Course Title (in English): Gas Recovery, Hydrocarbons, Hydrates

Course Title (in Russian): Добыча газа, углеводородные системы, гидраты

Lead Instructor(s): Istomin, Vladimir

Is this syllabus complete, or do you plan to edit it again before sending it to the Education Office?
The syllabus is a final draft waiting for approval (once approved the syllabus will be published on the public web-site and other systems)

Contact Person: Vladimir Istomin

Contact Person's E-mail: v.istomin@skoltech.ru

1. Annotation

Course Description
Natural gases characterization of the gas and gas-condensate fields. Traditional and non-conventional gas resources. Overview of technological complications (flow assurance) in gas production at different stages of field development.

Phase diagrams of hydrocarbon systems including water. General characteristics of phase transformations during reservoir development. A moisture content of natural gas.

Gas hydrates: basic physical and chemical properties. Two-phase and three-phase equilibria. Gas hydrates as a technological complication in gas production. Thermodynamic (methanol and MEG) and low-dosage (kinetic and anti-agglomerant) inhibitors.

Permafrost at northern gas fields: general characteristic, ice content, thermophysical and mechanical properties of frozen and thawed rocks. Wells and well clusters. Thawing and reverse freezing of rocks around the producing well. Simulation of the thermal interaction of well and permafrost rocks. Thermal regime of the operating well.

Gas gathering systems. Technological complications in the operation of infield systems. Gas hydrate control. Gas gathering systems at the late stages of field development (water accumulations, ice formation, sand, scales).

The main technological processes of gas treatment in field conditions (general overview).


Course Prerequisites / Recommendations

Student should have basic knowledge of thermodynamics and petroleum engineering (introduction course is sufficient).

2. Structure and Content

Course Academic Level

Master-level course suitable for PhD students

Number of ECTS credits

3

<table>
<thead>
<tr>
<th>Topic</th>
<th>Summary of Topic</th>
<th>Lectures (# of hours)</th>
<th>Seminars (# of hours)</th>
<th>Labs (# of hours)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to traditional and non-conventional gas resources.</td>
<td>Features of fluidal systems of gas and gas condensate fields: temperature and pressure, component composition of formation gases (including non-hydrocarbon components), residual saline water in the reservoir, gas condensate factor. Characterization of natural gases of the main fields of Russia. Traditional and non-conventional (incl. hydrates) gas resources.</td>
<td>3</td>
<td>1</td>
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</tr>
<tr>
<td>Permafrost at gas and gas-condensate fields.</td>
<td>The structure of permafrost at northern fields, ice content, thermophysical and mechanical properties of frozen and thawed rocks. Construction of production wells. Thawing and reverse freezing of rocks around the well. Simulation of the thermal interaction of wells and permafrost.</td>
<td>2</td>
<td>1</td>
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</tr>
<tr>
<td>Topic</td>
<td>Description</td>
<td>Credits</td>
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<tr>
<td><strong>Gas Hydrates. Properties and phase equilibria.</strong></td>
<td>Gas hydrates as clathrate compounds. Structures and composition of gas hydrates. Basic physical and chemical properties of hydrates. Two-phase and three-phase equilibria of gas hydrates. Influence of inhibitors on phase equilibria.</td>
<td>3</td>
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<tr>
<td><strong>Gas hydrate control. Thermodynamic and low-dosage inhibitors.</strong></td>
<td>Gas hydrates as a technological complication in gas production. Methods of prevention and liquidation of hydrate plugs in gas production systems. Inhibitors of hydrate formation. Thermodynamic and kinetic inhibitors, anti-agglomerates and low-dosage inhibitors. Effect of inhibitors on thermodynamics, kinetics and morphology of hydrates. Methanol and ethylene glycol as the main thermodynamic inhibitors.</td>
<td>3</td>
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</tr>
<tr>
<td><strong>Gas Hydrates in porous media.</strong></td>
<td>Gas hydrates in natural conditions (accomulations in permafrost and hydrate reservoirs). Laboratory study of hydrates in sediments. Influence of porous media on hydrate equilibria.</td>
<td>2</td>
<td></td>
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</tr>
<tr>
<td><strong>Low temperature processes.</strong></td>
<td>Low-temperature processes of gas treatment at gas-condensate fields. Isenthalpic and isentropic processes. The low-temperature separation (LTS) technology and design of equipment. Main modifications of the LTS processes (application of ejectors, turbo-expanders, gas-dynamic separators in process diagrams). Hydrate control at low temperature processes. Promising technological schemes for gas processing at field conditions.</td>
<td>4</td>
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<tr>
<td><strong>Application period.</strong></td>
<td>Reports of individual projects.</td>
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</tbody>
</table>

### 3. Assignments
## 4. Grading

### Type of Assessment

Graded

### Grade Structure

<table>
<thead>
<tr>
<th>Activity Type</th>
<th>Activity weight, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attendance</td>
<td>10</td>
</tr>
<tr>
<td>Test/Quiz</td>
<td>10</td>
</tr>
<tr>
<td>Homework Assignments</td>
<td>20</td>
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<tr>
<td>Projects</td>
<td>30</td>
</tr>
<tr>
<td>Final Exam</td>
<td>30</td>
</tr>
</tbody>
</table>

### Grading Scale

- **A:** 86
- **B:** 76
5. Basic Information

### Maximum Number of Students

<table>
<thead>
<tr>
<th></th>
<th>Maximum Number of Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall:</td>
<td>15</td>
</tr>
<tr>
<td>Per Group (for seminars and labs):</td>
<td>15</td>
</tr>
</tbody>
</table>

### Course Stream

Science, Technology and Engineering (STE)

### Course Term (in context of Academic Year)

Term 3

### Course Delivery Frequency

Every year

### Students of Which Programs do You Recommend to Consider this Course as an Elective?

<table>
<thead>
<tr>
<th>Masters Programs</th>
<th>PhD Programs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petroleum Engineering</td>
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</tbody>
</table>

### Course Tags

Engineering

6. Textbooks and Internet Resources

<table>
<thead>
<tr>
<th>Required Textbooks</th>
<th>ISBN-13 (or ISBN-10)</th>
</tr>
</thead>
</table>
### Recommended Textbooks

<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Year</th>
<th>ISBN-13 (or ISBN-10)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petroleum and Gas Field Processing</td>
<td>H.K. Abdel-Aal, Mohamed Aggour, M.A. Fahim</td>
<td>2003</td>
<td>9781482255928</td>
</tr>
<tr>
<td>Thermodynamics of Hydrocarbon Reservoirs</td>
<td>Abbas Firoozabadi</td>
<td>1999</td>
<td>9780070220713</td>
</tr>
<tr>
<td>Gathering and conditioning of gas on the northern gas fields of Russia</td>
<td>A.I.Gritsenko, V.A.Istomin, A.N.Kulkov, R.S.Suleimanov</td>
<td>1999 (in Russian)</td>
<td>5247038185</td>
</tr>
<tr>
<td>PVT and Phase Behaviour of Petroleum Reservoir Fluids</td>
<td>Ali Danesh</td>
<td>1998</td>
<td>9780444821966</td>
</tr>
<tr>
<td>Theoretical bases of phase transformations of hydrocarbon mixtures</td>
<td>Brusilovsky A.I.</td>
<td>2010</td>
<td>9785317037161</td>
</tr>
<tr>
<td>The prevention and Liquidation of gas hydrates in of gas production systems</td>
<td>Moscow, Istonin V.A. Kvon V. G.</td>
<td>2004 (in Russian)</td>
<td>na</td>
</tr>
<tr>
<td>Flow Assurance Solids in Oil and Gas Production</td>
<td>Jon Steinar Gudmundsson</td>
<td>2018</td>
<td>9781138737846</td>
</tr>
</tbody>
</table>

### Papers

<table>
<thead>
<tr>
<th>Title</th>
<th>Authors</th>
<th>Year</th>
<th>DOI or URL</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Return of Kinetic Hydrate Inhibitors</td>
<td>Tohidi B., Anderson R., Mozaffar H., and Tohidi F.</td>
<td>2015</td>
<td>10.1021/acs.energyfuels.5b01794</td>
</tr>
</tbody>
</table>

### 7. Facilities

**Equipment**
- Class room (up to 15 students)
- Projector;
- Microphone and audio system;
- Whiteboard/Flipchart/blue/black/red color whiteboard markers

**Software**
- HydraFLASH

### 8. Learning Outcomes
### Knowledge

Acquaintance with different aspects of gas production technology including flow assurance and phase transformation at gas recovery systems. Emphasis to Arctic gas and gas-condensate fields associated with permafrost.

Mechanisms of gas hydrates formation and decomposition in gas gathering systems and gas processing, as well as in porous media. Methods for calculation phase equilibria of hydrocarbon fluids, including water phases (liquid water, ice, gas hydrates). Phase diagrams of formation gases (gas-condensate reservoirs).

Interrelation among various aspects in flow assurance with emphasis to gas hydrates and hydrate inhibitors (influence of hydrate inhibitors on scale, corrosion etc.).

### Skill

Prediction of hydrate formation at gas recovery systems and selection of different inhibitors for hydrate control.

Choosing methods of field gas treatment depending on the composition of formation gases.

Design of gas gathering systems and prognosis of thermodynamic and hydrodynamic regimes of in-field pipelines. Flow assurance in gas gathering pipelines.

Calculations of gas dehydration systems by adsorption and absorption methods.

Low temperature technological processes (low temperature separation and its modifications) for gas processing at field conditions. Calculations of methanol or MEG consumption.

### Experience

Ability to work with research literature on petroleum engineering (in the field of gas hydrates and other flow assurance, gas gathering pipelines, gas treatment and processing).

Ability to make oral and written presentations in the area of gas hydrates and gas recovery.

Ability to work with specialized programme software (HydraFLASH etc.).

### 9. Assessment Criteria

**Input or Upload Example(s) of Assignment 1:**

**Select Assignment 1 Type**

Homework Assignments

**Input Example(s) of Assignment 1 (preferable)**

Describe the type of reservoir fluids.

Effect of composition on type of fluids.

Why do we need PVT tests?

Types of water being produced from reservoir.

**Or Upload Example(s) of Assignment 1**

https://ucarecdn.com/2c0b6e22-cc1c-40df-be64-a9b5e8cf97e9/
Carried out calculations by programme software HydraFLASH. Presentation of calculation results in table and graph forms (.doc and .xls files). Processing of the results and obtaining the correlations.

**Input or Upload Example(s) of Assignment 2:**

**Select Assignment 2 Type**

- Projects

**Input Example(s) of Assignment 2 (preferable)**

Examples of topics:

- Phase diagrammes for hydrocarbon systems: from two components to multicomponent gas mixtures
- Gas hydrate prevention by using MEG for off-shore conditions.
- Gas hydrate prevention by using MeOH for on-shore conditions.
- Inhibiting of gas hydrates by using composition "kinetic + thermodynamic inhibitors".
- Decomposition kinetic of gas hydrates in laboratory rig and in pipelines.
- Kinetic properties of thermodynamic hydrate inhibitors.
- Dehydration by TEG for off-shore conditions.
- Dehydration by DEG at the latest state of a field development.
- Gas dynamic separation.
- Flow diagrams for low-temperature absorption.

**Assessment Criteria for Assignment 2**

The individual project includes a report and presentation.

**Requirements to the report:**

2. Contents:
   a. statement of the problem;
   b. description of the current situation in this field regarding traditional and nontraditional stocks;
   c. example of new technologies implemented in the field;
   d. economic benefit justification;
   e. branch development consideration;
   f. conclusion;
   g. list of references.

**Requirements to the presentation:**

Students should use PowerPoint to create a presentation generalizing results of the individual project. The presentation must consist of 15-20 slides.

**Input or Upload Example(s) of Assignment 3:**

**Select Assignment 3 Type**

- Homework Assignments
Determine the conditions for hydrate formation (water-gas hydrates) for methane and gas-condensate gas. The results should be presented in a table and graphical forms.

Determine the effect of thermodynamic inhibitors (the shift depends on the inhibitor concentration in the aqueous solution). The results should be presented in a table and graphical forms.

The inhibitors are (the inhibitor distribution was made by professor V. Istomin early*): methanol, monoethylene glycol, diethylene glycol, triethylene glycol and electrolyte solutions (NaCl, KCl, MgCl2, mixture CaCl2 + MgCl2).

Calculate the water activity for your inhibitor solutions, depending on the inhibitor concentration at three temperatures (-20, 0 and +20 °C). The results should be presented in a table and graphical forms.

Present graphs of an effect of the hydrate formation conditions on the water activity in electrolyte solutions and make a thermodynamic correlation (delta T from the logarithm of water activity in solution).

Carried out calculations by programme software HydraFLASH. Presentation of calculation results in table and graph forms (.doc and .xls files).

Processing of the results and obtaining the correlations.
The first example of quiz:
How hydrate inhibitor impact on hydrate equilibrium line (give illustration)?
How to calculate methane hydrate number?
Wax in gas-condensate system.
Composition of water formation and scales.
Give schematically chart of phase envelope for hydrocarbon system.

The second example of quiz:
Gas the following composition is produced from a reservoir:
Methane: 85 mole% 
Ethane: 5 mole% 
Propane: 4 mole% 
i-Butane: 3 mole% 
n-Butane: 2 mole% 
i-Pentane: 1 mole% 
Reservoir temperature: 100 °C
Reservoir pressure: 300 bar
Salinity of formation/connate water: 10 wt% NaCl equivalent
Gas production rate: 3 million m3 per day
Pipeline condition: 50 bar and 10 °C

Some example of questions:
1. What is the type of reservoir fluid?
2. Calculate the amount of water produced from the reservoir
3. Calculate the amount water condensed in the pipeline
4. Is there any risk of hydrate?
5. If yes, how much methanol is required (only concentration in wt%)?
6. Calculate the amount in m3/day, assume 95 wt% purity (assume the density of methanol 790 kg/m3 and density of water 1000 kg/m3)?
7. Assume 3 °C safety margin, and recalculate the amount of methanol
8. Assume 30 bar drawdown in the reservoir and 3 °C safety margin and recalculate the amount inhibitor
9. Is a PVCap based KHI (assume a CIR of 5 °C) is an option? If it is an option how will it impact the amount of methanol?
10. Is dehydration an option? Yes, what should be the maximum water content? What are advantages/disadvantages of dehydration?
11. If a knock out drum (for separation of water at the wellhead) is installed at the wellhead (assume 55 bar and 20 °C), how will it impact the amount of condensed water in pipeline and amount of methanol (assume 3 °C safety margin and 30 bar drawdown)?

Assessment Criteria for Assignment 4
Test designed based on teaching materials. Normally test/quiz consist of 5-7 short question.

Input or Upload Example(s) of Assignment 5:

Select Assignment 5 Type
Final Exam

Input Example(s) of Assignment 5
Practical part:
1. a) To calculate the phase diagrams for the system: methane - ethane (files in world and excel)
   Composition CH4 90 mol.% - C2H6 10 mol.%
   CH4 80 mol.% - C2H6 20 mol.%
   CH4 70 mol.% - C2H6 30 mol.%
   b) To calculate three phase equilibrium line "liquid water - gas - gas hydrate" up to 20 °C (gas compositions are the same as in 1a)

Theoretical part:
2. The methods for Gas Hydrate prevention in wells and gas gathering systems.
3. Gas condensate fields in Eastern Siberia (gas composition, P-T condition, formation water, oil rims)

Assessment Criteria for Assignment 5
- Carried out calculations by programme software HydraFLASH.
- Presentation of calculation results in table and graph forms (.doc and .xls files).
- Processing of the results.

10. Additional Notes

Free Style Comments (if any)
- The full name of the course is "Gas Recovery, Phase Equilibria of Hydrocarbons and Gas Hydrates".