INTEGRATED CLOUD BASED HYDRATE SIMULATIONS – AN UPDATE

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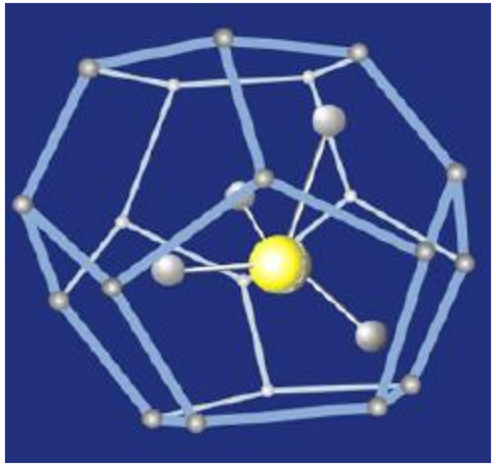
Engineered Solutions

BASIC PRESENTATION LAYOUT

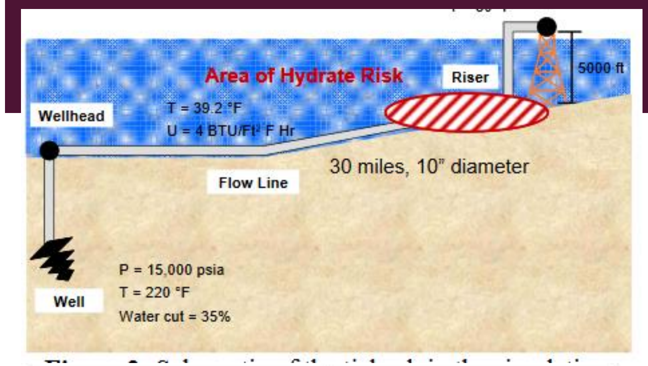
- Simple hydrate introduction
- The various simulator interfaces
  - Basic and advanced
- Basic science and solution process
- Gravity method
- Correlation methods
- The Ameripour Method
- Fetching data from the SCADA system
- General architecture and SCADA design
- Whats new in our development (unconventional gas/oil models)
- On-going development in existing modules
- References

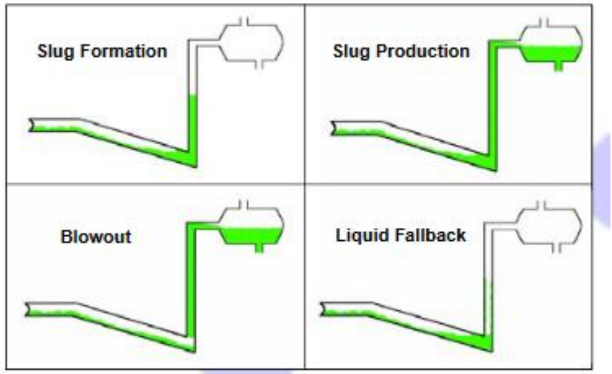
HYDRATES

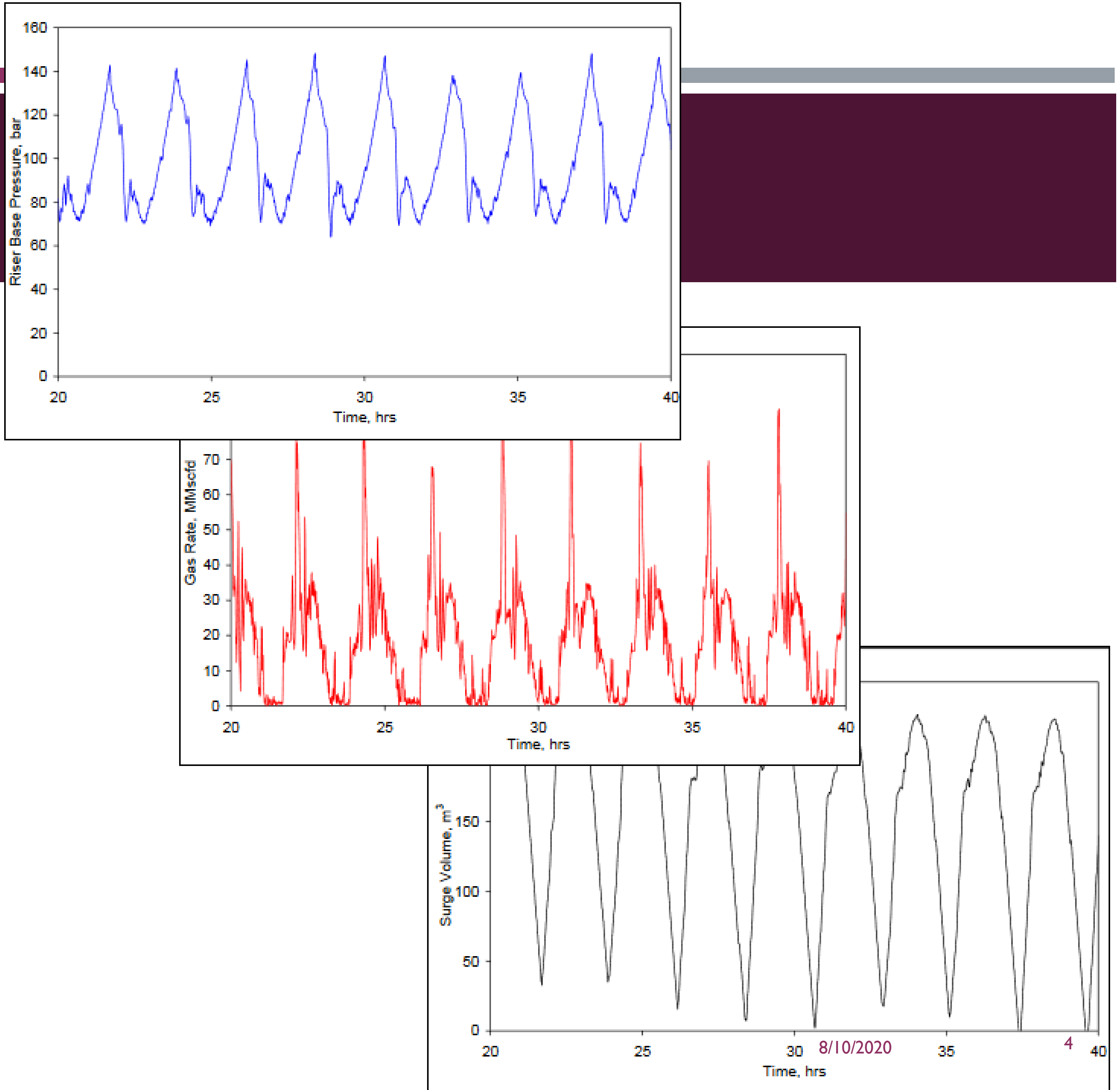
- Natural gas hydrates are "ice-like" structures composed of water and natural gas molecules. Under favourabe conditions of high pressure and low temperature, water molecules form cages which encapsulate gas molecules inside a hydrogen-bonded solid lattice.
- Hydrates have different dielectric constants and different thermal conductivity than ice.
- Hydrate forming conditions include:
  - Free water
  - Natural gas (N2, H2S, CO2, C1, C2, C3, iC4, nC4, iC5, nC5…)
  - Reduced temperature
  - Increased pressure



WHY DO WE CARE?







In this schematic, hydrates cause severe plugging and slugging with the formation of hydrates between a subsea location and rise (offshore)

WHY DO WE CARE?

The famous Petronas hydrate.

Blockage of pipe and flowline:

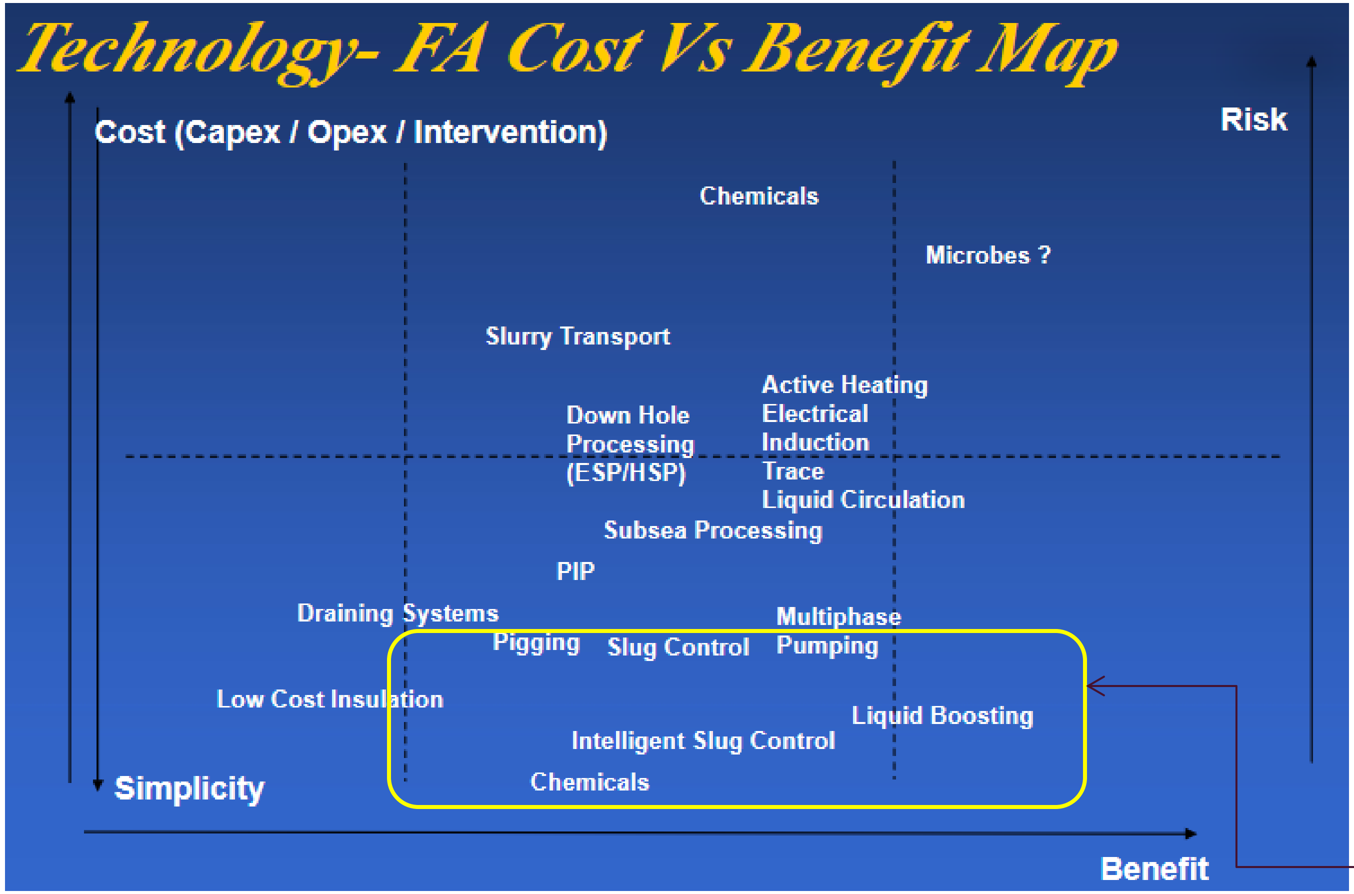
Plugs up to 6 miles
Plugs up to 40” pipe

Safety considerations

Implications for Brownfield decline

Gas hydrates may lead to several industrial problems, such as erosion and/or corrosion in pipelines, the blockage of transfer lines, compressor damage, etc., which cost millions of dollars in production facilities and transmission pipelines every year

WHAT ARE WE TRYING TO DO



Can we create a simple model based solution that may help to predict hydrates with relatively basic or traditional SCADA system. There are of course a number of modern CFD and complex modelling solutions, we are investigating a correlation based real-time Cloud solution.

In addition to time-consuming and expensive experiments, as well as complicated modeling methods, several correlations have been presented to facilitate hydrate formation prediction and interpretation.

These kinds of correlations are popular among engineers and researchers because they are simple and fast.

BASIC REMEDIES

- Reduce Pressure
- Increase Temperature
- Chemical (thermodynamic) inhibition
- Kinetic inhibitors
- Mechanical removal

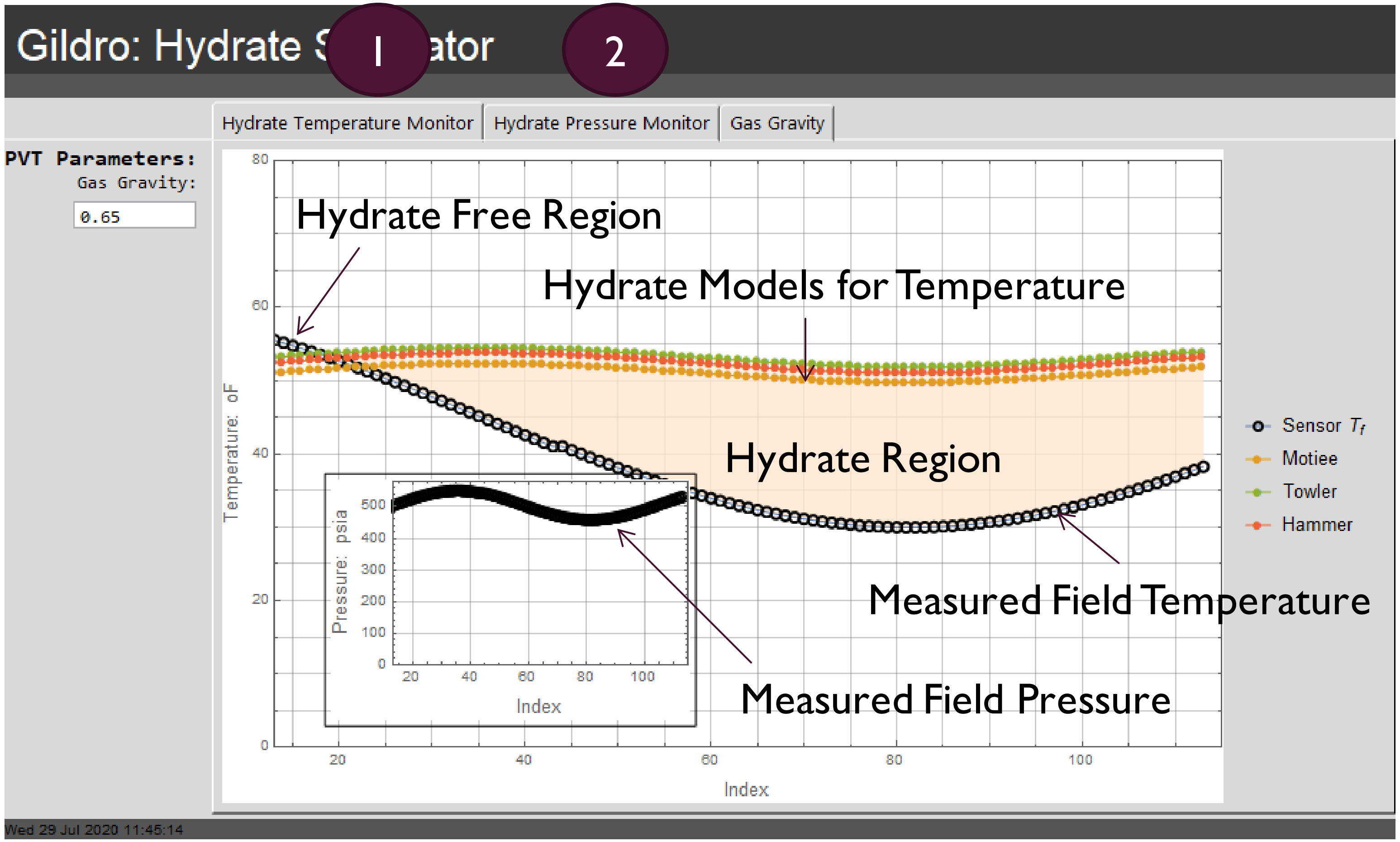
Can we automate this? Can we make a simple model that predicts in real-time as a well produces

THERMODYNAMICS

- Thermodynamic inhibitors
  - Electrolytes (salts) form ionic bonds with free water
  - Polar compounds (alcohols, glycols) compete with hydrates for hydrogen bonding

TWO INTERFACES
BASIC & ADVANCED

GILDRO: HYDRATE SIMULATOR: BASIC INTERFACE

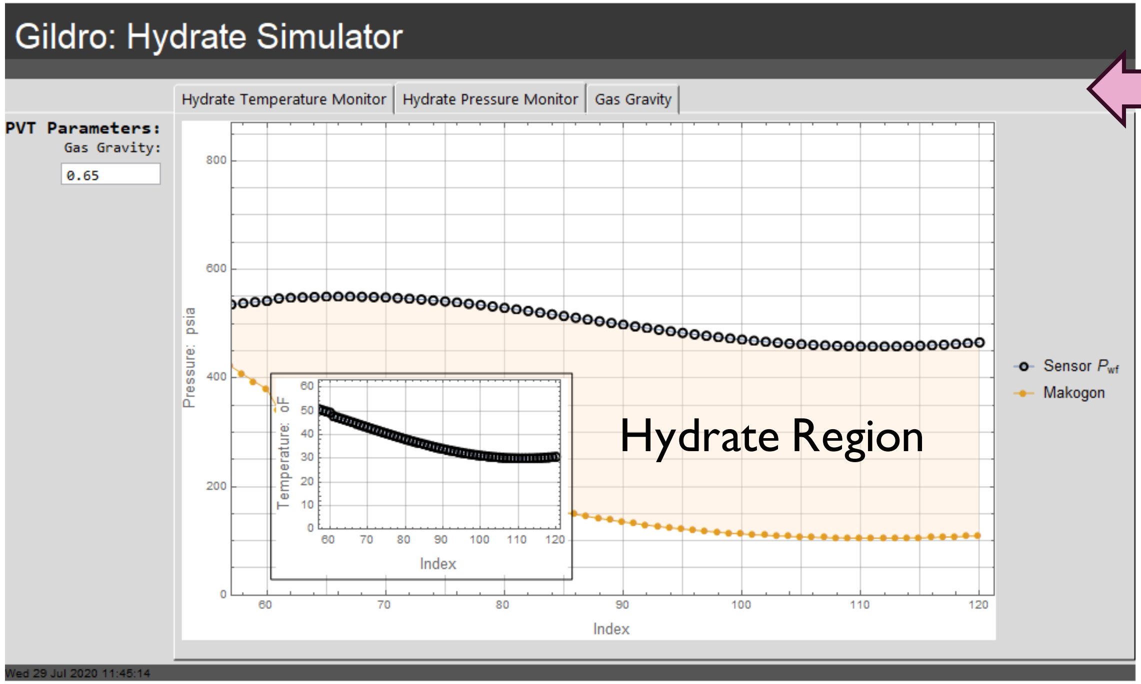


As field pressures and temperatures are obtained, various hydrate models instantly calculate potential hydrate conditions in two scenarios:

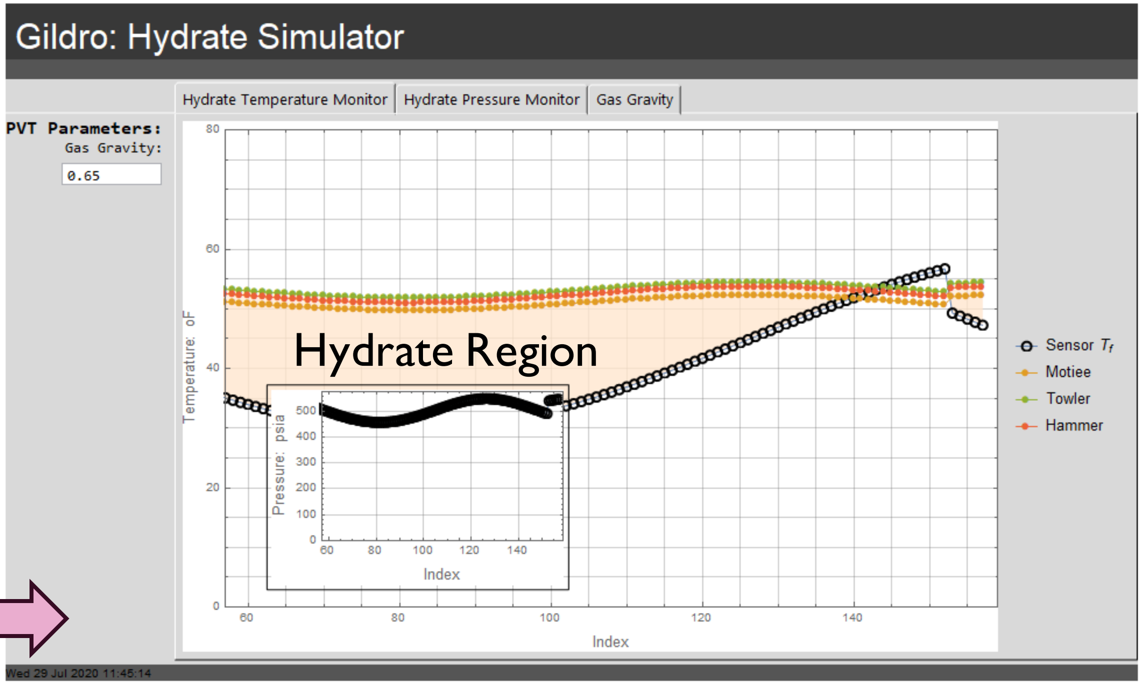
1. Given pressure data, calculate hydrate temperature and compare to field temperature.

2. Given temperature data, calculate hydrate pressure and compared to field pressure measurements

ANALYSIS BY EITHER TEMPERATURE OR PRESSURE

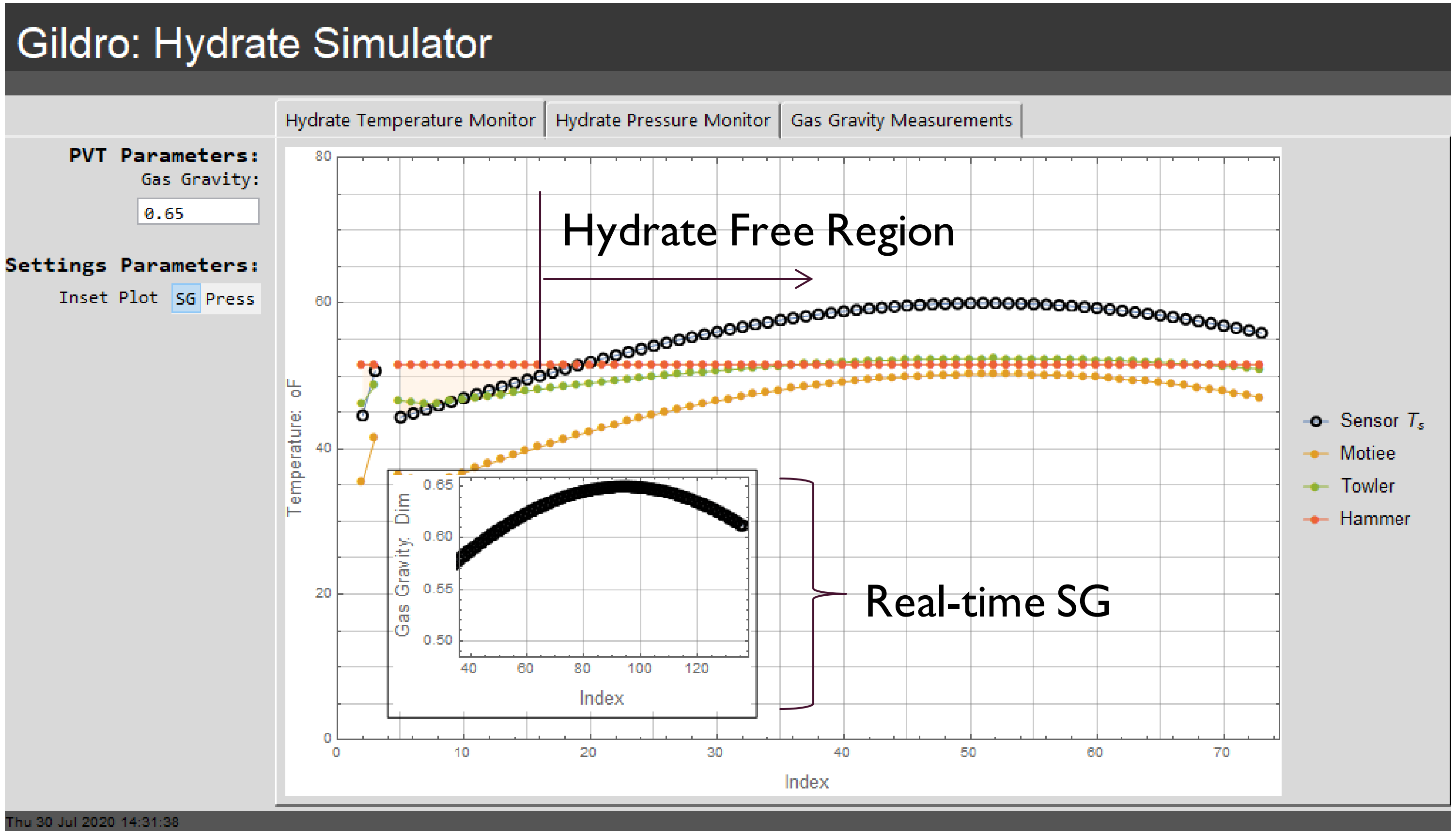


For a given pressure, the hydrate temperature is calculate. If $T_{sensor} < T_{hydrate,\ then}$ hydrates potentially form



For a given pressure, the hydrate temperature is calculate. If $P_{sensor} > P_{hydrate,\ then}$ hydrates potentially form

STATIC FLUID DENSITY OR DYNAMIC BY SENSOR



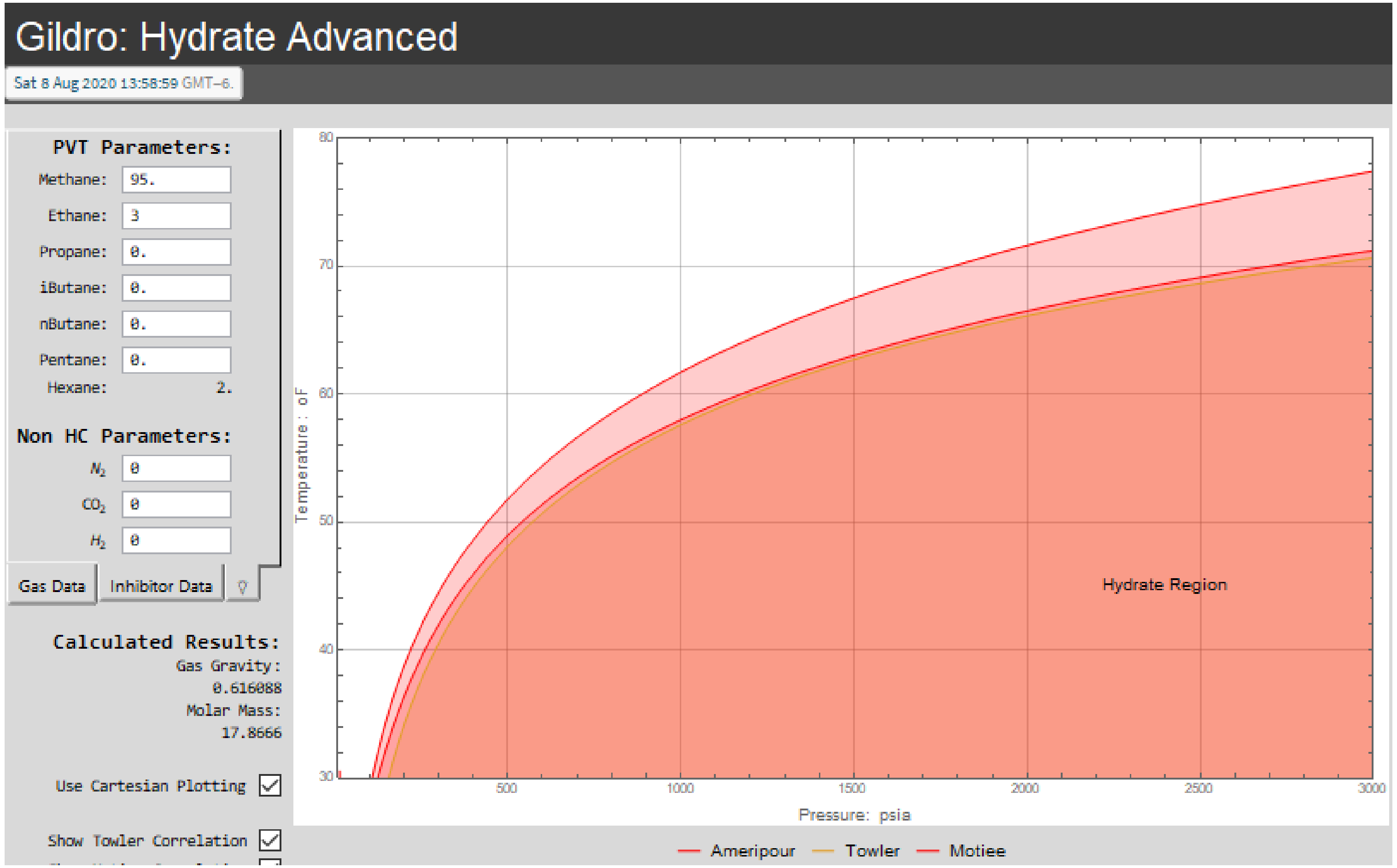
Common Specific Gravity Meters

3098 Gas Specific Gravity Meter: by Emerson
Mass Sense ® Gas Density Meter: by ISS

The system can be setup such that the operator can use a constant gas gravity, or linked a real-time SCADA acquired value.

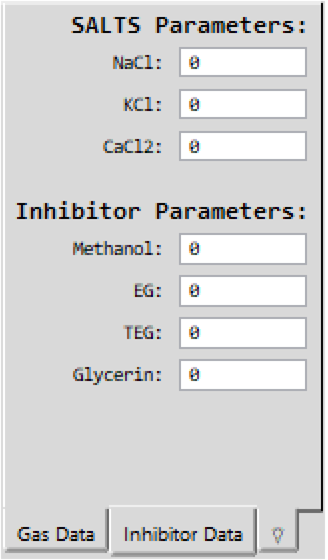
The system can be setup for any vendor or manufacturer

GILDRO: HYDRATE SIMULATOR: ADVANCED INTERFACE

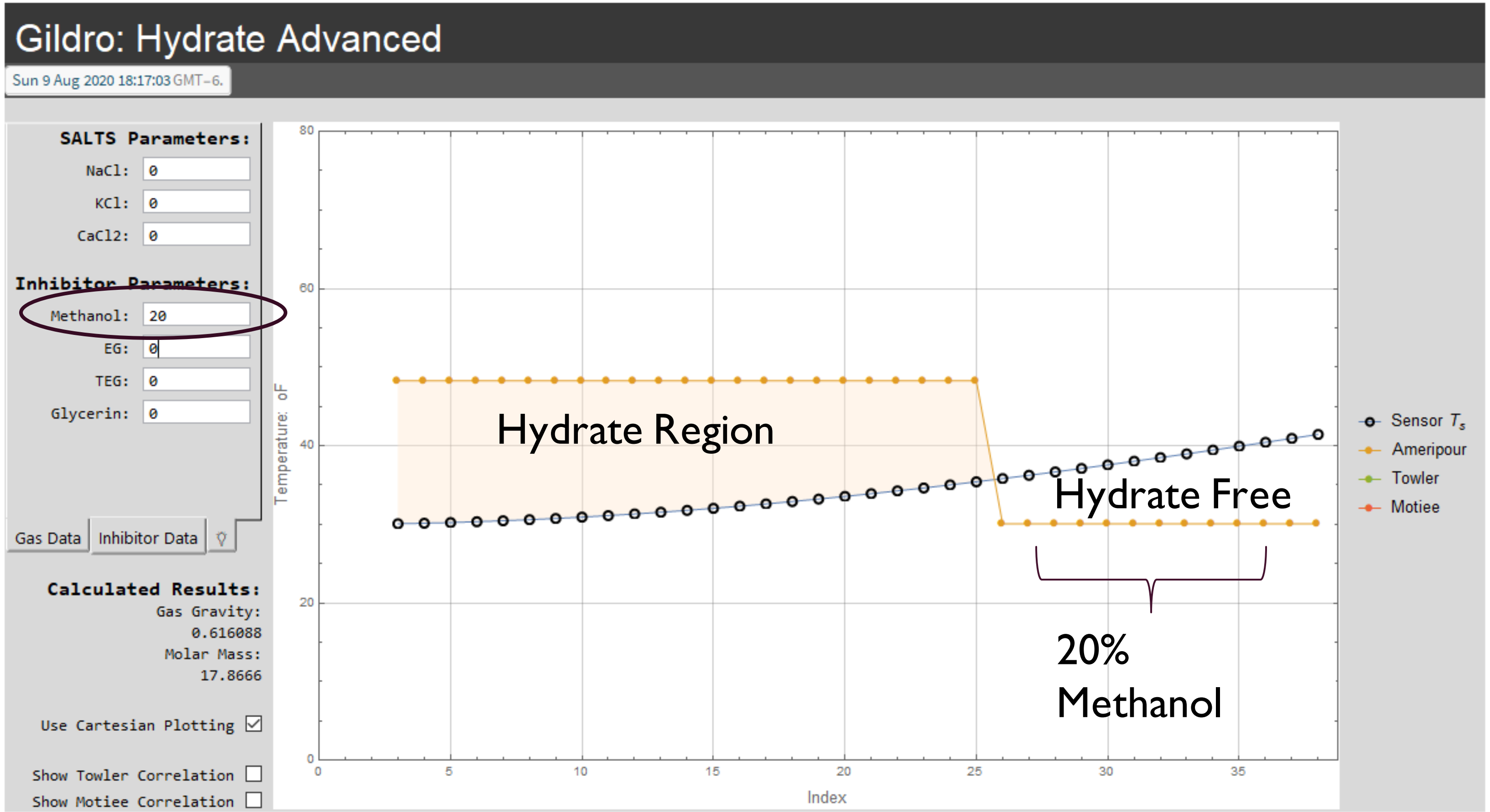


The advanced interface allows users to enter more complex gas mixtures as well as the inclusion of SALTS and Inhibitors

We can include and account for (by wt%) the common inhibitors found in industry



GILDRO: HYDRATE SIMULATOR: ADVANCED INTERFACE

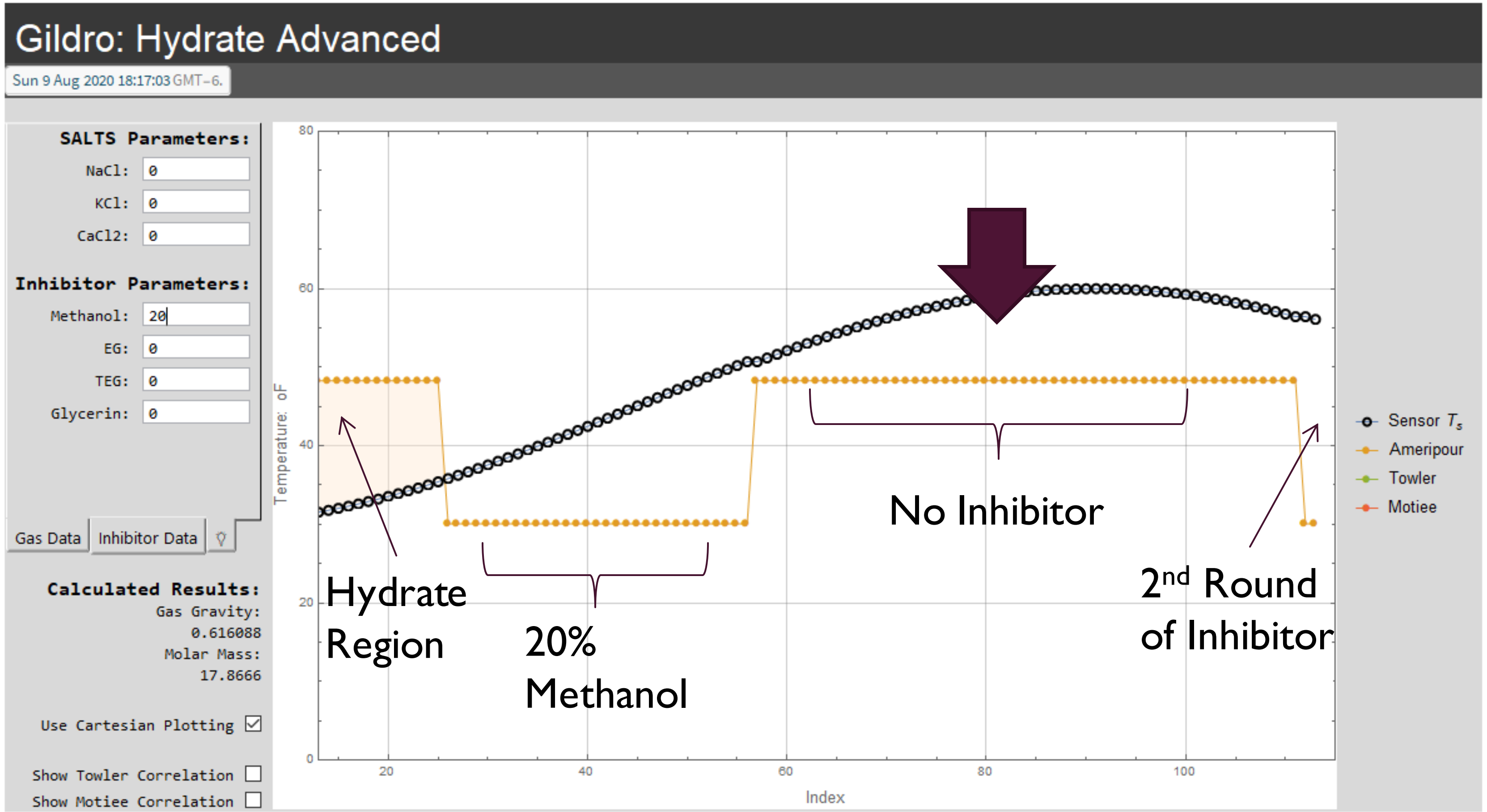


With the more advanced interface, we can monitor AND ADJUST for hydrates in real-time.

In this scenario, we see the impact of adding Methanol at 20% by weight.

These simulated examples were run at a constant line pressure of approximately 500 psia

GILDRO: HYDRATE SIMULATOR: ADVANCED INTERFACE



With the more advanced interface, we can monitor AND ADJUST for hydrates in real-time.

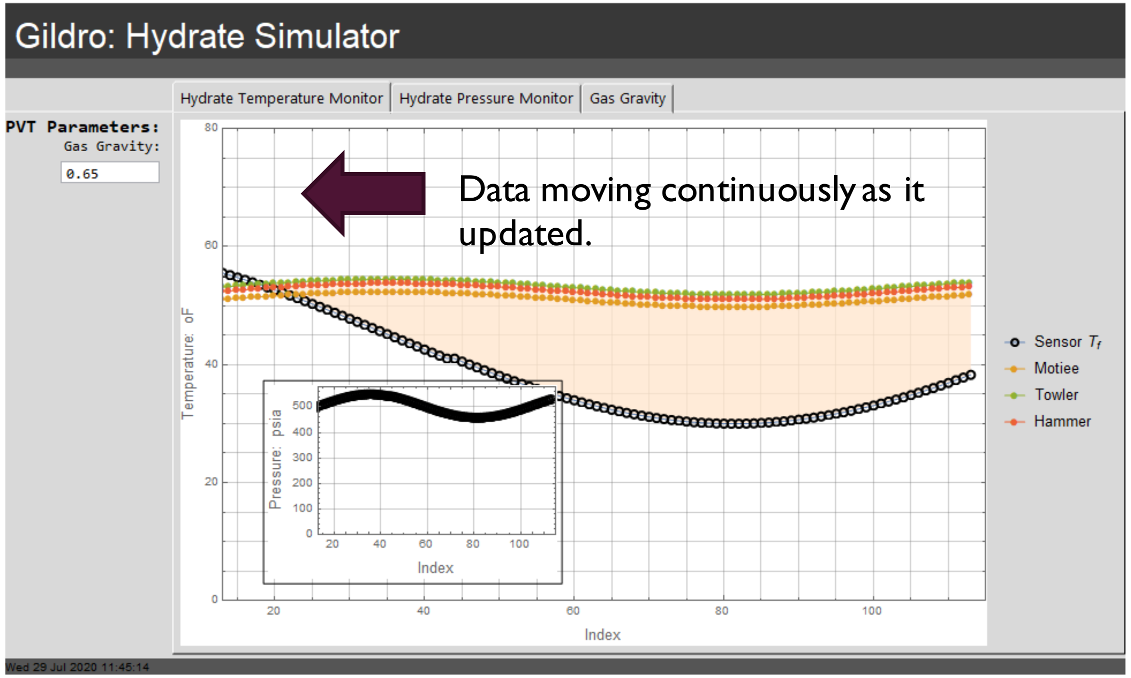
We can also estimate when to EXCLUDE inhibitors as shown ni this plot.

This can help with optimization of costs.

These simulated examples were run at a constant line pressure of approximately 500 psia

REAL-TIME

- Data is obtained directly from the Canary Historian as soon as it is effectively logged. The system has been designed to immediately perform hydrate calculations and update the various monitoring plots. The flow assurance specialist can easily watch as the data progresses in the live interface.



No more than 100 points are shown on the screen at any time – although this can be customized to specific needs

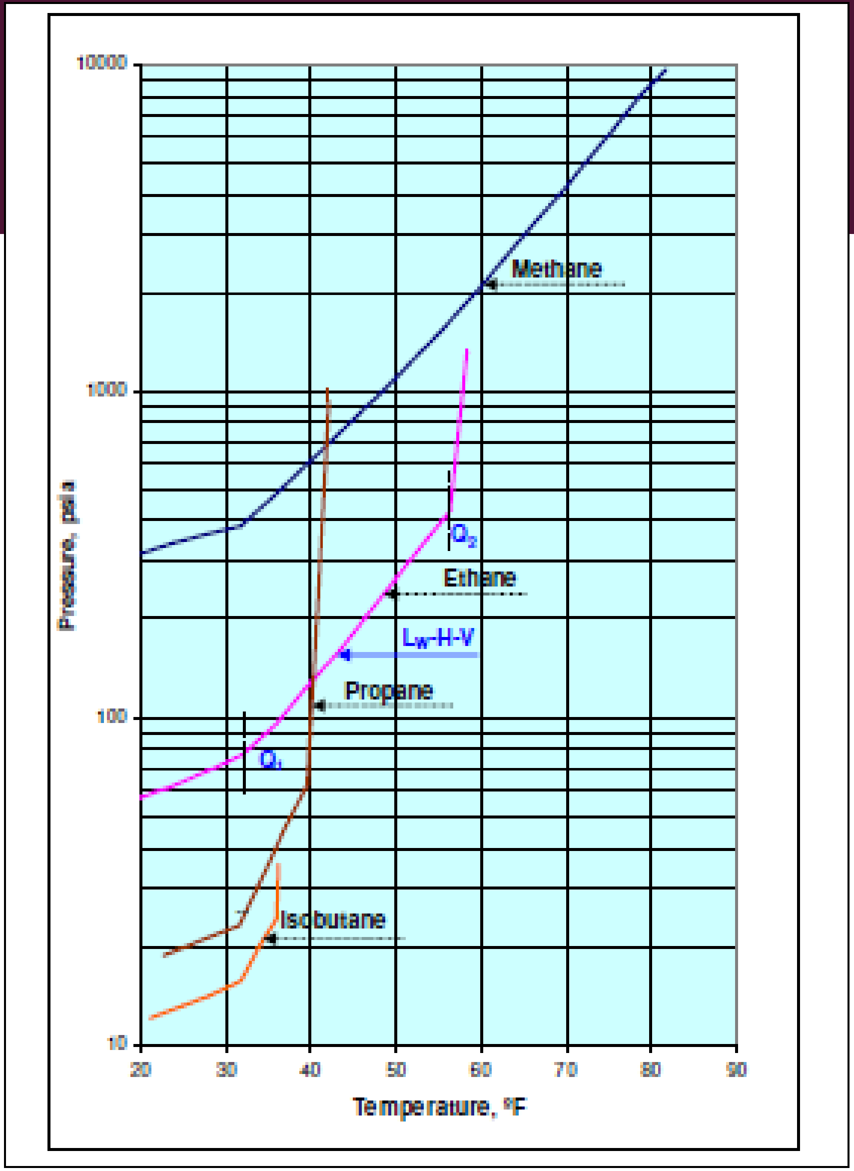
THE BASIC SCIENCE & APPROACH

THE SOLUTION PROCESS

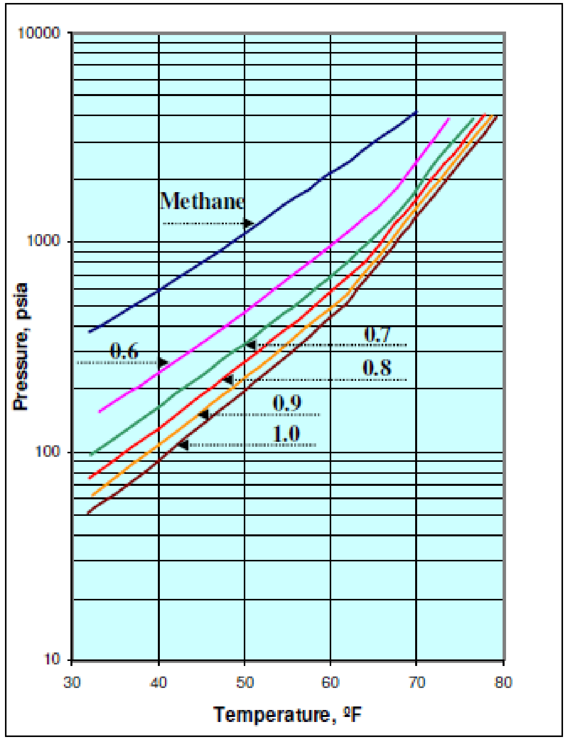
BASIC CONDITIONS FOR HYDRATES TO FORM

- The two major conditions that promote hydrate formation are (1) the gas being at the appropriate temperature and pressure, and (2) the gas being at or below its water dew point with "free water" present. For any particular composition of gas at a given pressure there is a temperature below which hydrates will form and above which hydrates will not form. As the pressure increases, the hydrate formation temperature also increases.
- If there is no free water, that is, liquid water, hydrates cannot form. Secondary conditions such as high gas velocities, agitation of any type, and the formation of a nucleation site may also help form hydrates. These secondary conditions are almost always present in the process piping stream
- For a given temperature (T), hydrate formation pressure (P) increasing HC size decreases

C_NH_{2N+1} IMPACT

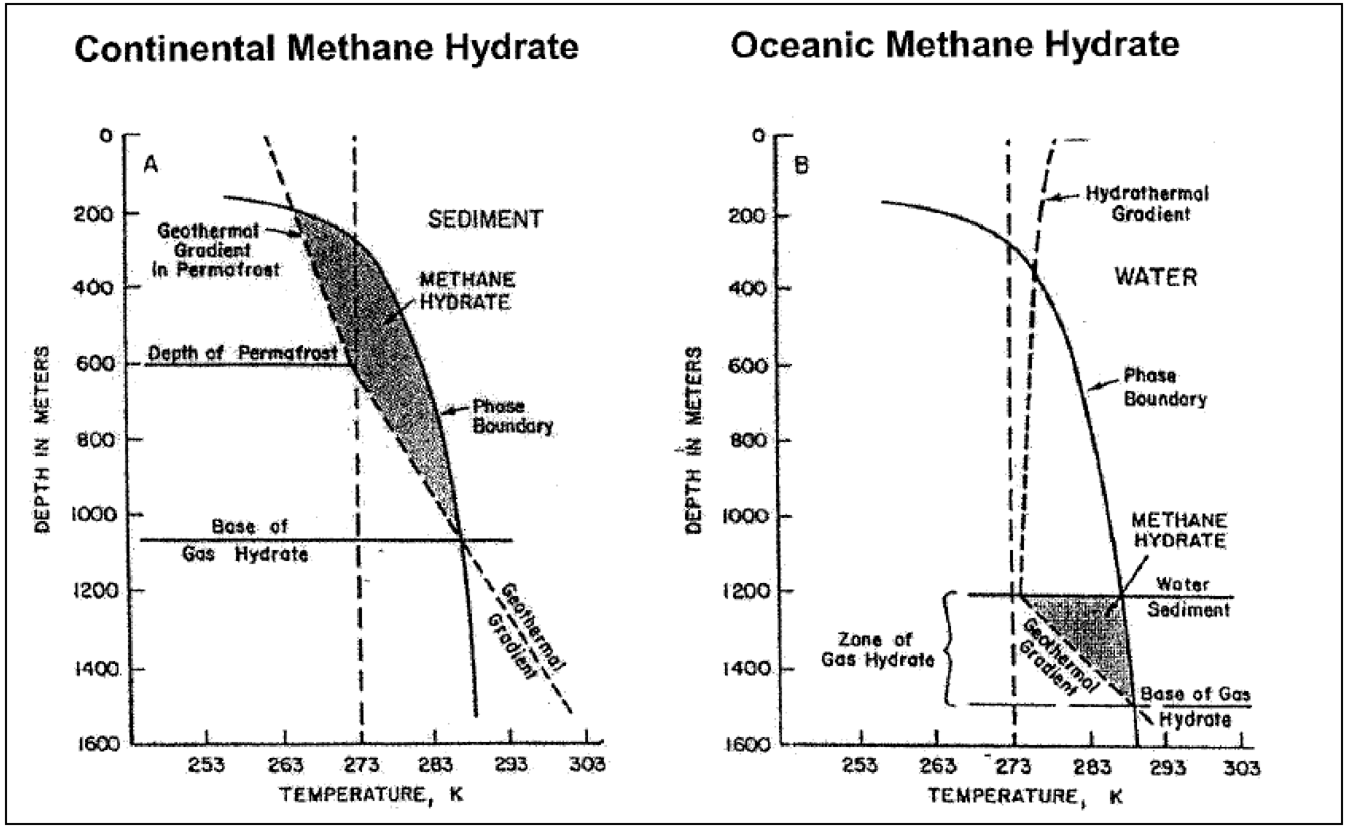


For a given temperature (T), hydrate formation pressure (P) increases as HC size decreases



Curves as function of specific gravity (SG)

ARBITRARY EXAMPLES OF HYDRATE FORMATION ZONES



TYPES OF HYDRATE MODELS

- There are few common methods for estimating hydrate conditions
  - Gas gravity methods – Developed by Katz in the 1940, charts or correlations presenting hydrate conditions basically as function of gas gravity. Numerous improvements since the work by Katz and his colleagues. In this work, we will focus heavily on advanced correlation presented by Ameripour [2005]. May also be called Hydrate Formation Curves
  - K-factor methods & Three phase L_W-H-V equilibria calculations
  - Thermodynamic methods
  - Equation of State (models with fugacity coefficients)

CORRELATION BASED ANALYSIS:

- The original models for the cloud based simulations were:
  - Motiee: Hydrate Temperature as function of Pressure
  - Towler: Hydrate Temperature as function of Pressure
  - Hammerschidt: Hydrate Temperature as function of Pressure
  - Mokogaon: Hydrate Pressure as function of Temperature
- But allows for more complex solutions such as those presented by
  - Ameripour: Hydrate Temperature and Pressure Solutions with complex gas composition, also accounting for electrolytes and inhibitors such as Salts and Glycols.

Although these correlations are as explicitly for calculating Hydrate temperature as function of pressure (or vice-versa).

Numerical manipulation allows for the inverse solution of any of the correlations (demonstrated later).

Many of the proposed correlations are T-explicit because pressure is often considered to be specified by process and/or transfer requirements, and hydrate formation temperature is the variable that is to be estimated.

HYDRATES: BASIC PREVENTION

- Salts (Thermodynamic Inhibitors)
  - Sodium Chloride
  - Potassium Chloride
  - Calcium Chloride
- Alcohols
  - Methanol
  - Ethanol
  - Isopropanol
- Glycol
  - Ethylene Glycol
  - Triethylene Glycol

NaCl is considered the most effective, with CaCl2 being the least useful. In the later part of this presentation, we address how to account for these effects in the real-time SCADA System using the Ameripour Correlation [2005].

Alcohols & Glycols, when dissolved in aqueous solutions, form hydrogen bonds with the water molecules and make it difficult for the water molecules to participate in the hydrate structure. In the later part of this presentation, we address how to account for these effects in the real-time SCADA System using the Ameripour Correlation [2005].

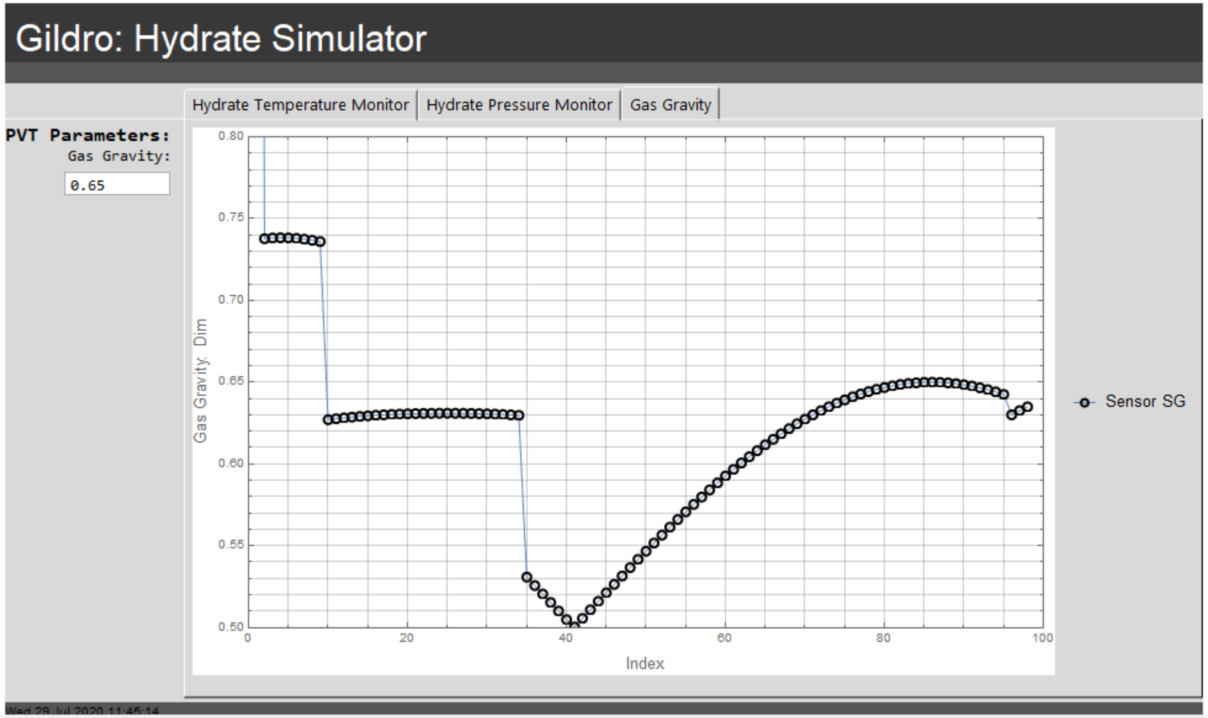
The strategy is to rendenere the formed hydrate into a pumpable slurry.

GAS GRAVITY METHODS

CORRELATIONS IMPLEMENTED IN THE REAL-TIME SYSTEM.

GAS GRAVITY:

- The system can be customized for two scenarios:
  - User specified gas
  - Real-time measurements which are used directly in hydrate calculations alongside real time measurements of pressure and temperatures
- The data in the plot below is simulated (and therefore gas gravity changes occur rapidly), the simulator can account for varying change in gas properties as long as a proper sensor is being logged at the historian.



PROBLEMS

- When development was began, we did a review of basic gas gravity methods (correlations). Although some variance in results were expected, the following slides show substantial differences in quality and ultimately we moved towards a more sophisticated model developed at Texas A&M

THE CORRELATIONS

TOWLER ET AL METHOD

- Towler performed a regression analysis of GPSA curves regression resulting a four coefficient correlation that requires the temperature, pressure, and specific gravity of gas.

$$T_h = 13.47\text{Log}[P] + 32.27\text{Log}[\text{SG}] - 1.675[\text{Log}[P] * \text{Log}[\text{SG}]] - 20.35$$

- While this equation is based on the GPSA chart, it is only accurate up to 65 F. Beyond that, it overestimates the temperature slightly (but is considered more accurate than Motiee correlation shown on the next page).

MOTIEE CORRELATION [1991]

- Motiee's correlation is well known and is used heavily throughout industry:

$$T_h = -238.24469 + 78.99667\,\mathrm{Log}[P] - 5.352544\,\mathrm{Log}[P] + 349.473877[\mathrm{SG}] - 150.854675[\mathrm{SG}] - 27.604065\,\mathrm{Log}[P][\mathrm{SG}]$$

KOBAYASHI ET AL [1987]

- We reviewed numerous sources in the literature and many forms of the Kobayashi correlation. However, we were not able to produce any meaningful results. Much the industry literature did not document the units of the equation (mentioned in the work by Ameripour [2009]). We tried several scenarios of various units without success. We also noticed that in some literature, the terms of gas gravity and pressure are reversed within identical equations.
- Eventually, we removed Kobayashi et al from our work

THE SIMPLE HAMMERSCHMIDT EQUATION

- We have also evaluated1934 Hammeschmidt equation. Although easy to use, this simple equation does not take into account the effect of specific gravity.

$$T_F = 8.9P^{0.285}$$

Where T (°F) & P (psia) are the temperature and pressure of hydrate formation. This easy-to-use equation does not take into account the effect of gas composition, or even gas gravity.

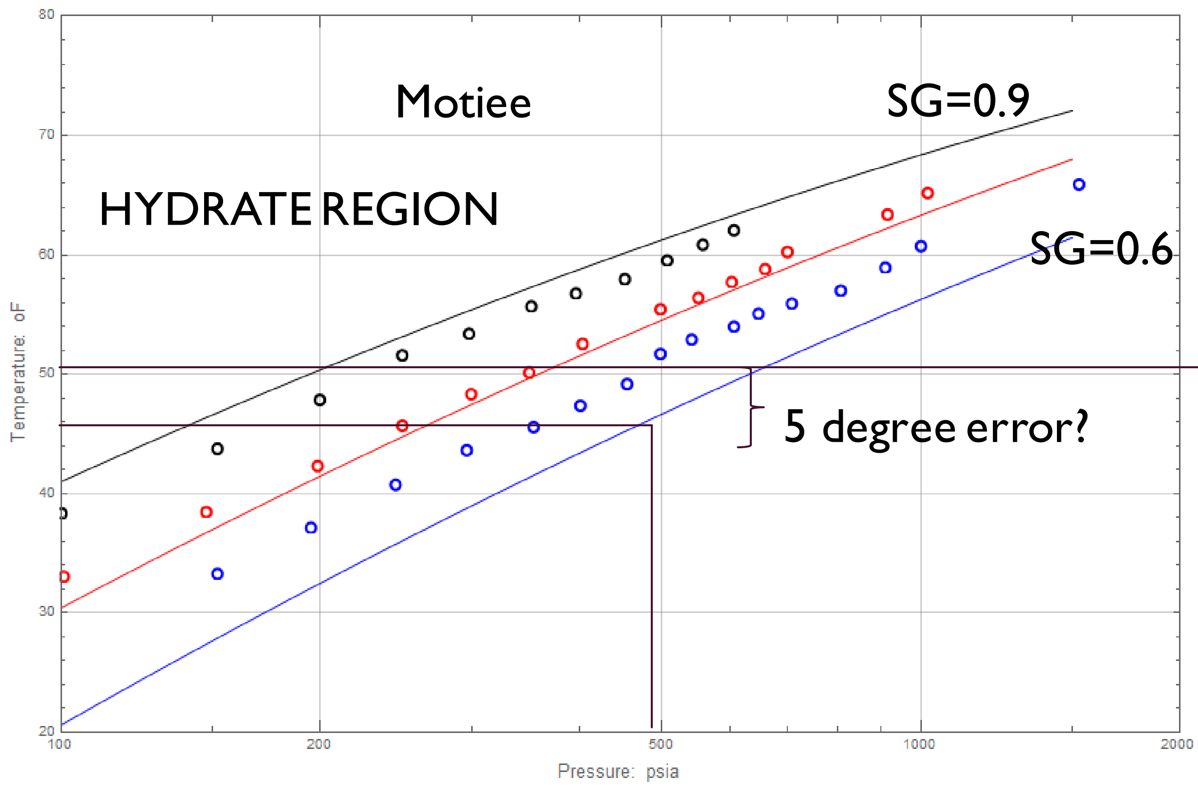
AMERIPOUR CORRELATION

- In 2009, Ameripour and Barrufet presented a correlation (containing several adjustable parameters.) for estimating both hydrate formation temperature and hydrate formation pressure.
- This correlation will be discussed in greater detail later in this presentation.

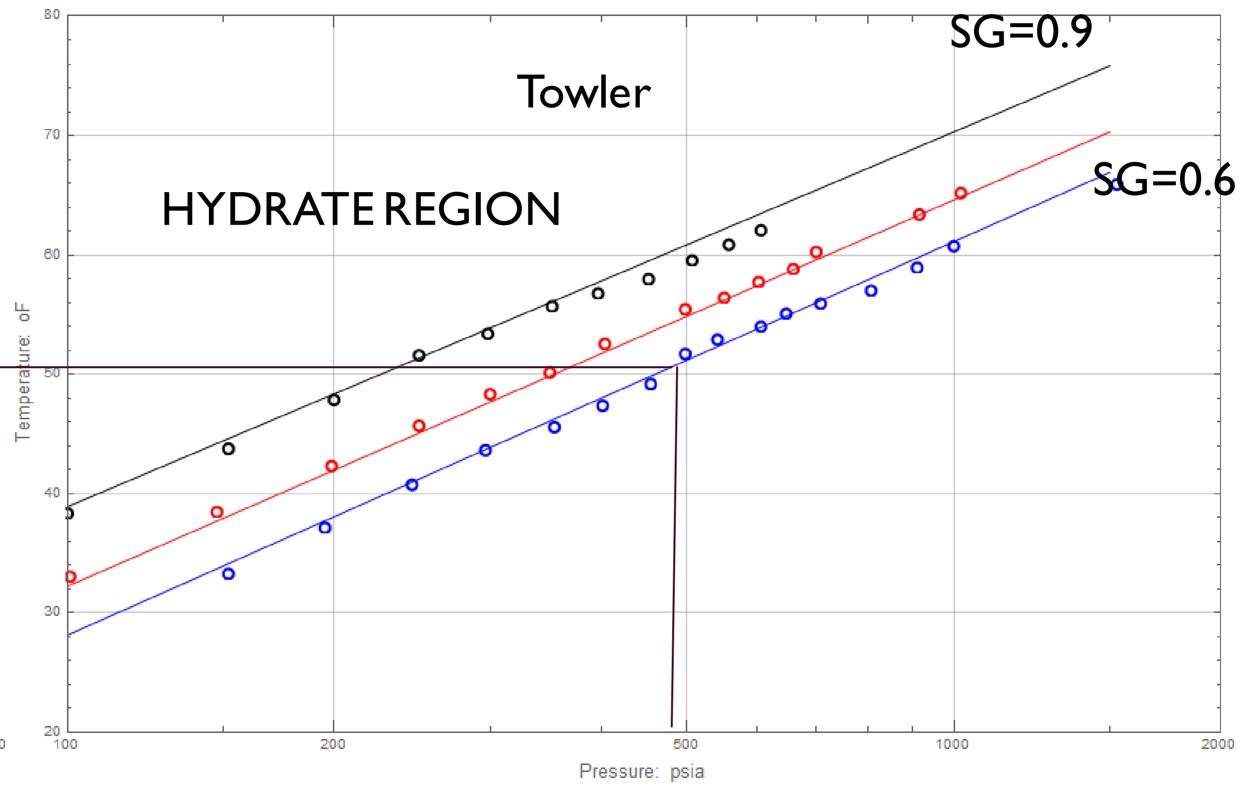
OTHER CORRELATIONS

- In 2009, Bahadori and Vuthaluru presented a complicated, but accurate correlation for estimating hydrate formation temperature. The authors recommend implementing different sets of adjustable parameters, for a total of 48 parameters, for different ranges of pressure and gas molecular weight.
- We have not yet reviewed this method for our system.

A COMPARISON BETWEEN MOTIEE AND TOWLER WITH GPSA

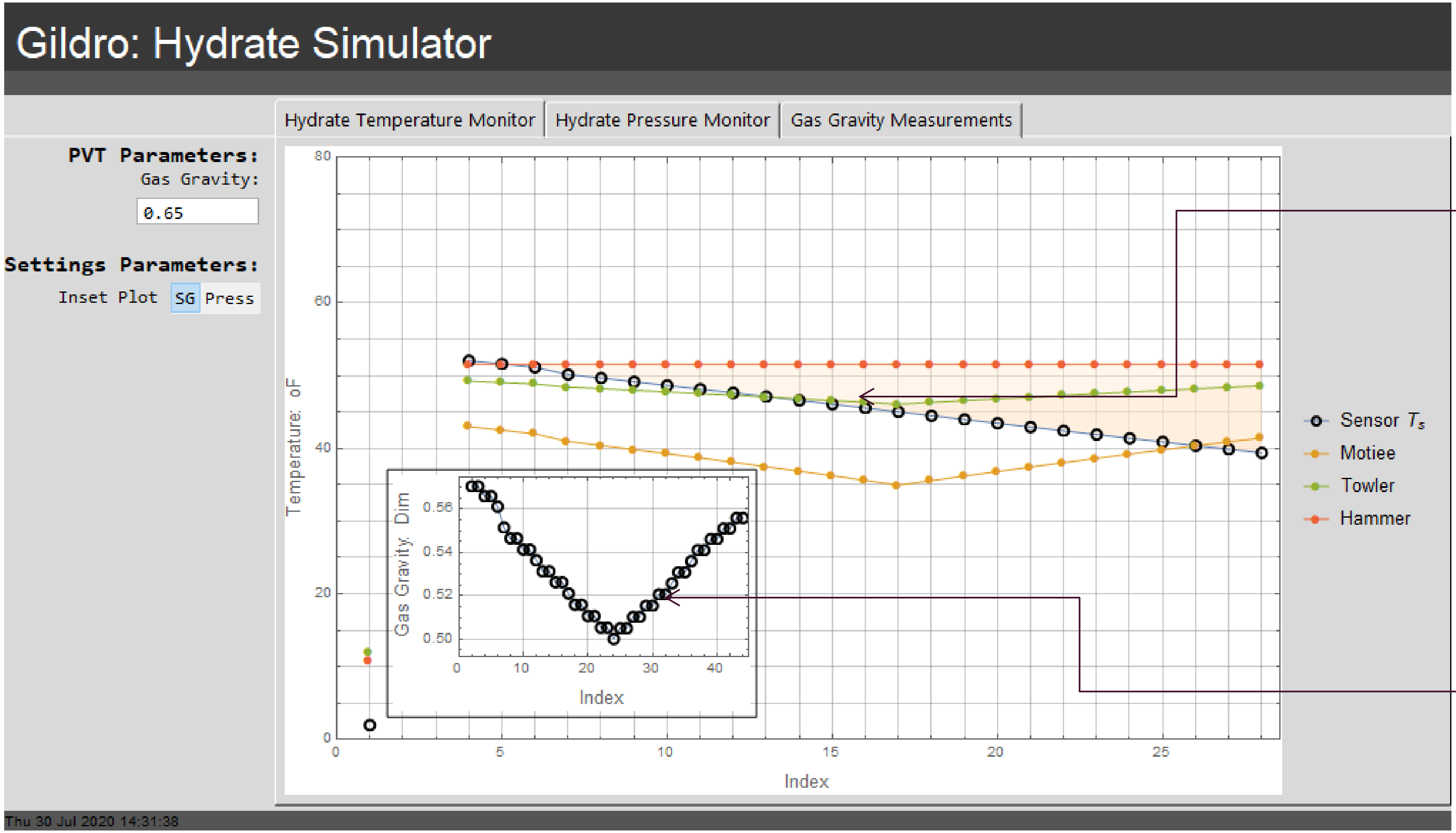


Poor agreement with GPSA Chart



Improved agreement with GPSA Chart

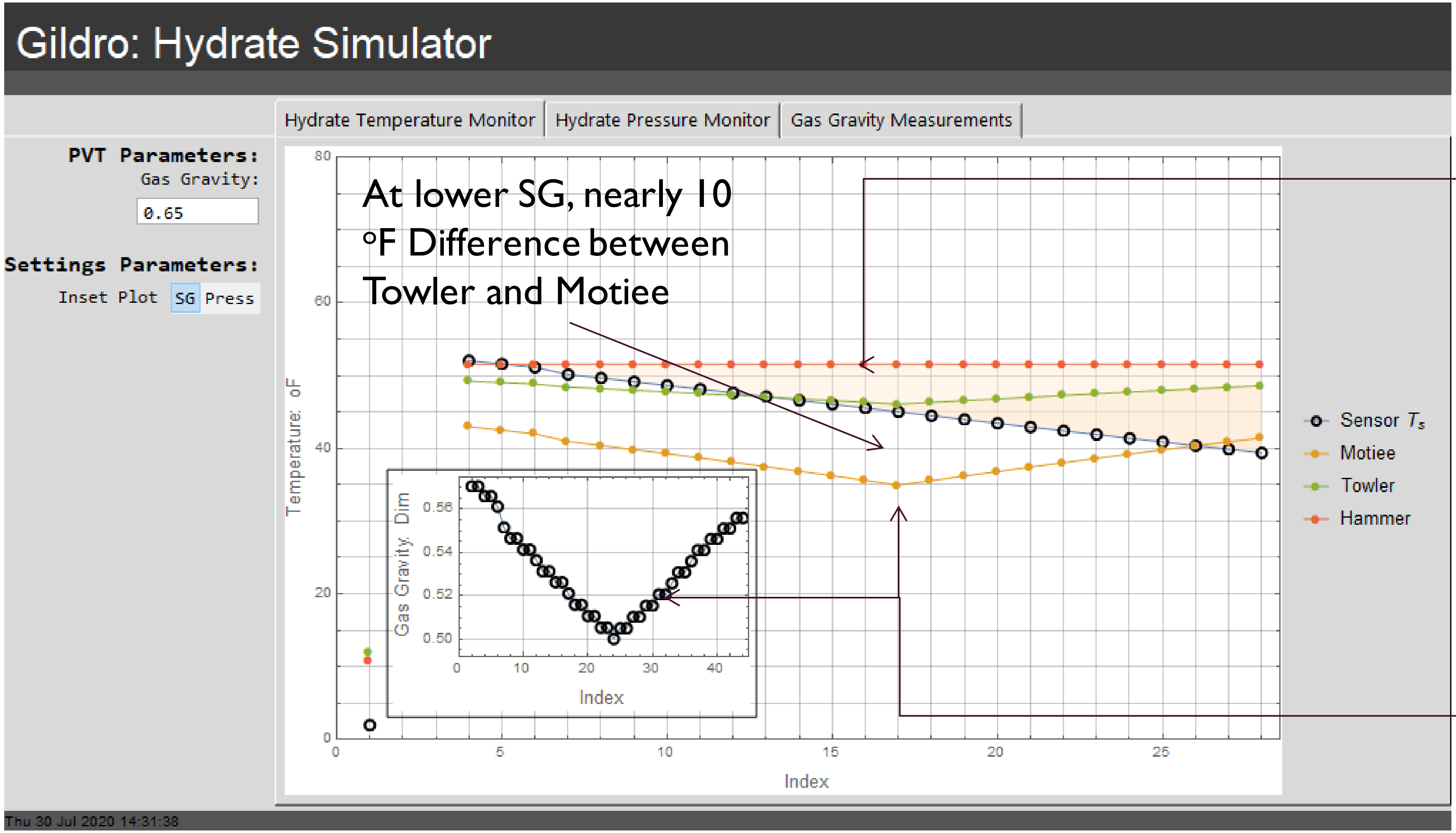
GAS GRAVITY SIMULATION RUNS #1



With a gas gravity change of 0.58 to 0.50, we see a 5oF change in hydrate formation temperature

SG Range = 0.50 to 0.58

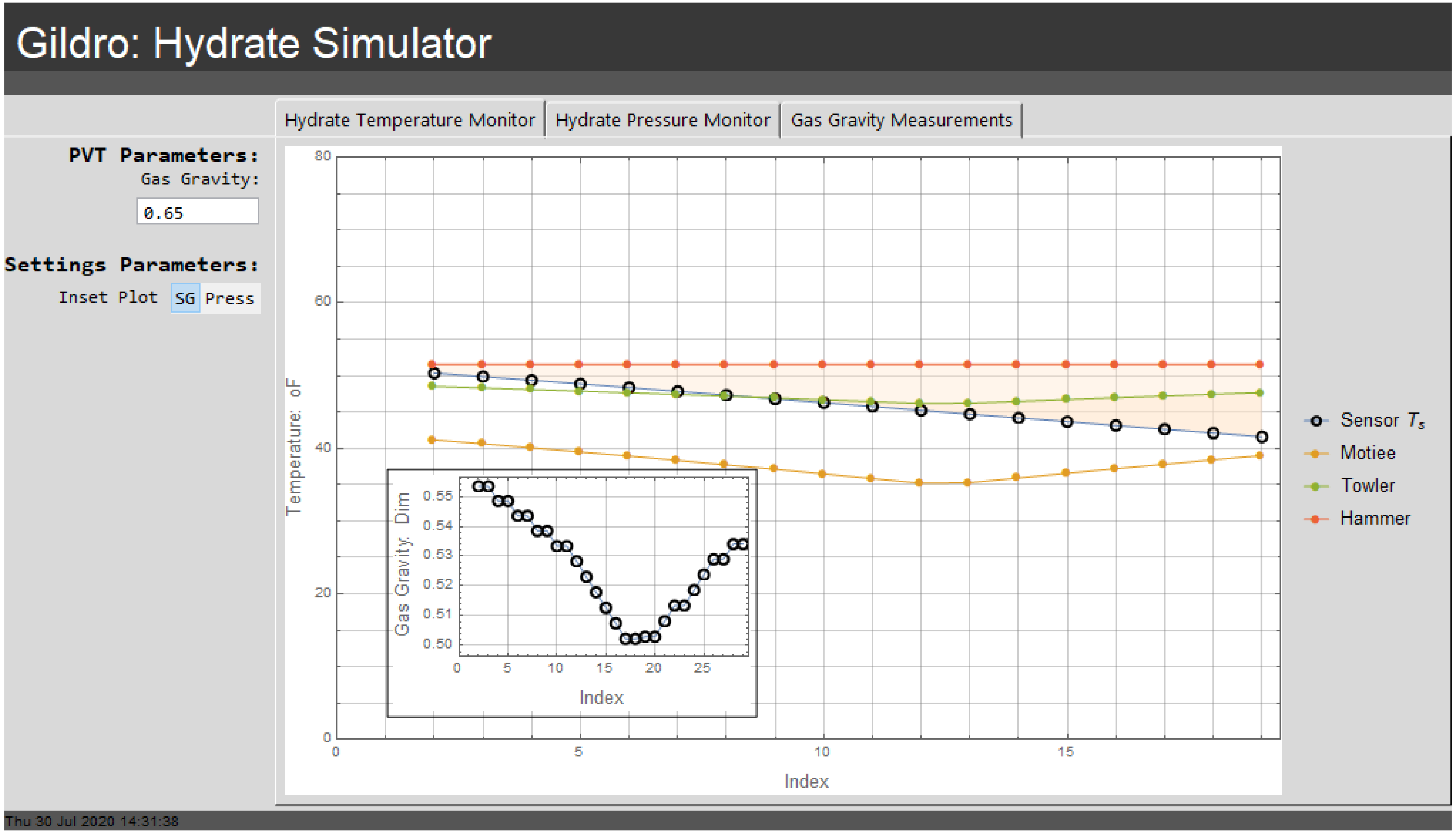
GAS GRAVITY SIMULATION RUNS #2



Believe it or not, the simpler Hammerschmidt provided closer results to the Towler equation, than Motiee

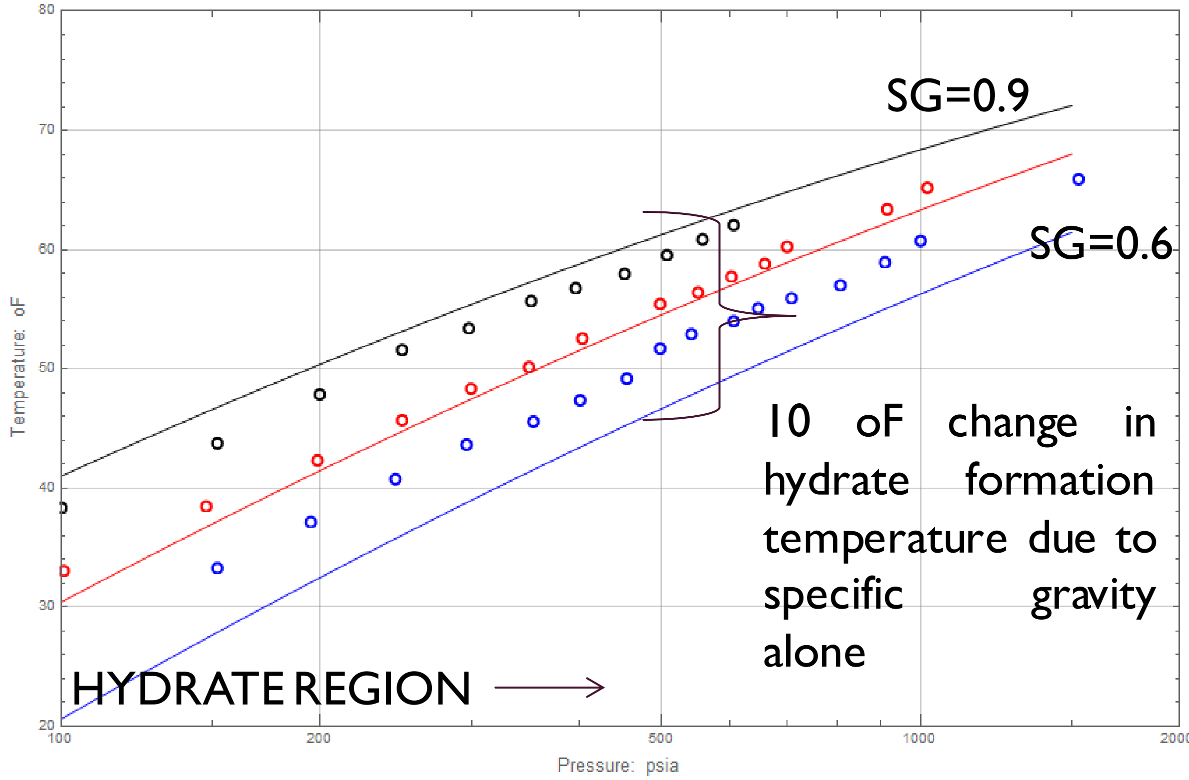
Inflection is due to changing gas gravity

GAS GRAVITY SIMULATION RUNS #2



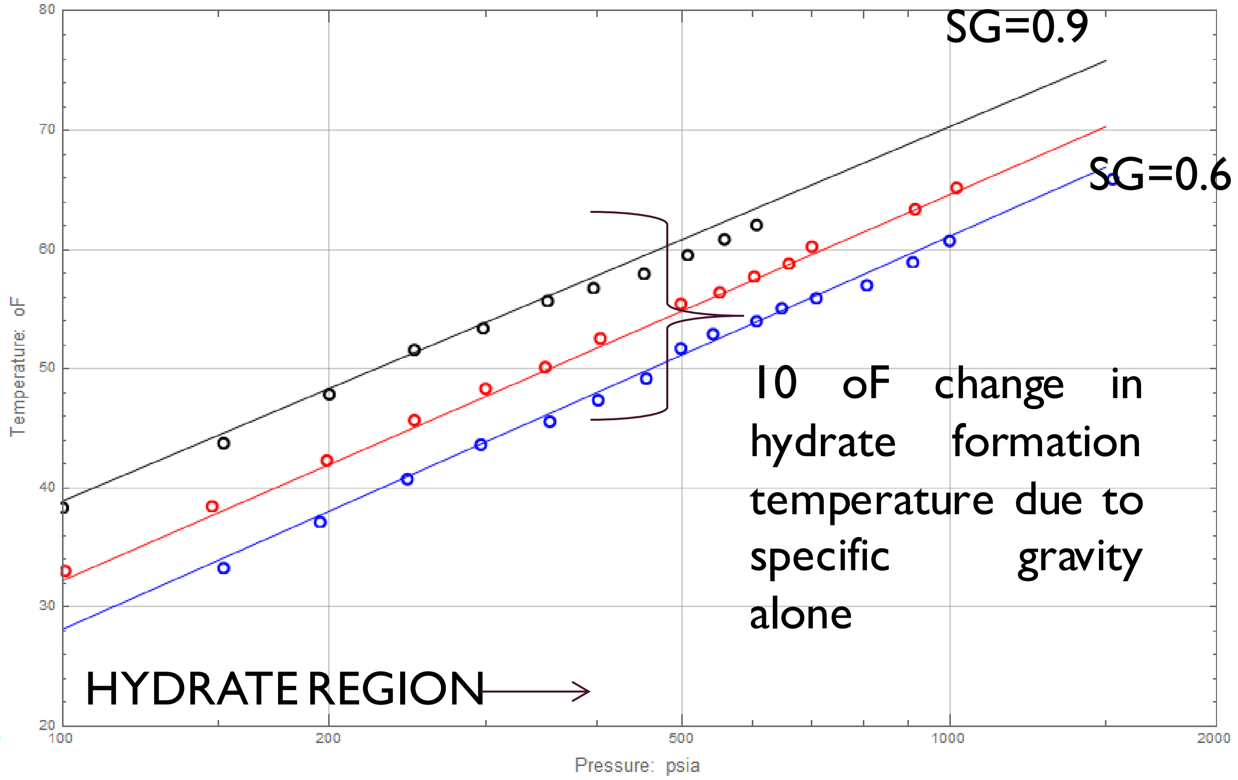
A COMPARISON BETWEEN MOTIEE AND TOWLER WITH GPSA

Motiee



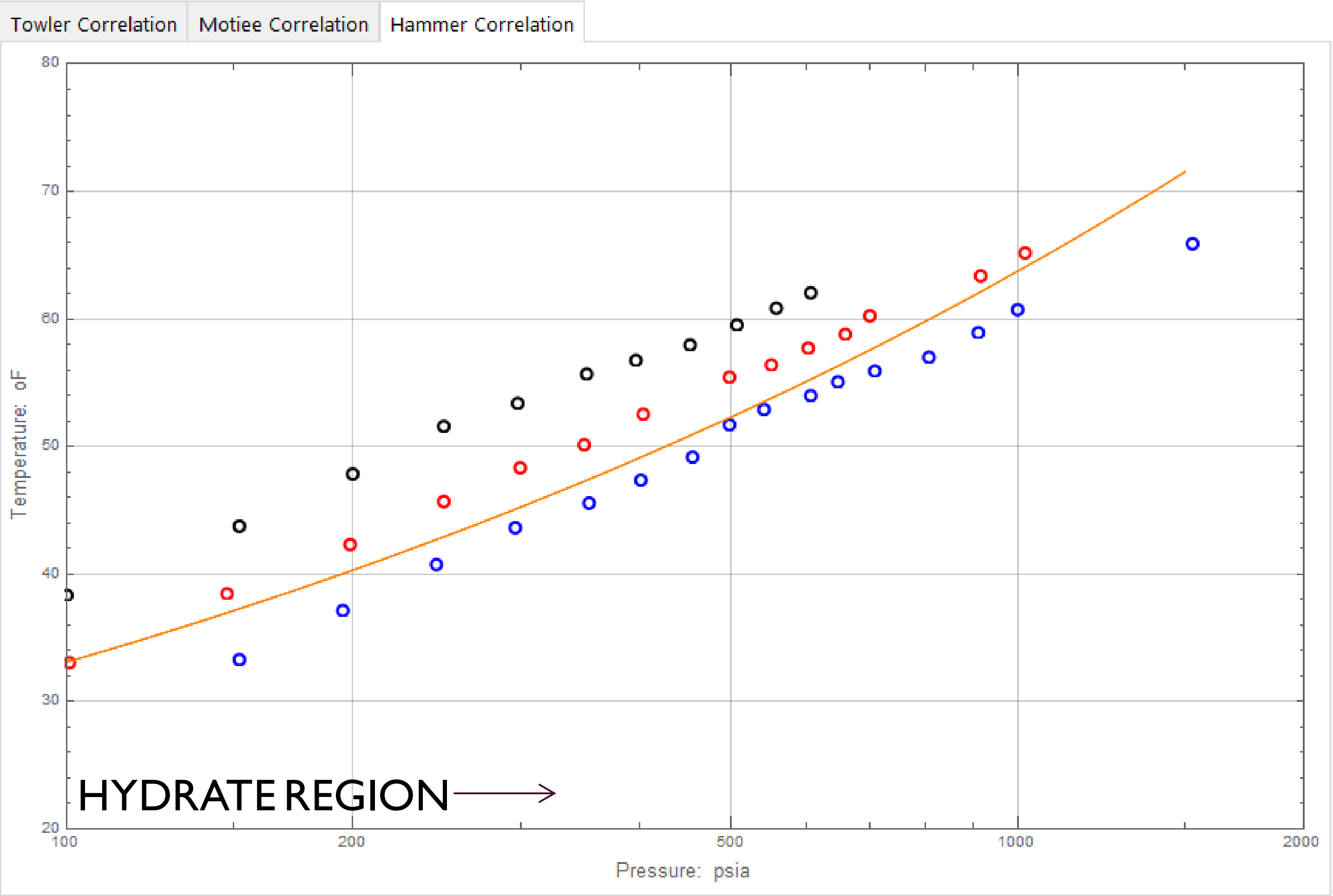
Poor agreement with GPSA Chart

Towler



Improved agreement with GPSA Chart

1934 HAMMERSCHMIDT CORRELATION



This correlation is really only suitable for gases with a specific gravity of around 0.65

PRESSURE EXPLICIT CORRELATIONS

- In 1981, the famous P-explicit correlation was presented by Makogon. A modified form of the Makogon correlation is presented below:

$$\log P_{\mathrm{MPa}} = \beta + 0.0497\left(T + \mathrm{kT}^2\right) - 1$$

$$\beta = 2.681 - 3.811\gamma + 1.679\gamma^2$$

$$k = 0.006 + 0.011\gamma + 0.011\gamma^2$$

γ= gas specific gravity

$\gamma = MW_{Gas}/MW_{Air}$

Where:

T (°C) & P (Mpa) are the temperature and pressure of hydrate formation.

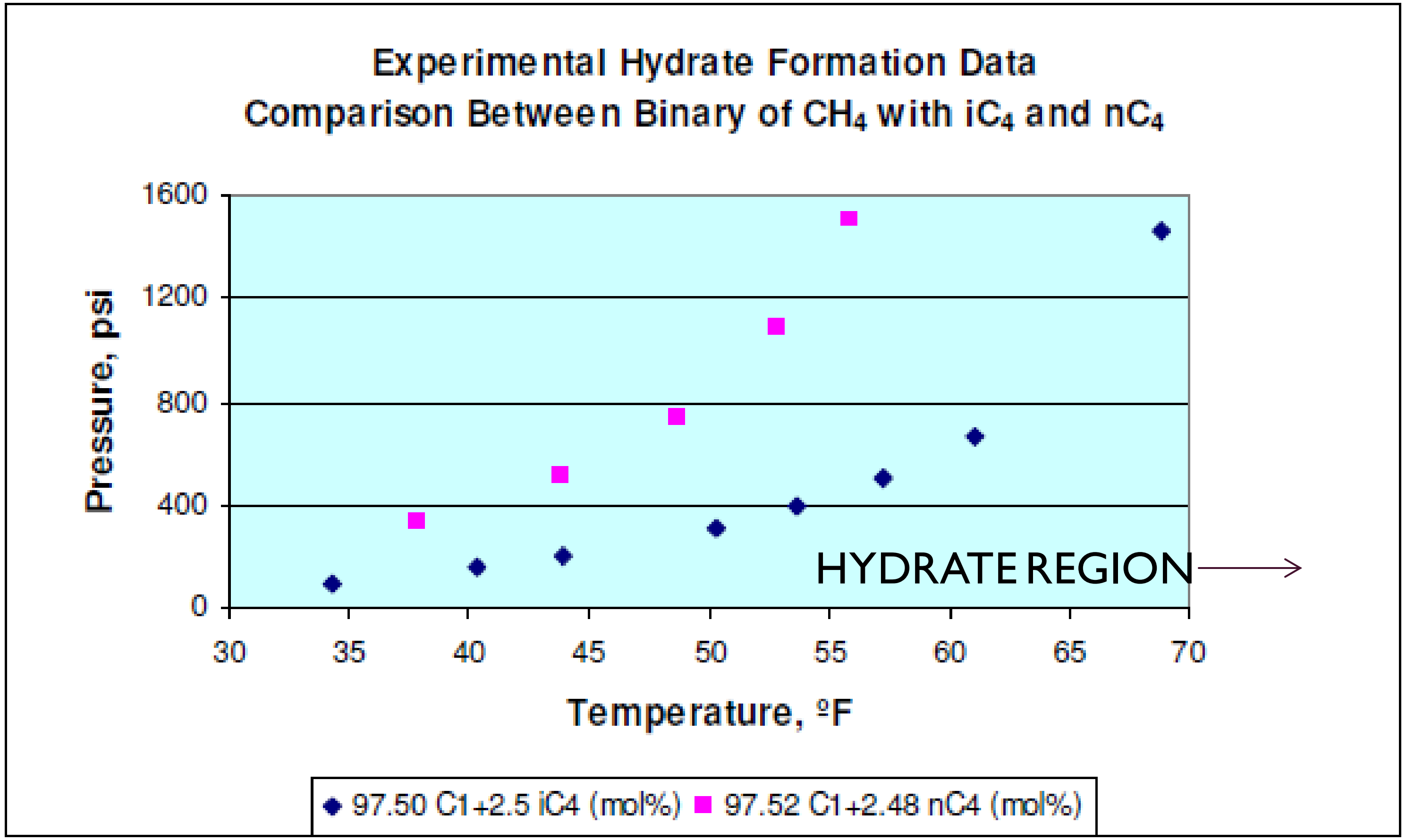
This equation uses specific gravity: γ

MW = Molecular Weight

GAS GRAVITY METHODS: SOME CONCERNS

- This method is simple and may be used for an initial estimation of hydrate formation conditions. Some analysts have challenged the gas gravity method - statistical analysis studies have shown that the calculated pressure for the same gas gravity with different mixtures may result in 50% error. Since method considers only the gas gravity of the components, if two components have equal molecular weights such as butane and isobutene, the method may estimate the same hydrate-formation temperature or pressure, although they should be different in reality.

LIMITATIONS OF "GAS GRAVITY" METHODS



"Although these two binary systems have the same molecular weight, they behave differently because the presence of some components such as isobutane in a mixture decreases the hydrate-formation pressure. Therefore, two systems with equal gas specific gravities do not necessarily form hydrates at equal pressures, but the presence of some components in a mixture has a very significant effect on determining the hydrate-formation pressure or temperature"

THE AMERIPOUR METHOD

THE AMERIPOUR SOLUTION

- Following the work of Ameripour, [2005], we modified the simulator so that it can predict the hydrate formation pressure for a given hydrate temperature or hydrate pressure for a given pressure for a single or multicomponent gas mixture with and without electrolytes and/or thermodynamic inhibitors.
- This solution behaves superior to the basic gas gravity methods which rely solely on gas gravity (however, this requires the system to be calibrated to a full gas analysis).
- The model accounts for natural gas composition
  - CH_4 through to C_7+
  - Non Hydrocarbons H_2S, CO_2, and N_2
  - Electrolytes / Salts: NaCl, KCl, and $CaCl_2$ ⟶ Lower than 20% wt
  - Glycols:
    - Methonal (CH_3OH), ⟶ Lower than 20% wt
    - Ethylene Glycol ($C_2H_6O_2$), Triethylene glycol – TEG ($C_6H_{14}O_4$), and Glycerol ($C_3H_8O_3$) ⟶ Lower than 40% wt
- The full solution is presented in the next page.

THE AMERIPOUR SOLUTION

$$\text{Ln}[T_{pr}] = b0 + b1 * (\text{Ln}[p])^2 + b2 * \left(\frac{\sum_{i=1}^{m} \frac{xEletro_i}{MWEletro_i}}{\gamma^2} \right) + b3 \left(\frac{\sum_{j=1}^{n} \frac{xInhib_j}{MInhib_j}}{\gamma^2} \right) + b4 * \gamma^2 + b5 * \left(100 - \sum_{i=1}^{m} xEletro_i \right) * \gamma^3 + b6 * (xCO2 + xH2S + xN2) +$$

$$b7 * \left(\sum_{j=1}^{m} \frac{xInhib_j}{MWInhib_j} \right) * (xCO2 + xH2S + xN2) + b8 * (xiC4 + xnC4) / \gamma^6 + b9 * \text{Ln}[\gamma] * \text{Ln}[p] + b10 * \text{Ln}[\gamma] * (\text{Ln}[p])^4 + b11 * \text{Ln}[p] / \gamma +$$

$$b12 * (\text{Ln}[p])^2 / \gamma + b13 * ((\text{Ln}[p])^3) / \gamma + b14 * ((\text{Ln}[p])^4) / \gamma + b15 * \text{Ln}[P_{pr}] + b16 * (\text{Ln}[P_{pr}])^2;$$

Where :

$$Thydrate = \text{Exp}[lntprtemp] * Tpc - 458.67$$

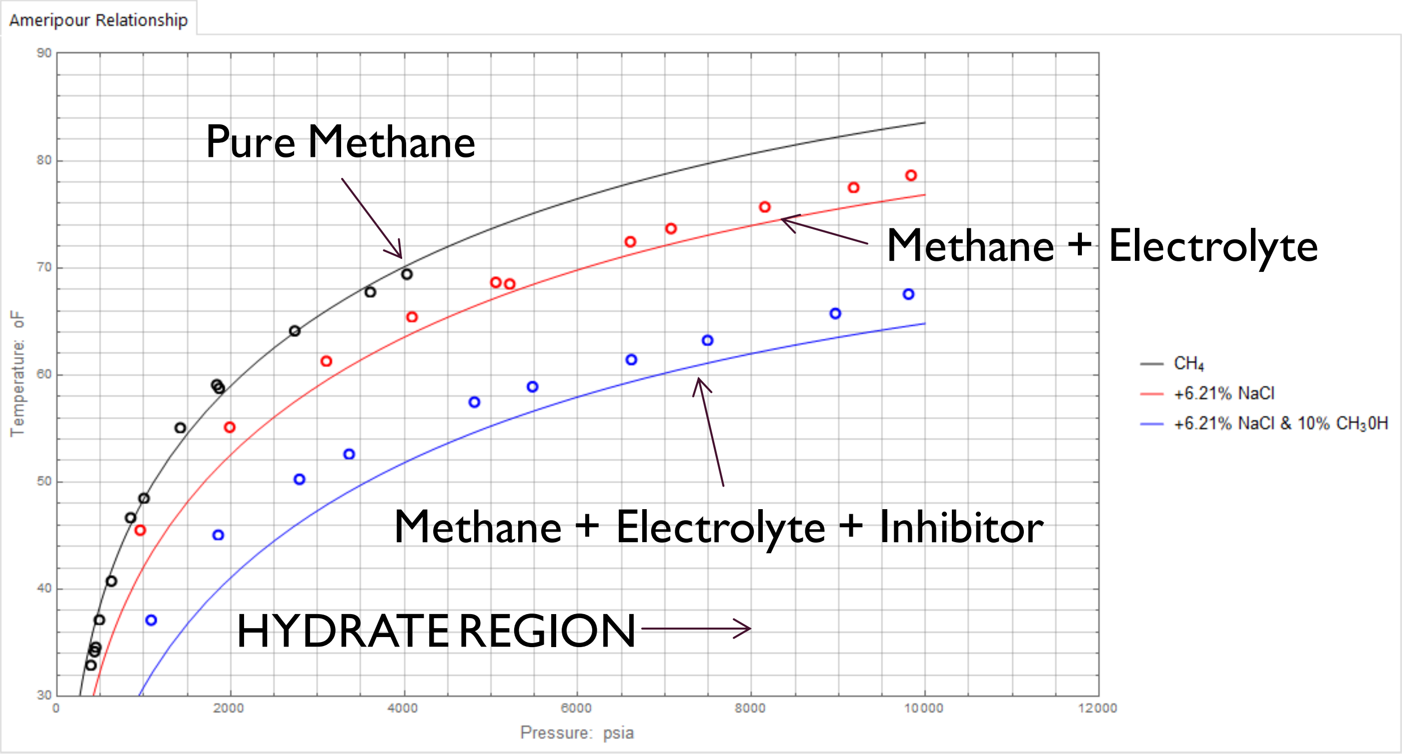
See next slide for information on variables

WHERE:

- P = pressure, psia
- X = Percent by Molecular Weight
  - {Hydrocarbons through to CO_2, H_2S, and N_2}
- Electrolytes {NaCl, KCl, CaCl2}
- Inhibitors {CH3OH EG TEG GL}
- γ = Specific Gravity of Gas
- P_{pr} = Pseudo reduced pressure
- T_{pr} = Pseudo reduced temperature
- bo, b1, b2,.. b16 (correlation variables as per Ameripour Solution).

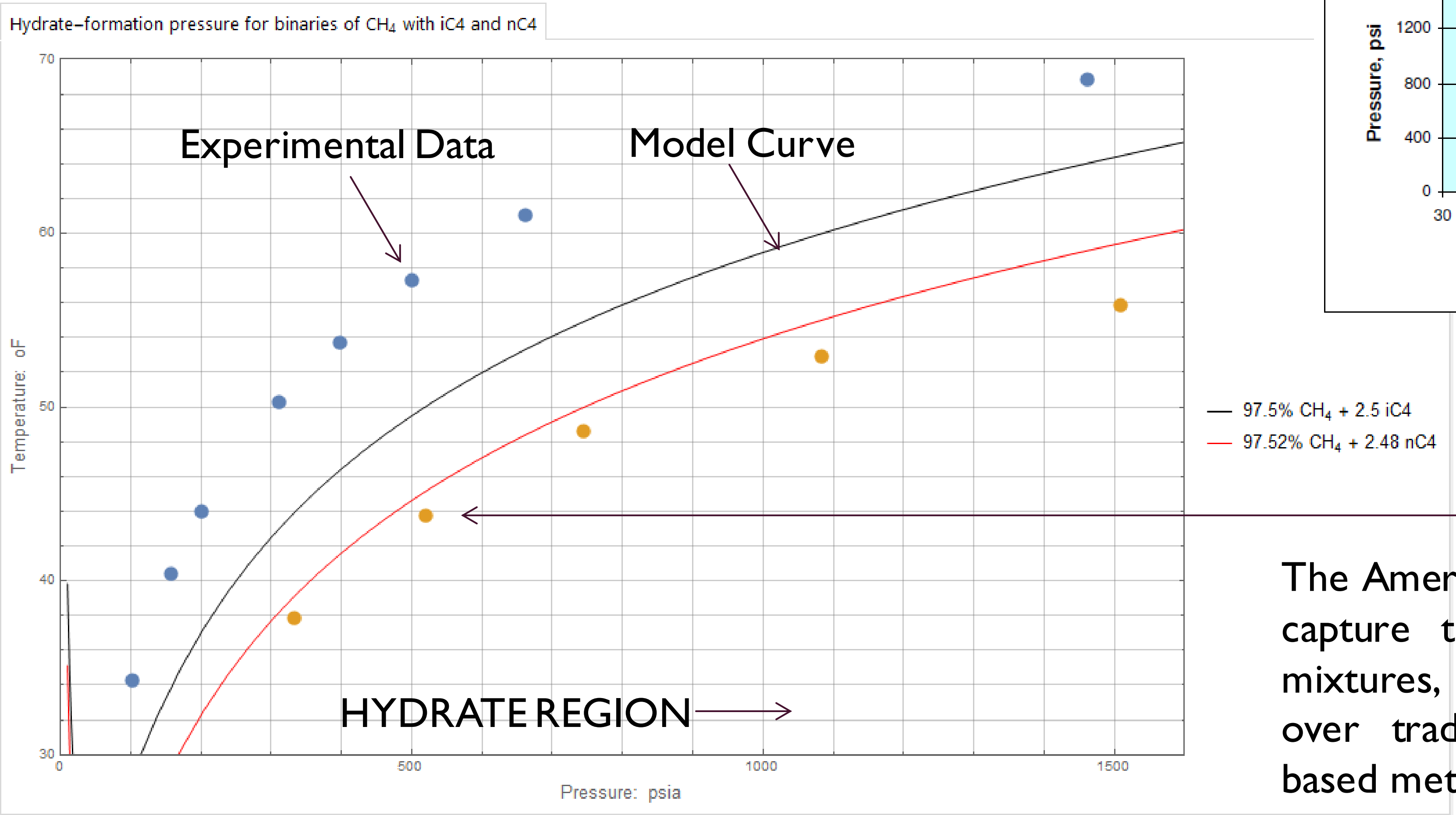
Note, the Piper et al Method is used for pseudo reduced temperature and pressure.

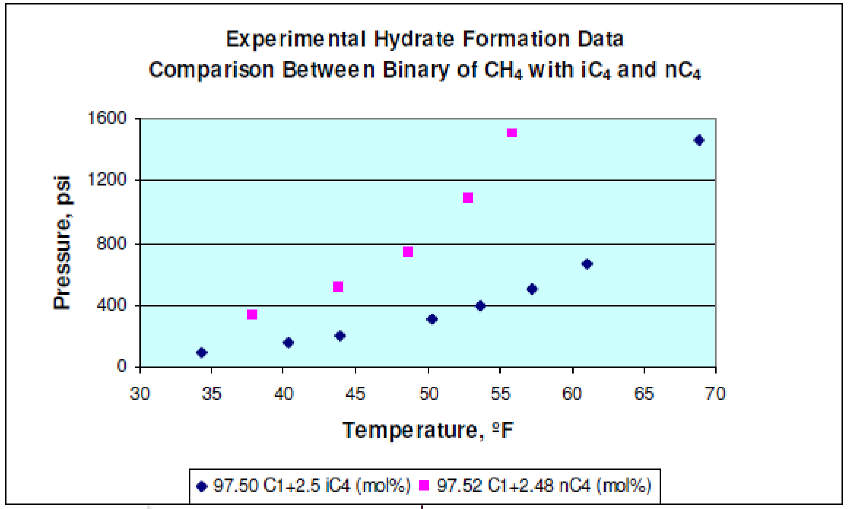
MODEL AGAINST EXPERIMENTAL DATA



In this slide, we reproduced the Ameripour model against her published field data. Although not perfect, initial testing shows an error of around 5 °F in some cases when adding inhibitors to the system.

COMPARISON BETWEEN BINARY OF: CH4 WITH ISOBUTANE & N-BUTANE





The Ameripour correlation does not entirely capture the behavior of all hydrocarbon mixtures, but is a significant improvement over traditional gas gravity / correlation based methods

FETCHING DATA

CODE SNIPPET: DATA RETRIEVAL WITH THE WOLFRAM LANGUAGE

```
RunScheduledTask[PdataA = URLExecute["http://LAPTOP-QC9NCDI2:55235/api/v2/getTagData", {"tags" → "LAPTOP-QC9NCDI2.GBGasField.Sine.Tag0001"
         }][[3]][[2]][[1]][[2]], 5 ];
```

Historian / Port | Well / Sensor

```
RunScheduledTask[
        TdataA = URLExecute["http://LAPTOP-QC9NCDI2:55235/api/v2/getTagData", {"tags" → "LAPTOP-QC9NCDI2.GBGasField.Sine.Tag0002"
         }][[3]][[2]][[1]][[2]], 5 ];
```

Historian / Port | Well / Sensor

```
RunScheduledTask[
        SGdataA = URLExecute["http://LAPTOP-QC9NCDI2:55235/api/v2/getTagData", {"tags" → "LAPTOP-QC9NCDI2.GBGasField.Sine.Tag0003"
         }][[3]][[2]][[1]][[2]], 5 ];
```

Historian / Port | Well / Sensor

The system is being designed such that analyst can select a well from the GUI and that is translated into a string which is shared with the historian.

Data Retrieval (Scheduled Tasks) can be specified to follow the logging rate of the filed or any time/ interval desired by the analyst. In this example, the data logger collects data at an interval of 5 seconds which is the same interval at which the historian is scanned.

We can design for any time period or design for date / time series based data

OTHER METHODS OF FETCHING DATA IN WOLFRAM LANGUAGE

- In addition to API connectivity, we can design and implement for:
  - Low-level SQL Read-Write Database operations
  - NoSQL Read-Write Database operations (such as MongoDB database)
  - Automated Excel, CSV, and text files
  - MQTT capability (the ability to connect directly to sensors and actuators)

GENERAL ARCHITECTURE

SOME SCADA CONCEPTS AND DEFINITIONS

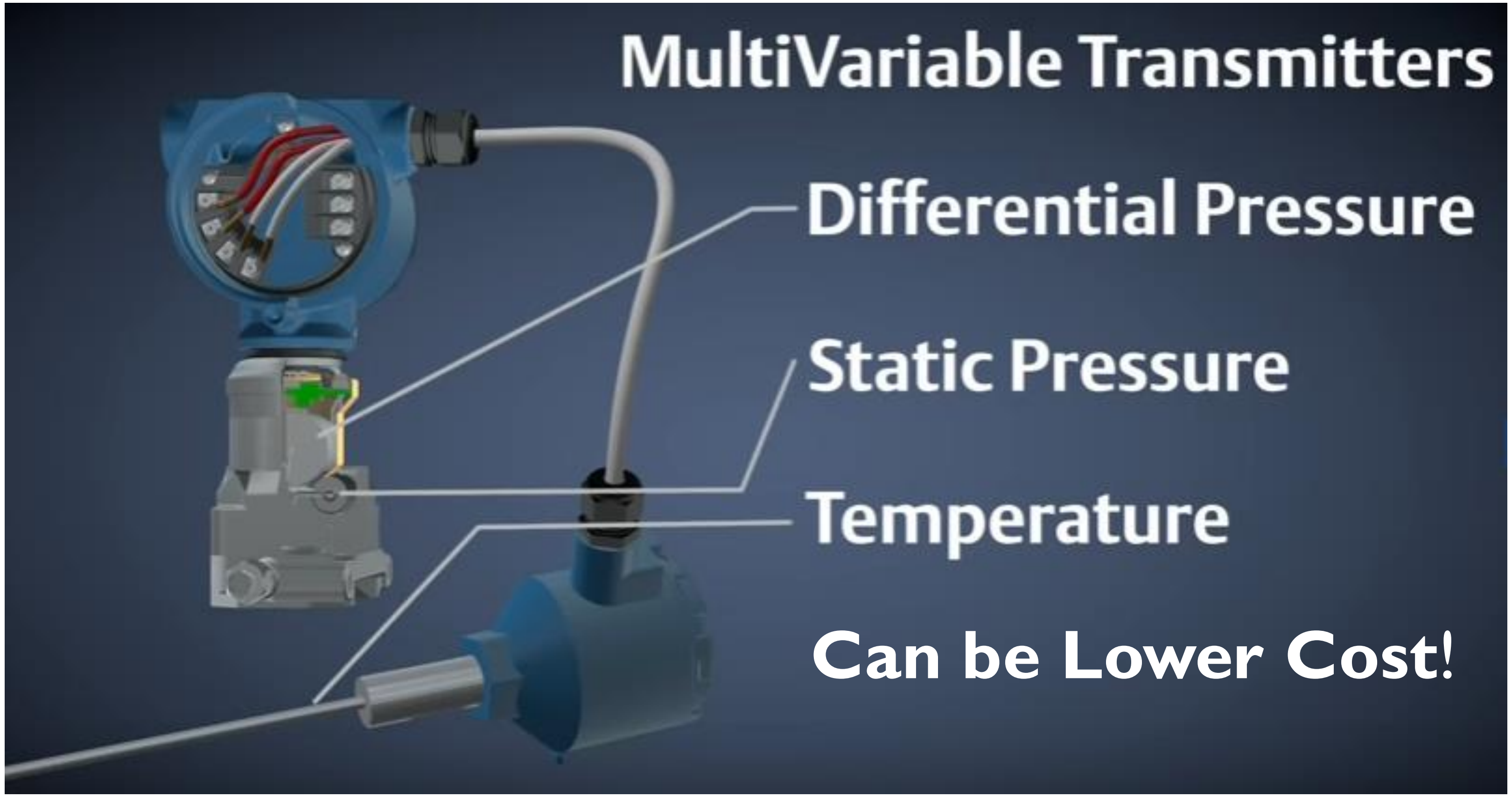
- **The Remote Terminal Unit** is a device that interfaces with objects in field (pumps, valves, alarms) until published to a master storage system or other device such as an eACM edge device. They are located at remote sites. They are often small and serve as local collection points for gathering information from sensors

- **SCADAPack** – Combines capabilities of RTU's with the power of programmable logic controller.

- **Multivariable transmitter** is a differential pressure **transmitter** that is capable of measuring a number of independent process variables, including differential pressure, static pressure, and temperature (this is the preferred meter for our production based modules such as Flowing Material Balance and so on).

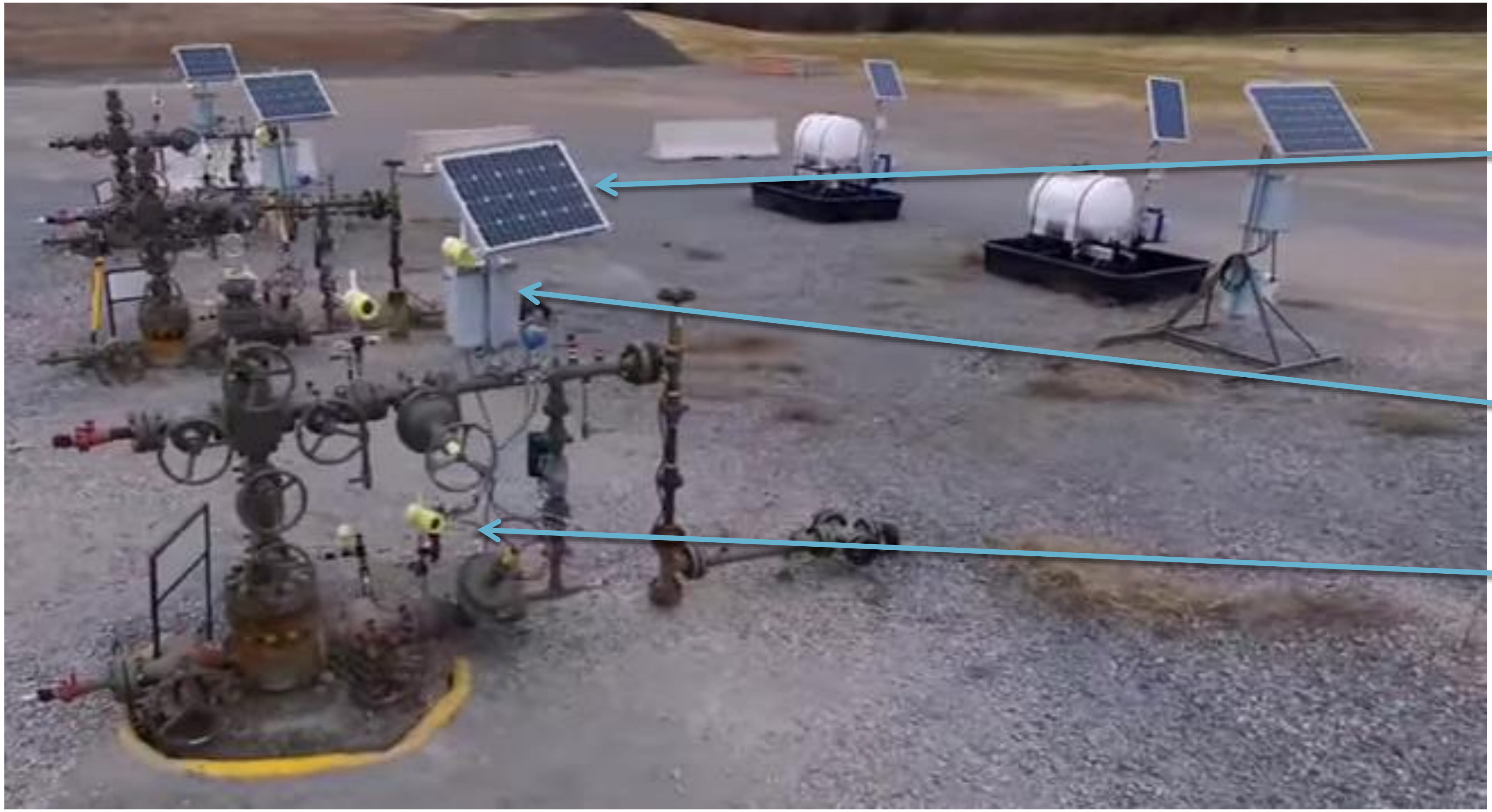
- Either of these devices can collect information from transmitters and sensors in the field.

EXAMPLE OF A MULTI VARIATE TRANSMITTERS

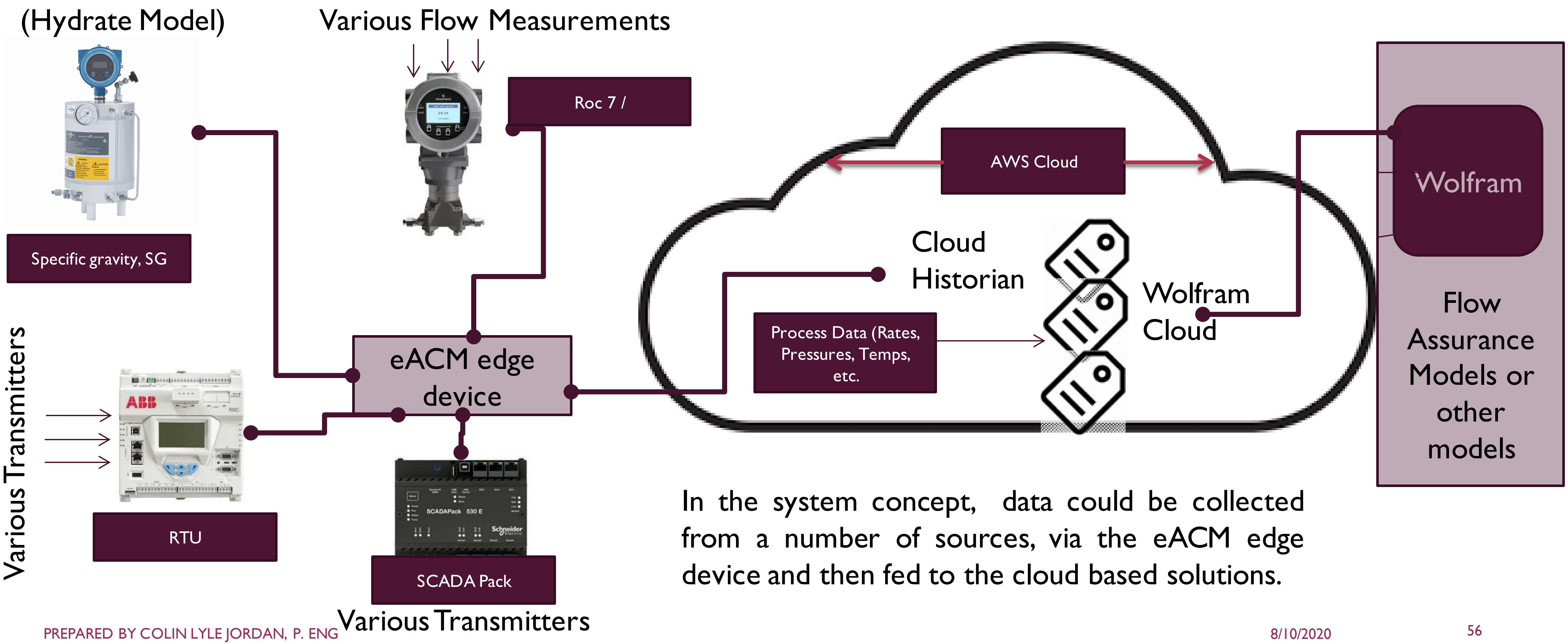


Can be programmed to calculate gas flow rate (as per AGA 8 or other protocols)

FIELD INSTALLATION OF RTU AND SIMILAR DEVICES



We can collect process data from any device or manufacturer. We are vendor neutral.
This example includes a specific gravity meter such

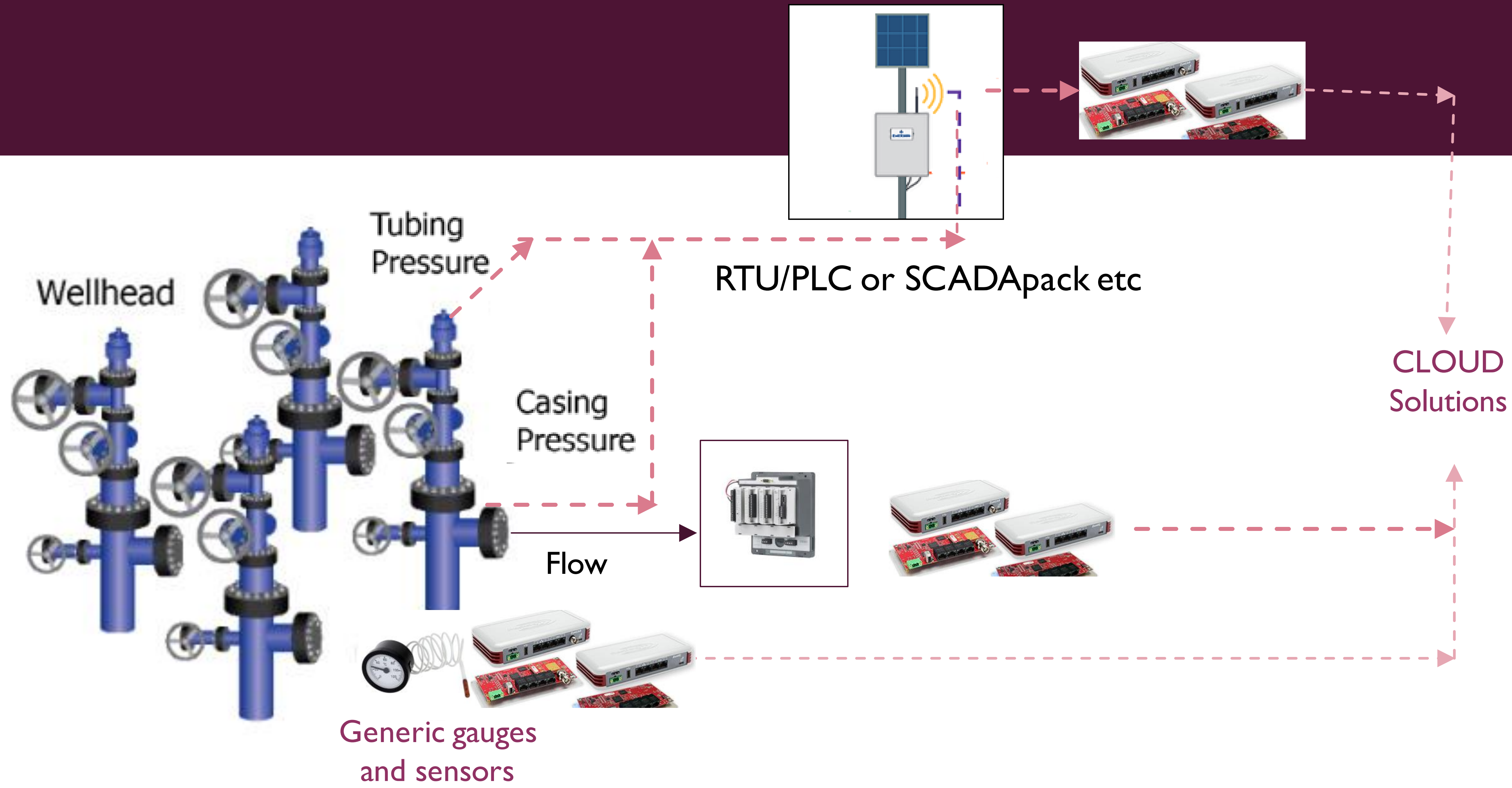


In the system concept, data could be collected from a number of sources, via the eACM edge device and then fed to the cloud based solutions.

ZUMLINK EDGE DEVICE WITH AUTOSOL SOFTWARE

This approach will convert virtually any field device such as flow computers, PLCs and Controllers to be MQTT-enabled.

MQTT communicates with the historian


Tubing
Pressure
Wellhead
RTU/PLC or SCADApack etc
CLOUD
Solutions
Casing
Pressure
Flow
Generic gauges
and sensors

WHY MQTT?

- While there are currently a number of competing IIoT technologies and protocols in play, the extremely lightweight overhead (2-byte header), publish/subscribe model, and bidirectional capabilities of MQTT are uniquely suited to meet the demands of industrial control systems.
- MQTT was created with the goal of collecting data from many devices and then transporting that data to the IT infrastructure. Because it is lightweight, and therefore ideal for remote monitoring.
- The lightweightness and efficiency of MQTT makes it possible to significantly increase the amount of data being monitored or controlled. Prior to the invention of MQTT, some estimate that approximately 80% of data was being left at remote locations, even though various lines of business could have used this data to make smarter decisions. Now MQTT makes it possible to collect, transmit, and analyze more of the data being collected.

WHY WOLFRAM?

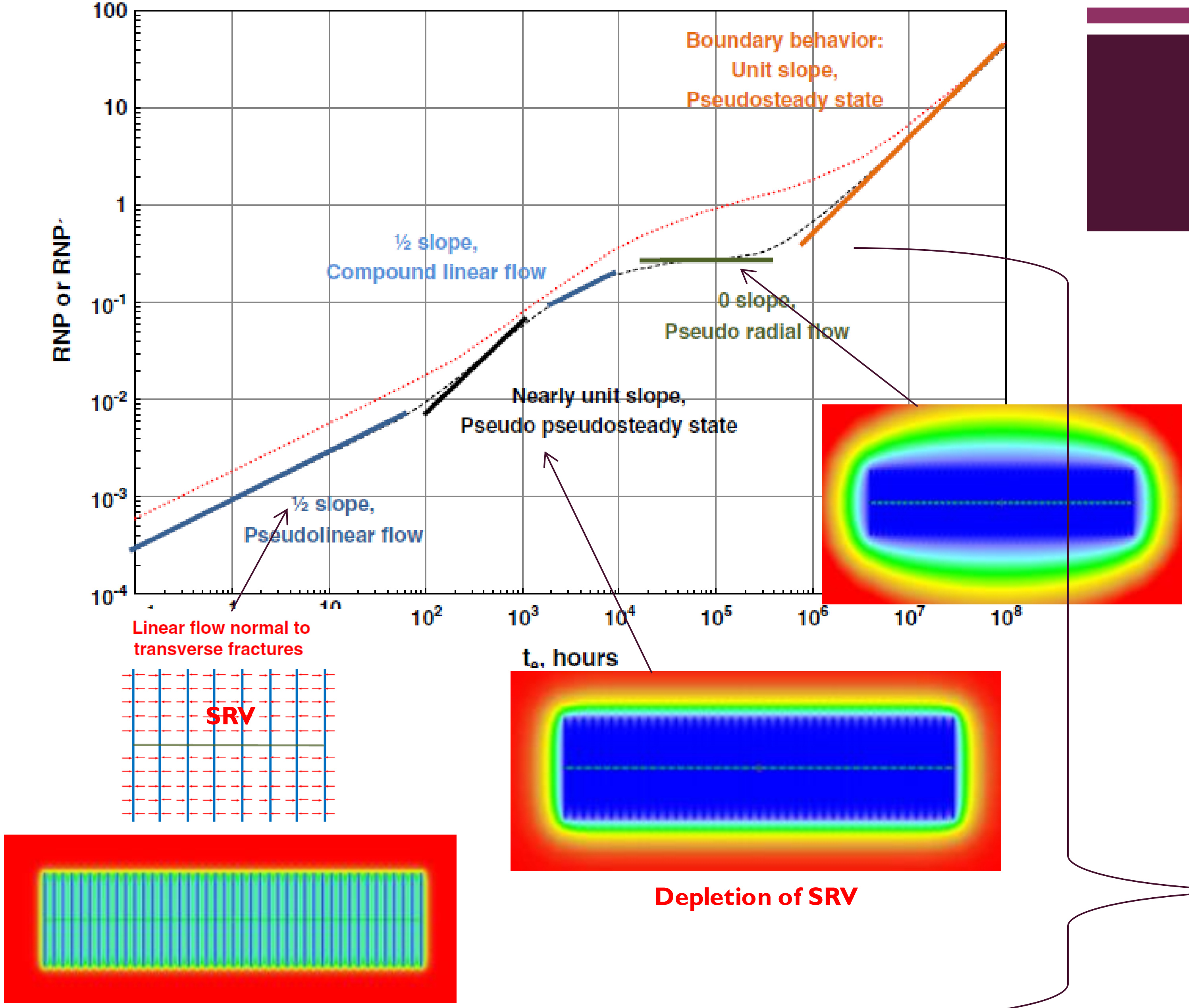
- Wolfram Cloud is supported for all major browsers including both OS and Windows systems.
- Connectivity with a number of Protocols and Standards including MQTT
- Private cloud support and connectivity such as Amazon EC2.

- The goal is run our cloud based historian and development platform (Wolfram Language) on Amazon EC2 or similar cloud services.

WHATS NEW IN OUR DEVELOPMENT

UPCOMING SHALE MODELS

- In addition to working towards a real-time based reservoir models, we have begun models for the rate/pressure analysis of complex wells with fractures and stimulated rock volume (SRV) analysis
- Work is has also begun on shale decline models including Duong's Model.

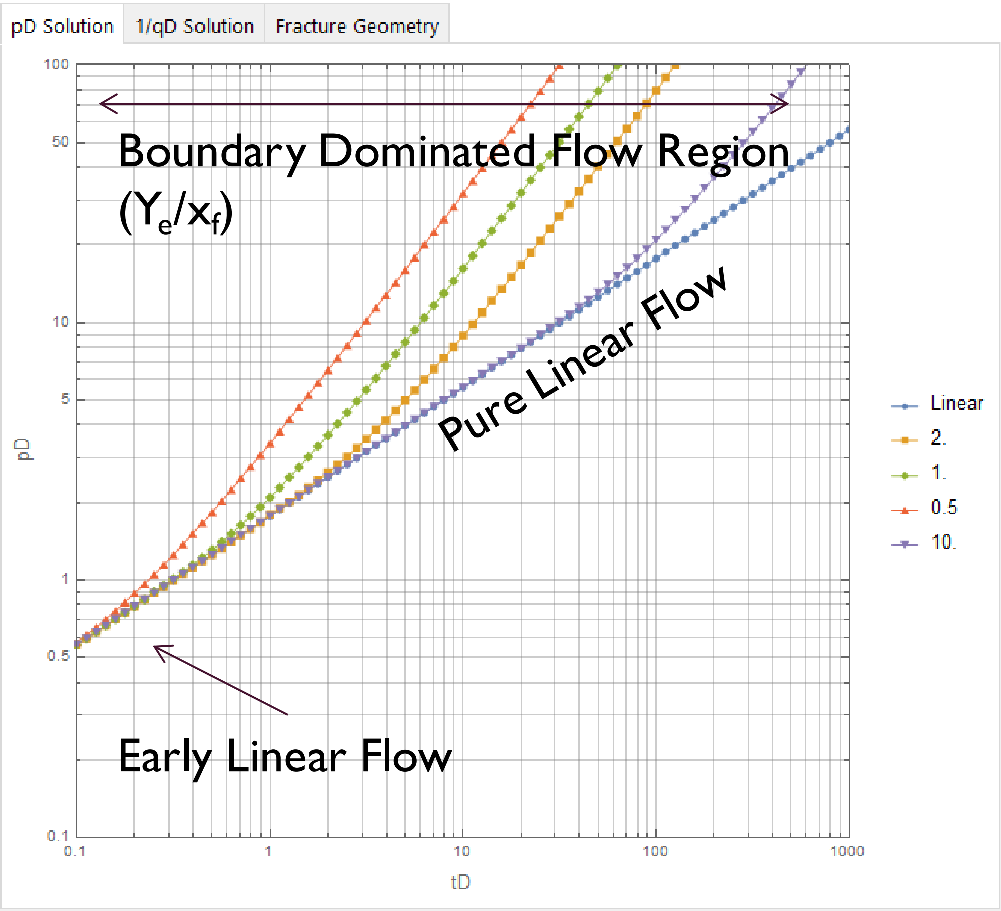


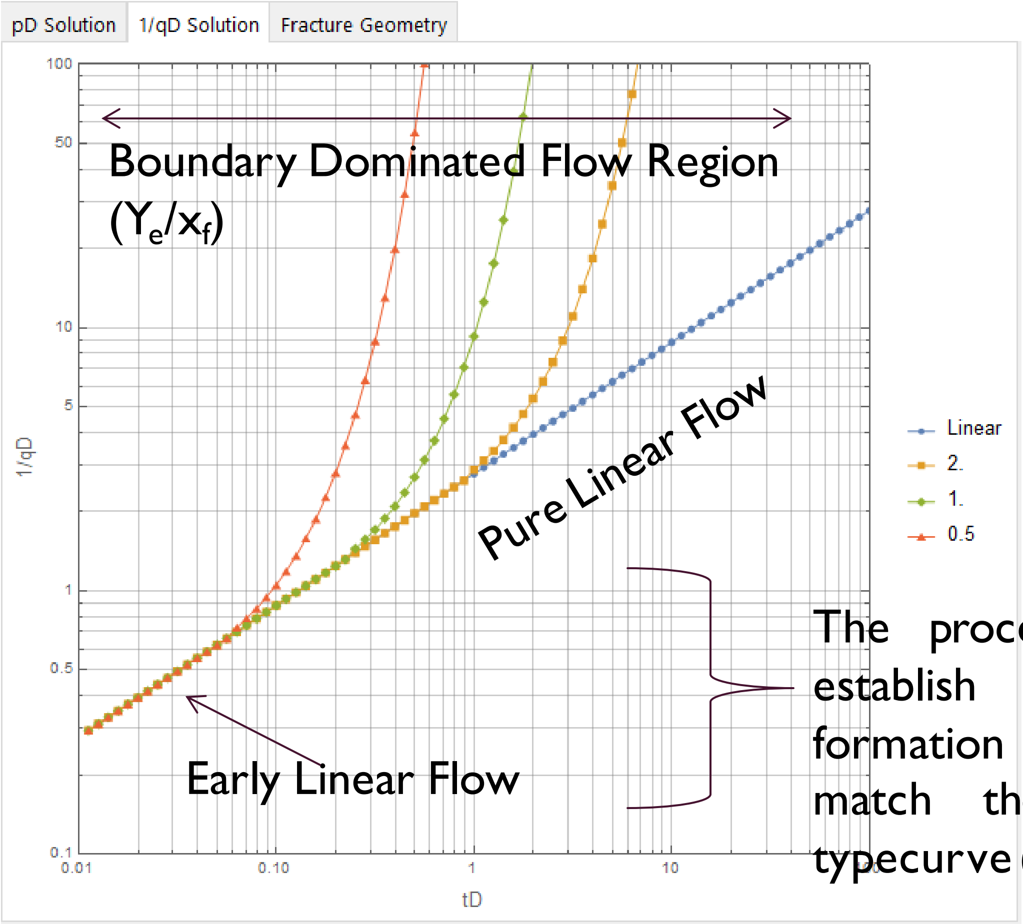
We have been the development of real-time pressure and rate analysis of MFHW in unconventional gas reservoirs.

Our initial typecurve and deliverability models follow the work of Wattenbarger, Clarkson [2009, 2012], Song and Economides [2010]

Our work thus far focuses on the properties of the SRV and surrounding formation.

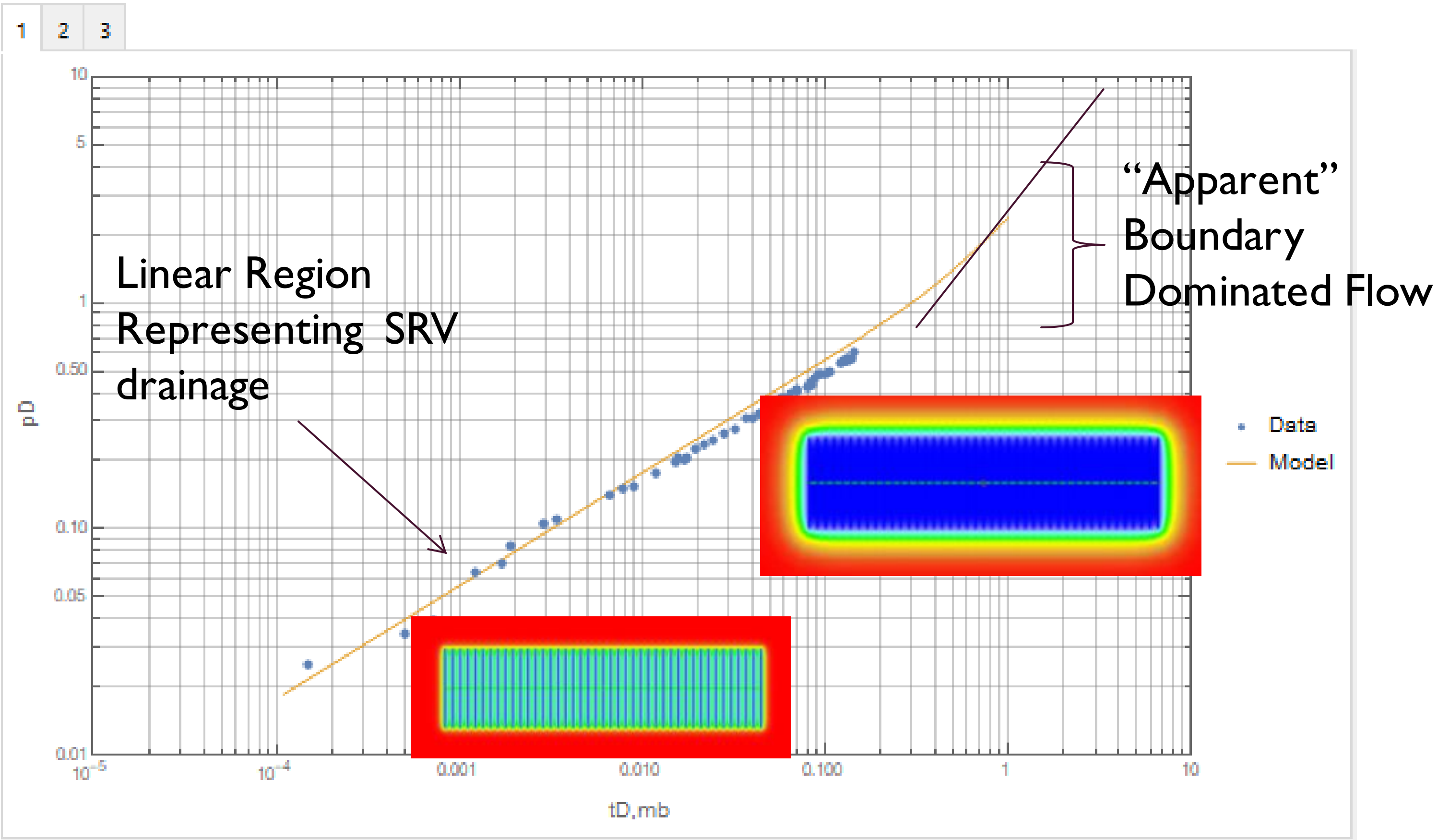
DEVELOPMENT AND CODING OF MFHZ CURVES AND MODELS





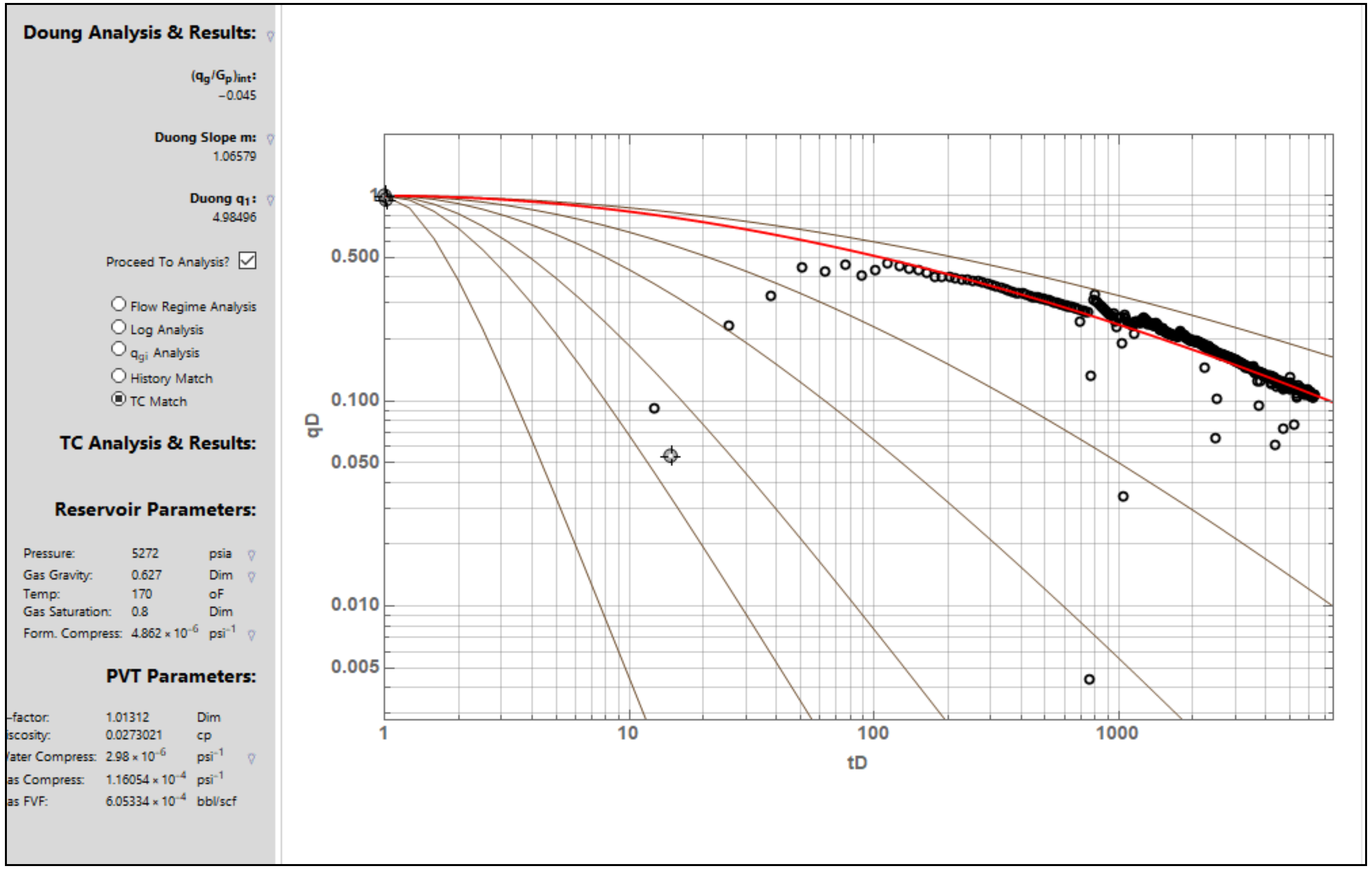
The procedure will be to establish fracture and formation parameters that match the field data to typecurve (or vice-versa)

MFHW TYPE CURVE, HISTORY MATCHING, AND FORECASTING



In addition to the typecurve procedure, we are building the forward modelling allowing use to the established reservoir parameters to generate deliverability forecasts.

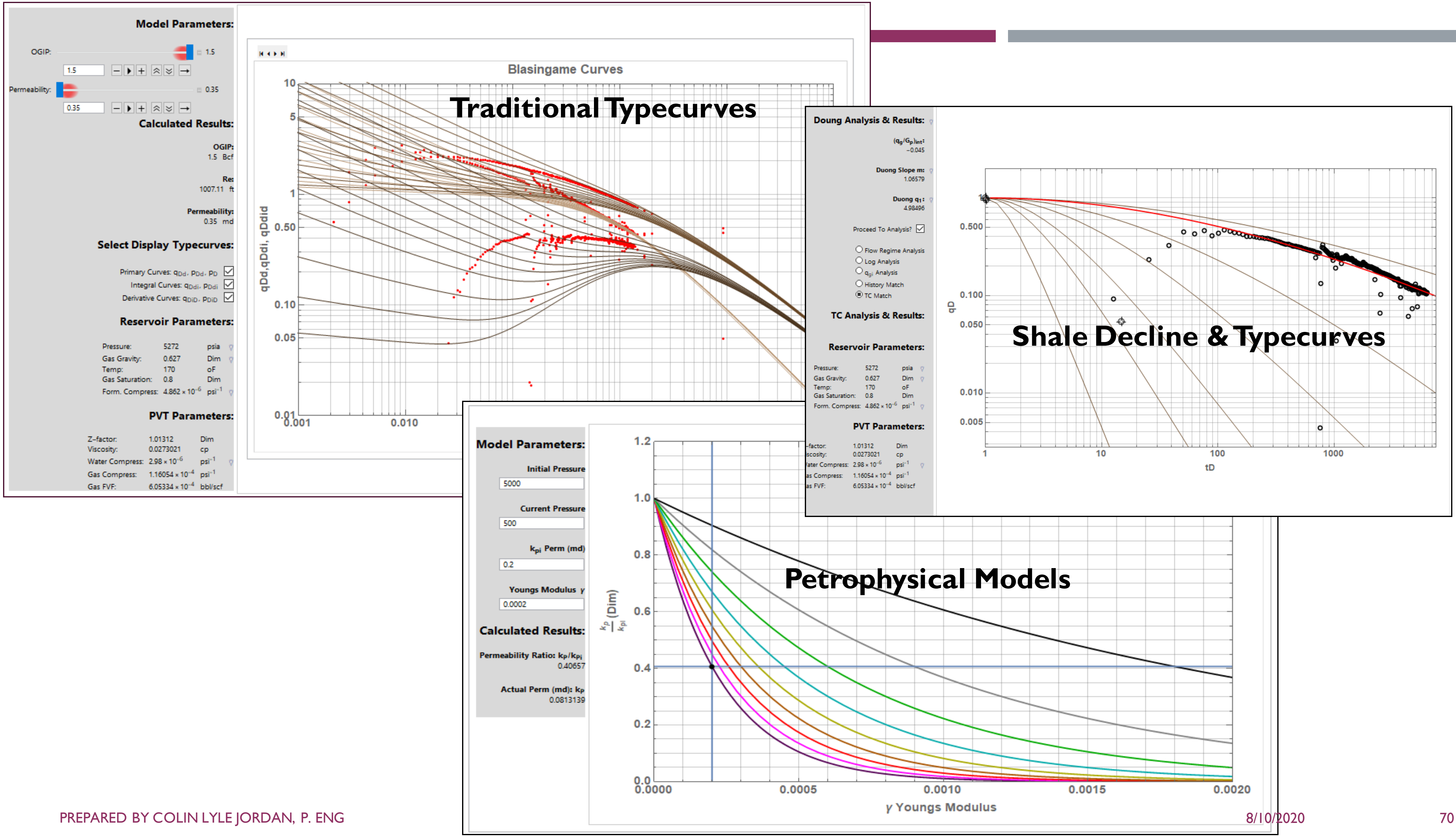
DUONG TYPE CURVE ANALYSIS FOR SHALES



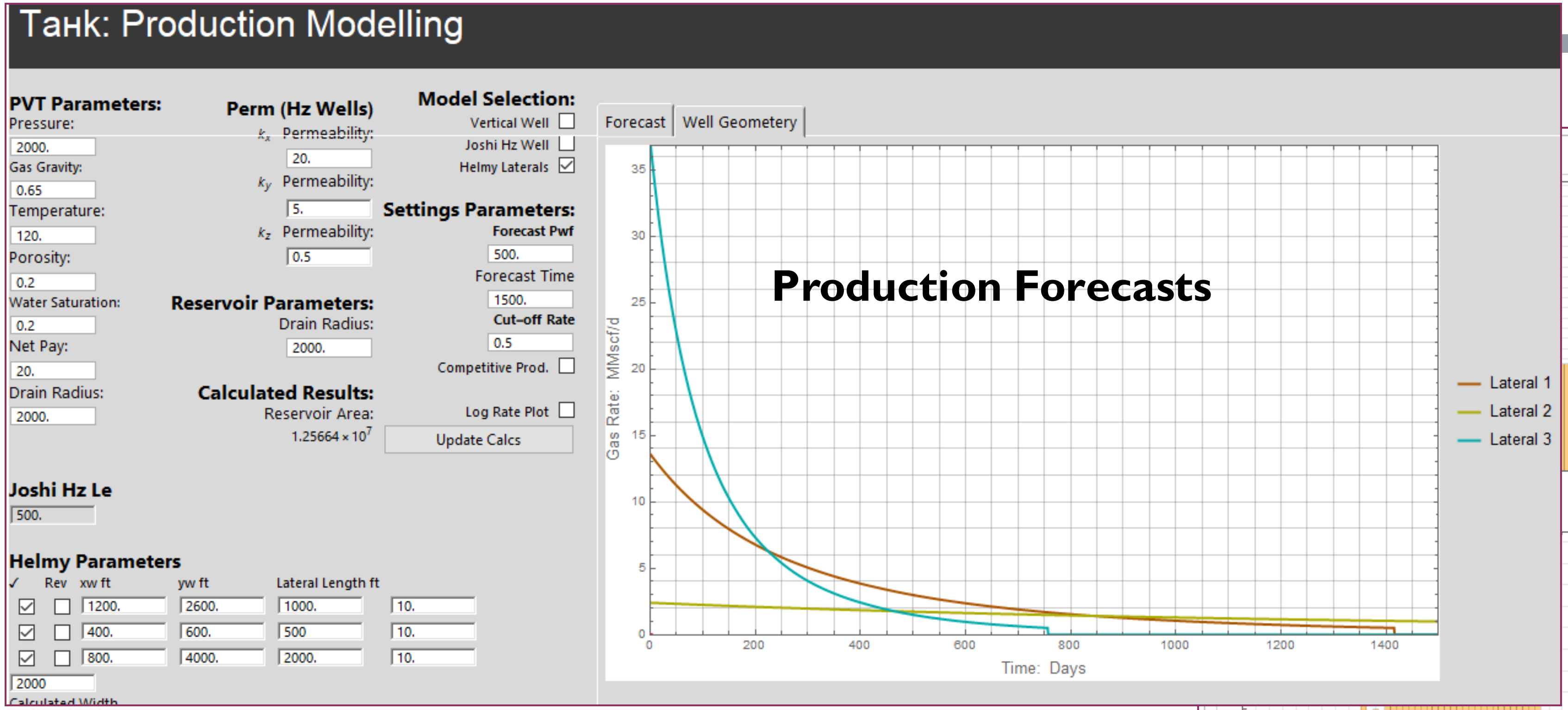
ON-GOING DEVELOPMENTS

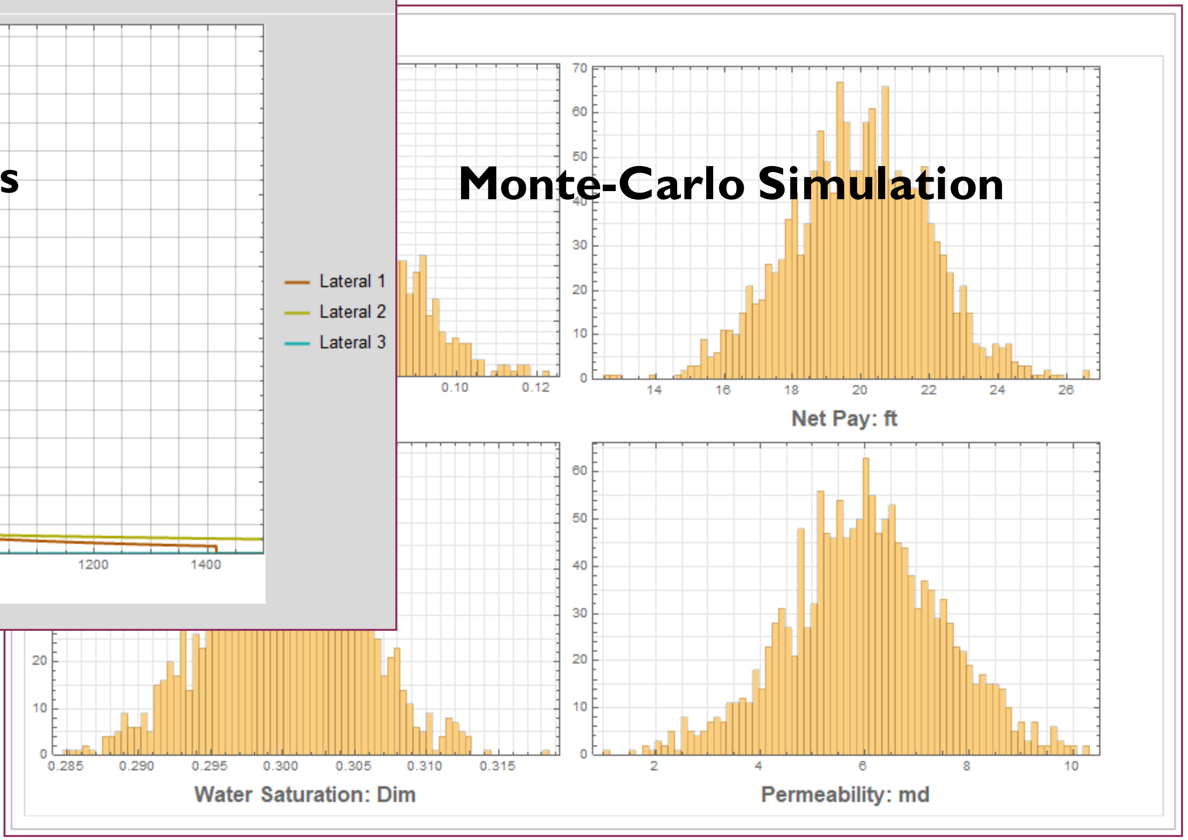
MATHEMATICA LIBRARIES & PACKAGES

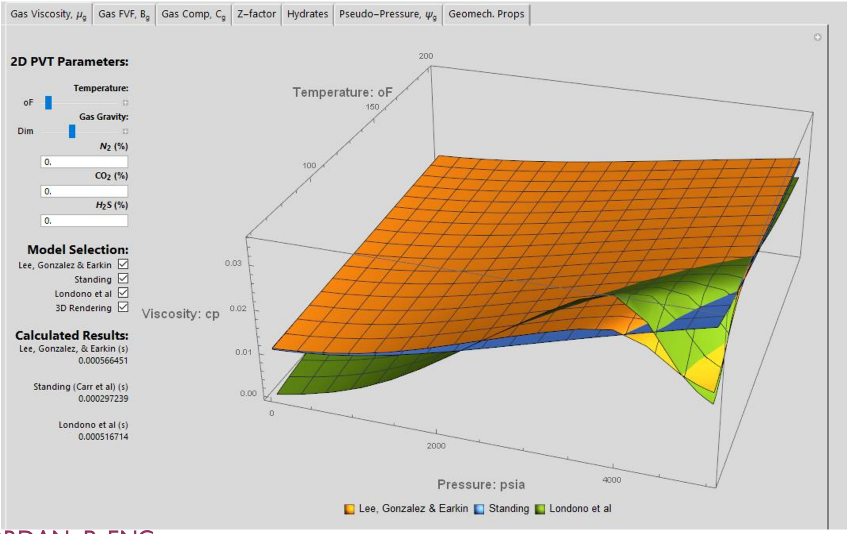
▪ PVT.m	(Basic oil, gas, and water correlations)
▪ CBMProps.m	(Isotherm and geomechanical properties)
▪ Hydrate.m	(A variety of P & T hydrate models)
▪ Bitumen .m	(Viscosity Relationships)
▪ MaterialBalance.m	(Simple and overpressured models)
▪ TransientSolutions.m	(Basic PTA/RTA models)
▪ DerivativeLibrary.m	(Automatically calculates a variety of traditional, logarithmic, and novel derivatives)
▪ ShaleDeclineModels.m	(Duong and other models)
▪ TankModels.m	(Vertical and Hz/Multi-lateral PSS models)
▪ Furui.m	(Under development, completion models)

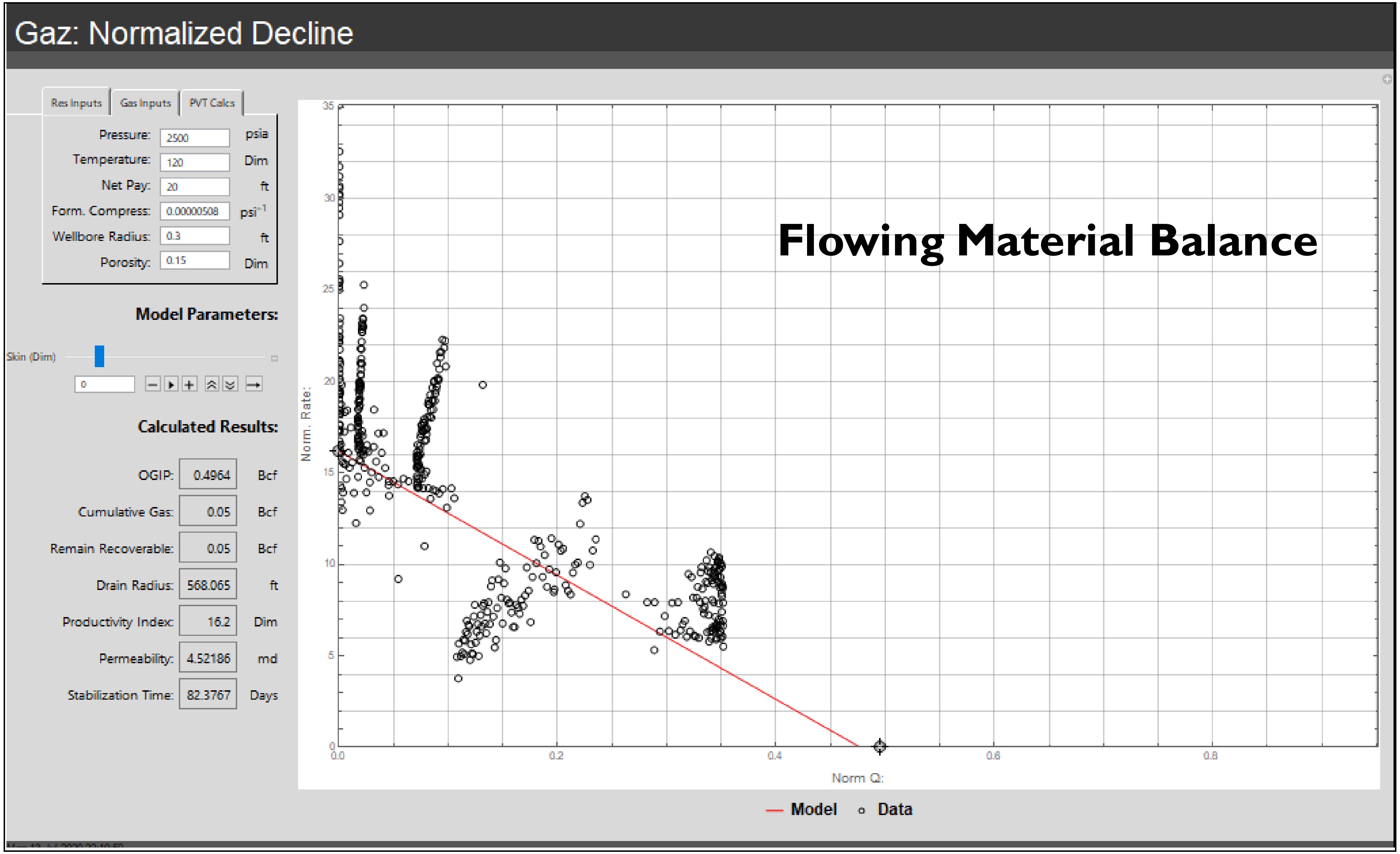


Traditional Typecurves
Blasingame Curves
Model Parameters:
Calculated Results:
Select Display Typecurves:
Reservoir Parameters:
PVT Parameters:
Shale Decline & Typecurves
Doung Analysis & Results:
TC Analysis & Results:
Petrophysical Models
γ Youngs Modulus


Танк: Production Modelling
PVT Parameters:
Pressure:
2000.
Gas Gravity:
0.65
Temperature:
120.
Porosity:
0.2
Water Saturation:
0.2
Net Pay:
20.
Drain Radius:
2000.
Perm (Hz Wells)
k_x Permeability:
20.
k_y Permeability:
5.
k_z Permeability:
0.5
Reservoir Parameters:
Drain Radius:
2000.
Calculated Results:
Reservoir Area:
1.25664×10^7
Model Selection:
Vertical Well
Joshi Hz Well
Helmy Laterals
Settings Parameters:
Forecast Pwf
500.
Forecast Time
1500.
Cut-off Rate
0.5
Competitive Prod.
Log Rate Plot
Update Calcs
Joshi Hz Le
500.
Helmy Parameters
Rev
xw ft
yw ft
Lateral Length ft
1200.
2600.
1000.
10.
400.
600.
500
10.
800.
4000.
2000.
10.
2000
Forecast
Well Geometery
Production Forecasts
Gas Rate: MMscf/d
Time: Days
Lateral 1
Lateral 2
Lateral 3


Monte-Carlo Simulation
Net Pay: ft
Water Saturation: Dim
Permeability: md


Gas Viscosity
Gas FVF
Gas Comp
Z-factor
Hydrates
Pseudo-Pressure
Geomech. Props
2D PVT Parameters:
Temperature:
Gas Gravity:
Model Selection:
Lee, Gonzalez & Earkin
Standing
Londono et al
3D Rendering
Calculated Results:
Lee, Gonzalez, & Earkin (s)
0.000566451
Standing (Carr et al) (s)
0.000297239
Londono et al (s)
0.000516714
Temperature: oF
Viscosity: cp
Pressure: psia
Lee, Gonzalez & Earkin
Standing
Londono et al


Gaz: Normalized Decline
Res Inputs
Gas Inputs
PVT Calcs
Pressure: 2500 psia
Temperature: 120 Dim
Net Pay: 20 ft
Form. Compress: 0.00000508 psi⁻¹
Wellbore Radius: 0.3 ft
Porosity: 0.15 Dim
Model Parameters:
Skin (Dim)
0
Calculated Results:
OGIP: 0.4964 Bcf
Cumulative Gas: 0.05 Bcf
Remain Recoverable: 0.05 Bcf
Drain Radius: 568.065 ft
Productivity Index: 16.2 Dim
Permeability: 4.52186 md
Stabilization Time: 82.3767 Days
Flowing Material Balance
Norm. Rate:
Norm Q:
Model
Data

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