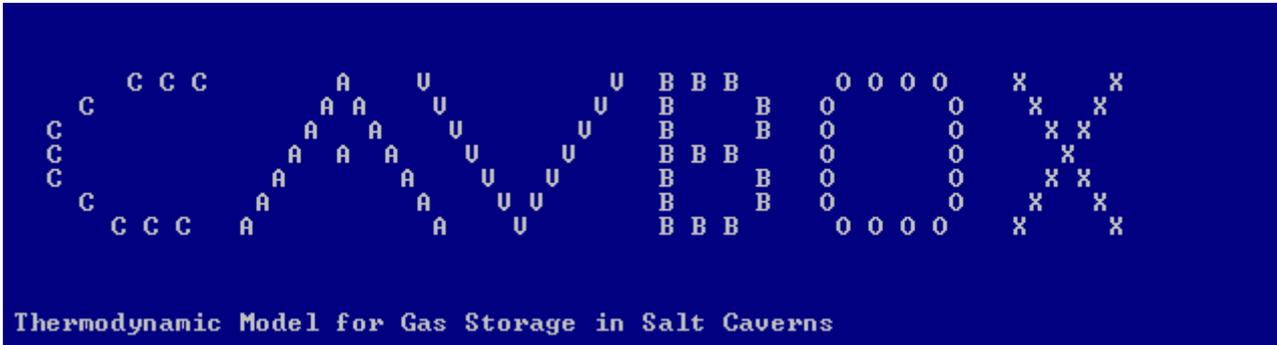




Consulting Reservoir Engineering



# CavBox-GUI Installation and User Manual

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# CavBox-GUI

## Installation and User Manual

### 1. Introduction

CavBox is a console program written in C++. It reads the gas rates and calculates the cavern pressure. The cavern volume can be variable. For the de-brining process the cavern volume and the fluid level in the cavern were calculated according to the Socon measurements giving a relation between depth and cumulative cavern volume. The gas temperature in the cavern is calculated regarding heat flow to the surrounding rock. The wellhead pressures are calculated considering the gas properties, flow rates, and the well tubing diameter.

When gas is injected into a cavern it is compressed and due to this compression the temperature of the gas increases. When the gas is produced from the cavern it is expanded and the temperature decreases. Further heat flows according to temperature differences to the surrounding salt and to the water which is left in the cavern.

The gas properties are considered in CavBox using the Hall-Yarborough correlation for the calculation of z-factors. The heating or cooling of the gas is calculated assuming adiabatic pressure change. The heat flow is accounted by a global function which calculates heat flow linear during a time step depending on the temperature difference between gas and rock/salt.

CavBox is using different files for input data and creates output files to be used for graphical display and post processing for storage in databases.

CavBox can be configured using a graphical user interface. Here the main properties can be edited and the CavBox console program can be started. The results can be shown in graphs. In the user interface adjustment to main parameters can be made performing a history match. The actual file configuration is store in a batch file that can be called from any other routine like CavBase.



## 2. Installation

CavBox is installed by running a windows command script. This script is started in the “Install” folder provided. All necessary files and other executables are stored in a sub-directory named “Files”. This documentation is stored in the folder “Documentation”.

A setup procedure for a software package called “Evidence” is called first. This package supplies all necessary libraries for the graphical user interface. Please use the default path for the installation in the windows program folder. Parts of the installation that are not needed will be removed.

The CavBox executables are copied to the folder .....

An installation is only necessary for the GUI, the executable CavBox ist started by CavBase. The input files needed to run a simulation have to be provided. The parameter file can be optimized using the GUI.

The command line to run the simulation is produced by running such simulation in the GUI. This is stored in files CavBox\_hm.bat and CavBox\_pred.bat.

### 2.1 Program directory

The directory, where CavBox and the required dll-files are stored has to be specified from the GUI file menu item.

The file names for a “project” can be stored and retrieved in the File-menu.

### 2.2 Options

In the Options window a working directory has to be specified, where all necessary files for the simulation are stored. Also the batch files invoking CavBox.exe will be stored in this folder.

Some other options for graphing can be accessed here. Only the tabs TMAGS, ECLIPSE-Graf, TMAGS-Graf and Graph, are relevant for the GUI. The other tabs were used in another context, where the GUI was derived from and cannot be removed at the moment.

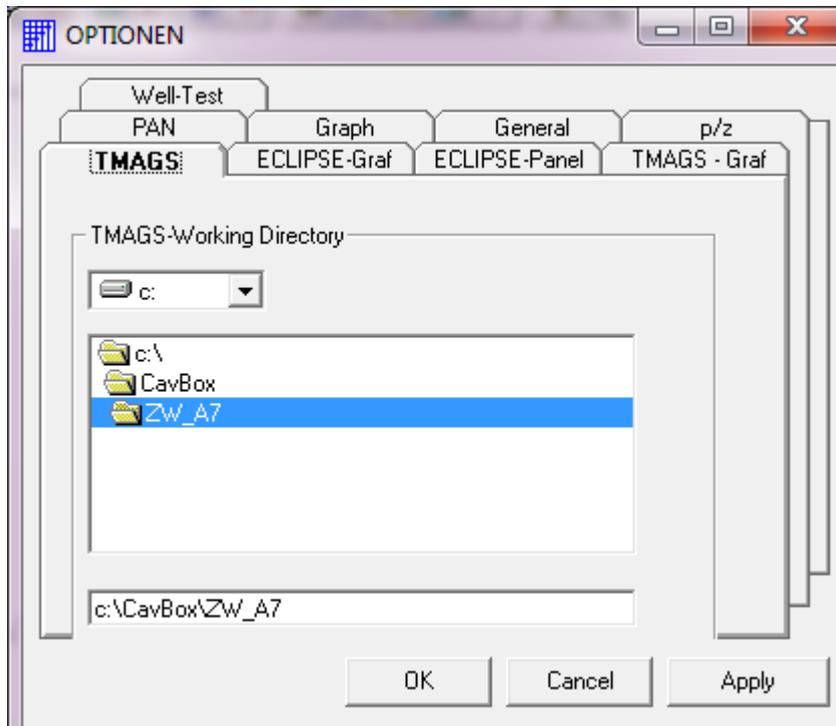


Figure 2-1: Options window



### 3. CavBox input files

In Figure 3-1 a picture of the graphical user interface is shown. On the right side the set of files needed for the calculation can be configured. The purpose of the files is described below in detail.

The text boxes show the parameters stored in the 1<sup>st</sup> file with the extension .prp

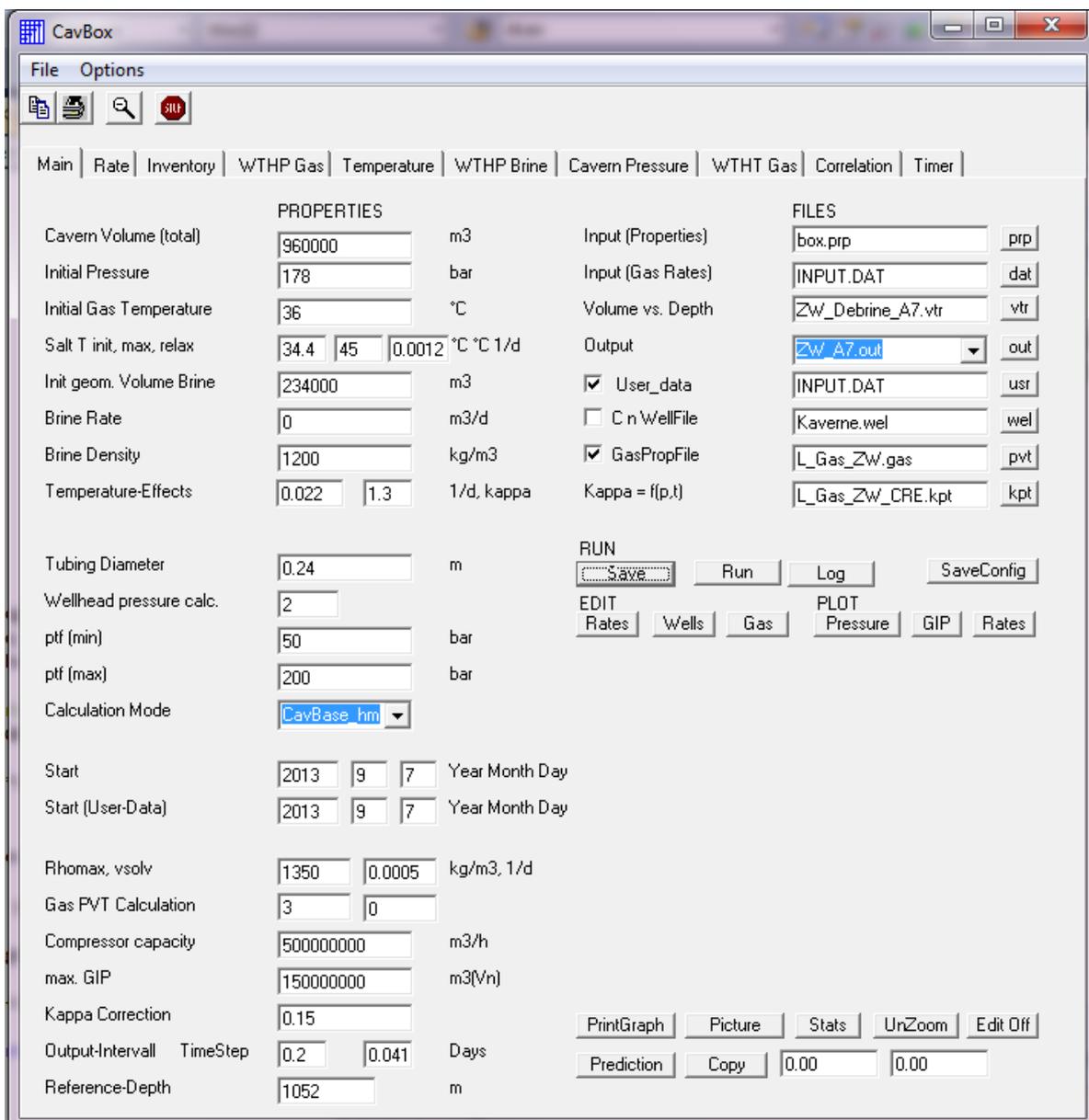


Figure 3-1: Main window of graphical user interface



### 3.1 Property file \*.prp

In this file the properties of the cavern are stored:

#### ***Cavern Volume***

This is the total geometrical volume of the cavern in m<sup>3</sup> including the volume of brine present in the cavern.

#### ***Initial pressure***

The initial pressure in the cavern at the reference depth in bar.

#### ***Initial gas temperature.***

The initial temperature in the cavern in °C. This temperature is used to calculate the initial gas inventory.

#### ***Salt temperature***

The temperature of the surrounding salt in °C. The 1<sup>st</sup> value is the initial salt temperature after debrining, the 2<sup>nd</sup> the max. salt temperature and the 3<sup>rd</sup> is a time constant determining how the temperature increases to the max. temperature.

#### ***Initial brine volume***

The volume of brine in the cavern in m<sup>3</sup>. The total storage volume is the total cavern volume minus the brine volume. The brine volume will change during the calculation if brine is produced from the cavern.

#### ***Brine rate***

A constant brine rate that can be applied. This is normally zero as the brine rate should be given time dependent in the rates file.

#### ***Brine density***

The initial density of the brine at start of the calculation in kg/m<sup>3</sup>. The density is used to calculate the well head pressure for brine production.

#### ***Temperature effects***

The 2 parameters are used to calculate the gas temperature in the cavern. The 1<sup>st</sup> is a time constant [1/d] for the heat flow from the gas to the surrounding salt. The 2<sup>nd</sup> is the adiabatic exponent that is used to calculate the temperature change of the gas during expansion or compression. The method used for the calculation as well as some correction modes are determined by the flag in the 2<sup>nd</sup> field "PVT-Calculation" below. The value of the adiabatic exponent is between 1.3 and 1.4, but may be smaller with respect to gas composition and other thermodynamic effects that may occur.

#### ***Tubing diameter***

The tubing diameter in m. It is possible to choose 1 or 2 wells in the option for the well



head pressure calculation. (variable pmin).

### ***Well head pressure calculation***

For the calculation of the well head static pressure 4 methods can be chosen. If this value is 0 or 2 the barometric formula is used with 1 or 2 wells in the cavern, for 1 and 3 the adiabatic expansion with 1 or 2 wells respectively.

### ***Maximum and minimum tubing head pressure***

The maximum and minimum tubing head pressures can be used to constrain the injection or production rate.

### ***Start date***

Internally CavBox is using calendar dates. A start date for the simulation can be defined. CavBase is providing input files for rates in decimal days from an arbitrary start. The decimal days in these input files are added to the start date.

### ***Start of user data***

The measured data to compare with simulated data can be provided in an extra file. As these data may have a different start date as the simulation, the data can be shifted by applying a correct start date here.

### ***Maximum brine density***

The maximum brine density that is obtained due to continuing salt solution in the brine-volume in the cavern. The time constant controls the solution rate. The brine density is used to calculate the brine tubing head pressure. The brine density is recalculated after injection of fresh water ("Botox").

### ***Minimum and maximum well head pressures***

These values are used to limit rates in prediction runs and for scaling of graphs for tubing head pressures.

### ***Calculation mode***

The calculation mode CavBase\_hm should be used for calibration runs / history matching. In other modes CavBox may not run properly.

### ***PVT-Calculation***

Control the calculation of gas compressibility factors. The gas analysis in the pvt-file is used, if the checkbox "GasPropFile" is checked. Otherwise default values are being used.

Parameter 1 (controls calculation procedure)

- 1 Hall-Yarborough
- 2 Hall-Yarborough using the DLL CREzfac



- 3 Hall-Yarborough with correction for dissolved water
- 4 Soave-Redlich-Kwong

A value of 3 gives the best performance. Other calculation methods can be implemented.

Parameter 2 (controls usage of kappa-values)

- 0 the kappa value is constant as given in the 1<sup>st</sup> field temperature effects
- 1 a value from the table read from the kappa file is being used.

### ***Kappa-Correction***

This is a value to test Kappa-tables. The value is subtracted from the table value.

### ***Compressor Capacity***

Limits rates in prediction runs.

### ***Max. GIP***

Max. storage capacity. This is only relevant in other calculation modes for planning and layout purposes. Use a value that is much higher than the maximum gas storage capacity.

### ***Output-Interval***

Controls the output of value in files used for graphs. This value is overwritten by the CONTROLS value from the CavBase file GASSTORE.INP.

### ***TimeStep***

For proper calculation the time step used should be small. A value of 1 h is recommended (0.04166 days). In the CavBase prediction mode this value is overwritten by the value read in the CONTROLS keyword from file GASSTORE.INP.

### ***Reference Depth***

The depth of the casing shoe.

## **3.2 Input File (Gas Rates) (\*.dat)**

Read the time from start of the simulation in days, the production/injection rate (+production, -injection), the well head temperature and the well head pressure. The 4<sup>th</sup> column is the fresh water rate ("Botox"), (-production, +injection)



0	-0.000041	35.000000	162.140000	0.000000
1	-0.000034	35.000000	162.140000	0.000000
2	-0.000070	35.000000	162.140000	0.000000
3	-0.000219	35.000000	162.140000	0.000000
4	-0.000002	35.000000	162.140000	0.000000
5	-0.000010	35.000000	162.140000	0.000000
6	-0.000358	35.000000	162.140000	0.000000
7	-0.000174	35.000000	162.140000	0.000000
8	-0.000581	35.000000	162.140000	0.000000
9	-0.000133	35.000000	162.140000	0.000000
10	-0.000030	35.000000	162.140000	0.000000
11	-0.000005	35.000000	162.140000	0.000000
12	-0.000412	35.000000	162.140000	0.000000
13	-0.000031	35.000000	162.140000	0.000000
14	0.000000	35.000000	162.060000	0.000000

### 3.3 Volume vs. Depth (\*.vtr)

Reads the volume vs. depths relationship. The file has 2 columns. These data are used for brine well head calculation and average cavern gas pressure.

### 3.4 Output (\*.out)

Several files are created with values for pressures and temperatures for graphing purposes.

### 3.5 User data (\*.usr)

This file contains information about measured data as time, rates, and pressures. In the case of CavBase runs the values are read from the INPUT.DAT file. This file has to be specified then..

### 3.6 C n WellFile (\*.wel)

Data from this file are not being used in CavBase simulations, nevertheless such file should be present for compatibility. The file has the following format.

```
# Anzahl der Werte
# Bohrung auf=1 C[m3/h] n Tub.Länge[m] Vert.Teufe[m] rTubing[m] cr A B m c maxRate[m3/d] max Wasser[m3/d]
2
K1 , 1 6000.000000 0.700000 1060.000000 1060.900000 0.244475 0.004000 0.000000e+000 0.000000e+000 1.000000e+001
1.000000e+000 1.000000 3000000.000000 19.200000 1.000000
K2 , 0 60.000000 0.700000 925.000000 822.900000 0.050800 0.004000 0.000000e+000 0.000000e+000 1.000000e+001
5.000000e+002 1.000000 720000.000000 19.200000 1.000000
```

### 3.7 GasPropFile (\*.gas)

Gives the gas analysis as shown below.

```
# ts[C] ps[bar] mw tc (K) pc[Pa] vc[m3/kg]
# # c1 c2 c3 ic4 nc4 ic5 nc5 c6 co2 n2 h2s
0 1.01325 18.017 200.867 4656482 0.00598
81.3 2.87 0.38 0.08 0.07 0.03 0.01 0.05 0.89 14.32 0.0
```



### 3.8 Kappa (\*.kpt)

Reads values for z, Cp and Cv for a set of pressures and temperatures. Values for calculation are interpolated in this table.

```
#p [Mpa]    T [K]    z    Cp    Cv
# values p,  values t
 8    7
12.00  283.15  0.796616  3.11264  2.30178
12.00  293.15  0.822749  2.83652  2.03723
12.00  303.15  0.845363  2.61491  1.81770
12.00  313.15  0.865029  2.43631  1.63457
12.00  323.15  0.882210  2.29155  1.48053
12.00  333.15  0.897285  2.17357  1.34977
12.00  343.15  0.910563  2.07694  1.23774
13.00  283.15  0.788398  3.26338  2.42070
13.00  293.15  0.815726  2.96533  2.14949
13.00  303.15  0.839400  2.72379  1.92193
13.00  313.15  0.860006  2.52755  1.73087
13.00  323.15  0.878022  2.36730  1.56955
13.00  333.15  0.893839  2.23569  1.43230
13.00  343.15  0.907777  2.12698  1.31453
14.00  283.15  0.781927  3.41406  2.52210
14.00  293.15  0.810231  3.09658  2.24897
14.00  303.15  0.834780  2.83702  2.01648
14.00  313.15  0.856171  2.62458  1.81955
14.00  323.15  0.874891  2.44998  1.65238
```

### 4. CavBox Graphs

Graphs for pressures and temperatures are shown according to the captions on the different tabs. Zooming is possible by pressing the right mouse button and dragging over the desired zoom area. Unzoom by pressing the button in the tool bar. Values are shown at the mouse position in the text boxes below the graphs.

The values are displayed vs. calendar time. The graph can be copied to the clipboard. An example is shown below. The dots are the measured values. Measured values are plotted if available.

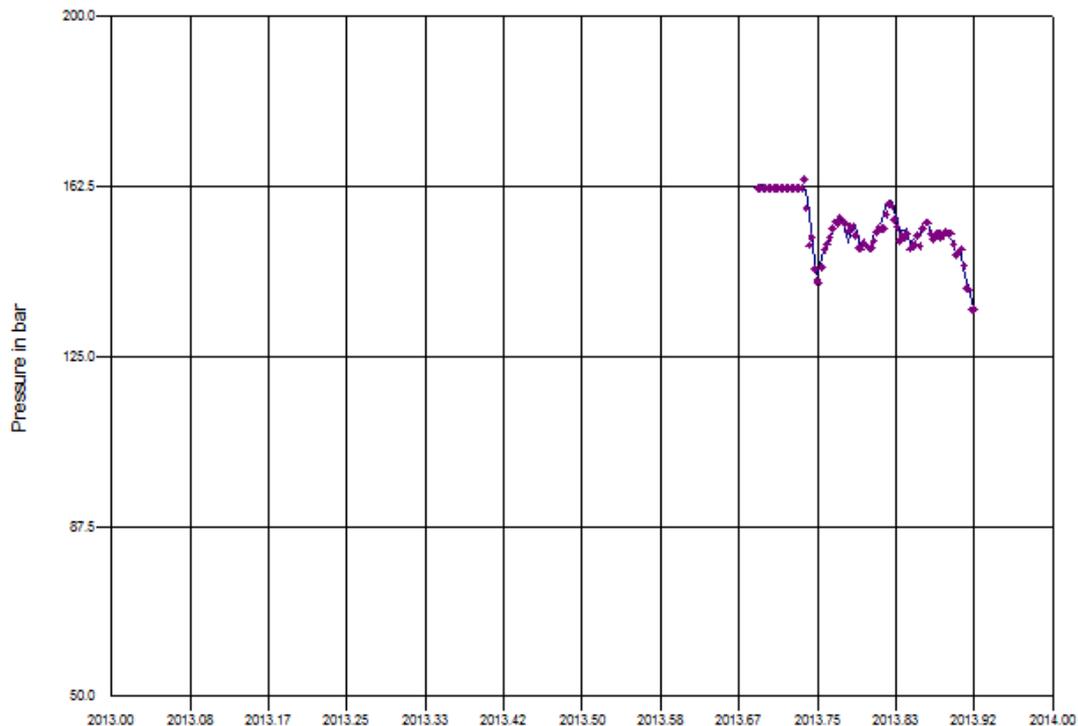


Figure 4-1: Graph example for well head pressure.

## 5. Correlation

The correlation between measured and calculated gas well head pressure is calculated and a graph is shown. The dotted line represents the calculated regression.

The window for the correlation is shown in Figure 5-1. By pressing the “Optimize” button a window is opened where an optimization of different parameters or sets of parameters can be performed. The optimization uses the correlation coefficient.

The minimum and maximum value for a parameter has to be defined. If this parameter is checked, simulations will be performed with 5 equally distributed values between these limits. Also sets of parameters can be chosen, then all possible combinations of the checked parameters will be calculated. Choosing too many parameters will make the simulation slow.

The results are written to a file. From this file the best value or sets of values can be retrieved by pressing the Results button. The values can be written to the main window by pressing “Accept”

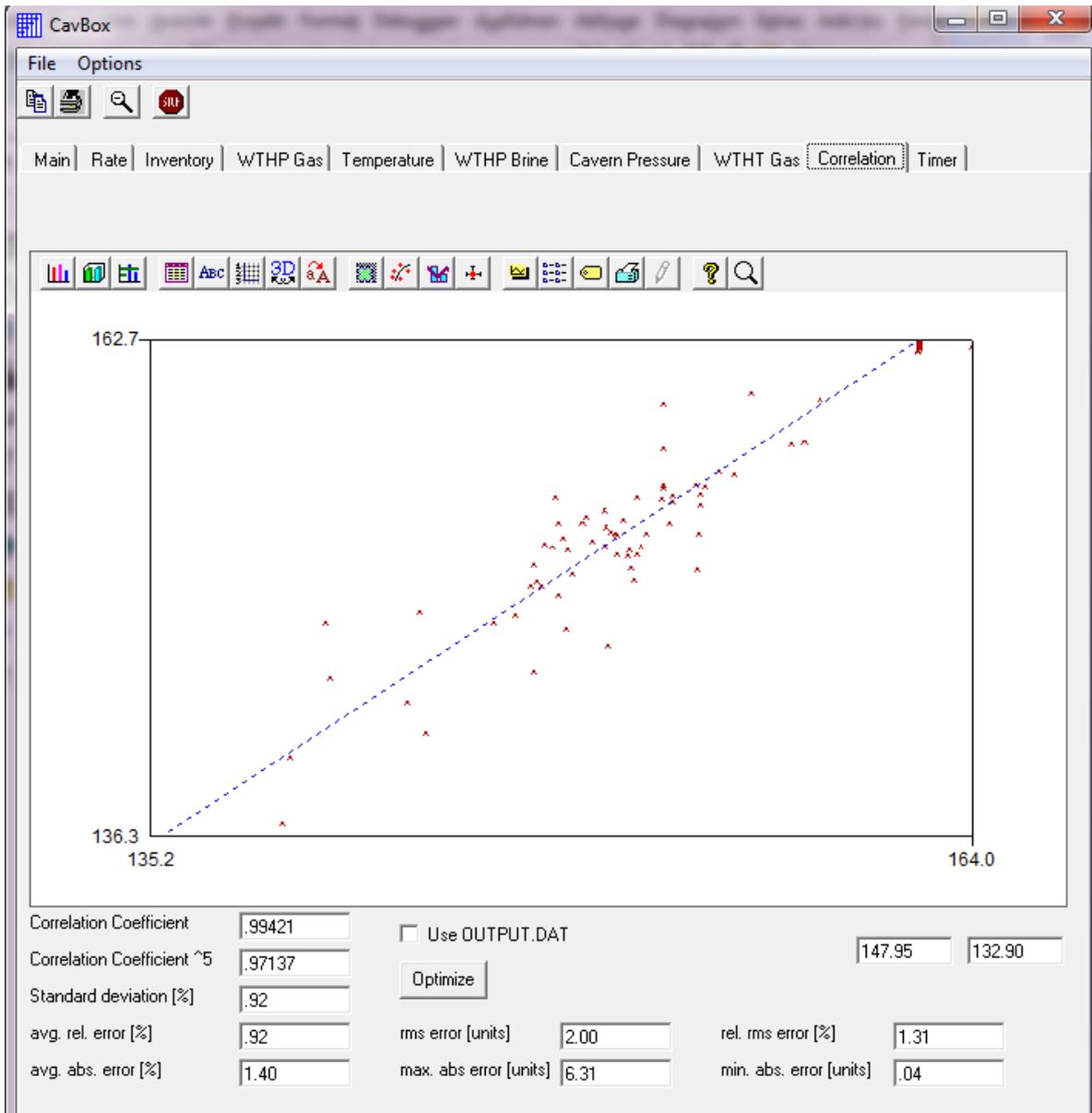


Figure 5-1. Correlation window

This procedure can help to find the best parameter set for a cavern. Nevertheless the user has to decide which parameters shall be used. It is e.g. possible that measured values are not correct and one should keep in mind that the values for well head pressures are averaged for a day and that this is not totally correct.



**Optimize** [minimize] [maximize] [close]

Parameters

Cavern Volume	<input type="text" value="930000"/>	<input type="text" value="980000"/>	<input type="checkbox"/>
Initial Pressure	<input type="text" value="176"/>	<input type="text" value="180"/>	<input type="checkbox"/>
Init. Gas Temp.	<input type="text" value="36"/>	<input type="text" value="40"/>	<input type="checkbox"/>
Salt Temperature	<input type="text" value="32"/>	<input type="text" value="36"/>	<input type="checkbox"/>
Init. geom. Vol. Brine	<input type="text" value="230000"/>	<input type="text" value="240000"/>	<input type="checkbox"/>
Time Constant	<input type="text" value="0.01"/>	<input type="text" value="0.03"/>	<input checked="" type="checkbox"/>
Kappa	<input type="text" value="1.2"/>	<input type="text" value="1.4"/>	<input type="checkbox"/>

Results

Cavern Volume	<input type="text" value="940000"/>
Initial Pressure	<input type="text" value="178"/>
Init. Gas Temp.	<input type="text" value="36"/>
Salt Temperature	<input type="text" value="32"/>
Init. geom. Vol. Brine	<input type="text" value="230000"/>
Time Constant	<input type="text" value="0.01"/>
Kappa	<input type="text" value="1.4"/>

Figure 5-2: Optimization window