WHyP

Westport **Hy**drate **P**rediction Program for Drilling Fluids

Developed by the Gas Hydrates Technology Group

USER'S MANUAL

Version 8.97

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1.0 Installation and system requirements

The program requires Windows 95 and MS Excel (version 5.0 or later) to be present on the hard drive of the host computer.

To install **WHyP**, insert the attached disk into Drive A. Create a directory for the new program on the hard drive. Copy the program to the new directory.

In addition to the standard Excel toolbars, two buttons should appear on the top of the screen (a green square icon to run the program, and a red diskette icon for saving the output). If these icons do not appear on the screen after copying the program to the hard drive, from the Excel toolbar menu click on **[View]** + **[toolbar]** then select the toolbars named *"WHYP - Westport hydrate prediction"* and *"Save WHyP Output".*

To run **WHyP** Click on the green square icon.

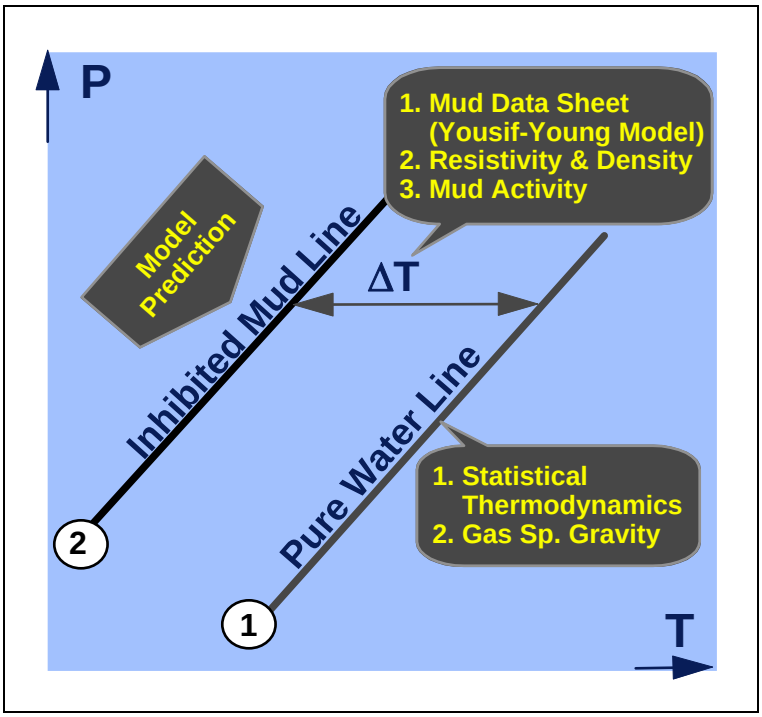
2.0 About WHyP

WHyP (**W**estport **Hy**drate **P**rediction Program for Drilling Fluids) is the state-of-the-art hydrate prediction model specifically tailored for use by drilling personnel. To use the model, only minimal prior knowledge of the phase behavior of natural gas hydrates is required. **WHyP** is Windows 95 compatible and is linked to an Excel interface for user friendly data input/output. The model is designed to be simple and easy to run while at the same time, maintaining high flexibility to accept a wide range of input data. The model can be run in a **prediction mode** or a **design mode**. The **design mode** is a unique feature added to allow an interactive execution of the program. With **design mode**, the user can determine the appropriate amount of a selected inhibitor to suppress hydrate formation at a given mudline pressure and temperature.

2.1 Prediction of the Hydrate Phase Line

The statistical thermodynamic theory of van der Waals and Platteeuw[1] represents the backbone for the **WHyP** model. This part of the model provides the main predictive tool for the hydrate phase equilibrium of pure water/natural gas systems (shown as line 1 in Figure 1).

FIGURE 1
MODEL COMPONENTS



WHyP accepts the following species in the gas mixer:

Accepted gas components					
Methane	C1	Heptane	n-C7	Hexadecane	n-C16
Ethane	C2	Octane	n-C8	Heptadecane	n-C17
Propane	C3	Nonane	n-C9	Octadecane	n-C18
Isobutane	i-C4	Decane	n-C10	Nonadecane	n-C19
Normal Butane	n-C4	Undecane	n-C11	Eicosane	n-C20
Isopentane	i-C5	Dodecane	n-C12	Carbon dioxide	CO2
Normal pentane	n-C5	Tridecane	n-C13	Nitrogen	N2
Cyclopentane	c-C5	Tetradecane	n-C14	Hydrogen sulfide	H2S
Hexane	n-C6	Pentadecane	n-C15		

In the absence of a reliable composition of the gas kick fluid, the statistical model of van der Waals and Platteeuw[1] cannot be used. To overcome this difficulty (lack of gas composition), a specific gravity correlation[2] is included in the program to determine the pure water line (line 1 in Figure 1). This correlation is less accurate and does not consider the effect of hydrate inhibitors. It is only to be used as a first estimate of the hydrate equilibrium temperature when gas composition data are not available. The specific gravity correlation introduced is an improvement over the previous method[2]. Included in the new specific gravity correlation are the hydrate equilibrium data measured since the publication of the

original method in 1944. The set of equations developed and included in this computer code are:

$$T, °F = -15.428 + 24.422 * \ln(\gamma_g) + 12.604 * \ln(P,psia) \quad (1)$$

$$P, psia = \text{Exp}\,[(T+15.428 - 24.422 * \ln(\gamma_g))/ 12.604] \quad (2)$$

2.2 Prediction of the Hydrate Temperature Suppression, ΔT

When the drilling fluid contains inhibitors, such as salts and glycols, other tools are required to determine the suppressing effect, or ΔT of these inhibitors. These tools (methods) which were developed as part of phase 1 of the Novel Hydrate Prediction Methods Joint Industry Project, are described in the following sections.

2.2.1 Drilling Fluid Composition Method

This method determines the hydrate temperature suppression, ΔT, from the weight percentage of each inhibitor in the mud formulation[3]. The method can be used for mixed inhibitors when the composition of the drilling fluid is known. The inhibitors considered in this method are:

Inhibitor	Concentration limit (wt %)
NaCl	26.0
KCl	24.0
CaCl2	30.0
NaBr	47.5
CaBr2	38.0
ZnBr2	55.0
Ethylene Glycol	40.0
Propylene Glycol	40.0
Glycerol	40.0
Polyalkylene Glycol	40.0
NaCOOH	44.5
KCOOH	50.0

2.2.2 Resistivity Method

This method determines the hydrate temperature suppression, ΔT, using the resistivity and density of the mud filtrate[4]. The resistivity and density used as input for this method must be measured at the same temperature. This method has not been validated yet for use with bromides and formate salts.

2.2.3 Mud Activity Method

This method uses the activity of the drilling fluid to predict the hydrate temperature suppression, ΔT.

The advantage of the activity and the resistivity methods is that the hydrate temperature suppression, ΔT, can be determined for a drilling fluid of unknown composition.

Finally by determining the phase line 1 and the ΔT, phase line 2 which represents the hydrate equilibrium conditions of an inhibited mud can be determined as illustrated in Figure 1.

3.0 Input data needed to predict hydrates

To predict the hydrate phase lines 1 and 2 shown in Figure 1, the following data are required:

3.1 The kick fluid

3.1.1 The GC analysis (composition) of the gas kick fluid
3.1.2 The specific gravity of the gas kick fluid

3.2 The drilling fluid

3.2.1 Weight percentages of any salts and/or polar compounds present in the mud formulation
3.2.2 The resistivity and density of the mud filtrate
3.2.3 The activity of the mud

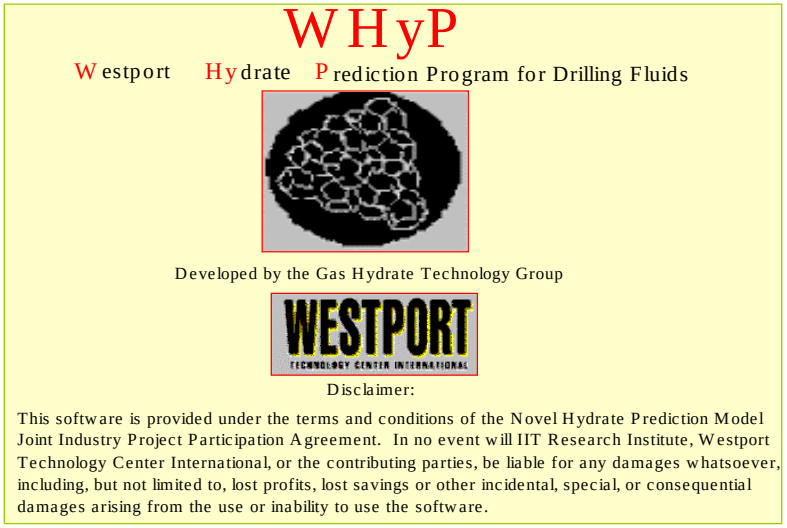
3.3 The pressure or temperature

To predict the hydrate equilibrium temperature, a pressure input is required. To predict the pressure, a temperature input is required. Neither input is needed if you request the program to determine the entire pressure-temperature equilibrium line.

4.0 Running WHyP

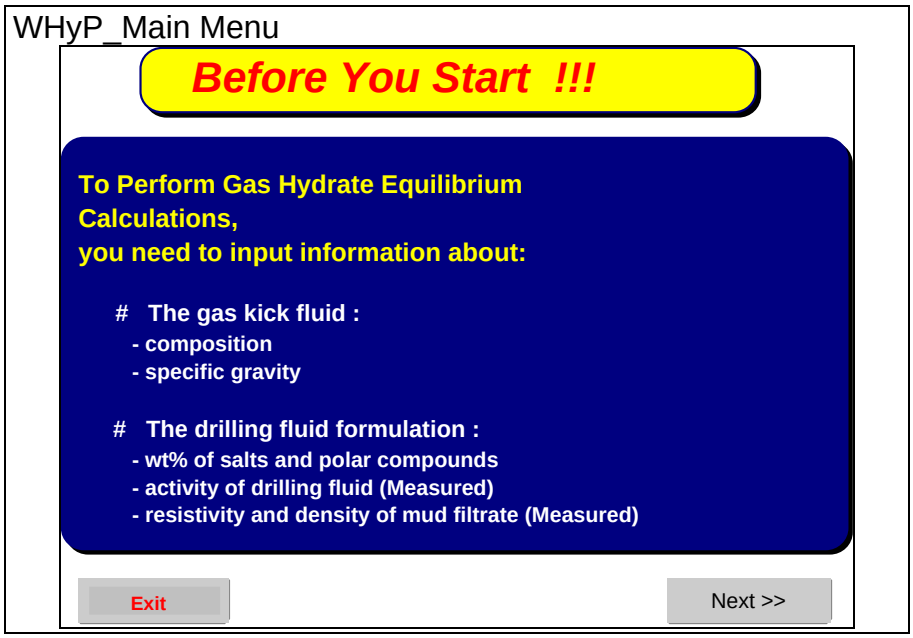
To run **WHyP**, click once the **green icon** ■ at the top of your screen (This icon should appear next to the standard Excel toolbar). Panel 4.1 will appear.

Panel 4.1



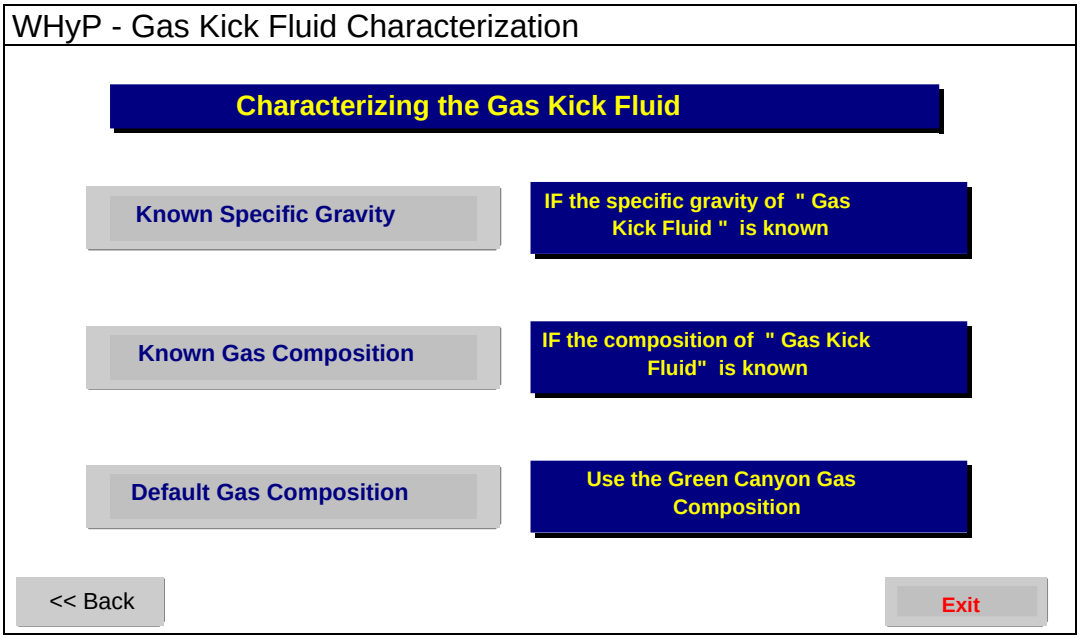
Click on this panel once to move to Panel 4.2.

Panel 4.2



Press Next >> to move to Panel 4.3.

Panel 4.3



The three buttons shown in **Panel 4.3** allow you to characterize the gas kick fluid based on the information available to you. For instance, if you have the gas kick fluid GC analysis, **Click on** Known Gas Composition. If the gas specific gravity is available to you instead of the gas composition, then **Click on** Known Specific Gravity. If no information is available about the gas kick fluid, then **Click on** Default Gas Composition. The default gas composition is the Green Canyon gas mixture shown in Table 1.

TABLE 1

Component	Mole %
Nitrogen	0.403
Methane	87.243
Ethane	7.57
Propane	3.08
Isobutane	0.510
N-Butane	0.792
Isopentane	0.202
N-Pentane	0.200

For a demonstration, **press** Default Gas Composition.
The Green Canyon Gas composition appears on the Panel 4.4.

Panel 4.4

WHyP - Gas Kick Fluid Composition

Input Gas Kick Fluid Composition (mole %)

C_1	87.243	C_7		C_{16}	
C_2	7.570	C_8		C_{17}	
C_3	3.080	C_9		C_{18}	
i-C_4	0.510	C_{10}		C_{19}	
n-C_4	0.792	C_{11}		C_{20}	
i-C_5	0.202	C_{12}		CO_2	
n-C_5	0.200	C_{13}		N_2	0.403
c-C_5		C_{14}		H_2S	
C_6		C_{15}			

Sum of mole% 100.000%

<< Back | Save Input File | Use Saved file | Next >>

With the composition of the gas kick fluid defined in Panel 4.4, the next step is to characterize the drilling fluid. **Press** Next >> to bring up Panel 4.1.1.

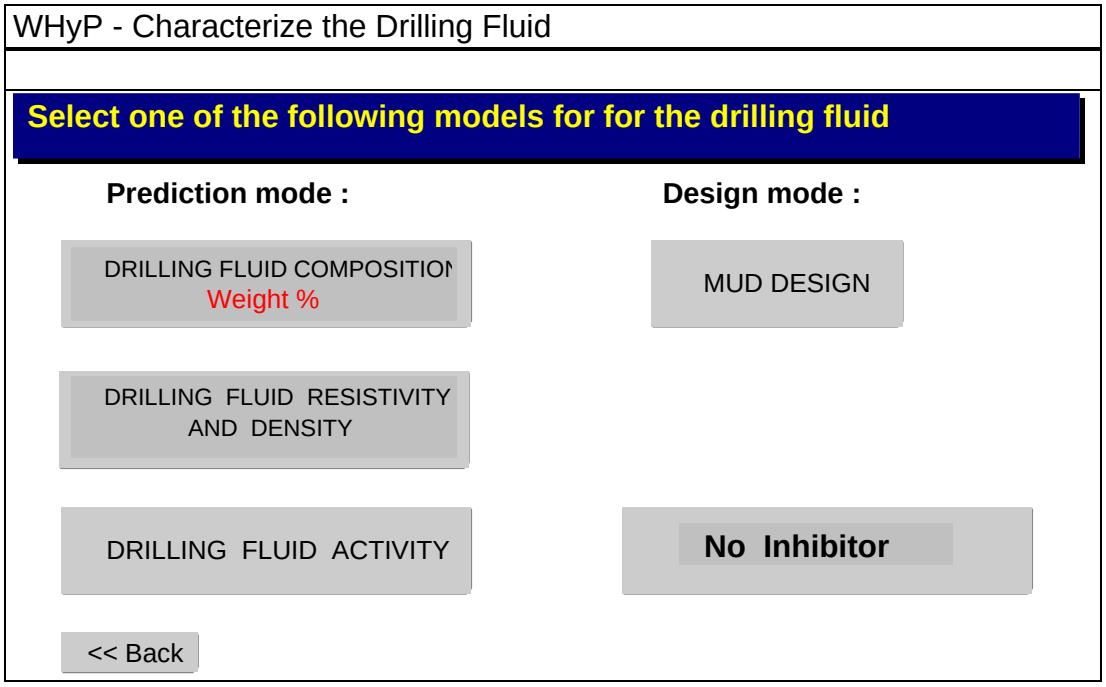
4.1 Using the Prediction Mode of WHyP

The options of Panel 4.1.1 allow you to run the program in a **Prediction Mode** or a **Design Mode**. The following section continues the demonstration by choosing the **Prediction Mode**. The options of Panel 4.1.1 related to the **Prediction Mode** were described in section 2.0 of this manual.

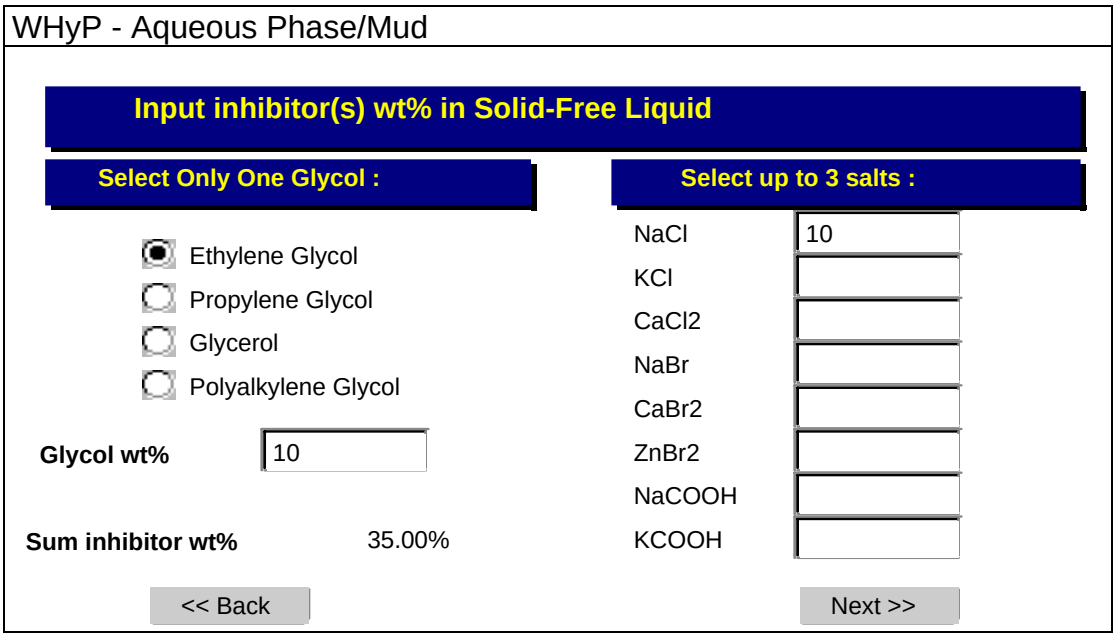
To continue the program demonstration assume that the mud system is formulated with 10wt% NaCl and 10wt% Glycerol. To input this information, **Press** DRILLING FLUID COMPOSITION Weight %. Panel 4.1.2 appears. To select a glycol, click on the name of one of the four glycols shown in Panel 4.1.2 and enter the wt% in the window **Glycol wt%** 10. For the salts, simply enter the wt% in the box next to the name of the salt.

Press Next >> to move to Panel 4.1.3 to select the type of hydrate calculation.

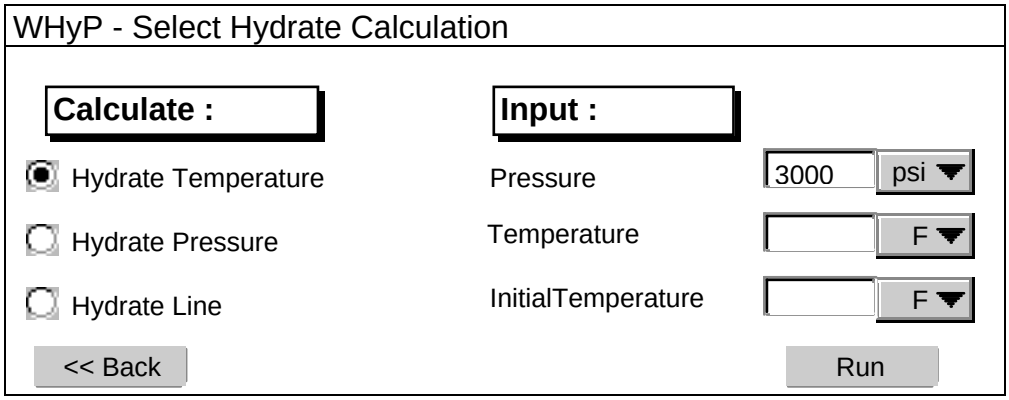
Panel 4.1.1



Panel 4.1.2



Panel 4.1.3



If you are interested in determining the hydrate equilibrium temperature, then **click once** on Hydrate Temperature and enter the pressure value under the input heading in the box next to pressure. The units of pressure can be changed by pressing the button psi. Similarly, if you are interested in determining the hydrate equilibrium pressure, click once on Hydrate Pressure and input the temperature value in the box next to temperature. The units of temperature can be changed by pressing the button F. The last option on Panel 4.1.3 is the prediction of the entire hydrate equilibrium line. This is done by selecting Hydrate Line and entering a value for the initial temperature in the corresponding box. A typical value for the initial temperature is 32°F(273.15K). Example 5.5 demonstrates this type of calculation.

To continue the program demonstration, **select** Hydrate Temperature, enter a pressure value of 3000 psi and **press** Run. The program calculates the hydrate equilibrium temperature at the selected pressure and returns the output shown in Panel 4.1.4.

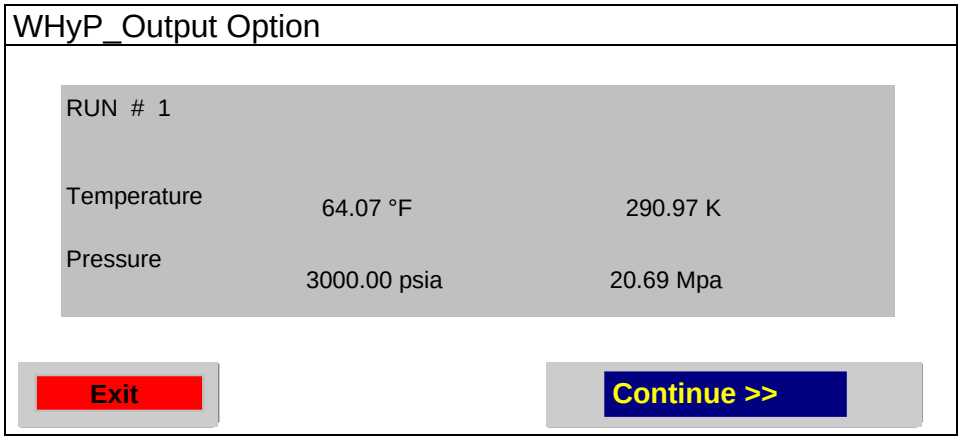
Note:

You can repeat the pressure or temperature prediction for a maximum of 10 times after which you must re-start the program.

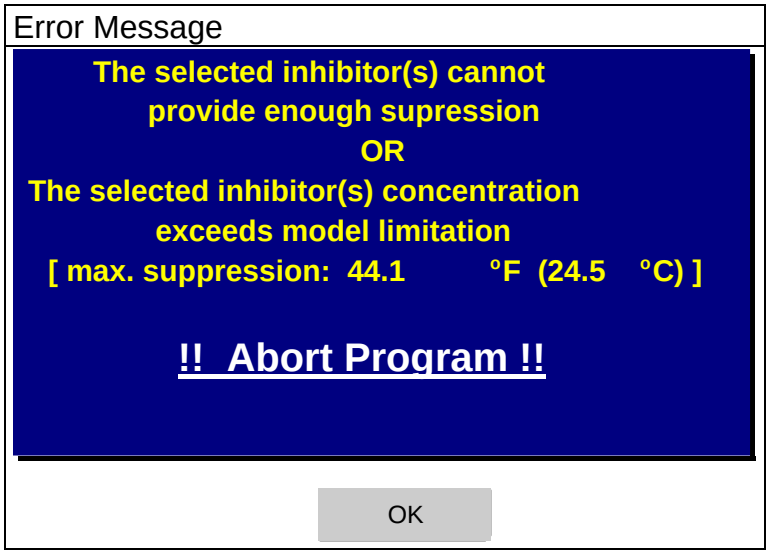
Warning!

Anytime the concentration of the selected inhibitor(s) exceeds the saturation limit or the model accuracy in predicting the hydrate temperature suppression, ΔT, the program will request that you abort with the message shown in panel 4.1.5.

Panel 4.1.4



Panel 4.1.5



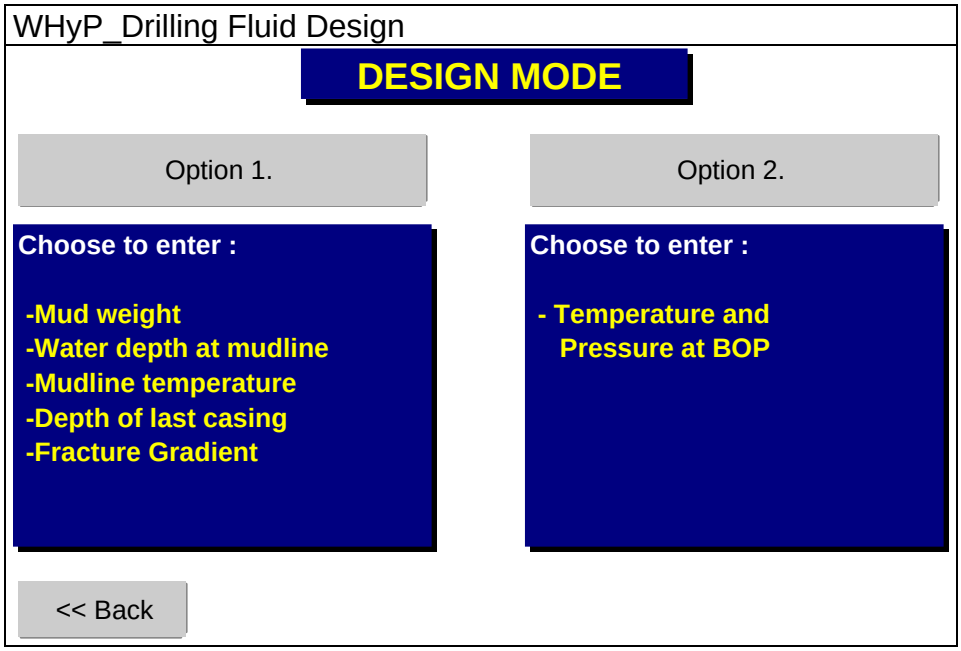
4.2 Using the Design Mode of WHyP

The design mode helps the user to interactively vary the amount and type of inhibitor to keep the mud system outside the hydrate region for a given BOP pressure and temperature.

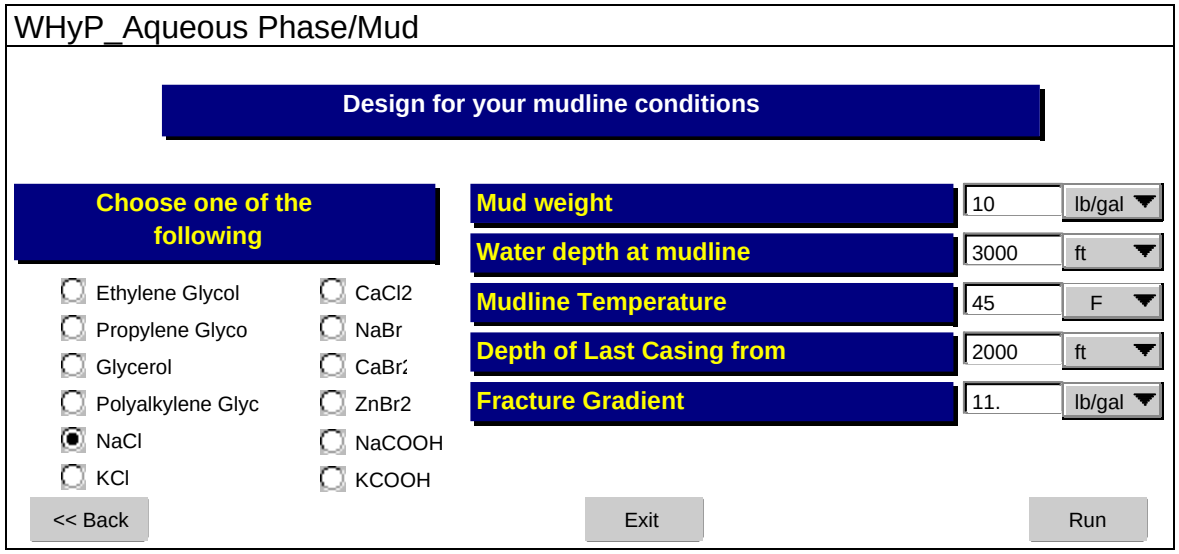
To activate this mode click MUD DESIGN on panel 4.1.1. Panel 4.2.1 will then appear. Panel 4.2.1 provides two options based on the data available to the user. **Press** Option 1. to demonstrate how this option works. Panel 4.2.2 should appear. On this panel, the user must select an inhibitor (NaCl was

selected for this demonstration) and input the specified data. With this input data, the program calculates the maximum pressure at the BOP. **Press** Run to calculate the amount of NaCl needed to suppress the hydrates under the given conditions. The results appear as shown in Panel 4.2.3.

Panel 4.2.1



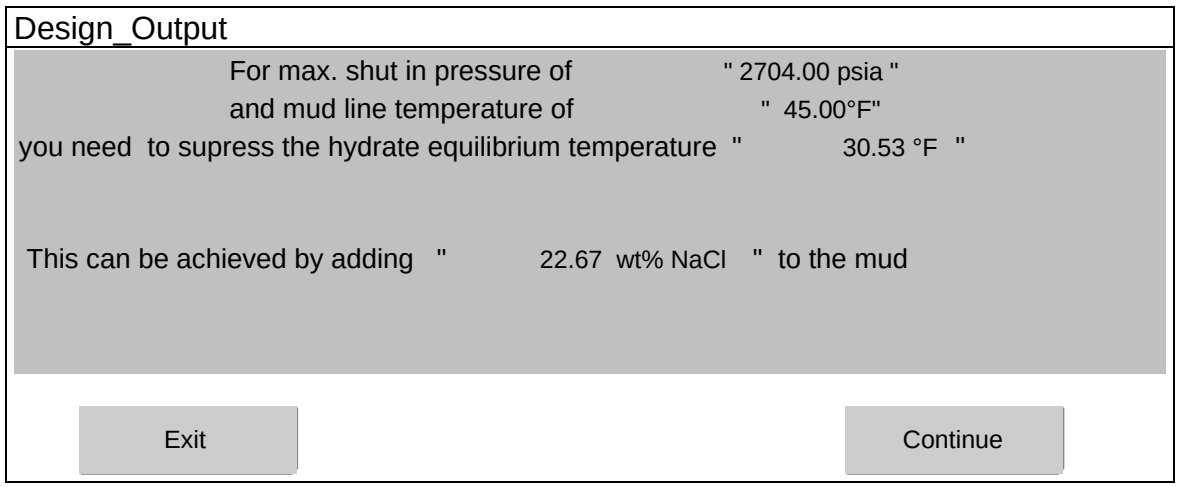
Panel 4.2.2



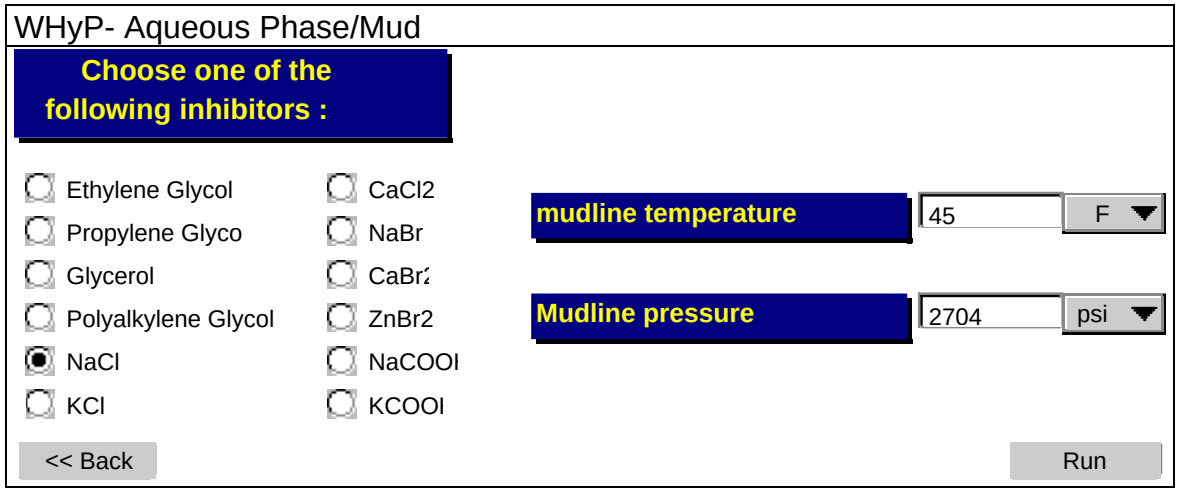
If you know the pressure and temperature at the mudline, then **select** Option 2. from Panel 4.2.1 which takes you to Panel 4.2.4. In this panel, select NaCl and enter, a mudline pressure of 2704 psia and temperature of 45°F. When the Run button is pressed an output similar to the one shown in Panel 4.2.3 will appear.

To change the type of inhibitor, or any of the input data, **press** the Continue button on Panel 4.2.3. Based on the option you are using, you will be returned to either Panel 4.2.2 or 4.2.4.

Panel 4.2.3



Panel 4.2.4



Warning!

If the selected inhibitor is not adequate to inhibit hydrates at the specified mudline pressure and temperature, the program requests that you abort with the message shown in panel 4.1.5.

5.0 Examples

Example 5.1– Prediction of the hydrate equilibrium temperature using the gas composition

Determine the hydrate equilibrium temperature at 3000 psia using the Green Canyon gas mixture with the following inhibitors in the drilling fluid:
a. no inhibitor
b. 10wt% KCl + 10wt% Glycerol
c. 5wt% KCl + 5wt% NaCl + 15wt% Glycerol
d. 10Wt% NaCl + 10wt% Ethylene Glycol

Solution:

a. no inhibitor

1. Run **WHyP** and proceed to Panel 4.3
2. Select [Default Gas Composition] from Panel 4.3.
3. Press [Next >>] on Panel 4.4.
4. Select [No Inhibitor] from panel 4.1.1
5. From Panel 4.1.3 select (•) Hydrate Temperature and enter pressure value of 3000 psia
6. Press [Run]

- The predicted hydrate equilibrium temperature at 3000 psia is 74.91°F
- The measured value is 76.2°F

b. 10wt% KCl + 10wt% Glycerol

1. Press [Continue >>] on Panel 4.1.4
2. Press [Next >>] on Panel 4.4
3. Select [DRILLING FLUID COMPOSITION Weight %] from panel 4.1.1
4. From Panel 4.1.2 select glycerol and enter its value of 10wt% then enter the wt% of KCl in the entry box next to KCl
5. Press [Next >>]

6. From Panel 4.1.3 select (◉ Hydrate Temperature) and enter pressure value of 3000 psia
7. Press [Run]

- The predicted hydrate equilibrium temperature at 3000 psia is 65.44°F
- The measured value is 68°F

c. 5wt% KCl + 5wt% NaCl + 15wt% Glycerol

1. Repeat steps 1-3 of b
2. From Panel 4.1.2 select glycerol and enter its value of 15wt% then enter the wt% of KCl and NaCl in the entry boxes next to their names
3. Press [Next >>]
4. Repeat steps 6 and 7 of b

- The predicted hydrate equilibrium temperature at 3000 psia is 60.91°F
- The measured value is 61.7°F

d. 10Wt% NaCl + 10wt% Ethylene Glycol

1. Repeat steps 1-3 of **b**
2. From Panel 4.1.2 select ethylene glycerol and enter its value of 10wt% then enter the wt% of NaCl in the entry box next to its name
3. Press [Next >>]
4. Repeat steps 6 and 7 of **b**

- The predicted hydrate equilibrium temperature at 3000 psia is 60.1°F
- The measured value is 62°F

Example 5.2– Prediction of the hydrate equilibrium temperature using the gas specific gravity

Recalculate a and b of Example 5.1 using the specific gravity of the Green Canyon gas (SG = 0.65) instead of its composition.

Solution:

a. no inhibitor

Option 1:

1. Press [Continue >>] on Panel 4.1.4
2. Press [<< Back] on Panel 4.4

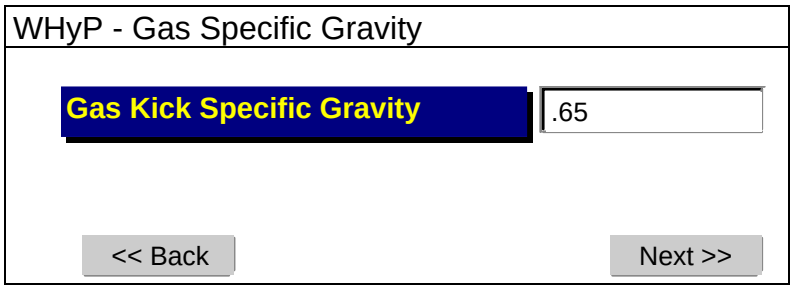
3. Select [Known Specific Gravity] from Panel 4.3
4. Enter the specific gravity value of 0.65 into Panel 5.2.1 Press [Next >>]
5. Select [No Inhibitor] from panel 4.1.1
6. From Panel 4.1.3 select (•) Hydrate Temperature and enter pressure value of 3000 psia
7. Press [Run]

- The predicted hydrate equilibrium temperature at 3000 psia is 74.96°F
- The measured value is 76.2°F

Option 2:

1. Run **WHyP** and proceed to Panel 4.3
2. Repeat steps 3-7 of option 1

Panel 5.2.1



b. 10wt% KCl + 10wt% Glycerol

1. Run **WHyP** and proceed to Panel 4.3
2. Select [Known Specific Gravity] from Panel 4.3
3. Enter the specific gravity value of 0.65 into Panel 5.2.1 and Press [Next >>]
4. Select [DRILLING FLUID COMPOSITION Weight %] from panel 4.1.1
5. From Panel 4.1.2 select glycerol and enter its concentration of 10wt% then Enter the wt% of KCl in the entry box next to KCl
6. Press [Next >>]

- The predicted hydrate equilibrium temperature at 3000 psia is 65.49°F
- The measured value is 68°F

Example 5.3– Prediction of the hydrate equilibrium temperature using the mud filtrate resistivity and density

Using the Green Canyon gas composition, determine the hydrate equilibrium temperature at 3000 psia for a mud sample with the following filtrate data:

Resistivity = 0.0817 ohm-m
Density = 1.0875 g/cc
Glycol density = 1.277 g/cc (Glycerol)
Glycol molecular weight = 92.11 g/mole (Glycerol)
Measurement temperature = 77°F

Solution:

1. Run **WHyP** and proceed to Panel 4.3
2. Select Default Gas Composition from Panel 4.3.
3. Press Next >> on Panel 4.4.
4. Select DRILLING FLUID RESISTIVITY AND DENSITY from panel 4.1.1
5. On Panel 5.3.1 select Glycol (glycerol in this example) and enter its density and molecular weight. Enter the filtrate resistivity, density, and the temperature at which they were measured in the indicated entry boxes. Press Next >>
6. From Panel 4.1.3 select Hydrate Temperature and enter pressure value of 3000 psia
7. Press Run

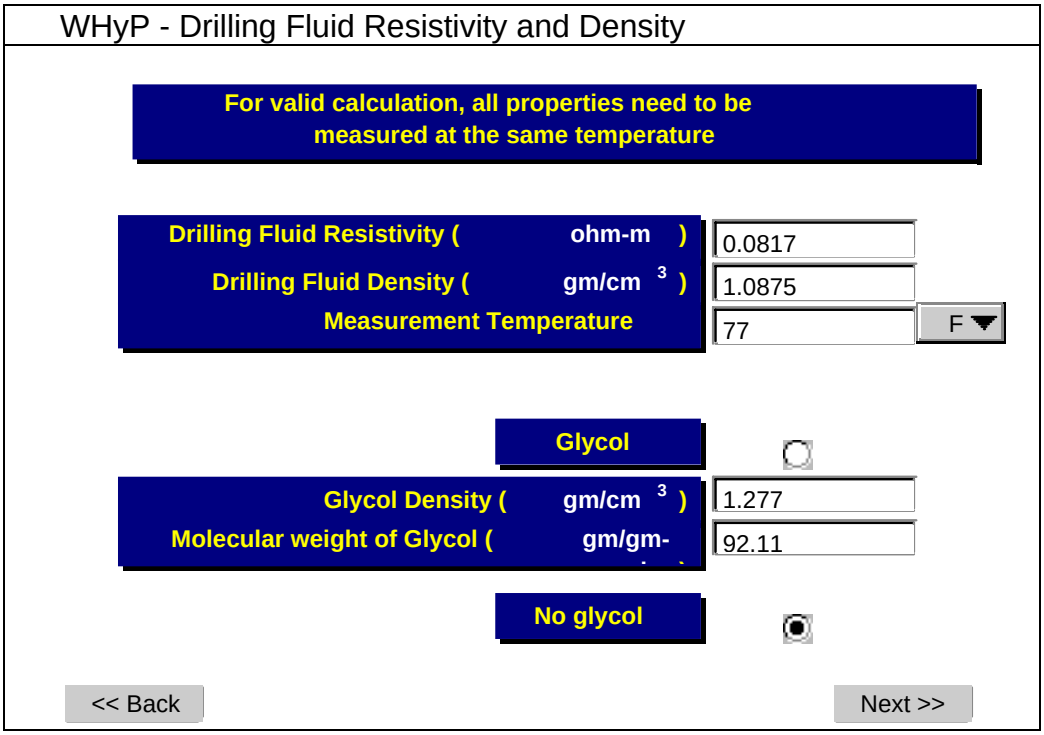
- The predicted hydrate equilibrium temperature at 3000 psia is 63.16°F
- The measured value is 68°F

Example 5.4– Prediction of the hydrate equilibrium temperature using the drilling fluid activity

Repeat Example 5.3 using the mud activity instead of the resistivity/density data. Mud activity = 0.9585 (Measured at 70°F)

1. Press Continue >> on Panel 5.3.1

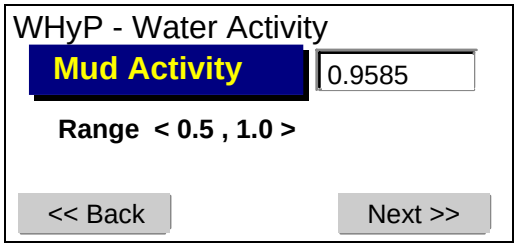
Panel 5.3.1



2. Press Next >> on Panel 4.4
3. Select DRILLING FLUID ACTIVITY from panel 4.1.1
4. Enter the mud activity of 0.9585 in the data box on Panel 5.4.1 and Press Next >>
5. From Panel 4.1.3 select Hydrate Temperature and enter pressure value of 3000 psia
6. Press Run

- The predicted hydrate equilibrium temperature at 3000 psia is 69.34°F
- The measured value is 68°F

Panel 5.4.1



Example 5.5– Prediction of the hydrate phase line of a gas mixture with no inhibitor in the drilling fluid

Determine the hydrate phase equilibrium line for the given gas composition. Assume no inhibitor in the drilling fluid.
90.6%C1, 6.6%C2, 1.8%C3, 0.5% iC4, 0.5% nC4 (McLeod, H.O., Campbell, J.M. (1961)

Solution:

1. Run **WHyP** and proceed to Panel 4.3
2. Select **Known Gas Composition** from Panel 4.3.
3. Enter the given gas composition on Panel 4.4 and Press Next >>
4. To save this gas composition for future use, Press Save Input File
5. A dialog box appears with the file name “Hydrate.WHI”. Use any filename with the extension “.WHI”.
6. If the mole% of the entered gas composition does not add up to 100%, the program will ask you if you want to normalize the composition. Press OK
7. Select **No Inhibitor** from panel 4.1.1
8. From Panel 4.1.3 select Hydrate Line, Enter Initial Temperature 273.15 K and Press Run
9. Select **View Results (Exit)** from Panel 5.5.1 if you desire to view the results and Exit program

- The program prediction is compared with the measured data of reference 5 as shown in Figure 2. The difference is within 2°K.

Panel 5.5.1

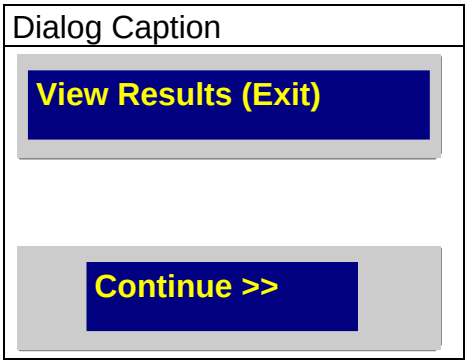
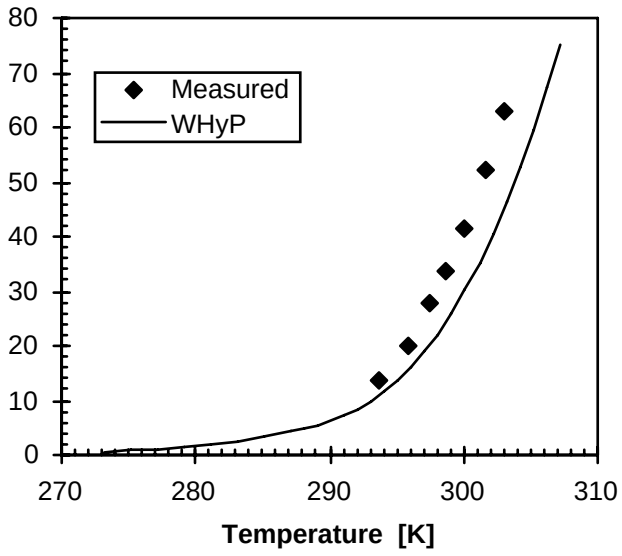


FIGURE 2
Hydrate Phase Equilibrium

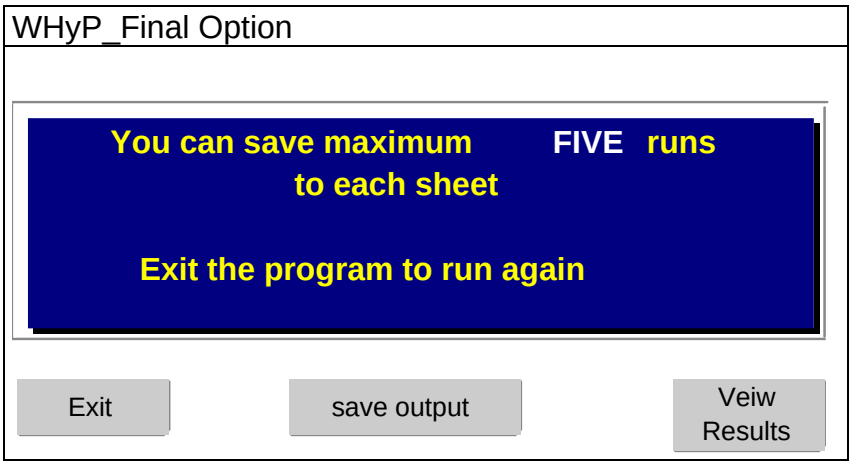


Note:

The user can select 

from Panel 5.5.1 to run other prediction cases. However, after five runs the program will display Panel 5.5.2.

Panel 5.5.2



6.0 References

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