Roll No.

PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

TEST 1

Sem & AY: Odd Sem 2019-20	**Date:** 01.10.2019
Course Code: PET 227	**Time:** 2.30 to 3.30 PM
Course Name: WELL TESTING ANALYSIS	**Max Marks:** 40
Program & Sem: B.Tech (PET) & V	**Weightage:** 20%

Instructions:

(i) All questions are compulsory

(ii) Assume the missing value. Assumption should be reasonable.

Part A [Memory Recall Questions]

Answer all the Questions. Each Question carries four marks. **(3Qx4M=12M)**

1. Write the Assumptions made to find a Workable Solution for Diffusivity Equation for Infinite Reservoir. (C.O.NO.1) [Knowledge]
2. Write the Pressure Equations for Infinite Reservoir and Pseudo-Steady State. (C.O.NO.1) [Knowledge]
3. Write the expression for Skin (S). What is the significance of Positive, Negative and zero skin? (C.O.NO.1) [Knowledge]

Part B [Thought Provoking Questions]

Answer both the Questions. Each Question carries four marks. **(2Qx4M=8M)**

4. What is the expectations of OIL Industry from a Well Test Analysis

   (C.O.NO.1) [Comprehension]

5. Write two limits of Time (t) for which Solution of infinite reservoir is valid. Write the significances of the two limits. What is oil formation volume factor and compressibility factor? (C.O.NO.1) [Comprehension]

Part C [Problem Solving Questions]

Answer both the Question. Each Question carries ten marks. (2Qx10M=20M)

6. Derive Pressure Equation for Reservoir Limit Test. Write the condition for arriving at the equation. Write the merit of the equation. (C.O.NO.2) [Comprehension]

7. Suppose a well is 250 feet due west of a north south trending fault. The well is flowing for 8 days @ 350 B/D. Suppose there is a shut-in well 500 ft due north of the producing well. Calculate pressure at the shut-in well at the end of 8 days. Where B=1.13. Pi =3000 psia, μ= 0.5 cp , k=25 md, h-50 ft, C_t = 2×10^{-5} psi^{-1}, Φ =0.16, s=5, r_w=0.333 ft. Ei (0.079) = -2.039, Ei (0.158) = -1.459.

(C.O.NO.1) [Application]

SCHOOL OF Engineering

Semester: 5th

Course Code: PET 227

Course Name: Well Test Analysis

Date: 01.10.19

Time: 1 hour

Max Marks: 40

Weightage: 20%

Extract of question distribution [outcome wise & level wise]

Q.NO	C.O.NO	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels			Thought provoking type [Marks allotted] Bloom's Levels			Problem Solving type [Marks allotted]			Total Marks
			K			C			A			
1	1	1	4									4
2	1	1	4									4
3	1	1	4									4
4	1	1				4						4
5	1	1				4						4
6	2	2				10						10
7	1	1							10			10
	Total Marks		12			18			10			40

K =Knowledge Level C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

[I hereby certify that All the questions are set as per the above guide lines. Mr. Kalpajit]

Reviewers' Comments

SCHOOL OF Engineering

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

SOLUTION

Semester: 5th

Course Code: PET 227

Course Name: Well Test Analysis

Date: 30/09/19

Time: 1 hour

Max Marks: 40

Weightage: 20%

Part A

(3Q x4 M = 12 Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
1	Reservoir is infinite Pressure =Pi at r= infinity and before production begins Well is a line source with zero radius, at the center of a cylindrical reservoir Well is producing at uniform constant rate of qB.	1+1+1+1	5
2	For infinite reservoir PI-P =- 70.6 qμB/kh Ei(-948ΦμCtr^2/kt) For and Pseudo-Steady State Pwf = Pi – 141.2 (qBμ/kh)[0.000527kt/ΦμCtr^2 + ln(re/rw)-3/4	2+2	5
3	Skin S = (K/Ks-1)ln(rs/rw) rw =radius of the well rs = outer radius of altered zone when well is damaged S is positive when well is stimulated/ fractured S is negative		10

Part B

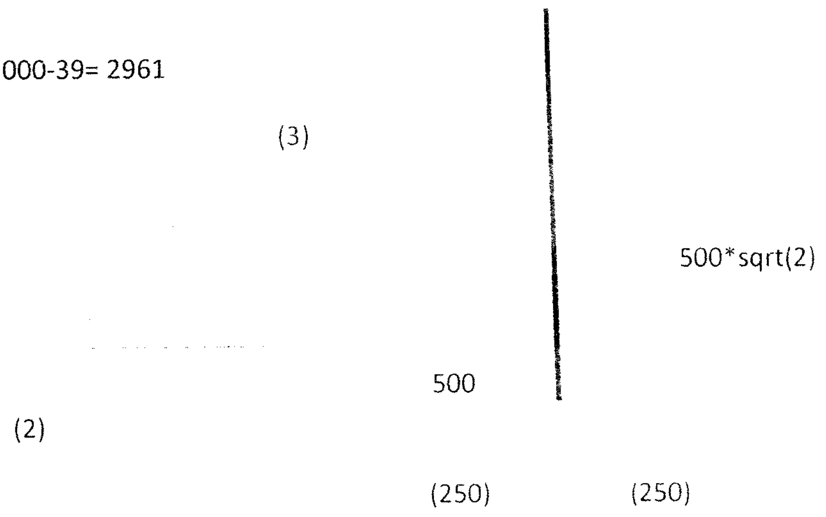
(2Q x4 M = 8 Marks)

Q No	Solution	Scheme of Marking	Max. Time require for eacl Questio
4	Reservoir Pressure, Permeability, Skin, AOFP, Idea of Reservoir Limit. From the value of Skin, Drillers may adjust Mud Wt . Variance of Permeability with different directions. Most permeable path.	1+1+1+1	5
5	t > 3.79x10^5 ΦμCtrw*2 /K for this time value Zero well radius (line well) assumption is satisfied. And t < 948 ΦμCtre*2 /K for this time value reservoir acts as a infinite reservoir, and reservoir Limit is not felt. For time greater than this reservoir boundary will be felt.		5

Part C

(2Q x10 M -20 Marks)

Q No	Solution	Scheme of Marking	Max. Time require for eacl Questio
6	We know if there is a boundary or fault near a well then we can write Pressure equation as (using Superposition principle) PI-P =- 70.6 qμB/kh [ln(1688ΦμCtRw^2/ktp) –2S] -- 70.6 qμB/kh Ei(-948ΦμCt4L^2/ktp) Now applying Horner's equation, we get -70.6 qμB/kh [ln(1688ΦμCtRw^2/k(tp+Δt) –2S] -70.6 (-q)μB/kh [ln(1688ΦμCtRw^2/kΔt) –2S] -70.6 qμB/kh Ei(-3792ΦμCtL^2/k(tp +Δt) -70.6 (-q)μB/kh Ei(-3792ΦμCtL^2/kΔt) If Δt>>tp, then we can write Ei function as ln function. We get Pi-pws = 70.6qBμ/kh[ln (tp +Δt)/Δt] + [ln (tp +Δt)/Δt]	6+2+2	15

	= 141.2qBμ/kh[ln (tp +Δt)/Δt] = 325.2qBμ/kh[log (tp +Δt)/Δt] For large value of Δt Ei func can be written as ln function. For large value of L or low value of K, Δt has to be vvv large. Merit: with this method from a single well by well testing we can predict reservoir boundadry. Normally which we get after drilling so many wells.		
7	{[-70.6*(0.5)*(1.13)]/25*50}* {350*Ei[948*(0.16)*(0.5)* 2*10^(-5)*(500)^2/25*8*24]} + {350*Ei[948*(0.16)*(0.5)* 2*10^(-5)*(500*sqrt(2))^2/25*8*24]} = -11.16892 * [Ei * (0.079) + Ei * (0.158)] = -11.16892 * [-2.039 -1.459] = -11.16892 * [-3.498] = 39 Pwf = 3000-39= 2961 	10	15

Roll No.													

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

PRESIDENCY UNIVERSITY
BENGALURU
SCHOOL OF ENGINEERING
TEST – 2

Sem & AY: Odd Sem 2019-20 **Date**: 19.11.2019
Course Code: PET 227 **Time**: 2.30 PM to 3.30 PM
Course Name: WELL TESTING ANALYSIS **Max Marks**: 40
Program & Sem: B.Tech (PET) & V **Weightage**: 20%

Instructions:

(i) *All questions are compulsory*
(ii) *Assume the missing value. Assumption should be reasonable.*

Part A [Memory Recall Questions]

Answer the Question. The Question carry ten marks (1Qx10M=10M)

1. Write down the steps to perform isochronal test. Draw the Pressure and flow rate history of a typical isochronal test. Write the following equation for the isochronal test:
   a) The transient equation for circular drainage area
   b) Transient radius of drainage

[5+2+3=10] (C.O.NO 4) [Knowledge]

Part B [Thought Provoking Questions]

Answer the Question. The Question carry twenty marks (1Qx20M=20M)

2. Write the following for the Pressure Draw down test.

a) What is Pressure Draw down test? [1M]
b) "*Draw down data are very noisy*"-Justify your answer. [1M]
c) What are the objective of Pressure draw test? [2M]
d) Write down the procedure for Pressure draw down test? [9M]
e) Which is the best candidate for pressure draw down test? [1M]
f) Write three advantage and three disadvantage of Pressure Draw down test. [6M]

[1+1+2+9+1+6=20] (C.O.NO 3) [Comprehension]

Part C [Problem Solving Questions]

Answer the Question. The Question carry ten marks **(1Qx10M=10M)**

3. Estimate the AOF from the data in the table given below obtained from a modified isochronal test using theoretical method.

[3.5+3.5+3=10] (C.O.NO 4) [Application]

Test	Duration (hours)	P_{wf} or P_{ws} (PSia)	q_g (MMscf/D)
Pretest shut in	20	1948	-
First flow	12	1784	4.50
First shut in	12	1927	-
Second flow	12	1680	5.60
Second shut in	12	1911	-
Third flow	12	1546	6.85
Third shut in	12	1887	-
Fourth flow	12	1355	8.25
Extended flow (stabilize)	81	1233	8.00
Final shut in	120	1948	-

SCHOOL OF Engineering

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

Semester: 5th

Course Code: PET 227

Course Name: Well Test Analysis

Date: 19.11.19

Time: 1 hour

Max Marks: 40

Weightage: 20%

Extract of question distribution [outcome wise & level wise]

Q.NO.	C.O.NO	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels			Thought provoking type [Marks allotted] Bloom's Levels			Problem Solving type [Marks allotted]			Total Marks
			K			C			A			
1	4	4	10									10
2	3	3				20						20
3	4	4							10			10
	Total Marks		10			20			10			40

K =Knowledge Level C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

SCHOOL OF Engineering

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

SOLUTION

Semester: 5th

Course Code: PET 227

Course Name: **Well Test Analysis**

Date: 19/11/19

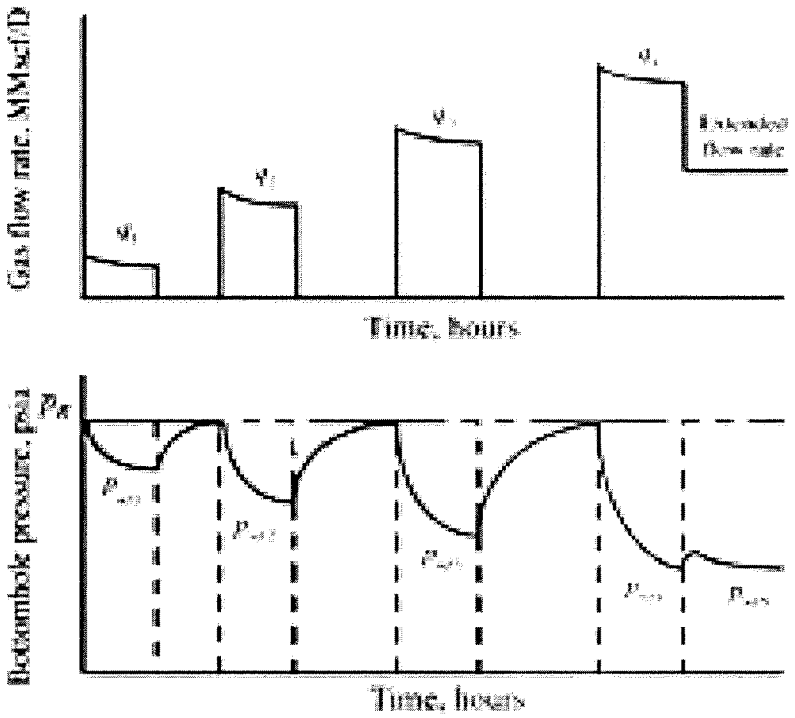
Time: 1 hour

Max Marks: 40

Weightage: 20%

Part A (3Q x4 M = 12 Marks)

Q .No	Solution	Scheme of Marking	Max. Time required for each Question
1	• The isochronal test is conducted by alternately producing the well then shutting it in and allowing it to build to the average reservoir pressure before the beginning of the next production period. • Pressures are measured at several time increments during each flow period. • The times at which the pressures are measured should be the same relative to the beginning of each flow period. • Because less time is required to build to essentially initial pressure after short flow periods than to reach stabilized flow at each rate in a flow-after-flow test, ***the isochronal test is more practical for low-permeability formations.*** • A final stabilized flow point often is obtained at the end of the test. **Fig. 1** illustrates an isochronal test.	**5+2+1.5+ 1.5**	**20**



$$p_p(p_s) - p_p(p_{wf}) = \frac{1.422 \times 10^6 qT}{k_g h} \times \left[\ln\left(\frac{1}{r_w}\right) + \ln\left(\frac{k_g t}{377\phi \bar{\mu}_g \bar{c}_t}\right)^{1/2} - \frac{3}{4} + s + Dq \right].$$

$$r_d = \sqrt{\frac{k_g t}{377\phi \bar{\mu}_g \bar{c}_t}} .$$

Part B

Q No	Solution	Scheme of Marking	Max. Time required for each Question
2	a. The measurement and analysis of pressure data taken after a well is put on production, either initially or following an extended shut-in period. b. Drawdown data are usually noisy, meaning that the pressure moves up and down as fluid flows past the gauges and minute variations in flow rate take place. This is especially true for new wells, in which well cleanup commonly occurs for days after production has begun. Such data are difficult to interpret, and the noise often obscures regions of interest to the analyst. c. The fundamental objective of drawdown testing is to obtain the average permeability of the reservoir rock within the drainage area of the well and to assess the degree of damage or stimulation induced in the vicinity of the wellbore through the drilling and	**1+1+2+9 +1+6**	20

completion practices. • Other objectives are to determine the pore volume and detect reservoir homogeneities within the drainage area of the reservoir.

d. Procedure

- The well is shut in for a period of time long enough to allow the pressure to equalize throughout the reservoir.
- The pressure equipment is lowered into the well.
- The flow is begun at a constant rate and the bottom hole pressure is measured continuously.
- Install the equipment on a well that has been shut-in and stable.
- "Stable" is defined as the shut-in well head pressure changing at a rate of less than 1 psi per hour.
- Check for leaks in the system after installation.
- The SPIDR system must be recording for at least 15 minutes prior to opening the well (check the box for the SPIDR system wake-up time).
- Begin flowing the well on a single choke size. If the well must be "stepped-up", try to get the well up to full rate within 30 minutes. Continue flowing on a constant choke size for the duration of the test. If shut-ins or flow interruptions occur during the course of the drawdown, try to get the well back on-line as soon as possible on the same choke size.

e. The drawdown test is used in the exploratory wells (new reservoirs) or the wells that have been shut in for buildup test and those wells whose loss of revenue due to production in buildup test can't be tolerated.

f. Advantage

- The main advantage of pressure drawdown is that there is no loss of cash flow due to shut in of the well during the test period.
- It also determines the boundaries of the reservoir and skin of formation.
- Suitable in new wells. With no need to lose production, reservoir size can be determined.

Disadvantage

- The main disadvantage of drawdown test is that difficulty to flow the well at constant rate.
- It doesn't determine the average reservoir pressure.
- The drawback to running a drawdown is that the rate may not be constant. However, changing the choke periodically to maintain a constant rate will cause more problems than letting the rate fluctuate. In order to get accurate analysis on a drawdown, it is critical that no choke changes occur during the test.

Part C (2Q x10 M =20 Marks)

<table>
<tr><th>Q No</th><th>Solution</th><th>Scheme of Marking</th><th>Max. Time required for each Question</th></tr>
<tr><td>3</td><td>

q_g (MMacf/D)	P_{ws} (Psia)	P_{wf} (PSia)	$P_{ws}^2 - P_{wf}^2$ (Psia^2)
4.50	1948	1784	612048
5.60	1927	1680	890929
6.85	1911	1546	1261805
8.25	1887	1355	1724744
8.00	1948	1233	2274415

We know that theoretical equation for stabilize flow and transient flow written in the form of

$$\bar{p}^2 - p_{wf}^2 = aq_g + bq_g^2,$$

$P_{ws}^2 - P_{wf}^2 / q_g = a + b\ q_g$--(A)

209060=a + b*8.25...(B)

184205=a + b*6.85...(C)

By subtracting equation (C) from equation (B) it is found that

b= 17753

Using b value for stabilize flow we get

$$a = \frac{(\bar{p}^2 - p_{wf}^2)_s - bq_{gs}^2}{q_{gs}}$$

a= 2274415-(17753*8^2)/8

a= 14277.875

Now we know that for AOF (Absolute Open Flow) Pwf=14.7 PSia

So, using the below formula value of AOF

</td><td>3.5+3.5+3</td><td>20</td></tr>
</table>

	$$\bar{p}^2 - p_{wf}^2 = aq_g + bq_g^2$$ 19482-14.72=142277.88* q(AOF)+ 17753* q(AOF)2 Solving for q(AOF) q=11.51 MMSCF/D		

Roll No												

GAIN MORE KNOWLEDGE
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PRESIDENCY UNIVERSITY
BENGALURU

SCHOOL OF ENGINEERING

END TERM FINAL EXAMINATION

Semester: Odd Semester: 2019-20
Course Code: PET 227
Course Name: WELL TESTING ANALYSIS
Program & Sem: B.Tech (PET)& V

Date: 28 December 2019
Time: 9.30 AM to 12.30 PM
Max Marks: 80
Weightage: 40%

Instructions:
(i) Read the all questions carefully and answer accordingly.
(ii) Scientific and nonscientific calculator are allowed
(iii) Question paper consist of three parts

Part A [Memory Recall Questions]

Answer all the Questions. Each Question carries 4 marks. (5Qx4M=20M)

1 Write four assumption. of diffusivity equation. (C.O.No.1) [Knowledge]

2. Explain briefly the different regions present in actual buildup test with diagram. (C.O.No.2) [Knowledge]

3. Write four difference between the Pressure draw down test and buildup test. (C.O.No.3) [Knowledge]

4. Explain briefly modified isochronal test. How it is differ from isochronal test? (C.O.No.4) [Knowledge]

5. What are the main objectives of Interference test? Briefly explain how it is conducted? (C.O.No.5) [Knowledge]

Part B [Thought Provoking Questions]

Answer all the Questions. Each Question carries 10 marks. (4Qx10M=40M)

6. Write the answer for the following question
   a. Derive Pressure equation for a flowing well in a reservoir where there exists a fault/boundary. (C.O.No.1) [Comprehension]
   b. Derive the equation of slope (m) to find permeability from buildup test with diagram. (C.O.No.2) [Comprehension]

7. Write short notes on
   a. Drill Stem Test (DST).
   b. Describe Interference test. (C.O.No.5) [Comprehension]

8. As a Reservoir Engineer in an oil company before performing well testing write a report on advantage and disadvantage of Flow after flow and Isochronal test. Which method can be adopted? Justify your answer. (C.O.No.4) [Comprehension]

9. Describe different Type Curves. Explain how they are used in well test analysis.

(C.O.No.4) [Comprehension]

Part C [Problem Solving Questions]

Answer the Question. The Question carries 20 marks. (1Qx20M=20M)

10. What is Absolute Open Flow (AOF)? Draw one IPR graph and show the AOF point and no flow point. Estimate the Absolute Open Flow from the data in the table given below obtained from a modified Isochronal test using theoretical method.

(C.O.No.4) [Application]

Test	Duration (hours)	P_{wf} or P_{ws} (PSia)	q_g (MMscf/D)
Pretest shut in	20	1948	-
First flow	12	1784	4.50
First shut in	12	1927	-
Second flow	12	1680	5.60
Second shut in	12	1911	-
Third flow	12	1546	6.85
Third shut in	12	1887	-
Fourth flow	12	1355	8.25
Extended flow (stabilize)	81	1233	8.00
Final shut in	120	1948	-

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE
REACH GREATER HEIGHTS

END TERM FINAL EXAMINATION

Extract of question distribution [outcome wise & level wise]

Q.NO.	C.O.NO (% age of CO)	Unit/Module Number/Unit /Module Title	Memory recall type [Marks allotted] Bloom's Levels	Thought provoking type [Marks allotted] Bloom's Levels	Problem Solving type [Marks allotted]	Total Marks
			K	C	A	
Q. NO1	C.O.1	Unit-I	4	-	-	4
Q. NO2	C.O.2	Unit-II	4	-	-	4
Q. NO3	C.O.3	Unit-III	4	-	-	4
Q. NO4	C.O.4	Unit-IV	4	-	-	4
Q. NO5	C.O.5	Unit-V	4	-	-	4
Q.NO.6	C.O. 1 & 2	Unit-I & II	-	10	-	10
Q.NO.7	C.O. 5	Unit-V	-	10	-	10
Q.NO.8	C.O. 4	Unit-IV	-	10	-	10
Q.NO.9	C.O. 4	Unit-IV	-	10		10
Q.NO.10	C.O. 4	Unit-IV	-	-	20	20
	Total Marks		20	40	20	80

K =Knowledge Level   C = Comprehension Level, A = Application Level

Note: While setting all types of questions the general guideline is that about 60%

Of the questions must be such that even a below average students must be able to attempt, About 20% of the questions must be such that only above average students must be able to attempt and finally 20% of the questions must be such that only the bright students must be able to attempt.

I hereby certify that all the questions are set as per the above guidelines.

Faculty Signature:

Reviewer Commend:

Format of Answer Scheme

SCHOOL OF ENGINEERING

GAIN MORE KNOWLEDGE REACH GREATER HEIGHTS

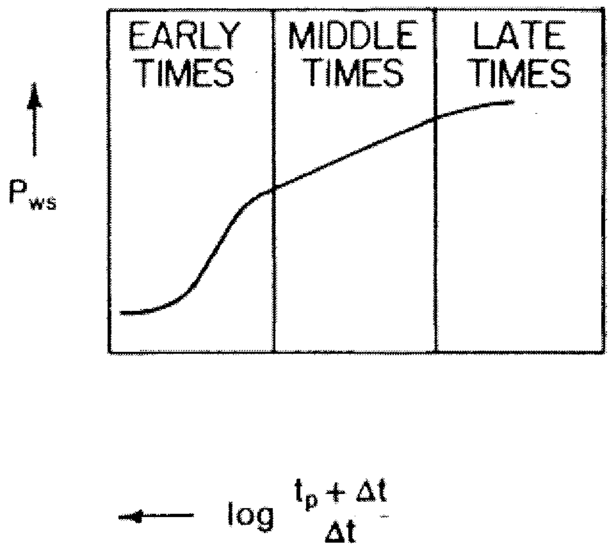
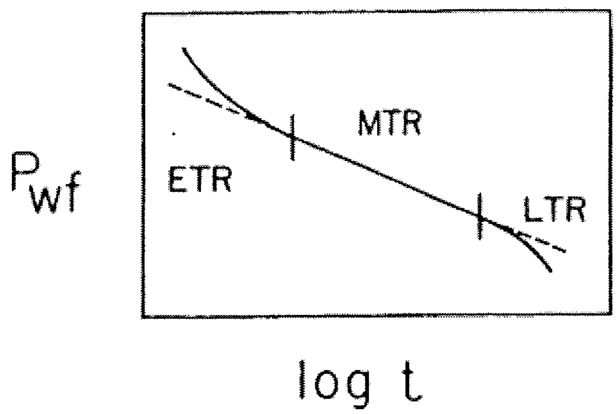
SOLUTION

Semester: Odd Sem. 2019-20
Course Code: PET-227
Course Name: Well Test Analysis
Program & Sem: B.Tech & 5th Sem

Date: 28th Dec'19
Time: 9.30 AM- 12.30 PM
Max Marks: 80
Weightage: 40%

Part A (5Q x 4M = 20Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
1	The diffusivity equation was derived under the following assumptions: • Isothermal flow • A single fluid phase • Constant isotropic permeability • Fluid viscosity independent of pressure • Compressibility independent of pressure • Low fluid compressibility	4	5
2	**Early-Time Region** As we have noted, most wells have altered permeability near the wellbore. Until the pressure transient caused by shutting in the well for the buildup test moves through this region of altered permeability, there is no reason to expect a straight-line slope that is related to formation permeability. (We should note that the ideal buildup curve – i.e., one with a single straight line over virtually all time – is possible for a damaged well only when the damage is concentrated in a very thin skin at the sandface.) **Middle-Time Region** When the radius of investigation has moved beyond the influence of the altered zone near the tested well, and when afterflow has ceased distorting the pressure buildup test data, we usually observe the ideal straight line whose slope is related to formation permeability. (This straight line ordinarily will continue until the radius of investigation reaches one or more reservoir boundaries, massive heterogeneities, or a fluid/fluid contact.)	3+1	10

	Late-Time Region Given enough time, the radius of investigation eventually will reach the drainage boundaries of a well. (In this late-time region pressure behavior is influenced by boundary configuration, interference from nearby wells, significant reservoir heterogeneities, and fluid/fluid contacts.)  Fig. 2.4 – Actual buildup test graph. 		
3	Pressure drawdown tests are conducted by producing the well at a known rate, or sequence of rates, while measuring changes in pressure with time. Data from drawdown tests can be very noisy. These tests are considered when the economic environment requires a minimum loss of production time. Pressure buildup tests are conducted by producing the well, and then shutting it in while measuring changes in pressure with time. Ideally, the flow preceding the shut-in would at least be long enough for the rates to stabilize. The quality of data obtained from buildup tests is far superior to that of	**2+2**	**10**

	drawdown tests because the rates are stable (zero). When analyzing data from buildup tests, it is valuable to analyze the drawdown and buildup data.		
4	The time to build up to the average reservoir pressure before flowing for a certain period of time still may be impractical, even after short flow periods. Consequently, a modification of the isochronal test was developed to shorten test times further. The objective of the modified isochronal test is to obtain the same data as in an isochronal test without using the sometimes lengthy shut-in periods required to reach the average reservoir pressure in the drainage area of the well. Modified isochronal test is conducted like an isochronal test, except the shut-in periods are of equal duration. The shut-in periods should equal or exceed the length of the flow periods. Because the well does not build up to average reservoir pressure after each flow period, the shut-in sandface pressures recorded immediately before each flow period rather than the average reservoir pressure are used in the test analysis. As a result, the modified isochronal test is less accurate than the isochronal test. As the duration of the shut-in periods increases, the accuracy of the modified isochronal test also increases. Again, a final stabilized flow point usually is obtained at the end of the test but is not required for analyzing the test data.	**2+2**	**10**

5	Interference tests have two major objectives. They are used (1) to determine whether two or more wells are in pressure communication (i.e., in the same reservoir) and (2) when communication exists, to provide estimates of permeability k and porosity/compressibility product, ϕc_t, in the vicinity of the tested wells. An interference test is conducted by producing from or injecting into at least one well (the active well) and by observing the pressure response in at least one other well (the observation well). Fig. 6.1 indicates the typical test program with one active well and one observation well. As the figure indicates, an active well starts producing from a reservoir at uniform pressure at Time 0. Pressure in an observation well, a distance r away, begins to respond after some time lag (related to the time for the radius of investigation corresponding to the rate change at the active well to reach the observation well). The pressure in the active well begins to decline immediately, of course. The magnitude and timing of the deviation in pressure response at the observation well depends on reservoir rock and fluid properties in the vicinity of the active and observation wells.	2+2	10

Part B (4Q x 10M = 40 Mark

Q No	Solution	Scheme of Marking	Max. Time required for each Question
6	**a.** We know if there is a boundary or fault near a well then we can write Pressure equation as (using Superposition principle) PI-P =- 70.6 qμB/kh [ln(1688ΦμCtRw^2/ktp) –2S] -- 70.6 qμB/kh Ei(-948ΦμCt4L^2/ktp) Now applying Horner's equation, we get -70.6 qμB/kh [ln(1688ΦμCtRw^2/k(tp+Δt) –2S] -70.6 (-q)μB/kh [ln(1688ΦμCtRw^2/kΔt) –2S] -70.6 qμB/kh Ei(-3792ΦμCtL^2/k(tp +Δt) -70.6 (-q)μB/kh Ei(-3792ΦμCtL^2/kΔt)	5+5	25

If Δt>>tp, then we can write Ei function as ln function.

We get

Pi-pws = 70.6qBμ/kh[ln (tp +Δt)/Δt] + [ln (tp +Δt)/Δt]

= 141.2qBμ/kh[ln (tp +Δt)/Δt]

= 325.2qBμ/kh[log (tp +Δt)/Δt]

b.

$$p_i - p_{ws} = -70.6\frac{qB\mu}{kh}\left\{\ln\left[\frac{1{,}688\,\phi\mu c_t r_w^2}{k(t_p+\Delta t)}\right] - 2s\right\}$$

$$-70.6\frac{(-q)\,B\mu}{kh}\left[\ln\left(\frac{1{,}688\,\phi\mu c_t r_w^2}{k\Delta t}\right) - 2s\right],$$

which becomes

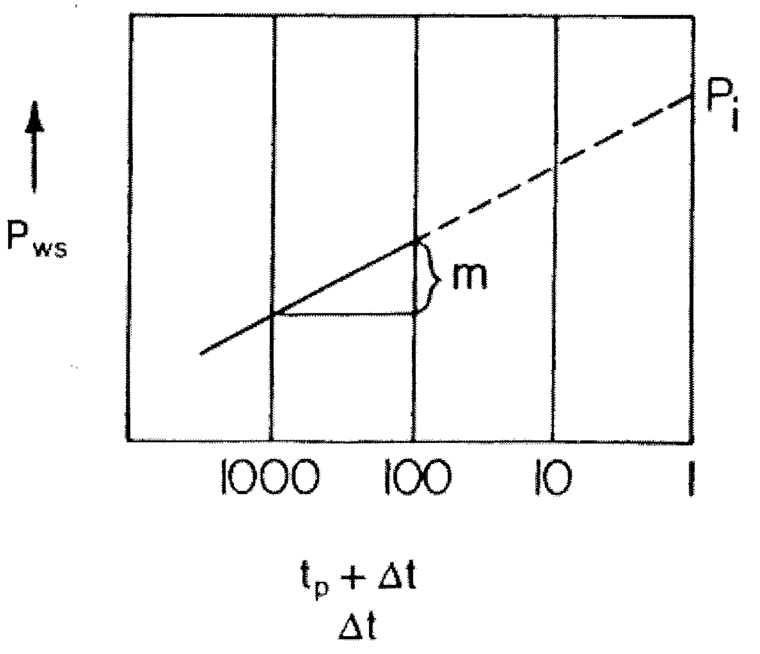
$$p_{ws} = p_i - 70.6\frac{qB\mu}{kh}\ln\left[(t_p+\Delta t)/\Delta t\right],$$

or

$$p_{ws} = p_i - 162.6\frac{qB\mu}{kh}\log\left[(t_p+\Delta t)/\Delta t\right]. \quad \ldots (2.1)$$

The form of Eq. 2.1 suggests that shut-in BHP, p_{ws}, recorded during a pressure buildup test should plot as a straight-line function of log $[(t_p+\Delta t)/\Delta t]$. Further, the slope m of this straight line should be

$$m = -162.6\frac{qB\mu}{kh}.$$



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a. Drillstem test (DST)

$$c_r = \frac{1.36 \times 10^{-6}}{0.08} = 17 \times 10^{-6}\ \text{psi}^{-1}.$$

6.4 Drillstem Tests

A drillstem test (DST)[8,9] provides a means of estimating formation and fluid properties before completion of a well. Basically, a DST is a temporary completion of a well. The DST tool is an arrangement of packers and valves placed on the end of the drillpipe. This arrangement can be used to isolate a zone of interest and to let it produce into the drillpipe or drillstem. A fluid sample is obtained in the test; thus, the test can tell us the types of fluids the well will produce if it is completed in the tested formation.

With the surface-actuated valves on a DST device, it is possible to have a sequence of flow periods followed by shut-in periods. A pressure recorder on the DST device can record pressures during the flow and shut-in periods. The pressures recorded during the shut-in periods can be particularly valuable for estimating formation characteristics such as permeability/thickness product and skin factor. These data also can be used to determine possible pressure depletion during the test.

To illustrate how a typical DST is performed, we will examine a schematic chart (Fig. 6.16) of pressure vs. time from a test with two flow periods and two shut-in periods.

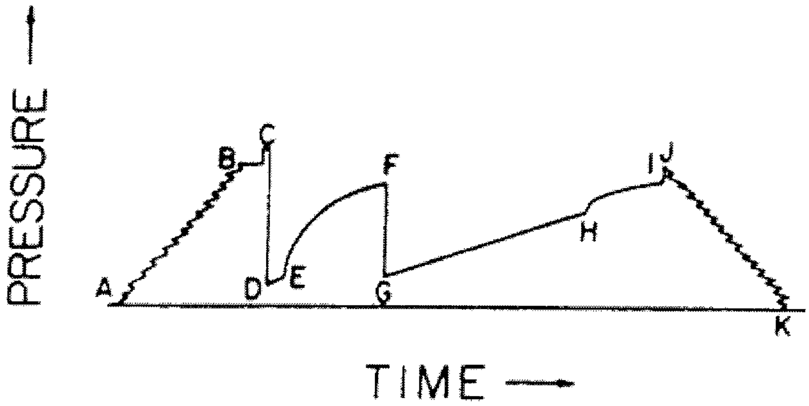
At Point A, the tool is lowered into the hole. Between Points A and B, the ever-increasing mud-column pressure is recorded; at Point B, the tool is on bottom. When the packers are set, the mud column is compressed and a still higher pressure is recorded at Point C. The tool is opened for an initial flow period, and the pressure drops to Point D as shown. As fluid accumulates in the drillstem above the pressure gauge, the pressure rises. Finally, at Point E, the well is shut in for an initial pressure buildup test. After a suitable shut-in period, the well is reopened for a second final flow period, from Point G to Point H. This final flow period is followed by a final shut-in period (from Point H to Point I). The packers are then released, and the hydrostatic pressure of the mud column is again imposed on the pressure gauge. The testing device is then removed from the hole (Point J to Point K).

The initial flow period is usually brief (5 to 10 minutes); its purpose is to draw down the pressure slightly near the wellbore (perhaps letting any mud-filtrate-invaded zone bleed back to or below static reservoir pressure). The initial shut-in period, often 30 to 60 minutes, is designed to let the pressure build back to true static formation pressure. This initial shut-in pressure on a DST may be the best measurement made of static reservoir pressure.

The second flow period is designed to capture a large sample of formation fluid and to draw down the pressure in the formation to the maximum distance and extent possible within the time that is possible to allow for the DST – frequently 30 minutes to several hours. The second shut-in period is designed to obtain good pressure buildup data so that formation properties can be estimated. In addition, comparison of the final (or extrapolated) pressure from the second shut-in period to the initial shut-in pressure can indicate that pressure depletion has occurred during the DST and that the well thus has been tested in a small, noncommercial reservoir. The desired length of the second shut-in period varies from equal to the second flow period (for high-permeability formations) to twice the length of the second flow period (for low-permeability formations).

Theory much like that used for an ordinary pressure buildup test following production at constant rate is used for analyzing the shut-in periods on a DST. This is true even though the flow rate preceding a shut-in period in a DST usually decreases continuously. Usually, the *average* production rate can be used as a good approximation in buildup test analyses; this average rate of production is determined by dividing the fluid recovery by the length of the flow period.

To analyze the buildup test, we plot p_{ws} vs. log $(t_p + \Delta t)/\Delta t$, where t_p is now the *actual* flowing time at the average rate q. The permeability/thickness product is found from the relationship $kh = 162.6\, qB\mu/m$. Usually, a fluid sample will not yet have been analyzed in the laboratory; accordingly, correlations (Appendix D) relating μ and B to produced fluid properties must be used.



b. Interference test.

- The isochronal test is conducted by alternately producing the well then shutting it in and allowing it to build to the average reservoir pressure before the beginning of the next production period.

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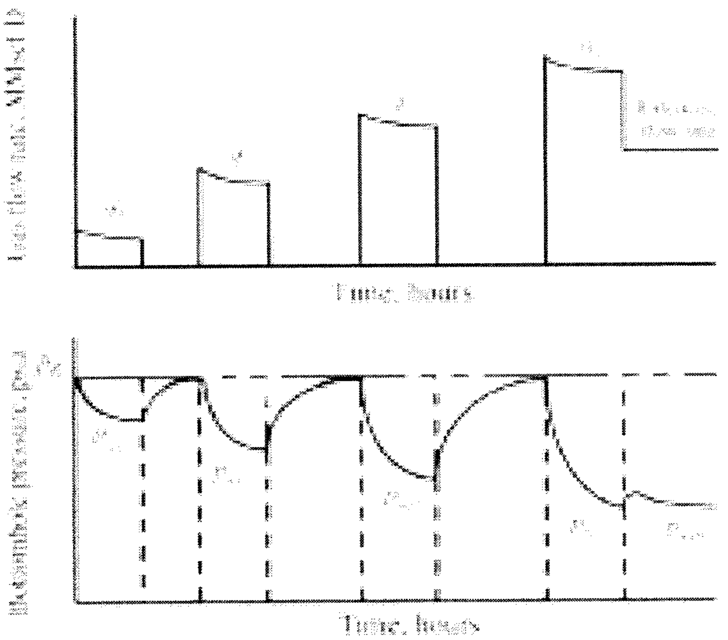
- Pressures are measured at several time increments during each flow period.
- The times at which the pressures are measured should be the same relative to the beginning of each flow period.
- Because less time is required to build to essentially initial pressure after short flow periods than to reach stabilized flow at each rate in a flow-after-flow test, ***the isochronal test is more practical for low-permeability formations.***
- A final stabilized flow point often is obtained at the end of the test. **Fig. 1** illustrates an isochronal test.



$$p_p(p_s) - p_p(p_{wf}) = \frac{1.422 \times 10^6 qT}{k_g h} \times \left[\ln\left(\frac{1}{r_w}\right) + \ln\left(\frac{k_g t}{377\phi\bar{\mu}_g\bar{c}_t}\right)^{1/2} - \frac{3}{4} + s + Dq \right].$$

$$r_d = \sqrt{\frac{k_g t}{377\phi\bar{\mu}_g\bar{c}_t}}.$$

8	Gas well deliverability tests have been called backpressure tests because they test flow against particular pipeline backpressure greater than atmospheric pressure. The backpressure test is also referred to as a flow-after-flow test, or a multipoint test. In this testing method, a well flows at a selected constant rate until pressure stabilizes, i.e., pseudo-steady-state is reached. The stabilized rate and pressure are recorded; the rate is then changed and the well flows until the pressure stabilizes again at the new rate. The process is repeated for a total of three, four, or five rates. The behavior of flow rate and pressure with time is illustrated in Figure 4.8 for		25

qsc increasing in sequence. The tests may be run in the reverse sequence. A plot of typical flow-after-flow data is shown in Figure 4-9.

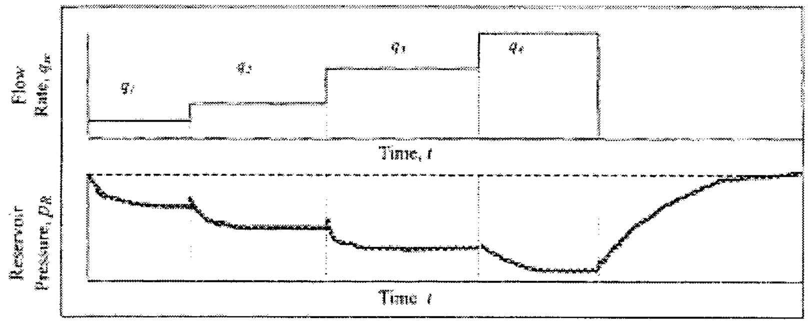


Figure 4–8. Conventional flow rate and pressure diagrams.

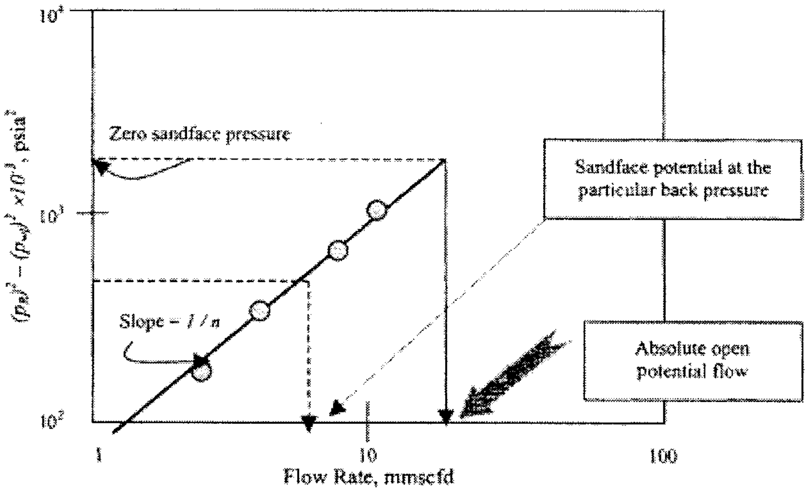


Figure 4–9. Deliverability test plot.

The isochronal test consists of alternately closing in the well until a stabilized or very nearly stabilized pressure ~pR is reached and the well is flowed at different rates for a set period of time t, the flowing bottom-hole pressure pwf at time t being recorded. One flow test is conducted for a time period long enough to attain stabilized conditions and is usually referred to as the extended flow period. The behavior of the flow rate and pressure with various time periods is shown in Figure 4-6. The characteristic slope n, developed under short flow conditions, is applicable to long-time flow conditions. Also, the decline in the performance coefficient C is a variable with respect to time.

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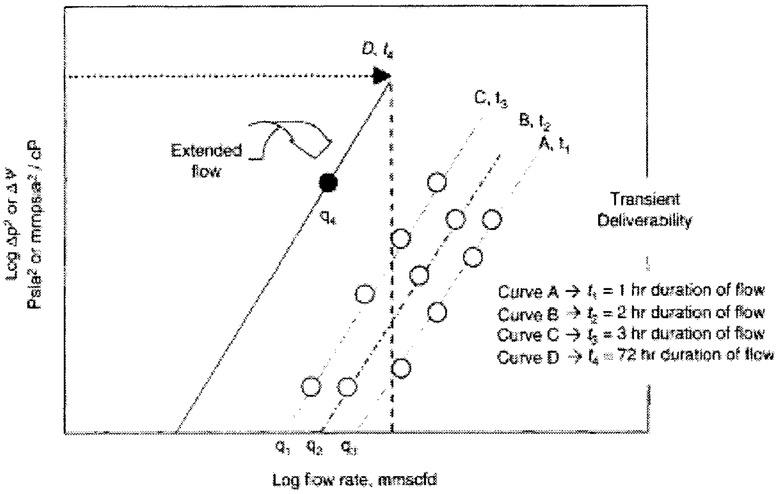

Figure 4–6. Isochronal performance curves.

$$n = \frac{\log q_{sc1} - \log q_{sc2}}{\log \Delta(p)_1^2 - \log \Delta(p)_2^2}$$

where C is the performance coefficient, and n is the exponent corresponding to the slope of the straight-line relationship between qsc and (~p2 R — pfy plotted on logarithmic coordinates (see Figure 4-5). Exponents of n < 0.5 may be caused by liquid accumulation in the wellbore.
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This chapter discusses the quantitative use of type curves in well test analysis. The objective of this chapter is limited basically to illustrating how a representative sample of type curves can be used as analysis aids. Other major type curves in use today are discussed in the SPE well testing monograph.[1] However, type curves for specialized situations are appearing frequently in the literature, and even that monograph is not completely current. We hope that the fundamentals of type-curve use presented in this chapter will allow the reader to understand and to apply newer type curves as they appear in the literature.

Specific type curves discussed include (1) Ramey *et al.*'s type curves[2-4] for buildup and constant-rate drawdown tests; (2) McKinley's type curves[5,6] for the same applications; and (3) Gringarten *et al.*'s[7] type curves for vertically fractured wells with uniform flux.

4.2 Fundamentals of Type Curves

Many type curves commonly are used to determine formation permeability and to characterize damage and stimulation of the tested well. Further, some are used to determine the beginning of the MTR for a Horner analysis. Most of these curves were generated by simulating constant-rate pressure drawdown (or injection) tests; however, most also can be applied to buildup (or falloff) tests if an equivalent shut-in time[8] is used as the time variable on the graph.

Conventional test analysis techniques (such as the Horner method for buildup tests) share these objectives. However, type curves are advantageous because they may allow test interpretation even when wellbore storage distorts most or all of the test data; in that case, conventional methods fail.

The use of type curves for fractured wells has a further advantage. In a single analytical technique, type curves combine the linear flow that occurs at early times in many fractured reservoirs, the radial flow that may occur later after the radius of investigation has moved beyond the region influenced by the fracture, and the effects of reservoir boundaries that may appear before a true MTR line is established in a pressure transient test on a fractured well.

Fundamentally, a type curve is a preplotted family of pressure drawdown curves. The most fundamental of these curves (Ramey's[2]) is a plot of dimensionless pressure change, p_D, vs. dimensionless time change, t_D. This curve, reproduced in Fig. 4.1 (identical to Fig. 1.6), has two parameters that distinguish the curves from one another: the skin factor s and a dimensionless wellbore storage constant, C_{sD}. For an infinite-acting reservoir, specification of C_{sD} and s *uniquely* determines the value of p_D at a given value of t_D. Proof of this follows from application of the techniques discussed in Appendix B. If we put the differential equation describing a flow test in dimensionless form (along with its initial and boundary conditions), then the solution, p_D, is determined uniquely by specification of the independent variables (in this case, t_D and r_D), of all dimensionless parameters that appear in the equation, and of initial and boundary conditions (in this case, s and C_{sD}). Further, in most such solutions, we are interested in wellbore pressures of a tested well; here, dimensionless radius, $r_D = r/r_w$, has a fixed value of unity and thus does not appear as a parameter in the solution.

Thus, type curves are generated by obtaining solutions to the flow equations (e.g., the diffusivity equation) with specified initial and boundary conditions. Some of these solutions are analytical; others are based on finite-difference approximations generated by computer reservoir simulators. For example, Ramey's type curves were generated from analytical solutions to the diffusivity equation, with the initial condition that the reservoir be at uniform pressure before the drawdown test, and with boundary conditions of (1) infinitely large outer drainage radius and (2) constant *surface* withdrawal rate combined with wellbore storage, which results in variable *sandface* withdrawal rate. A skin factor, s, is used to characterize wellbore damage or stimulation; as we have seen, this causes an additional pressure drop, Δp_s, which is proportional to the instantaneous sandface flow rate (which changes with

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4.3 Ramey's Type Curves

Ramey's[2] type curves were generated for the situation of a constant-rate pressure drawdown test in a reservoir with slightly compressible, single-phase liquid flowing; sufficient homogeneity such that the radial diffusivity equation adequately models flow in the reservoir; uniform pressure in the drainage area of the well before production; infinite-acting reservoir (no boundary effects during the flow period of interest for test analysis purposes); constant withdrawal rate at the surface; and wellbore storage and concentrated wellbore damage or stimulation characterized by a skin factor, s. This list of assumptions is tedious, but it is also important. When one or more of these assumptions is not valid in a specific case, there is no assurance that use of the type curves can lead to a valid test interpretation. (Some of these limitations can be removed, as we will note later in this chapter. Of major importance is that the curves can be used for buildup tests and for gas well tests.) The result of Ramey's work is shown in Fig. 4.1.

Some important properties of these curves follow.

1. Examination of the analytical solution on which the type curves are based shows that, at earliest times when wellbore unloading is responsible for 100% of the flow in a drawdown test (or afterflow rate equals rate before shut-in in a buildup test), Δp is a linear function of Δt (Δp is pressure change since the test began and Δt is time elapsed since the test began). Thus, the log Δp-logΔt curve is also linear with a slope of unity (a 45° line) and the wellbore storage constant C_s can be determined from any point (Δt, Δp) on this line (Fig. 4.2) from the relation

4.4 McKinley's Type Curves

McKinley[5] proposed type curves with the primary objective of characterizing damage or stimulation in a drawdown or buildup test in which wellbore storage distorts most or all of the data, thus making this characterization possible with relatively short-term tests.

In constructing his type curves, McKinley observed that the ratio of pressure change, Δp, to flow rate causing the change, qB, is a function of several dimensionless quantities:

$$\frac{\Delta p}{qB} = f\left(\frac{kh\Delta t}{\mu C_s}, \frac{k\Delta t}{\phi\mu c_t r_w^2}, \frac{r_e}{r_w}, \frac{\Delta t}{t_p}\right).$$

Type curves with this many parameters would be difficult, if not impossible, to use. Accordingly, McKinley simplified the problem in the following way.

1. He assumed that the well has produced sufficiently long (essentially to stabilization) that the last group, $\Delta t/t_p$, is not important.

2. He ignored boundary effects except approximately and, thus, ignored r_e/r_w in the basic logic used to construct the type curves.

4. To take into account the remaining parameters that *do* have a significant influence on test results, McKinley plotted his type curves as Δt (ordinate) vs. $5.615\ C_s\Delta p/qB$ (abscissa), with the single parameter $kh/5.615\ C_s\mu$. A small-scale version of McKinley's curves is shown in Fig. 4.6.

5. Note that the skin factor s does not appear as a parameter in the McKinley curves. Instead, McKinley's curves assess damage or stimulation by noting that the earliest wellbore-storage-distorted data are dominated by the effective near-well transmissibility $(kh/\mu)_{wb}$; thus, a type-curve match of the earliest data in a test should allow calculation of this quantity. Later, after wellbore storage distortion has diminished, the pressure/time behavior is governed by the transmissibility in the formation, kh/μ; this quantity also can be estimated from a type-curve match – but for the later data only.

6. McKinley approximated boundary effects by plotting the simulator-generated type curves for about one-fifth log cycle beyond the end of wellbore storage distortion (where the curve has the same shape as for $C_s = 0$) and then making the curves vertical. This step roughly simulates drainage conditions of 40-acre spacing. Note that this gives the curves early-, middle-, and late-time regions – but remember that the curves were designed to be used primarily to analyze *early-time* data. When the curves are applied to drawdown tests, they *must* be applied to early-time data only; they do not properly simulate boundary effects in drawdown tests.

3. Gringarten type curves for fractured reservoir

fractures with two equal-length wings were created. The curves discussed in this section assume *uniform flux* into the fracture (same flow rate per unit cross-sectional area of fracture from wellbore to fracture tip). High fracture conductivity is required to achieve uniform flux, but this is not identical to an infinitely conductive fracture (no pressure drop from fracture tip to wellbore), as Gringarten *et al.* demonstrated.[7]

The study was made for finite reservoirs (i.e., boundary effects become important at later times in the test). The reservoir is assumed to be at uniform pressure, p_i, initially. The type curve (Fig. 4.11), developed for a constant-rate drawdown test for a slightly compressible liquid, also can be used for buildup tests (for $\Delta t_{max} \le 0.1\ t_p$) and for gas wells* using the modifications discussed earlier. Wellbore storage effects are ignored.

All the dimensionless variables and parameters considered important are taken into account in Fig. 4.11, which is a log-log plot of p_D vs. $t_D r_w^2/L_f^2$ with parameter x_e/L_f. In these parameters, L_f is the fracture half-length and x_e is the distance from the well to the side of the square drainage area in which it is assumed to be centered. Dimensionless pressure has the usual definition,

$$p_D = \frac{kh(p_i - p_{wf})}{141.2\ qB\mu}\ \text{(drawdown test)},$$

and

$$\frac{t_D r_w^2}{L_f^2} = \frac{0.000264\ kt}{\phi\mu c_t L_f^2} = t_{DL_f}. \qquad (4.17)$$

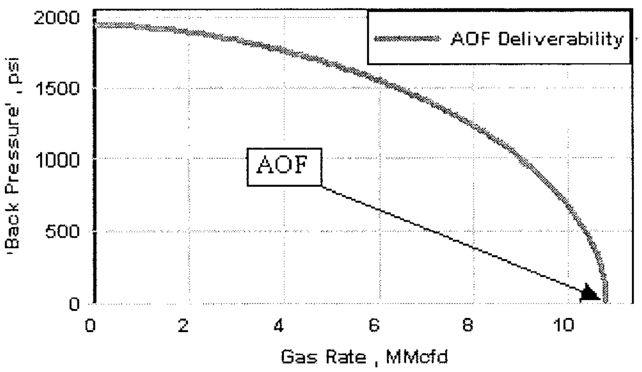
Several features of Fig. 4.11 are of interest:

1. The slope of the log-log plot is 1/2 up to $t_{DL_f} = 0.16$ for $x_e/L_f > 1$. This is linear flow. We have shown that, in linear flow,

Part C (1Q x 20M = 20Marks)

Q No	Solution	Scheme of Marking	Max. Time required for each Question
10	The absolute open flow (AOF) potential of a well is the rate at which the well would produce against zero sand face back pressure. It is used as a measure of gas well performance because it quantifies the ability of a reservoir to deliver gas to the wellbore. Deliverability tests make possible the prediction of flow rates against any particular back pressure, including AOF when the back pressure is zero.	3+3+14	30

I.P.R.



q_g (MMacf/D)	P_{ws} (Psia)	P_{wf} (PSia)	P_{ws}^2 - P_{wf}^2 ($Psia^2$)	P_{ws}^2 - P_{wf}^2/ q_g
4.50	1948	1784	612048	136011
5.60	1927	1680	890929	159094
6.85	1911	1546	1261805	184205
8.25	1887	1355	1724744	209060
8.00	1948	1233	2274415	

We know that theoretical equation for stabilize flow and transient flow written in the form of

$$\bar{p}^2 - p_{wf}^2 = aq_g + bq_g^2,$$

P_{ws}^2 - P_{wf}^2/ q_g=a +b q_g---(A)

209060=a + b*8.25…………………………………………..(B)

184205=a + b*6.85…………………………………………..(C)

By subtracting equation (C) from equation (B) it is found that

b= 17753

Using b value for stabilize flow we get

$$a = \frac{(\bar{p}^2 - p_{wf}^2)_s - b q_{gs}^2}{q_{gs}}$$

a= 2274415-(17753*8^2)/8

a= 14277.875

Now we know that for AOF (Absolute Open Flow) Pwf=14.7 PSia

So, using the below formula value of AOF

$$\bar{p}^2 - p_{wf}^2 = a q_g + b q_g^2$$

19482-14.72=142277.88* q(AOF)+ 17753* q(AOF)2

Solving for q(AOF)

q=11.51 MMSCF/D