Loading: Discharge of clear water from W.C.$_1$
Bargraph Identification:

1. 25-ft. length of 1/2-in. I.D. tubing installed on each vent standpipe.
2. Same as 1. except a 1-ft. length of 1-in. steel pipe substituted on the main vent.
3. Same as 2. except an 18-ft. length of 1-1/4-in. steel pipe used for the main vent.

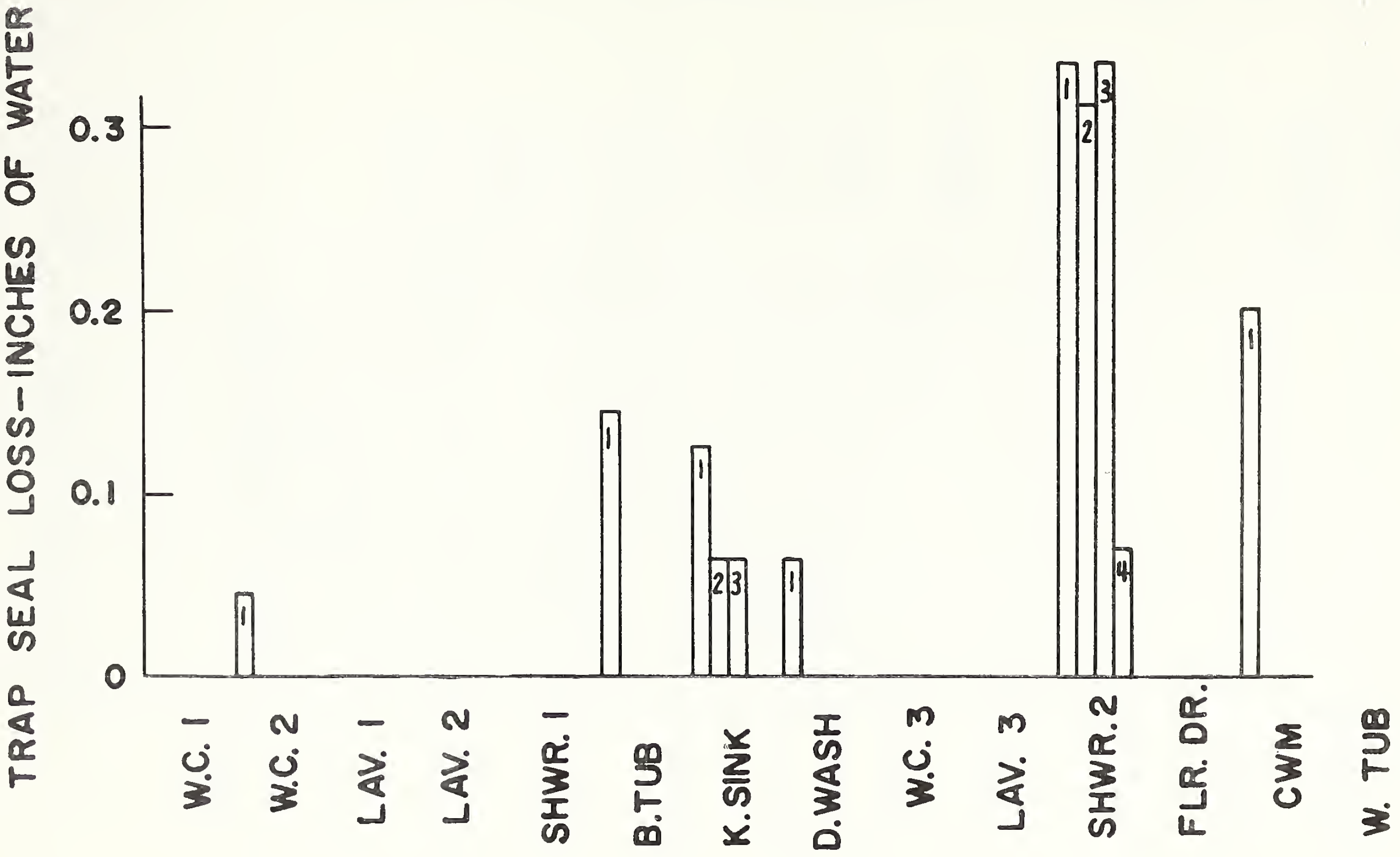

Figure 9. Trap seal losses as affected by shortening or enlarging vents.
Loading: All lower level fixtures discharged simultaneously.
Bargraph Identification:

1. 25-ft. length of 1/2-in. I.D. tubing installed on each vent standpipe.
2. Same as 1. except a 1-ft. length of 1-in. steel pipe used for the main vent.
3. Same as 2. except an 18-ft. length of 1-1/4-in. steel pipe was used for the main vent.
4. Same as 1. except 1-ft. lengths were used.

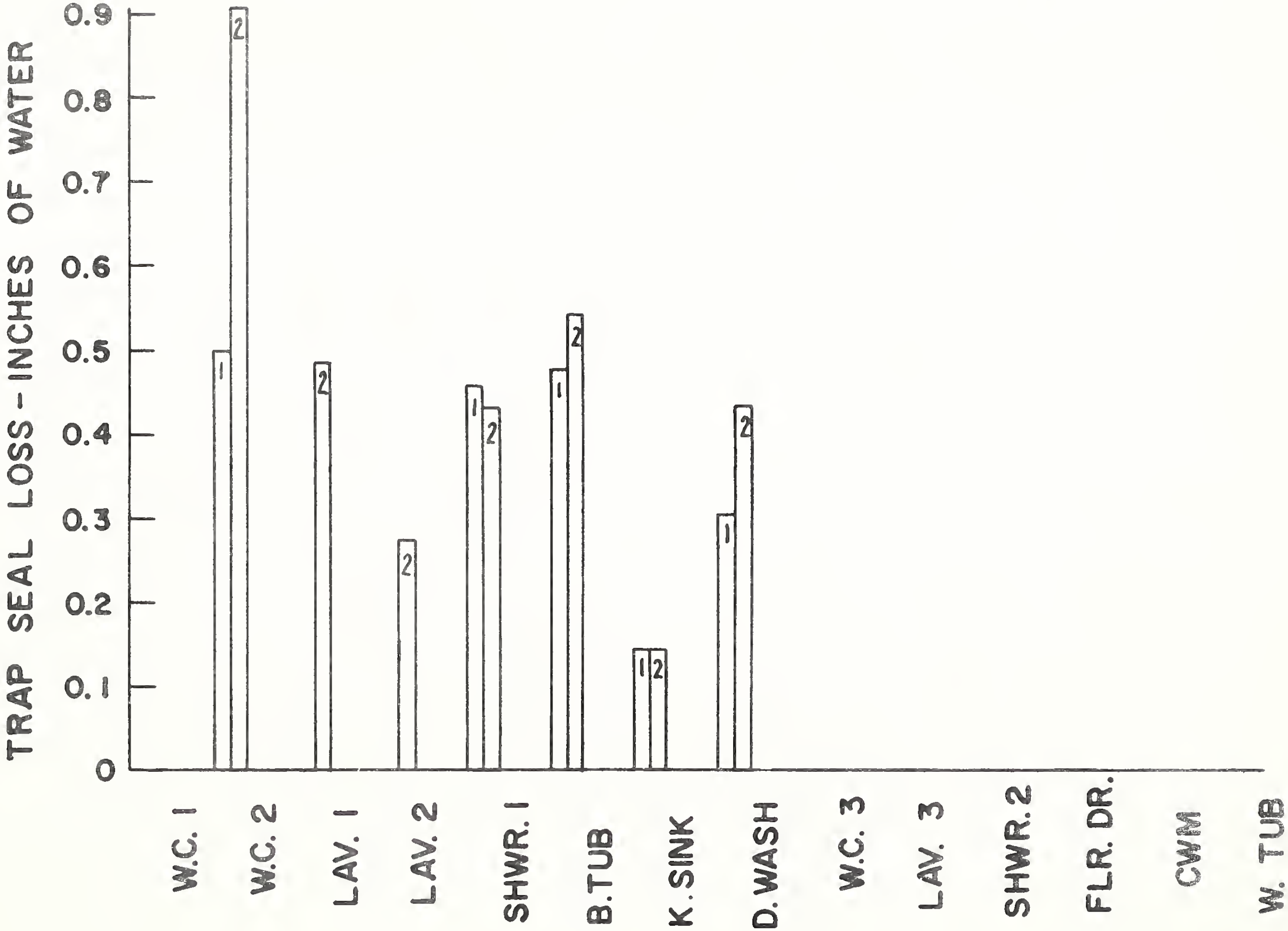

Figure 10. Trap seal losses as affected by closing sink and dishwasher vents.
Loading: Discharge of clear water from W.C.$_1$
Venting: 1/2-in. I.D. tubing 1-ft. long attached to all vent standpipes.
Bargraph Identification:
1. All vents open.
2. Sink and dishwasher vents closed----all others open.

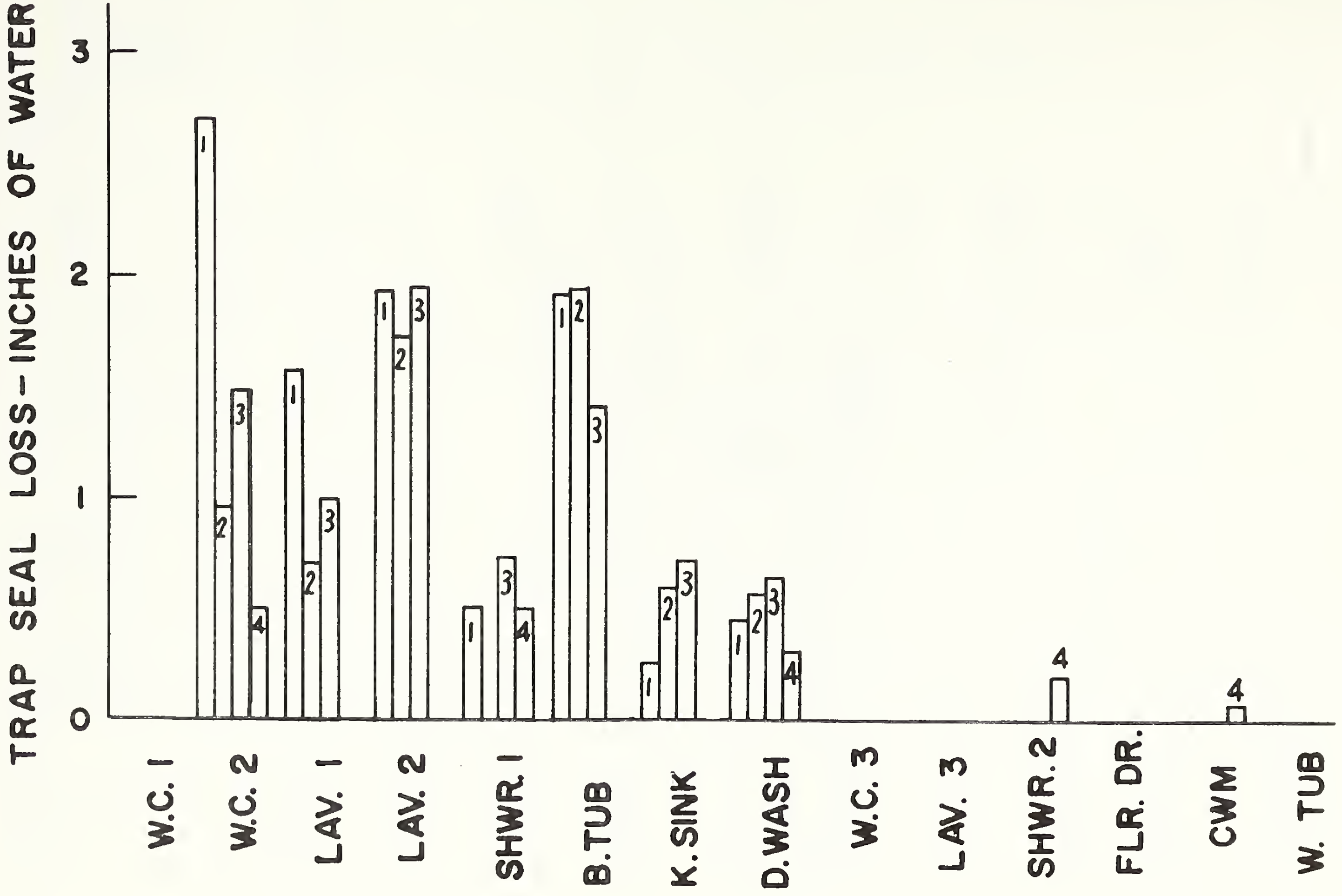

Figure 11. Trap seal losses as affected by length of vents and closure of vents.
Loading: Clear water discharge of W.C.$_1$
Venting: 1/2-in. I.D. tubing attached to all vent standpipes.
Bargraph Identification:
1. 50-ft. vents sealed
2. 50-ft. vents open
3. 25-ft. vents open
4. 1-ft. vents open

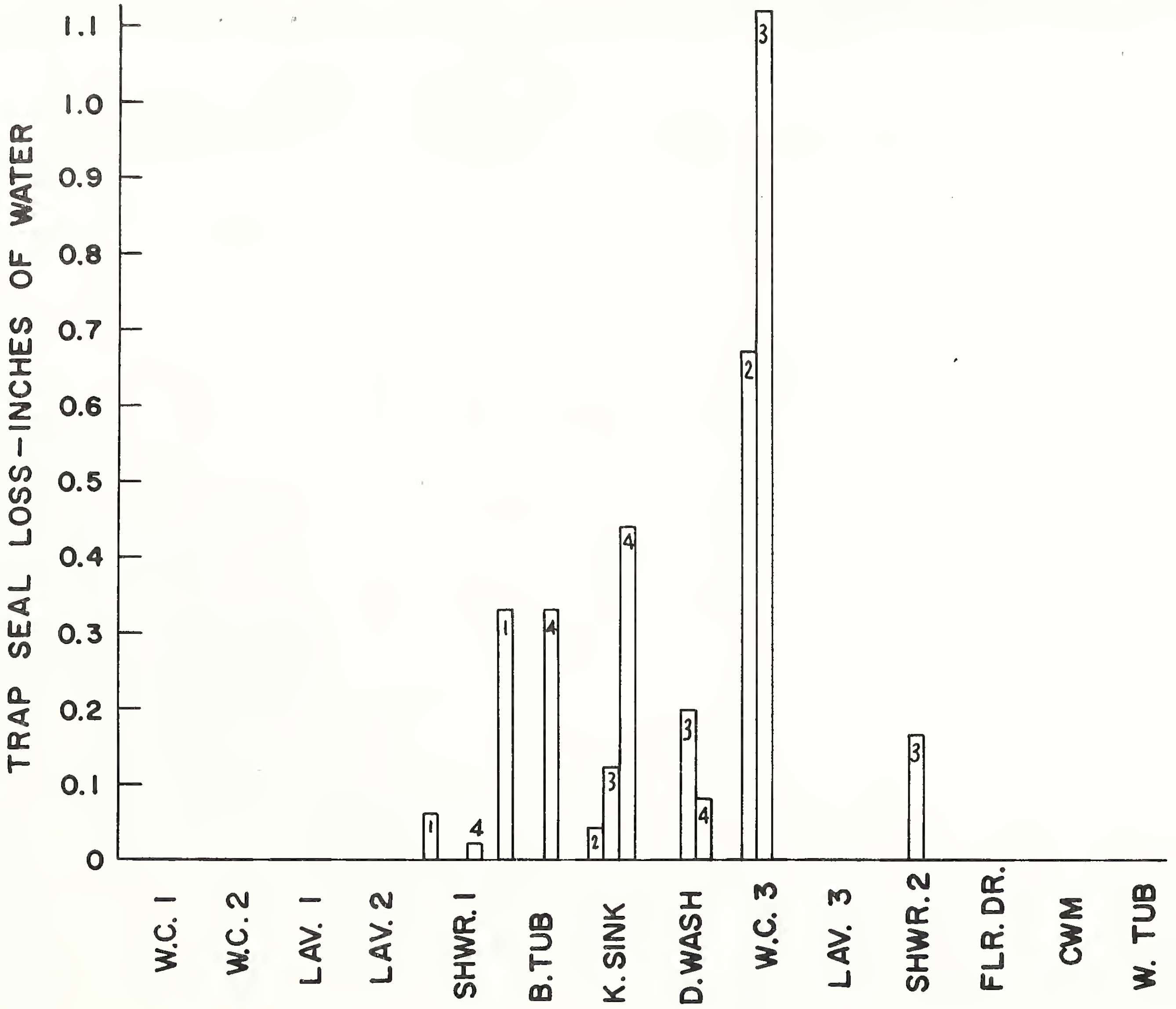

Figure 12. Trap seal losses as affected by detergent in sink.
Loading: Discharge of $S_1$ & $S_2$.
Venting: 1/2-in. I.D. tubing 1-ft. long attached to all vent standpipes.
Bargraph Identification:

1. Discharge of clear water from $S_1$ & $S_2$.
2. Discharge of detergent solution from $S_1$ & $S_2$, 16 ml of detergent in each compartment. (system not purged of suds between successive test runs).
3. Same as 2. except grinder running (system not purged of suds between successive test runs).
4. Same as 3. except system purged of suds after each test run.

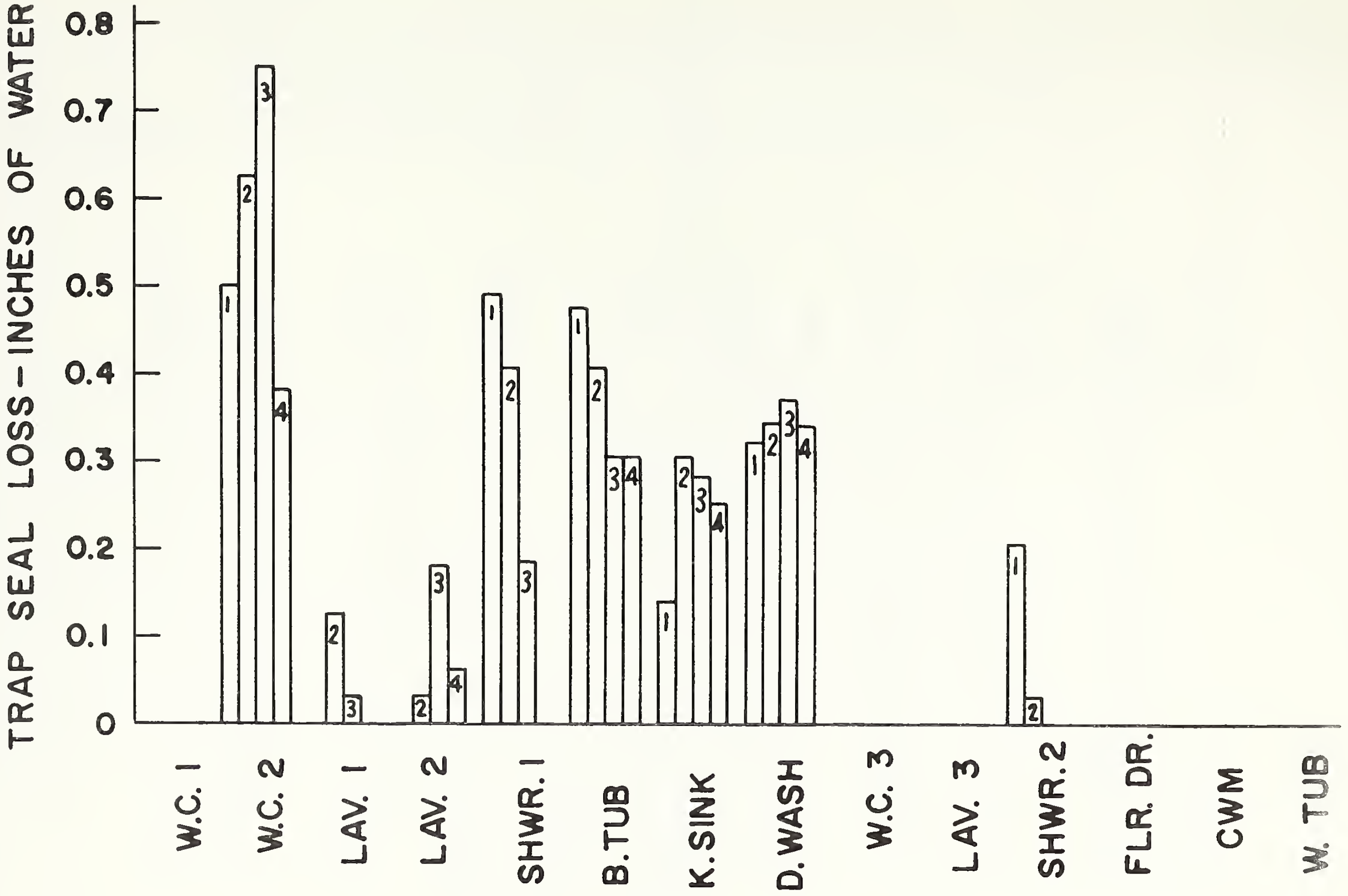

Figure 13. Trap seal losses as affected by solids in loading.
Loading: Discharge of W.C.$_1$
Venting: 1/2-in. I.D. tubing 1-ft. long attached to all vent standpipes.
Bargraph Identification:

1. Clear water discharge
2. 1 solid
3. 2 solids
4. 3 solids

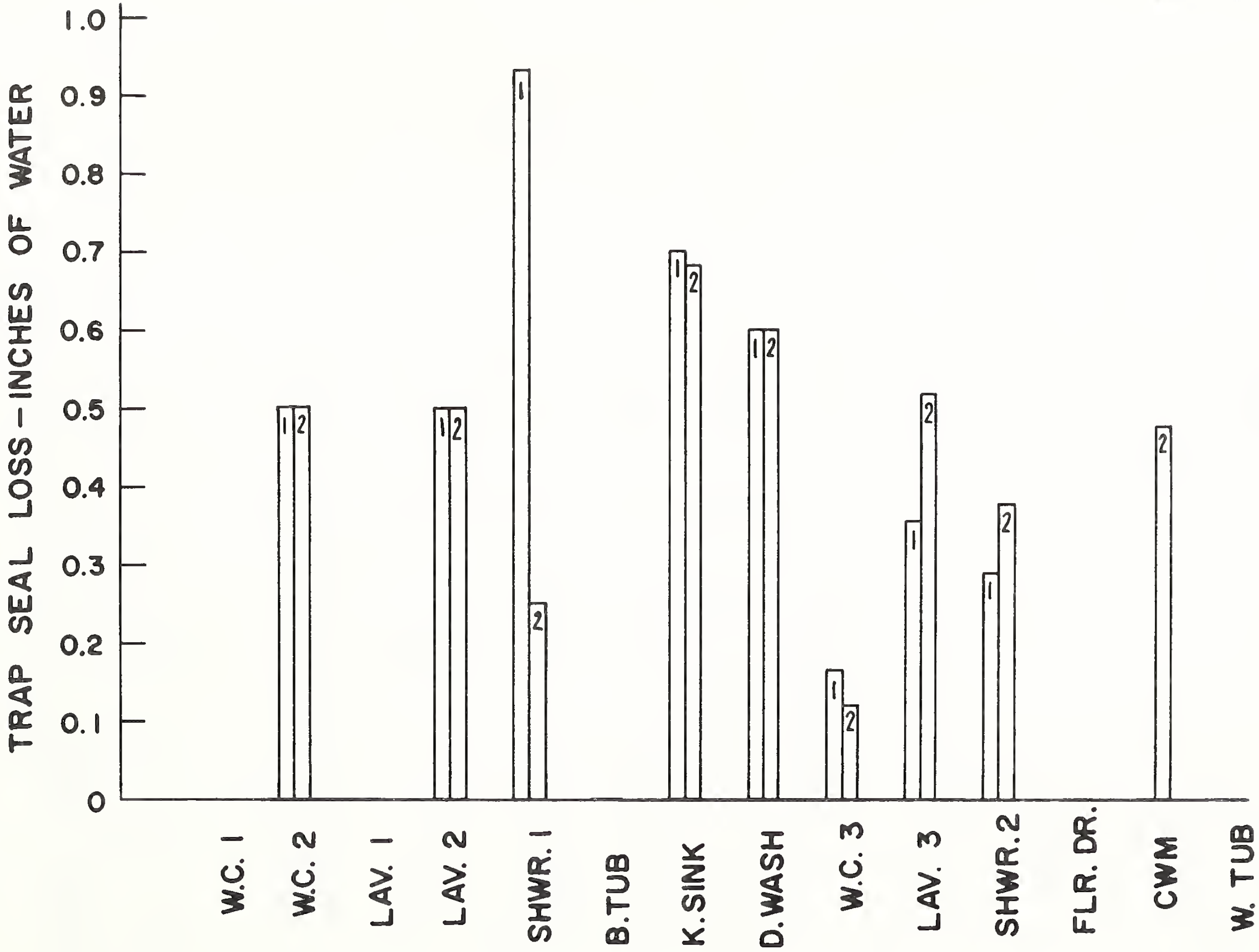

Figure 14. Trap seal losses as affected by detergent in clothes washing machine.
Loading: Discharge of W.C.$_1$, Lavatory$_1$, & Bathtub simultaneously followed 5 sec. later by W.C.$_3$ & clothes washing machine simultaneously.
Venting: 1/2-in. I.D. tubing vents 25-ft. long installed on all except the main vent. An 18-ft. length of 1-1/4-in. steel pipe installed on the main vent.
Bargraph Identification:
1. Clear water.
2. 200 ml of detergent powder in automatic clothes washing machine.

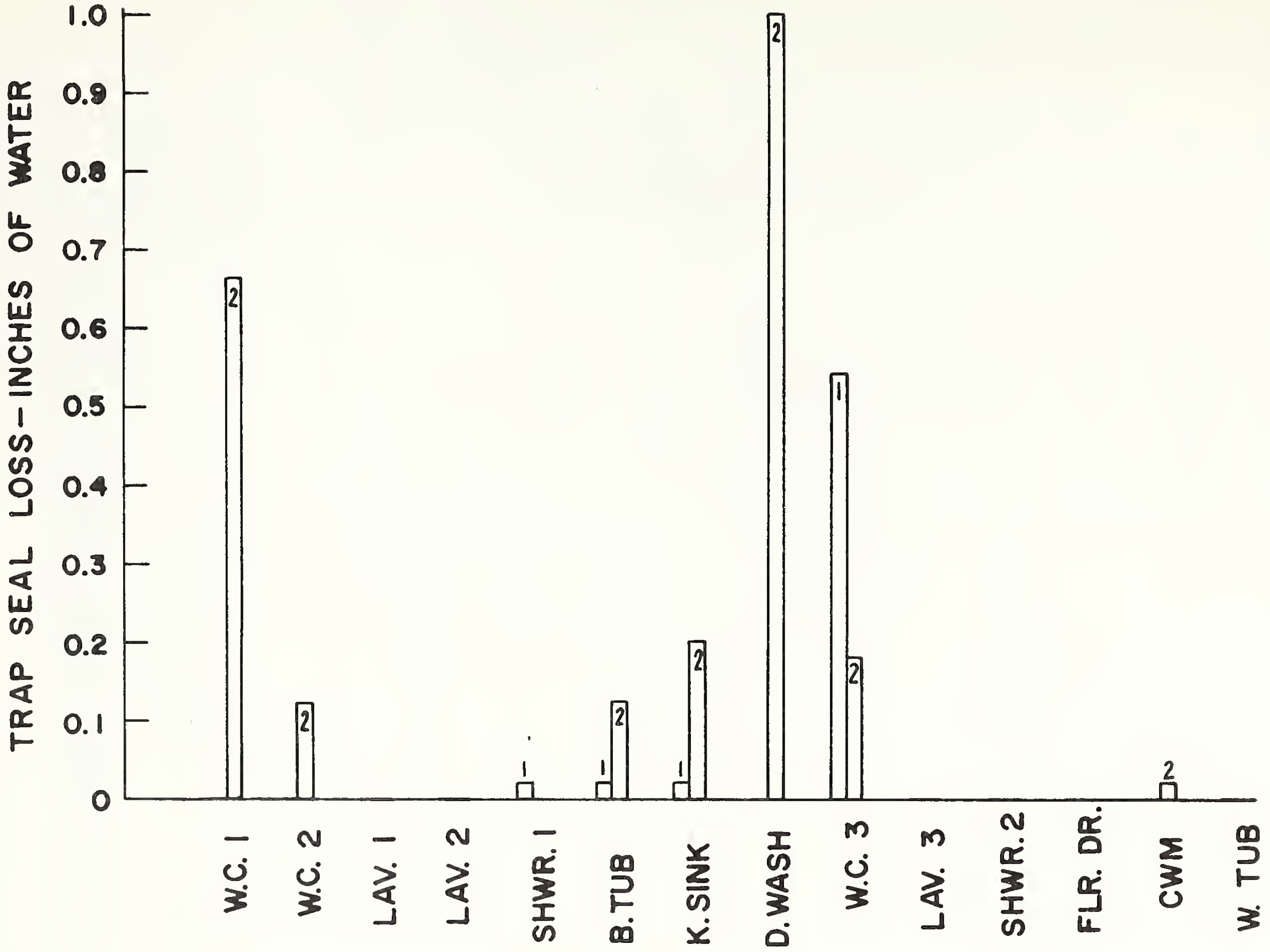

Figure 15. Trap seal losses as affected by detergent in lavatories.
Loading: Simultaneous discharge of $\text{Lavatory}_1$ & $\text{Lavatory}_2$.
Venting: 1/2-in. I.D. tubing vents 25-ft. long installed on all except the main vent. An 18-ft. length of 1-1/4-in. steel pipe installed on the main vent.
Bargraph Identification:
1. Clear Water
2. 8 ml of detergent in each lavatory.

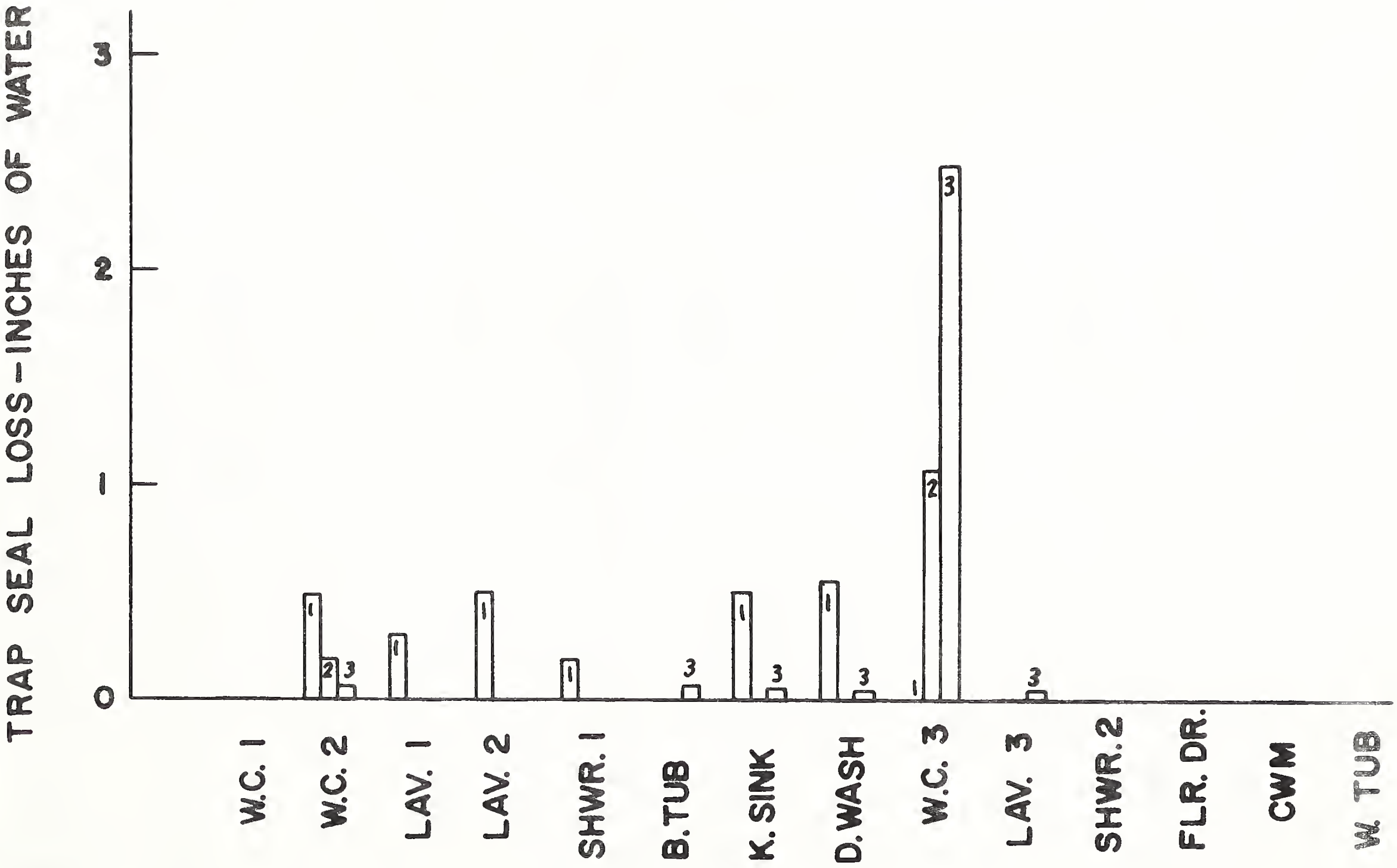

Figure 16. Trap seal losses as affected by detergent in bathtub.
Loading: Discharge of W.C.$_1$ & Bathtub simultaneously.
Venting: 1/2-in. I.D. tubing vents 25-ft. long installed on all except the main vent. An 18-ft. length of 1-1/4-in. steel pipe installed on main vent.
Bargraph Identification:

1. Clear water loading.
2. 16 ml of detergent in bathtub.
3. Same as 2, but 48 ml used.

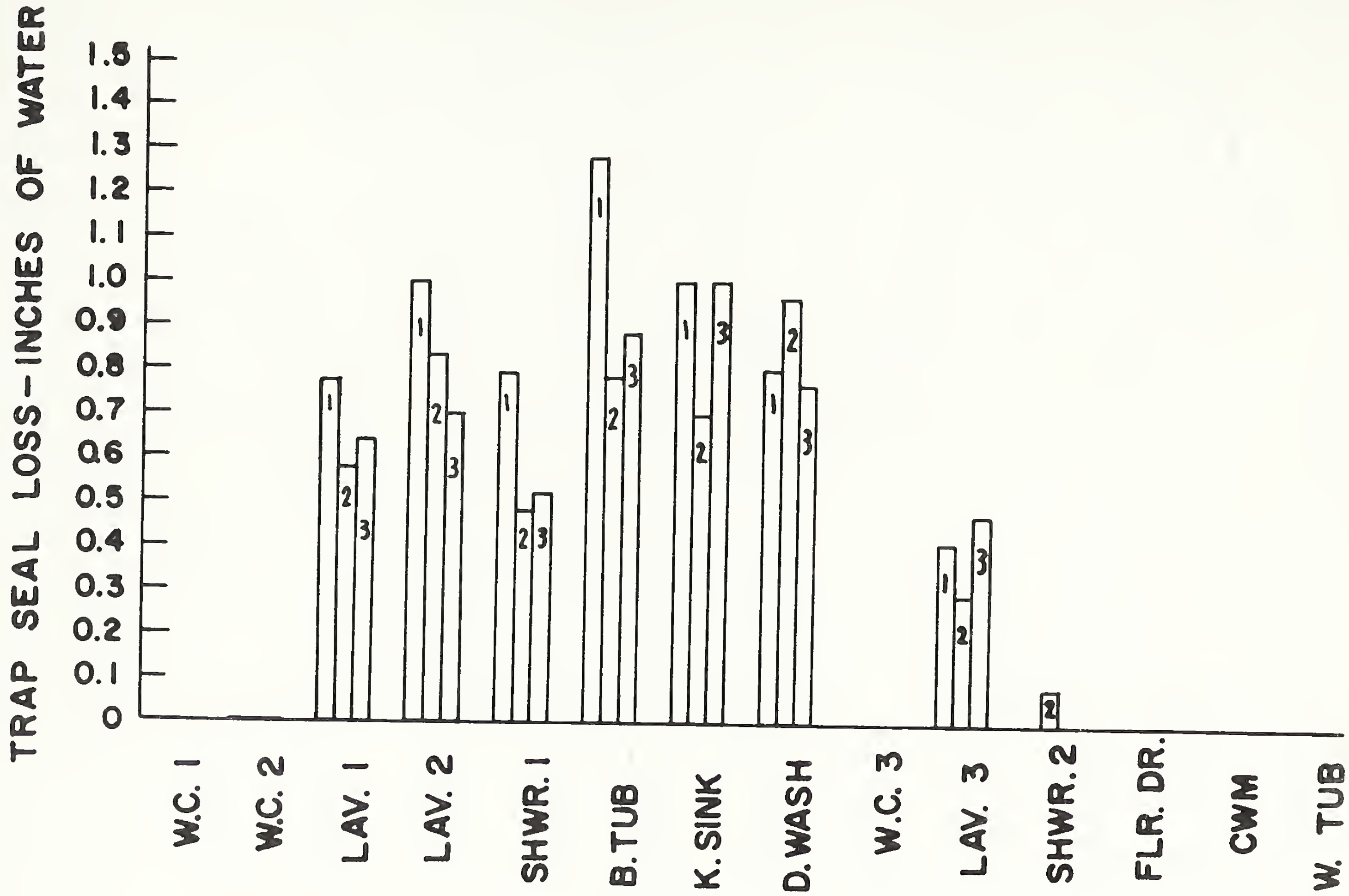

Figure 17. The effect of varying the discharge timing in a sequence load.
Loading: W.C.$_1$ & W.C.$_2$ simultaneously followed by W.C.$_3$ t sec. later.
Venting: 1/2-in. I.D. tubing vents 25-ft. long installed on all vents except the main vent. An 18-ft. length of 1-1/4-in. steel pipe installed on the main vent.
Bargraph Identification:
1. t = 5 sec.
2. t = 3 sec.
3. t = 7 sec.

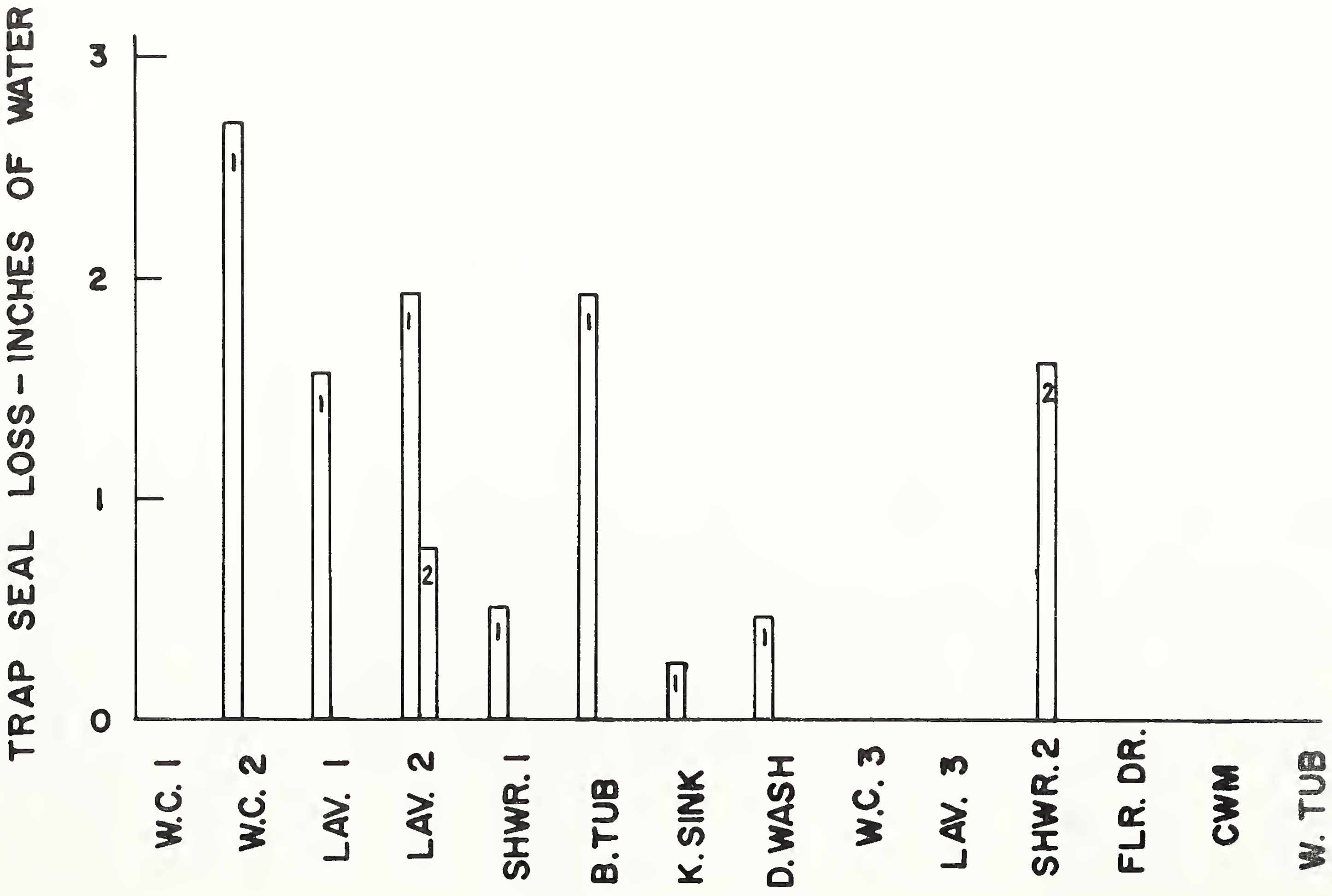

Figure 18. Trap seal losses with closed vents.
Bargraph Identification:
1. Discharge of W.C.$_1$, clear water.
2. Discharge of all fixtures simultaneously, clear water.