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NATIONAL BUREAU OF STANDARDS REPORT

8006

PROGRESS REPORT NO. 2

ON

FLUID DYNAMICS OF PLUMBING

by
R. W. Beausoliel

For Use ommittee,

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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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FLUID DYNAMICS OF PLUMBING

by
R. W. Beausoliel

for

The National Association of Home Builders

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U. S. DEPARTMENT OF COMMERCE
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ABSTRACT

This progress report, the second in a series, presents a physical description of a test plumbing system constructed at the National Hydraulics Laboratory. It represents a type that might be used in a one-story single bath, slab on grade house. The report contains air rates in individual fixture vents, water depths and average velocities in the drain, trap seal losses, and pneumatic pressures occurring on the drain side of traps subjected to induced siphonage. Test loads comprised single fixture discharge, simultaneous discharge of two or more fixtures, and discharge of selected combinations of fixtures in sequence. A number of test results were compared for individual fixture vents open and closed.

1. INTRODUCTION

1.1 Purpose of Investigation

The general purpose of the investigation is to study aspects of the fluid dynamics of plumbing systems such as installed in one- and two-story houses which have not been covered adequately by previous research. Some phases of previous research done in the past which seemed particularly difficult to instrument at the time may be investigated again in a more efficient manner through the use of newly developed instrumentation techniques.

The main purpose of this report is to give an insight into the operation of a simulated plumbing system with various conditions of venting and hydraulic loading.

At this time it seems reasonable to focus attention on the two extreme conditions which are defined as operation with maximum venting and operation with minimum venting. The sequence of hydraulic loading was held constant during both extremes; therefore, the effects of venting can readily be compared to the effects of no venting in terms of trap seal losses, water depth in the drain, etc. A test with some degree of venting between these extremes was also included.

Another purpose of this report is to present further information on the relationship between air flow, water flow, and air pressures in a test stack designed so that independent variables can be changed in a systematic fashion.

1.2 Authorization

The project was approved by the National Bureau of Standards under the Grants-In-Aid program on December 21, 1962 as outlined in a letter from Dr. R. D. Huntoon, Deputy Director of the National Bureau of Standards, to Mr. John R. Dickerman, Executive Vice President, National Association of Home Builders. Financial support in the amount of $25,000 was provided by NAHB on May 10, 1962 and acknowledged by NBS in a letter dated May 28, 1962 from Mr. D. E. Parsons, then Chief, Building Research Division, to Mr. Dickerman. It was understood that the cost of the work would not exceed $25,000 per year over a period of two years.

2. PRELIMINARY ACTIVITY

An advisory committee was organized for the purpose of reviewing the work at appropriate stages, making recommendations, and furnishing advice on questions raised by the project staff. The functions of the committee are advisory only. The committee comprises the following persons:

Mr. Ralph Johnson
Technical Director
National Association of Home Builders

Mr. Robert Schmidtt
Chairman, NAHB Research Committee

Mr. James Simpson, Chief
Standards and Technical Studies Section
Architectural Standards Division
Federal Housing Administration

Mr. Malcolm Hope
Assistant Chief
Division of Environmental Engineering
Department of Health, Education, & Welfare

Mr. D. E. Parsons
Consultant to the Director
National Bureau of Standards

Mr. John French, Hydraulic Engineer
Fluid Mechanics Section
Mechanics Division
National Bureau of Standards

Mr. Robert Wyly, Hydraulics Engineer
Codes and Safety Standards Section
Building Research Division
National Bureau of Standards

3. ACCOMPLISHMENTS

3.1 Construction of the Test Plumbing System (See Fig. 1)

The main building drain, soil stack, and stack vent were constructed of standard weight nominal 3 inch cast iron soil pipe. The branch of the building drain serving the kitchen sink and washine machine drains was constructed of standard weight nominal 2 inch cast iron soil pipe. A slope of 1/4 inch per foot was maintained for these drains. All the soil pipe utilized neoprene sealed joints with the exception of the water closet fitting and the connections to galvanized iron pipe. Vertical cast iron drains for the individual fixtures terminated with 2 inch cast iron hubs extending 4 inches above the floor to simulate slab on grade construction. Nominal, standard weight, galvanized 1 1/2 inch pipe was caulked into these hubs and extended vertically to connect with the individual fixture vents and drains. The washing machine drain was of nominal 2 inch standard weight galvanized pipe from the 2 inch "P" trap to the 2 inch cast iron hub. The washing machine vent was of nominal 1 1/2 inch galvanized iron pipe, standard weight.

The water closet was connected to the soil stack by way of a 4 x 6 x 16 closet bend which in turn connected to a 3 x 4 Washington reducing combination Y and eighth bend.

Combination Y and eighth bends and long sweep quarter bends were used elsewhere in the system with the exception that the 1 1/2 cast iron bath tub "P" trap connected to the bath tub drain below the floor level through a 2 x 1 1/2 sanitary tapped tee.

The roughed-in drain was subjected to a 15 foot head of water to detect any leaks. The completed system was subjected to air pressure equivalent to 2 inches of water. The pneumatic pressure head remained quite constant for a period of one half hour, thus indicating a tight system.

The fixtures used are as follows:

Lavatory, ledge back, white, 20" x 18"
Water Closet, siphon jet type
Two Compartment Flat Rim Kitchen Sink, 32 x 21
Bath Tub, 5 ft recessed type
Washing Machine, automatic

3.2 Instrumentation

Residual trap seals were measured with glass piezometers in combination with short graduated scales. The water closet seal was measured with an electric point gage.

Fluctuating or rapidly changing pneumatic pressures and water depths were measured with the aid of strain gage bridge type pressure transducers and a multichannel recording oscillograph. Miniature pitot-static tubes were used to sense air movement in the stack vent and individual fixture vents. Static air pressures and water heads were transmitted to the transducers or indicating devices through short lengths of plastic tubing leading from tubing connectors located in the pipe walls. These connectors are standard 1/8 national pipe thread fittings. See Figure 2 for measurement locations and symbol designations.

The lavatory, bath tub, and sinks were calibrated to determine the average rate of discharge and duration of discharge for any given initial water depth above the outlet orifice rim. The water closet was calibrated on a mechanical integrating device which provided data for computing average discharge rates over successive short time intervals during fixture operation. The washing machine discharges were collected against time in a container for which the relation between depth and volume was established. The machine has two distinct successive events: a drain event followed by a spin-spray event. The sprays comprise 4 discharges of 7 seconds each over a period of 2 minutes. The drain event discharges 16.4 gallons of water during 60 seconds. The spray discharges a total of 4 3/4 gallons of water during 120 seconds. All fixtures were supplied with a constant water pressure of 50 psig (constant within ±3 psig). The calibration curves for these fixtures are shown in Figures 3-8.

The fixture discharges were actuated by means of a battery of solenoids which in the case of all fixtures other than the water closet and washing machine pulled the drain plugs completely clear of the fixtures; consequently, there was no interference to flow introduced by the drain plugs. The water closet was actuated by a solenoid and the flush tank linkages. All of the solenoids were controlled by a group of single-pole, single-throw toggle switches. A toggle switch was used to operate the washing machine which was prefilled and preset on the drain event. By using an accumulative seconds counter a predetermined schedule of discharges could be imposed on the system by a single operator.

3.3 Test Procedure

A. All Vents Open

1. Water depths, and average velocities in the 3 inch building drain, and air rates in the individual fixture vents and stack vent were determined for each fixture discharged individually. Residual trap seals were measured. A velocity traverse was made at depth "D" (see Figures 1 and 2) during the water closet discharge.

2. The fixtures were discharged in combination. The water closet was discharged; two seconds later the bath tub and the two compartment kitchen sink were discharged simultaneously. For a mode of comparison, these fixtures were again discharged as indicated, but the discharge was superimposed on the washing machine discharge during the time the washing machine was draining from full condition. The washer was started 4 seconds prior to the water closet discharge. The same variables were measured as indicated under (1) above.

3. All fixtures were discharged simultaneously. The same variables were measured as indicated in (1) above.

B. <u>All Vents Closed</u>

The above procedure was repeated except that in place of air rate trap seal pressure readings on the drain side of the trap were taken when a seal loss was detected.

C. <u>All Vents Open Except Those for the Lavatory and Bath Tub</u>

Residual trap seals were measured after the fixtures were discharged in the following manner: individual fixture discharges, the washing machine followed by sink No. 1, 2 seconds later, washing machine followed 2 seconds later by the bath tub and both sink compartments simultaneously, and all fixtures simultaneously. During these discharges, trap seal pressures were taken on the drain side of the trap for all fixtures not in operation.

4. RESULTS

4.1 <u>All Vents Open With Individual Fixture Discharges</u>

Air rates in the stack vent and individual vents, and water depths in the building drain for individual fixture discharges were the first dependent variables studied through the use of the experimental plumbing system. This information suffices as a foundation upon which to build more complicated modes of system loading, and it can be looked upon as minimum loading or a lower reference for the comparison of effects of various loading modes. The peak water depths in the drain measured at the stations shown in Figures 1 and 2 for each fixture discharge are given in Figure 9. These peak water depths are accurate to within ±5% of the actual depths viewed by means of visual inspection. To perform this inspection, glass tubes and scales were connected externally in place of the transducers to form a closed loop from top to bottom of the drain and the maximum rise of water observed for a given fixture discharge was recorded and compared with the value obtained by the transducer for the same discharge. The peak depths measured at stations D, E, and F are not necessarily the maximum depths anywhere in the drain - if this be the case it is purely coincidental. It is obvious, however, that the measurement points chosen span the point of maximum depth in the drain. Depth D as a general rule is less than depth E and depth F is less than depth E but greater than depth D. The average velocities between D-E and E-F in the 3-inch drain are shown in Table 1 for the operation of each fixture. The velocities at D and E and F are somewhat higher than this average. Taking into account the extra time necessary to obtain all of the velocities, at each station, the decision was made to take velocities at station D as an indication of the magnitude of the discrepancy between the averages and the actual values at each station. To obtain the average velocities the time intervals between the initial impact of water at stations D and E and stations E and F were obtained from the oscillograph record. Knowing the distance between these positions on the drain, it was a simple matter to obtain the average velocities over these legnths of the drain. The velocity at station D was obtained with a static pitot tube. The velocity decreased as the tube was lowered into the stream and increased as the tube was moved upward. In other words, it was found that the velocity at the bottom of the pipe was less than the velocity at the crest of the surge. This variation of velocity with depth appears to be small. The plot of the pitot tube traverse is shown in Table 1. This velocity traverse was obtained only for the water closet discharge with all vents open.

Air rates were obtained using small pitot tubes located in the stack vent and individual fixture vents. The effects of small changes in specific weight, relative humidity, and of inaccuracies in the instrumentation were considered negligible. For analysis of computation, incompressible flow of dry air at a constant pressure of 14.7 psia and a temperature of 60°F was assumed.

The error introduced by assuming the average velocity to be 0.80 times the indicated centerline velocity is probably the largest source of error in the measurement of air rates in the vents. The velocity factors determined by other experimenters range from 0.75 to 0.90, depending on a number of factors.[1/] Thus, indicated air flow rates obtained by the procedure used in this investigation could be in error by perhaps as much as ±10%.

1/ Fluid Meters "Their Theory and Application" Report of ASME research committee on fluid meters fifth edition, 1959, page 182, paragraph 317.

Another factor of unknown magnitude may be introduced by turbulence and non-symmetrical distortion of velocity profile. This could be corrected by increasing a straight pipe upstream from the pitot tube by say 50 to 100 pipe diameters or by installing straightening vanes, but these measures appear to be beyond the scope of the present investigation for practical reasons.

The trap seals were checked after each fixture operation and no losses were indicated for any individual fixture operation.

4.2 All Vents Open with Combinations of Fixture Discharges

The combination of fixture discharges chosen seem to include some loadings which might be encountered in the actual system and were heavy enough to cause trap seal losses, but it cannot be said that the heaviest possible fixture loading was included. Perhaps a combination with a different time sequence would create a loading condition worse than this or worse than all fixtures discharged simultaneously. The possibilities are many and varied. In any case, the loadings selected were applied throughout the experiment. These loadings were used for the two extreme conditions of venting so that the full effect of venting on the water depths, trap seal losses, and pressures in the system could be observed. One load combination chosen comprised the discharge of the water closet, then, two seconds later, the simultaneous discharge of sink number one and the bath tub. For comparison, another combination was used as follows: the washing machine was set on the drain event and the water closet discharged four seconds later, followed by the discharge of the bath tub and sink number one as described before. A third combination comprised the simultaneous discharge of all fixtures. The peak water depths in the drain are shown in Figure 11 for the loadings indicated above. No trap seal losses were detected during any of these loadings.

4.3 All Vents Closed with Individual Fixture Discharges

The maximum or worst loading conditions are obviously approached when all of the vents are closed. All phases of the test with vents open as described under section 4.1 were repeated with vents closed.

Referring to Figure 12, a comparison of water depths in the building drain for a lavatory discharge of 1.8 gallons of water is presented for the system with vents and without vents. There was a tendency to lose some of the sink trap seal during the second run without vents. About 1/16 inch of seal was lost. The rest of the seal depths remained unchanged, during the second run.

Figure 13 shows the comparison of water depths for a water closet discharge during complete venting and without venting. During the first of three runs without venting the following trap seals experienced slight losses: the sink - 1/8", the bath tub - 1/8", and the washing machine - 1/16".

Figure 14 shows the comparison of water depths for the kitchen sink draining one and two compartments at a time for the vented system and the unvented system. The following trap seal losses were observed with vents closed: the discharge of sink number one caused 15/16" loss of the water closet seal, 1/16" of the bath tub seal, and 2" of the washing machine trap seal. The discharge of sink number two caused 1/16" loss of the bath tub trap seal, and 9/16" of the washing machine trap seal. The discharge of both sink number one and sink number two caused 13/16" loss of the water closet trap seal, and 1 15/16" loss of the washing machine trap seal.

Figure 15 shows a comparison of water depths for the discharge of the washing machine during the drain event with venting and without venting. There was a loss of 1/8" from the water closet seal with the vents closed. No other seal losses were observed during the three runs taken.

Figure 16 shows a comparison of water depths for the discharge of the bath tub with venting and without venting. No seal losses were observed.

Referring to Table 1, a comparison of the average velocities in the drain lengths D-E and E-F is shown for the conditions of all vents open and all vents closed off during the discharge of individual fixtures. No trap seal losses were detected either with or without venting.

4.4 All Vents Closed and Combinations of Fixture Discharges

The same combinations of fixture discharges were used for this condition of all vents closed as were used during the tests with all vents open, as described under section 4.2.

Figure 17 gives a comparison of the water depths in the 3-inch drain with vents open and without vents for the simultaneous discharge of the bath tub and compartment number one of the two compartment kitchen sink two seconds after the initiation of the water closet discharge. With no venting the following trap seals were lost: the kitchen sink lost 1 9/16" of trap seal and the washing machine lost 1 7/16" of trap seal.

Figure 18 gives a comparison of the water depths in the 3" drain with vents open and without vents similar to that shown in Figure 17 except that in this case the washer had been operating for 4 seconds prior to the water closet discharge. With no venting the following trap seals were lost: the

the kitchen sink lost 2 1/16" of trap seal and the lavatory lost 11/16" of trap seal depth.

Figure 19 gives a comparison of the water depths in the 3" drain with vents open and without vents for all fixtures discharged simultaneously. The following fixtures experienced seal losses during simultaneous discharge of all fixtures. The lavatory consistently lost 1 3/4 inches of seal during each of the three runs. The water closet lost an average of 1/2 inch of seal. The bath tub and washer replenished their own seals due to trailing discharge occurring after the sink, water closet, and lavatory had completed their discharges.

4.5 All Vents Open Except the Bath Tub and the Lavatory Vents

No seal loss from the lavatory trap was detected as a result of individual fixture loadings with the exception that 1/16" was lost when the water closet was discharged. The lavatory trap seal pressure varied by ±0.1 inch of water from atmospheric pressure.

The following combinations of fixture loadings were applied without a detectable lavatory seal loss: washing machine followed by sink No. 1 2 seconds later, washing machine followed 2 seconds later by simultaneous discharge of the bath tub and both sink compartments, and all fixtures discharged simultaneously. The following combinations of fixture discharges caused a loss of lavatory trap seal: (a) the washing machine discharged, followed 2 seconds later by the water closet, causing a lavatory seal loss of 1/16" with a peak seal pressure of +0.04 inches of water; (b) the washing machine discharged then 5 seconds later, the bath tub and two compartment sink discharged simultaneously, followed by the water closet 10 seconds after the start of the washing machine, causing lavatory seal loss of 3/16".

The bath tub trap seal experienced no loss during individual fixture loadings and during the discharge of all fixtures simultaneously. When both sinks were discharged followed by the water closet 2 seconds later, the tub trap seal loss amounted to 3/16" brought about by a positive seal pressure of +2.0 inches of water. When the washing machine was discharged followed by both sinks 5 seconds later and the water closet 10 seconds later, a seal loss of 1/8" with a seal pressure of +2.5 inches of water was experienced by the bath tub trap.

5. AIR DEMAND AS A FUNCTION OF STACK LENGTH AND INLET FITTING TYPE FOR A 2 IN. TEST STACK

This work is a continuation of that reported in section 3.4 of Progress Report No. 1. A complete description of the test setup was given in the earlier report. In brief the test setup comprised an experimental 2 inch stack 22 feet in length constructed of standard weight, galvanized iron pipe assembled in such a way as to facilitate the shortening of the stack length. Water was introduced into this stack from a branch through a recessed, cast iron, screwed 2 x 2 sanitary tee type drainage fitting. Air was introduced through the stack vent extending upward from the fitting. Water and air flow rates as well as air pressures were measured.

The long term objective is to obtain data on this stack with different inlet fitting types, different stack lengths, and different diameters of branch and stack. Information on air rate (or demand), stack length, fitting type as affected by water rate, and other independent variables is needed in order to provide a rational basis for vent pipe system design.

5.1 Results and Conclusions Pertaining to Air Demand Vs. Stack Length and Inlet Fitting Type

Figure 21 shows a plot of air flow as a function of water flow. This plot is similar to that shown in section 3.4 of report No. 1. The plot compares the effect on the system of changing the drainage fitting. From a practical point of view, it is significant that for a given water flow rate the air flow associated with the use of the long-turn T-Y was greater than that with the sanitary tee; consequently, the pressures, throughout the length of the stack, were closer to atmospheric pressure when the long-turn T-Y fitting was used than when the sanitary tee fitting was used. More protection for trap seals against the effects of induced siphonage would be maintained through use of the long-turn T-Y for introducing water to a stack.

At this time, little or no data is available on the change of air rate with stack length variation under the condition of a constant water rate input. This information is needed particularly for stacks one and two stories in height. Earlier investigations have utilized stacks of the order of 30 feet in height. In an initial attempt to explore the effect of stack length on air rate, the length of the stack was increased from 22 feet to 35 feet. Figure 22 shows a plot of air rate as a function of water rate for the two stack lengths. The effect of changing the drainage fitting type is again seen in this plot.

It can be concluded from this plot that the amount of air that is required by a system increases as the distance from the base of the soil stack to the horizontal branch increases. This indicates that, in general, long soil and waste stacks require more venting than short ones, and that stack vents for short stacks need not be as large as for long stacks.

6. CONCLUSIONS PERTAINING TO THE VENTING STUDY

With all vents open, no trap seal losses were experienced during any of the fixture loadings. From this it is concluded that the venting is adequate to protect the trap seals even under the most severe loading condition.

With all vents closed off, no more than two fixtures experienced trap seal losses at one time during the discharge of one fixture. (see Table 3). The washing machine received the largest trap seal losses during these discharges which indicates that a blockage of venting action through the piling up of water occurred in this 2 inch drain. This drain diameter should be increased. If the drain were larger, air would be able to flow above the water from either the washing machine vent or the kitchen sink vent; therefore, the trap seals would be less subject to failure and perhaps one of these vents might be eliminated.

It seems that both the bath tub and lavatory vents could possible be removed. Referring to section 4.5, it will be seen that the lavatory lost only 1/16 inch of seal during a peak seal pressure of ± 0.1 inch of water. This was caused only by the water closet discharge. After the loss of an initial 0.1 inch of seal, no more seal should be lost from this fixture.

The water depths shown in the report are primarily presented at this time to indicate the order and magnitude or change in the depths during the extreme venting conditions. We intend to expand our depth sensing instrumentation through the installation of more pressure transducers on the drain. When more water depth measurements are available in conjunction with degrees of system venting, it is hoped that more can be said about the effect of venting on these depths. Although none of these recorded depths indicate a full drain, it is believed that at times a full drain does exist at the junction of the 3 inch drain and the 2 inch branch. Positive pressures on the drain side of the bath tub trap seem to indicate this. (see section 4.5).

The trap seal losses reported in sections 4.3 and 4.4 included both the case of induced siphonage; that is, the loss of the trap seal from a fixture not in operation caused by the operation of another fixture or fixtures, and the loss of trap seal from a fixture in operation. This latter case is not necessarily self-siphonage, but may be a combination of siphonage and self-siphonage. Self-siphonage is defined as the loss of trap seal from an operating fixture which is brought about as a result of its own discharge. Seal pressures (on the drain side of the trap) were determined only for the case of trap seal loss from a fixture not in operation. These seal pressures and losses are shown in Tables 3 and 4. A third type of trap seal loss was observed occasionally. This occurred after the passage of a positive trap seal pressure. The mechanism of loss consists primarily of the seal surface being elevated above the initial full trap seal surface level on the fixture side of the trap. The instantaneous potential energy developed at the instant of maximum positive seal pressure is transferred to kinetic energy upon the reduction in positive seal pressure. The momentum of the trap seal liquid may be sufficient to cause water to spill over the trap weir as it overshoots the initial position. The amount of loss depends upon the maximum positive seal pressure and upon the rate of reduction of this pressure.

Occasionally a combination of both positive and negative pressures on the seal occurred during one loading pattern. Figure 20 is a rather dramatic example of this case. This graph shows the history of trap seal failures for the washing machine and lavatory.

7. PROPOSED WORK FOR THE NEXT REPORTING PERIOD

One of the main purposes of this study is to determine the effectiveness of different degrees and methods of venting in retention of trap seals and maintenance of gravity flow. From the results, it is hoped that some indications will be available about what vents could be safely eliminated or if not eliminated what minimum size of pipe will be adequate to protect the trap seals and allow the system to function in a satisfactory manner as far as hydraulics and pneumatics are concerned. Of course, in order to learn something about the effects of venting, the degree of venting has to be the independent variable and all other possible variables held constant.

The two variables of importance that should be held constant are the system configuration and at least one hydraulic loading. This particular hydraulic loading will be the same as that used throughout this report and, namely; the discharge of the water closet followed by the simultaneous discharge of compartment No. 1 of the kitchen sink and bath tub two seconds later. By utilizing this loading consistently, the effect of degrees of venting on water depths and average velocities in the drain may be seen.

It is expected that the instrumentation will be broadened to include more transducers on the building drain. This will give a more complete record of the velocities and depth along the drain. Other fixture discharge combinations will be used with each degree of venting including the one indicated above. These combinations of fixture discharges will be used to determine the combinations if any that least affect the trap seals and the ones that cause the greatest trap seal loss.

The degree of venting can be varied through thirty possible arrangements of the five vents open and closed. For instance, one vent may be closed off and four remain open or four may be closed and one remain open. This approach yields ten degrees of venting. Also, if two vents are shut off, three will remain open. There are twenty possible degrees of venting between this mode and the converse mode of three closed and two open. Also, degree of venting can be changed by replacing the existing vents with smaller commercial sizes. It is possible to vary the individual fixture vents through the following nominal commercial pipe sizes: 1/8", 1/4", 3/8", 1/2", 3/4", 1", and 1 1/4". The stack vent may be varied through this size range plus 1 1/2", 2", and 2 1/2" sizes. Of course, it is understood that much of the work indicated above may be undesirable from the standpoint of time required for its completion, or may be unnecessary from obvious considerations, but in general any particular system responds to the various degrees of venting that can be produced between the two extremes of no venting and complete venting.

Table 1

AVERAGE VELOCITY IN 3" BUILDING DRAIN FOR INDIVIDUAL FIXTURE USE
(D-E = 10 1/4 ft, E-F = 5 3/4 ft)

Fixture	Vents Open Average Velocity fps		Vents Closed Average Velocity fps	
	D-E	E-F	D-E	E-F
Water closet	2.56	2.88	3.1	2.9
Lavatory	2.77	2.88	3.4	2.87
Bath tub	2.56	2.88	2.87	2.62
Washing machine	3.01	2.88	3.02	2.88
Sink Number 1	2.85	2.88	3.42	2.88
Sink Number 2	2.56	2.88	2.57	2.88
Sink Numbers 1 & 2	3.42	2.88	3.66	3.38

Table 2

AVERAGE VELOCITY IN 3" DRAIN FOR COMBINATION FIXTURE USE

Fixture Combinations	Vents Open Average Velocity fps		Vents Closed Average Velocity fps	
	D-E	E-F	D-E	E-F
Washing machine on drain event, 4 seconds later water closet discharged, then bath tub and compartment No. 1 of the two compartment sink	3.41	2.88	2.93	3.83
Same as above without the washer	3.93	3.29	3.26	3.59
All fixtures simultaneously	2.19	3.38	3.31	3.31

Table 3

SEAL PRESSURES AND TRAP SEAL LOSSES FOR FIXTURES NOT IN USE DURING THE USE OF INDIVIDUAL FIXTURES WITH ALL VENTS CLOSED

Fixture In Use	Trap Seals Affected	Seal Pressures, Inches of Water	Trap Seal Losses, Inches of Water
Lavatory	Sink	-0.06	0.06
Sink No. 1	Bath tub	-0.10	0.03
Sink No. 1	Automatic washer	-2.66	2.00
Sink No. 2	Automatic washer	-1.00	0.44
Sink No. 1 Sink No. 2	Bath tub Automatic washer	-0.15 -2.36	0.03 1.75
Water closet	Bath tub	+0.22	0.125
Automatic washer	Sink	+0.27, -0.12	0.17
Bath tub			No losses

Table 4

SEAL PRESSURES AND TRAP SEAL LOSSES FOR FIXTURES NOT IN USE DURING COMBINATIONS OF FIXTURE DISCHARGES WITH ALL VENTS CLOSED

Fixtures In Use	Trap Seals Affected	Seal Pressures, Inches of Water	Trap Seal Losses, Inches of Water
Water closet discharged, then 2 seconds later sink No. 1 and the bath tub simultaneously	Automatic washer	-2.72	1.28
Same as above except that the automatic washer was started on the drain event 4 seconds prior to the water closet discharge	Lavatory	-2.2	1.75

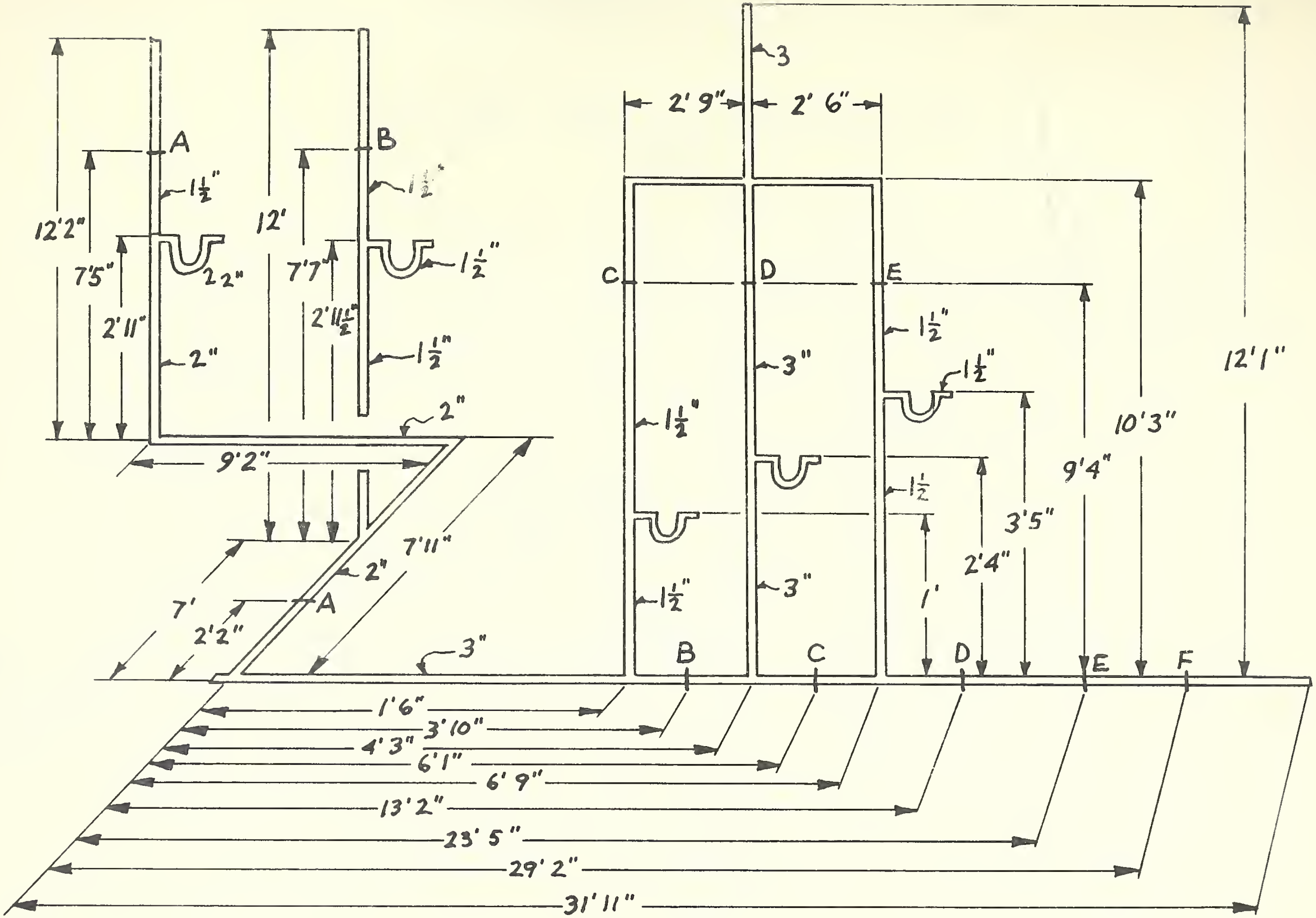

Figure 1. Dimensional description of the 1 bath, slab on grade plumbing system (See Figure 2 for symbol designations)

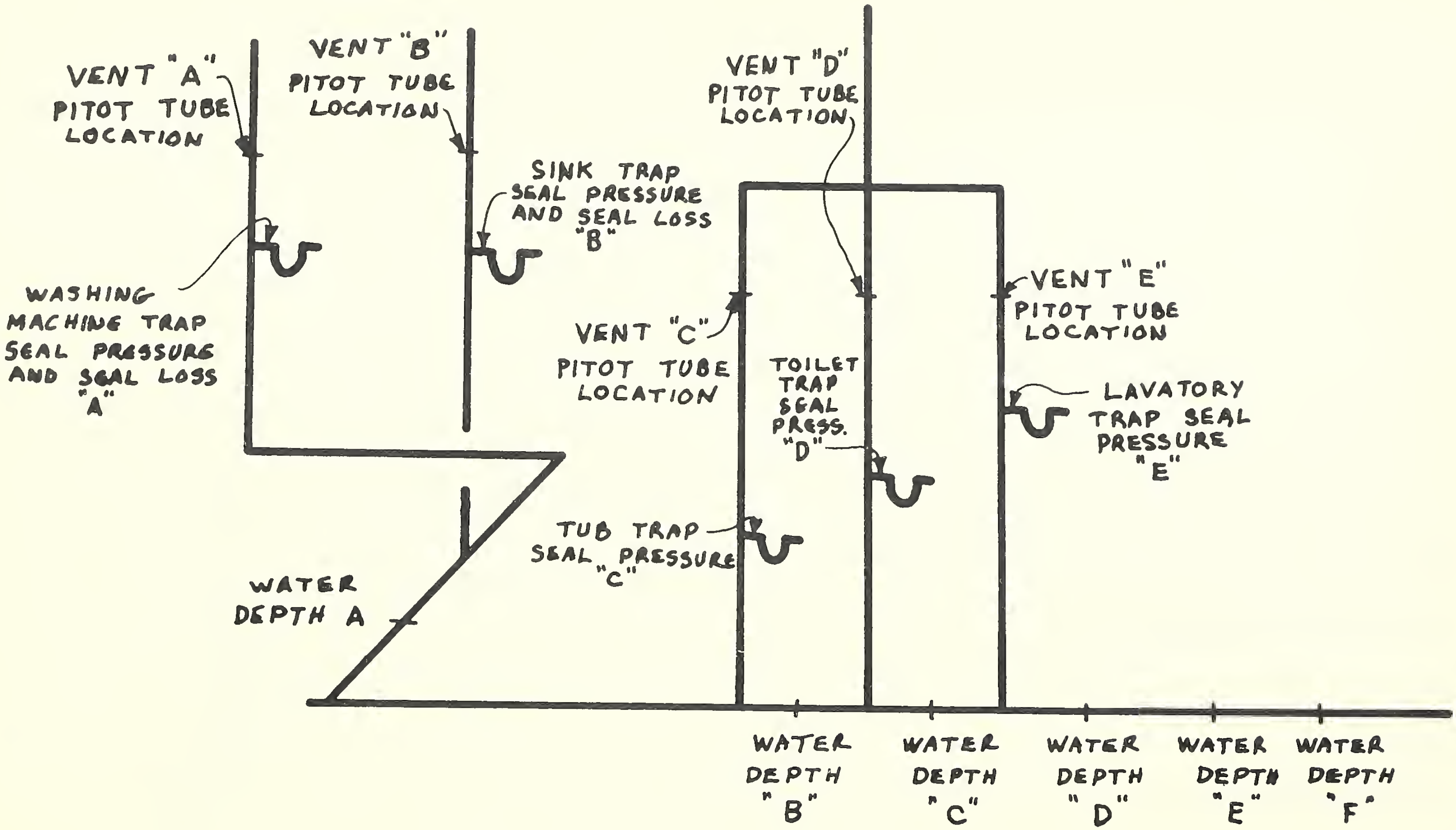

Figure 2. Measurement location and symbol designation

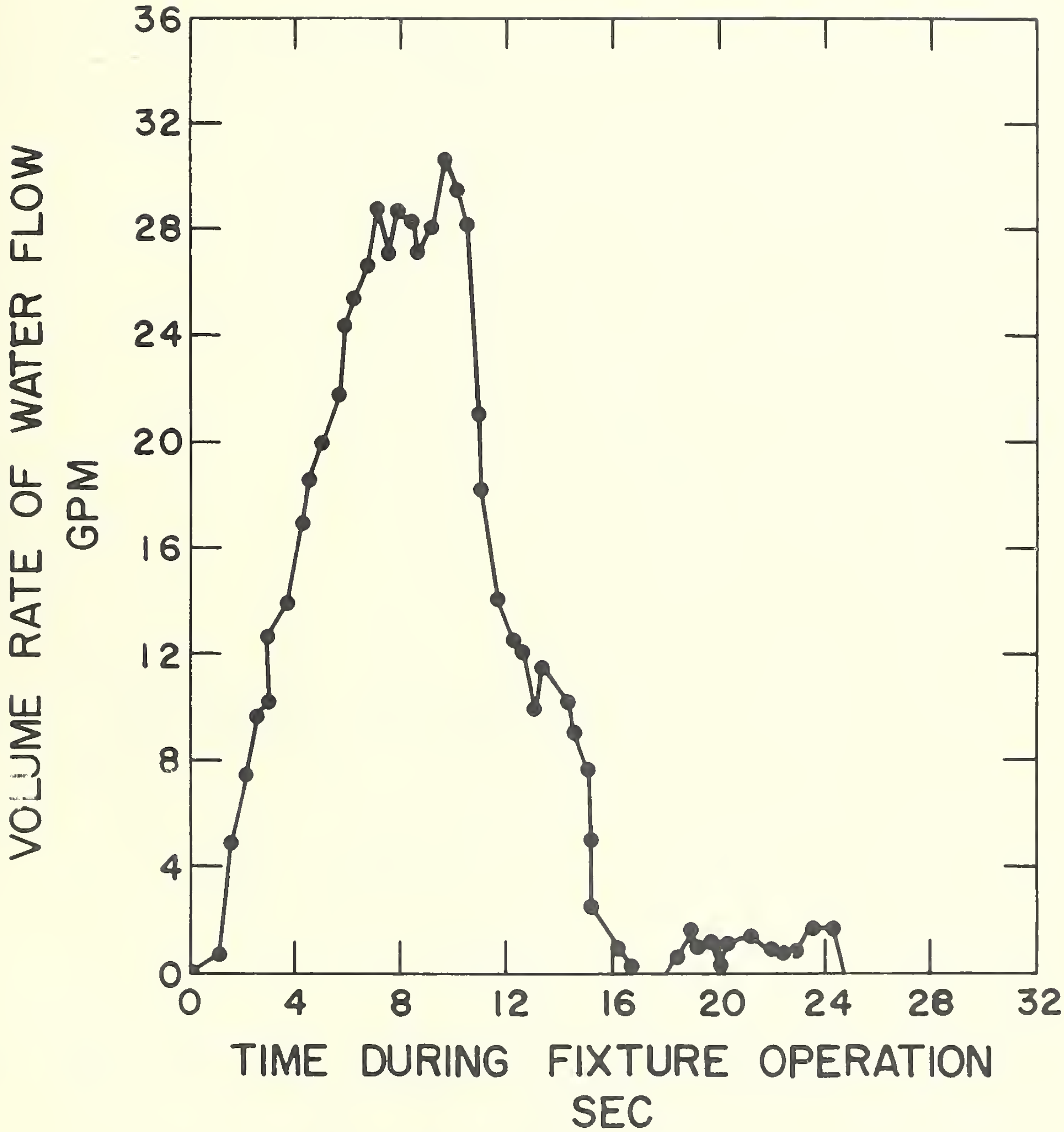

Figure 3. Flushing characteristics of water closet

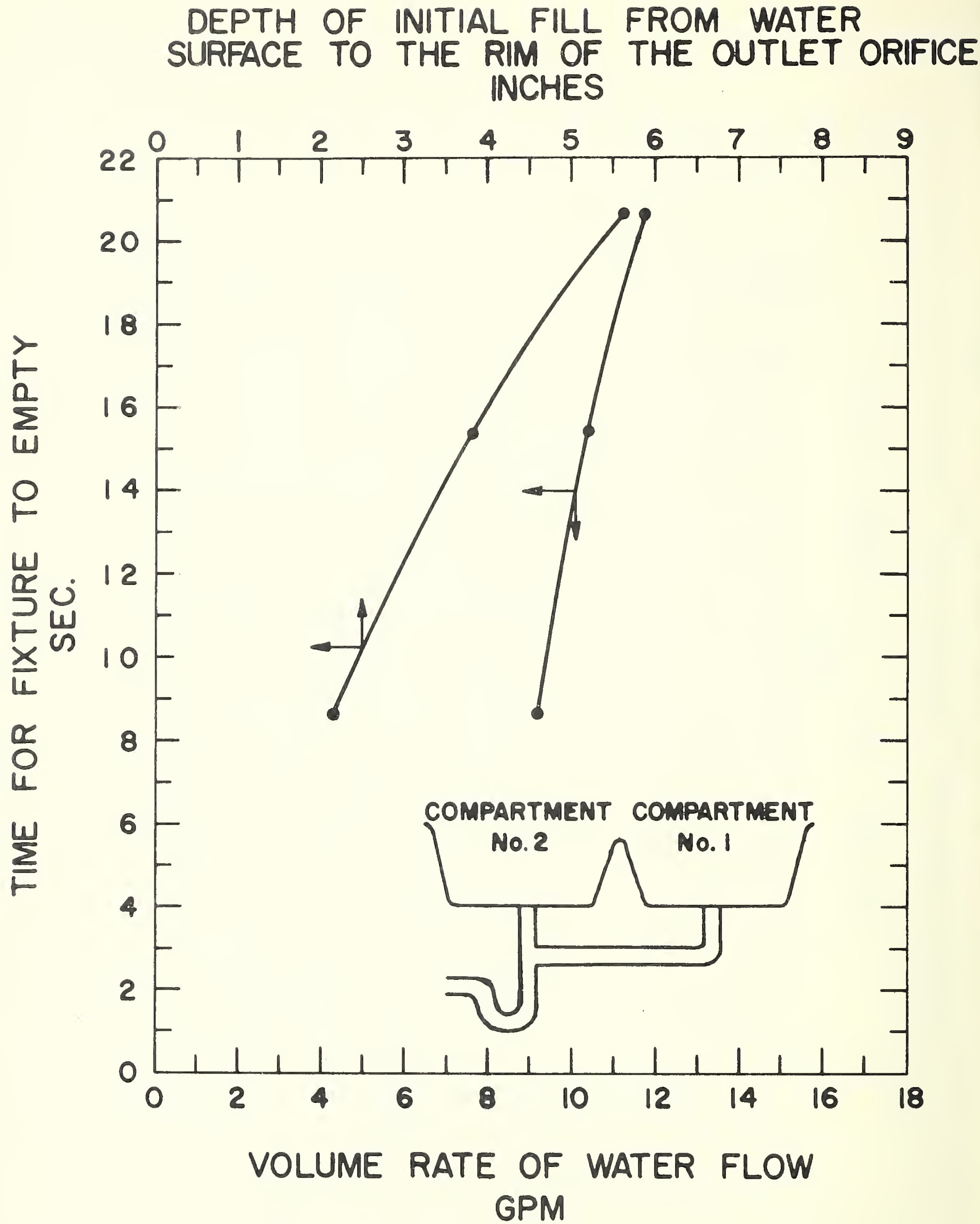

Figure 4. Drain characteristics of two-compartment kitchen sink, both compartments draining simultaneously

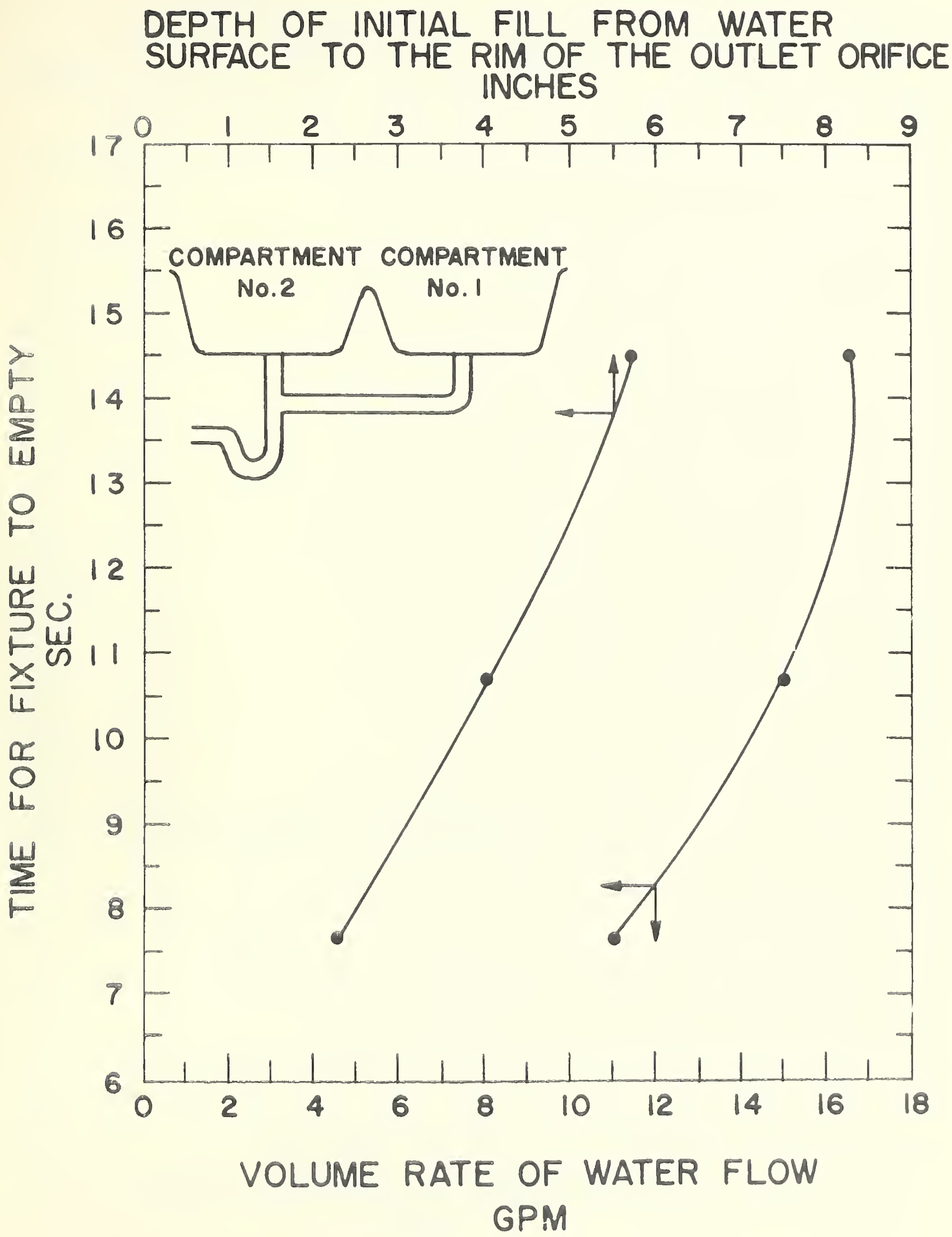

Figure 5. Drain charac_eristics of No. 1 compartment of two compartment kitchen sink

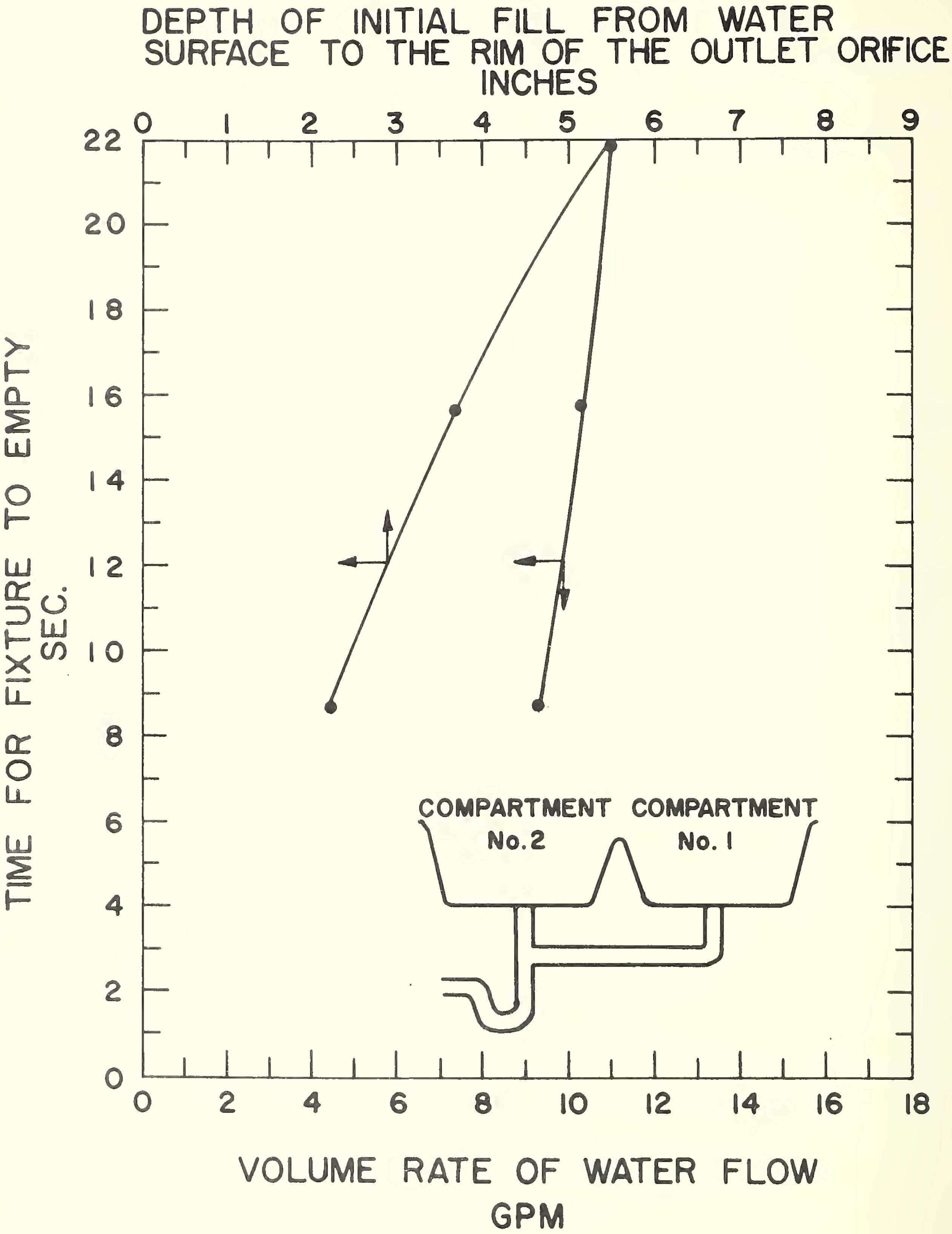

Figure 6. Drain characteristics of No. 2 compartment of two compartment kitchen sink

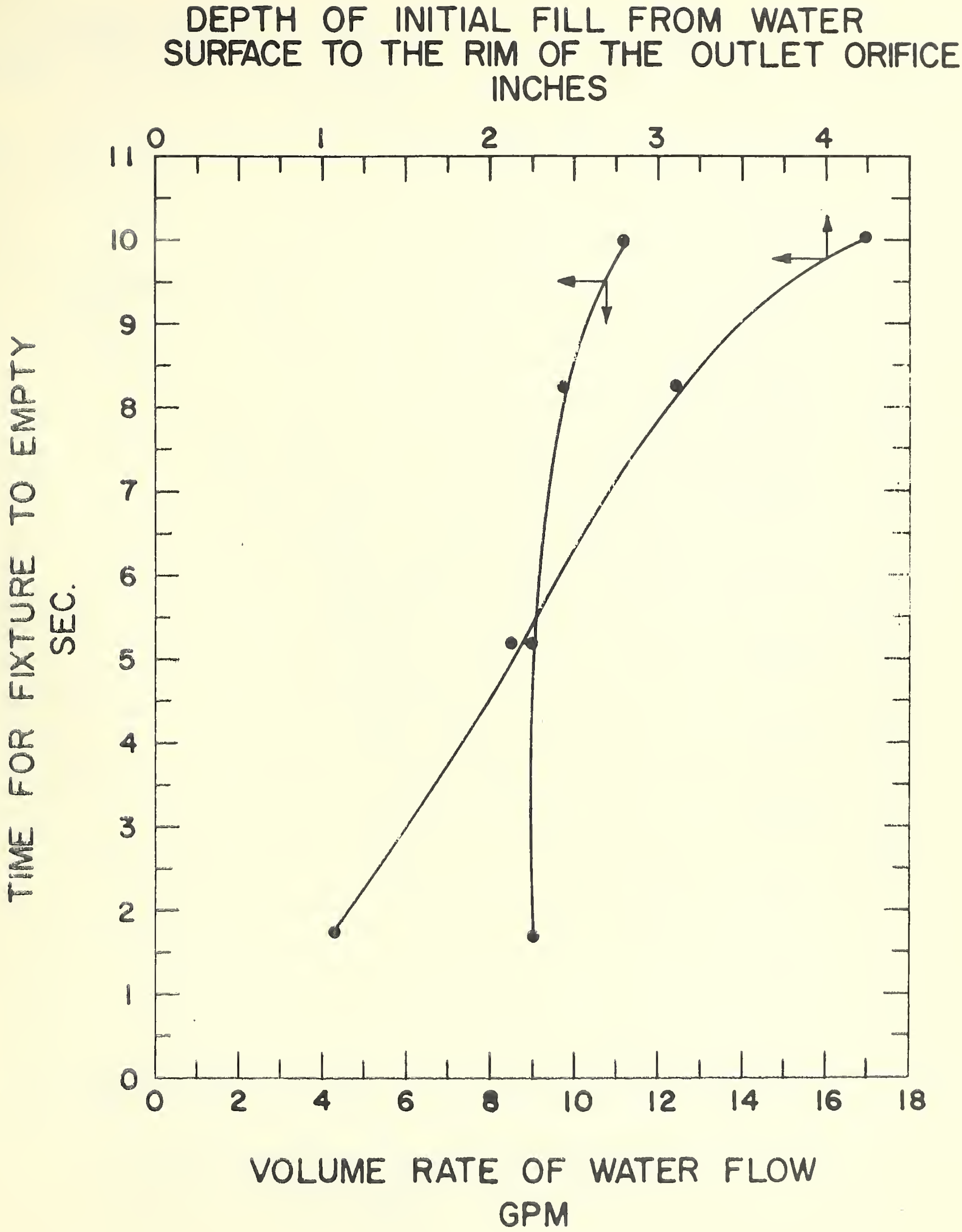

Figure 7. Drain characteristics of lavatory

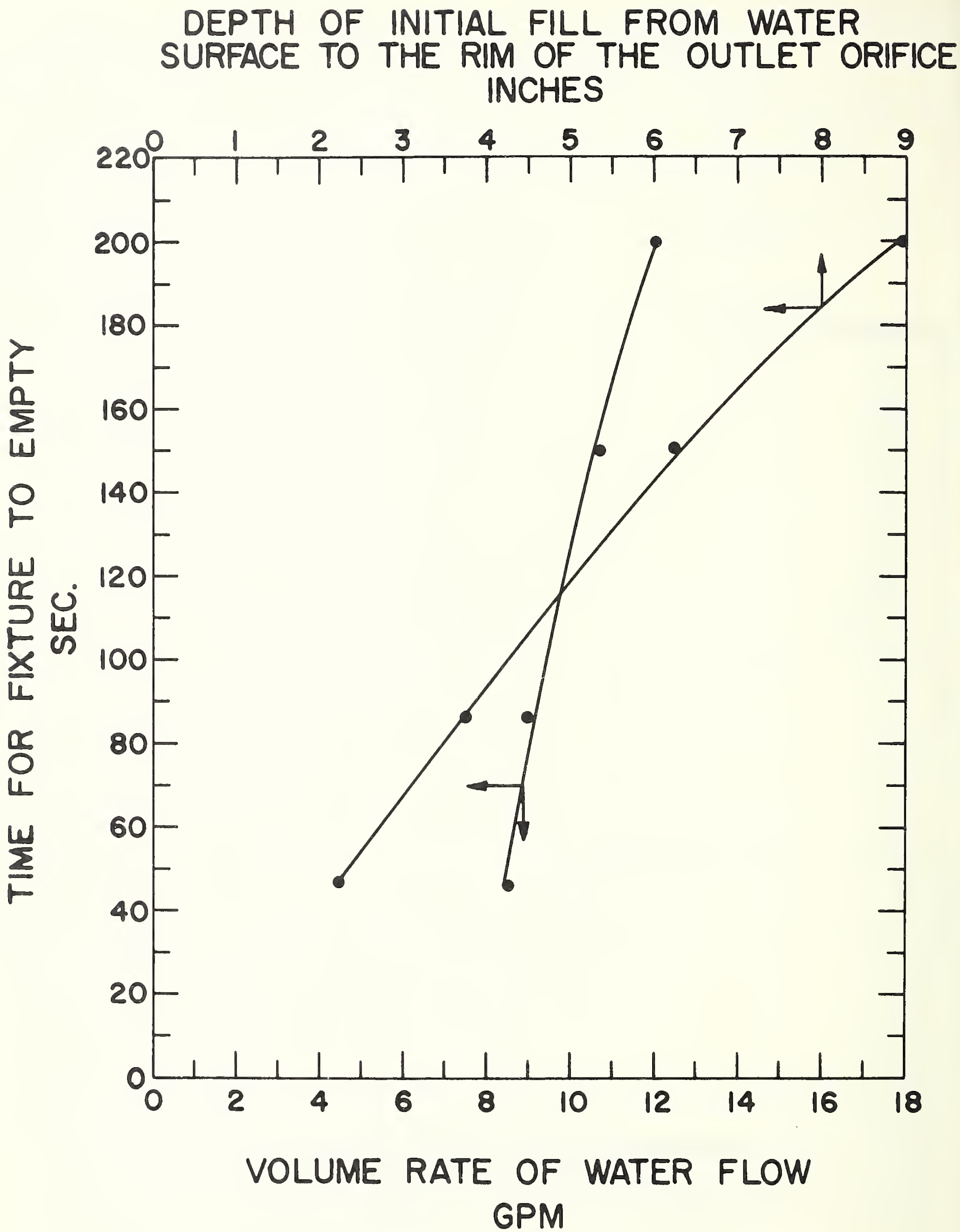

Figure 8. Drain characteristics of 5' recess-type bath tub

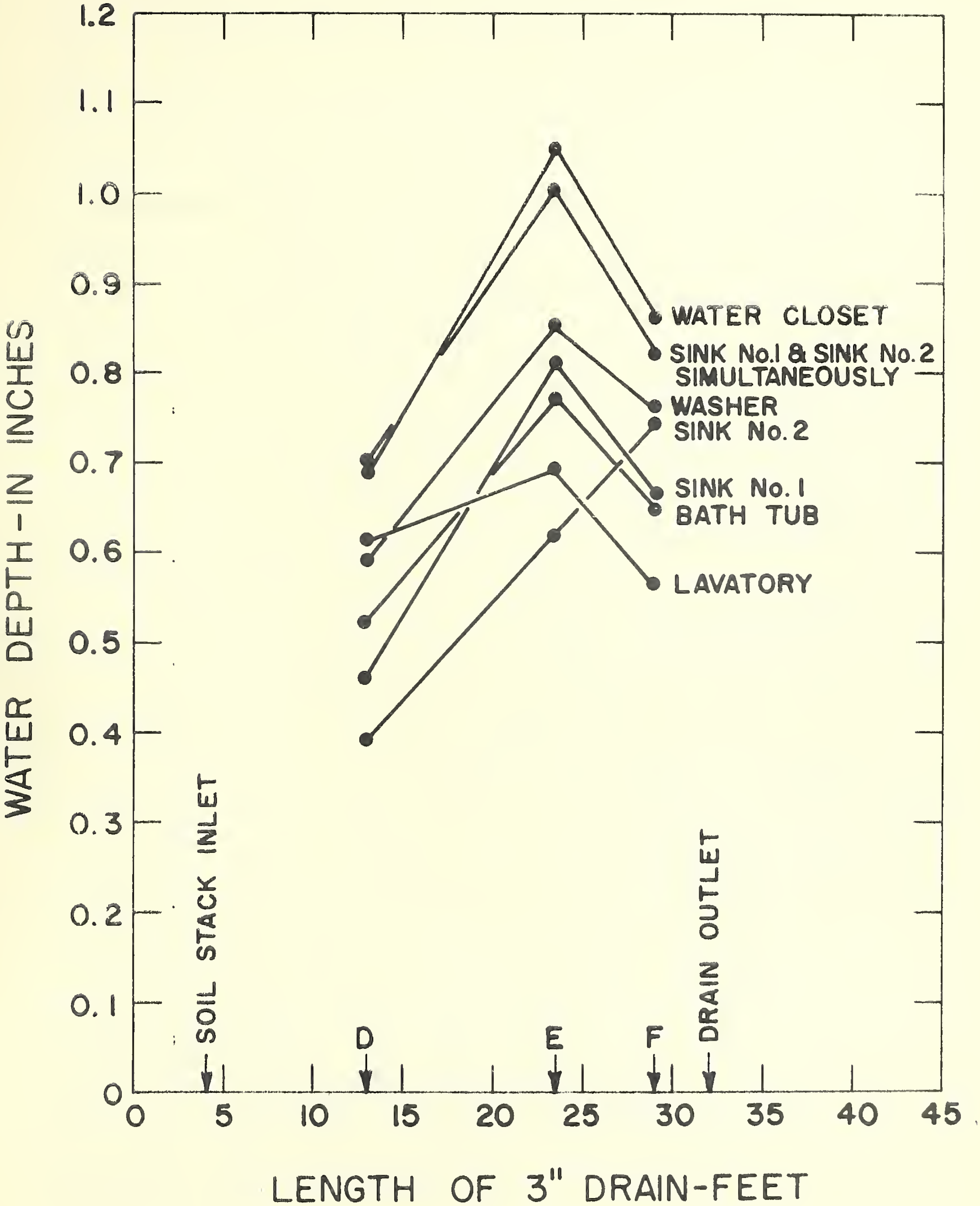

Figure 9. Water depths in 3" drain for individual fixture use with all vents open

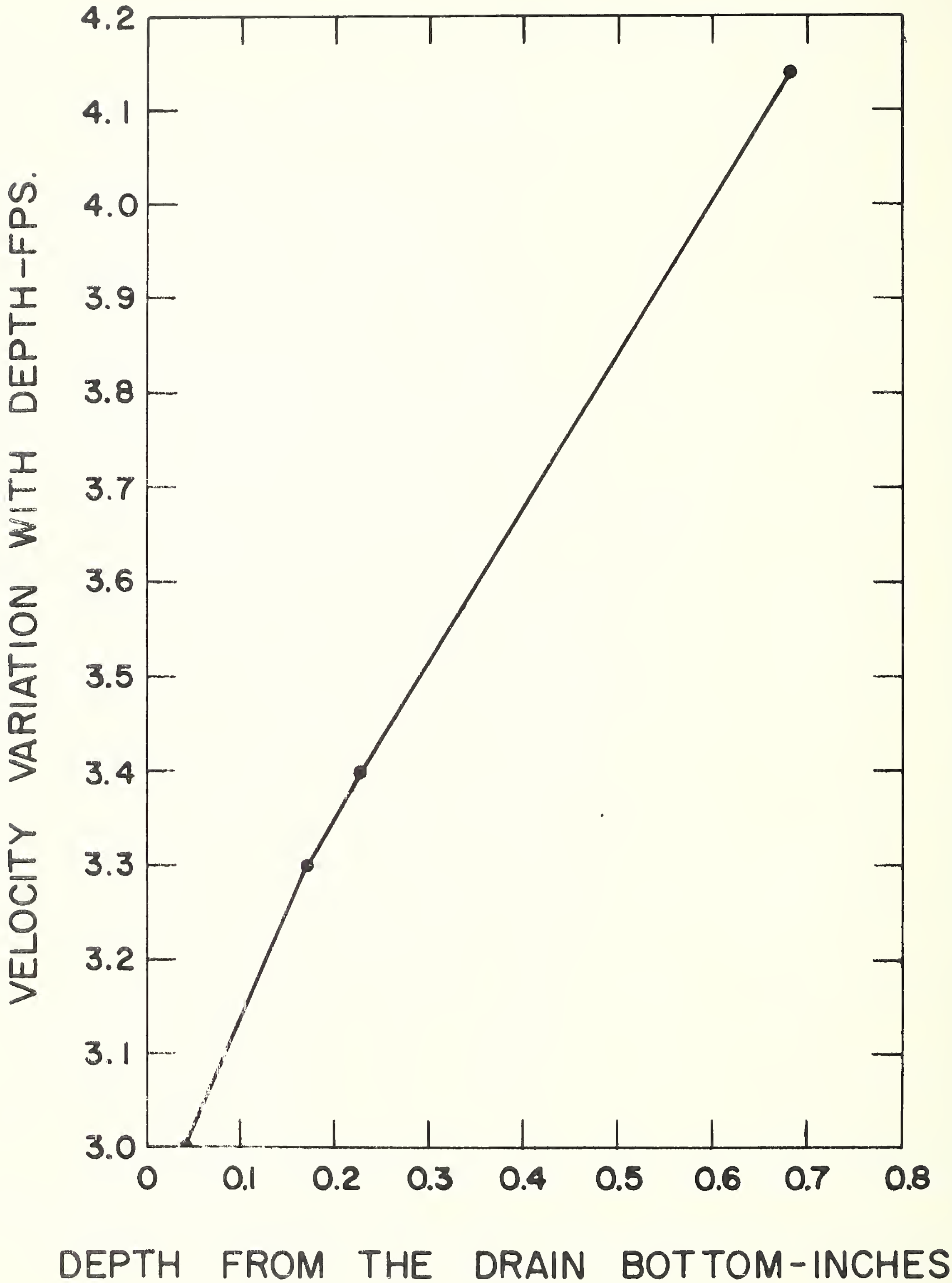

Figure 10. Variation of velocity with depth at "D" on the 3" drain during a water closet discharge with all vents open

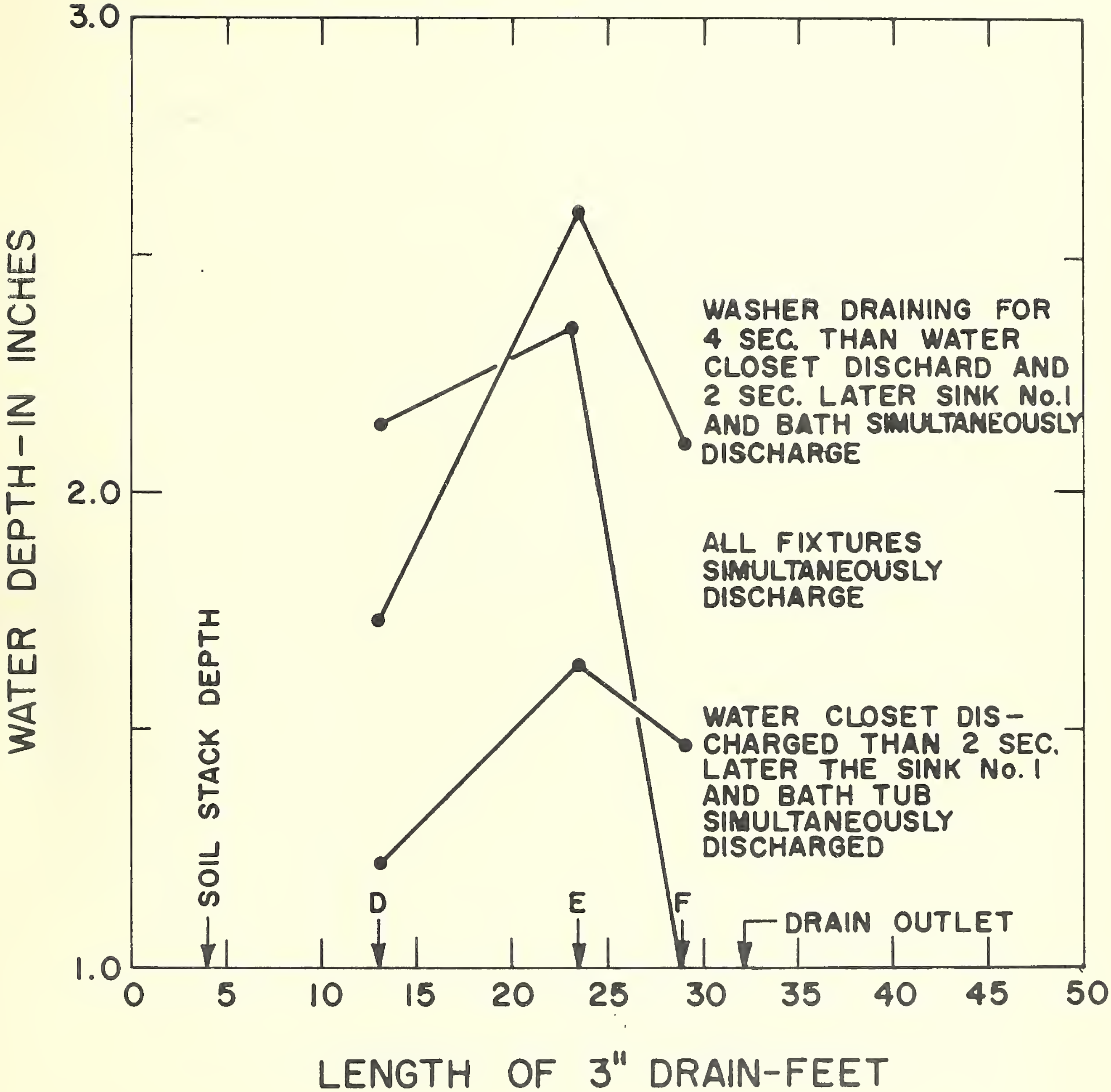

Figure 11. Water depths in 3" drain for fixtures discharged in combinations with vents open

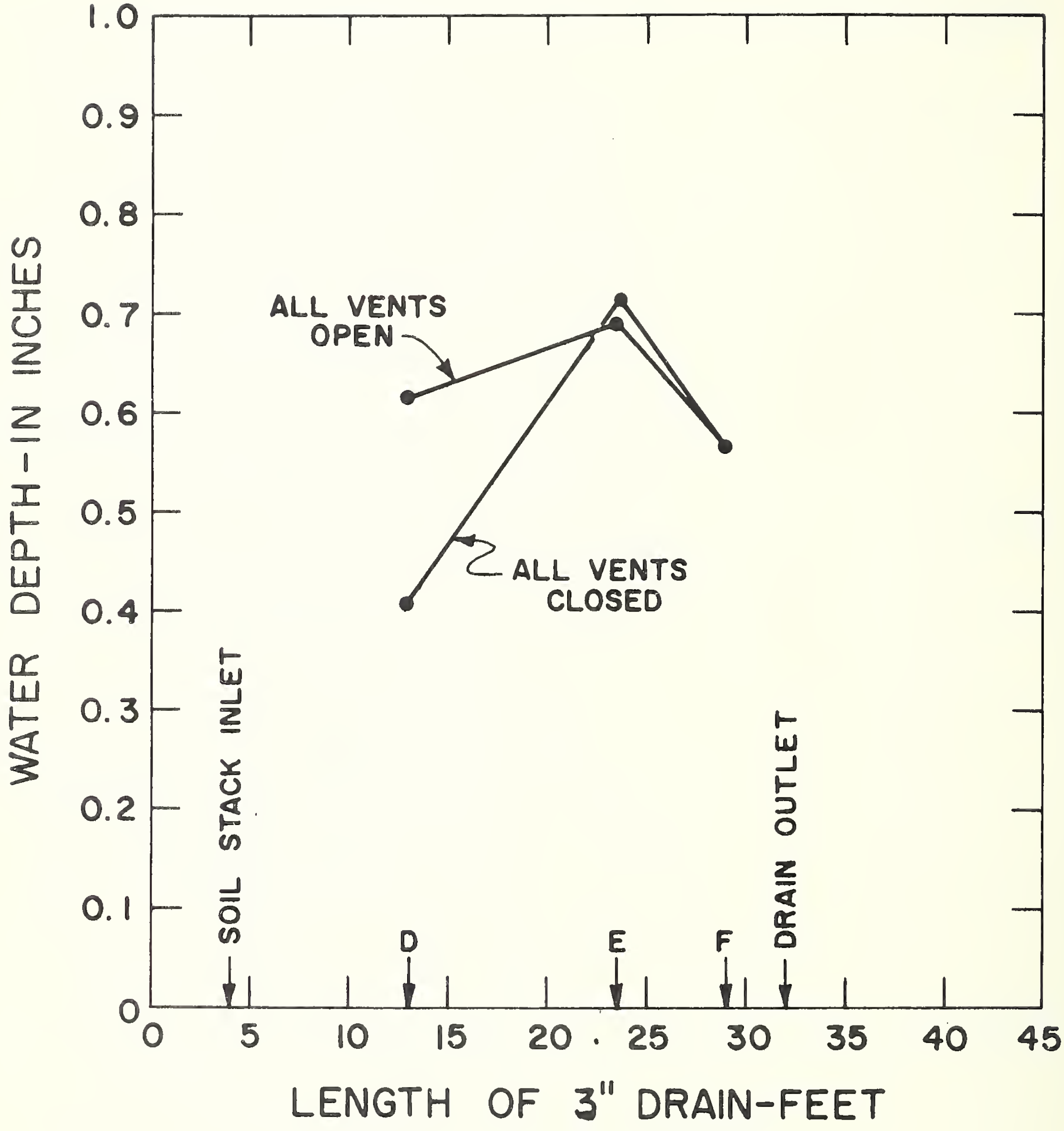

Figure 12. Water depths in the 3" drain for lavatory discharge with vents closed and with vents open

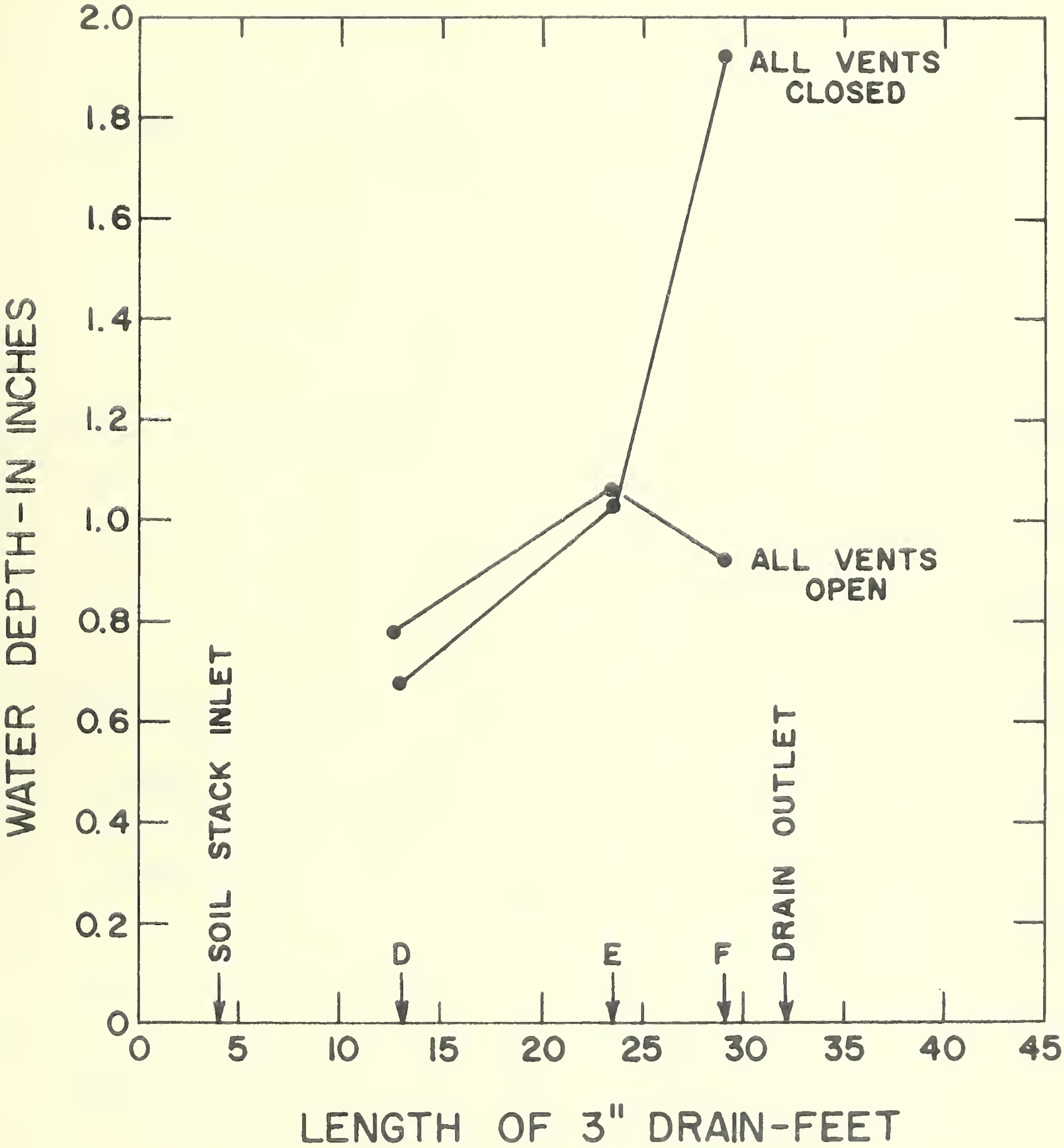

Figure 13. Water depths in the 3" drain for water closet discharge with vents open and with vents closed

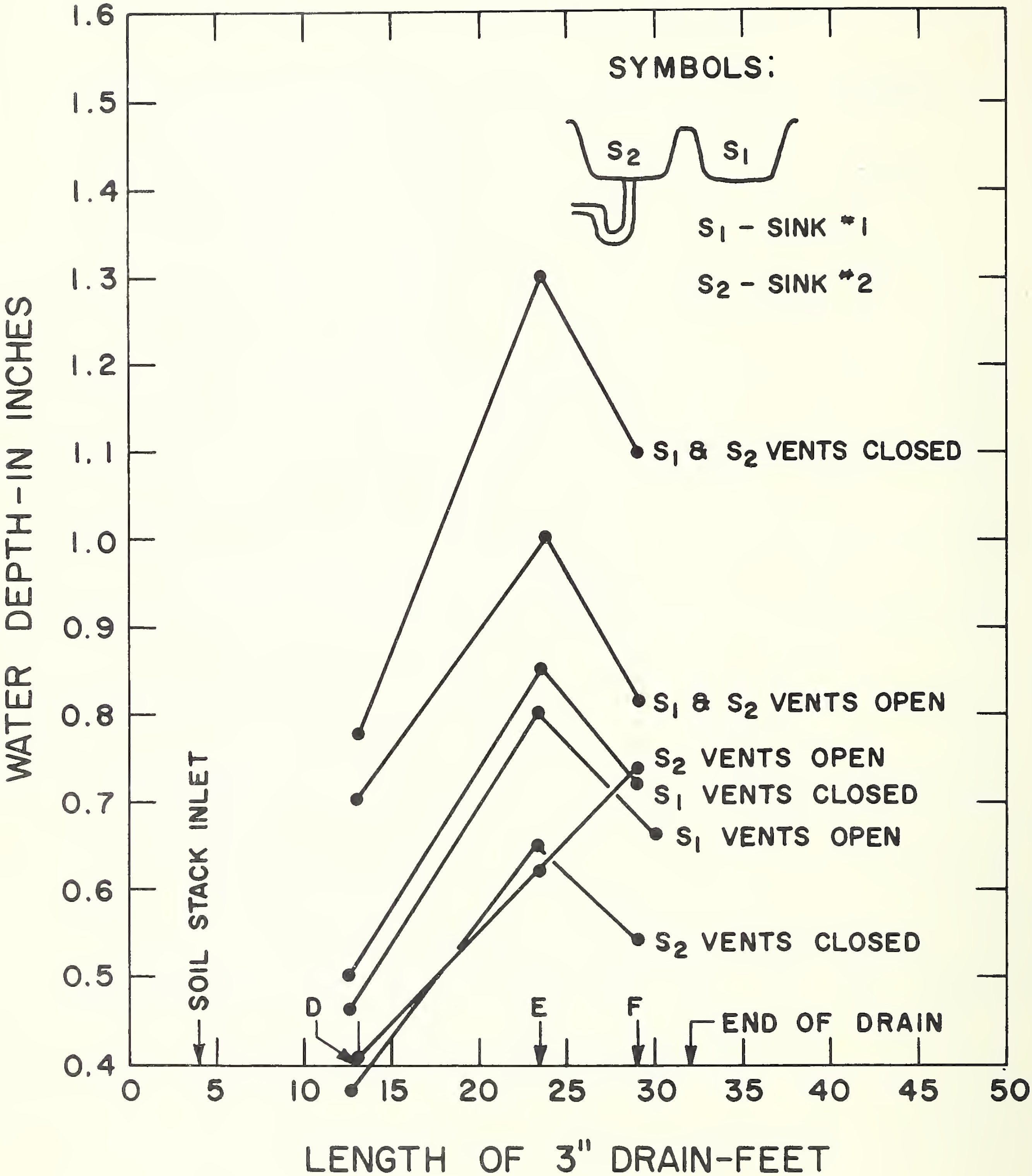

Figure 14. Water depths in 3" drain during two compartments discharged simultaneously and during the discharge of one compartment at a time with vents open and with vents closed

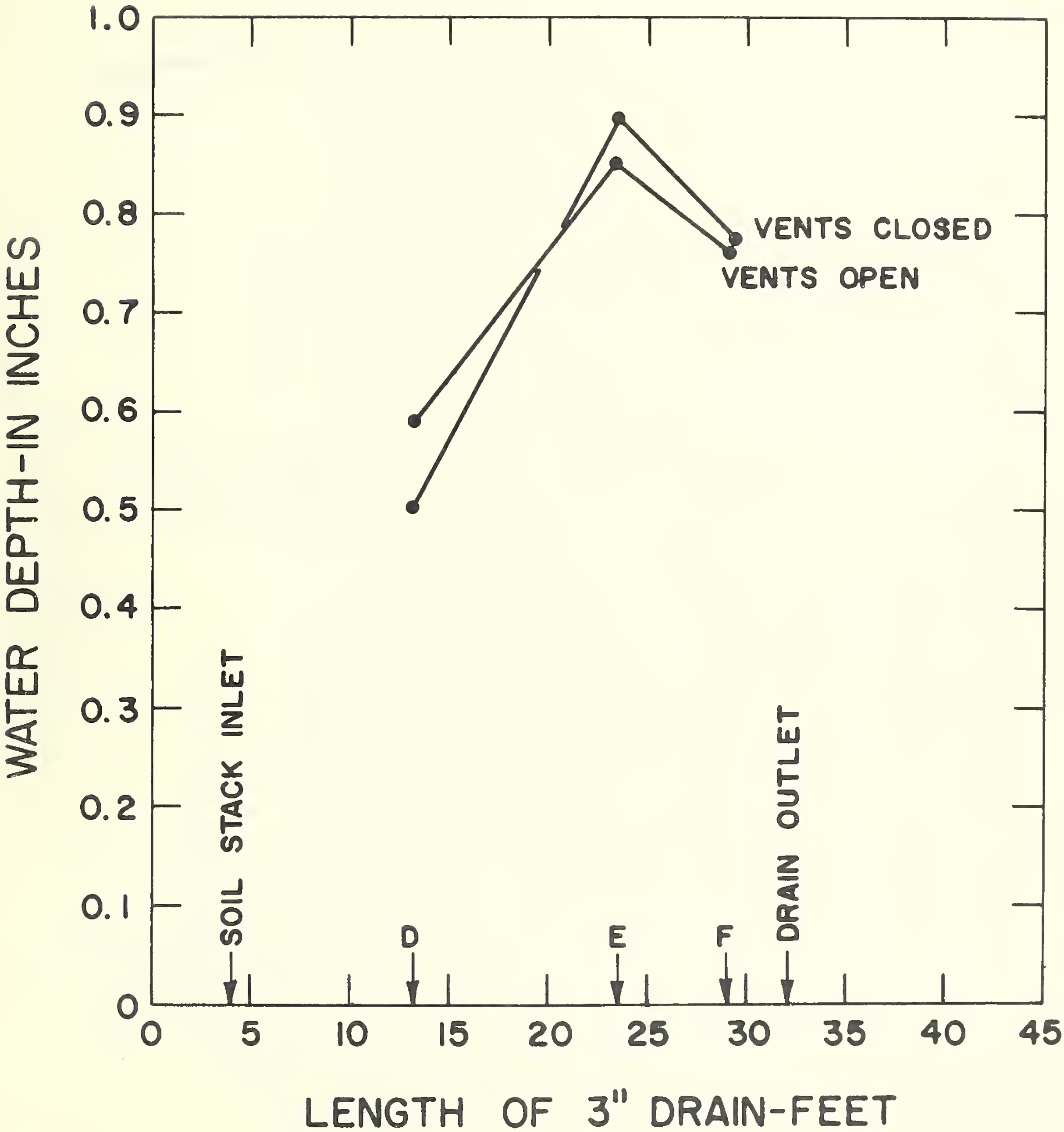

Figure 15. Water depths in 3" drain for the washing machine discharging during the drain event with all vents open and with all vents closed

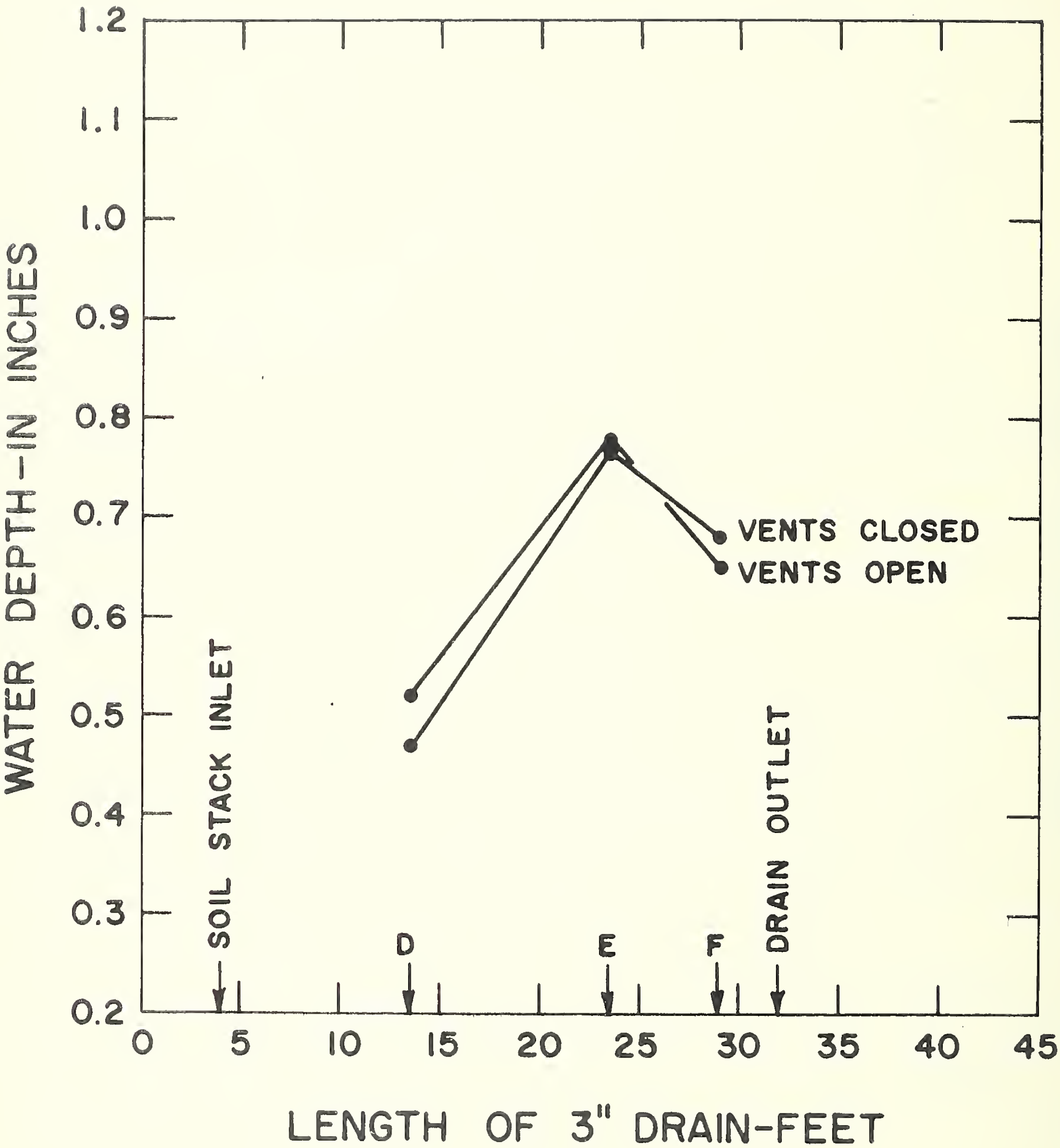

Figure 16. Water depths in 3" drain for the bath tub discharging from half full water level with vents open and with vents closed

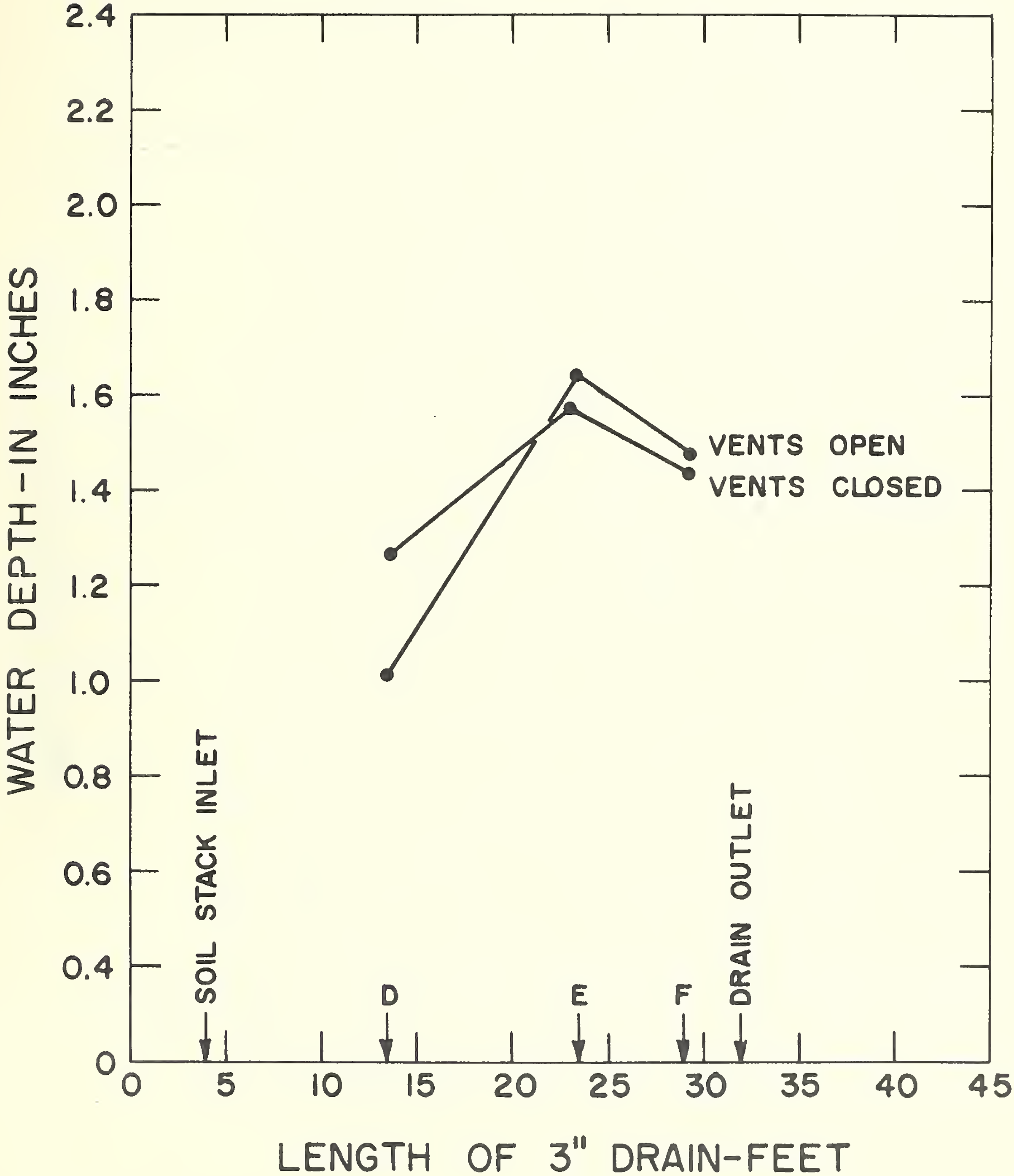

Figure 17. Water depths in 3" drain for the discharge of compartment No. 1 of the sink simultaneously with the bath tub 2 seconds after a water closet discharge with vents open and with vents closed

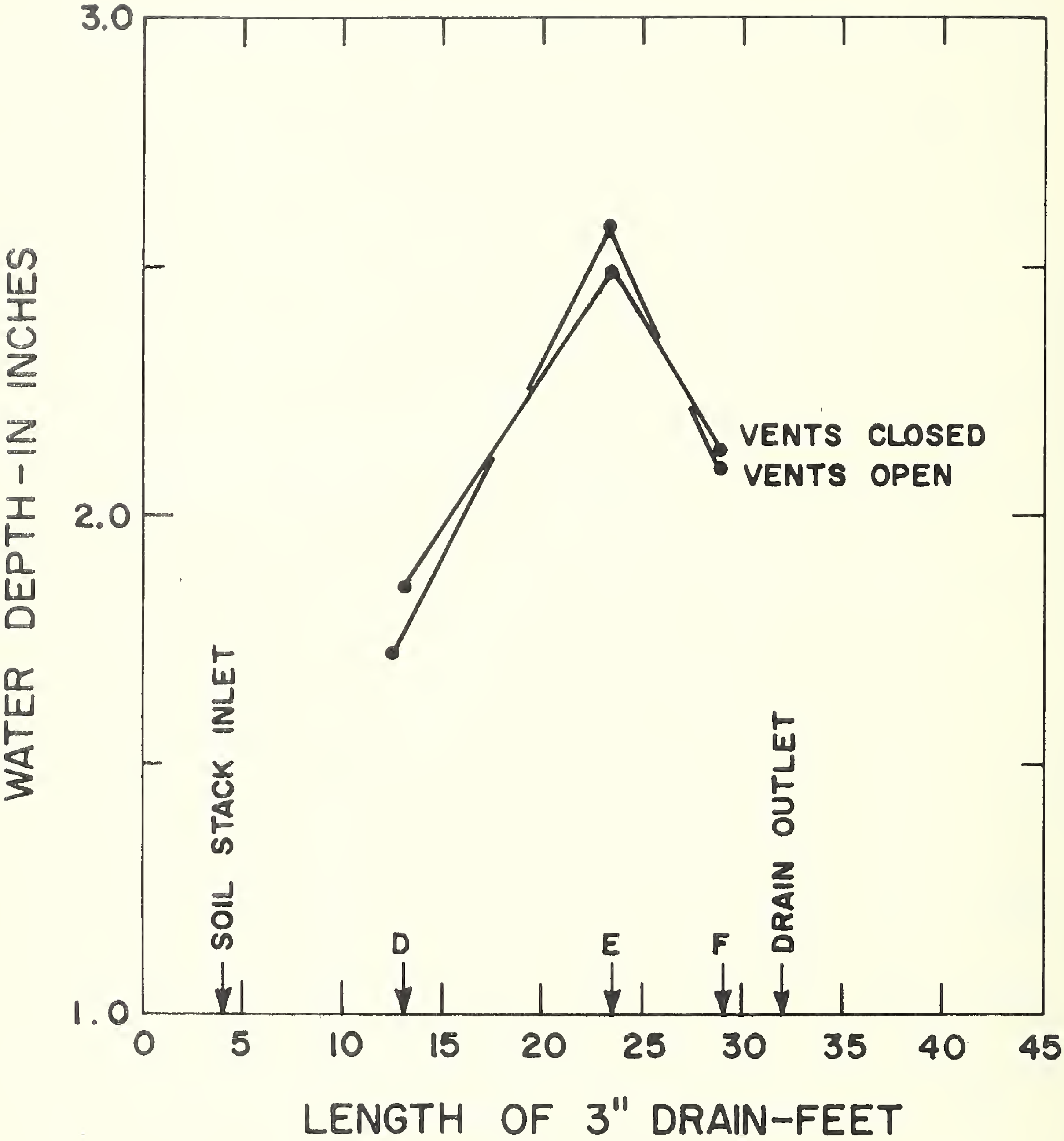

Figure 18. Water depths in 3" drain for the washer discharging during the drain event, the water closet discharged 4 seconds later then 2 seconds after the water closet discharge, the simultaneous discharge of the bath tub and compartment No. 1 of the two compartment kitchen sink with vents open and vents closed

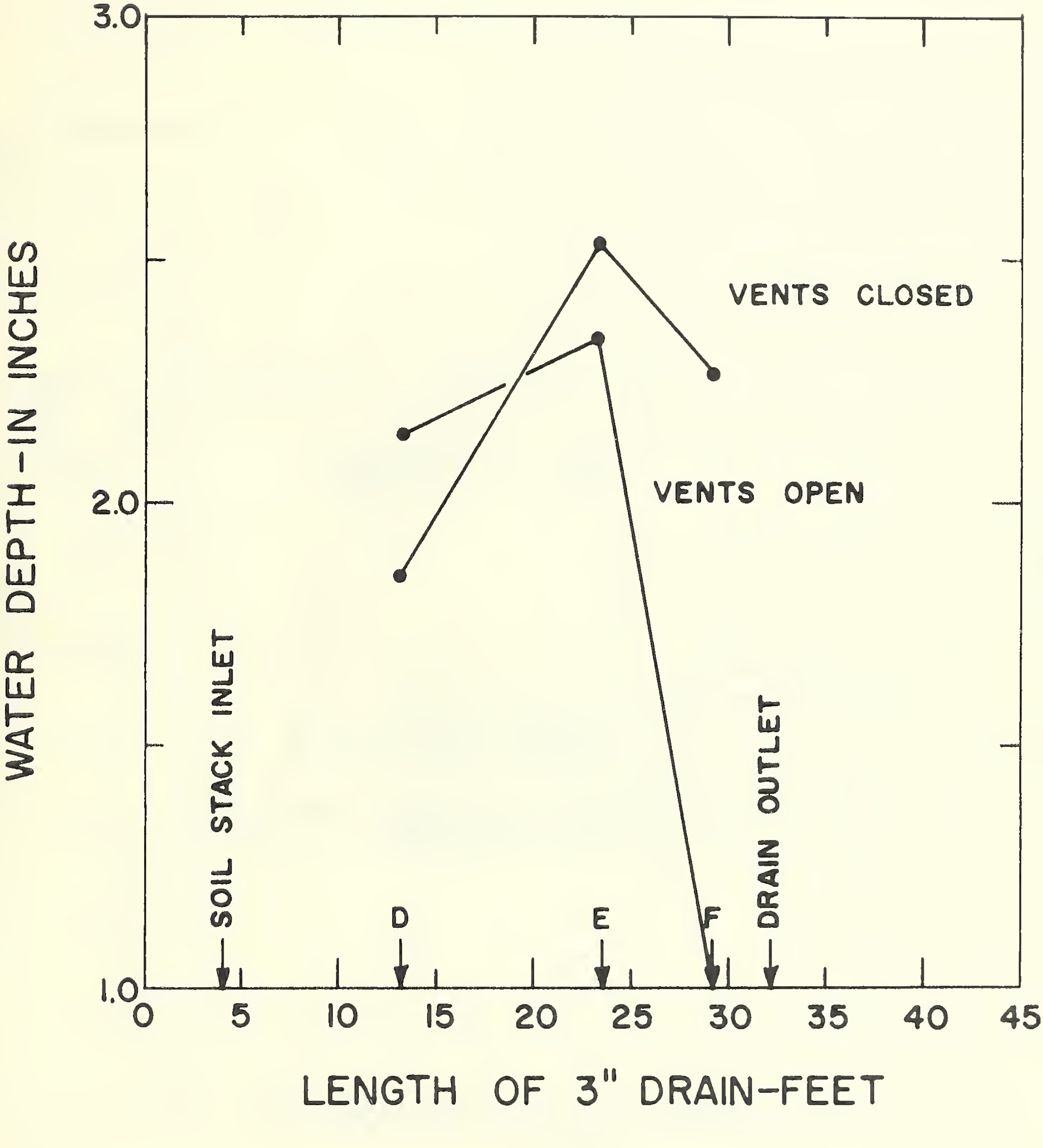

Figure 19. Water depth in 3" drain for the discharge of all fixtures simultaneously with and without vents

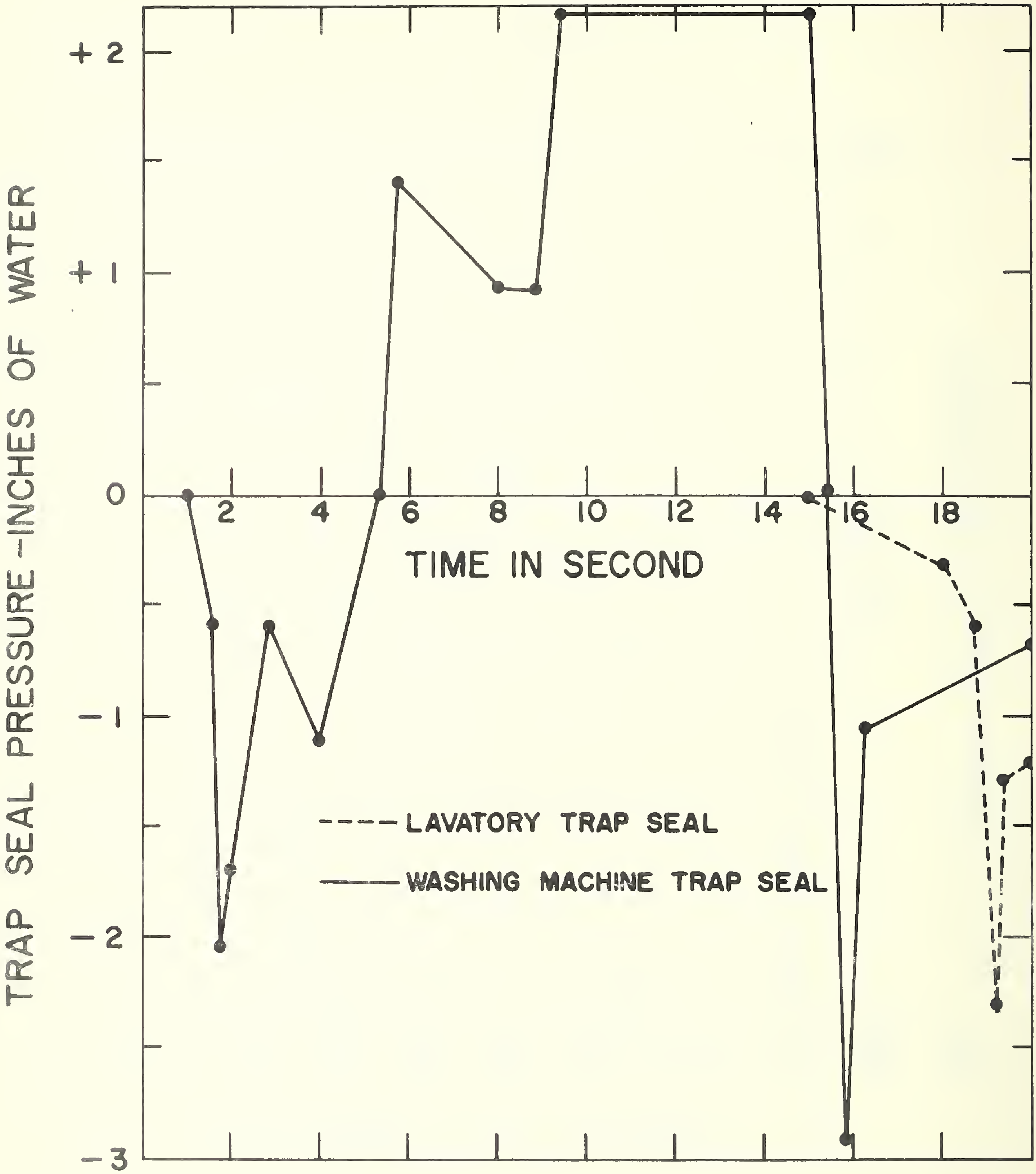

Figure 20. Lavatory and washing machine trap seal pressures versus the time during the discharge of the water closet then two seconds later the discharge of the two compartment kitchen sink and tub simultaneously with all system vents closed

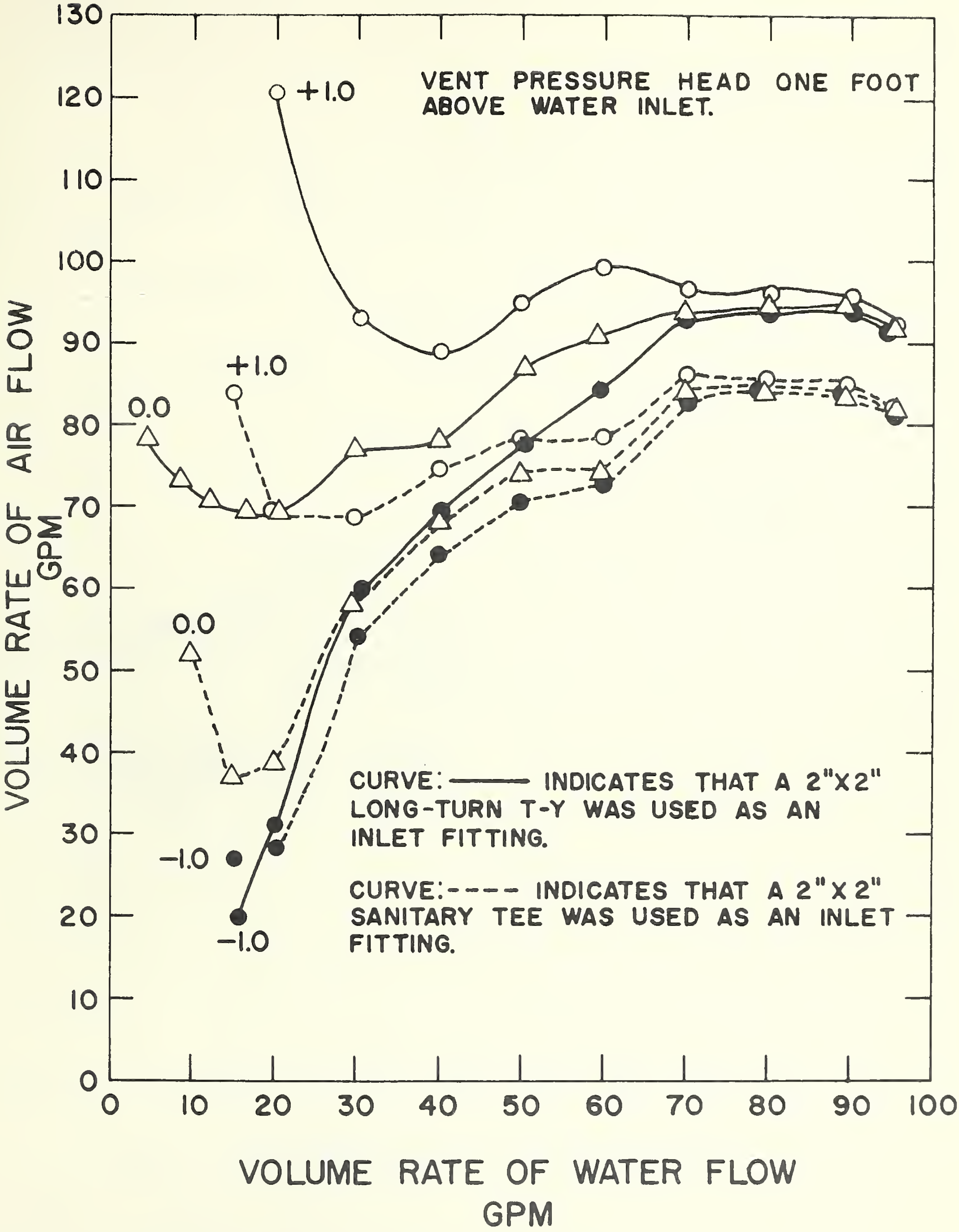

Figure 21. Air demand as a function of water flow rate and vent pressure, for 2" test stack. The following symbols indicate the air pressure in the stack vent at a point located one foot above the water inlet:

O indicates +1.0 inches of water
△ indicates 0.0 inches of water
● indicates -1.0 inches of water

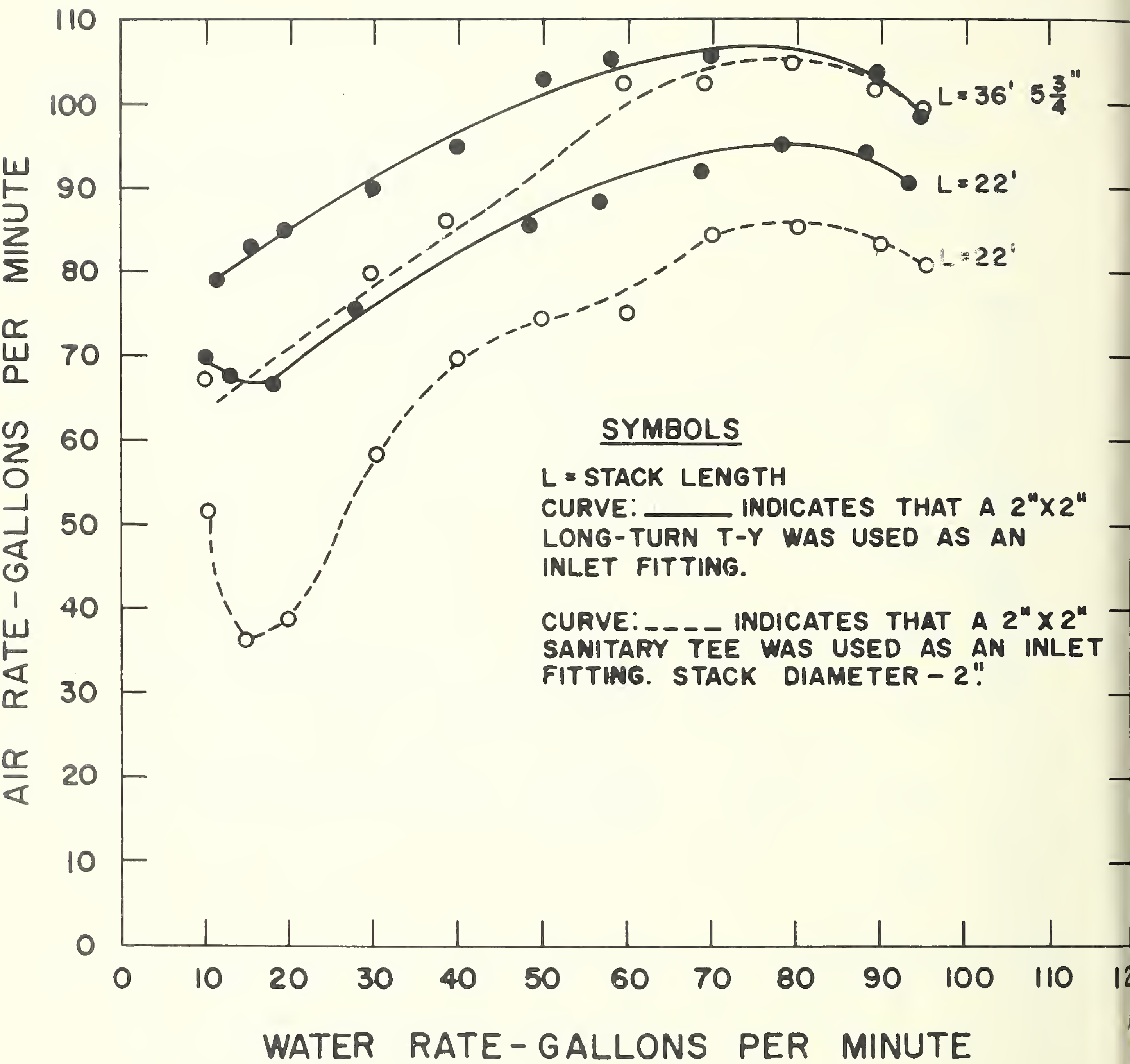

Figure 22. Air rate versus water rate for a change in stack length and inlet fitting type (The static pressure of the air flow was held at atmospheric pressure at a point in the stack vent one foot above the horizontal branch through which the water was introduced into the system. Stack and stack vent were 2" diameter.)

U. S. DEPARTMENT OF COMMERCE
Luther H. Hodges, *Secretary*

NATIONAL BUREAU OF STANDARDS
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