Hunter's Horizontal Drain Capacities and the *UPC*

Story by Dan Cole

In *Uncovering the Missing Hunter's Curve* (*Official*, Sept./Oct. 2013), I demonstrated that the probability curve developed by Dr. Roy Hunter in the early 1920s is still the basis for sizing vertical drainage stacks in the *Uniform Plumbing Code (UPC®)*. I also mentioned that his method of probability developed for vertical stacks was not applied toward horizontal branches, building drains, or building sewers. Rather, he utilized a mean flow rate based on an assumed frequency of use. This article will discuss the methodology Dr. Hunter used for horizontal pipe sizing, demonstrating how he derived the capacities of horizontal drains in fixture units and how they have been adopted in the *UPC* drainage sizing table. When discussing the *UPC*, we will be revealing significant divergences from Hunter's drain capacities that will need interpretation.

As with the probability model for drainage stacks, tables for horizontal drain capacities are published in Recommended Minimum Requirements for Plumbing, Report BH13. The 1928 edition is an updated revision of the original 1924 publication resulting from continued research at the National Bureau of Standards. A further progress revision was published in 1931 distinguishing capacities of horizontal branches from capacities of house drains and sewers. We will be referring only to the 1928 edition since the *UPC* adopted the horizontal drainage table from this revision and not from 1931.

The development of horizontal capacities was not as convoluted and onerous as what we have previously seen for vertical stacks, yet we shall meet with some complexities and modifying factors that do not allow a straight forward formula such as the Manning's formula used in other model codes. Instead of just presenting the tables from Report BH13, we will recreate the tables to surface underlying assumptions. Although the very complex and cumbersome probability model for drainage stacks was not used, a probable modifying factor was introduced. Further modifications were needed based on empirical data resulting in several steps of development before the final sizing table was realized. Discharge flow rates in horizontal piping are still converted in terms of fixture units based on the water closet value of six fixture units as discussed previously in *Uncovering the Missing Hunter's Curve*.

Development of the Horizontal Pipe Sizes

Dr. Hunter's starting point was to calculate pipe capacities flowing full under its own head (i.e. without static head) at ¼-inch per foot slope using Darcy's formula,

$$V = \sqrt{\frac{2gDh}{fl}} \quad \text{(Equation 1)}$$

Where V = velocity in feet per second; g = acceleration due to gravity (32.2 ft/sec^2); D = diameter of pipe in feet; h/l = head gradient per length of pipe in feet (slope); f = friction coefficient. Once determining the velocity, it is a simple calculation to find the flow rate using the formula

$$q=2.448d^2v \quad \text{(Equation 2)}$$

where q = gallons per minute; d = diameter of pipe in inches; and v = velocity in feet per second.

When evaluating the friction factor by solving for f in the Darcy formula given Hunter's computed velocities, we find Hunter assuming turbulent (unsteady) flow for rough pipe conditions with a friction factor (f) ranging from 0.06 for three-inch diameter pipe to 0.05 for twelve-inch diameter pipe. This yields an absolute roughness (ε) of approximately 0.01 for pipe sizes three-inch to six-inch in diameter and approximately 0.02 for pipe sizes eight-inch to twelve-inch in diameter when referencing the Moody chart. This indeed verifies what Hunter confessed in his report, that his calculations assumed a rough pipe condition from old cast iron pipes lined with deposit, which needs a brief comment.

Dr. Hunter had argued for decreasing pipe capacity relative to changes of pipe roughness due to aging (Water-Distributing Systems for Buildings, Report BMS79, 1941). We see this allowance for aging influencing his calculations from the beginning of his published works whether for drainage or water pipes and is somewhat ignored today with pipe material other than cast iron or galvanized steel. Whether choosing a C-factor in the Hazen-Williams formula, or an n-factor in the Manning's equation, the tendency may be to choose the manufacturer's recommended coefficient for smoothness under pristine conditions when calculating capacity without consideration of aging or conditions of actual service. The plumbing engineer should consider how to modify the friction factor relative to the actual conditions of service. This point is being emphasized only to raise awareness of the role the friction coefficient plays in calculating pipe capacity.

Table 1 capacities are derived using Equations 1 and 2 that reproduce the same results found in Report BH13. The column displaying the friction factor is added to exhibit the friction coefficient that Hunter used in the Darcy formula. When comparing to Manning's formula, capacities are approximate when using n = 0.014 for smaller cast-iron pipe diameters and n = 0.016 for larger cast-iron pipe diameters.

Pipe Size (inches)	Capacity (gpm)	Friction Factor (f)
3	51.3	0.0619
4	109.6	0.0571
5	196.5	0.0542
6	313.1	0.0530
8	656.0	0.0510
10	1,149.0	0.0507
12	1,838.0	0.04932

Table 1 Capacities of Cast Iron Pipes Flowing Full at ¼"/ft

Having established pipe capacities, Dr. Hunter's next step was to transform the flow rate into fixture units. The previous article demonstrated that a fixture unit is a rate of flow; one fixture unit being one cubic feet per minute or 7.5 gallons per minute. To transform the capacities in Table 1 into fixture units, we would expect to divide the capacity by 7.5. However, this is not what Dr. Hunter did. This is where he introduced a factor of probability when transforming capacity into fixture units. In order to do this, Dr. Hunter translated the flow rate into probable number of toilets that would generate the pipe's capacity. Assuming that each toilet discharged a volume of five gallons and that this would occur once every minute during peak use, the estimated mean rate of flow is calculated by Q/T, or 5/1. Hence, pipe capacities were divided by five that yielded the probable number of toilets equivalent to the pipe's capacity (see Table 2). For example, 22 toilets discharging 5 gallons per minute into a four-inch pipe yields the pipe capacity of 110 gpm.

Pipe Size (inches)	Capacity (gpm)	Probable Number of WC Discharge per Minute Q/T = 5/1
3	51.3	10
4	109.6	22
5	196.5	39
6	313.1	63
8	656.0	131
10	1,149.0	230
12	1,838.0	368

Table 2 Equivalent Number of Water Closets for Pipe Capacity

The results in Table 2 were problematic for Dr. Hunter seeing that the estimates for the probable number of toilets were too high for three-inch diameter pipe and too low for twelve-inch diameter pipe. Testing had shown that only three toilets closely spaced on a three-inch horizontal drain with a ¼-inch per foot slope discharge successfully. With an additional fixture discharging, the flushes became sluggish. Therefore, three toilets discharging into a three-inch drain is the approximate limit of the drain. The probable number of ten toilets would certainly over-charge the three-inch drain. On the other end, Dr. Hunter considered that the storage capacity is greater in the twelve-inch pipe and that run-off is the controlling factor and congestion is improbable since an average flush rate of once a minute per toilet cannot be maintained in a system large enough to require a 12-inch drain. Therefore, Dr. Hunter permitted the estimate for a 12-inch drain to be increased to twice its value assuming run-off based on a flush frequency of once every two minutes instead of one minute.

To resolve this problem, Dr. Hunter corrected Table 2 by grading the values between the tested value for three-inch pipe and the assumed doubled capacity for a 12-inch pipe. Column three in Table 2 was adjusted by multiplying the number of estimated toilets by a graduating corrective factor that reduced the number of toilets to three for three-inch diameter pipe and that doubled the number of toilets for 12-inch diameter pipe. These modifying factors are seen in Table 3 and reproduce the same results in column 4 published in Report BH13.

Below: Table 3 Modifying Factors

Far right: Table 4 Pipe Capacity in Fixture Units at ¼-inch per foot

Pipe Size (inches)	Probable Number of WC Discharge per Minute Q/T = 5/1	Modifying Factors	Adjusted Number of WCs
3	10	0.3	3
4	22	0.75	16
5	39	0.923 (0.9)	36
6	63	1.20	75
8	131	1.65 (1.85)	216
10	230	1.83 (1.9)	420
12	368	1.96 (2.0)	720

In recreating Table 3, we discover our first discrepancy with the published report as noted in parentheses in column 3. In the third column notice the values on the left side and the parenthetical values on the right side. The modifying factors on the left side yield the actual results in column 4 that appear in Report BH13, whereas Dr. Hunter cites the modifying factors on the right side. Obviously, the parenthetical values for five-inch and 12-inch pipe are rounded values and will yield slightly different values than what the tables in the report show. We can only assume that 1.85 for eight-inch diameter pipe may be a typographical error and that 1.9 for 10-inch pipe has been mistakenly rounded up since these would yield a significant difference than what is shown in the tables in the report.

Having adjusted the equivalent number of toilets for safe and practical discharges per pipe diameter, the number of toilets was then transformed into fixture units by multiplying by a factor of six (each toilet valued at six fixture units). This yielded the recommended pipe capacities in fixture units per pipe diameter (see Table 4). The pipe capacities in fixture units in Table 4 are for slopes at ¼-inch per foot. The fixture units will need to be adjusted for slopes at 1/8-inch and ½-inch per foot.

Pipe Size (inches)	Adjusted Number of WCs	Pipe Capacity in Fixture Units
3	3	18
4	16	96
5	36	216
6	75	450
8	216	1296 (1392)
10	420	2520
12	720	4320

Before showing the adjustments made to the fixture units based on differing slopes, we need to point out another discrepancy found when recreating Table 4. The discrepancy is noted in parentheses in column 3. The BH13 Report shows the pipe capacity in fixture units for eight-inch pipe as 1,392. We cannot explain this other than as possible errata in the published report where the third digit should have been a 2. Unfortunately, this errata affected eight-inch pipe capacities in fixture units for varying slopes as will be shown below.

Considering that the head varies with respect to varying slopes of pipe and that run-off will vary as the square roots of the total heads, the use of Darcy's formula suggests that slopes of 1/8, 1/4, and 1/2 inch per foot will vary the pipe capacity by the ratio 36:51:80. Based on the estimates of three-inch pipe discussed above, Hunter modified the ratios for smaller pipe diameters (Table 5).

Pipe Size (inches)	Slope Ratios 1/8:1/4:1/2
3	5:6:7
4	4:5:6
5	3:4:5
6	2:3:4
8 +	Darcy Formula 36:51:80

Left: Table 5 Slope ratios per pipe size

To calculate the pipe capacity in fixture units for varying slopes using the ratios, multiply the pipe capacity in fixture units by the appropriate ratio. For example, to calculate the fixture unit capacity for three-inch pipe at 1/8-inch per foot slope, multiply 18 fixture units by the ratio 5/6. For 1/2-inch slope, multiply 18 fixture units by the ratio 7/6. As we continue this calculation for the rest of the pipe diameters, we derive the final table for capacities of horizontal drains in fixture units (Table 6).

(77/6=12.8 toilets) and round up the number of toilets to an even number (14), then we yield 84 fixture units as given in the table. Continuing across the table at 1/2-inch per foot slope, 115 fixture units convert to 19.2 toilets, and when rounded to 19 toilets yields 114 fixture units.

The discrepancy noted for five-inch pipe at 1/2-inch per foot slope is a difference of one toilet. If we accept the modifying factor in Table 3 as 0.9, the adjusted number of toilets would be 35, yielding 210 fixture units (although BH13 displays 36 and 216 respectively in the tables). Applying the ratios to 210 fixture units to calculate fixture units at 1/2-inch per foot slope would yield 262.5 fixture units and rounding up to the nearest toilet yields what is given with 264 fixture units. Applying the same for the lesser slope still yields the same value as given.

Obviously, the error we noted earlier for eight-inch pipe (1,392 fixture units) affected the values for 1/8-inch and 1/2-inch per foot slopes when the ratios were applied. Accepting the value of 1,392 fixture units for 1/4-inch slope, the calculated values for 1/8-inch and 1/2-inch per foot slopes would have been 988 and 2,227 fixture units, respectively. The calculated 988 fixture units

Pipe Size (inches)	Slope 1/8-inch per ft.	Slope 1/4-inch per ft.	Slope 1/2-inch per ft.
3	15	18	21
4	77 (84)	96	115 (114)
5	162	216	270 (264)
6	300	450	600
8	920 (990)	1296 (1392)	2074 (2220)
10	1789 (1800)	2520	3956 (3900)
12	3067 (3084)	4320	6912

Lower left: Table 6 Capacities of Horizontal Drains in Fixture Units

Once again, when recreating the table published in Report BH13 we meet with several discrepancies in comparison. The values posted on the left side of the columns are derived from using the ratios provided in Table 5. The values in parentheses are the actual values published in Report BH13. An explanation for each discrepancy follows.

Beginning with four-inch diameter pipe at 1/8-inch per foot slope, we notice that if we convert 77 fixture units to number of toilets

are equivalent to 164.7 toilets and rounding up to 165 toilets yields 990 fixture units. The calculated 2,227 fixture units for eight-inch pipe is equivalent to 371.2 toilets, which were rounded down to an even number (370), yielding 2,220 fixture units as given in the report.

Moving down the table for the remaining pipe sizes we notice the same pattern of rounding. For 10-inch pipe, converting 1,789 fixture units to number of toilets (298.2) and rounding up to 300 yields 1,800 fixture units; converting 3,956 fixture units to number of toilets (659.3) and rounding down to 650 yields 3,900 fixture units. For 12-inch pipe, converting 3,067 fixture units to number of toilets (511.2) and rounding up to 514 toilets yields 3,084 fixture units.

Where calculated values translated to even number of toilets, no rounding occurred. Hence, we conclude that the published values are rounded to the nearest toilet in fixture units, or rounded to a chosen near even number. The rounding is somewhat inconsistent and arbitrary.

No rounding to an even number of toilets was applied for three-inch pipe diameter. The possibility of overcharging the drain is greatest for three-inch diameter pipe and no more than three toilets were permitted as mentioned earlier. For lesser slope than ¼-inch per foot, only two toilets were permitted with an extra allowance of three fixture units. For ½-inch per slope, three toilets were permitted with the same extra allowance of fixture units as the lesser slope.

In The Missing Hunter's Curve, we were able to calculate the estimated flow rate for drainage stacks by using Dr. Hunter's estimating curve. For horizontal drains, calculating estimated flow rates is more problematic. Of course we could work our way backward and calculate the pipe capacities shown in Tables 1 and 2, but that would be misreading Table 6. Table 6 is showing the practical pipe capacities in terms of toilets rather than flow rates. The modifying factors introduced in Table 3 implicitly alter the probable average mean flow rate of five gallons per minute. For example, the modifying factor for 12-inch pipe altered the probable average mean flow rate to five gallons every two minutes, or 2.5 gallons per minute for each toilet rather than five gallons per minute. The modifying factor for three-inch pipe altered the probable average mean flow rate to approximately 17 gallons per minute for each toilet, which allows only three toilets to correspond to the pipe's capacity of 51 gallons per minute. Three toilets closely spaced seemed to indicate that the pipe's capacity was reaching its limit. But was it reaching its limit of 51 gallons per minute?

The problem the modifying factors were attempting to correct was the differing flow characteristics between surge flows and continuous flows yet to be realized by Dr. Hunter. Only later, did Dr. Hunter begin to experiment and analyze surge flows. The surge flow is the temporary peak flow from the immediate discharge of a fixture into the drain. The surge flow will quickly flatten out and assume terminal velocity for the diameter and slope of the pipe, which then becomes a continuous flow and can be calculated as a mean flow rate. The 1931 revision of BH13 premiered this distinction, which later came to full development in the Plumbing Manual BMS66 published in 1940. What limited the three-inch pipe capacity was the three toilets closely spaced together. The discharges were not average mean flows applicable for building drains and sewers, but were surge flows in horizontal branches. The modifying factors do not make this distinction, and calculating flow rates is a graduating mixture of surge flows in three-inch pipe to mean flows in 12-inch pipe. For this very reason, Dr. Hunter later developed separate tables for sizing horizontal drains depending on whether they were primary or secondary; horizontal branches receiving surge flows or building drains and building sewers where the stream is tending toward continuous flow that can be expressed in a mean flow rate.

Horizontal Pipe Sizes Adopted in the *UPC*

Having demonstrated how Dr. Hunter derived capacities for horizontal drains in fixture units, we will now turn our attention to the *UPC* table for horizontal drains and compare it with BH13. The earliest archived edition of the *UPC* we have is from 1946. Table 7 compares the 1946 edition with Report BH13 showing *UPC* modifications in red. Notice that the corresponding values are for slopes at ½-inch per foot according to BH13. We will come back to this when considering *UPC* modifications.

The UPC diverges significantly from BH13 with respect to four-inch pipe capacity and we will discuss this momentarily. The Western Plumbing Officials (now IAPMO) did not allow any drainage flow into 1 ¼-inch diameter pipe (until the 1973 committee permitted one fixture unit) and had limited 1 ½-inch pipe

Pipe Size	1 ¼	1 ½	2	2 ½	3	4	5	6	8	10	12
BH 13	1	3	8	-	21	114	264	600	2220	3900	6912
UPC 1946	0	1	8	14	21	180	256	600	2200	3900	6912

Pipe Size	1 ¼	1 ½	2	2 ½	3	4	5	6	8	10	12
UPC 1950	0	1	8	14	27	180	256	600	2200	3900	6912
UPC 1961	Adds to the title of the table , "Based on ¼"/ft. Slope"										
UPC 1964	0	1	8	14	35	180	356	600	2200	3900	6912
UPC 1973	1	1	8	14	35	216	428	720	2640	4680	8200

Top: Table 7 Comparative Tables in Fixture Units

Below: Table 8 *UPC* Fixture Unit Modifications

diameters to one fixture unit. The *UPC* fixture unit value for 2½-inch diameter pipe is an interpolated value since BH13 did not list that size in its table.

Although the discrepancies between fixture units for five-inch pipe (a difference of one toilet) and for eight-inch pipe (a difference of three toilets) is insignificant, the explanation for the *UPC* modifications eludes us. These values do not round to a whole number when translating into number of toilets as do the other values as explained previously. If the fixture unit value for eight-inch pipe was rounded to the nearest hundredth place, then there is no explanation why this didn't occur for the fixture unit values for 12-inch pipe. Since the fixture unit values are matching exactly for pipe diameters of six-inch and greater, we may postulate that the *UPC* fixture unit value for eight-inch pipe should reflect the same as BH13.

The discrepancy in fixture unit values for four-inch pipe is problematic and significant. It reflects a difference of 11 toilets between BH13 and the *UPC*. We do not find this fixture unit value in the 1931 revision of BH13, but we do find it in the Plumbing Manual BMS66 (1940) as well as in the ASA A40 National Plumbing Code (a tentative draft was proposed in the early 1940s by a committee that included three representatives from the Western Plumbing Officials Association). However, the 180 fixture units in both BMS66 and ASA A40 is only for a primary branch or building drains and sewers at 1/8-inch per foot slope, which does not correspond with all the other fixture unit values that are at ½-inch per foot. This explanation would only deepen the mystery and not explain why no other fixture unit values from BMS66 or the ASA A40 code were adopted in the *UPC* if indeed this value was borrowed from either one of them. Unfortunately, we must leave this fixture unit value unresolved and without explanation.

Further modifications in fixture units were made for horizontal drains from 1950 to 1973 when the last modifications were made for horizontal drains. These modifications are presented in Table 8 and displayed in red. It is readily observable that the most significant changes to the *UPC* horizontal pipe size table were made in 1973.

We have no archived information why the capacity for three-inch pipe in fixture units was increased to either 27 or 35 fixture units. The *UPC* continued to limit the number of toilets to two for a three-inch horizontal drain (until 1970). So the increase was not for a greater allowance of toilets, but only to allow additional fixtures such as sinks, tubs and showers. How the actual fixture unit values were derived is unknown.

In 1961, the clause "Based on ¼"/ft. Slope" was added to the title of Table 4-3 and remains in the current edition of the *UPC* as a footnote. The fixture unit values remained

Pipe Size (inches)	Slope 1/8-inch per ft.	Slope 1/4-inch per ft.	Ratio
4	180	216	216/180 = 1.2
5	400	480	480/400 = 1.2
6	660	790	790/660 = 1.2
8	1600	1920	1920/1600 = 1.2
10	2700	3240	3240/2700 = 1.2
12	4200	5000	5000/4200 = 1.2

Table 9 Fixture Units per Slope in the Plumbing Manual BMS66, Table 807slope

the same as what we see for 1950. This added clause is a significant error, which was exacerbated in 1973 as we shall discuss further below. We have already demonstrated that the fixture unit values for horizontal drains were based on ½-inch per foot slope according to BH13. The 1961 mistake surfaced because the *UPC* has never provided fixture unit values for differing slopes. We can only surmise that the code committee lost awareness of where and how horizontal pipe sizing was derived. How the committee incorrectly decided on the ¼-inch per foot slope is unknown. The fixture unit values do not even remotely compare with sizing tables at ¼-inch per foot slope in other codes.

In 1964, we saw the fixture unit value for five-inch pipe increase by 100 fixture units. This was a very odd modification unless the hundredth digit was an error and it should have remained 256. However, this modification remained in place up to 1973. No explanation can be discovered for this increase and is incomparable with other codes.

We find the most significant modifications to the horizontal pipe sizing in 1973. During the 1973 code cycle, the technical committee agreed that the fixture unit values for pipes sizes four inches and greater were not based on ¼-inch per foot slope, but rather 1/8-inch per foot! This added error upon error. The committee removed the ¼-inch per foot reference from the title of the table and moved it to a footnote. The footnote additionally provided a multiplier that purportedly reduces the fixture unit values for 1/8-inch per foot slope.

Wrongfully assuming that the fixture unit values for pipe diameters four inches and larger were based on 1/8-inch per foot slope instead of ¼-inch per foot slope (when in fact they were based on ½-inch per foot slope), the fixture unit values were increased by a diversity factor of 1.2. This diversity factor was determined by the ratio in fixture unit values between 1/8-inch per foot slope and ¼-inch per foot slope according to the Plumbing Manual BMS66 (the ratios are the same for the ASA Code as adopted by the two other model codes). Table 9 demonstrates how this diversity factor was derived.

To decrease the fixture unit values from ¼-inch per foot slope to 1/8-inch per foot slope the diversity factor is 0.833, which is the factor noted in the *UPC* footnote (rounded to 0.8). Using the diversity factor of 0.833 to modify the fixture unit values in the 1973 table will actually reduce the fixture unit values to ½-inch per foot slope and not 1/8-inch per foot slope. The present fixture unit values in the *UPC* for pipe sizes four-inch and larger have been significantly increased based on mistaken assumptions. Furthermore, the constant slope ratios in the Plumbing Manual differ from the slope ratios in BH13 as displayed in Table 5, which are not constant.

The resulting 1973 *UPC* horizontal pipe capacities in fixture units for pipe diameters of eight-inches and greater is unprecedented and significantly transcends pipe capacities by 34 to 46 percent when compared to any other model plumbing code, including the Federal Plumbing Manual BMS66 (1940), which was a significant advancement from BH13. When applying the diversity factor of 0.8 toward the 1973 pipe sizes four-inch to six-inch, the resulting capacities are less than any other model plumbing code capacities for 1/8-inch per foot slope by 4 to 18 percent.

The *UPC* sizing table for horizontal drains has progressed no further since the 1973 modifications. Perhaps the saving grace for the exaggerated capacities for larger pipes is that Hunter's 1928 estimates were soon dated. Like the original probability model for drainage stacks, Dr. Hunter also abandoned this model for horizontal drains. Hunter continued to modify the tables as we have previously noted, and by 1940 he provided completely new drainage capacity tables that were published in the Plumbing Manual BMS66 based on a new probability model and a better understanding of surge flows and continuous flows in a drainage system. In the 1940 Plumbing Manual we already see Dr. Hunter increasing the capacity in fixture units for horizontal pipe diameters of four to six inches that are greater than the *UPC* 1973 modifications.

Dr. Hunter's pioneering work published in Report BH13 is one of the most significant contributions toward applied science in plumbing system hydraulics, laying the foundation for the formulation of essential regulations and sound rules of practice for plumbing design. When originally published, letters to the National Bureau of Standards (NBS) urged its continued publication for use as a textbook in institutions of higher learning for plumbing engineers. Today, this publication is rarely known or referenced. Yet the model codes are still built upon this foundation.

It seems apparent from Dr. Hunter's work that Report BH13, though foundational, was expected to be under constant revision in accordance with the progress of research. In fact, the National Bureau of Standards continued such investigations many decades after Hunter's final work in 1940 and the published results are still advantageous for plumbing engineers and code bodies as markers pointing to the next needed research for continual development of the plumbing code.

If nothing else, this article serves as a marker pointing to needed research on drainage systems designed with low-water consumption fixtures that could influence the development of new pipe sizing tables for vertical and horizontal drains. Flow rates, water volumes, and the duration of toilet discharges have decreased, affecting the probability of overlapping surge discharges and the mean flow rate in building drains and sewers. Also, consumer awareness is increasing, resulting in behavioral changes tending toward water conservation and less demand upon the plumbing system. How does this impact pipe capacity in terms of fixture units? Can there be increased groupings of fixtures in a common branch for a given pipe size if there is less chance of overlapping? Can the venting system be reduced if the discharge load is decreased? These are only a few questions encouraging further research. Until a path is forged for such plumbing research, code development for system pipe sizing design will remain stagnant. Therein lies the present challenge facing the plumbing code.