

**WHyP**

**W**estport **H**ydrate **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.

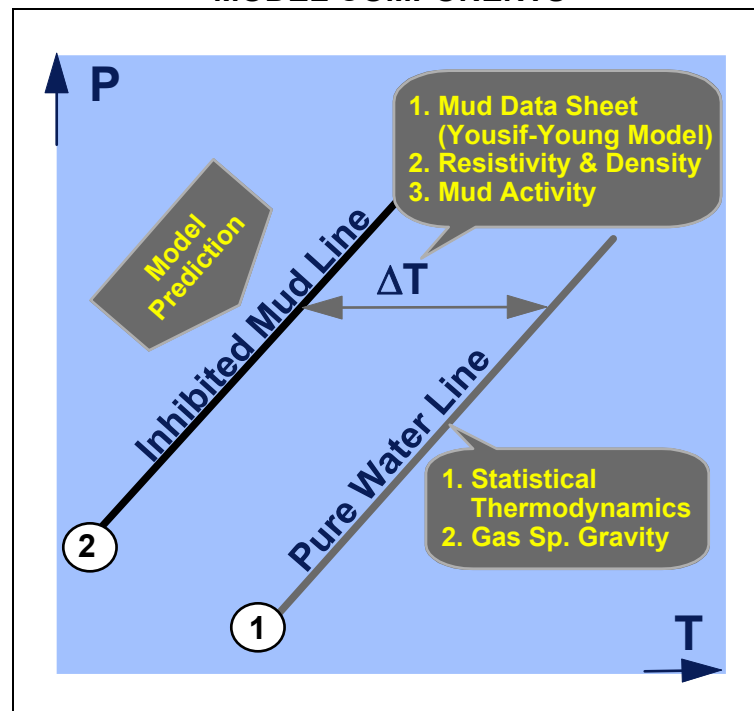
## 2.0 About WHyP

**WHyP** (**W**estport **H**ydrate **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<sup>1</sup> 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	CO <sub>2</sub>
Normal pentane	n-C5	Tridecane	n-C13	Nitrogen	N <sub>2</sub>
Cyclopentane	c-C5	Tetradecane	n-C14	Hydrogen sulfide	H <sub>2</sub> S
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<sup>1</sup> cannot be used. To overcome this difficulty (lack of gas composition), a specific gravity correlation<sup>2</sup> 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<sup>2</sup>. 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:

$$T, \text{ }^\circ\text{F} = -15.428 + 24.422 * \ln(\gamma_g) + 12.604 * \ln(P, \text{psia}) \quad (1)$$

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

## 2.2 Prediction of the Hydrate Temperature Suppression, $\Delta T$

When the drilling fluid contains inhibitors, such as salts and glycols, other tools are required to determine the suppressing effect, or  $\Delta T$  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,  $\Delta T$ , from the weight percentage of each inhibitor in the mud formulation<sup>3</sup>. 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
CaCl <sub>2</sub>	30.0
NaBr	47.5
CaBr <sub>2</sub>	38.0
ZnBr <sub>2</sub>	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,  $\Delta T$ , using the resistivity and density of the mud filtrate<sup>4</sup>. 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,  $\Delta T$ .

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

Finally by determining the phase line 1 and the  $\Delta T$ , 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

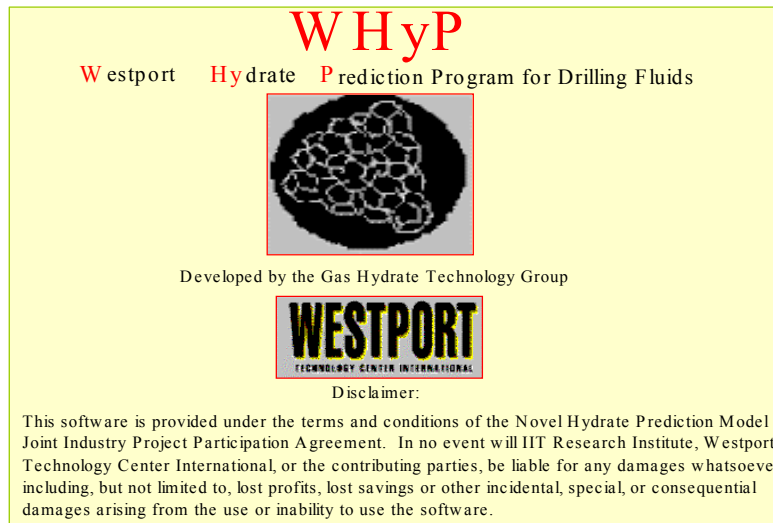
### ***3.3 The pressure or temperature***

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

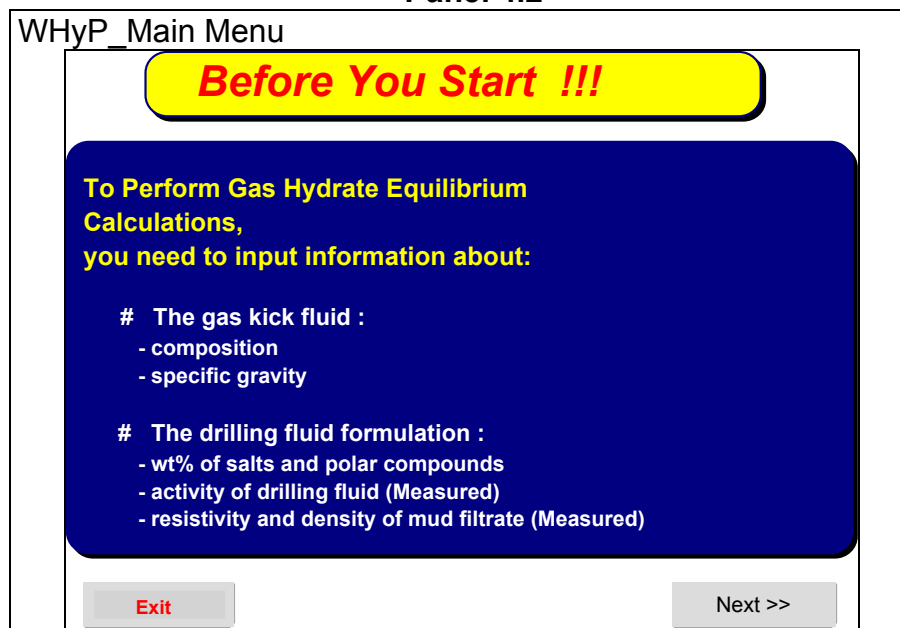
To run **WHyP**, click once the **green icon**  at the top of your screen (This icon should appear next to the standard Excel toolbar). Panel 4.1 will appear.

### Panel 4.1



Click on this panel once to move to Panel 4.2.

### Panel 4.2



Press  to move to Panel 4.3.

### Panel 4.3

WHyP - Gas Kick Fluid Characterization

**Characterizing the Gas Kick Fluid**

<input type="button" value="Known Specific Gravity"/>	IF the specific gravity of " Gas Kick Fluid " is known
<input type="button" value="Known Gas Composition"/>	IF the composition of " Gas Kick Fluid" is known
<input type="button" value="Default Gas Composition"/>	Use the Green Canyon Gas Composition

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** . If the gas specific gravity is available to you instead of the gas composition, then **Click on**

.

If no information is available about the gas kick fluid, then **Click on** . 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



**Default Gas Composition**

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

**Panel 4.4**

Input Gas Kick Fluid Composition (mole %)			
<b>C<sub>1</sub></b>	87.243	<b>C<sub>7</sub></b>	<input type="text"/>
<b>C<sub>2</sub></b>	7.570	<b>C<sub>8</sub></b>	<input type="text"/>
<b>C<sub>3</sub></b>	3.080	<b>C<sub>9</sub></b>	<input type="text"/>
<b>i-C<sub>4</sub></b>	0.510	<b>C<sub>10</sub></b>	<input type="text"/>
<b>n-C<sub>4</sub></b>	0.792	<b>C<sub>11</sub></b>	<input type="text"/>
<b>i-C<sub>5</sub></b>	0.202	<b>C<sub>12</sub></b>	<input type="text"/>
<b>n-C<sub>5</sub></b>	0.200	<b>C<sub>13</sub></b>	<input type="text"/>
<b>c-C<sub>5</sub></b>	<input type="text"/>	<b>C<sub>14</sub></b>	<input type="text"/>
<b>C<sub>6</sub></b>	<input type="text"/>	<b>C<sub>15</sub></b>	<input type="text"/>
		<b>C<sub>16</sub></b>	<input type="text"/>
		<b>C<sub>17</sub></b>	<input type="text"/>
		<b>C<sub>18</sub></b>	<input type="text"/>
		<b>C<sub>19</sub></b>	<input type="text"/>
		<b>C<sub>20</sub></b>	<input type="text"/>
		<b>CO<sub>2</sub></b>	<input type="text"/>
		<b>N<sub>2</sub></b>	0.403
		<b>H<sub>2</sub>S</b>	<input type="text"/>
		Sum of mole%	100.000%
<span style="border: 1px solid gray; padding: 2px;">&lt;&lt; Back</span>	<span style="border: 1px solid gray; padding: 2px;">Save Input File</span>	<span style="border: 1px solid gray; padding: 2px;">Use Saved file</span>	<span style="border: 1px solid gray; padding: 2px;">Next &gt;&gt;</span>

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,

DRILLING FLUID COMPOSITION  
Weight %

**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% . 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**

WHyP - Characterize the Drilling Fluid

**Select one of the following models for for the drilling fluid**

**Prediction mode :**

DRILLING FLUID COMPOSITION  
Weight %

DRILLING FLUID RESISTIVITY AND DENSITY

DRILLING FLUID ACTIVITY

**Design mode :**

MUD DESIGN

No Inhibitor

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**Panel 4.1.2**

WHyP - Aqueous Phase/Mud

**Input inhibitor(s) wt% in Solid-Free Liquid**

**Select Only One Glycol :**

Ethylene Glycol  
 Propylene Glycol  
 Glycerol  
 Polyalkylene Glycol

Glycol wt%

Sum inhibitor wt% 35.00%

**Select up to 3 salts :**

NaCl	<input type="text" value="10"/>
KCl	<input type="text"/>
CaCl2	<input type="text"/>
NaBr	<input type="text"/>
CaBr2	<input type="text"/>
ZnBr2	<input type="text"/>
NaCOOH	<input type="text"/>
KCOOH	<input type="text"/>

<< Back Next >>

### Panel 4.1.3

WHyP - Select Hydrate Calculation

<p><b>Calculate :</b></p> <p><input checked="" type="radio"/> Hydrate Temperature</p> <p><input type="radio"/> Hydrate Pressure</p> <p><input type="radio"/> Hydrate Line</p> <p style="text-align: center;"><input type="button" value=" &lt;&lt; Back"/></p>	<p><b>Input :</b></p> <p>Pressure <input style="width: 50px;" type="text" value="3000"/> <input type="button" value="psi ▼"/></p> <p>Temperature <input style="width: 50px;" type="text"/> <input type="button" value="F ▼"/></p> <p>InitialTemperature <input style="width: 50px;" type="text"/> <input type="button" value="F ▼"/></p> <p style="text-align: center;"><input type="button" value=" Run"/></p>
--	---

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 . 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 . 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** . 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,  $\Delta T$ , the program will request that you abort with the message shown in panel 4.1.5.

### Panel 4.1.4


WHyP_ Output Option		
RUN # 1		
Temperature	64.07 °F	290.97 K
Pressure	3000.00 psia	20.69 Mpa
<b>Exit</b>		<b>Continue &gt;&gt;</b>

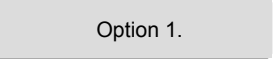
### Panel 4.1.5

Error Message
<p><b>The selected inhibitor(s) cannot provide enough suppression OR The selected inhibitor(s) concentration exceeds model limitation [ max. suppression: 44.1 °F (24.5 °C) ]</b></p> <p><b><u>!! Abort Program !!</u></b></p>
OK

## 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  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  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**

WHyP\_Drilling Fluid Design

**DESIGN MODE**

Option 1.

Option 2.

**Choose to enter :**

- Mud weight
- Water depth at mudline
- Mudline temperature
- Depth of last casing
- Fracture Gradient

**Choose to enter :**

- Temperature and Pressure at BOP

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## Panel 4.2.4

WHyP- Aqueous Phase/Mud

**Choose one of the following inhibitors :**

<input type="checkbox"/> Ethylene Glycol	<input type="checkbox"/> CaCl <sub>2</sub>
<input type="checkbox"/> Propylene Glyco	<input type="checkbox"/> NaBr
<input type="checkbox"/> Glycerol	<input type="checkbox"/> CaBr <sub>2</sub>
<input type="checkbox"/> Polyalkylene Glycol	<input type="checkbox"/> ZnBr <sub>2</sub>
<input checked="" type="checkbox"/> NaCl	<input type="checkbox"/> NaCOOI
<input type="checkbox"/> KCl	<input type="checkbox"/> KCOOI

**mudline temperature** 45 F ▼

**Mudline pressure** 2704 psi ▼

<< Back Run

**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



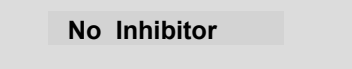

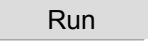
### Example 5.1– Prediction of the hydrate equilibrium temperature using the gas composition

Determine the hydrate equilibrium temperature at 3000 psia using the Green Canyon gas mixture with the following inhibitors in the drilling fluid:



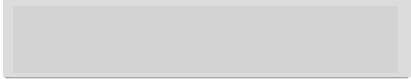

- no inhibitor
- 10wt% KCl + 10wt% Glycerol
- 5wt% KCl + 5wt% NaCl + 15wt% Glycerol
- 10Wt% NaCl + 10wt% Ethylene Glycol

#### **Solution:**


##### **a. no inhibitor**

- Run **WHyP** and proceed to Panel 4.3
  - Select  from Panel 4.3.
  - Press  on Panel 4.4.
  - Select  from panel 4.1.1
  - From Panel 4.1.3 select  and enter pressure value of 3000 psia
  - Press 
- The predicted hydrate equilibrium temperature at 3000 psia is 74.91°F
  - The measured value is 76.2°F

##### **b. 10wt% KCl + 10wt% Glycerol**

- Press  on Panel 4.1.4
- Press  on Panel 4.4
- Select  from panel 4.1.1
- 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
- Press 



6. From Panel 4.1.3 select  and enter pressure value of 3000 psia

7. Press 

- 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 

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 

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  on Panel 4.1.4

2. Press  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**

WHyP - Gas Specific Gravity

**Gas Kick Specific Gravity**

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Next >>

#### 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 **No Inhibitor** 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



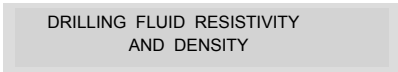


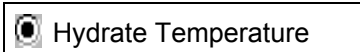

Density = 1.0875 g/cc

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  from Panel 4.3.
3. Press  on Panel 4.4.
4. Select  from panel 4.1.1
5. On Panel 5.3.1 select  (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 
6. From Panel 4.1.3 select  and enter pressure value of 3000 psia
7. Press 
  - 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  on Panel 5.3.1

## Panel 5.3.1

WHyP - Drilling Fluid Resistivity and Density

For valid calculation, all properties need to be measured at the same temperature

Drilling Fluid Resistivity ( ohm-m ) 0.0817

Drilling Fluid Density ( gm/cm<sup>3</sup> ) 1.0875

Measurement Temperature 77 F

Glycol

Glycol Density ( gm/cm<sup>3</sup> ) 1.277

Molecular weight of Glycol ( gm/gm- ) 92.11

No glycol

<< Back Next >>

2. Press  on Panel 4.4
3. Select  from panel 4.1.1
4. Enter the mud activity of 0.9585 in the data box on Panel 5.4.1 and Press
5. From Panel 4.1.3 select  Hydrate Temperature and enter pressure value of 3000 psia
6. Press 
  - The predicted hydrate equilibrium temperature at 3000 psia is 69.34°F
  - The measured value is 68°F

**Panel 5.4.1**

WHyP - Water Activity

**Mud Activity**

Range < 0.5 , 1.0 >

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

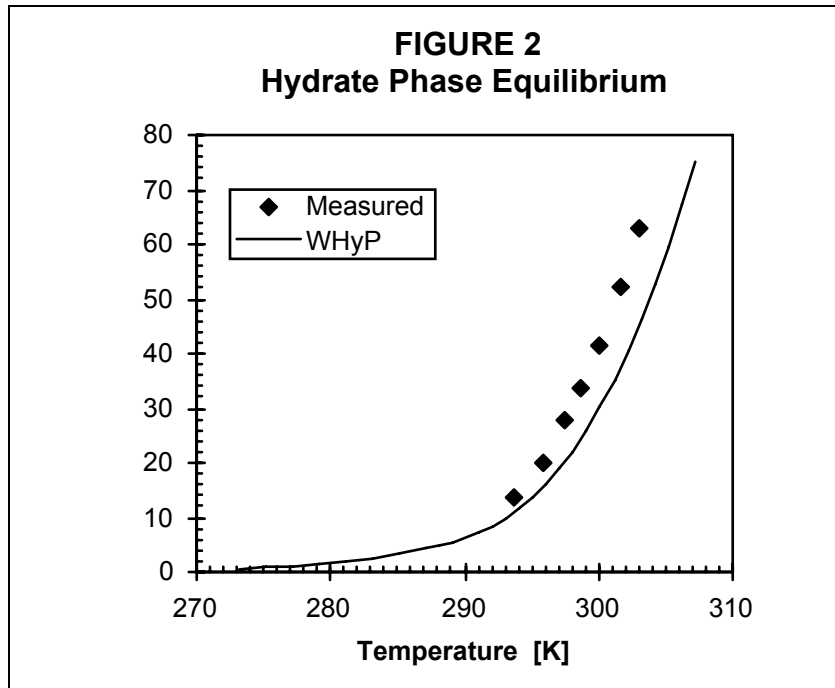
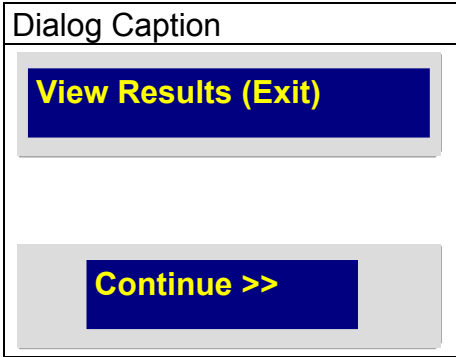
Determine the hydrate phase equilibrium line for the given gas composition. Assume no inhibitor in the drilling fluid.

90.6%C1, 6.6%C2, 1.8%C3, 0.5% iC4, 0.5% nC4 (McLeod, H.O., Campbell, J.M. (1961))

#### Solution:

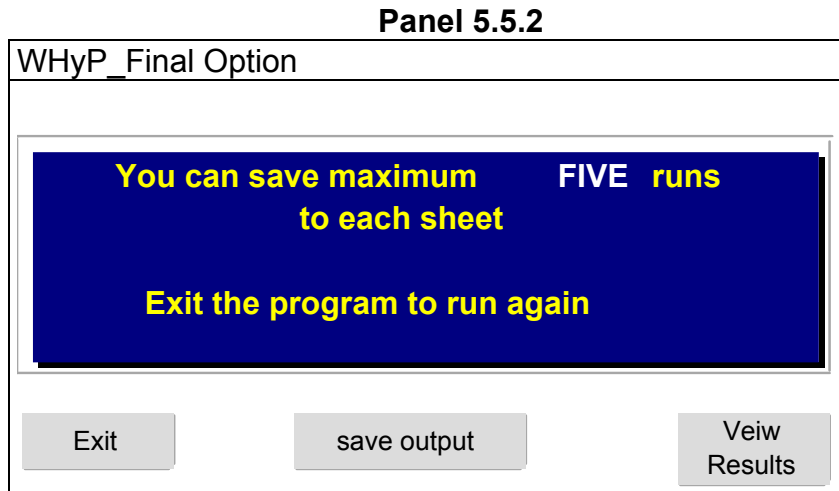
1. Run **WHyP** and proceed to Panel 4.3
2. Select **Known Gas Composition** from Panel 4.3.
3. Enter the given gas composition on Panel 4.4 and Press **Next >>**
4. To save this gas composition for future use, Press **Save Input File**
5. A dialog box appears with the file name “Hydrate.WHI”. Use any 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   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



**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.



## 6.0 References

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5. McLeod, H.O., Campbell, J.M., JPT, 13, 590, 1961.