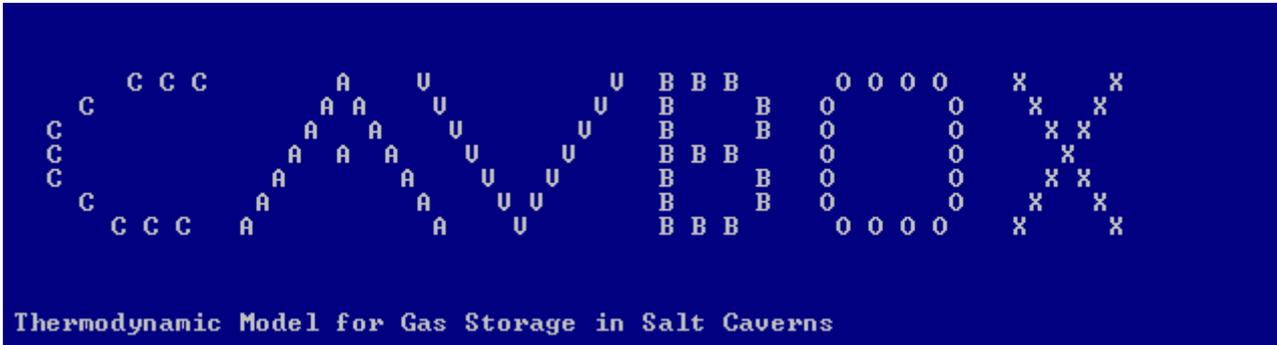




Consulting Reservoir Engineering



CavBox-Console Installation and User Manual

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CavBox-Console-Program 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 are 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.

The program calculates well head pressure, well head temperature, casing shoe pressure and average cavern temperature and pressure.



2. Installation

CavBox is an exe console program, no installation is required. The file Box.exe has to be copied to the folder where it should run. This directory has to be defined by CavBase. All necessary input files have to be provided in this folder.

For other z-factor calculations than described below the appropriate library should be present in the program directory. For the already implemented procedures this is the library CREzfac.dll. It is provided along with box.exe.



3. CavBox input files

In **Fehler! Verweisquelle konnte nicht gefunden werden.** 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 program should be started as follows:

```
box "c:\CavBox\ZW_A7\ZW_A7.prp" "c:\CavBox\ZW_A7\INPUT.DAT"  
"c:\CavBox\ZW_A7\ZW_A7.out" "CavBase_hm"  
"c:\CavBox\ZW_A7\Kaverne.wel" "c:\CavBox\ZW_A7\L_Gas_ZW.gas"  
erfg564880912c01d4g "c:\CavBox\ZW_A7\  
"c:\CavBox\ZW_A7\ZW_Debrine_A7.vtr"  
"c:\CavBox\ZW_A7\L_Gas_ZW_CRE.kpt"
```

It is essential to use the quotes and blanks between the parameters as shown above.

- Parameter 1: property file name / full path
- Parameter 2: filename for input data / full path
- Parameter 3: file name for output data for graphs / full path
- Parameter 4: flag for calculation mode can be "CavBase_hm" or "CavBase_pred"
- Parameter 5: full path to wellfile
- Parameter 6: full path to gas property file
- Parameter 7: erfg564880912c01d4g
- Parameter 8: path to working directory (must have 2 quotes at end)
- Parameter 9: full path to file with cavern shape data
- Parameter 10: full path to file with kappa data

The format of the files is described in the following.

3.1 Property file *.prp

In this file the properties of the cavern and thermodynamically constants are stored. In the following these items are described. The CavBox variable name is referenced in brackets []. This variable name is also used in the comment lines of the input file as shown below.

```
# gip pi t jaqu saqu h cw tstep  
960000 178 36 34.4 234000 0.15 0 0.0416666667  
# pmax paqu pmin pminf pmaxf hystd hystf hystw  
0.23 1200 1 50 200 0.022 1.3 3  
# startdate  
2013 9 7  
#Startdate user  
2013 9 8  
# outf C n kompr  
0.2 1350 0.0005 500000000  
#TargetGIP RefDepth Histflag Wellfile GasFile Acalcflag tcalclflag Sofafalg  
150000000 1052 1 0 1 0 1 0
```

***Cavern Volume [gip]***

This is the total geometrical volume of the cavern in m³ including the volume of brine present in the cavern.

Initial pressure [pi]

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

Initial gas temperature [t]

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

Salt temperature [jaqu] [Acalcflag] [Sofaflag]

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

Initial brine volume [saqu]

The volume of brine in the cavern in m³. 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.

Kappa-Correction [h]

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

Brine rate [cw]

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.

TimeStep [tstep]

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.

Tubing diameter [pmax]

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).

Brine density [paqu]

The initial density of the brine at start of the calculation in kg/m³. The density is used to calculate the well head pressure for brine production.

Well head pressure calculation [pmin]



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 [pminf, pmaxf]

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

Temperature effects [hystd, hystf]

The 2 parameters are used to calculate the gas temperature in the cavern. The 1st is a time constant [1/d] for the heat flow from the gas to the surrounding salt. The 2nd 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 2nd 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.

PVT-Calculation [hystw]

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

[hystw] (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.

Start date [ijahr, imon, itag]

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 [kjahr, kmon, ktag]

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.

Output frequency [outf]

Controls the frequency of output in days to files used for plotting. The output for CavBase is controlled in GASSTORE.INP

Maximum brine density [C]



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").

Brine dissolution constant [n]

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").

Compressor Capacity [kompr]

Limits rates in prediction runs.

Max. GIP [t_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.

Reference Depth [rteufe]

The depth of the casing shoe.

History match flag [hmflag]

Not being used. Should be 0.

Wellflag [welflag]

Determines if well data should be read from file. Has to be 0 for CavBox runs.

Gasflag [gasflag]

Determines if gas composition is read from file (1) or if default values are used (0).

Acalcflag [Acalcflag]

Not being used. Should be 0.

Kappa calculation mode [tcalcflag]

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

In other modes CavBox may not run properly.



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 4th column is the fresh water rate (“Botox”) or brine production rate, (-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 Output (*.out)

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

3.4 Calculation mode

The calculation mode CavBase_hm should be used for calibration runs / history matching.

3.5 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
```

3.6 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
```

3.7 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.

3.8 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, value 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
```