Manual

DHWcalc

Tool for the Generation of Domestic Hot Water (DHW) Profiles on a Statistical Basis

Version 2.02b (March 2017)

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DHWcalc was developed within the scope of the Solar Heating and Cooling Program of the International Energy Agency (IEA-SHC), Task 26: Solar Combisystems, with financial support by the *German Federal Ministry of Economics and Labour (BMWA)*.

The authors would appreciate any remarks and comments, as well as information about papers, reports, and thesis for which the profiles have been used.

DHWcalc

Manual

There are no specific hardware requirements to run DHWcalc. To start the program, the executable program file *DHWcalc_2-02*.exe needs to be started. All output files will be saved in a new subdirectory within the directory of the executable.

Contents

Updates since Version 2.0

From Version 2 on, all updates will be documented in this section.

Version 2.02b (March 2018):

An error of version 2.02a was corrected: Accidently, only every 400. timestep was considered for the distribution of draw-offs. Therefore, much higher draw-off volumes were distributed throughout an only limited number of timesteps.

An error of versions 2.0 to 2.0a was corrected: When properties were loaded **from an ini-file** and the profile was generated immediately without changing other settings, the changed (loaded) value of the mean daily draw-off volume was not activated.

Version 2.02a (October 2017):

An error of version 2.02 was corrected: A bug in the calculation of holiday periods stopped the program during the creation of single household load profiles.

Version 2.02 (August 2017)

With the update to version 2.02 some existing functions are revised and some new functions are implemented.

Some principal changes are listed hereafter.

Series of Load Profiles and Initialisation of the Random Generator

With a new function, the user can generate not just one, but a series of load profiles. In a series one of the parameters **mean daily draw-off volume**, **max flow rate** and **mean flow rate** (only for one category) can be gradually changed by user-defined steps. Since version 2.02 the mean daily draw off volume influences the initialisation of the random generator, which is used for the statistical distribution of volume flows. By gradually changing the mean daily draw off volume, a series of load profiles with nearly the same consumption but different random distributions can be generated.

Further information can be found on pages 16 and 19. Because of the altered initialisation of the random generator, profiles that were generated in the version 1.10 cannot be reproduced in newer versions.

Save/Load Properties

With version 2.02 it is possible to save all user inputs into an *ini-file*. This enables the user to restore all inputs from the file, after closing and reopening the program. Additionally, an Excel-Tool is provided, which enables the user to generate an equivalent *ini-file*. Further information can be found on page 17 of the manual.

Fixed Gaussian Function for the Calculation of Flow Rate Probabilities

A bug sneaked into the Gaussian function calculating the probability of flow rates. This bug is fixed since the version 2.01.

Incorrect equation:	Corrected equation:
$prob(\dot{V}) = \frac{1}{\sqrt{2 \cdot \pi} \cdot \sigma} \cdot e^{-\left(\frac{\dot{V}-\dot{V}_{mean}}{\sigma}\right)^2}$	$prob(\dot{V}) = \frac{1}{\sqrt{2 \cdot \pi} \cdot \sigma} \cdot e^{\frac{(\dot{V}-\dot{V}_{mean})^2}{2 \cdot \sigma^2}}$

Holiday Periods

The user interface for choosing holiday periods in single family households was reworked. Now any number of holiday periods with different relative consumptions can be set. Further explanations are listed on page 13. Additionally, the bug causing the error message ‘X is not a valid floating point value’ was fixed.

Progress Bar

Since version 2.02 a progress bar shows how far the calculation of the load profile has progressed.

Seasonal Variations

To set seasonal variations a second function was added to the existing one. The new function allows the user to set a probability for each month of the year. More information can be found on page 12 of the manual.

The calculation of the sine function was revised. Now the maximum consumption will be set on the correct day of the year.

Changing Parameters in the Main Window

Changing of some parameters in the main window of earlier versions resulted in a reset of all parameters already set in the Probability Distributions and Draw-off features windows. This problem is fixed with version 2.02. Only changing the time step duration will result in a reset of the parameters set in the flow windows.

Daylight Saving Time

In Version 1.10 the activation of the Radio-Button ‘Daylight saving time’ did not lead to consideration of daylight saving time in the load profile. This bug is fixed with Version 2.0x. When daylight saving time is applied now, all draw-offs between 1. April and 31. October will be rescheduled by one hour, as explained on page 7.

1 Introduction

DHWcalc is a program to generate Domestic Hot Water (DHW) profiles. The generated profiles are saved as text-files, containing lists of flow rate values for each time step. For single-family houses, most values of the list equal to zero, with only few non-zero flow rate values in between, distributed over the total duration. An example of a three-day period of a DHW-profile for a single-family house is shown in Figure 1.1.

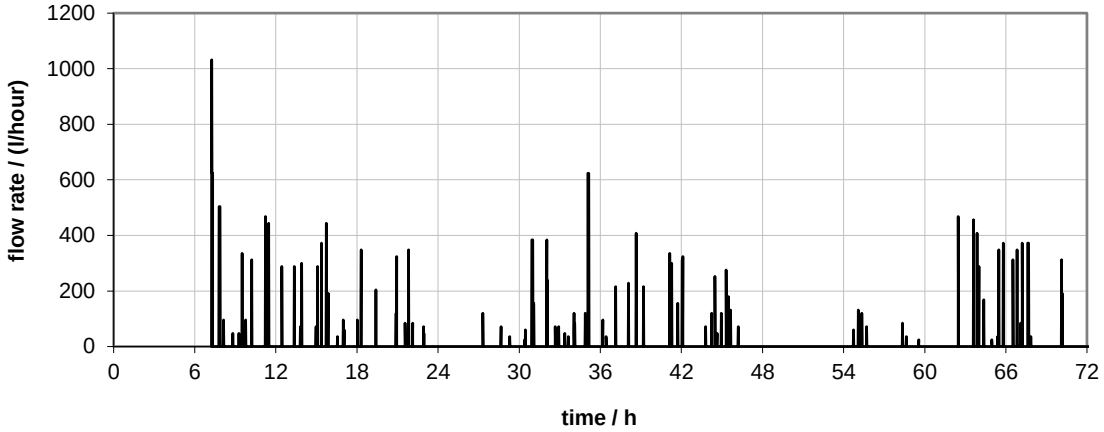


Fig. 1.1: Example of a DHW-profile for a single-family house. Time step: 1 min.

The program distributes DHW draw-offs throughout the year with statistical means, according to a probability function. Both reference conditions for the draw-offs (flow rates, durations etc.) as well as reference conditions for the probability function (daily probabilities for draw-offs etc.) can be specified by the user.

To run the program, double-click the *DHW_25.exe* file.

The program starts with the main window *FormMain*. It contains of the segments *House type, Settings, Single load profile, Series of load profiles and Save/Load properties*, which are described in the following section.

2 Interface

2.1 Main Window (FormMain)

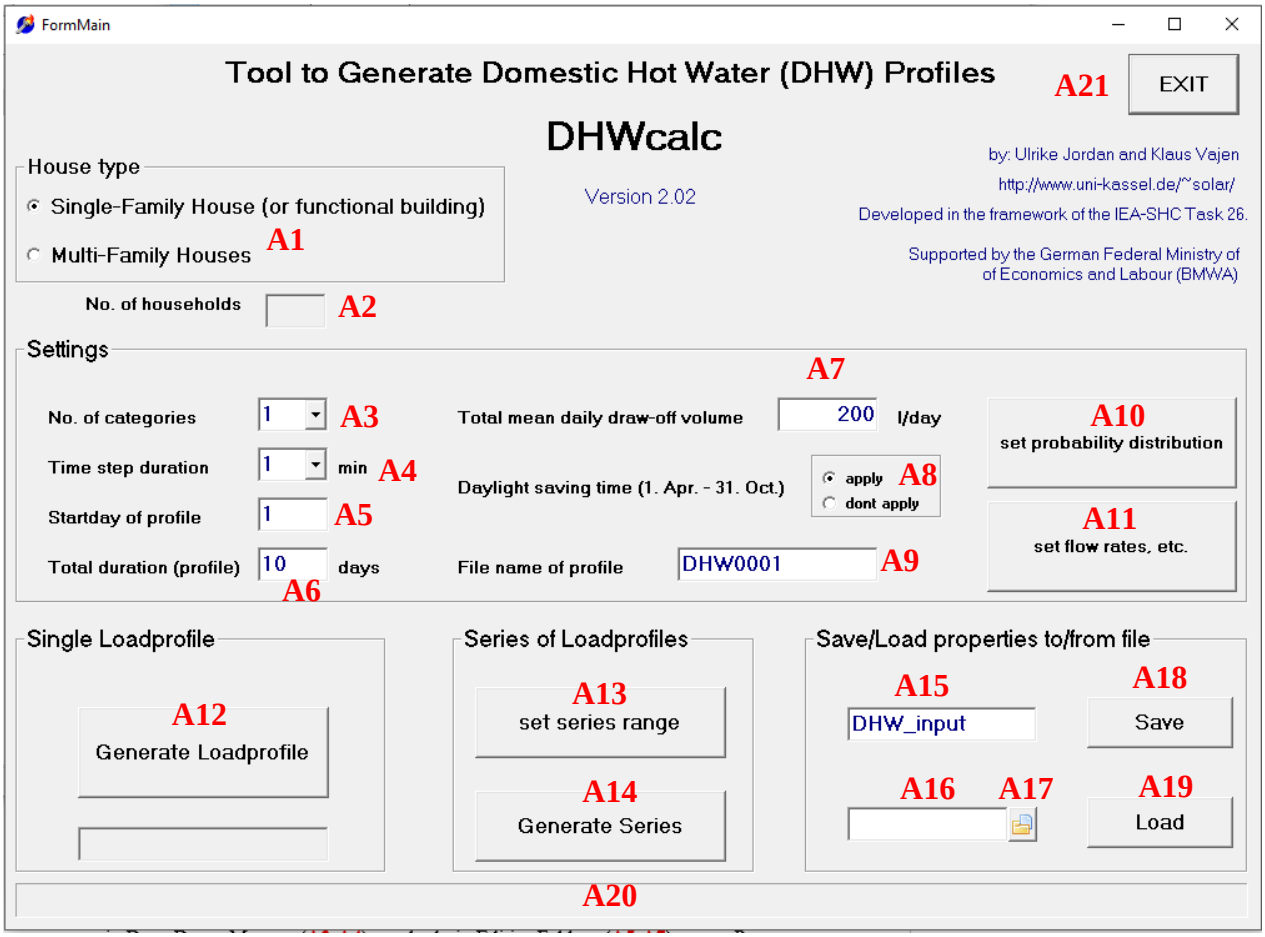


Fig. 2.1: Main window: FormMain.

The main window (Fig. 2.1) consists of:

- radio-buttons (**A1**), to choose between the options single-/multi-family house,
- an edit-box (**A2**) to define the number of households (for multi-faimily houses),
- two drop-down menus (**A3-A4**) and three edit-boxes (**A5-A7**), to edit profile parameters,
- radio-buttons to apply/disable European daylight saving time (**A8**),
- an edit-box to insert the name for the draw-off profile (**A9**),
- three buttons to open windows for further parameter settings (**A10, A11, A13**),
- one button to start the algorithm for a single draw-off profile (**A12**),
- one button to start the algorithm for a series of draw-off profiles (**A14**),
- two edit-boxes (**A15-A16**), a browse-button (**A17)** and two buttons to save (**A18**) or load (**A19**) all inputs into or out of an ini-file,
- a progress-bar (**A20**), which illustrates the progression of the calculations and
- a button to exit the program (**A21**).

The following reference conditions and functions are located in the main window:

- ***Single or Multi Family House (A1):***
  The only distinction between single and multi-family houses made in the program, is concerning the holiday-periods, described in section 2.2.4. All settings for the holiday periods are to be made in the form *FormProb1*, which opens when the button set probability distribution is clicked (**A9**). If the button Multi Family House is checked, the number of households (which equals to the number of holiday periods) can be specified (**A2**). If it is not specified, the number of household is set to the default value of one.

- ***Number of categories (A3):***
  Either one or four categories with different flow rate levels, durations and frequencies can be defined. The settings are made in different windows, which open when the button set flow rates etc. (**A10**) is clicked (see section 2.3**Fehler! Verweisquelle konnte nicht gefunden werden.**).

- ***Time step duration (A4) in minutes:***
  Marks the minimum tine interval between two draw-off starts and thereby the minimum time duration of a draw-off. The profile consist of an integer value of the flow rate in litre/hour for each time step in the total profile duration. Only fixed values between 1 and 60 minutes can be chosen. The draw-off durations (to be defined in the one of the windows ‚FormFlow_1Cat' or ‚FormFlow_4Cat') need to be multiple integers of the profile time step.

- ***Start day of the profile (A5):***
  The profile can start on any day of the year. The start day affects the probabilities (seasonal, weekday, holiday-period) for draw-offs. Jan. 1st is regarded as the first day of the year. With start day 1, 2, … the first weekday of the profile is a Monday, Tuesday, ... respectively

- ***Total duration (A6) in days:***
  Duration of the DHW-profile (usually 365 days). Determines the size of the output file. The number of values for the flow rate given in the load profile output file equals to the total duration (in minutes) divided by the time step duration.

- ***Total mean daily draw-off volume (A7) in litre/day:***
  For multi-family houses, not the mean daily draw-off volume per household, but the **total** draw-off volume of the multi-family house must be entered.

- ***Daylight saving time (A8):***
  If the radio-button '*apply*' is activated, the European daylight saving time will be considered in the calculation of the draw-off profile by preponing every draw-off in the period between 1. April and 31. October (days 90 up to including 304) by one hour.

- ***File name of profile (A9):***
  The file name must only consist of numbers, letters and underscores. The four output files are saved in a subdirectory named after the file name of the profile and their names are extended by the following endings: *_DHW.txt*, *_Vdot.txt*, *_log.txt*, respectively *_sum.txt*. For further information regarding the output files refer to section 0.

- ***Probability functions and draw-off specifications*** (volumes and durations):
  Will be specified in separate windows, which can be accessed by clicking the buttons set probability distribution (**A10**) and set flow rates etc. (**A11**). Further information regarding these windows can be found in the sections 2.2 and 2.3.

- ***Series of load profiles (A14):***
  When a series of load profiles is generated one parameter is gradually varied. The parameter to be varied can be specified in the window accessed by clicking the button set series range (**A13**), which is explained in section 2.4. The parameters to be varied are the *mean daily draw-off volume*, the *maximum flow rate* or the *mean flow rate per draw-off* (for a profile with only one category).

- ***Save/Load properties (A15-A19):***
  This segment allows to save all inputs (in all windows) made by the user and to restore them at another point in time. This function is described closely in section 2.5.

- ***Progress-Bar (A20):***
  The progress bar illustrates the progress of the calculation. If a series of load profiles is generated, the progressbar shows only the progress of every single load profile, not the total progress.

To exit the program, press the EXIT button in the top right corner of the window (**A21**).

2.2 Probability Distribution Window

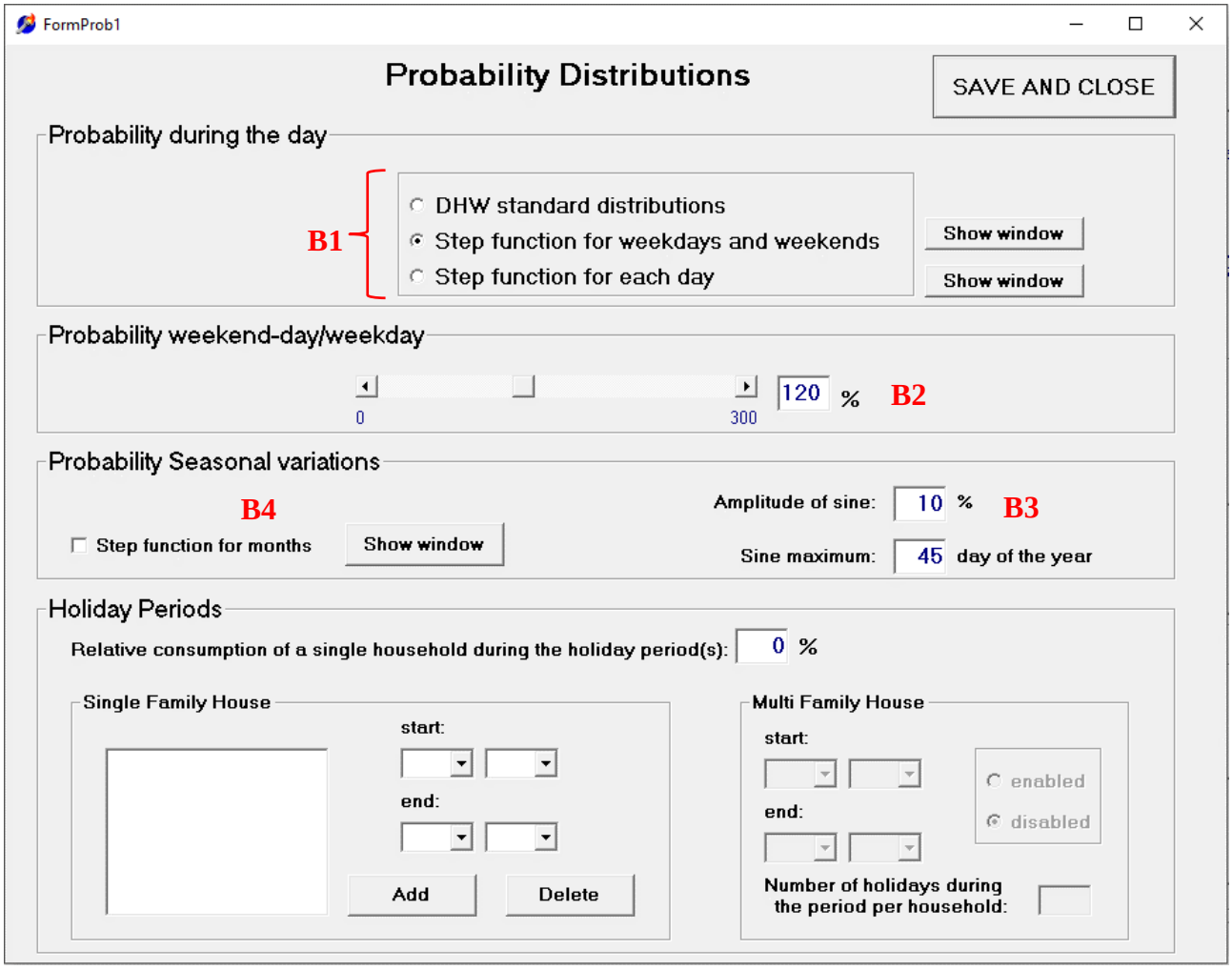


Fig. 2.2: Window for defining reference conditions of the probability distribution

To spread the flow rates throughout the time period for the profile, the cumulated frequency method was applied. This method is based on the integral function of a probability function. The method is described in section 3.

The probability function of draw-offs is described by the product of probability functions for seasonal, daily, and week-daily variations of DHW-consumption as well as a step function for consideration of holiday periods:

$$p(t) = p_{day}(t) \cdot p_{weekday}(t) \cdot p_{season}(t) \cdot p_{holiday}(t)$$

The following subsections explain which reference conditions that can be defined for the probability function.

2.2.1 Probability during the day (*B1*):

One of three options can be chosen:

1) **Default distributions per IEA-Task 26**: This is a pre-defined probability distribution based on Gaussian and step functions as shown in Fig. 2.3. Four categories of loads are defined. For two categories (small and medium draw-offs) a constant probability for draw-offs is assumed during daytime and night-time, respectively. For the other two categories (shower and bath) Gaussian distributions with peaks in the morning and evening, respectively, are defined to describe the probabilities during the day. Each category-profile is generated separately and superposed afterwards.

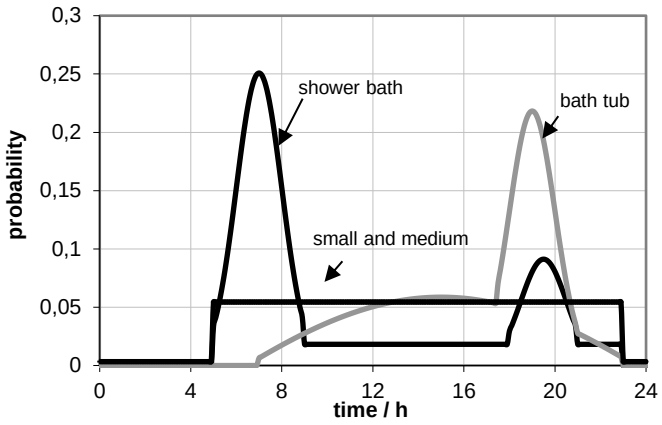


Fig. 2.3: Probability distribution load during the day.
Category 1 and 2: For small and medium draw-offs the probability is distributed equally between 5:00 and 23:00 h.
Category 3: Bath
Category 3: Shower

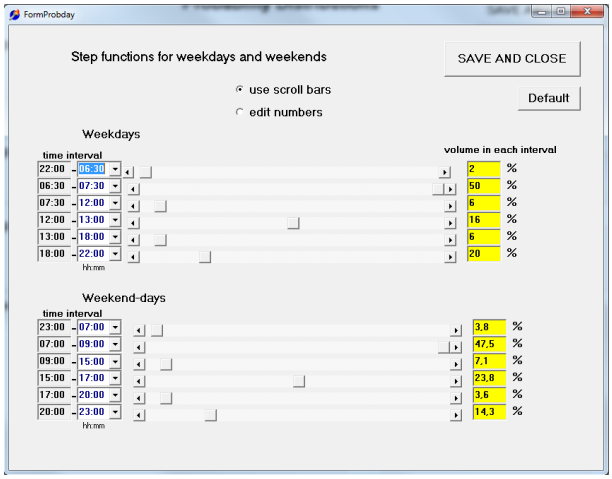


Fig. 2.4: Window to define the daily probability distributions as two different step functions, one for weekdays, the other one for weekend-days for up to 6 time period each.

!!! Attention !!!

The standard daily probability distribution as shown in Fig. 2.3 can only be chosen if the number of categories set in the main form is set to 4.

2) **Step functions for weekdays and weekend-days**: Fig. 2.4. Figure 2.4 Two daily probability step functions can be defined with this option, one for weekdays and one for weekend-days. Therefore, the probability for a draw-off at a certain time of each day is equal from Monday to Friday, and it is equal on Saturdays and Sundays. Up to six time-step intervals can be defined for each period.
The values in the yellow windows p_{step} show the part of the mean daily draw-off volume for each time interval in percent of the total mean daily draw-off volume. The values in the boxes increase, when either the corresponding time interval is enlarged or the scroll bar next to the box is moved to the right.
p_{step} is calculated with:

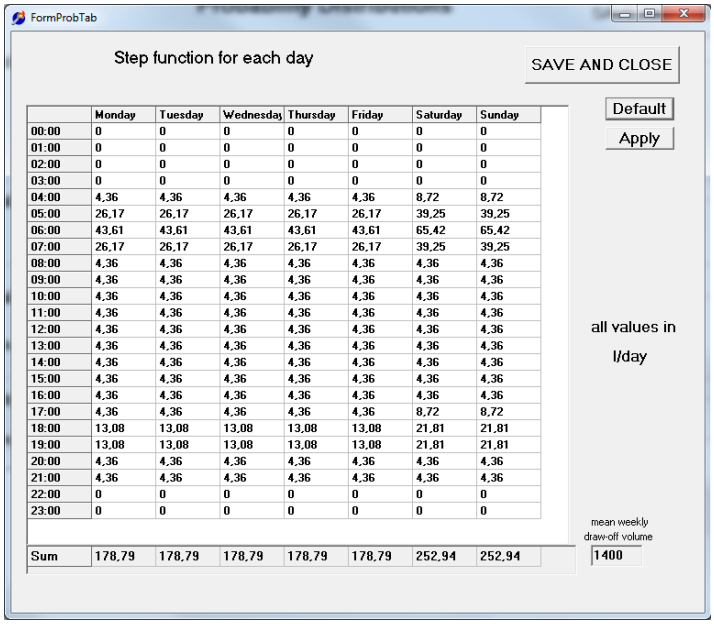
$$p_{step}^{i} = \frac{\Delta t_{step}^{i} \cdot pos^{i}}{\sum_{j=1}^{6}\left(\Delta t_{step}^{j} \cdot pos^{j}\right)}, \text{mit i, j } = 1 \ldots 6 \text{ und } pos^{i} \epsilon\, [0, 100]$$

pos^{i}: scroll bar position of the six time steps I with values between 0 and 100.

Δt_{step}^{i}: time step intervals, time 2 (white time box) – time 1 (grey time box)

If the radio-button at the top of the window is set to use scroll bars, the boxes on the right side of the scroll-bars can not be edited.

3) **Step functions for each day**: The third option provides the possibility to apply special consumption patterns, which differ much for the different days of the week, e.g. for sport halls or hospitals. A mean draw-off volume (in litres) can be set for each hour of the week. When the Default button is pressed, the values are set as shown in Fig. 2.5. When the Apply button is pressed or when the window is closed, the values are normalized, to reach the right value for the total draw-off volume. (In the example shown in Fig. 2.5 to 1400 l/week, mean daily draw-off volume: 200 l/day).



	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
00:00	0	0	0	0	0	0	0
01:00	0	0	0	0	0	0	0
02:00	0	0	0	0	0	0	0
03:00	0	0	0	0	0	0	0
04:00	4,36	4,36	4,36	4,36	4,36	8,72	8,72
05:00	26,17	26,17	26,17	26,17	26,17	39,25	39,25
06:00	43,61	43,61	43,61	43,61	43,61	65,42	65,42
07:00	26,17	26,17	26,17	26,17	26,17	39,25	39,25
08:00	4,36	4,36	4,36	4,36	4,36	4,36	4,36
09:00	4,36	4,36	4,36	4,36	4,36	4,36	4,36
10:00	4,36	4,36	4,36	4,36	4,36	4,36	4,36
11:00	4,36	4,36	4,36	4,36	4,36	4,36	4,36
12:00	4,36	4,36	4,36	4,36	4,36	4,36	4,36
13:00	4,36	4,36	4,36	4,36	4,36	4,36	4,36
14:00	4,36	4,36	4,36	4,36	4,36	4,36	4,36
15:00	4,36	4,36	4,36	4,36	4,36	4,36	4,36
16:00	4,36	4,36	4,36	4,36	4,36	4,36	4,36
17:00	4,36	4,36	4,36	4,36	4,36	8,72	8,72
18:00	13,08	13,08	13,08	13,08	13,08	21,81	21,81
19:00	13,08	13,08	13,08	13,08	13,08	21,81	21,81
20:00	4,36	4,36	4,36	4,36	4,36	4,36	4,36
21:00	4,36	4,36	4,36	4,36	4,36	4,36	4,36
22:00	0	0	0	0	0	0	0
23:00	0	0	0	0	0	0	0
Sum	178,79	178,79	178,79	178,79	178,79	252,94	252,94

Fig. 2.5: Window to define the daily probability distributions as a different step function for each day of the week with a step size of 1 hour.

SN: If '*daily step functions'* is selected, then '*Probability Weekend-day/Weekday'* (**B2**) should be set to 100 %.

2.2.2 Probability relation weekend-day/weekday (B2):

Proportion of mean draw-off volume on weekend-days compared to weekdays. Can be specified by moving the scroll-bar or entering a value within the range of 0 to 300 % into the edit-box.

Example:

$$\frac{p_{weekend-day}}{p_{weekday}} = 120\ \%\ and\ \bar{V}_{day} = 200\frac{l}{day}$$

=> Daily mean draw-off volumes: $\bar{V}_{Mon} = \bar{V}_{Tue} = \bar{V}_{Wed} = \bar{V}_{Thu} = \bar{V}_{Fri} \approx 189\ l$

$$\bar{V}_{Sa} = \bar{V}_{Su} \approx 227\ l$$

2.2.3 Seasonal variations

For seasonal variations one of two options can be chosen:

1) ***Sine function for seasonal variation (B3)**:*

   The seasonal variations are described by a sine function with a period of 365 days. The amplitude of the sine function and the day of the year at which the sine maximum occurs can be set (Fig. 2.6).

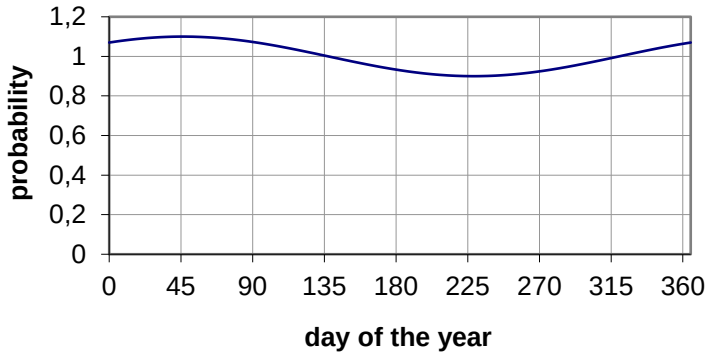


Fig. 2.6: Example for a sine function to describe the seasonal variation of the probability.

Default settings
- Amplitude: 10 %;
- Position of maximum: Day 45

2) ***Step function for seasonal variations (B4):***
   By checking the checkbox '*Step function for months'*, the sine function is deactivated and a step function can be set.
   By checking the box a window (Fig. 2.7) will appear. In the window the probability for each month (range: 0..200 %) can be set with scrollbars.

The edit-box and the drop-down-menu on the top can be used to generate a sine function by clicking on the Default button. This is only to help to set a step function which slightly varies from the sine function. But any function can be chosen.
If an unvaried sine function is desired, it is recommended to uncheck use the first Option, because that function will be calculated in a higher resolution than monthly.

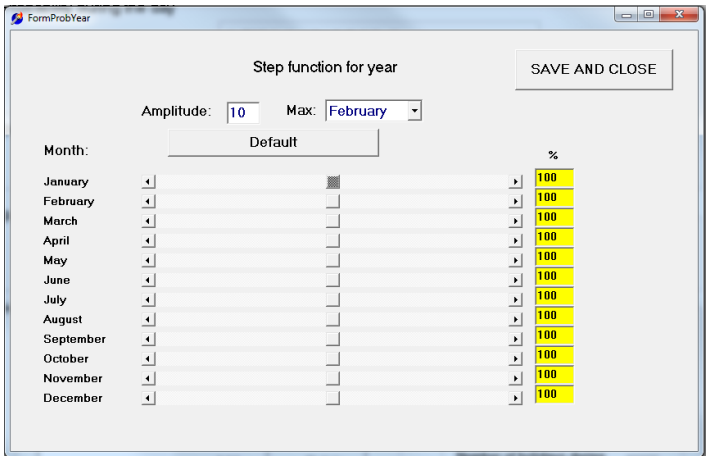


Fig. 2.7: Step function for seasonal variations

2.2.4 Holiday periods

During a holiday period, a reduced hot water consumption can be considered. The consumption can be reduced to a minimum of 0 l/d and will be distributed over the remaining time (excluding the holiday period). The probability of the consumption, as percentage of the regular probability for a draw off, is specified in an edit-box (Fig. 2.8, **C1**).

For single-family houses, any number of holiday periods can be defined. To set the dates for a holiday period the drop-down menus seen in Fig. 2.8 (**C2**) are used. For each period a different relative hot water consumption can be specified. This must be done before the holiday period is added to the list. To add the specified holiday period to the list (**C3**), the Add button must be pressed. Overlapping holiday periods in single-family households will be treated as regular holiday periods where only the relative consumption of the holiday period is considered, that is the furthest down in the list.

By clicking the Delete button, the highlighted holiday period in the list can be deleted.

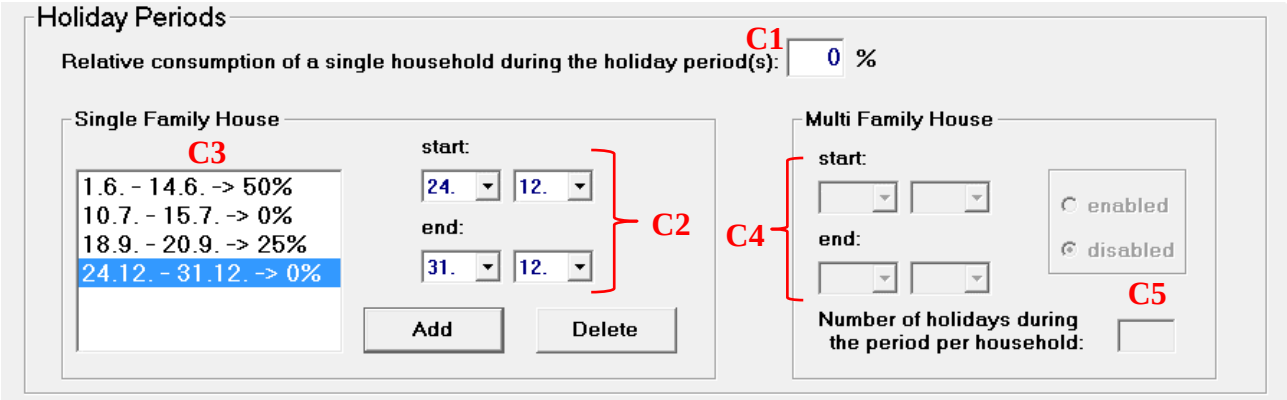


Fig. 2.8: Einstellung der Urlaubsperioden. Ausschnitt aus dem Fenster zur Definition von Randbedingungen der Wahrscheinlichkeitsverteilungen

For multi-family houses a long period (of usually a few months) marks the whole period, within which holidays are considered for each household of the house (**C4**). The start date for each single holiday period is generated with a random generator. The duration of the holiday periods of each household (default value: 14 days) can be specified in the edit-box to the right (**C5**). The relative consumption for holiday periods in multi-family houses is too specified in the edit-box above (**C1**).

2.3 Flow Windows

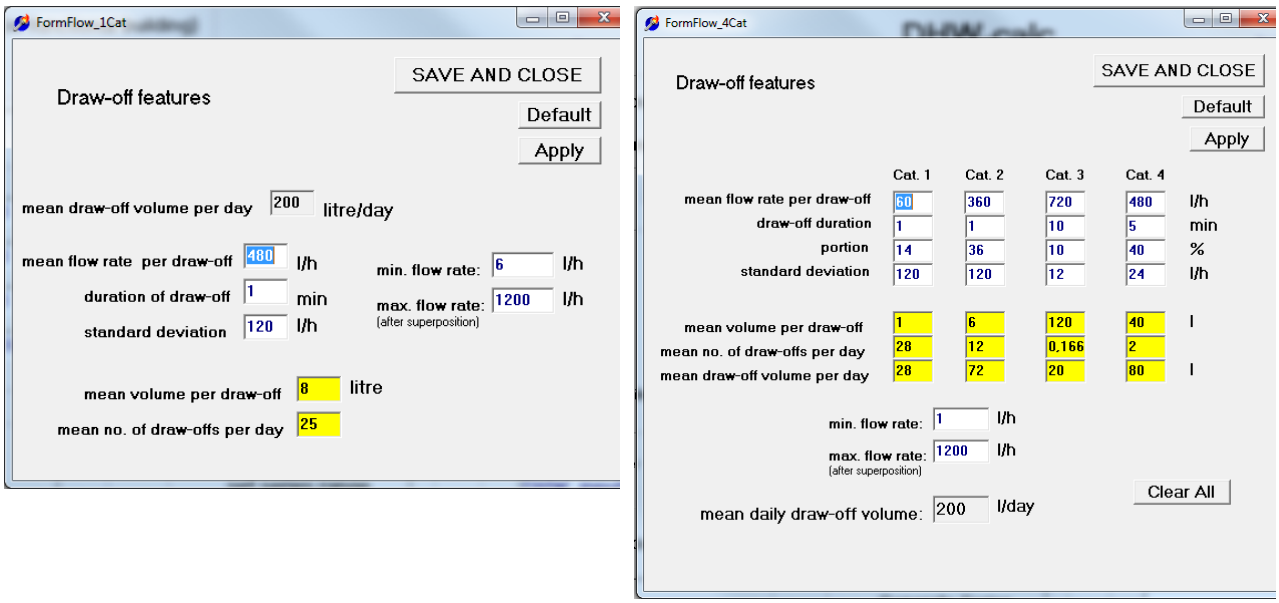


Fig. 2.9 a) und b): Flow Windows to specify flow rates, draw-off durations and the standard deviation of the Gaussian distribution of flow rates for one draw-off category (a) or for up to 4 draw-off categories (b)

If the button Set flow rates (**A11**) in the main window is pressed, a new window, for the specification of reference conditions for draw-offs, will be opened:

- If the number of categories is set to **one** in the main window, the window FormFlow_1Cat (Fig. 2.9 a) will open,
- if the number of categories is set to **four** in the main window, the window FormFlow_4Cat (Fig. 2.9 b) will open.

Only the values in the white boxes can be modified. The value for the mean daily draw-off volume is only shown for information purposes in this window. It must be set in the main window (**A7**) before the Flow window is opened. The values in the yellow boxes are calculated automatically. In some cases, they are not calculated immediately. Then, the Apply button can be used to show the updated values. However, the use of the apply button is optional. All updated values are stored automatically if the window is closed.

The following reference conditions can be defined:

- ***Mean flow rate:*** Peak of the Gaussian curves, shown in Fig. 2.10.
- ***Draw-off duration****:* Must be a multiple integer oft he profile time step.
- ***Standard deviation****:* Determines the width oft he Gaussian curves.
- ***Minimum flow rate.***
- ***Maximum flow rate****:* For multi-family houses, the total maximum flow-rate (sum for all households after superposition).

For four categories only:

- ***Portion****:* Percentage of volume assigned to each category.

For each category a mean flow rate is defined. The values of the flow rates for the profile are spread around the mean value with a Gaussian-distribution:

$$prob(\dot{V}) = \frac{1}{\sqrt{2 \cdot \pi} \cdot \sigma} \cdot e^{\frac{(\dot{V} - \dot{V}_{mean})^2}{2 \cdot \sigma^2}}$$

with σ: standard deviation.

A flow rate step size of 0.1 l/min = 6 l/h is defined by the program.

Fig. 2.10 shows the flow rate distributions applied if the default-values are chosen in the window '*draw off features*'. The curves show Gaussian flow rate distributions for four categories. The categories represent small and medium draw-offs, shower, and bath. In the figure, the total duration of draw offs during a year is shown as a function of the flow rate.

Default values for four categories:

mean flow rates:	1, 6, 8 und 14 l/min;
Standard deviation (for all categories):	2 l/min;
Durations of draw-offs:	1, 1, 5 und 10 min;

(Remark: When the simulation time step is changed, the product of the standard deviation and draw-off duration is kept constant. The values can be changed again individually, though.)

The minimum and maximum flow rates $\dot{V}_{min}$ and $\dot{V}_{max}$ are determined by twice the standard deviation σ:

$$\dot{V}_{min} = \dot{V}_{mean} - 2 \cdot \sigma \quad \text{und} \quad \dot{V}_{max} = \dot{V}_{mean} + 2 \cdot \sigma \, .$$

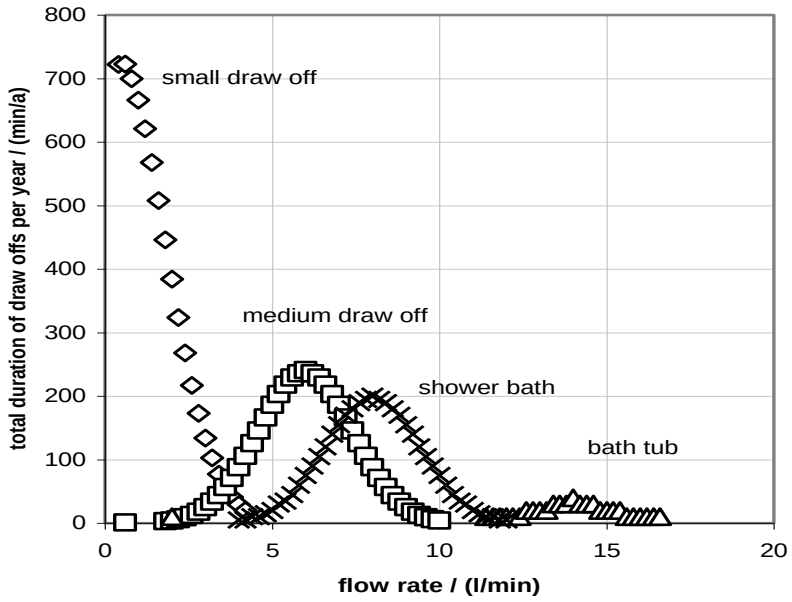


Fig. 2.10: Example for flow rate distributions for four categories with default values.

2.4 Generating a Series of Load Profiles

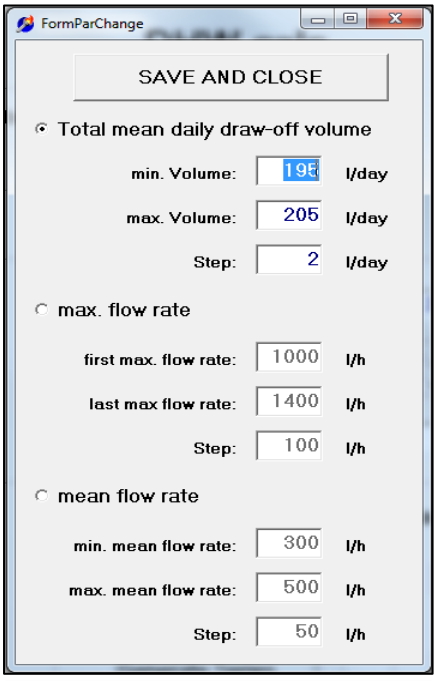


Fig. 2.11: Window to specify parameters for series of load profiles.

With the version 2.02 it is possible to create a series of load profiles. Three parameters can be varied automatically with predefined, uniform steps.

To set the parameters, press the button set series range in the main window (**A11**). A new window opens (Fig. 3.11).

The following three parameters can be varied:

1. mean draw-off volume
2. maximum flow rate
3. mean flow rate (only for one category)

In a series of load profiles only one parameter can be varied at a time.

- Click on the radio-buttons to select the parameter.
- Set the first value, the last value and the step size in the edit-boxes. These values determine the number of load profiles generated.

Be aware that a high number of profiles can result in a long calculation time.

The corresponding entry for the varied parameter in the main window or the flow window will be overwritten by the parameter variation.

By pressing the Generate Series button in the main window, the program will start generating the before specified series of profiles. At the end of the filename, that was entered by the user, the function will add a sequential number for each load profile.

2.5 Save/Load Properties

This function allows the user to save all inputs to an ini-file, in order to be able to re-load all properties when the program and re-started.

To save all properties enter a filename into the edit-box next to the Save button in the main window (Fig. 2.1). All properties (from every window) will be saved to the file '*filename.ini*'. This file will automatically be saved in the same directory as the executable (*DHWcalc_2-02.exe*).

To load properties from an ini-file the name of the ini-file must be entered into the edit-box next to the Load button. To select an ini-file, there is a button to open a browse window next to the edit-field. Any ini-file and its path will be entered in the edit-box automatically.

Alternatively, it is possible to enter the filename manually. In this case make the file must be placed in the same directory as the as the executable and have the ending *.ini*.

By clicking on the Load button all properties will be re-loaded from the chosen ini-file.

2.6 Excel Tool

The ini-file can also be created or modified manually with the help of an Excel tool. To do this, enter the desired inputs into the orange cells within the tool. The tool automatically generates the output. Copy this output (i.e. parameter names and corresponding values, green cells) from the Excel-file into an ini-file. A more detailed explanation is included in the Excel file.

Plausibility checks of the input values are not implemented into the Excel tool. Wrong entries can lead to errors or in the worst case cause the program to crash.

3 Mathematical Description: Cumulated Frequency Method

The transient probability function is calculated as the product of daily, weekly, seasonal probability distributions and the holiday step functions for every time step:

$$p(t) = p_{day}(t) \cdot p_{weekday}(t) \cdot p_{season}(t) \cdot p_{holiday}(t)$$

For the function of the probability distribution during the day $\boldsymbol{p_{day}(t)}$ one of three options can be chosen:

1.) A superposition of Gaussian functions as shown in Fig. 2.3.
2.) Two step functions, one applied on weekdays, the other one on weekend-days. Up to six time intervals can be defined for the step functions (see form in Fig. 2.4).
3.) A step function can be defined for each day of the week with a step size of 1 hour (see form in Fig. 2.5).

$\boldsymbol{p_{weekday}(t)}$ is a function to take different mean draw-off volumes on weekdays compared to weekend-days into account. For example, if the scroll bar for the *Probability Weekend-day/Weekday* is set to 120 %, it follows

$$p_{weekday}(t) = \begin{cases} 0.95 \; f\ddot{u}r \; t \in Werktage \; Mo. - Fr. \\ 1.15 \; f\ddot{u}r \; t \in Wochenend - Tage \end{cases}$$

If '*daily step functions*' is selected in the probability distribution window for $p_{day}(t)$, then $p_{weekday}(t)$ should be set to 1.

$\boldsymbol{p_{season}(t)}$ is described as a sine function (Fig. 2.6) or as a step function (Fig. 2.7) set by the user.

$\boldsymbol{p_{holiday}(t)}$ is described as a step function with the value 1 for most time steps. Only in the defined holiday periods the function drops to the user specified values.

The integral I(t) over the probability function p(t) from the start time t_{min} to the time t

$$I(t) = \int_{t_{min}}^{t} p(t)\, dt$$

is then normalized. For each draw-off a random value with ran ∈ [0,1] is generated. The time step t in which each draw-off occurs is then given by the dependent variable of the integral function $ran = I(t)$ (see Fig. 3.1).

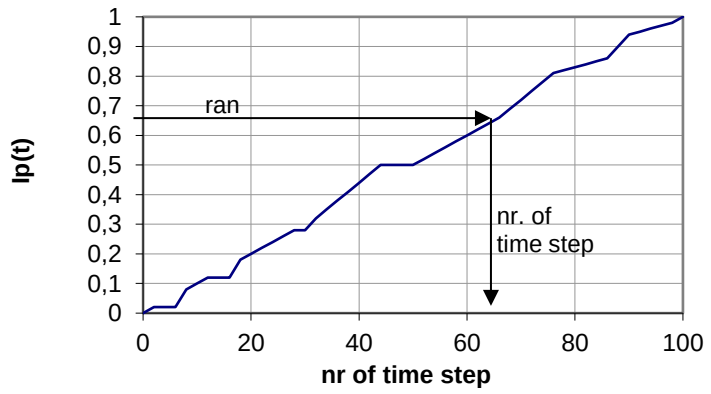


Fig. 3.1: Cumulated frequency method: Random values for each draw-off are distributed over the time period according to the probability integral function Ip(t).

SN: The random values are generated by a random generator. The random generator is initialized by the product of the total mean daily draw-off volume and the number of the category (1-4). In order to generate several load profiles with similar loads but different distributions, the total mean daily draw-off volume can be slightly iterated. For example, from 199.9 → 200.0 → 200.1 l/d.

4 Output Files

Four output files are delivered and stored in a subdirectory, which is created in the directory of the executable *DHWcalc_2-02.exe.*

- Filename_DHW.txt
- Filename_Vdot.txt
- Filename_sum.txt
- Filename_log.txt

The file *Filename_DHW.txt* contains a value for a DHW flow rate in litre/hour for each time step in the duration chosen. For example, an annual profile with a time step of 6 minutes contains 87 600 lines with the same number of integer values. For single-family houses and small multi-family houses and rather small time steps, most values of this file are zero.

The file *Filename_Vdot.txt* summarizes the draw-offs. It contains two values in each line, separated by a semicolon. The first value is the flow rate (in litres/hour), the second one is the number of the time step, in which the flow is drawn.

The file *Filename_sum.txt* contains of five lists:

1) Sum of draw-off volume for **every day**,
2) sum of draw-off volumes, drawn in a specific hour for **every day**,
3) sum of draw-off volumes, drawn in a specific hour for **weekdays**,
4) sum of draw-off volumes, drawn in a specific hour for **weekend-days**,
5) every day which is a holiday. For multi-family houses the holidays of each household will be listed.

0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
0
130
0
269
183
0
0
0
0
53
0
0
0
0
…

Fig. 4.1: Example for a part of the output file *Filename_DHW.txt*.

130;28
269;30
183;31
53;36
43;53
63;72
61;74
66;77
60;81
222;124
69;125
125;126
58;127
54;169
60;172
60;174

Fig. 4.2: Example for the output file *Filename_Vdot.txt*.

sums of daily draw-off volumes
124,4
139,9
93,8
138,8
78,1
278,5
308,5
sums of draw-off volumes of each hour of the day
8,4
0
0
7,3
9,8
8,6
0
875
179,8
15,8
31,5
29,2
222,4
0
0
115,8
89,5
0
81,3
120
90,7
101,4
13,5
0
holidays of household(s), numbers correspond to day of year
1
2
3
4
5

Fig. 4.3: Example for the output file *Filename_sum.txt*. Sums of weekdays and weekend-days are not shown.

The European Daylight Saving Time (‘summer time’) is not taken into account in the listing of *Filename_sum.txt*. Due to the fact that the daily probability distributions are shifted by one hour during the summer months, the values in the list of the hourly draw-off volumes do not reflect the daily probability distributions exactly.

The file *Filename_log.txt* supplies information about all input data supplied by the user. An example logfile is shown below in Fig. 4.4.

```
LOGFILE  DHW0001_log.txt


for a single family house


Total duration:         10 days
Start day :             1. day of the year
Mean daily draw-off vol.: 200 l/day
No. of categories:      1
Time step duration:     1 min


FLOW RATE SETTINGS

Mean flow Rate:         480 l/h
Duration of draw-off:   1 min
sigma:                  120 l/h
min. flow rate:         6 l/h
max. flow rate:         1200 l/h


PROBABILITY FUNCTION SETTINGS

Step function probability distribution for weekdays + weekend-days

Mean DHW-volume tapped during 6 time periods:
weekdays
time period   ratio of daily DHW-volume
22:00-06:30     2 %
06:30-07:30     50 %
07:30-12:00     6 %
12:00-13:00     16 %
13:00-18:00     6 %
18:00-22:00     20 %

weekend-days
time period   ratio of daily DHW-volume
23:00-07:00     3,8 %
07:00-09:00     47,5 %
09:00-15:00     7,1 %
15:00-17:00     23,8 %
17:00-20:00     3,6 %
20:00-23:00     14,3 %

Ratio of the mean daily draw-off volume tapped
  on weekend-days/on weekdays: 120 %
Seasonal Variations:
  Sine amplitude: 10 %
  Day of sine maximum: 45
Holiday Periods:
  1.1. - 5.1. -> 50%
```

Fig. 4.4: Example of the file *Filename_log.txt*.

5 Examples of daily draw-off volumes

Single-family house. Daily load over the course of the year.

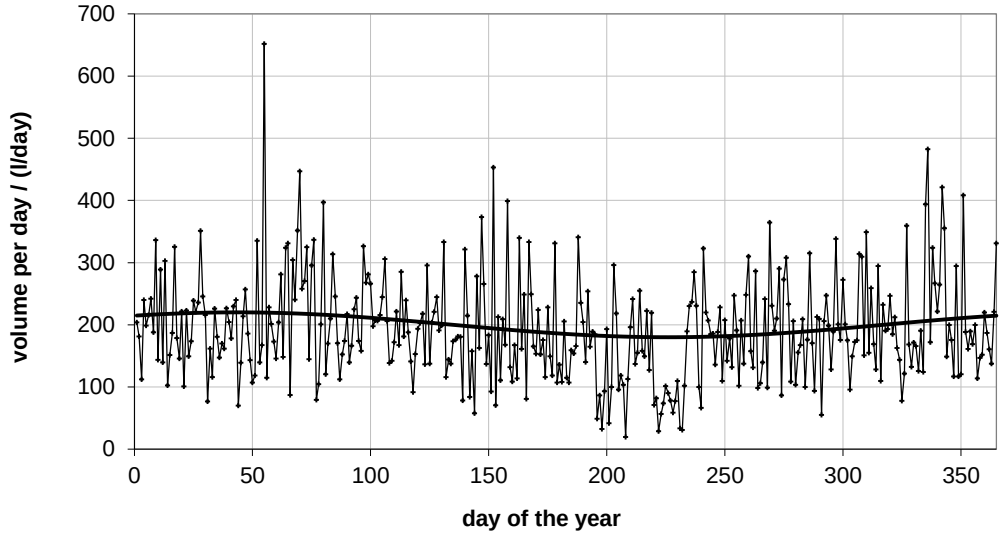


Fig. 5.1: Distribution of draw-off volume per day during the year (mean value on holidays: 100 l/day, on other days: 200 l/day,). The sine function, used to calculate the probability during the year with an amplitude of 20 l/day (10% of the mean daily draw-off volume) is shown with a solid line. Two periods of reduced discharge are taken into account, between Jul. 14th (196. day) and Jul.28th and between Aug. 8th (221. day) and Aug. 22nd (marked with grey lines).

Ten-family house. Daily load over the course of the year.

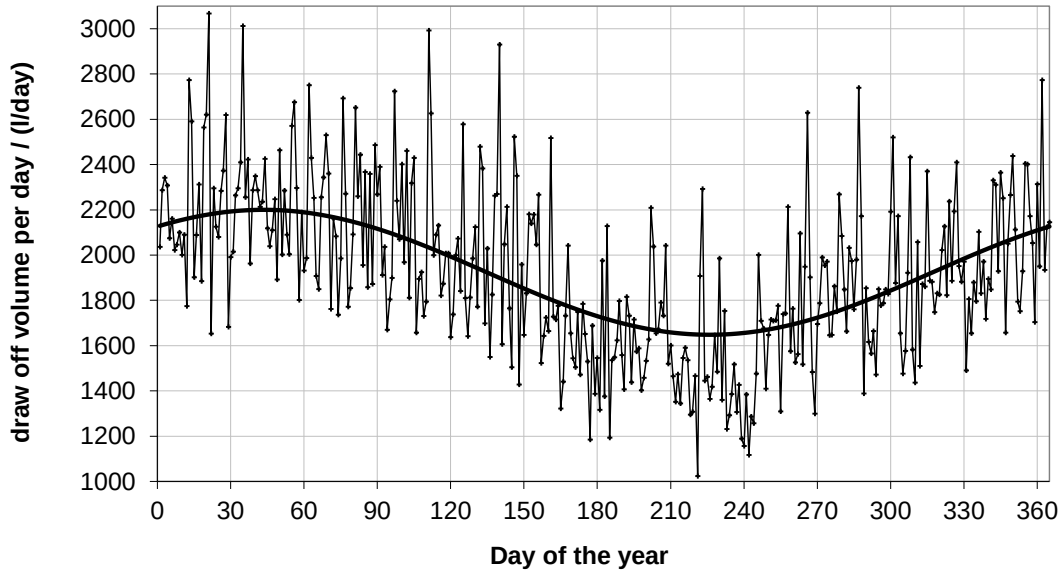


Fig. 5.2: Distribution of the total daily draw-off volume during the year for a ten-family house (mean value: 2000 l/day). Solid line: average consumption in the course of the year. Two weeks holidays between June 1st and Sept. 30th for each household.
Tagesverbräuche des Zapfprofils eines Zehnfamilienhauses (Durchschnittsverbrauch: 2000 l/day). Obere Sinuskurve: Durchschnittlicher Tagesverbrauch im Jahresverlauf. Zwei Urlaubswochen zwischen 1 . Juni und 30. September für jeden Haushalt.