IBHS

Ingenieurbuero Samoticha
für Verfahrenstechnik

HS-PsiDrop

Calculating the pressure loss in gaseous channels

Version 3.2

User guide

1   Contents

2   General information

This chapter describes:
- what was the purpose of creating this program
- what is meant by calculating the pressure loss and how it is carried out
- what objects are placed at the disposal in the program, to image the gaseous canals system
- how to calculate the pressure loss when the load is changed
- what results are supplied by the program

2.1 Uses of the program

The aim of this program is to determine the pressure course and its waste in the canals, where gas flows. It shall facilitate and automate the simple, but time-consuming calculations of the pressure course in the gaseous canals in the power plant, emission control installations, ventilation, etc.

The group of the program's receivers, as the users, are engineers, who plan such objects, or operate them. This program calculates the pressure lengthwise the gas path, that means: it investigates the pressure variation from the start to the final point of the installation (not the canals' network).

The huge advantage of the program is the ease, with which the individual elements of the canal are introduced to the data. It is done by dragging and dropping the selected element (e.g. knee) with a mouse to the table of elements, giving several parameters and the program automatically calculates the flow resistance coefficients (further called Zeta coefficients, or short Zeta). There is no need in searching the proper calculation methods and tables in the literature, and interpolation of the discovered data.

In the program, there were implemented several canal elements classes, like e.g. straight segments, knees (sharp, segment and circular etc.). For the elements not included in the program, the element "Black Box" was provided. With its help, it is possible to introduce all the pressure resistances, which can be calculated using the Zeta coefficient – defect : Zeta coefficient has to be defined on one's own.

The further elements class, which are present on the gas path, are apparatus. The pressure loss, which take place in them, is known (by the experience or documentation, offers) and it is converted into the other loads, if desired.

2.2 Methods of pressure loss calculation

The path, where the gas flows is defined. Static pressure is known at the beginning. The calculations proceed in the direction of the flow. One by one, there are calculated Zeta coefficients, pressure loss of the given element, and the pressure on its outlet is updated. Until the end of the calculations, one should move this way. If there are apparatus on the gas path, their pressure loss are calculated directly, that is: not using the Zeta coefficient, but the known pressure loss is taken into account. Their pressure loss is only matched with the actual load conditions (gas data).

If on the gas path, there is a fan, or other device which actively changes the pressure (e.g. pressure regulator), the calculation becomes more complicated. The point, where the pressure shall remain constant (because of the regulation) is defined. The calculations from the fan to the following such point (Reference Point) occurs by iteration, because the

pressure behind the fan is not known in advance. The notions and applications of the various elements will be precisely described in the following chapter.

However, the same rules are in force when calculating the gaseous canals as when calculating the pipelines, but the variety of structural execution is very large, and they are different in each installation. Therefore, one is forced to use many tables and diagrams to define the necessary Zeta coefficients. For many elements, it is impossible to find in the literature methods of such calculations, so that Zeta often has to be estimated.

The pressure loss are calculated according to rather simple rules. For various elements, gas data and flow resistance Zeta coefficients are required. Then, calculation is realized by pattern

$$\Delta P = \varsigma \cdot \frac{w^2 \rho}{2} \qquad\qquad (1)$$

The difficulty consists in finding Zeta. In the literature, there can be found methods of calculating the flow resistance coefficient, but usually for the limited number of elements. In the pipeline technology, there are used only few, usually normalized, fittings. In the case of gaseous canals, the situation looks completely different. Here, the designer needs literature sources with many elements. Such information source is for example "Handbook of hydraulic resistance" by I.E.Idelchik. The book describes calculation methods for the huge amount of different knees, fittings, throats and other local resistances. But when one carries out the calculations according to these methods, he promptly finds, that these methods are rather complicated and defining Zeta for each element requires a huge work contribution. For the majority of the elements, they are dependent on gas data and they change together with the load. Therefore, calculating the pressure loss for the new installation load is, in practice, as time-consuming as the first calculation.

The HS-PsiDrop Program takes these routine actions over the designer. At the first calculation, it supports the user with the comfortable editor. After entering the data, usually the canal elements' geometry, Zeta is automatically calculated for each load. It is possible to enter 6 load definitions.

As a result, the program supplies the pressure loss tables of the individual elements, canal segments and the whole system. Besides, the pressure increases in the fans. It shows and prints the static and dynamic pressure course and also the gas flow's speeds.

2.3 Elements in files

The following objects, to describe the canals system configuration, were provided. Some of them are the abstract elements (which do not exist in the channel) – like e.g. definitions of segments, Reference Points – the other describe the canal parts' behavior, e.g. apparatus.

For calculating the pressure loss in the industrial installation, various sources of the pressure variation should be treated in a different way. Therefore, several classes of such elements were introduced. These classes are:

Definition of the segment

For the calculation, the gas data are necessary. Definition of the segment can define it. The elements, which change the gas data, update it for the next elements. However sometimes, it is necessary to enter the new gas data. In such case, the segment definitions are entered. Besides, it is easier to navigate in the file divided into segments. The definition of the segment can be "inactive", that is: leave the date unchanged.

The definition of the segment contains the following data:

- Name of the segment
- Indication, that it does not change the gas data, or:
- Gas volumetric flow in the standard conditions
- Its temperature
- Gas composition

The characteristics of the gas are determined on the basis of the given composition, temperature and the calculated pressure.

Fan

This program enables to calculate the canals with the fans. More fans can be connected one by one. To introduce the fan, the following data are given:

- Name
- Section of the outlet
- Indication, that the temperature increase should be taken into account. Then additionally:
- Efficiency of the fan

Except from fans, the other elements actively changing the pressure can be entered this way, e.g. pressure regulator.

Between one fan and another, or before the calculation end, the Reference Point must be given – the point of the constant (controllable) pressure.

Apparatus

The pressure loss caused by the apparatus is not calculated using the Zeta coefficients, but it is given directly. Apparatus have got too complicated structure, to make it possible to calculate [ist] pressure loss by mapping from the typical elements of the canal. On the other hand, [ist] pressure loss are, in the specified conditions (at the specified loads) known. At the other loads, there occurs the recalculation into the actual gas data. The relationship between the pressure loss and the gas data can be various. Therefore, there was provided the possibility of giving the power, which maps the relationship. It depends on this power, how the given apparatus reacts on the modification of the gas amount. When the turbulent flow is advanced, the power=2 is applied, in the other case between 1 and 2. In some cases, when the apparatus is regulated dependent on its pressure loss (e.g. filters) the power=0 can be given, to separate the pressure loss from the amount of gas.

To define the apparatus, the following data are given:

- Name
- Pressure loss the definition load[1]
- Power
- Indication, that gas in the apparatus does not change, or the data at the outlet:
- Volumetric flow in the standard conditions
- Temperature
- Gas composition

---

[1] Definition load is the first to be defined. It forms when creating the new file.

Reference Point

"Reference Point" is the name for the place in the canal, where the static pressure has to receive the previously given value. Such point lies in the beginning of the calculated canal. The start pressure must be known. If there are any fans in the gas path, on each of them must such point be given. E.g. gas is introduced to the system with the pressure P1 and because of the pressure loss, it attains before the fan P2. The fan compresses the gas to P3. Behind the fan, the pressure falls because of the further waste to P4. To be able to unequivocally define the compression in the fan, pressures P1 and P4 must be entered as the "Reference Point".

Run of the gas duct
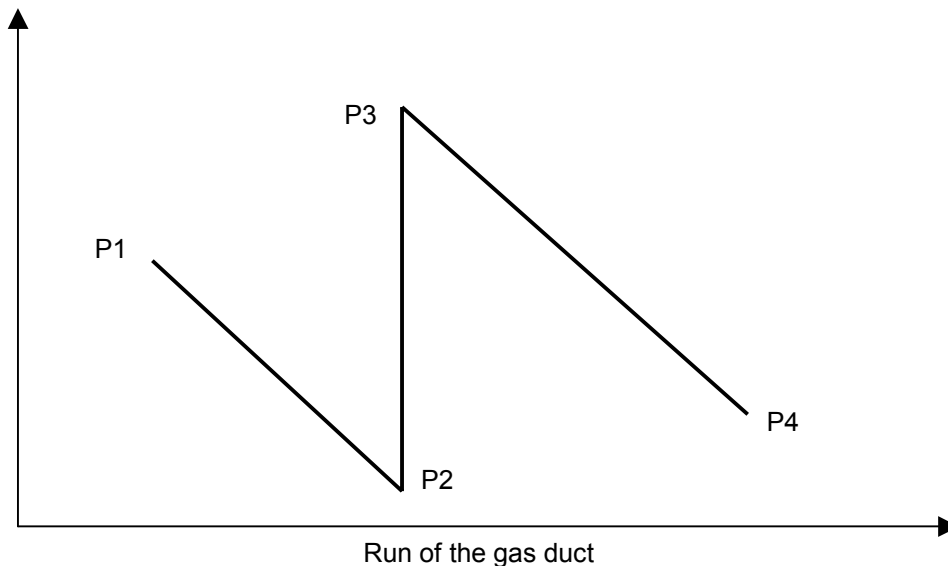
Height change

This element allows entering the height differences, which generate the hydrostatic pressure by the specific gravity differences. This effect should not be underestimated. E.g. the combustion gas (16% water, 10% CO_2, 4% oxygen at 180°C) have the specific gravity 0,7615 kg/m³. At the typical for the power plants height differences of the order of 40 m, there forms the hydrostatic pressure of 2,08 mbar.

Fittings

The most common objects, there will be the elements of canals, like knees (sharp, segment), T-fitters, throats, straight segments and other. The pressure loss, which they cause, is calculated with the Zeta coefficients. The program calculates it automatically. Only the element "Black Box", which can represent everything, requires giving Zeta by the user.

These elements placed in the table describe the gas path. They are entered in the order of the gas flow. After entering several parameters for each element, the system is defined in the file.

2.4 Load cases

The industrial installations work, dependent on necessities, at the different loads. E.g. in the power plant the amount of combusted fuel decides of the parameters, which have an

influence on the pressure course in the conduits of the combustion gases. The loads are defined by:

- Volumetric flow of the gas
- Gas temperature
- Its composition
- Proportions of flows in T- fittings and Black-Boxes
- Pressure in the start point
- Environment temperature

These parameters determine the Reynolds number, which has an influence on Zeta in many elements of the canal. Besides, the dynamic pressure changes. Apparatus (e.g. filters, gas washers, heat exchangers) cause pressure loss in the different work conditions. The modified pressure at the beginning influences the pressure level in the whole system, and it has an influence on the fans' capacity. The other environment parameters enlarge or lower the natural draught in the installations.

This program enables recording and calculating to 6 defined loads. For calculation in the other loads, one should only give the changeable parameters. If there are no changes in the structure of the canals themselves, the calculation proceeds very promptly and easily.

2.5 Results

After the calculation, the user can analize the results. The program gives the following information:

- Table with all the important data
- Graphical presentation of the static pressure course lengthwise the canal
- Graphical presentation of the flow speed course
- Graphical presentation of the dynamic pressure course
- Graphical presentation of the pressure loss of all the elements for comparison and determination of the greatest obstacles
- Segments balance
- Fans balance

All the results (except for the pressure loss comparison) can be printed .

3	Work with program

In this chapter, there will be given the information, which present the program operation and explain the data structure. That is:

- how to operate the dialogue element
- how the mail application window looks like
- how to map the gaseous canals in the table
- how to define the loads and calculate pressure loss

3.1 General information about the operation

This program is designed, so as the operation occurs by intuition. In the main window, dependent on the status, there is presented the editor with table, in which simultaneously occurs the results presentation in this table or graphically.

3.1.1 Dialogues

The program communicates with the user by the dialogues. They base on the following rules:

- If not all of the required data were entered, the button OK. is locked. The reason of such situation is often explained by the button "Help"
- The elements of the dialogue, which contain the false data, are usually presented in yellow, or if they await giving the section – in light blue. When the data is correct, they change into white.
- Text areas, which await numbers or accept only the proper characters
- The cross sections are given as follows

Cross section	Keys	Presenta-tion as	Remarks
Circular Diameter 1200 mm	D1200	ø1200	**D** for "Diameter"
Quadratic 2000 x 2000 mm	Q2000	2000	**Q** for "Quadrat"
Rectangular 3000 x 4000	3000 x 4000	3000 x 4000	

3.2 New project

To begin the new project, one should select **File/New** in the menu. Before it will be possible to map the canal configuration, it is necessary to give the general project data and create the first segment definition. To make it, two dialogs appear one by one.

3.2.1 „File information" dialogue

Firstly, the dialogue „File information" appears.
Here the information about the object are given

- Object name
- Description
- Overpressure at the start
- Section at the start

about the user
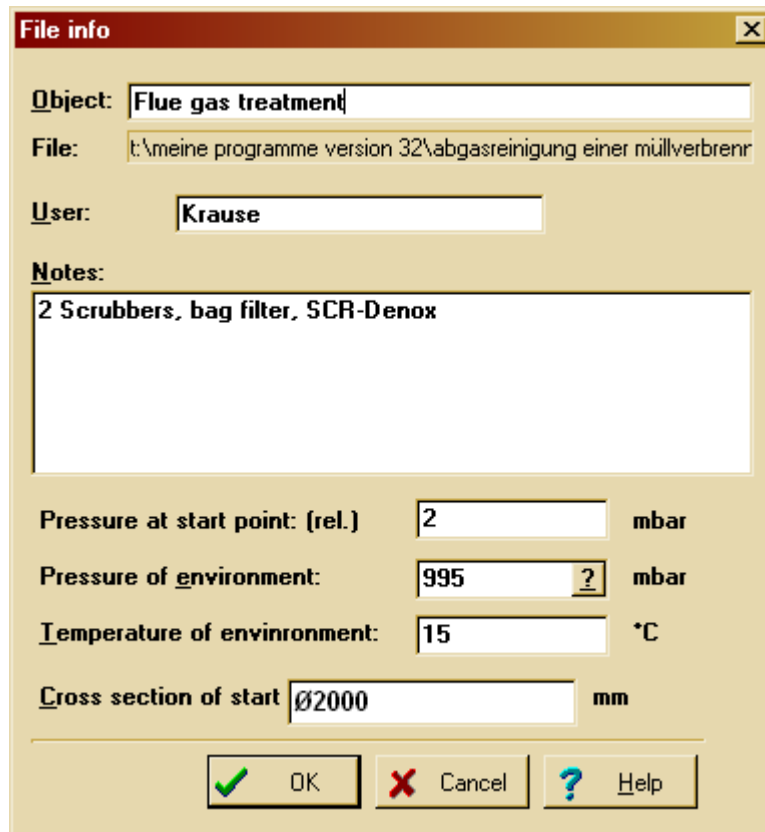
- Surname of the user

and about the environment

- Environment pressure
- Environment temperature

The object name and the surname of the user appear on the printouts. The other data are necessary for the calculation.

Illustration 1   "File information" dialogue

Overpressure at the start is the static gas pressure in the place, where the calculation starts. The pressure differences in relation with the environment are given, so that this number can be negative.

The environment pressure (absolute) is necessary to calculate the gas pressure course lengthwise the installation. If unknown, it can be calculated from above the sea level.

The environment temperature will be necessary to calculate the hydrostatic pressure.

The section at the start determines the section at the calculation beginning.

3.2.2 "Segment definition" dialogue

Then, the first dialogue is defined. The dialogue appears:

Illustration 2 "Segment definition" dialogue

The following data are given:

Name. The segments can be named at will. As names, there can be used the sequence of characters, having a length of 35 characters.

Data on the outlet - unchanged. This switch shows, if the gas data after the segment definition is modified and will be given. In the first segment, they have to be given.

Volumetric flow is given in the standard conditions for the wet gas

Temperature of the gas.

Composition of the gas in volumetric per cents. The participation of nitrogen is calculated automatically.

3.3 Canal edition

In the table, the calculated canal will be mapped.

3.3.1 Main window description

The main window of the program during edition looks like this
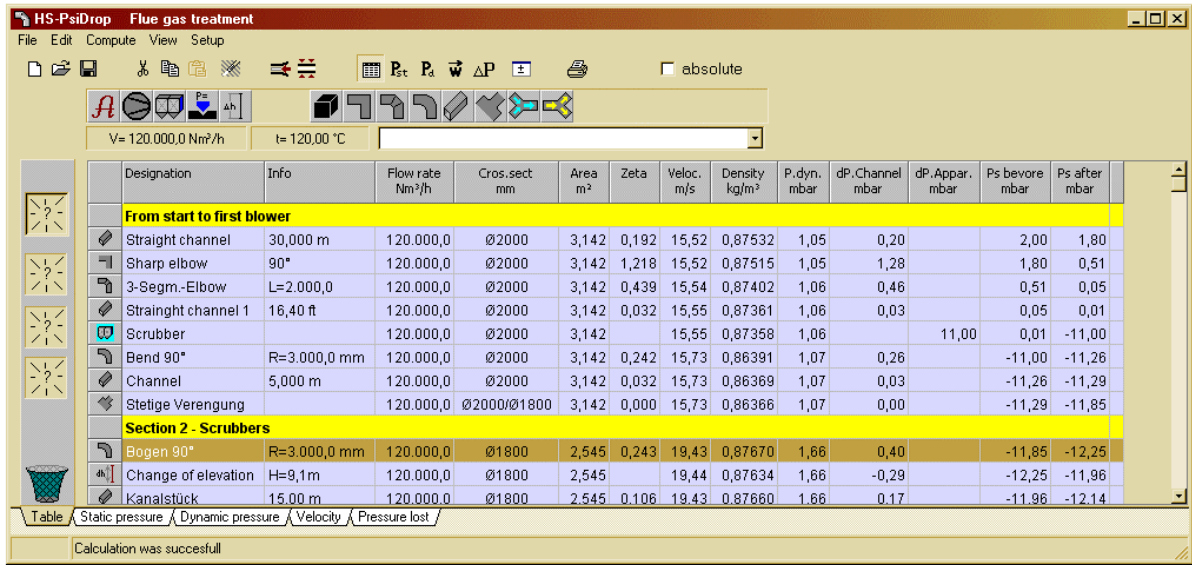
Illustration 3   Main window during the edition

Under the toolbar, there is the gallery of elements, which appear in the canals

Illustration 4   Gallery of the canal elements

These symbols present (from left to right)
- Segment definitions
- Fan
- Apparatus
- Reference Point
- Height differences

Further, there follow the elements, calculated by Zeta coefficient
- Black Box
- Sharp knee
- Segment knee
- Circular knee
- Straight canal
- Expansion/throat
- Inflow
- Ramification

Directly over the table, there are the information about the actually marked element (flow and temperature). On the right, there is a combo-box with all the segment definitions.

By the left edge of the window, there are 4 clipboards for the canal elements. Using the mouse, the elements can be dragged and dropped between the table and these clipboards.

3.3.2 Entering the new elements

To enter the new elements, they are dragged and dropped from the gallery to the proper row of the table. Then, there appears the dialogue for entering the parameters of this element. Dependent on the sort of the element, the dialogues are different.

To describe the fan, it shall be named. The section on the outlet enables calculation of the dynamic pressure behind the fan.

Compression causes heating of the gas. It is the higher, the more compressed the gas is and the lower is the efficiency of the fan. "Active pressure variation" can automatically consider the temperature variation, providing the option **Automatically count the temperature leap** is on, and the **efficiency coefficient** will be given.

Illustration 5   Fan definition

To introduce the apparatus (or any other component, which pressure loss is known and it is not calculated using the Zeta coefficient), the following data are given:

The pressure loss refers to the actual definition load when editing the canal. As the definition load, there should be chosen such, in which the pressure loss of all the apparatus is known.

The power describes how the pressure loss changes dependent on the gas flow. In the majority of apparatus, there occurs the turbulent flow, so that the power=2 is usually used (square relationship of the pressure loss to the flow speed). In the apparatus with the laminar flow, this relationship is linear (Power=1). If the pressure loss shall remain constant at the various loads (e.g. at the regulation to the constant pressure difference) the Power=0 should be given.

Usually, the gas data change in the apparatus. There shall be given the gas data on the outlet of the apparatus.

Illustration 6   Apparatus definition

To define the "Reference Point" there shall be given only the required (over-) pressure at this place.

Illustration 7   "Reference Point" definition

To define the height difference, there shall be given only these differences (in the direction of the flow). This element considers the hydrostatic pressure which forms at the different gas specific gravities in the canal, and the air in the environment. "The height difference" does not present any really existing element. The element, in which the height difference occurs (canal, apparatus), shall be entered separately. Therefore, the vertical canals with hot gas should be represented by the couple of the elements: "Canal + height difference". With the falling canals, the negative height difference is given.
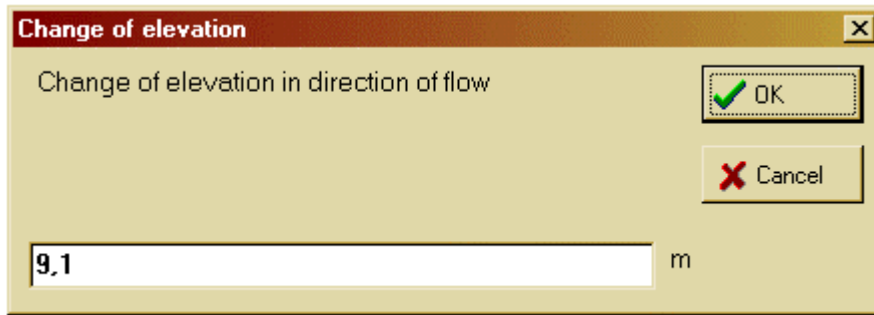
Illustration 8   Presenting the height difference

 Because of the huge flexibility of this element, there is given relatively much data.
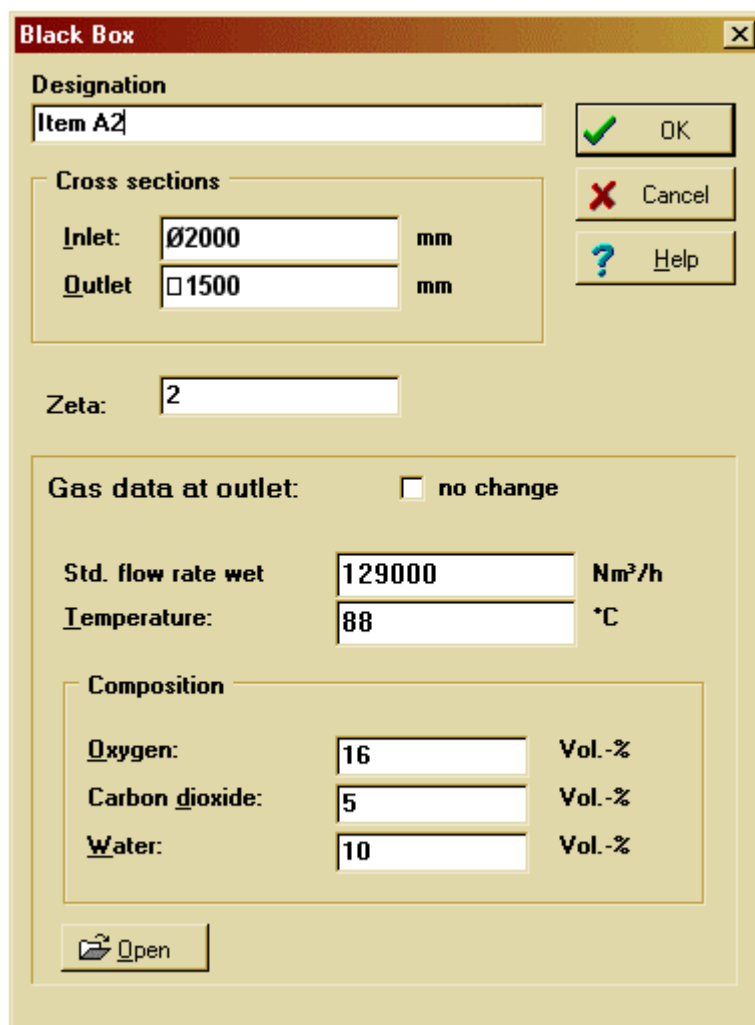
Illustration 9   Black Box definition

Besides the name, the following data are given:

Sections on the outlet can be various.

Zeta in the Black Box must be entered by the user. Black Box represents all the elements calculated by the Zeta coefficient, for which there were no automatic calculations provided.

Because of the possibility to change the gas data in such element, the gas data can be newly defined. If the data do not change, there should be set the options Gas data on the outlet – unchanged. In the other case, the new gas data shall be given.

◆ ◆ ◆

The other elements of the canal, which are calculated by the Zeta coefficient, use the common dialogue to enter the data. In the upper part, there are symbols of placed at the disposal sorts of elements of the chosen class. On the figure: 8 parts of segment knees. By clicking on one of these symbols, the choice is made. Then the schema and the short description appears. On the right side of the area where the parameters are entered.
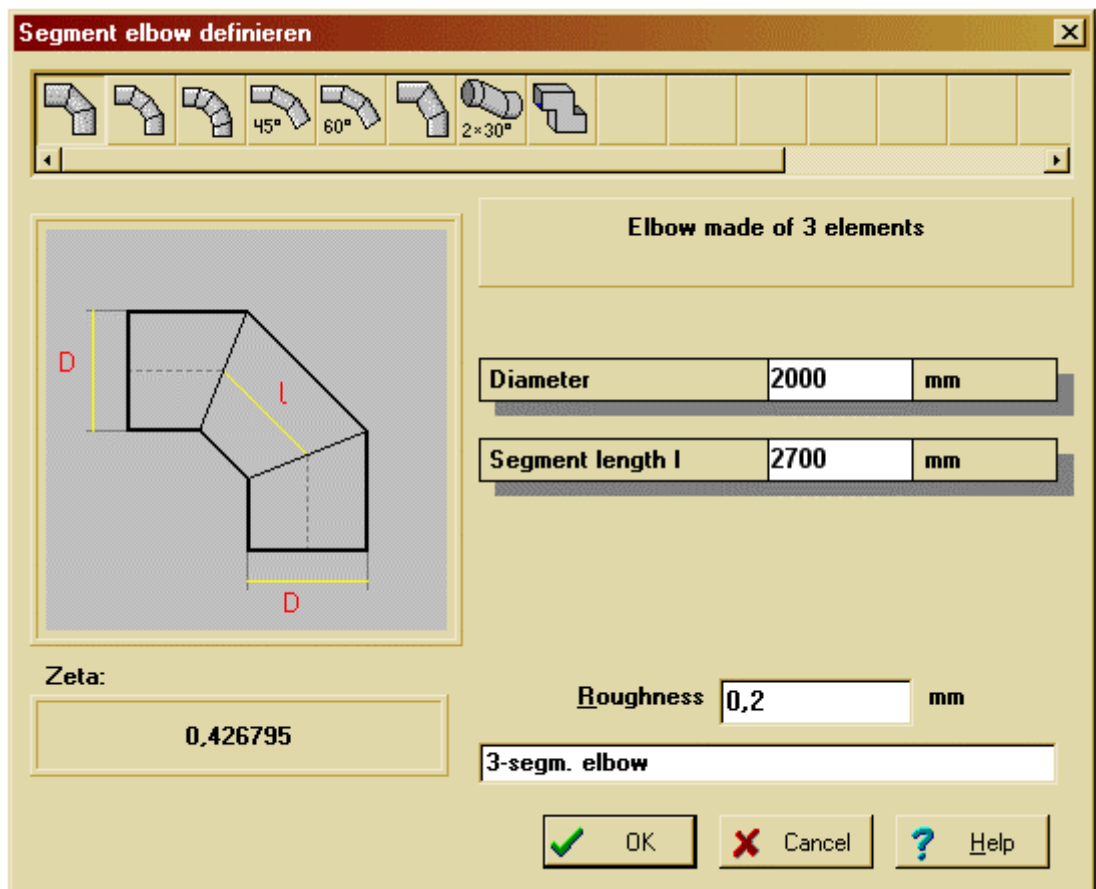
Illustration 10   Definition of the element calculated by Zeta

Some sorts of elements require giving the cross sections. Then, the background of the text area is light blue.

After entering all the data, there appears the value of Zeta coefficient. With some of the data it is not possible. The reason can be the exceeding of the expiry limits of the given Zeta calculation method. Then, instead of Zeta, there appears the error report. This dialogue can not be finished without the valid Zeta value. In such case, there should be applied the element Black Box, and the Zeta value shall be calculated and estimated on one's own.

The name of the element can be changed.

3.3.3 Changes in the canal configuration

All the elements can be changed, moved, removed or there can be placed new elements between the existing ones. The way to proceed is typical for Windows. To enter the empty row one shall select from the menu **Edit/Insert empty row**.

3.4 Calculating the pressure loss

After entering the data, if there is no error, there occurs the definition load calculation. Then the results can be printed and analyzed. Various methods of presenting the results are achieved by the menu **View**. Then the menu **Calculate** is also active.

If the other load than the defined load is to be calculated, there should be chosen the menu **Calculate/Load**. There appears the dialogue to select the previously defined loads or the definition of the new one. In the field **Info**, there appears the description of the chosen load.
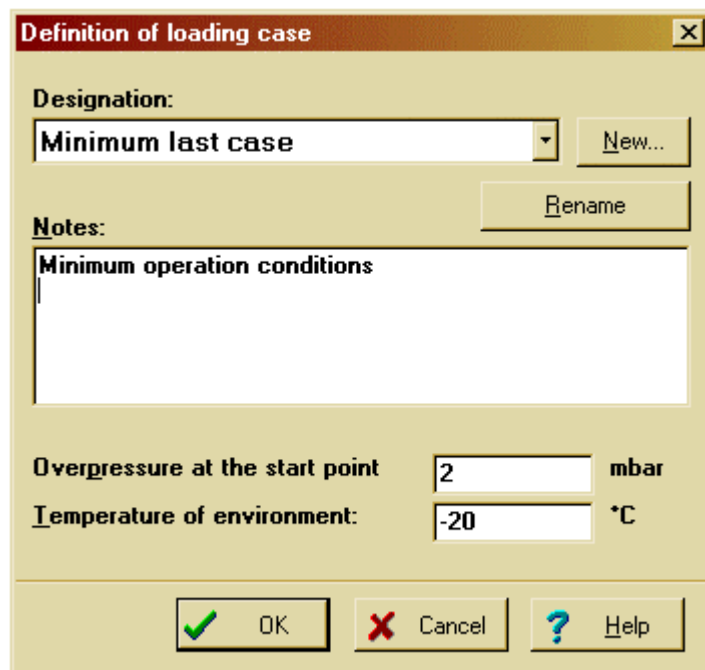
Illustration 11   Load case selection

Overpressure at the start depends on the load. Here this pressure can be entered. For the negative pressure – the negative number.

The environment temperature is required for calculating the hydrostatic pressure (e.g. chimney draught). If the file does not contain the elements from the class "Height difference", the number is not used – though, it must be given.

In case of definition load, the calculation starts immediately after closing the dialogue. In the other loads, the program awaits also the additional data. The table changes its appearance. The elements, which do not require any update are presented in gray, they are not changeable.

The elements, which parameters change together with the load, are given in the last column red designation with the text "EDIT". These elements should be edited, necessarily downhill.

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Illustration 12   Main window when editing the load case

Inflow and outflow in the ramifications can also be dependent on the load. To introduce these changes, the special dialogue appears.
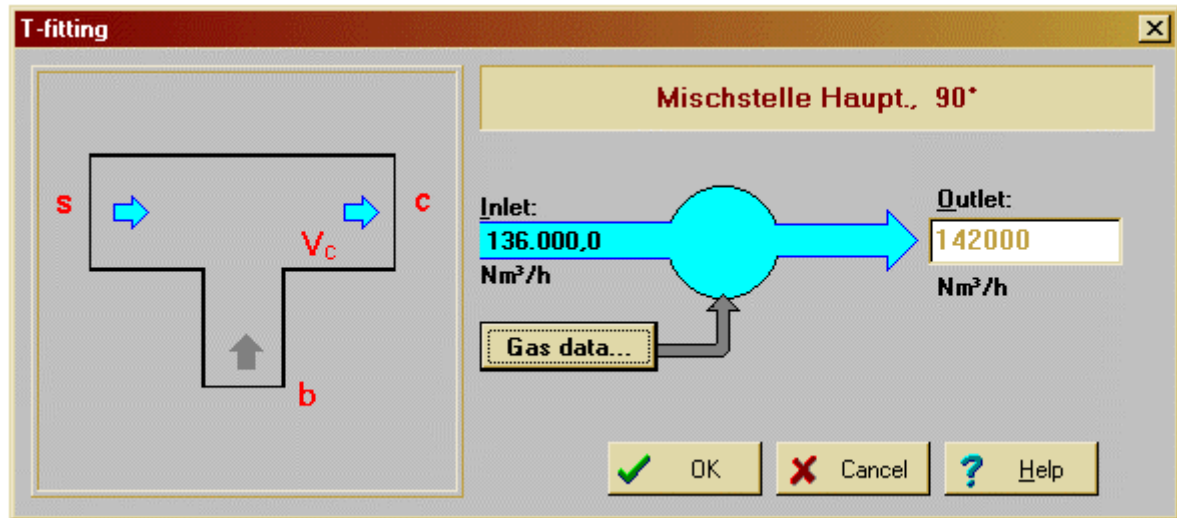

Illustration 13   Inflow/outflow update

On the left, there appears a sort of ramification. On the right, there appears the data. In case of inflow, the data of the inflowing gas is given. With the distributor, only the volumetric flow on the outlet.

The Zeta coefficients are being updated during the calculation. It may occur, that there will not form any result, because e.g. the Reynolds number limits have been exceeded, or for the other sake. Then, the program gives out the report. The calculation can, however, be continued. The program uses the Zeta value from the definition load.

4   Accuracy discussion

Calculating the pressure loss is all the time rather art, than science. It based on scientific experiences, but the numbers, which appear, are always burdened with errors. First of all, in as complicated constructions as the gaseous canals, there is a huge interpretation area. What results from this?

1. The program described here does not substitute the engineering knowledge. It should give help to the experienced user.
2. The results shall be treated with the same care, as if they were calculated "manually".
3. Calculation methods come mainly from "Handbook of hydraulic resistance" by I.E.Idelchik. This book is a very valuable source, but it was unfortunately badly published. Mistakes, like reference marks to non-existing tables, wrongly indexed, and the formulas negating each other, often occur. I took great pains to correct such shortcomings, and I hope, that my interpretation was right.

5   Units system

This program enables working in the units of international SI system of measure, and also in the alternative, optionally defined by the user, system of units. It is possible to switch between these systems during work.

> **C A U T I O N !**
>
> The alternative system of measure units is defined by the user, therefore:
>
> **the user himself is responsible for the correctness of the recalculation definitions!**
>
> This refers also to the optional conversions already included in the newly installed programs. The user is obliged to check its correctness, before he starts using it!
>
> Especially, the standard gas condition may be differently defined, therefore it recalculates into the standard in the SI system (0°C, sea level) can be different.

The recalculation definitions are used together by all the programs. The changes are made as follows:

Hit menu **Setup/International…** and generate the settings dialogue. Here the units system can be chosen. The changes are made after pressing **Edit…** button. Then, the window with the defined recalculations table appears:

Illustration 14   List of units recalculations

After marking the row and using the button **Edit...** the selected recalculation can be edited.

Illustration 15 Defining the recalculation

This example illustrates the definitions of temperature recalculations between "°C" and "°F". At the bottom of the dialogue, there can be tested the correctness of the entered data and set the number of digits after comma.

6   License agreement

Application range

This program can be used on the optional amount of computers within the company. Installation in the networks and the simultaneous installation on many computers of this company is allowed. The amount of simultaneously used licenses is regulated by the purchase of dongles or the hire contracts made.

The subject of the contract

This program is the work protected by law in the meaning of the intellectual property law. The rights to this program belong to "Ingenieurbuero Samoticha fuer Verfahrenstechnik". The indication of the author included in the program shall not be removed or changed. The subject of the contract is this program, its description and any other appendices written and the materials included in files. These are further called "software".

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