Hunter Fixture Unit Probability/Uncertainty

Dr. Lawrence S. Galowin
lgalowin@nist.gov, larrygales@earthlink.net
Dan P. Cole
Dp.cole@hotmail.com, ICC, IAPMO, IPIA

Abstract

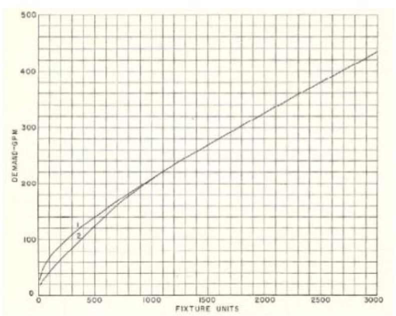
Hunter Fixture Units revisions study was initiated for IAPMO code pipe sizing tabulations to water/energy conserving fixtures/appliances (1). This method for pipe sizing in building water systems applications remains a current United States practice. Different values from the original report have evolved over time. Initial focus is on residential buildings and commercial buildings sector at a later time. This study presents progress from search efforts for timely data sources. Current field data is essential to updated needs for loadings in pipe sizing procedures. Computer program preliminary calculated indications show reduced water demand flow rates from predictive curves. Data source information from field measurements illustrates impacts from reduced water consumption with energy/water efficient appliances and fixtures. Preliminary revision aspects for new lowered fixture unit values are shown from preparations for later recommendations to be made.

Key Words
Hunter Fixture Units, Dr. Roy Hunter, plumbing water supply, building water pipe sizing, and residential building water needs

1 Introduction

Excerpt - The probabilistic method for buildings plumbing systems pipe sizing has a historic adoption of the method "Hunter Fixture Units" and in BMS 65 Foreword– Lyman J. Briggs, Director National Bureau of Standards stated ***"… report deals with one of the factors which must be considered in the selection of adequate yet economical sizes for plumbing systems – namely the load …"***
Closing by Dr. Hunter stated ***"… impossible to determine or to estimate closely either the maximum demand load … that will occur in***

Estimate Curve for Design Purposes



service. …estimate the loads having a certain probability ...” (1)
Plumbing code revision needs for Hunter Fixture Units were initiated by a task group to prepare recommended water pipe sizing changes of IAPMO code. Recent field test investigations offer some details on user needs from measured events with field dynamic test data acquisition systems. Results from relative ranking for new water savings equipment indicates changes for appliances/fixtures status as parts of total water consumption. New information leads to scrutiny: “What are the Hunter Curves and Should They Still be Used for Sizing” (2004 energy conference report - author unknown). Changes are significantly overdue since Energy Policy Act - 1992 (EPACT) along with other conservation recent endeavors by the Alliance for Water Efficiency (AWE) and Water Sense program of U.S. Environmental Protection Agency (EPA). D. Cole called for revisions in American Society of Plumbing Engineers (ASPE) publication. Hunter Fixture Units revisions study was initiated to recognize newest water/energy conserving fixtures/appliances utilizations. The method for water systems pipe sizing design in codes remains a United States practice. However, numerically lessened values from the original report have been adopted in prior years’ efforts. This focus on multi-family buildings will be followed for commercial sector. Frequent similar but broadened research on water pipe sizing have been frequent CIB W62 topics at Symposia.

Selected field test data on energy/water conserving fixture/appliances factors are discussed with emphasis on residential occupancy data. Dr. Hunter in 1940 introduced the probabilistic model developed from limited data sources on fixture usages at the time. Fixture Unit chart(s) changes are anticipated from data for newer water closets, showers, dishwashers, washing machines, faucets and urinals. Applications of alternate probabilistic techniques have been applied/derived by researchers (e.g., Monte Carlo method, AWWA research sponsored studies (2)).

Reductions in numerical fixture values became a code listing modernization practice but retention of the original curve persisted. Tracking the curve to lowered values of fixture units result in lower flow rates. But, tracing along Hunter curve implicitly assumes aspects of “universality”; as if the curve had an invariant derivation as the sole probabilistic generalization method and no revision required.

2 Change Needs Identified

Reductions for fixtures/appliance energy/water changes were mandated for conservation purposes [e.g., WCs – from 5 gallon down to 3.5 gallon and legislative follow-on in 1992 Energy Policy Act {EPACT} to 1.5 gallon and now a new AWE 1.28 gallon]. No engineering needs of new pipe sizing requirements for plumbed systems were attempted. Significant changes now appear in proportions of total water usages determined from recent retrofit field measurement comparisons that show

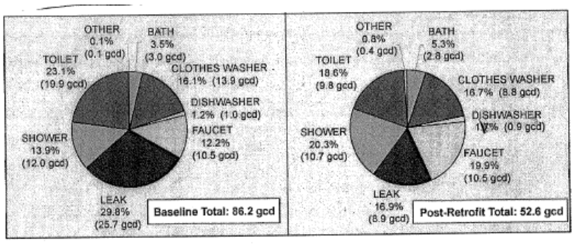


Figure ES.1 Comparing pre-retrofit (on the left) and post-retrofit (on the right) indoor per capita water use percentage including leakage

significant proportional reductions in utilization. Comparisons of pre- retrofit and post retro-fit water usages show new devices adoptions changed proportions from measured sites. Current energy conservation concerns have provided impetus for water reductions (hot water, pumping, water treatment plants, and grey water/reuse applications). Elsewhere, pipe sizing modification needs have been reported annually at CIB W62 Symposia by many investigators.

2.1 Adjustment Fundamentals

Water closets (WCs) usages previously were known to be the major factor of total consumption in dwellings - more than 40%. Now, with 1.5 gallon WCs and reduced fixtures consumption of appliances, shower flow rates with WCs represent about 20%. (leakages impacts appear but not all dwellings updated). Probable simultaneous loads distributions require studies of consumption data from measured site(s) on instant flow rates and patterns of usages, e.g., measured times for shower, clothes washer and faucet operation. The Hunter study applied flush valve and tank water closets (WCs) and baths from limited data sets for original probability determinations. Now, residential single family, small and large multi-family residential units in buildings need to account for laundry, dishwasher installations, and often with two or more bath/shower/toilet facilities.

At CIB W62 seminars detailed field measurements in buildings for time varied water events have been reported (3, 4, 5, 6). U.S. field dynamic measurements in field measured events reports that are oriented to energy requirements and overall water saving fixture achievements. Those data sources/analyses for loadings do not have a focus on instantaneous water demands; many provide verifications for user energy/water conservation elements but overlook time dependent water usages.

3 Aspects from Initial Outlook

Interim - Planned Studies:

a. Establish data sources with real time user profiles (beyond single family units for multi-family buildings). Assemble aspects for plumbing factors of concern.
b. Water conservation verifications from data emphasis on conservation fixtures/appliances and satisfaction ratings appear. Aspects on i nfluences of geographic locales and weather cycles have not related to energy differences of water supply temperatures into buildings. Trends will be sought.
c. Seek multi-family buildings real time records, analyses of instantaneous usages, occupant density, living areas and demographic data. Impacts of reuse and gray water supply substitutions for potable water upon s izing for building applications have direct consequences on potable water pipe sizing demand for selective functionary purposes.
d. Comparative and/or supplementary means for modifications from essential assumptions/fundamentals applied in BMS 65 report will be further analyzed for applications in an adopted probability method,.

e. Study and make determinations if modifications to multi-simultaneous events analyses and alternative probability formulations (e.g., Monte Carlo usages) are sufficient for replacements in procedures.
f. Investigate variants in methods applied to study water flow rate needs based on differentiating demand dependencies between volumetric requirements from flow rate time needs. Consider potentials of separating needs into a method for measures on sufficiency of supply. Determine operational requirements of filling water volumes in closet tank, dishwasher, and clothes washer from volumetric control sensor(s) prior to initiating start, rather than flow rates established methods now commonplace (implementing action only after complete fill). For pumping provisions in appliances activity inflow alternative for filling alone may be sufficient; then, almost any reasonable entry flow rate may be feasible. Impacts can result in moderate pipe flow supply rates.
g. Extensions may be foreseen for in-depth studies on related reduced flow rates and quantities impacts for the drainage/sewer systems.

4 Information, Resources Applied

Water conservation field data from transient data measurements reported are often based upon Meter-Master/Trace Wizard system utilizations (7). Recorded data signal results from detections of 'magnetic rotational elements' in water meters that produce detectable/recordable signal; the signal counter generates impulse information to a detector/ conversion record "counter" for instantaneous water usage events. Those permit accurate quantification by trained users for individual event distinctive "signatures" to determine the appliance or fixtures generating the demand. Those identify the device functioning for water flow rates and specific operation time intervals (preset events or user choice/control). The example shown does not indicate simultaneous incidents. Other survey information forms, or inquiries, also provide user satisfaction and acceptability or hint effectiveness/satisfaction. Most field data available is for single family home evaluations; that may be for ease of instrumentation/data recording with fewer complications/costs. Specific needs as an unfulfilled high priority exist for dynamic data measurements in multi-family and commercial buildings. Many buildings types have been studied and reported at CIB W62 seminars with field data and modeling for daily water requirements.

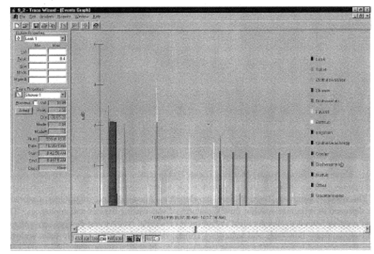
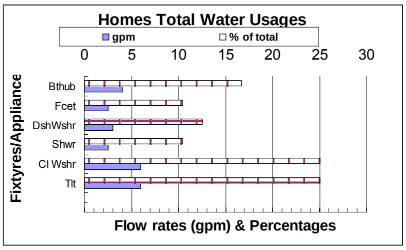

four pink events). For water uses that have multiple discrete events making up a complete cycle (e.g., a clothes washer or dishwasher), the first event in the series is identified with the event name plus the '@' symbol.

Figure 11. Typical Trace Wizard Output Screen Used in Meter-Master Data Processing

It is interesting to note that the shower event shown on the screen in Figure 11 begins with a small spike and then settles down to a flow of about 2 gpm. This shower was taken in a bathtub that also has a shower fixture. The initial spike represents the water being turned on at the bathtub faucet and let run before the bathtub shut-off was activated sending the water to the lower-flow-rate showerhead.



4.1 Single Family Data Examples

From field data report a listing of data sought was presented which influenced the depths of study; not all

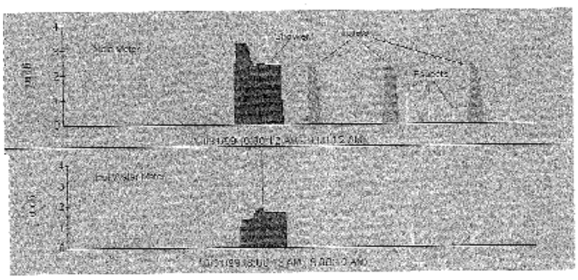


Figure 1: Simultaneous Flow Traces from Main (top) and Hot Water (bottom) Meters

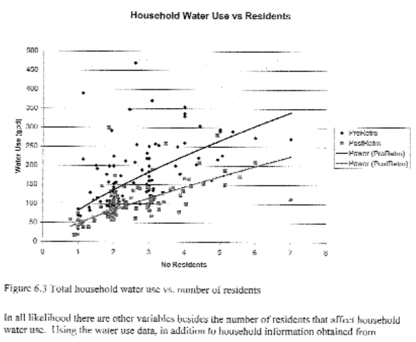
the items were recorded. The added column shows my added values
as estimates for anticipated further considerations of ranges. Not all fourteen elements were recorded. The field sample data figure provides a record with the recorded flow rates. In the figure a bathtub startup spike - from initial turn-on of bath faucet then change to a shower event of user time of 7 to 9 minutes) appeared. Also seen are other instances of actions but apply to the user applications and actions or patterns of usages but not discussed therein.

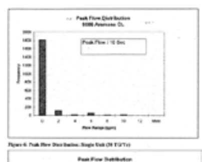
Fixture/Appliance Flow Rate (approx. gpm)	
Toilet	Tank types (1.5 gal) 4 -9 Flushometer types 20-25
Clothes Washer	2.5 - 6
Shower	2.5
Dishwasher	2 – 4 (Hot Water)
Faucet	2.5
Bathtub	3 - 6
Irrigation	-
Cooler	-
Hot tub	-
Other	-
Leak	-

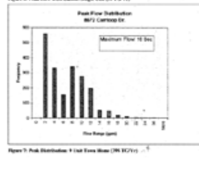
Since time is an integral aspect of this type of data collection then the morning, mid-day and evening patterns in family usage instances and activities for that particular household schedules would be deduced for users within the dwelling. Other needs remain for details of fixed or variable controls on laundry, dishwasher installations; also, specifics of bath/shower/toilet need to be established. In evaluation of the measurement accuracy and sufficiency a hot water measurement by independent water meter comparison with the Trace Wizard method was made. Results indicated agreement from both techniques for ranges of differing water flow rates over specific time intervals.

Similar, but differing requirements exist in commercial buildings, sport arenas, public gathering assemblies, and commercial or conference buildings may be determinable, but becomes a greater complex problem.
Extrapolations to apartments are uncertain due to occupant/family usages that may differ in apartment units since different, or fewer, installed appliances often occur. Additionally, living conditions can be different due to income and site locales. Also, conditions of work and school schedules or strikingly different occupant events can occur. Single occupancies are usually much different.

Influences of occupants' data for number of persons remain an open need or for people impacts. One study provided correlations that indicate greater peak water usages with larger numbers of individuals that increased flow rate ranges. The data appears with a correlation model. Data for aspects on elder persons or degrees of dependence, bed-ridden illness, impacts of children/ages, and mixed age distributions or child activities (pre-school, sports) can influence such patterns. Other desired aspects include comparative values for baths and showers, laundry frequency, dishwasher (scheduled) usages and specifics on demand preferences. Those







facilitate analyses of patterns as plausible for assumed commonality elements (e.g., teens utilize specific space cleaning/required bathing and also unusual clothes washing frequency from hobbies or sports activities).

4.2 Other Sampling Aspects

Broad test data assembly data from occupied dwellings usages (utilization of Meter-Master/Trace Wizard system) in 1188 ho mes had special emphasis for hot water detection statistics for fixtures of concern (9). Compilations showed peak flows above 7.5 gpm in 15,716 events recorded from total recorded. All data indicated **indoor peak flows at or below 7.5 gpm occurred 99% of the total** **with only 1% at top.** Segregated highest flow events were – clothes washer cycles 45.6%, toilet flushes 23.9%, 13.5% unknown, 12.2% showers, and 4.9% remainder baths, faucets, hot tubs and miscellaneous indoor usages. Of particular note is the small fraction of baths found in use. Simultaneous toilet flush and clothes washer cycles occurred. Other detailed analyses for the top 1% extreme events were with half between 7.5 and 8.5 gpm. Unknown needs remain for size/occupancy populations, family distributions, details of house size, number of bedrooms, number of bathrooms, age of the house, cost of water, hot water (analyses) and accounting for mains water supply temperatures.

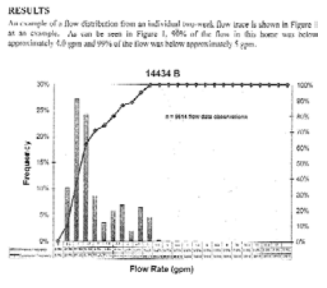


Figure 1: Example Flow Trace Graph

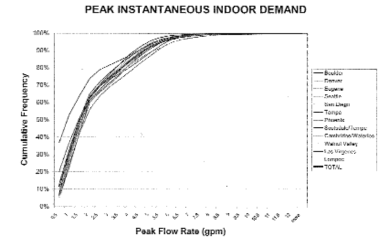
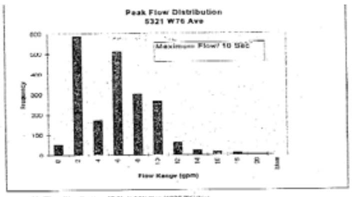
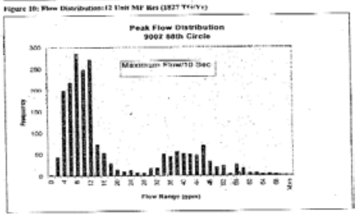


Figure 7: Peak instantaneous demand distributions from all 12 REUWS study sites





Other data considerations related to manual or pre-set control of selector options prior to operation are required; such settings impact patterns of water (hot and cold) demands.

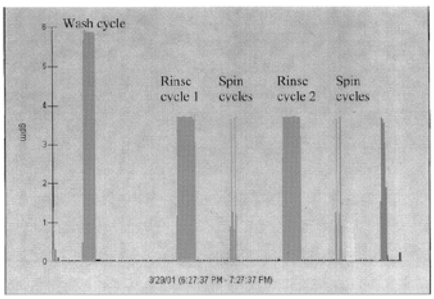


Figure 3.16 Sample clothes washer flow trace, 1990 Whirlpool Heavy Duty

This machine often operated with only a single rinse cycle.

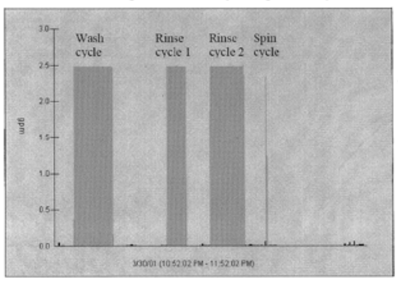
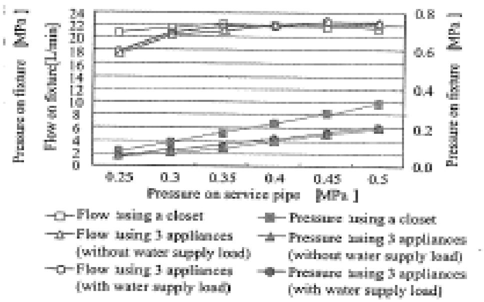


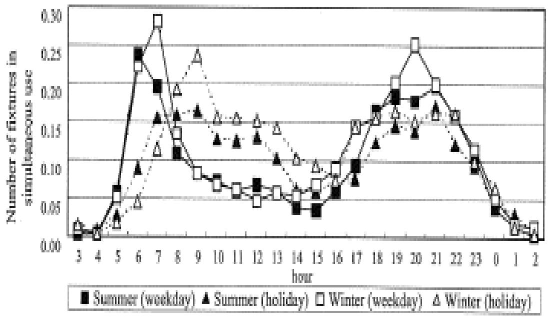
Figure 3.15 Sample clothes washer flow trace, 1995 Maytag Super Capacity

Clothes washer data points to total time durations of about one an hour for all cycles. Preset fixture flow rate schedules should be made available from manufacturer sources. Investigators need data on pre-set water levels (mixed hot and cold) for fill requirement. Illustrated peak flow rate changes shows 6 gpm down to 3.6 gpm, another fixture uses 2.5 gpm for comparable user instances recorded (also user choice may exist). Similarly, changes may occur in dishwashers. Options for differing water flows in cycles/flow rates and time periods is important in modeling considerations of water demand peaks with distinctions of cold and hot water supply. Knowledge for alternative several cyclic pre-programmed settings, or user choices, is necessary for modeling efforts. Variable settings for water flow options complicate modeling considerations of probable water demand peaks.

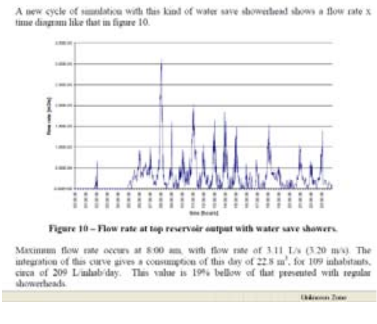
5 Multi-Family Aspects

Multi-family building usage investigations in a four-story partially occupied building site show data for season's trends was shown with modest shifts that reflect user activities (5). The authors indicated ".. frequency of occurrence of the number of





appliances used simultaneously from the measurement results was close to the results deduced from the Poisson distribution based on the average number of appliance used simultaneously". No occupant information was noted or user patterns revealed. Distributions indicate daily peak patterns in morning/evening with greatest usages and for both seasons. These data show two peaks - morning and evening - daily water usage distributions that correspond to reports for morning/evening periods as usually greatest demands. Those are similar to test data from single family homes. Of great interest is that less than 30 % of all plumbing fixtures were simultaneously used. Other information illustrated pipe pressures with `differing patterns. Experiments conducted separately in four floors triggered simultaneous event trials with impacts for supply pressures (test setup a part of a 100 m test tower). Simultaneous loads resulted in inadequate pressures for minimal requirements at fixtures; such pressure conditions are failures for desired performance. Other washing machine and dishwasher operations were not specifically noted. External activities may contribute to patterns, e.g., sport or entertainment at varied times. Scheduled utilization(s) periods may be dictated e.g., school periods, family clothing laundry loads planning, dinner, dishwashing and sleep but were not indicated.



A study of modeling plumbing utilizations of fixtures for simultaneous loads was applied to multi-family seven floor apartment building with 28 dwellings occupancies (9). The simulation model predicts daily instant water requirements for time dependent flows over 24 hours. Predicted values (as noted by the investigators) far exceed values known or anticipated. However, this capability that projects transients to user time dependencies advances steps to reality analyses of predicting plumbing demand factors. Another study included aspects from chaos theory application into a modeling means with a basis from real usage data.

A computer programmed model (10) for predicting building loads from generated random event schedules for hourly profiles of average event characteristics was listed from on-going literature search. The profiles average provides event characteristics and daily volumes. The method allows user entries for event flow rates and parameters for probable events and standard deviations (allowed set-up by prescribed users).

fified in the 2007 release of Excel.

An example set of events for a three-bedroom house in Las Vegas is shown in Fig. 7. The graph covers the period of March 1-8. Clustering of events and variations in event volume were visible, as we would expect in an actual household.

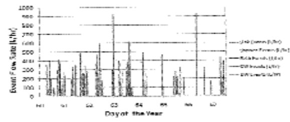


Fig. 7 Final event schedule for the time period March 1-8 for a three-bedroom house in Las Vegas

Validation

Once the event schedules were generated, we compared the output event characteristics with the inputs entered into the DHWcalc software to make sure the results were consistent. Table 5 summarizes the validation of several important event characteristics for the five end-uses, including average flow rate (μ_E), standard deviation of flow rate (σ_E), event frequency, and annual water use. Most parameters matched up very well except for σ_E, which was smaller than we specified for all five end-uses. In other words, there was not as much event to event variability as we wanted. Another concern was that sink event characteristics were not consistent with the input parameters, except for the annual flow volume. We have contacted the creators of DHWcalc to find the cause of these discrepancies and to make corrections if warranted.

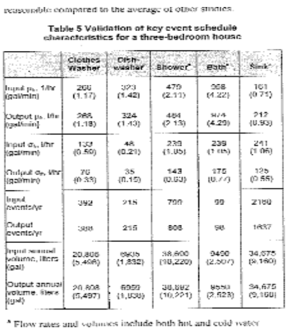
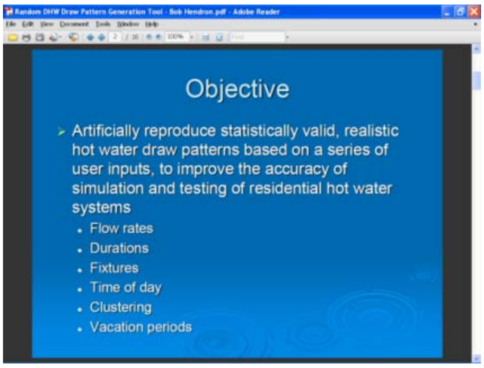

reasonable compared to the average of other studies.

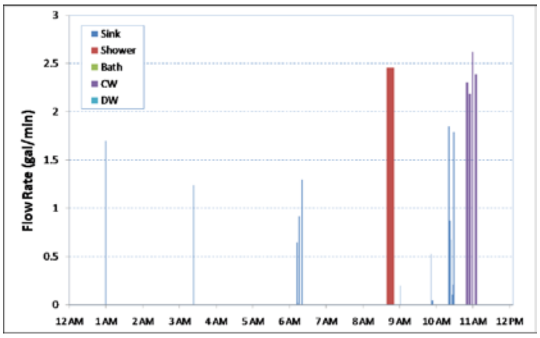
Table 5 Validation of key event schedule characteristics for a three-bedroom house

	Clothes Washer	Dish-washer	Shower*	Bath*	Sink*
Input μ_E, l/hr (gal/min)	266 (1.17)	323 (1.42)	479 (2.11)	958 (4.22)	161 (0.71)
Output μ_E, l/hr (gal/min)	268 (1.18)	324 (1.43)	484 (2.13)	974 (4.29)	212 (0.93)
Input σ_E, l/hr (gal/min)	133 (0.59)	48 (0.21)	239 (1.05)	239 (1.05)	241 (1.06)
Output σ_E, l/hr (gal/min)	76 (0.33)	35 (0.15)	143 (0.63)	175 (0.77)	125 (0.55)
Input events/yr	392	215	799	99	2190
Output events/yr	388	215	808	98	1837
Input annual volume, liters (gal)	20,806 (5,496)	6905 (1,832)	38,690 (10,220)	9490 (2,507)	34,675 (9,160)
Output annual volume, liters (gal)	20,808 (5,497)	6959 (1,838)	38,682 (10,221)	9550 (2,523)	34,675 (9,160)

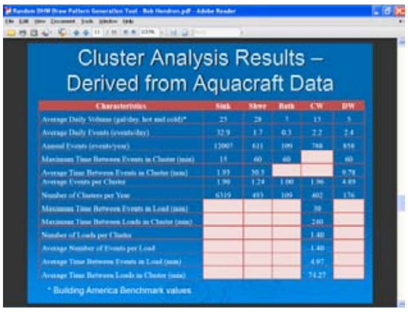
* Flow rates and volumes include both hot and cold water

In a conference presentation another means for determining hot water requirements with energy emphasis aspects illustrates field data





applied to another study (11). A twelve hour test data set of fixture demand data (from Aquacraft site test data was applied illustrated. Note the field data graph of data usages (Aquatech data) has no WC usages either as a suppressed signal or realistic in the time period example and no simultaneity events. The energy needs application results indicate an unspecified probability predictive approach (that may be in a document report). The emphasis on energy driven aspects appears here as the paramount driver.



6. Actual Multifamily Building Representation

Field studies data from single family and several apartment buildings was reported for water usages of different size apartment buildings (15). No user patterns or demographic data was provided by the investigators. The data sets list several apartment buildings monitored for presented information. Result comparisons to Hunter Fixture Units showed widely differing values. No data on specifics for plumbing fixtures installed were shown. These field tests were conducted after Federal requirements in 1992 EPACT (showers and WCs) and several sites were indicating as ‘pre’ and others ‘post’. Increased fixture units for larger buildings but measured flow rate values appear different for with same Fixture Units (whichever definitions of Hunter units applied).

The sample multi-family buildings tests show realistic data for multi-family comparisons applicable to purposes of this study. This source offers data over small ranges of apartments on t otal usages without discrete fixture actions reported in differing apartment buildings. Added factors that would contribute to understanding of the specifics of user demands were not shown. Effects of

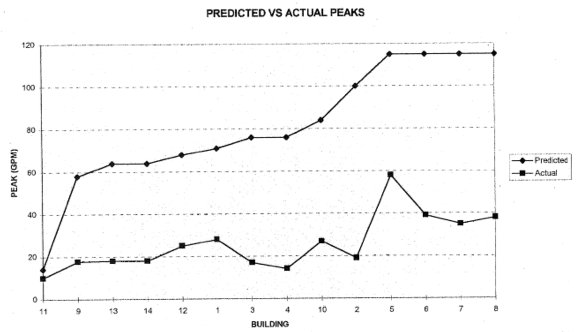


Table 15: Predicted and Actual Peak Demands in Multifamily Accounts

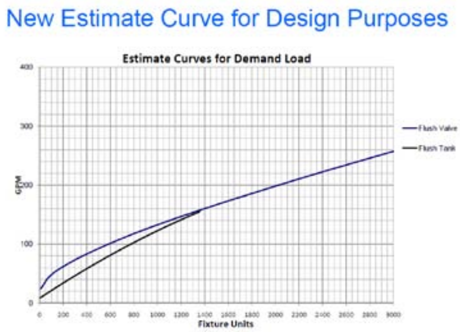
CITY	ADDRESS	FIXT. UNITS	TAP SIZE	HUNTER CURVE PREDICTED (gpm)	ACTUAL MEASURED (gpm)	OUTDOOR MEASURED (gpm)
Westminster	9006_Ammons	20	0.75	14	10	
Westminster	8782_Allison	168	1.5	58	18	41
Westminster	6870_W91	204	1.5	64	18	
Westminster	5321_w76th	204	1.5	64	18	
Westminster	8672_Carrloop	216	1.5	68	25	
Glendale	6775 West Ida Drive	231	1.5	71	28	
Littleton	Heritage Creek	260	1	76	17	
Littleton	Heritage Creek	260	1	76	14	
Westminster	9002_88th	296	2	84	27	68
Littleton	Heritage Creek	386	1.5	100	19	
Boulder	2707 Valmont Road	460	2	115	58	
Boulder	2707 Valmont Road	460	2	115	39	
Boulder	2707 Valmont Road	460	2	115	35	
Boulder	2707 Valmont Road	460	2	115	38	

Figure 12, shows the comparison between actual and predicted peak flows for the 14 multifamily accounts but sorted in order from smallest to largest number of fixture units. This graph shows that for small buildings the difference is smaller, but that as the size of the project increases the variation between the actual and peak flows increases as well.

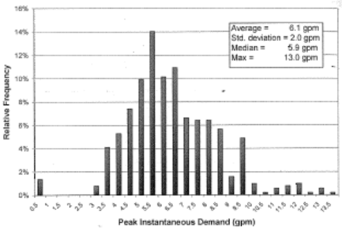
occupants are lacking here but in other reports greater numbers raises water usage; the one greatly different suggests occupancy major differences. These data were applied (below) in comparisons with new demand curve determinations originated in this startup effort. Initial progress is shown from trial calculations of newly developed Hunter method with introduction of new values applied for current fixtures and appliances in fixture demands. Sub-variants from the method in later studies will attempt to expand such significant changes based on da ta for varied equipment and impacts on usages realities. These data are further discussed below.

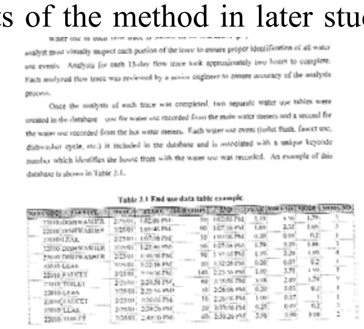
7. Multi-family Potentials in Trial Calculations

Hunter binomial probability computations from D. Cole computer program development provides rapid determinations for assumed concept conditions. Compared computer results with BMS 65 showed validations. New trial determinations with current fixtures/appliances factors indicate distinguishingly differing values for current WCs of flushometer and tank types. Evidence for new weighting units is essential to the revisions entirety of procedures for code listings. From these results new appliance/fixtures weighting units for the method will be required. Further explorations and thrusts for design method applications with chartings will proceed with comparisons from lessened demand field usages data.



Groundwork Additional Data Elements - Initial aspects from data sources pointed to trial calculations of existing Hunter method but modified for new water saving fixture demands. Sub-variants of the method in later studies will evaluate other aspects for significant changes from details of available information for varied equipment. Those may extend to examples of hot/cold ratios required in appliances/fixtures water supply needs. Particular aspects also may arise from variable user control compared to pre-set factory controls that alter water use profiles for probabilistic modeling alternatives. Data limitations need to be overcome as noted. The example peak at nearly 6 gpm overall in a dwelling is in line with other limited data reported usages. Projection to a multi-family building would result in 60 gpm for a 10 unit apartment building.




analyst must visually inspect each portion of the trace to ensure proper identification of all water use events. Analysis for each 15-day flow trace took approximately two hours to complete. Each analyzed flow trace was reviewed by a senior engineer to ensure accuracy of the analysis process.

Once the analysis of each trace was completed, two separate water use tables were created in the database one for water use recorded from the main water meters and a second for the water use recorded from the hot water meters. Each water use event (toilet flush, faucet use, dishwasher cycle, etc.) is included in the database and is associated with a unique keycode number which identifies the house from which the water use was recorded. An example of this database is shown in Table 2.1.

Table 2.1 End use data table example

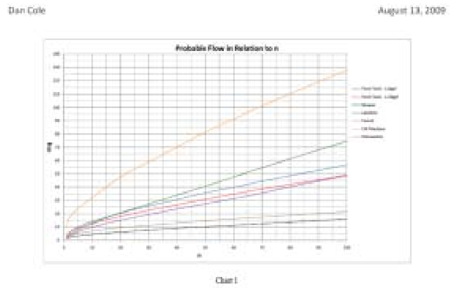
8 Multy-Family Building Representations

The data shown above for several apartment buildings on water usages for homes and different size apartment buildings show useful apartments data (12). No details for specific needs on apartment population, patterns or demographic data appear. Several apartment buildings and homes were monitored with records provided. Those lists showed comparisons to Hunter Fixture Units with large differences. These data had no defined sets of actual plumbing fixtures installed (tests were conducted after Federal 1992 limits on s howers and WCs) for lesser water consumption. However, through direct contact with the author the status could not establish such information.

Distinctions for baths and showers, tank or flushometer valve WCs are essential but do no t appear. Developments with data to confirm new results would require listing modifications for the other appliance/fixtures as adopted weighting units as rooted in the fixture unit method. Those activities do not exclude other considerations, or formulating other simultaneity methodology, as a m eans to the problem. This sample of multi-family buildings tests provides realistic data for a few multi-family comparisons. The tabulations indicate results that compared Hunter Fixture Units. Unknown is whether those are American Water Works Association (AWWA) equivalents or usual plumbing means. The author hints at conventional units apply. Information note is that different AWWA standards (13, 14) may have applied. University theses present studies supported by AWWA that provide differing probabilistic techniques for variable event predictions (2). The concern for AWWA interests result from need for 'mains pipe sizing supply' to buildings.

8.1 Computer Trial Calculated Models

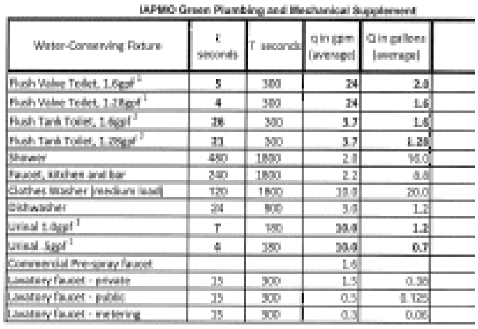
New initial appraisals for code applications/lists of fixtures and appliances were initiated with sparse applicable field data. Computed probability values example



Two tables are produced relative to the two types of reduced gallons per flush toilets, namely the 1.6gpf and the 1.28gpf. This will result in differing ratios of fixture units as seen in Table 2. The tank-type toilets are weighted on the decimal scale of base ten. The remaining fixtures are weighted proportionately to the toilet.

Two things need to be observed in Table 2. First, public and private distinction still needs to be made. The probability function is primarily based on congested use in public places. Based on statistical data Hunter received on apartment hotels in New York City, he reduced the fixture units for residential, apartment and private bathrooms by half (see BMS65, 16-18). When applying fixture units against the curve for estimating the demand of single-family dwellings, the private fixture units will be used (see page 6).

Secondly, the clothes washing machine is the heaviest demand for a single use fixture, and the relative fixture unit is extraordinarily high. Hence, there is needed research for this appliance to determine appropriate time intervals regarding both the intervals of cyclical demand



IAPMO Green Plumbing and Mechanical Supplement

Water-Conserving Fixture	t seconds	T seconds	q in gpm (average)	Q in gallons (average)
Flush Valve Toilet, 1.6gpf [1]	5	300	24	2.0
Flush Valve Toilet, 1.28gpf [1]	4	300	24	1.6
Flush Tank Toilet, 1.6gpf [2]	26	300	3.7	1.6
Flush Tank Toilet, 1.28gpf [2]	21	300	3.7	1.28
Shower	480	1800	2.0	16.0
Faucet, kitchen and bar	240	1800	2.2	8.8
Clothes Washer (medium load)	120	1800	10.0	20.0
Dishwasher	24	900	3.0	1.2
Urinal 1.0gpf [1]	7	180	10.0	1.2
Urinal .5gpf [1]	4	180	10.0	0.7
Commercial Pre-spray faucet			1.6	
Lavatory faucet - private	15	300	1.5	0.38
Lavatory faucet - public	15	300	0.5	0.125
Lavatory faucet - metering	15	300	0.3	0.08

Calculations:
gpm = gal/secs * 60
gal. = gpm(secs)/60
secs = gal/gpm *60

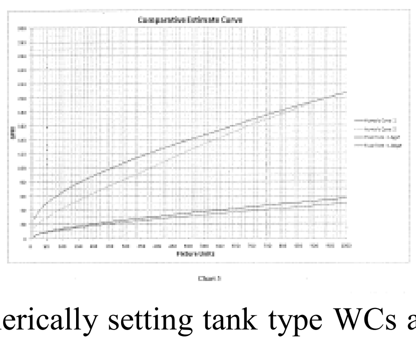
[1] Empirical Values based on American Std. Data
[2] Empirical data from WDI, Geberit, FluidMaster
Chapter 4 Green Values
By Calculation
Assumed Values

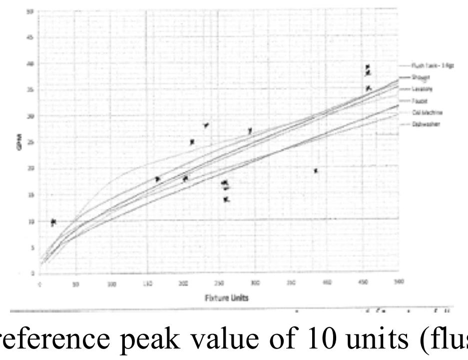
numerical tests and applications trials were based on t he known established method but based upon newer lowered fixture water consumption values. The computer application trials were made with new fixtures and appliances values. The newly Modified Hunter Fixture Units Trial curves are shown in the new estimate curve figure. Large reductions from initial Hunter curves were demonstrated and further considerations remain to be studied. Comparisons of differing reduced water consuming fixtures and appliances are continuing in the investigation for code applications/lists for fixtures and appliances will continue. Clearly, need to apply newly computed values for replacement of the initial Hunter curves was demonstrated.

8.2 Data Comparisons Achieved

Multiple occupant building data with measured water consumption provided predicted new curves comparisons (illustrated). The newly charted reduced fixture units' probable determinations are shown with multi-family field test results. The Fixture Units applied uncertainty implies that possibly ± 20 % error variation may exist for Fixture Units of data but the flow rates measurement values determined from measured tests. Data points are from apartments and compared with the reduced Hunter Units based upon

Charts 5 and 6 are comparative charts displaying Hunter's Curve against the revised curves for single-family dwellings.





numerically setting tank type WCs at the reference peak value of 10 units (flushometer will be studied later). An initial level of confidence can be made for verification of the ``initial correlation thrust”. Further study for exactness remains to be evaluated. Note: adjusted values for tank fixture unit of 10 as referral level is unusual in this probability method. No 1.28 gal flush WCs existed at the time, so comparison is for 1.5 gal WCs and shower flows of 2.5 gpm. Some differences seen at the same fixture units may result simply from differences due to larger occupant numbers (as previously shown from single family data analyses). These examples illustrate importance of occupants and apartment parameters with other demographics or factors of life style patterns and employment impacts as other occupant factors.

9. Recommendations and Conclusions

Continue studies from wide-ranging test data sources, e.g., CIB W62 symposia reports on measured actual water consumption and diverse buildings. Integrate critical aspects from realistic plumbing sciences and physical realities for engineered systems and code purposes applications (as noted in chapter 8 of new book b y by Prof. John A. Swaffield). S tudy concepts/potentials for **separately distinguishing flow-rate and volumetric basis water supply** for elements in predictive methods probability factors applied to fixtures/appliances functions. Those distinctions for distinguishing elements may be (a) flow rate usages (b) volumetric needs. Then, if two distinct parameters for separate fixtures/appliances classes result the development for separate distinct predictive (different) methods may emerge for setting supply performance requirements. Other needs are: (a) Prepare draft recommended tables for code changes and/or modifications in timely manner for submittals to code timing dates schedules. (b) Examine other literature sources, especially National Energy Research Laboratory (NERL) and other Western areas conference papers. (c) Seek additional acquisition of stored data (private communications with AQUACRAFT) concerning time dependency records. (d) Seek real time data sources for validations and apply to in-depth analyses for variants of the Hunter Method. (e) Extend data multi-family buildings reviews with particularly noted needs as density (occupants), patterns of usages, and alternative usages by adults/children. (f) Critically evaluate underlying principles in applications of alternate probability formulations. An outcome with upper and lower value sets of flow curves may become applicable and modified referral tables with distinct differences of assigned fixtures as probability formulations tests may suggest.

10 References

1. Hunter, R. B., Estimating Loads in Plumbing Systems, BMS 65, National Bureau of Standards, Washington D.C. December 1940
2. Ladd, J. S., An Evaluation and Pressure-Driven Design of Potable Water Plumbing Systems, Virginia Polytechnic Institute and State University - Requirements Master of Science, Civil Engineering, Blacksburg, Virginia , May 2005
3. Murakawa, S., et al, Calculation for Loads of Hot Water Demand with the Hot Water Storage Tank System in Houses, CIB
4. van der Schee, W. G., Water Systems in High Rise Residential Buildings, Guide lines for Design and Construction, CIB W62 Symposium on Water Supply and Drainage for Buildings, Dusseldorf, Germany, 2009

5. Ichikawa, N., Trends in and Recent Research into Direct Water Supply Systems in Japan, CIB W62 Symposia, Sept. 7-9 209, Dusseldorf, Germany, 2009
6. Gonçalves, O. M., Petrucci, A. L., Distribution Systems in Buildings, CIB W62 Ankara, Turkey, September, 2003
7. DeOreo, W.B., Mayer, P.W. Meter-Master/Trace Wizard Aquatech and Field Data; End uses of Hot Water in Single Family Homes From Flow Trace Analysis, East Bay Report, Aquacraft, Inc., Boulder CO; 7a. DeOreo, W. B., Mayer, et al, Save Water and Energy Education Program (SWEEP), Residential End Uses of Water (REUWS,); Residential Post drought Changes in Residential Water Use, Aquacraft, Boulder CO Feb 2006
8. Hendron, R., J. Burch, Development of Standardized Domestic Hot Water Event Schedules from Residential Buildings, Energy Sustainability, Long beach Ca., June 27-30, 2007
9. A Model Computer Program Referral from DHWcalc at Kassel University, Germany -The "Software Schedules" Application by R. Hendron, J. Burch, Development of Standardized Domestic Hot Water Event Schedules from Residential Buildings, Energy Sustainability 2007 Long beach Ca., June 27-30 2007
10. Random DHW Draw Pattern Generation Tool Bob Hendron, NREL - ACEEE Hot Water Forum May 14, 2010
11. Hendron, R., ACEEE Hot Water Forum, NREL, May 2010 [The "Software Schedules" Application] A Model Computer Program Referral by DHWcalc at Kassel University, Germany - Random DHW Draw Pattern Generation Tool
12. DeOreo, W. B., Analysis of Summer Peak Water Demands in Westminster, CO, Aquacraft, Boulder, Co, 1996, 12a Burch, J., Development of Standardized Domestic Hot Water Event Schedules from Residential Buildings, Energy Sustainability 2007; Residential Post drought Changes in Residential Water Use, Aquacraft. CO Feb 2006,
13. ANSI/AWWA C651 "Sizing Services Lines and Meters." Manual of Water Supply Practices, Second Edition, American Water Works Association 1974 Denver
14. AWWA Manual, M22, Sizing Water Service Lines —M22, Second Edition American Water Works Association, 1974 standard,

<u>Full std info</u>

AUTHOR - Dr. Lawrence Galowin – consultant - former National Institute of Standards and Technology (NIST) leader in plumbing research, is retired - Guest Researcher.

Consultant in: desalination developments, wave energy & RO pumping for potable water and by Slow Sand Filtering. Serves on ASME national plumbing standards committees and continues plumbing research select aspects.