Report No. 93

MAXIMUM INSTANTANEOUS WATER CONSUMPTION

Prepared by:
Working Group on Instantaneous Water Consumption of the Distribution Committee

Nieuwegein, September 1986

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RESPONSIBILITY

This report summarizes the results of the measurements performed on the maximum instantaneous water consumption by various specific categories of consumers. This involves categories of consumers such as those in apartment buildings, offices, schools, old age homes and nursing homes, sports complexes and farms.
The measurements were mostly performed in 1976, 1977 and 1978, but supplemented in 1982 by the Working Group on Instantaneous Water Consumption of the Distribution Committee.
During the preparation of this report, the Working Group was made up as follows:

L.J. Zwierstra	N.V. Waterleiding Friesland (President)
L.G.D. de Zee	N.V. Waterleiding Friesland (Secretary)
P.L.M. de Coo	Waterleidingbedrijf Midden-Nederland
J.P. Muller	Provinciaal Waterleidingbedrijf van Noord-Holland
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In addition, C. van Duuren from the Waterleidingbedrijf Midden-Nederland and C.A.L.G. Reniers from the Duinwaterleiding van 's-Gravenhage were closely involved in the activities.
An earlier stage included the efforts of the following individuals, among others: P. van de Berg, J. Boorsma (President), W. Kleine (Secretary),

L.M. Mudde, F.G. van Naerssen and a large number of other colleagues from the other water supply companies.
In addition, the Working Group owes many thanks to dr. J.A.J. Faber from the Institute for Mathematical Statistics, Royal University of Utrecht. Dr. Faber acted as advisor and undertook the statistical processing of the measurement results.

A single measurement costs an average of 3500 dfl. As a result of these costs, the measurement program per category remained limited. For financial reasons, only a few preliminary measurements were performed in the category of farms. The results are included in this report, but without drawing conclusions.

UDC: 628.171.5 : 727.1 : 155
696.11.001.24
Key Words: peak water consumption, tap units, design guidelines, service pipes

SUMMARY

The Working Group on Instantaneous Water Consumption of the Committee on Distribution of KIWA performed measurements on the maximum instantaneous water consumption by a number of specific categories of consumers. Measurements were performed in residences, offices, schools, old age homes, nursing homes and sports complexes.
The goal was that of determining whether it is reasonable, in designing feedlines to drinking water installations (still) to utilize the $Q\sqrt{n}$-method, used up to the present time.
The conclusion of the Working Group is that design guidelines adapted to different situations should be provided.
In addition, in the new guidelines, use is made of variables which should advantageously be followed in design.

For residential buildings with individual metering per residential unit, the new design guideline is:

$$q_{max}(m^3/h) = 0{,}378 + 0{,}061 \times (\sqrt{\text{tap units}}) + 0{,}0014 \times (\text{tap units} \times \text{occupation density}).$$

If there is a common meter or no meter at all, the anticipated maximum instantaneous consumption values are higher by, respectively, 0.5 m^3/h and 1 m^3/h.

In school buildings, the maximum instantaneous consumption is determined to a high degree by the presence or absence of flush heads.
Thus, if flush heads are present, the maximum consumption is determined from the maximum output (in dm^3/s) of a flush head, plus the maximum consumption of the other tap points to be expected according to the $Q\sqrt{n}$-method. In school buildings without flush heads, the measurement results approach those obtained according to the $Q\sqrt{n}$-method. However, in this case, the minimum quantity required for fire fighting then often appears to become of determining significance.

In the case of old age homes and nursing homes, it appeared necessary to know the number of elderly individuals or patients cared for.
The following are recommended as design formulas:
for old age homes

$$q_{max}(m^3/h) = 4{,}236 + 0{,}033 \times (\text{no. of elderly individuals});$$

for nursing homes

$$q_{max}\ (m^3/h) = 8{,}125 + 0{,}047 \times (\text{no. of patients}).$$

For office buildings, it is important to know the number of employees. In addition, it seems reasonable to make a distinction between offices with and without toilet rinsing faucets (flush heads).
The recommended design formula is:
for office buildings without toilet rinsing faucets

$$q_{max}(m^3/h) = 5{,}27 + 0{,}0067 \times (\text{no. of workers});$$

for office buildings with toilet rinsing faucets

$$q_{max}\ (m^3/h) = 9{,}37 + 0{,}0110 \times (\text{no. of workers}).$$

In sports halls and sports field complexes, the following formulas may be used:

for sports halls

q_{max} (m^3/h) = 6,171 + 0,227 x (no. of showers)

for sports field complexes

q_{max} (m^3/h) = 4,688 + 0,415 x (no. of playing fields).

INTRODUCTION

1.1 Goal

In order to calculate the diameter of a service pipe te be utilized, the anticipated maximum instantaneous consumption of the building in question must be known.
In order to determine this maximum instantaneous consumption, it is necessary to consider the number of apparatus units in place and the required capacity. Not all units of apparatus will always be in use simultaneously in each instance. It is known that the larger the number of installed tap points in a building, the more the simultaneity of their use will decline relatively.
Up to the present time for the design of installations, a formula has often been used, developed by the German Association of Gas and Water Experts (DVGW), wherein a relationship is formed between the maximum instantaneous consumption and the number of tap units in an installation.
This formula is: $q_{max} = q\sqrt{n}$, where
q_{max} = maximum instantaneous consumption in liter/h
q = capacity of one tap unit in liter/h
n = number of tap units.

In other words: the total load of an installation with n tap units each having a volume flow of q liter/h amounts to $\sqrt{n}$ times the capacity of one tap unit. Here, a tap unit is defined as:
the volume flux of a tap point of the size of q liter/h. In practice, a value of 300 liters/h is generally assumed (0.083 dm^3/sec), for example, in the case of a mixing faucet in a sink. Each tap

point is expressed in a number of tap units (see Appendix 1).
The differences in simultaneity of taps in the case of various categories of consumer, however, may also give rise to differences in designs. Naturally, it is difficult to achieve clarity in the general guidelines, but the question is whether it is justifiable.

The following categories can be distinguished:
- single family residences;
- multifamily buildings;
- schools;
- old age homes and nursing homes;
- office buildings;
- sports complexes;
- farms.

In order to study whether it is possible and reasonable to (still) use one method for all categories, the Distribution Committee formed a Working Group which was supposed to develop a recommendation for the calculation of service pipes, adapted to the use made of the drinking water installation.
In order to complete this, the following steps were distinguished:
- the determination, based on measurements, of the maximum instantaneous consumptions of various categories of water users;
- attempting to establish a correlation between the maximum instantaneous water consumption of a specific category and a number of easy to determine variables. These variables should be able to be estimated (preferably easily), or otherwise they are not reasonable for a design estimation;
- on the base of the results obtained, to establish design guidelines with respect to the dimensio-

ning of pipelines for installations in premises of various categories of water users.

In general, sufficient information is available concerning water consumption in single family residences. The category was, therefore, left out of consideration. (In other words, the $Q\sqrt{n}$-method mentioned can be used for designing feed lines and designing the drinking water installation.)
Concerning the other categories of water users, for more background information, the reader is referred to the separate technical reports.
However, this does not apply for farms, where only a few simple preliminary measures were employed. In addition, no statistically reliable conclusions can be drawn from this and, therefore, this was not separately reported on.

The available Technical Reports (in Dutch) are, respectively: Maximale momentane waterverbruiken in woongebouwen (SWE 240); Maximale momentane waterverbruiken in kleuterscholen en lagere scholen (SWE 247); Maximale momentane waterverbruiken in bejaarden- en verpleegtehuizen (SWE 84.007); Maximale momentane waterverbruiken in kantoorgebouwen (SWE 84.008) en Maximale momentane waterverbruiken in sporthallen en op sportveldcomplexen (SWE 84.009).

1.2 The design of pipelines

Various design rules are present for the different parts of a water distribution system.
The most common methods are lined up in Figure 1.

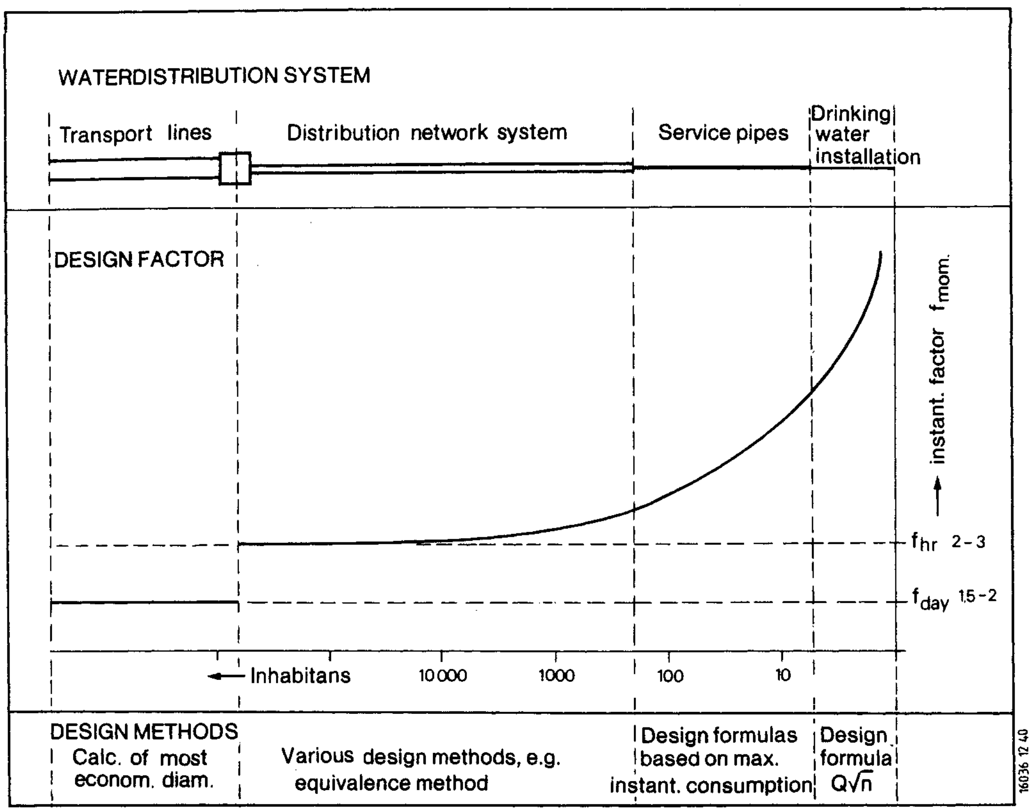


Figure 1 - The relationship of parts of a water distribution system to be designed, design factors and recommended design methods

The determination of the required diameter of a service pipe is completely governed by the water demand of the immediate environment downstreams the considered service connection.
For various categories of consumers, the drinking water installation present or to be designed will play a great role.

The pressure losses occuring in case of the use of the generally small range of diameters coming into consideration in most cases give direct conclusions regarding the diameter that should be selected.
The determination of the diameter of a service pipe in the vicinity of the decisive points in a supply area is most critical. The minimum pressure to be guaranteed at that site is increased by the pressure loss in the service pipe. If this pressure loss is relatively high, all the water pumped at the pumping station should be "raised up" somewhat more.
Drinking water installations in residences and buildings, as already reported, are designed until now in general using the Q√n-method designated.

2 MEASUREMENT METHOD

2.1 Considerations prior to the measurement

Maximum instantaneous water consumption

The maximum instantaneous water consumption is defined as: the quantity of water flowing through a pipeline during a given running time. The maximum instantaneous consumption depends on the indicated running time. The shorter the running time becomes, the more the maximum instantaneous consumption increases.

For example, a recorder chart of measured consumption shows: in a running time of B minutes a consumption of 400 dm^3, and in a running time of A minutes a consumption of 2600 dm^3, wherein A = 10B.

Then, in the first case, the consumption in B minutes is 400 dm^3, and in the second case, in B minutes = $\frac{2600}{10}$ = 260 dm^3.

The relationship between the maximum instantaneous consumption and the running time to be maintained

It was found from previous measurements that if the running time is made less than 1 second, no change occurs in the maximum instantaneous consumption. The explanation for this is that household apparatus open and close slowly.

In the case of running times of less than 1 second, large increases and decreases in the volume flux occurring are thus to be anticipated.

As a result of the mass inertia of the water, the changes in withdrawal occurring in running times of

less than 1 second are not noticeable.
In addition, as a result of the inertia of the measurement apparatus, the changes possibly occurring within 1 second should not be recorded. On the basis of this, it is concluded that the use of a running time of less than 1 second should not result in a change in the maximum instantaneous consumption (q_{max}).
When a longer running time is used, the maximum instantaneous consumption decreases. In the case of a running time of 8 seconds, for example, there is a reduction of about 4 %, and in the case of a running of up to 30 seconds, a reduction amounting to a maximum of 10 %.
On the basis of the design data, a drinking water installation should function well. This is understood to mean, among other things, that no undesirable pressure fluctuations should occur during use of the tap points.
In residential buildings, the most frequent problem caused by pressure fluctuations is changes in temperature of the water, for example, during showering, when anyone else in the building turns on a faucet or flushes the toilet.
The Working Group has found if these pressure fluctuations occur within 1 second, the impediment mentioned should not occur. For this reason, the base time for determination of the maximum instantaneous consumption was maintained at 1 second.

Maximum instantaneous consumption and possible determining factors for this

Before beginning with measurement, it would be desirable to know the factors by means of which the maximum instantaneous consumption should be able to

be determined. Insofar as these quantities may possibly reflect the maximum instantaneous consumption, these are used as variables in the statistical processing.
The degree to which these quantities were actually of determining significance for the maximum instantaneous consumption only became clear following the statistical processing. For each category of "users" a number of factors (variables) is considered.

1. For residential buildings:
   - the number of residences, the number of inhabitants, daily and annual use (these factors are closely correlated);
   - the number of tap points, type of bathing facility (shower or tub);
   - method of water supply: individual metering, central metering or no metering;
   - city, region and time of year.

   In order to study these influences, the measurements were performed in the supply regions of various water supply companies. A total of 28 measurements were performed.

2. For schools:
   The government has given clear guidelines regarding the size of sanitary facilities to be provided per room, per building. This means that only a limited number of measurements (three schools) were necessary in order to obtain sufficient information. The measurements were also limited to lower schools (elementary schools and nursery schools).

3. For old age and nursing homes:
   - the number of elderly or nursing patients present.

   Since most existing and newly constructed old age and nursing homes can accomodate fewer than 250 individuals, in these measurements, emphasis was placed on buildings with this general accomodation capacity.
   The following were measured altogether: 12 old age homes and 11 nursing homes.

4. For office buildings:
   - the number of employees;
   - the tap points present in the buildings;
   - the type of toilet flushing (flush unit for the water closet or flush unit for an urinal);
   - the presence of special water consuming installations, such as humidifiers or cooling towers;
   - the floor area;

   A total of 29 measurements were performed.

5. For sports complexes:
   Here, a distinction is made between sports halls and sports field complexes. Clear advisory guidelines exist. This is in contrast to school complexes, where the guidelines are mandatory in terms of sanitary provisions for washing and clothing facilities.
   For sports halls, the guidelines are established in Technical Bulletin No. 7 of the Netherlands Sports Federation.
   For sports field complexes, a different guideline was established in Technical Communications Nos. 22 and 23 of the Netherlands Sports Federation.
   Measurements were performed in 11 sports halls and 10 sports field complexes.

Number of measurements

In view of the costs per measurement, an attempt was made to limit the number of measurements per category of consumers to be investigated insofar as possible.

2.2 Measurement apparatus used

The measurement apparatus used (see figures 2 and 3) consists of a water meter with pulse generator to be installed in the supply line and a pressure recorder with strip chart.

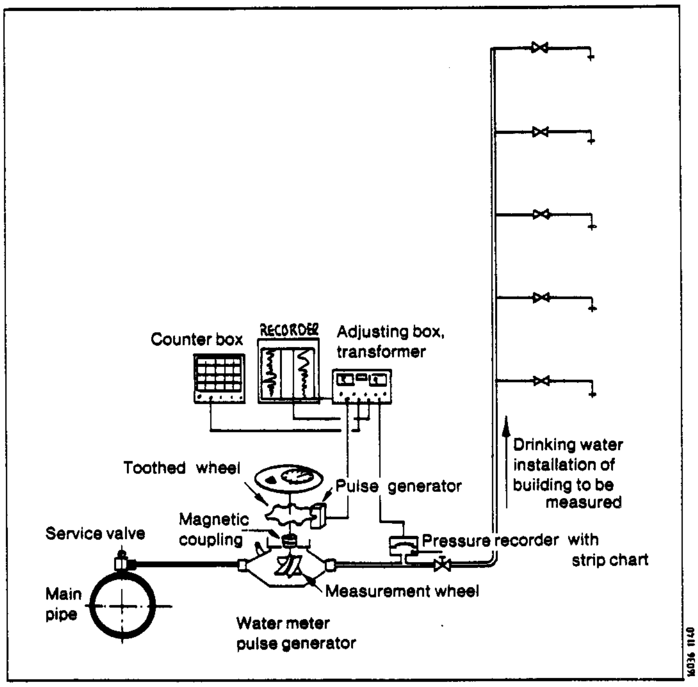


Figure 2 - Schematic set-up and operation of the measurement apparatus

The resulting electric signals are conveyed over a cable to the flow and conversion box and from there to a recorder and counter box.
The converter box is used, on one hand, to convert

the varying power uptake of the water meter and, on the other hand, the voltage changing with the pressure, of the pressure recorder to a variable direct current.

For detailed information on the measurement apparatus, the reader is referred to Technical Report (in Dutch) SWE 240, Maximum momentane waterverbruiken in woongebouwen (Maximum instantaneous water consumption in residential buildings).

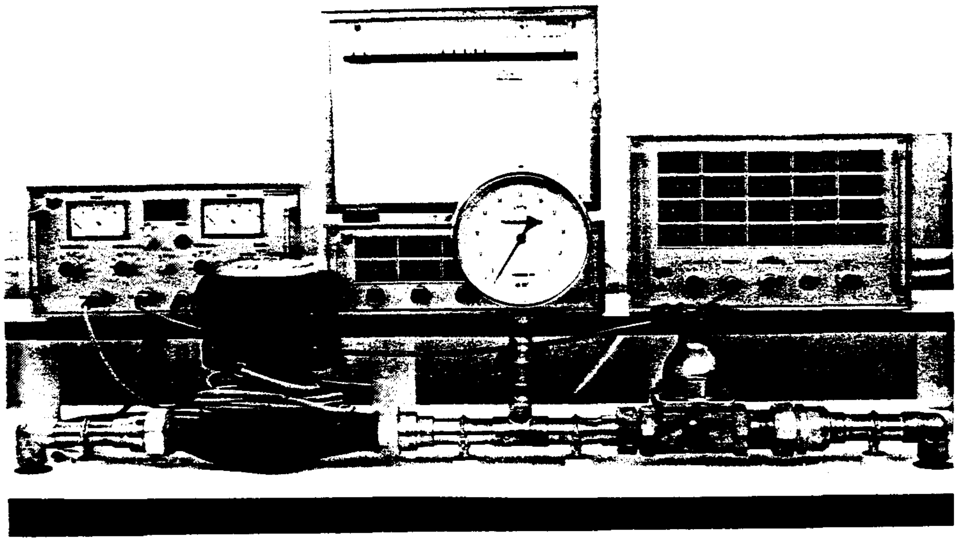


Figure 3 - Measurement apparatus

In the measurements, the recorder section is generally used for the following:

1. Premises without central hot water supply. The total volume flow of cold water and the pressures occurring are measured and, if necessary, the turning on and off of the pumps is recorded;
2. Premises with central hot water supply. The total volume flow of hot and cold water to the hot water supplier are recorded.

The counting box also receives its signal from the flow box. This is used to total the duration in seconds of the various volume flows occurring.

2.3 Measurements

The water consumptions occurring are measured in the central cold water feed line toward the object to be measured.
The actual measurement is always preceded by an extensive preparation concerning the collection and establishment of technical and administrative data regarding the object in question as well as site determination of the measurement and including the following:

- the time point and duration for installation and the removal of the measurement apparatus;
- the availability of electric current close to the set-up point.

The information relevant for the measurement report is obtained by having each owner of one of the facilities being measured keep a card for filling in data.
The industrial installation, piping and apparatus are shown in a diagram so that full information was available for designing.

A measurement period of 14 days per facility was maintained. Including the installation, set-up and removal of the apparatus, each measurement took about three weeks.
The measurement data are collected daily and processed on daily sheets. In order to obtain comparable values insofar as possible the daily, whenever possible, are filled out at the same time.
In the cases in which water delivery was partly accomplished by means of a booster installation and partly through the network pressure, measurements

are performed at two points and averaged.

In the case of office buildings, in many instances, an installation was encountered which had a so-called boilerless booster installation.
The recording water meter was then placed in front of the booster installation so that actually the pressure of the pumps was measured.
Since the distributor which regulates the pump installation often has a small capacity, it may be assumed that $q_{pump} = q_{max}$.
Climate control installations were put out of operation or could be eliminated from the measurement.

2.4 Statistical treatment of measurement data

The goal of the measurements was to relate the measured maximum instantaneous water consumption to a number of explanatory, conveniently measurable variables. On the basis of the relationships found, the maximum instantaneous consumption of an installation to be constructed in the category in question was to be simulated.
This is only possible if the value of the explanatory independent variables can be determined well both during the measurement and during the construction of a new building. For a residential building, these are, for example: the tap units, the number of rooms and the occupancy. For an old age or nursing home: the number of elderly people or patients, respectively.

In the establishment of the measurement program, the considerations were started from the fact that, in principle, it is preferable to measure more objects during a short time rather than only a few objects over a long time. The more objects are measured, the better an impression can be obtained regarding the variability from one object to the next.

The measurement data were handled by the linear regression method; among other things, use was made of a technique which is known as stepwise regression. The purpose of this is to write the maximum instantaneous consumption as a linear function of a number of explanatory variables.

If y_i is the maximum instantaneous consumption of the i^{th} object measured and x_{1i}, ..., x_{ji}, ..., x_{ki} are the values of the k explanatory variables (tap units, etc.) of the i^{th} object, then in the first step in the model, the variable x_j is selected which correlates best with y.

Then, the following steps are performed identically.

The final equation thus has the form:

$$y = a + b_1 x_1 + ...b_p x_p.$$

Here, p is a function of the number of steps, and a, b_1 ... and b_p are estimated regression coefficients. The regression coefficient is the change in the maximum instantaneous consumption per unit x_j of the explanatory variable.

In addition, an estimate of the accuracy of the representation is also desired. For this purpose, a 95 % confidence interval is calculated for the building to be newly constructed.

The values of the maximum instantaneous consumption used for the calculations are average of the maximum instantaneous consumption per day generally over a period of 14 days, depending on the measurement period per category.

Remarks

1. No particular remarks need be made regarding the statistical processing of the measurement data for the residential buildings.

2. In schools, the type and number of sanitary facilities are prescribed by the chief construction inspector. This establishment of uniformity has a limiting effect on the differences in instantaneous water consumption from one school to another. The measured values in school buildings approach the values found with the $Q\sqrt{n}$ method. In many (calculated) cases, however, the required quantity of water for fire fighting is of determining significance.
   Therefore, in this category, the application of statistical techniques would be meaningless.

3. In processing the data for the old age homes and nursing homes, a relationship was established between the maximum instantaneous consumption and:
   - the number of elderly individuals or nursing patients;
   - the number of elderly nursing patients and the number of resident employees;
   - the number of tap units.

   As previously mentioned, there were 12 old age homes and 11 nursing homes. It was initially imagined that these could be combined, since:
   - the buildings were of similar types;
   - the number of each of homes was small.

   Upon closer analysis, the variability in q_{max} in

the case of nursing homes was found to be so large that it was decided to consider this group separately.
Thus, as a result, the regression analysis indicated that the best relationship was found with the number of elderly of nursing patients cared for. Reality has shown that an old age center or a nursing home can be expected always to be completely occupied.

4. For measurements in office buildings, according to the regression technique it appears that several models give equally good results.
   The selection was consequently made on the basis of practical considerations, namely, the need for an easy to use model suitable for practical application.

5. For processing the measurement data of the sports halls and sports field complexes, the measured maximum instantaneous consumptions were plotted against a number of possible related variables.
   For sports halls these were:
   the number of showers, the number of toilet and urinal taps, the number of tap units and the net playing surface.
   For sports field complexes these were:
   the number of showers, the number of urinal taps, the number of tap units and the number of playing fields.
   It was found from the regression analysis that the best results were obtained by establishing for sports halls a relationship with the number of showers, and for sports field complexes, a relationship with the number of playing fields.

3 RESULTS

3.1 Residential buildings

On the basis of this investigation, the Working Group set up draft guidelines for:

- the determination of q_{max} for feedlines to a premise with no more than 150 tap units and for (rise-)lines in a premise;
- the determination of q_{max} for pipelines and installations to a premise with more than 150 tap units.

It was found that the following may be considered as the most suitable variables: the tap units, the degree of occupancy of the residences according to the General Bureau for Statistics (CBS) and metering method. This equation is less simple than the equation used in practice until the present time.

The following equation was found:

$$q_{max}\ (m^3/h) = -0{,}069 + 0{,}061 \times (\sqrt{\text{tap units}}) + 0{,}0014 \times (\text{tap units} \times \text{degree of occupancy}) + 0{,}447 \times (\text{metering method}).$$

The applicability of the equation depends on the interval for which the measurement was performed. For the tap units in this case, it ranges from just over 100 to nearly 3000.

For a total survey of the tap units to be maintained for the various types of tap points, the reader is referred to Appendix 1.

The measurements were performed for a degree of occupancy of 1 up to and including 2,5. The $Q\sqrt{n}$-method is adequately usable for a degree of occu-

pancy of 3 or more.
The table below gives the degree of occupancy according to CBS for residences broken down according to the number of rooms, without kitchens.

No. of rooms without kitchens	1	2	3	4	5	6	7	8
Degree of occupancy	1	1	2	2½	3	4	4	4

The method of metering (individually metered, centrally metered, not metered) can be indicated by a simple code. The number 1 is to be filled in for individual metering, the number 2 for a central meter and the number 3 for the non-metered case.
For the individual metering, the equation found, therefore reads:

$$q_{max}(m^3/h) = 0{,}378 + 0{,}061 \times (\sqrt{\text{tap units}}) + 0{,}0014 \times (\text{tap units} \times \text{degree of occupancy}).$$

For central metering, the equation is:

$$q_{max}(m^3/h) = 0{,}825 + 0{,}061 \times (\sqrt{\text{tap units}}) + 0{,}0014 \times (\text{tap units} \times \text{degree of occupancy}).$$

In the absence of metering, the equation is:

$$q_{max}(m^3/h) = 1{,}272 + 0{,}061 \times (\sqrt{\text{tap units}}) + 0{,}0014 \times (\text{tap units} \times \text{degree of occupancy}).$$

Also see Appendix 2.

If, in the design of a supply line for a residential building, even the number of tap units is not known, for an estimation of q_{max}, it is possible to utilize the graphs in Appendix 3.

3.2 Schools

As was noted in section 2.4, statistical techniques were not meaningful for the category of schools.
The most important conclusion which can be drawn on the basis of the measurement results is as follows: The maximum instantaneous consumption is determined in high degree by the presence or absence of washing faucets and the applicable fire fighting requirements.
For schools with washing faucets or shower rooms, the minimum required quantity for fire control is not of determining significance.

If washing faucets are present, the maximum instantaneous consumption always consists of the consumption caused by the action of one or two washing faucets or one washing faucet with a simultaneously present domestic utilization. The latter combination appears to be of determining significance.
If washing faucets are present, the maximum instantaneous consumption is, therefore, determined from the maximum capacity (in dm^3/sec) of a washing faucet, plus the maximum consumption by the other tap points to be expected in accordance with the tap units. For school buildings without washing faucets, the measurement results approach the values obtained according to the $Q\sqrt{n}$ method. However, the minimum required quantity for fire fighting often appears to be of determining significance.
For school buildings without multiple stories, one fire hydrant is sufficient, and for school buildings with one extra story, two fire hydrants should supply the necessary yield.
Depending on the necessary pressure for this spray

mount, the withdrawal due to the use of a single fire hydrant should be minimally 0.375 dm^3/sec (1.35 m^3/h) and maximally 0.77 dm^3/sec (2.76 m^3/h). In the pressure loss calculation and diameter determination for the drinking water installation to be designed, the minimal yield of 0.375 dm^3/sec was always taken as the starting point.
In connection with the generally small scope of drinking water installation in schools, the Working Group thought that, in general, it is necessary to include in the calculations for the household use the possibility of simultaneous occurrence of household and fire fighting demands.
Since the washing areas in the gymnastics are often seperately located, the use of the centrally located showers - with their longer running times - should, in contrast, be possible simultaneously with the use of the fire hydrants.

In summary, it can be stated that, in general, a comparison is necessary between a calculation of the maximum instataneous consumption (using the $Q\sqrt{n}$-method) and the maximum required fire fighting capacity of (for each story) one fire hydrant in order to ascertain what is of determining significance.
In the smaller school buildings frequently encountered - for example, with two rooms, or schools with the minimum number of tap points - with a maximum instantaneous consumption which is lower than the maximum quantity required for fire hydrants, the quantity required for the fire hydrant is of determining significance.

3.3 Old age homes and nursing homes

In the measurements, on the basis of differences in daily living, a distinction is made between old age homes and nursing homes.
In the processing of the measurement data, it was found that the maximum instantaneous water consumption encountered can be more readily explained by means of the maximum number of elderly individuals or patients present than by the number of tap units.
As the new draft guidelines for old age homes, the Working Group recommends that the following be used:

$$q_{max}(m^3/h) = 4{,}236 + 0{,}033 \times (\text{no. of elderly individuals});$$

and for nursing homes:

$$q_{max}(m^3/h) = 8{,}125 \times 0{,}047 \times (\text{no. of patients}).$$

Also see Appendix 4.

For a combination of homes for the elderly and nursing homes, no special draft guideline was established. A common sense relationship exists between the two draft guidelines and depends on the expected situation.

3.4 Office buildings

In connection with the anticipated differences in maximum instantaneous consumption in offices with and without toilet sinks, the measurements in these two categories are uniformly distributed.
On the basis of these measurements, the maximum instantaneous water consumption per facility and per day can be determined.
The processing of the measurement data revealed the following:

- the preliminary classification of the objects to be measured in the two above-mentioned categories to be correct in accordance with the results obtained;
- for determining the maximum instantaneous water consumption, the most suitable variable coming under consideration is the number of workers expected.

The use of special installations, such as humidification, cooling towers and the like, is not included in these values. In the existing case, the maximum instantaneous consumption found should, therefore, be increased by these consumptions. On the basis of the investigation, the Working Group has established draft guidelines for the determination of q_{max} for feed lines to offices (with more than 100 workers and fewer than 1200 workers), with or without the provision of toilet rinsing faucets.

The recommended design formula for office buildings without toilet rinsing faucets is:

$q_{max}(m^3/h) = 5,27 + 0,0067 \times$ (no. of workers)

and for office buildings with toilet rinsing faucets:

$q_{max}(m^3/h) = 9,37 + 0,0110 \times$ (no. of workers).

See also Appendix 5.

3.5 Sports complexes

It was found from the processing of the measurement results that for determining the maximum instantaneous consumption for sports halls is the number of showers present appears to be the most suitable variable, and for sports field complexes, the number of playing fields.

Thus, from the investigation, two calculation bases

were established in the form of a draft for design worksheets in this connection.
The recommended design formulas designated in these draft worksheets are:

- for sports halls:
  $q_{max}(m^3/h) = 6,171 + 0,227 \times (\text{no. of showers})$
- for sports field complexes:
  $q_{max}(m^3/h) = 4,688 + 0,415 \times (\text{no. of playing fields})$.

See Appendix 6.

3.6 Farms

In the category of farms the investigation has been limited to some preliminary measurements on farms with stalls and runs.
The results were collected in several graphs (see Appendices 7 and 8). The calculated maximum instantaneous consumption according to the $Q\sqrt{n}$-formula in the case in question is presented.

4 COMPUTATIONAL EXAMPLES

4.1 Residential buildings

The diameter of the feed line to be designed is to be determined for a residential building consisting of 188 residential units.
For this purpose, it is necessary to know the expected maximum instantaneous consumption. The number of residences is: 366.
The following tap points are present in the residential buildings (these are likewise expressed in the number of tap units with the aid of Appendix 1).

No.	Tap possibilities	Tap units (t.u.)
188	Kitchen mixing faucets	752
6	Bathroom sink mixing faucets	6
188	Shower mixing faucets	188
194	Large toilet tanks	48,5
88	Small basin faucets	22
190	Washing machine faucets	760
4	Miscellaneous faucets	16
	Total	1792,5

The number of tap units is 1792,5.

According to the $Q\sqrt{n}$-method, the maximum instantaneous consumption can be expected to be:
$q_{max} = 0,083 \ x\sqrt{1792,5} = 3,51 \ dm^3/s = 12,7 \ m^3/h.$

According to the new draft guidelines, we have:
$q_{max} = -0,069 + 0,061 \ x \ (\sqrt{\text{tap units}}) + 0,0014 \ x$ (tap units x density of occupation) + 0,447 x (metering method).

In the case of individual metering, the equation is:

q_{max} = 0,378 + 0,061 x ($\sqrt{\text{tap units}}$) + 0,0014 x (tap units x occupation density).

The occupation density is 1,95 (number of inhabitants divided by number of residential units).
q_{max} = 7,85 m³/h.

If there is central metering, use is made of the formula:

q_{max} = -0,825 + 0,061 x ($\sqrt{\text{tap units}}$) + 0,0014 x (tap units x occupation density).

q_{max} = 8,30 m³/h.

If there is no metering whatsoever, we have
q_{max} = 8,75 m³/h.

At the time of designing this service line, the number of residents was not yet accurately known. However, the number of rooms per residential unit was known (three rooms and a kitchen). According to the CBS table, this, therefore, corresponded to an occupation density of 2.
Draft values utilized here should, therefore, amount, respectively, to 8,0, 8,4 and 8,9 m³/h.
If only the number of residential units to be constructed is known (namely, 188) and nothing else, a q_{max} of 12 m³/h is then found with the aid of the graph in Appendix 3.

4.2 Schools

A combined elementary and nursery school consists of two storeys and contains two play/workrooms

(toddlers) and six regular rooms.
The total number of tap units is 71,5. Using the $Q\sqrt{n}$-method, the maximum instantaneous consumption is:

$q_{max} = 0,083 \times \sqrt{71,5} = 0,7\ dm^3/s = 2,5\ m^3/h.$

The minimum quantity of fire fighting water is (one fire hydrant per floor):
$2 \times 0,375\ dm^3/s = 0,75\ dm^3/s = 2,7\ m^3/h$
and is, therefore, of determining significance.

If a gymnasium is located at a certain distance from the above-mentioned school but with centrally operating showers, the calculation of the maximum instantaneous consumption is different.
The household portion of the changing room at the gymnasium, for example, contains 8,75 tap units. There are also 10 showers and 5 foot wash basins. It is to be expected that all the showers and wash basins may be used simultaneously.
The maximum instantaneous consumption that must be anticipated is, therefore, in case of normal use:

$q_{max} = 0,083 \times \sqrt{(71,5 + 8,75)} + 10 \times 0,083$ (shower) $+ 5 \times 0,056$ (foot wash basin faucet) $= 0,28\ dm^3/s = 1,85\ dm^3/s = 6,7\ m^3/h.$

The maximum instananeous consumption is:
$0,75\ dm^3/s + 0,83\ dm^3/s = 1,58\ dm^3/s = 5,7\ m^3/h.$
In this case, normal use is of determining significance.

4.3 Old age homes and nursing homes

A total of 230 elderly people are permanently housed in an old age home. The total number of tap units is 1658. The maximum instantaneous consumption according to the $Q\sqrt{n}$-method should, therefore,

be 0,083 x $\sqrt{1658}$ = 3,38 dm^3/s = 12,2 m^3/h.
According to the new draft guideline, we can begin from the formula:

q_{max} = 4,236 + 0,033 x (no. of elderly individuals).

Then, there follows from the calculation as the maximum instantaneous consumption:

q_{max} = 11,8 m^3/h.

There are 200 patients in a nursing home. The number of tap units is 4171. The maximum instantaneous consumption according to the $Q\sqrt{n}$-method is:

0,083 x $\sqrt{4171}$ = 5,4 dm^3/s = 19,4 m^3/h.

Making use of the formula from the new draft guideline:

q_{max} = 8,125 + 0,047 x (no. of patients), we derive a maximum instanataneous consumption of

q_{max} = 17,5 m^3/h.

4.4 Office buildings

An office building is designed for 512 employees. The drinking water installation comprises, among other things, the following parts:

No.	Tap possibilities	Tap units (t.u.)
4	Kitchen faucets	16
10	Kitchen mixing faucets	40
29	Wash stand faucets	29
17	Wash stand mixing faucets	17
2	Shower mixing faucets	2
14	Tap faucets ½"	56
1	Household dishwashing machines	4
6	Automatic coffee makers	3
66	Large tanks (toilet)	16,5
	Total	183,5

If the toilets are required with rinsing faucets rather than with large tanks, the calculations should be performed with 7920 t.u. Then the total tap units will be 8087 t.u.
According to the $Q\sqrt{n}$-method, the maximum instantaneous consumption should, therefore, be:
- for the installation with large tanks:
  $q_{max} = 0{,}083 \times \sqrt{183{,}5} = 1{,}12\ dm^3/s = 4{,}05\ m^3/h$;
- for the installation with rinsing faucets:
  $q_{max} = 0{,}083 \times \sqrt{8087} = 7{,}46\ dm^3/s = 26{,}87\ m^3/h$.

Remark
This last value is somewhat high. In practice, this type of result has led to the use of various (empirical) formulas which come out somewhat lower.
In general, the $Q\sqrt{n}$-formula is used without taking into consideration the presence of rinsing faucets. For this purpose, a quantity is then separately ennumerated, in which in one way of another, some simultaneity is taken into consideration in the use of the rinsing faucets.

According to the new draft guideline, in which a distinction is also made between the situation with and without rinsing faucets, the maximum instantaneous consumptions are, respectively:

- without rinsing faucets:
  q_{max} = 5,27 + 0,0067 x (512) = 8,7 m³/h;
- with rinsing faucets:
  q_{max} = 9,37 x 0,0110 x (512) = 15,0 m³/h.

4.5 Sports complexes

In a sports hall 24 water-saving showers are present (corrected relative to the output of a normal shower, this number is 12).
The total number of tap units is 1215.
Question: the maximum instantaneous consumption.
According to the $Q\sqrt{n}$-method, the maximum instantaneous consumption should be:
$q_{max} = 0{,}083 \sqrt{1215} = 2{,}9$ l/s = 10,4 m³/h.
Using the new draft guideline, thus the formula
q_{max} = 6,171 + 0,227 x (no. of showers), the maximum instantaneous consumption becomes
q_{max} = 8,9 m³/h.

On a sports field complex with four sports fields, the number of tap units is 806.
Using the $Q\sqrt{n}$-method, a maximum instantaneous consumption of $q_{max} = 0{,}08 \times \sqrt{806} = 2{,}37$ dm³/s = 8,5 m³/h would be found.
With the new draft guideline q_{max} = 4,688 + 0,415 x (no. of playing fields), the maximum instantaneous consumption would be q_{max} = 6,3 m³/h.

5 CONCLUSIONS

In the introduction, the question was raised of whether it is possible and reasonable to (still) proceed from a single method for all categories of users. Although it is still possible to use the existing $Q\sqrt{n}$-method, it was made quite clear in the preceding chapters that this leads to excessive anticipated volume flows for some specific categories of consumers.

The draft guidelines recommended in this report have their limitations. They are based on a small number of measurement objects and measurements.

The confidence interval, based on the average of the observations, is fairly broad. However, the new draft formulas provide sufficient insight into the anticipated maximum volume flow.

For an installation to be designed to a given situation, a sufficient number of specific data are known so that it should be possible to achieve a justifiable design. The variables which are used in the new draft guideline are readily estimated and logical.

For the experienced designer faced with a situation which falls outside the application area of the new design guidelines, it is possible with the background knowledge forming the basis for the draft guidelines, with the guidelines themselves and possibly the old $Q\sqrt{n}$-method to achieve adequate insight in order, nevertheless, to obtain a good design.

The new design guidelines actually apply only for the design on service pipes. However, it may happen that certain pipes in a large drinking water installation are comparable to service pipes. Such pipes can, therefore, also be designed as such.

In the establishment of the new draft guidelines, it was clearly found that the use of rinsing faucets in an installation has a great effect on the design. These may have been used too freely in a number of design installations. The disadvantages linked with the use of such faucets, namely, the high required pressure, heavy feed lines and especially for small children, difficulty in use, in general are not significant compared to the advantage of being inmmediately ready for the next user.

In addition, in the design of feed lines to schools, especially if rinsing faucets are not employed, the maximum required volume flow for fire extinguishing is often of determining significance.

6 LITERATURE REVIEW

Commissie aanleg binnenleidingen van het KIWA: Richtlijnen voor de aanleg van drinkwaterinstallaties in woningen; 6e druk, juni 1983. (In Dutch)

Zwierstra, L.J.; Onderzoek naar optredende maximale momentverbruiken in woongebouwen; H_2O 19/78, p. 435-438 (1978). (In Dutch)

Werkgroep Momentane Waterverbruiken van de Commissie Distributie van het KIWA; Maximale Momentane Waterverbruiken in woongebouwen; Keuringsinstituut voor Waterleidingartikelen KIWA N.V.; SWE nr. 240 (1979). (In Dutch)

Sollman, M.; Qn moet; H_2O 10/79 p. 217 - p. 224 (1979). (In Dutch)

Tessendorf, H.; Peakdemands - results of the German research programme; Special subject nr. 5 IWSA (1980).

Werkgroep Momentane Waterverbruiken van de Commissie Distributie van het KIWA; Maximale Momentane Waterverbruiken in kleuterscholen en lagere scholen; Keuringsinstituut voor Waterleidingartikelen KIWA N.V.; SWE nr. 247 (1980). (In Dutch)

Wijntjes, W.C.; Piekverbruik en watermeters; H_2O 10/82 p. 232 - 238 (1982). (In Dutch)

Köppl, H.; Der Spitzenwasserbedarf und seine Auswirkung auf die Bemessung von Hausanschlussleitungen und Messgeräte; BBR Heft 7/juli 1983; p. 245-248 (1983).

Werkgroep Momentane Waterverbruiken van de Commissie Distributie van het KIWA; Maximale Momentane Waterverbruiken in bejaarden- en verpleegtehuizen; Keuringsinstituut voor Waterleidingartikelen KIWA N.V.; SWE nr. 84.007 (1985). (In Dutch)

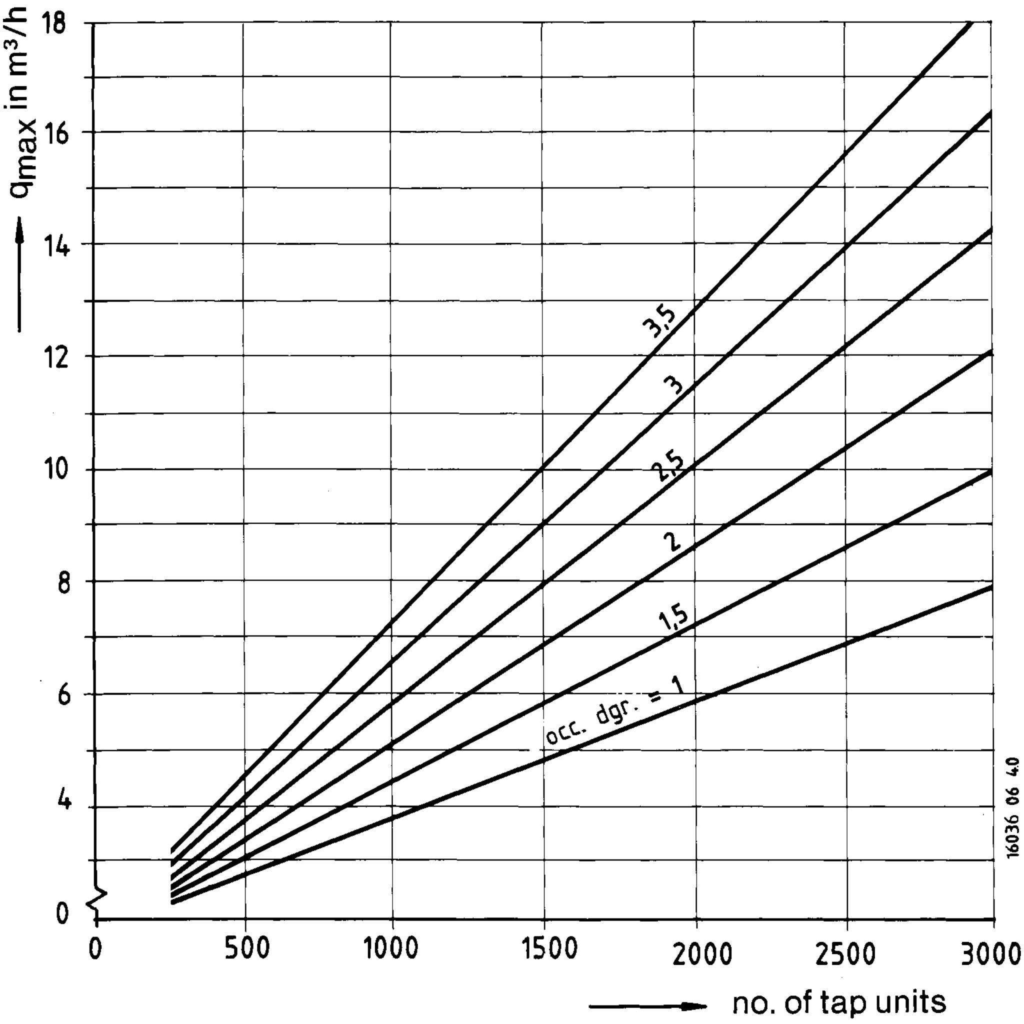
Werkgroep Momentane Waterverbruiken van de Commissie Distributie van het KIWA; Maximale Momentane Waterverbruiken in kantoorgebouwen; Keuringsinstituut voor Waterleidingartikelen KIWA N.V.; SWE nr. 84.008 (1985). (In Dutch)

Werkgroep Momentane Waterverbruiken van de Commissie Distributie van het KIWA; Maximale Momentane Waterverbruiken in sporthallen en op sportveldcomplexen; Keuringsinstituut voor Waterleidingartikelen KIWA N.V.; SWE nr. 84.009 (1985). (In Dutch)

APPENDICES

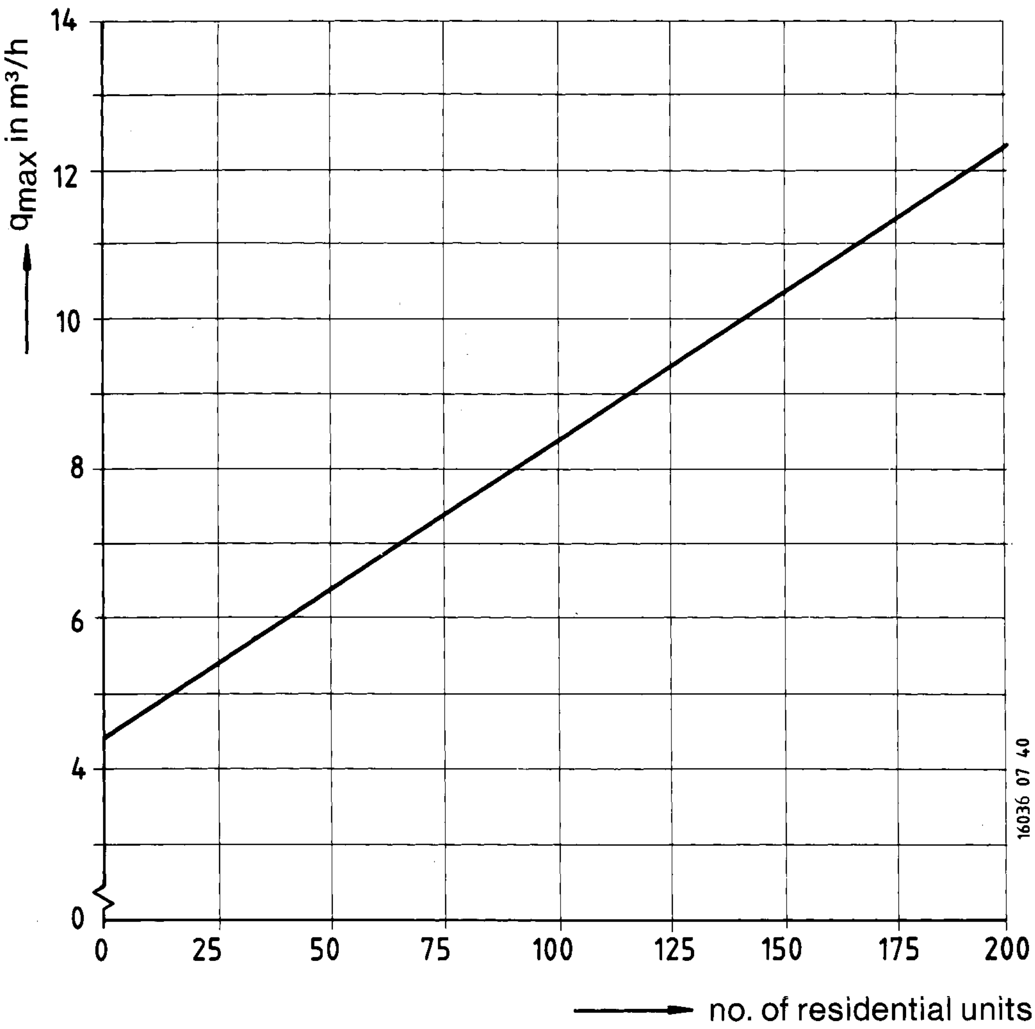
Tap units per tap possibility

Description	Rated diameter	Tap units
1 Kitchen faucet	1/2"	4
2 Kitchen faucet	2 x 1/2"	4
3 Kitchen mixing faucet	1/2"	4
4 Kitchen mixing faucet	3/4"	4
5 Kitchen mixing faucet	2 x 3/4"	4
6 Wash basin faucet		1
7 Wash basin mixing faucet		1
8 Shower mixing faucet		1
9 Bath mixing faucet		9
10 Large tank for urinal		1/4
11 Large tank for water closet		1/4
12 Urinal rinsing faucet		72
13 Toilet rinsing faucet		144
14 Small basin faucet		1/4
15 Small basin mixing faucet		1/4
16 Drinking fountain		1/4
17 Tap faucet	3/8"	1
18 Tap faucet	1/2"	4
19 Tap faucet	3/4"	9
20 Tap faucet	1"	36
21 Front of building faucet		4
22 Garbage disposal faucet	1/2"	4
23 Garbage disposal mixing faucet	1/2"	4
24 Automatic washing machine		4
25 Tank-type washing machine, household		4
26 Tank-type washing machine, industrial		9
27 Automatic coffee maker		1/2
28 Coffee break machine		1
29 Automatic fresh beverage machine		1/4
30 Laboratory faucet	1/2"	4
31 Laboratory mixing faucet	1/2"	4
32 Wash basin		4
33 Dark room automatic developer		1
34 Kitchen boiler		9
35 Sterilizer		4



Relationship q_{max} - tap units and degree of occupancy in non-metered residential buildings.

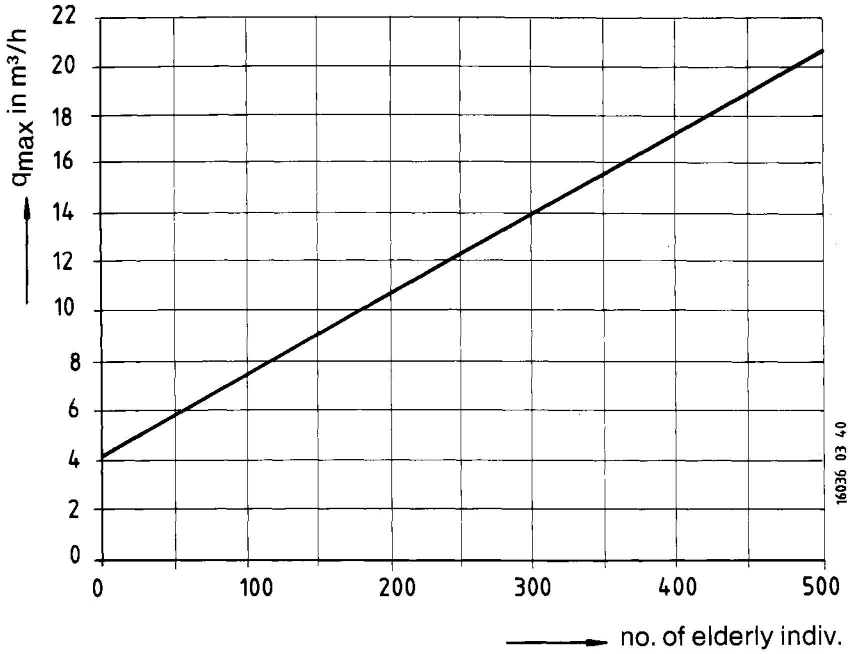
The values obtained with the aid of this graph can be reduced by 0,3 dm^3/s (1 m^3/h) in the case of individually metered premises and by 0,15 dm^3/s (0,5 m^3/h) in the case of centrally metered premises.



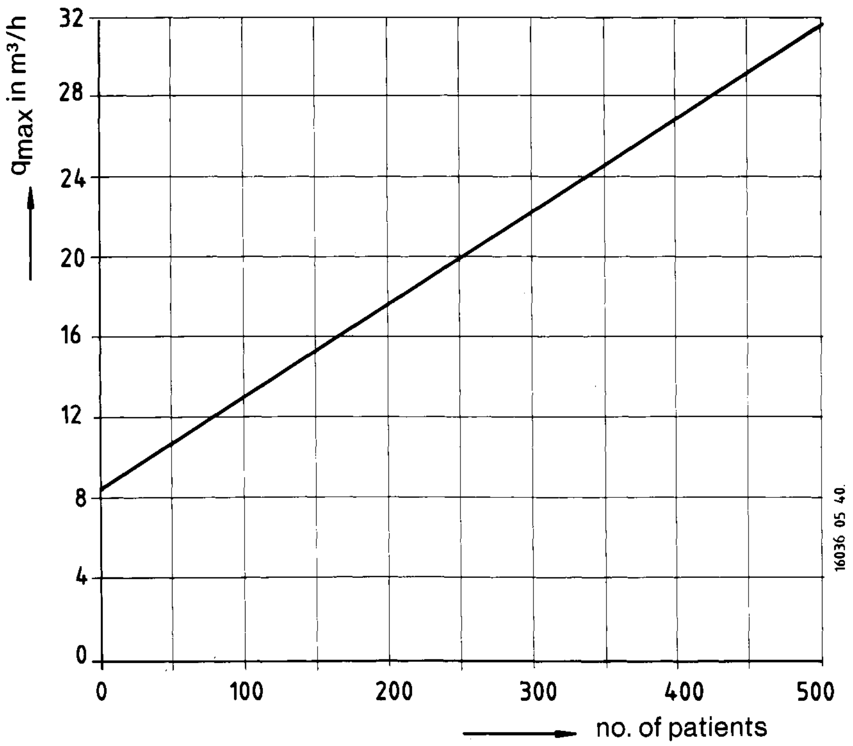
Relationship between q_{max} and number of residential units

It is not known at the time of designing the feed line whether the residences are to be metered and whether they will have baths or showers. The occupation density is also not known in advance. The equation to be used is:

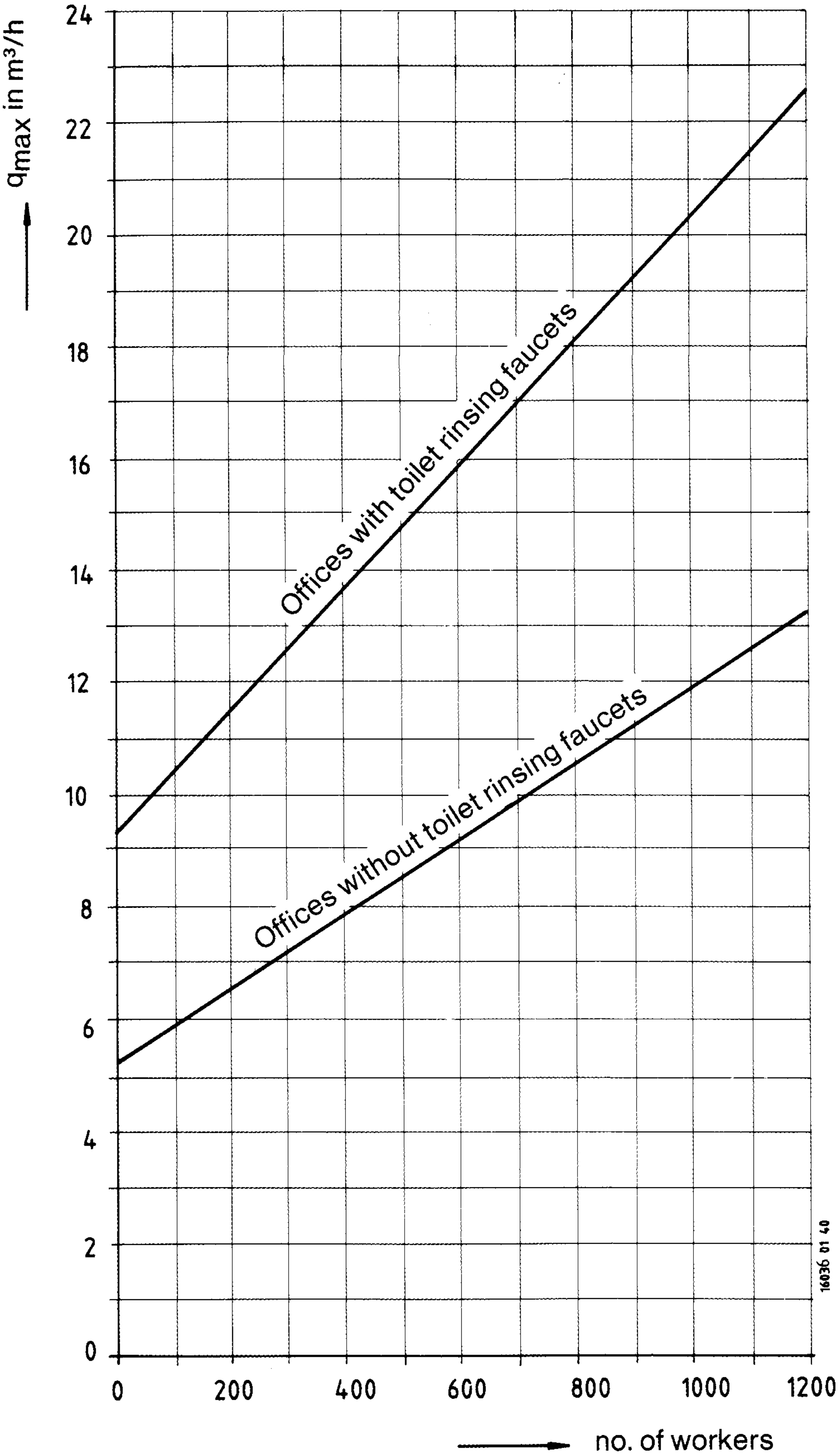
q_{max} (m^3/h) = 4,341 + 0,041 x (no. of residential units).



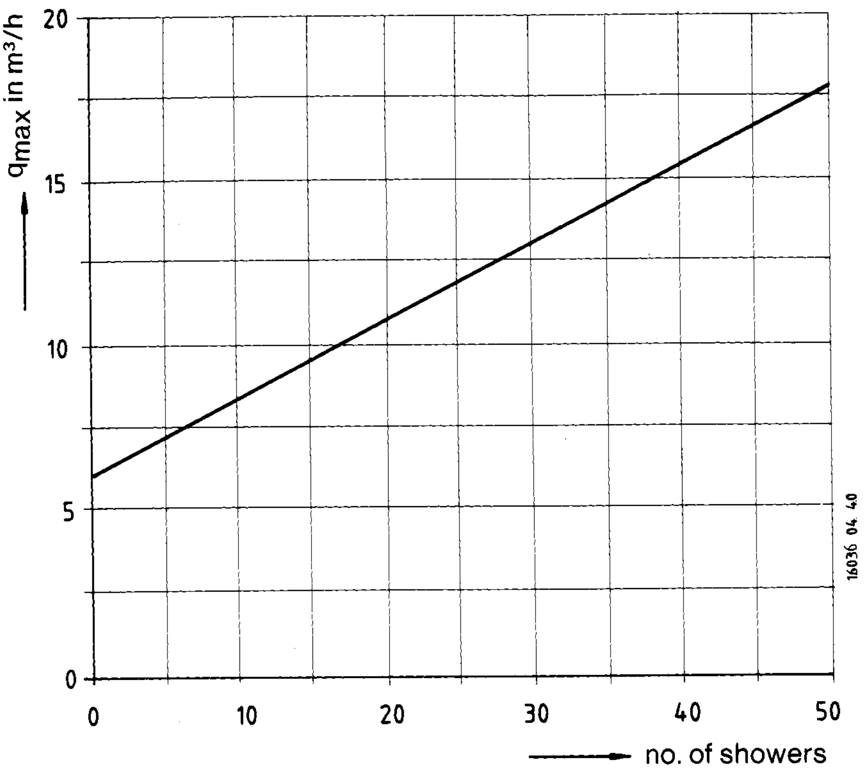
Relationship q_{max} - no. of elderly individuals in an old age home



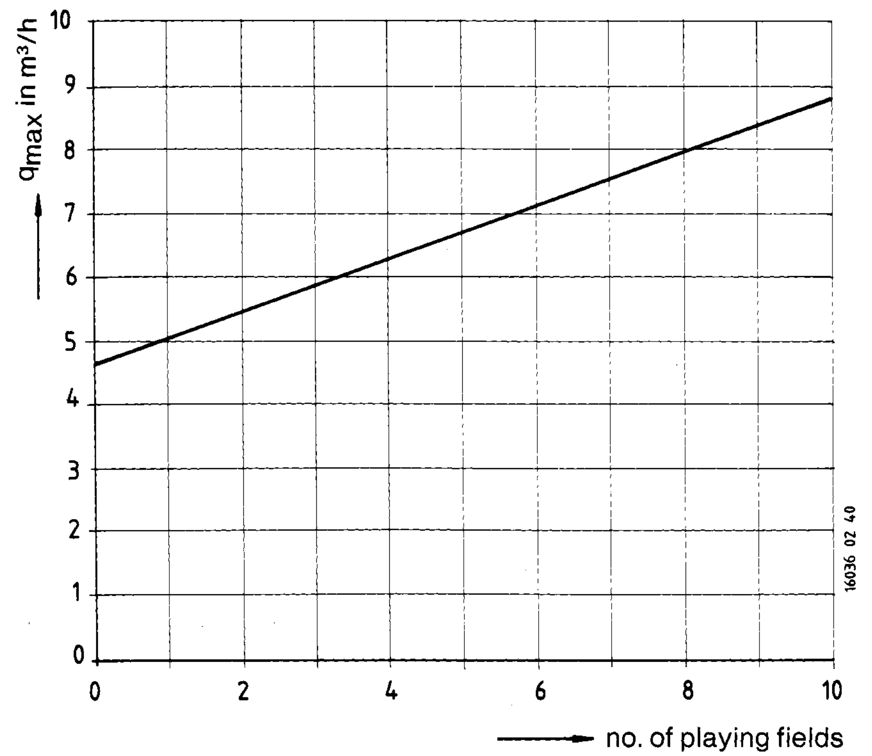
Relationship q_{max} - no. of patients in a nursing home



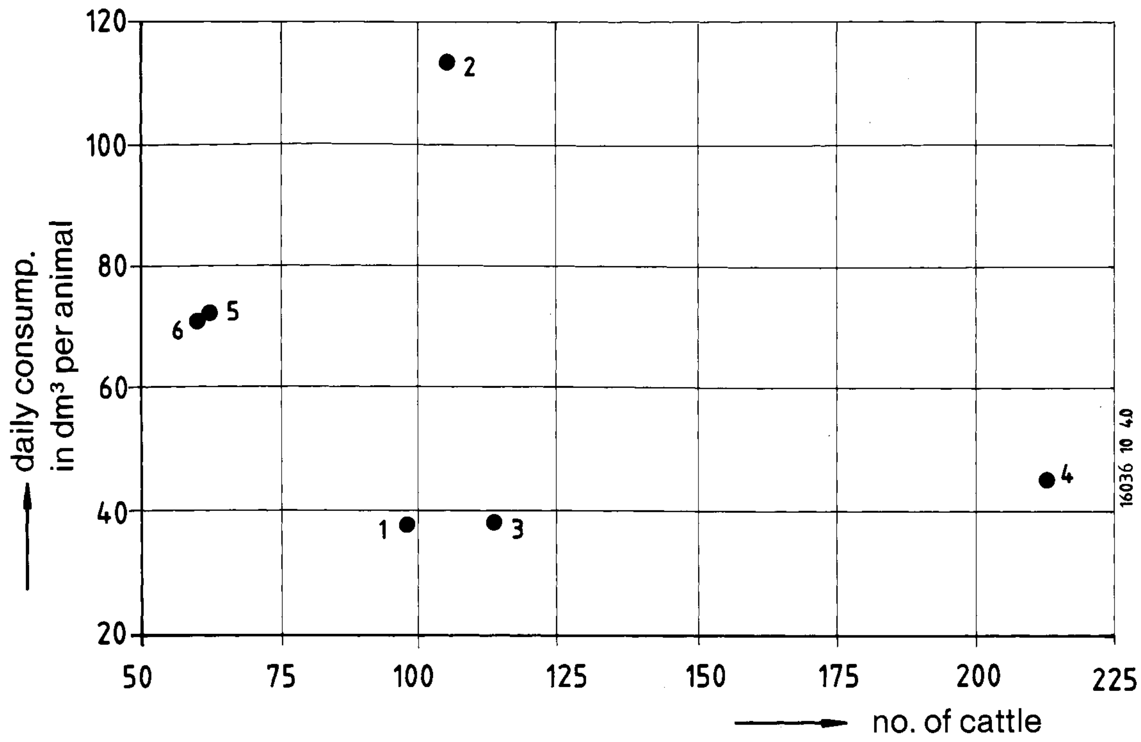
Relationship q_{max} - no. of workers in office buildings with and without toilet rinsing faucets



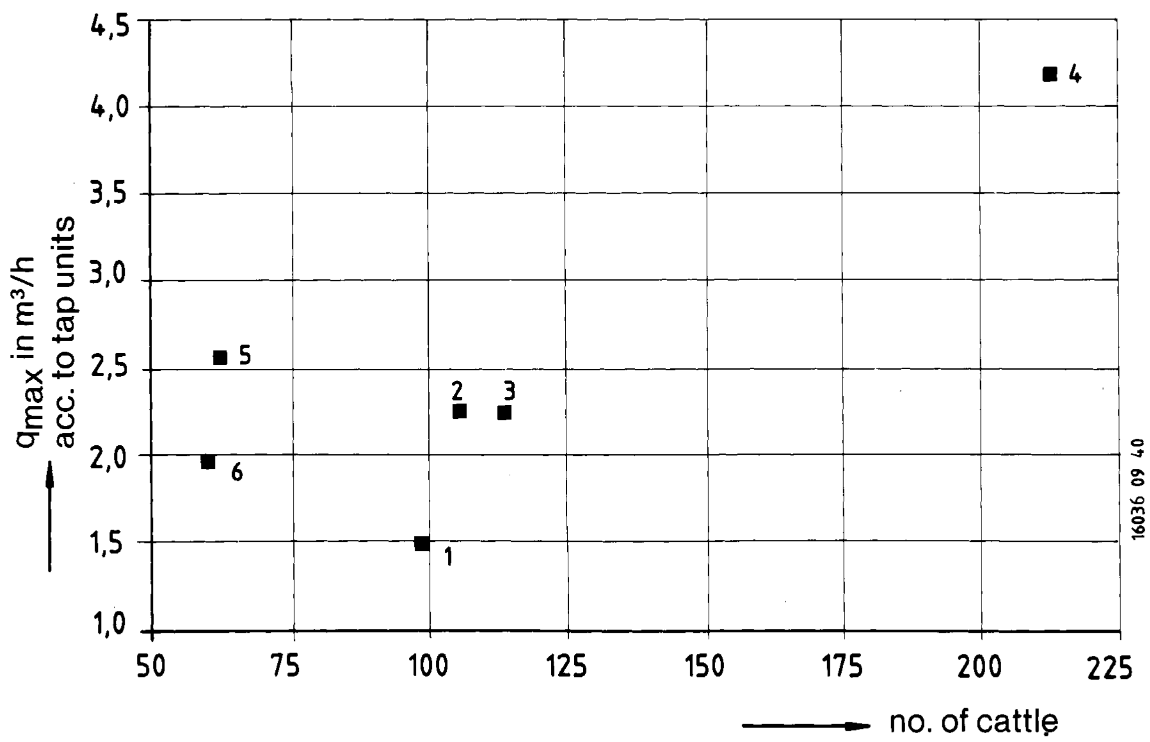
Relationship q_{max} - no. of showers in sports hall



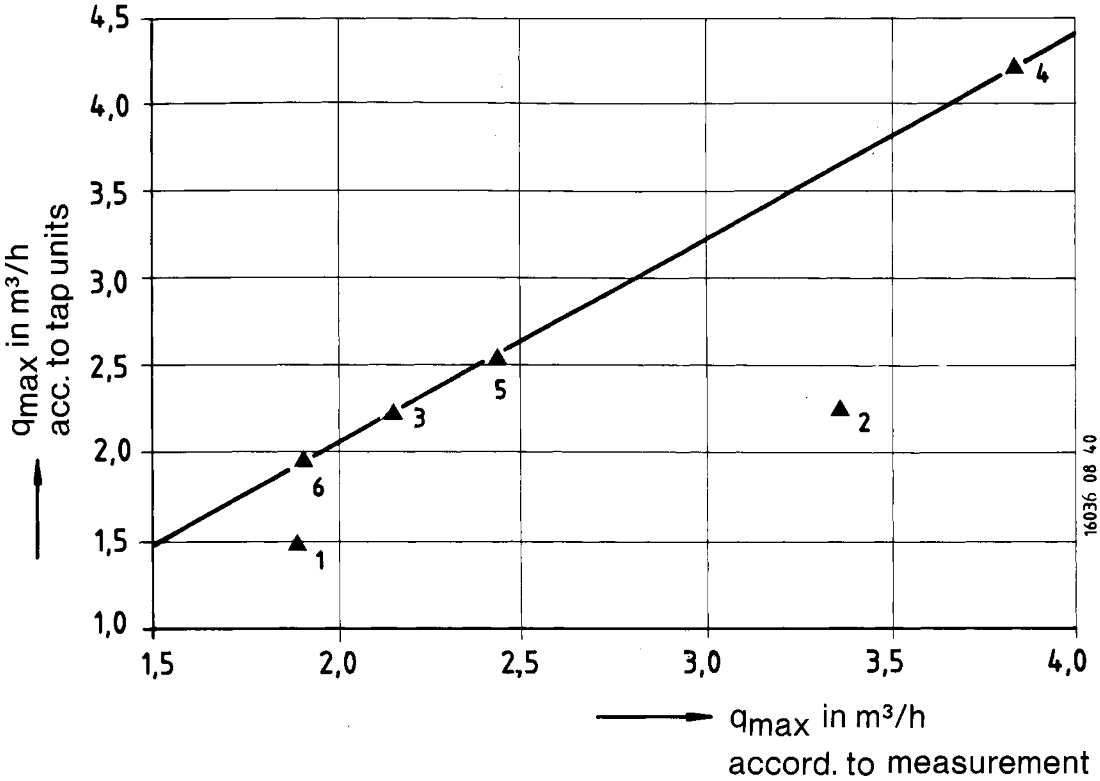
Relationship q_{max} - no. of playing fields in a sports field complex



Measured daily consumptions in dm^3 on a farm with stalls and runs for the animals



Relationship q_{max} - no. of cattle according to the $Q\sqrt{n}$ - method on farms having barns with runs



Relationship q_{max} according to the measurements and q_{max} according to the $Q\sqrt{n}$-method on farms with stalls and runs