Petroleum Engineering 613 — Natural Gas Engineering
Syllabus and Administrative Procedures
Spring 2005

Instructor(s):

Instructor: Dr. Tom Blasingame (Section 501)
Office: RICH 815
Lecture: MWF 13:50-14:40 a.m. RICH 302
Office Hours: by appointment — or if my office is open, I am available.
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Texts: (Available at MSC Bookstore, can also be ordered directly from SPE (probably at reduced rates), you must be an SPE member — SPE (800) 456-6863)

1. Lee, W.J. and Wattenbarger, R.A.: *Gas Reservoir Engineering*, SPE (1996).

Reference Materials:

1. Course materials for this semester are located at:

   `http://pe.tamu.edu/~t-blasingame/P613_05A/`

2. An extensive compilation of reference notes, old text materials, etc. are located at:

   `http://pe.tamu.edu/~t-blasingame/P613_reference/`

   Note: The most materials are in given in .pdf files and some of these files are quite large — you should not open these files on the server, but rather, you should DOWNLOAD the .pdf to your local computer.

3. Journal articles (to be made available in electronic formats)

4. Other text materials:
   a. Katz, D. L., Cornell, R., Kobayashi, R., Poettmann, F. H., Vary, J. A., Elenblass, J. R., & Weinaug, C. G.: *Handbook of Natural Gas Engineering* (McGraw–Hill, New York) (1959)........(electronic format)
   b. Rawlins, E. L. and M. A. Schellhardt, *Backpressure Data on Natural Gas Wells and Their Application To Production Practices*, Monograph 7, U.S. Bureau of Mines, Washington, D C, (1936)........(electronic format)
   c. Energy Resources and Conservation Board, 1975, *Theory and Practice of the Testing of Gas Wells*, third edition, Pub. ERCB-75-34, ERCB, Calgary, Alberta........(electronic format)

Basis for Grade:

Homework/Projects 90%
Class Participation 10%
total = 100%

Grade Cutoffs: (Percentages)

A: < 90 B: 89.99 to 80 C: 79.99 to 70 D: 69.99 to 60 F: < 59.99

Policies and Procedures:

1. Students are expected to attend class ***every session***.
2. Policy on Grading
   a. It shall be the general policy for this course that homework, quizzes, and exams shall be graded on the basis of answers only — partial credit, if given, is given solely at the discretion of the instructor.
   b. All work requiring calculations shall be properly and completely documented for credit.
   c. All grading shall be done by the instructor, or under his direction and supervision, and the decision of the instructor is final.
3. Policy on Regrading
   a. Only in very rare cases will exams be considered for regrading; *e.g.*, when the total number of points deducted is not consistent with the assigned grade. Partial credit (if any) is ***not*** subject to appeal.
   b. Work which, while possibly correct, but cannot be followed, will be considered incorrect — and will not be considered for a grade change.
   c. Grades assigned to homework problems will not be considered for regrading.
   d. If regrading is necessary, the student is to submit a letter to the instructor explaining the situation that requires consideration for regrading, the material to be regraded must be attached to this letter. The letter and attached material must be received within one week from the date returned by the instructor.
4. The grade for a late assignment is ***zero***. Homework will be considered late if it is not turned in at the ***start of class*** on the due date. If a student comes to class after homework has been turned in and after class has begun, the student's homework will be considered late and given a grade of zero. ***Late or not, all assignments must be turned in.*** A course grade of ***Incomplete*** will be given if any assignment is missing, and this grade will be changed only after all required work has been submitted.
5. Each student should review the University Regulations concerning attendance, grades, and scholastic dishonesty. In particular, anyone caught cheating on an examination or collaborating on an assignment where collaboration is not specifically allowed will be removed from the class roster and given an F (failure grade) in the course.

Petroleum Engineering 613 — Natural Gas Engineering
Course Description, Prerequisites by Topic, and Course Objectives
Spring 2005

Course Description

Graduate Catalog: Flow of natural gas in reservoirs and in wellbores and gathering systems; deliverability testing; production forecasting and decline curves; flow measurement and compressor sizing.

Translation: From the reservoir through the sales line—we will try to study every aspect of natural gas systems. PVT properties, flow in porous media, flow in pipes and thermodynamic properties will be studied. We will use the Lee and Wattenbarger and the ERCB texts as guides — as well as numerous technical papers that go into much more depth of detail for a particular problem. We will focus on well testing, deliverability analysis, and decline curve analysis, as well as wellbore flow phenomena.

Prerequisites by Topic: Differential and integral calculus, Ordinary and partial differential equations, Thermodynamics, Fluid dynamics and heat transfer, Reservoir fluid properties, and Reservoir petrophysics.

Course Objectives

The student should be able to:

- Estimate oil, gas, and water properties pertinent for well test or production data analysis using industry accepted correlations and laboratory data.
- Sketch pressure versus time trends and pressure versus distance trends for a reservoir system exhi-biting transient, pseudosteady-state, and steady-state flow behavior.
- Derive the steady-state and pseudosteady-state relations for gas flow (including rigorous and semi-analytical relations for boundary-dominated flow behavior). In addition, the student must be able to derive, in complete detail, the pressure, pressure-squared, and pseudopressure forms of the diffusivity equation for a real gas.
- Derive the material balance equations for a volumetric dry gas reservoir, an "abnormally-pressured" gas reservoir, and a water-drive gas reservoir. The student should also be familiar with the generalized (i.e., compositional form) of the material balance equation for a gas condensate reservoir.
- Derive and apply the conventional relations used to calculate the static and flowing bottomhole pressures for the case of a dry gas. The student should also be familiar with proposed techniques for wet gases.
- Derive/present models for wellbore storage and phase redistribution (gas systems).
- Derive the "skin factor" variable from the steady-state flow equation and be able to describe the conditions of damage and stimulation using this skin factor. The student should also be familiar with models for "variable" skin effects due to non-Darcy flow, well cleanup, and gas condensate banking (radial composite model).
- Analyze and interpret flow-after-flow (4-point) and isochronal flow tests.
- Derive the analysis and interpretation methodologies (*i.e.*, "conventional" plots and type curve analy-sis) for pressure drawdown and pressure buildup tests (liquid or gas reservoir systems). Also, be able to apply dimensionless solutions ("type curves") and field variable solutions ("specialized plots") for the analysis and interpretation of well test data.
- Design and implement a well test sequence, as well as a long-term production/injection surveillance program. This includes the design of single and multipoint deliverability tests.
- Analyze production data (rate-time or pressure-rate-time data) to obtain reservoir volume and esti-mates of reservoir properties for gas and liquid reservoir systems. The student should be able to use "decline curves," "decline type curves," and other techniques of analysis for production data.
- The student should be familiar with the reservoir engineering tools used to analyze/interpret the perfor-mance of the following gas reservoir types:
  - — Gas condensate reservoir systems
  - — Low permeability/unconventional reservoirs
  - — Low pressure gas reservoirs

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Spring 2005 (Spring Break: 14-18 March 2005)

Date			Topic	Reading
Module 1 Introductory Concepts				
January	17	M	University Holiday	
	19	W	Course Introduction/Review of Syllabus	(Syllabus — Spring 2005)
	21	F	Introduction: historical perspectives, types of tests, etc.	ERCB Ch. 1, Katz Ch 1-2,9
	24	M	Reservoir performance behavior (introduction)	ERCB Ch. 2, LW Ch. 5
	26	W	Properties of reservoir fluids	ERCB App. A, LW Ch. 1, Katz Ch 3-5,12, Hnd
	28	F	Properties of reservoir fluids	ERCB App. A, LW Ch. 1, Katz Ch 3-5,12, Hnd
Module 2 Gas Material Balance and Boundary Dominated Flow Behavior				
	31	M	Fundamentals of fluid flow in porous media (general)	ERCB Ch. 2, LW Ch. 5, Katz Ch 2, Hnd
February	02	W	Fundamentals of fluid flow in porous media (gas)	ERCB Ch. 2, LW Ch. 5, Katz Ch 2, Hnd
	04	F	Gas material balance (simple case)	LW Ch. 10, Katz Ch 12, Hnd
	07	M	Gas material balance ("abnormal" pressure case)	LW Ch. 10, Hnd
	09	W	Gas material balance (water influx case)	LW Ch. 10, Hnd
	11	F	*IPR* concepts for gas wells	ERCB Ch. 3, LW Ch. 4, Hnd
	14	M	Semi-analytical performance equation ($q(t)$ vs. t) for gas wells	Hnd
Module 3 Wellbore Phenomena and Near-Well Reservoir Behavior				
	16	W	Wellbore phenomena: Calculation of static/flowing bottomhole pressures (gas)	ERCB App. B, LW Ch. 4, Hnd
	18	F	Wellbore phenomena: Calculation of static/flowing bottomhole pressures (gas)	ERCB App. B, LW Ch. 4, Hnd
	21	M	Wellbore phenomena: Wellbore storage/phase redistribution models (gas)	LW Ch. 5, Hnd
	23	W	Near-well impediments to flow — the skin factor and condensate banking	ERCB Ch. 2, LW Ch. 5, Hnd
	25	F	Near-well impediments to flow — the skin factor and condensate banking	ERCB Ch. 2, LW Ch. 5, Hnd
Module 4 Well Test Analysis				
	28	M	Deliverability testing of gas wells (Introduction)	Hnd (Rawlins/Schellhardt), Katz Ch 9,11
March	02	W	Deliverability testing of gas wells	ERCB Ch. 3, LW Ch. 7, Katz Ch 9,11, Hnd
	04	F	Well test analysis: Fundamentals (solutions, plots, simple analysis, etc.)	ERCB Ch. 4-5, LW Ch. 6, Katz Ch 10
	07	M	Well test analysis: Fundamentals (solutions, plots, simple analysis, etc.)	ERCB Ch. 4-5, LW Ch. 6, Katz Ch 10
	09	W	Well test analysis: Model-based analysis (Unfractured wells)	ERCB Ch. 7, LW Ch. 6, Hnd
	11	F	Well test analysis: Model-based analysis (Fractured Wells)	ERCB Ch. 7, LW Ch. 6, Hnd
	Spring Break: 14-18 March 2005			
	21	M	Well test analysis: Model-based analysis (etc.)	ERCB Ch. 7, LW Ch. 6, Hnd
	23	W	Well test analysis: Well test design	ERCB Ch. 4-5, LW Ch. 8, Hnd
	25	F	Reading Day (*No Classes — Good Friday*)	
Module 5 Analysis and Modelling of Production Data				
	28	M	Analysis of production data: Data acquisition, cataloging, and retrieval	LW Ch. 9, Hnd
	30	W	Analysis of production data: Conventional decline curve analysis	LW Ch. 9, Hnd
April	01	F	Analysis of production data: *EUR* analysis	Hnd
	04	M	Analysis of production data: Model-based analysis	LW Ch. 9, Hnd
	06	W	Analysis of production data: Model-based analysis	LW Ch. 9, Hnd
	08	F	Analysis of production data: Model-based analysis	LW Ch. 9, Hnd
Module 6 Special Topics in Gas Reservoir Engineering				
	11	M	Performance of gas condensate reservoir systems	Katz Ch 12, Hnd
	13	W	Low permeability/unconventional gas reservoirs (characterization)	Hnd
	15	F	Low pressure gas reservoir systems	Hnd
	18	M	Underground storage of natural gas	Katz Ch 18, Hnd
	20	W	Underground storage of natural gas	Katz Ch 18, Hnd
	22	F	Special topics (analysis of well performance data from low permeability gas reservoirs)	Hnd
	25	M	Special topics (analysis of well performance data from low permeability gas reservoirs)	Hnd
	27	W	Special topics (analysis of well performance data from low permeability gas reservoirs)	Hnd
	29	F	Special topics (TBA)	Hnd
May	02	M	(dead day) Software for the analysis of well test data	Hnd
	03	T	(redefined day ("Friday")) Software for the analysis of production data	Hnd
May	10	T	Final Exam/Project - RICH 302 from 03:30 - 05:30 p.m. (MWF 01:40 - 02:50 p.m.)	