A5) “Hunter” Fixture Units Development

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Abstract

“Hunter Fixture Units” appear tabulated and referenced in worldwide variations for plumbing design for pipe sizing and capacity determinations. Dr. Hunter applied binomial probability theory in application to simultaneous events of water usages and drainage discharge events for design parameters of building plumbing systems. His publications presented graphs/tabulations for pipe sizing. The derived basis from binomial theory frequency analyses of usages resulted in tabulations that provided a means for selecting pipe sizes for adequacy/functions. From limited actual building usage patterns, data, and extended laboratory research the necessary piping requirements for both supply and discharge emerged in tabulations and design curves.

Dr. Hunter at National Bureau of Standards undertook plumbing research 1921 to his demise in 1943.
The planned identified future reports were not undertaken.

Keywords

Plumbing design, building drainage, potable water systems; building pipe sizing; plumbing codes; waste and water plumbing; plumbing detain methods; fixture units
1. Introduction

Plumbing systems actuations occur randomly and intermittently with variable magnitudes (probability for such events). Dr. Hunter introduced binomial probability theory for simultaneous events for water pipe supply and drainage systems that set sizing requirements. Improved procedures for loading tables were recognized as a need by the Coordinating Committee for a National Plumbing Code. Codification resulted from ‘fixture units’ (dimensionless) for probable instances in building pipe sizing for water supply and drainage design. The water supply and drainage loading tables in plumbing design applications were based upon loads in ‘dimensionless fixture units’ as created from probability of simultaneous events introduced for water supply and drainage design as applied in model codes and handbooks. Prolonged illness and subsequent death of Dr. Hunter left barren the detailed descriptions applied in preparing the technical paper on pipe sizes determinations/computation.

Design to codes for water supply and drainage requirements follow procedures with tabulated “Hunter Fixture Units”. From mid-last century into this era, the uncertainty factors in engineered systems sizing requirements demand for variations inherent to design loading results from determinations for unknowns with variability determinations from probability principals. Recent engineered sizing by adaptation of probability determinations adapted from post-1940 plumbing systems loadings variability concepts by Dr. Hunter found application to central air operations for hood/air duct loads/power needs of station/plant loads with great uncertainty of demand functions (2). That probability application of uncertainties drew on a referral to Dr. Roy Hunters’ applications to plumbing systems’ fixtures user loadings (1). Similarities for random events probability theory to engineered systems for sizing water and waste piping systems relied on uncertainties from usage variations in applications that led to a probability basis a means of quantifying a probable ‘not to exceed’ failure rate. Uncertainty impacts from incalculable variables in many engineering methods require probability - as developed for plumbing systems system sizing parameters design approximations.
Dr. Hunter in BMS 65 stated:

“INTRODUCTION” - Simplification and standardization must comply with accepted health regulations and minimum requirements for plumbing, which in turn should be based on scientific principles, The report deals with one of the factors, on which minimum requirements should be based, the maximum load to be provided for in plumbing systems. Other reports are planned dealing with water supply and water distribution systems in buildings, principles of building drainage, and principles of venting.

“PURPOSE” - Purpose of this series of papers is to collect in organized manner information obtained by the author over a number of years (from 1921 to research of 1937-1940) on plumbing, together with results from research (1937 - 1940) on plumbing with intervening experiments and interpreting results in a form suitable for direct and practical applications. It hoped that this series of papers will supply logical answers to questions pertaining to pipe sizes and design of plumbing construction.

Primary source documents (1, 3) present graphical (illustrated) and tabulated loads results from probability theory applied to plumbing systems design requirements by
Dr. Roy Hunter. His research extended over more than two decades. His detailed research/analyses and introduction from binomial probability theory applied to specific fixtures functions/user demands. Currently details developed for pipe sizing in plumbing remains applicable with modified details.

The “fixture units” terminology appears for pipe sizing of plumbing systems design and regulatory information in “Hoover Code(s)” (5, 6, 7) with different definition from the 1940 probability concept. Use of the terminology applied to both design and regulatory requirements.

Observations (members of the committee) regarding use of water closets in public places resulted in definition “… intent established rate of discharge of ordinary wash basin at about 7.5 gpm, so near to one cubic foot minute that it was taken as the definition of one fixture unit... in the initial usages. Terminology code changes occurred after the research applications adopted from probability principles analyses based upon actual fixture usages (supply or discharge) from defined user functions.

1.2 Secretary of Commerce - Herbert Hoover Recognition - 1924 (4)

Three sequenced reports (4, 5, 6) - recommendation of Dept. of Commerce Building Code Committee. Reports - BH2, BH 13 – (same title – ‘24, ‘28, ’32 - known as “Hoover Codes”) were initially requested by Secretary of Commerce Herbert Hoover (later 31st President). Statement from the 1924 code “… Actual practice has been
governed by opinions and guesswork, often involving needless costly precautions which many families could ill afford. The lack of generalized principles is responsible to a certain extent for the contradictory plumbing regulations in different localities …”. Illustrations are shown (1931) and cited elements made for continued research at NBS were noted with identification for the historically significance from NBS plumbing research by Dr. R. B. Hunter (he was a leader in plumbing research at National Bureau of Standards from 1921 to 1943). The acknowledgment stated “Especial commendation should be given to Dr. R. B. Hunter for his ingenious and accurate physical investigations of the hydraulics and pneumatics of drainage systems under various conditions of use” (Chapter 7 extended contents on “Sizes of Soil, Vent and Waste”).

1.2 Earlier Competence - Back to 1924

Initial documentation published in 1924 from developments of team efforts established a new Plumbing Code; examples form that initial report are illustrated.

1.3 Supplementary Information

The prolonged illness and death of Dr. Hunter left barren details/descriptions applied in preparing the report for fixture units based upon binomial probability of simultaneous events. A July 29, 1946 draft report (following WWII) by John French (7) undertaken to investigate Dr. Hunters’ files provided indications of source materials but was not published. Selected information for sources and basis of formulation of fixture units as developed and published were sought as set in a directive “… examining Dr. Hunter’s files” dated. Selected materials for information/suppositions from records/assumptions attempted to establish the
origins/resources and applications in Dr. Hunter’s developments. The primary focus of the task was “...to reconcile requirements of “A.S.A Plumbing Code and Plumbing Manual BMS 66”. That apparently was not resolved although conclusion stated was not to support the ASA version based upon differences between the methods form that study. (Note - ASA – American Standards Association refers to a Standards Committee (AESC) - AESC became the American Standards Association (ASA) in 1928. ASA was reorganized (1966); in 1969 became United States of America Standards Institute (USASI) and now ANSI.

R. Wyly (8) comments related Fixture Units background developments and sources that noted aspects of Dr. Hunter investigations. Comments provided limited indications of tests that Hunter had previously conducted and selected testing results. The research efforts enlarged the database from testing and gave newer design data for larger and complex plumbing drainage system configurations not previously evaluated and data tables presented in the report. Extension of fixture units sizing for capacities of drainage systems was proposed for needs future efforts for applications to larger drainage systems.

1.4 Other Research

Researchers at other U.S. and worldwide plumbing testing facilities were underway (illustrated) but it is unknown to what extent collaborative undertakings were undertaken. U.S. specialists shared inputs and were involved in the evolution of the “Hoover Codes”. Referrals to the studies of such investigations appear in the Hoover code outcomes. Later efforts by Dr. Hunter from continuing research
apparently led to advances for **FIXTURE UNITS concepts** developments with probability basis from continuity of research activities on an independent path.

Elsewhere, plumbing systems applications for varied design methods continued. An example from a 1962 report from Great Britain, twenty years following Hunter’s report, maintained pipe-sizing methods from earlier basis of flow designations that applied to pipe sizing design as recommended practice.

### 2. Publications Noted

**Background** - Information preceding the 1940 Hunter report directed for pipe sizing designs for plumbing systems based upon “Hoover Code(s)” (4, 5, 6). Sample illustrations shown indicate source basis applied to establishment of purposes. Methods for plumbing system design plumbing requirements for designers’ for system services capacities buildings resulted from collaborative efforts. Implementation to regulatory purposes established systems’ requirements in locales for regulatory acceptances (where codes applied). Hoover Code terminology applied “Fixture Unit” terminology but not as Hunter later established as integral with probability concept usage.

The water closets served as a basis for fixture of supply and drainage parameters that required detailed data input from test data for fixture discharge profiles (quite varied). Sample illustration indicates use of a tracing technique for recording time varying water closets’ discharges into a collection chamber that provided measurement records noted in the figure. A test configuration balance (also shown) had provision for elimination of water discharge loading impacts. Data for collected volumes as function of discharge time indicated many profiles with multi-peaked outflow profiles (formatted as flow rate vs. time).

Over time Hunter Fixture Units modifications occurred but with few detailed study reports or detailed analyses/evaluations as codes/manuals adopted newer requirements. Recent investigators applied probability Monte Carlo event computer methods to random loadings, some for multistory buildings (reported at CIB W62 Symposia). Such concerns need address. Extensive data sources reported by researchers to CIB W62 on usages applicable to design requirements have been on diverse user-required capacities and consumption in restaurants, exercise facilities, hot tubs/bath-houses and tall buildings. Simultaneity usage patterns concerns from very recent water
conservation actions (significantly less duration times) may result in limitations for simultaneous event history with reductions of ‘overlapping’ simultaneous events/functions.

3. Target Documents

Subsequently the model codes adopted Dr. Hunter procedures that also appears in handbooks for domestic and worldwide usages (often locally altered tabulations). Current U.S. codes include similar tabulations but now modified and altered for water conservation needs, and appear in reference handbooks by plumbing and water utility sources. Frequent referral and terminology identification to “Hunter” persists in current times. Tabulated ‘fixture units’ for water supply and drainage design for fixture loads remain a primary dimensionless system for established code applications requirements for pipe sizing in buildings1.

From the report: The Foreword by Lyman J. Briggs, Director of NBS, states: “… additive reports in the Building Materials and Structures series will be written”. “This report deals with one of the factors which must be considered in the selection of adequate yet economical sizes of pipes for plumbing systems – namely, the load to be expected from a given number and kind of plumbing fixtures”…….“This report deals … in the selection of adequate yet economical sizes of pipes for plumbing systems – namely, the load to be expected from a given number of fixtures and kind of plumbing fixtures… ‘….. “…estimating loads …, it will be understood that such numerical values, when not the actual results of Bureau tests or experiments, represent the author’s judgment in regard to the most suitable factor to use in the application of the method, and that these are not to be regarded as standard values, unless after approved as such by a representative and authoritative body.”

The author’s Abstract stated: “.. that a method of estimating the demand and sewage loads for which the provision should be made in designing plumbing systems in order that the service may be satisfactory. … The relative load producing values of different kinds of commonly used plumbing fixtures are analyzed, and a table is developed giving relative load weights in terms of a load factor called the ‘fixture unit. An estimate curve developed by the means of the probability function is given, and its use in conjunction with the table of fixture units is illustrated.”

1 Decades later “DRAINET” developed by Prof. Swaffield provides computer numerical solutions for transient partially filled drainpipe attenuated drain flow dynamics (9) with solid(s) waste transport.
Section II - effort extent in “Purpose” provides: “...organized from the mass of information obtained by the author over a number of years, beginning with the investigation in 1921 of plumbing of small dwellings, and including...... current research (1937-40) on plumbing for low cost housing, together with the results of intervening experiments related to plumbing requirements, and to interpret the results of these investigations in a form suitable for direct and piratical application. ...”

3.1 Associated Reports

Dr. Hunter provided application based utilizations based on Fixture Units descriptive usages. Few reports show publication date sequences that vary, possibly due to Institute required review procedures (3, 10). Example of the Plumbing Manual applications specific to water distribution systems provides fixture water supply application for sizing demonstrates that noted differences from existing methods (at the time) for new Fixture Units utilization of Hunter method.

The figure compares demand estimates in gpm usage from the so-called probability function in manual of 1923 with new mode. There, demand cited in gallons per minute directly for several fixtures shows indicated estimated irregularities cited as erroneous since “... the estimates for given increments in numbers of fixtures should gradually approach a constant minimum as the total number increases.”. The discussion suggested “… tendency to oversize supply pipes does not lie in any inherent fault in the probability function, but in the method …. but a table which does not provide for the probability, or rather the improbability, of overlapping between or among two or more groups of different kinds” (3).
Tabulated ‘fixture units’ for water supply and drainage design remained a primary system established in code requirements (modified over time) as changes developed for altered required fixture capacities.

4. Requirements - Loadings - References

Many design and code examples appeared for required sizing practices in the tabulated listings of Hoover codes. From the ’32 version tabulated required drains and stacks loadings of drainage elements from fixture units (definition of that time) examples are shown. Later Hunter developments from probable loading developed listings based upon probability of simultaneous event conditions differed substantially.

Fixture Unit applications of the method in plumbing systems design were necessary for implementations with explanatory introductions and details/explanations to water supply and drainage systems. Differences cited needs for achieving descriptive documentation for design and use in regulatory applications with requirements and rules illustrated for applications to demonstrating compliance. Even in the “Plumbing Manual” (3) there appears “…still a marked lack of agreement among recommended plumbing requirements” and also the purpose indicated that “.. intended to serve as a guide in their own work and as recommended procedure where local codes do not govern.”
The undertaking by J. French (7) was an attempt to seek greater knowledge of the basis for Hunter’s published reports.

4.1 Perspectives

Indicated research aspects noted on Dr. Hunter investigations by R. Wyly (..) in related materials on Fixture Units developments are to the point of the topic. Comments in the report provided test series limitations or indications from certain historic parts of past testing methods. Report applications to water demand pipe system sizing from tabulated fixture units were described and special concerns indicated in table footnotes. For drainage systems utilization of Fixture Units ratings concerning implications from the earlier reports and results from additional test series introduced later interpretations for drain loadings as derived from detailed testing series and results/conclusions.

From earlier Hunter test efforts rather unique experimental developments were noted and indicated test experimental illustrations. Water closet discharge profiles and drain connected indicated attenuation of flows were determined.

That prior research demonstrated surge attenuation from water closets interacting with other pipe flows. The attenuation of surge waves combined with other essentially steady fixture outflows (washbasins, showers, and baths) had become an aspect of needed data applied to developments in tabulated correlations developed for fixture units. Newly measured distributions of attenuated water closet surges also were developed but shown as
normalized water depth to drain diameter but substantiated earlier measured data forms. Extensions for tabulated loadings results to design applications for allowed loadings in determining allowable total drainage discharges (not in Fixture Units) for design purposes was not made. The methods extended scope of tables to buildings greater than three stories or more in height and for systems with relatively small horizontal branches. The Wyly study showed tabulated results that indicated the extent of capacity increases in drains when surges occurred. As stated: “capacities for hydraulics in steady gravity driven flows are constant” and “of limited value in solution of problems of surge flow”. Further, for surge flows “hydraulic elements vary both with distance and time at any cross-section”. The tabulated test indications ranged over values from two to five times the capacity for steady flow conditions. Expanded series of tests for branch drain discharges into main drain (few varied conditions) with unsteady flow from branch loadings were undertaken. Compilations into broad tabular data listings for applications to branch installation designs resulted.

5. Hunter BMS 65 (1)

The report Foreword by the Director L.J. Briggs, states “This report deals with one of the factors which must be considered in the selection of adequate yet economical sizes of pipes for plumbing systems — namely, the load to be expected from a given number and kind of plumbing fixtures. Also, “...it will be followed by other reports in the Building and Materials and Structures series dealing with other aspects of plumbing problems”.

From the authors’ Introduction “Simplification and standardization must comply with accepted health regulations and minimum requirements for plumbing, which in turn should be based on scientific principles, The report deals with one of the factors, on which minimum requirements should be based, the maximum load to be provided for in plumbing systems. Other reports are planned dealing with water supply and water distribution systems in buildings, principles of building drainage, and principles of venting.” And in the “Purpose” there appears “this series of papers is to collect in organized manner
information obtained by the author over a number of years (from 1921 to research of 1937-1940) on plumbing, together with results from research (1937 - 1940) on plumbing with intervening experiments and interpreting results in a form suitable for direct and practical application. It is hoped that this series of papers will supply logical answers to questions pertaining to pipe sizes and design of plumbing construction”.

Selected report materials indicate Fixture Units developments for the adopted technique and methodical procedure adopted. Developed materials apparently resulted from the depths of efforts from prior studies, acquisition of vast amounts of test data, analytical determinations and organized compilations of comprehensive sets of data from many prior years of research.

Selection of minimum pipe size requires accurate flow capacities for conditions to be used for load and to know accurately the load the pipe will be called upon to carry. Pipe flow formulae (usual means of estimating pipe capacities of pipes) expressions are based upon dynamic equilibrium
and applies only to the irregular and intermittent flows that occurs in plumbing systems during that time (usually very short) and in that section of the pipe in which the variable factors involved (velocity or volume rate of flow, pressure, or hydraulic gradient, and hydraulic radius) are constant and applies only to the particular conditions – namely, condition of uniform continuous flow in the pipe. Hence, conventional pipe formulae applies to irregular and intermittent flows that occur in plumbing systems only during that time (usually very short) and in sections which the variables involved (velocity or volume rate of flow, pressure, or hydraulic gradient, and hydraulic radius) are constant. That descriptive explanation was an attempted explanation for conditions of “steady state approximations” utilization.


Applications of Fixture Units for practical implementation procedures were provided in the Manual (3). Anticipated benefits from newly developed procedures and applications were indicated to be:
- Especially for large buildings;
- Better sewage transport
- More satisfactory operation
- More economical construction.

The report background had past committee actions with input or reviews for the new document. It is divided into two parts -
(1) General and basic requirements; Subject matter not likely to need frequent revision, and
(2) Matter likely to need revision to keep abreast of current standards when revision is advisable.

Detailed sample to both water supply and drainage applications illustrate use of Fixture Units. No distinctions or differentiation for utilizations of Fixture Units separately or for needs of adjustments from initial developments. The BMS 65, where the origins and

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2 Early recognition for dynamics’ essential details were not readily established at that time of his research.
source indications were provided, the supply/discharge seemingly appear commingled for further applications. **That issue of whether there exists a need to distinguish or utilize the aspects together or separately remains open and the subject requires further considerations.** Are there any limitations or assumed utilizations to both aspects of piped plumbing applications? Scrutiny of those developed bases/descriptions for developed and recommended Fixture Units from probability of simultaneous events requires further study since of implied generalities to both water supply and drainage does not appear or specifically addressed in published discussion of the earlier developments as applied directly in BMS 66.

Report applications provide illustrative examples with discussion of usages to applications for many aspects of plumbed systems in small and large buildings and extension to roof drainage applications/ combinations with drains and storm systems. However, the examples do not discuss the aspects of load simultaneity of the system but imply such states. Sample from the report indicates the breadth.

J. FRENCH 1946 Report (7)

The task of researching Dr. Hunter's files following WW II was an attempt to establish aspects from research and developments in setting the new method of Fixture units into applications that had indicated

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### Notes

- **Report 8.4** (6092): Allocation for Possumo Water—To note a small project above a road in walk to a vacuum that stores water from the wall into the road, the following allocation are made: If two pipelines are available with one of different diameters, after 60% of the water used in the higher and 40% of the water in the lower, or if the water used in the lower and 60% of the water in the higher, or if the water used in the higher and 60% of the water in the lower, or if the water used in the lower and 60% of the water in the higher.
- **Section 8.4.1.1**: For one wall only, add 50% of the water used in the higher and 50% of the lower. forexample, if 150% of the water used is in the higher and 50% of the water used is in the lower, add 50% of the water used in the higher and 50% of the water used in the lower.
- **Figure 8.4.1.1**: Illustrates allocation for Possumo Water—To note a small project above a road in walk to a vacuum that stores water from the wall into the road, the following allocation are made: If two pipelines are available with one of different diameters, after 60% of the water used in the higher and 40% of the water used in the lower, or if the water used in the lower and 60% of the water used in the higher, or if the water used in the higher and 60% of the water used in the lower, or if the water used in the lower and 60% of the water used in the higher.
differences from the then accepted standard. The draft report was not published; several aspects from a copy are indicated from materials assembled for the report.

A few examples are reproduced from that study to illustrate selected report findings. That source indicated the limited extent of information found (or determined) from the files and records and limited resource materials found. The study specific “Conclusions” (shown in the reproduction) indicates “recommending that the Bureau (NBS) should not concur in publication of the proposed (at the time) code”. Several additional findings reported that newer considerations by Hunter after the initial reports (BMS 65 & 66) publication seemed likely. Other selected indications are provided in the copied materials.
Sec. 3297. Shaping Trains and Sewers (Sanitary Only).

(a) Horizontal branches — the maximum number of fixture units installed on a horizontal branch of a given diameter shall not exceed the values given in Column (2) of Table I.

(b) Primary branches — the maximum number of fixture units drained into a primary branch of given diameter and slope shall not exceed the values given in Column (3) to (6) of Table I, except as provided for in paragraph (c) of this section for pressure drainage conditions.

(c) Secondary branches and Main Building Drains (Sanitary System only). If the building drain has one primary branch only, or not more than one secondary branch of 3-inch diameter or larger, the main building drain shall be of the diameter required by rule 3 for primary branches, except as provided by paragraph (b) of this section for pressure drainage conditions. If the building drain has two or more primary branches of 3-inch diameter or greater, the number of fixture units drained into the main building drain and its secondary branches may be increased by 10 percent, of the number permitted for a primary branch of the same diameter and slope, for each primary branch upstream from the secondary branch or main in question within the limit given in Table I, provided

1. that the building drain and its secondary branches are laid at a uniform slope,

2. that all connections are made by means of single-wythe fittings, and

3. that no primary branch which extends less than 15 feet in length at grades before connecting to the main or a secondary branch shall be counted in applying this rule. The provisions of paragraph (c) shall not apply except when construction plans showing the size, length, and grade of such branch are submitted for approval by the authority having jurisdiction.

(d) Pressure drainage conditions. In cases where horizontal branch or other trapped drain connects to the sanitary drainage system within 3 feet above the grade line of the building drain (sewage ejection excepted), the permissible number of fixture units as given by Table I for primary branches and expressed under paragraph (c) for secondary branches and main building drain may be increased by the factor (1 + 1/3 y/h), where y is the total fall in feet in the building drain including its longest branch and h is the elevation in feet of the lowest horizontal branch above the horizontal plane through the end of the main building drain. The provisions of this paragraph shall not apply except when construction plans as required for the application of paragraph (c) showing in addition the elevation of the lowest horizontal branch on all plans in the system and details relating to any other proposed connections such as a sewage ejector, are submitted to and approved by the authority having jurisdiction.

(e) Building sewers. The building sewer, if laid at the same slope as the main building drain or at a greater slope, shall be of the same diameter as the main building drain.

If for any reason it is necessary to increase the slope of the building sewer below that of the building drain, the diameter of the building sewer shall be such that its capacity for non-pressure drainage (paragraph (c)), as given by Table I (columns (5) to (8)) for main building drains for the slopes to be installed, is equal to or greater than the number of fixture units to be carried and the diameter of the building sewer for pressure drainage (paragraph (d)) shall be such that building drains for the slopes to be installed, is equal to or greater than the number of fixture units to be carried and the diameter of the main building drain.
8. Conclusions & Recommendations

The review provides an historical perspective for insights on methods developed that introduced “Hunter Fixture Units” into practices for plumbing systems and continues as a means for plumbing engineers/designers and as applied in adopted local authorities’ applications for plumbing code requirements.

Considerations for further study involving probability analyses have broadly expanded by computer numerical methods applications of Monte Carlo and other techniques applicable to random event(s) theory and interpretations. Extensive field usage data from CIB W62 colleagues’ presentations to W62 provide resources that offer opportunities to generalize and further evaluate statistical loadings/simultaneity aspects. Those efforts could contribute greatly to current thrusts for water conservation.

Function times for water closets have decreased to about four seconds for water closet discharges for new reductions of water consumption - down to about four or five liters, or 1.28 gallons, that vastly alters probable simultaneous event overlaps. With that factor for probable simultaneity a decrease of probable t/T value occurs (about 250 %) and then simultaneity for concurrent events in usages may not correlate with the fixture unit value of six as adopted in the Hunter curves/report.
Direct computational designs based upon numerical methods of solution for the governing dynamic equations for flow in partially filled pipes (also full bore flow techniques) also provides means for plumbing system designs (as advanced by Prof. Swaffield and Heriot-Watt team with several others). This alternate method avoids tabulated listings and provides great flexibility with competency for individual design basis of many building applications and usage(s) for specifics applied to conventional and individualistic design applications. Detailed study comparisons would be a useful evaluation for decisions on applications from conventional tabulated values to more exact method for plumbing systems designs.

9. Presentation of Author

Dr. Lawrence Galowin is a consultant, formerly a National Institute of Standards and Technology (NIST) leader in plumbing research; now retired but serves as Guest Researcher. Consultant in: desalination developments by wave energy pumping for RO methods & potable water relief by Slow Sand Filtering. He also serves on ASME national plumbing standards committees, and continues performance parameters research.

10. References

4. Recommended Minimum Requirements for Plumbing in Dwellings and Similar Buildings, Report of the Coordinating Committee for a National Plumbing Code, Dept. of Commerce, Domestic Series No. 28, July 1923 (Hoover Code ’24)
5. Hoover Code 28, Revised August 1928
11. Appendix

I. From Section III Definitions and Symbols (1): Clarity of special defined elements:
A number of terms employed in the plumbing industry, and a few that are now
introduced for the first time, are defined in the sense to be used in this (and later
papers) of this series. Included are following listed elements and others in the report:

- plumbing system
- building main
- water distributing system
- sanitary system
- plumbing fixture
- drain
- fixture drain
- waste pipe
- soil pipe
- stack
- horizontal branch
- building drain
- building sewer
- primary branch; secondary branch
- vent or vent pipe
- vent stack or main vent
- Demand load; Sewage load
- Charging load
- Receiving capacity
- Terminal velocity

Design factor $m$ is the particular value of $r$ out of $n$ fixtures that will be found in
operation a selected fraction of the time under the assumed conditions of use.
 Fixture unit, or load fact, is a numerical factor which measures on some arbitrary
scale the load producing effect of a single plumbing fixture of a given kind. The use
of the fixture unit makes it possible to reduce the load-producing characteristics to a
common basis.
 Specific symbols follow:
$n$ = the total number of fixtures or supply openings of a given kind in the system.
$r$ = the number of fixtures out of a total of $n$ which at any given instant of observation
are found operating to impose a demand load on the supply system, or a sewage load
on the drainage system.
$m$ = the design factor (definition above)
$q$ = the average volume rate of flow, in gallons per minute, to or from a plumbing
fixture during actual operation. $Q$ = the total volume of water in gallons that flows or
is discharged by a fixture at each use.
$t$ = average duration of flow in seconds for a given kind of fixture for one use
$T$ = average time in seconds between successive operations of any given fixture of a
particular kind
$\tau$ = time interval in seconds such that the event in question (for example, exactly $r$
fixtures will be found operating will occur for an aggregate off 1 second
$C_n^r$ = number of combinations of $n$ things taken $r$ at a time
$p_r^n$ = probability of exactly $r$ fixtures out of a total of $n$ fixtures being found in
operation at an arbitrary instant of observation
$\sum_{r=m}^{n} p_r^n$ = the probability that some number of fixtures between $r=m$ and $r=n$,
inclusive, will be found operating at an arbitrary instant of observation
II. From (8) the Reference List provides some insights into topics that were of interest in a selected number of plumbing research efforts following WW II.

8. References


[16] F. Sommer, Studies made on vertical drains at 100 mm diameter, Trade School, Bern, Switzerland, 1963.
