Drill Stem Testing

BACKGROUND

Objective

Drill stem testing provides a method of temporarily completing a well to determine the productive characteristics of a specific zone. As originally conceived, a Drill Stem Test provided primarily an indication of formation content. The pressure chart was available, but served mainly to evaluate tool operation.

Currently, analysis of pressure data in a properly planned and executed DST can provide, at reasonable cost, good data to help evaluate the productivity of the zone, the completion practices, the extent of formation damage, and perhaps the need for stimulation.

Reservoir Characteristics

Reservoir characteristics that may be estimated from DST analysis include:

—*Average Effective Permeability*—This may be better than core permeability since much greater volume is averaged. Also, effective permeability rather than absolute permeability is obtained.

—*Reservoir Pressure*—Measured, if shut-in time is sufficient, or calculated, if not.

—*Wellbore Damage*—Damage ratio method permits estimation of what the well should make without damage.

—*Barriers—Permeability Changes—Fluid Contacts*—These reservoir anomalies affect the slope of the pressure buildup plot. They usually require substantiating data to differentiate one from the other.

—*Radius of Investigation*—An estimate of how far away from the wellbore the DST can "see."

—*Depletion*—Can be detected if reservoir is small and test is properly run.

In summary, the DST, properly applied, has become a very useful tool for the Well Completion Engineer.

DST Tools

1-surface pressure control valve

2-Drill pipe

3-Reverse circulation valve

4-Drill collar

5-Closed in pressure Valve

6-Reverse circulating ports

7-flow chocke

8-Tester valve

9-Pressure recorder

10-Hydraulic Jar

11-Packer

12-Tail pipe Anchor

DST Operational Procedure

After condition the hole (circulating the drilling mud) many times to cleaned it, the drillstring equipped with previous tools is running into hole to make DST test .DST test is usually composed of two flow periods and two shut in periods as follows:

1-Initial flow period: This flow period is ranged from 5 to 10 min.The objective of this flow period is to relieve the payzone from increasing pressure caused by setting of packer.

2-Initial shut in period: This shut in period is ranged from 30 to 60 min.The purpose of this shut in period is to established static reservoir pressure(P_i).

3-Final flow period: This period extended about 60 min.The purpose of this period is to measure flow rate and to evaluate the formation for some distance from the well(radius of investigation).

4-Final Shut in Period: This period extended from 30 min to 1hr.The purpose of this period is to calculate reservoir characteristics such as permeability ,skin factor,and transmissibility .

<u>DST Pressure Behavior(Pressure.vs. Time plot)</u>

The entire sequence of previous flow and shut in periods is reordered on pressure chart(as plot between pressure and time during flow and shut in periods on pressure chart)as shown in the following figure:

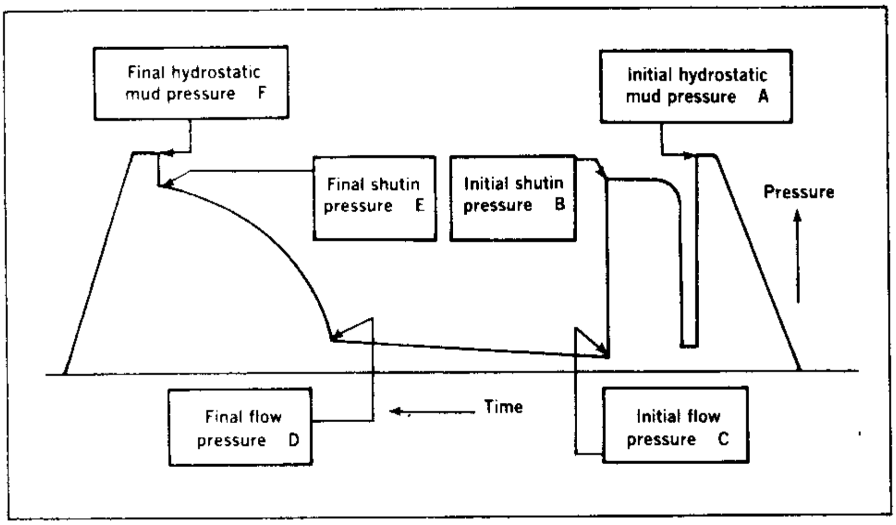


FIG. *3-13—Sequence of events in a DST.*

<u>General considerations</u>

The following factors should be considered for successful DST testing:

1-condition the hole: By circulating drilling mud many times in order to clean the hole from cuttings

2-Reducing pressure surge caused by running in drillpipe in the hole by lowering of drill pipe at low velocity.

3-Placing packer seat in true gage section of hole oppsite a dense and consolidated formation

4-Use of water cushion (placing a certain length of water inside the drill pipe to reduce collapse (external) pressure on drill pipe,pressure drop on the formation and across the packer)

Analysis of DST Data

The data of the second shut in period of pressure chart (shut in pressure and and shut in time) can be analyzed by using Horner equation as follows:

$$Pws = Pi - \frac{162.6Q\mu B}{Kh} . log \frac{tp+\Delta t}{\Delta t} \qquad \text{……………………(1)}$$

Where Pws=static bottom hole pressure during pressure build up,psig

tp:flowing (producing) period,min

Δt:shut in time(min)

Pi: initial reservoir pressure,psig

Q: produced oil rate,bbl/day

μ:oil viscosity,cp

B:oil formation volume factor,bbl/stb

K:formation permeability,md

h:net formation thicknes,ft

**The assumptions of above Horner equation's are:

- radial flow
- Homogenous reservoir
- Steady state flow condition
- Infinite reservoir
- Single phase flow

Horner's equation can be written as straight line equation as follows:
Y=a-mx   where a=intercept   m=slop

Or equation (1) will be:

Pws=Pi-m log($\frac{tp+\Delta t}{\Delta t}$)

Thus when plotting Pws.vs. ($\frac{tp+\Delta t}{\Delta t}$) on semi-log paper or Pws.vs. $log\,\frac{tp+\Delta t}{\Delta t}$ on liner scale paper will yield straight line of slop m equal to:

m=(162.6 QμB)/Kh

with unit of slop(m) equal to psi/cycle (pressure change over one cycle)

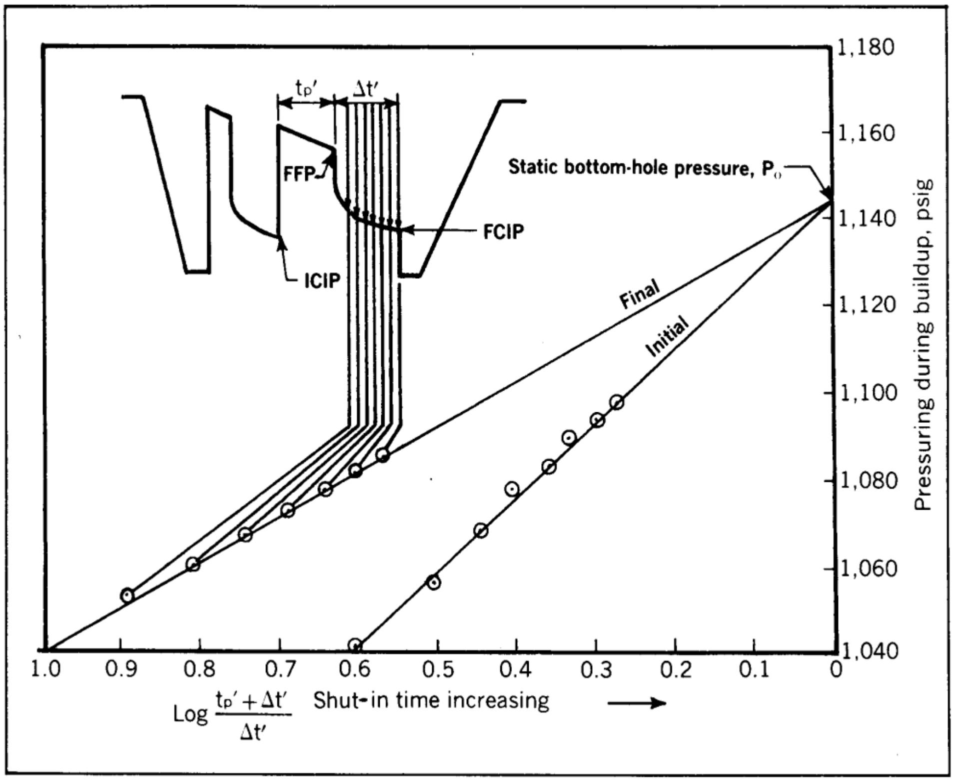


FIG. 3-15—*Idealized Horner buildup plot.*

In ideal DST all points line up as straight line ,but in actual DST few points are lie on straight line due to "After flow or wellbore storage" effects which cause deviation from straight line.Four points at least are needed to determine the straight line.

<u>Reservoir Parameters Obtained by DST Analysis</u>

1-Permeability(K):

After determining the slop(m) of straight line from Horner plot ,the average effective permeability can be calculated as follows:

$K=\frac{162.6Q\mu B}{mh}$ md

2-Static Reservoir pressure(Pi)

This pressure is obtained by extrapolating the Horner straight line to an infinite shut in time at:

A-$(\frac{tp+\Delta t}{\Delta t})$=1 if Horner plot on semi log paper

B- $log\frac{tp+\Delta t}{\Delta t}$=0 if Horner plot on linear scale paper

3-Skin Factor(s)

The formation damage of tested zone during DST test can be determined by calculation of Skin factor from the following equation:

$$S = 1.151\left[\frac{Pi - Pff}{m} - log\frac{K\ tp}{\phi\mu Crw2} + 3.23\right]$$

Where:

S= skin factor,dimensionless

P_i initial static reservoir pressure,psi

P_{ff}: Final flow pressure(from pressue chart),psi

M: slop of straight line,psi/cycle

ϕ: $porosit$

μ:fluid viscosity,cp

C:Fluid compressibility,psi^{-1}

r_w: wellbore radius,ft

k:effective permeability, md

tp:flowing (producing)period,min

4-Radius of investigation(ri)

Is the distance that pressure transient has moved into formation following rate change in a well.Van Poolen presented the following equation for calculating (ri) in an infinite radial flow system:

$$r_i = \sqrt{\frac{k\, t'_p}{5.76 \times 10^4 \phi \mu c}}$$

r_i = radius of investigation, ft

t'_p = flow time in minutes

Ex:Given the following data of DST test:

Formation thickness=50 ft: Net thickness=10 ft:porosity=0.1:Total compressibility=$8.4*10^{-6}$ psi^{-1}

Length of oil recovery=600 ft composed of :

1-Drill collar length=300 ft :Capacity of drill collar=0.0061 bbl\ft

2-Drill pipe length=300 ft:capacity of drill pipe=0.0142 bbl\ft

Oil gravity=35^{o}(API) :oil viscosity=1.5 cp:oil formation volume factor=1.15 bbl\stb Reservoir Temperature=120 F^{o}

Wellbore radius=4 in

Initial flow period=5min

Initial shut in period=30 min

Final flow period=60 min

Final shut in period=45 min

Initial closed in pressure=1910 psi

Final flow pressure=350 psi: Final closed in pressure=1765 psi

The following are the final shut In readings with its corresponding shut in pressure taken from pressure chart :

Shut in time(Δt),min	shut in pressure(Pws),psi
5	965
10	1215
15	1405

20	1590
25	1685
30	1725
35	1740
40	1753
45	1765

Calculate: 1- Initial static reservoir pressure(pi)

2-permeability of reservoir

3-skin factor and radius of investigation

Solution:

1-flow(producing) period(tp)=Initial flow perio+final flow period

tp =5+60=65 min

Construct the Horner's build up plot data as follows:

Pws(psi)	**Δt(min)**	**(tp+ Δt)\ Δt**
965	**5**	**14**
1215	**10**	**7.5**
1405	**15**	**5.33**
1590	**20**	**4.25**
1685	**25**	**3.6**
1725	**30**	**3.16**
1740	**35**	**2.85**
1753	**40**	**2.62**
1765	**45**	**2.44**

Plot pws (y-axis)vs. (tp+Δt)\ Δt (log scale x-axis) on semi log paper and draw straight line passed throught the last points ,then calculate the slop of this line(m) over one cycle of the x-axis . from the plot

M=372 psi\cycle

Extrapolate the straight line to (tp+∆t)\ ∆t=1 and read the intersection on y-axis as Pi(initial reservoir pressure).from the plot the extrapolation give

Pi=1910 psi

Note: you can plot on linear scale by ploting Pws .vs.log(tp+∆t)\∆t and get straight line of slop=372 psi\cycle and Pi=1910 psi at intercept log(tp+∆t\∆t)=0 as shown below:

2-Volume of recovered oil=volume of drillcollar+volume of Drillpipe

Vo=length of drillcollar*capacity of Drillcollar+length of drill pipe*capcity of drill pipe

Vo= 300*0.0061+300*0.0142=6.09 bbl

Oil rate(Qo)= oil volume\producing time

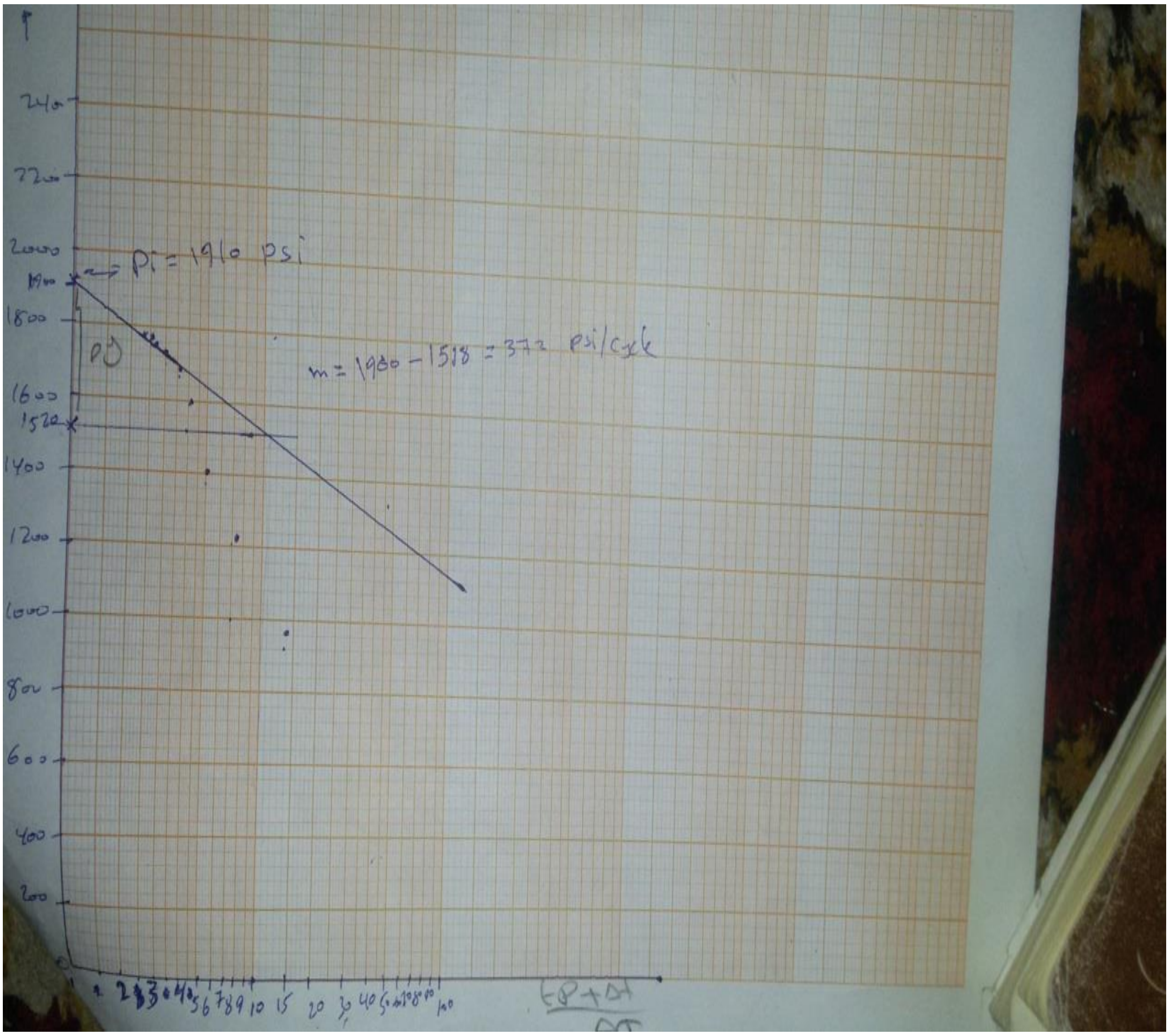
Qo= (6.09 bbl\65 min) *1440 min\day=135 bbl\day

K=162.6(135*1.5*1.5)\(372*10)=10.2 md

3-

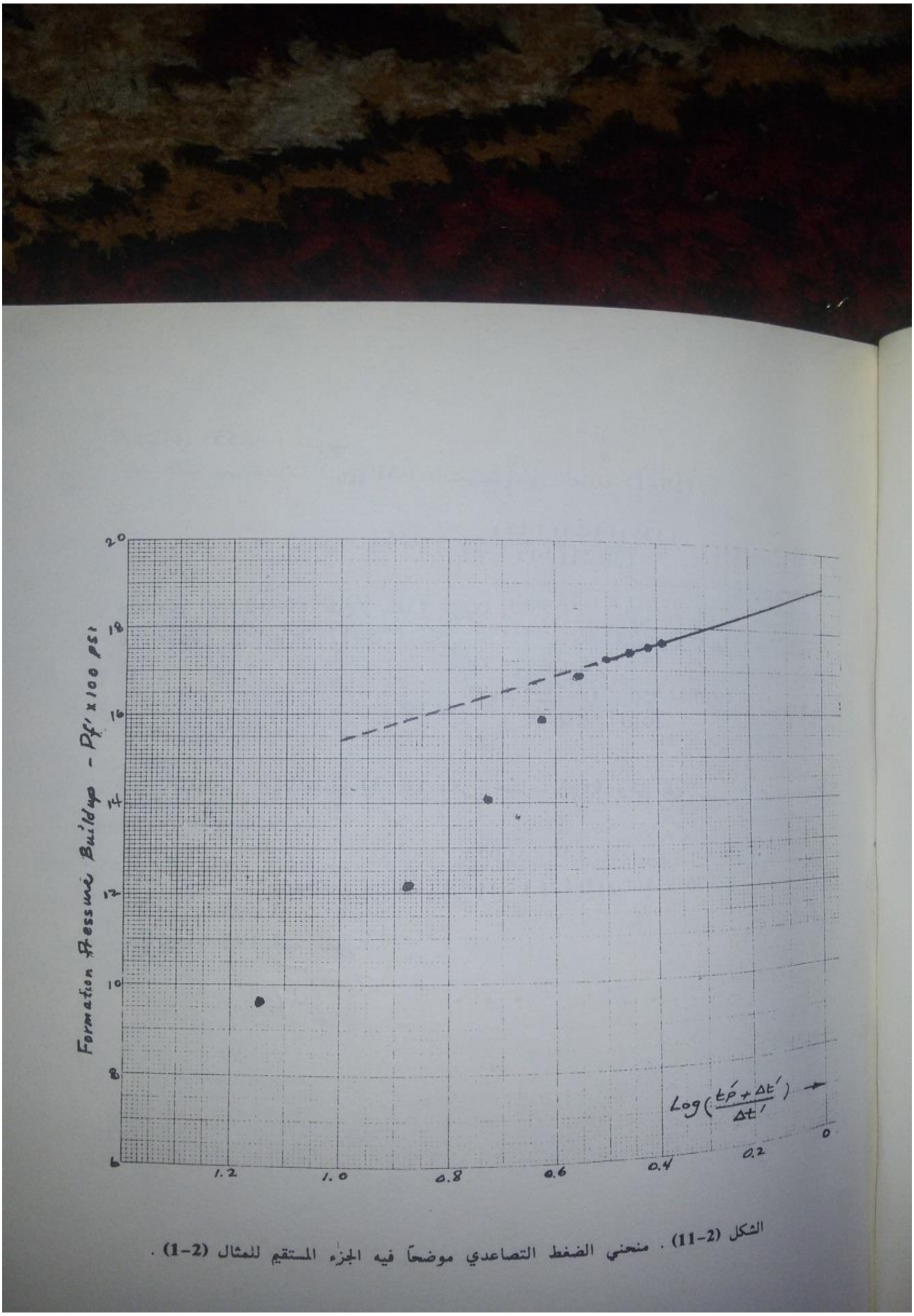
$$S=1.151\left[\frac{1910-350}{372}+3.23-\log\frac{10.2*\ 65\backslash 60}{0.1*1.5*0.333^2*8.4*10^{-6}}\right] = -0.55$$

$Ri=(10.2*65\backslash 5.76*10^4*0.1*1.5*8.4*10^{-6})^{0.5}=95.6$ ft



Plot of Example on semi log paper(Pws on y-axis, tp+∆t\∆t on x-axis)

Δ



الشكل (11-2) . منحني الضغط التصاعدي موضحاً فيه الجزء المستقيم للمثال (1-2) .

Plot of Example on linear scale(Pws on y-axis, log(tp+Δt\Δt) on x-axis)