Well Test Interpretation

SKM4323

INTRODUCTION

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WEEK 01

Definition

A means of assessing reservoir performance by measuring flow rates and pressures under a range of flowing conditions and then applying the data to a mathematical model.

Well Test

- In most well tests, a limited amount of fluid is allowed to flow from the formation being tested. The formation is isolated behind cemented casing and perforated at the formation depth or, in openhole, the formation is straddled by a pair of packers that isolate the formation.

Well Test…/2

- During the flow period, the pressure at the formation is monitored over time. Then, the formation is closed (or shut in) and the pressure monitored at the formation while the fluid within the formation equilibrates.

Well Test…/3

- The analysis of these pressure changes can provide information on the size and shape of the formation as well as its ability to produce fluids.

Well Test Objectives

The objectives of a well test usually fall into three major categories:

(a) reservoir evaluation,

(b) reservoir management,

(c) reservoir description.

Reservoir Evaluation

- To reach a decision as how best to produce a given reservoir (or even whether it is worthwhile to spend the money to produce it at all) we need to know its deliverability, properties, and size.
- Thus we will attempt to determine the reservoir conductivity (kh, or permeability-thickness product), initial reservoir pressure, and the reservoir limits (or boundaries).

Reservoir Evaluation…/2

- At the same time, we will sample the fluids so that their physical properties can be measured in the laboratory.
- Also, we will examine the near wellbore condition in order to evaluate whether the well productivity is governed by wellbore effects (such as skin and storage) or by the reservoir at large.

Reservoir Evaluation…/3

- The conductivity (kh) governs how fast fluids can flow to the well. Hence it is a parameter that we need to know to design well spacing and number of wells.
- If conductivity is low, we may need to evaluate the cost-effectiveness of stimulation.

Reservoir Evaluation…/4

- Reservoir pressure tells us how much potential energy the reservoir contains (or has left) and enables us to forecast how long the reservoir production can be sustained.
- Pressures in the vicinity of the wellbore are affected by drilling and production processes, and may be quite different from the pressure and the reservoir at large.
- Well test interpretation allows us to infer those distant pressures from the local pressures that can actually be measured.

Reservoir Evaluation…/5

- Analysis of reservoir limits enables us to determine how much reservoir fluid is present (be it oil, gas, water, steam or any other) and to estimate whether the reservoir boundaries are closed or open (with aquifer support, or a free surface).

Reservoir Management

- During the life of a reservoir, we wish to monitor performance and well condition.
- It is useful to monitor changes in average reservoir pressure so that we can refine our forecasts of future reservoir performance.
- By monitoring the condition of the wells, it is possible to identify candidates for workover or stimulation.

Reservoir Management.../2

- In special circumstances, it may also be possible to track the movement of fluid fronts within the reservoir, such as may be seen in water flooding or in-situ combustion.
- Knowledge of the front location can allow us to evaluate the effectiveness of the displacement process and to forecast its subsequent performance.

Reservoir Description

- Geological formations hosting oil, gas, water and geothermal reservoirs are complex, and may contain different rock types, stratigraphic interfaces, faults, barriers and fluid fronts.
- Some of these features may influence the pressure transient behavior to a measurable extent, and most will affect the reservoir performance.

Reservoir Description…/2

- To the extent that it is possible, the use of well test analysis for the purpose of reservoir description will be an aid to the forecasting of reservoir performance.
- In addition, characterization of the reservoir can be useful in developing the production plan.

Reservoir Description…/3

- It is important to acknowledge that there is a limit to the level of detail that can be achieved in a reservoir description.
- Pressure transmission is an inherently diffusive process, and hence is governed largely by average conditions rather than by local heterogeneities.

Types of Tests

- Drawdown Test
- Buildup Test
- Injection Test
- Falloff Test
- Interference Test
- Drill Stem Test (DST)

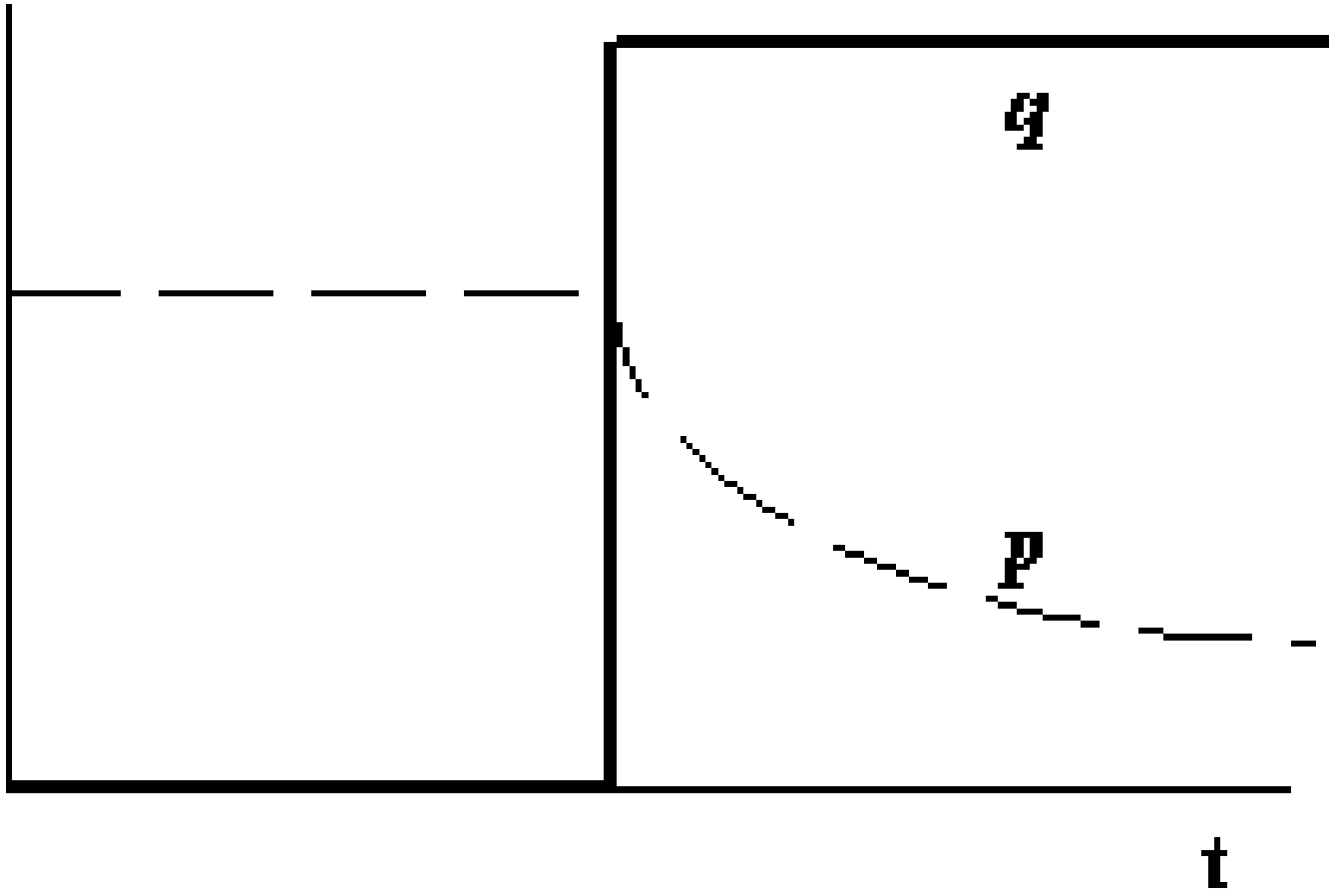
Drawdown Test

- In a drawdown test, a well that is static, stable and shut-in is opened to flow. For the purposes of traditional analysis, the flow rate is supposed to be constant.
- Many of the traditional analysis techniques are derived using the drawdown test as a basis. However, in practice, a drawdown test may be rather difficult to achieve under the intended conditions. In particular:
  - it is difficult to make the well flow at constant rate, even after it has (more-or-less) stabilized, and
  - the well condition may not initially be either static or stable, especially if it was recently drilled or had been flowed previously.

Drawdown Test…/2

- On the other hand, drawdown testing is a good method of reservoir limit testing, since the time required to observe a boundary response is long, and operating fluctuations in flow rate become less significant over such long times.

Drawdown Test…/3



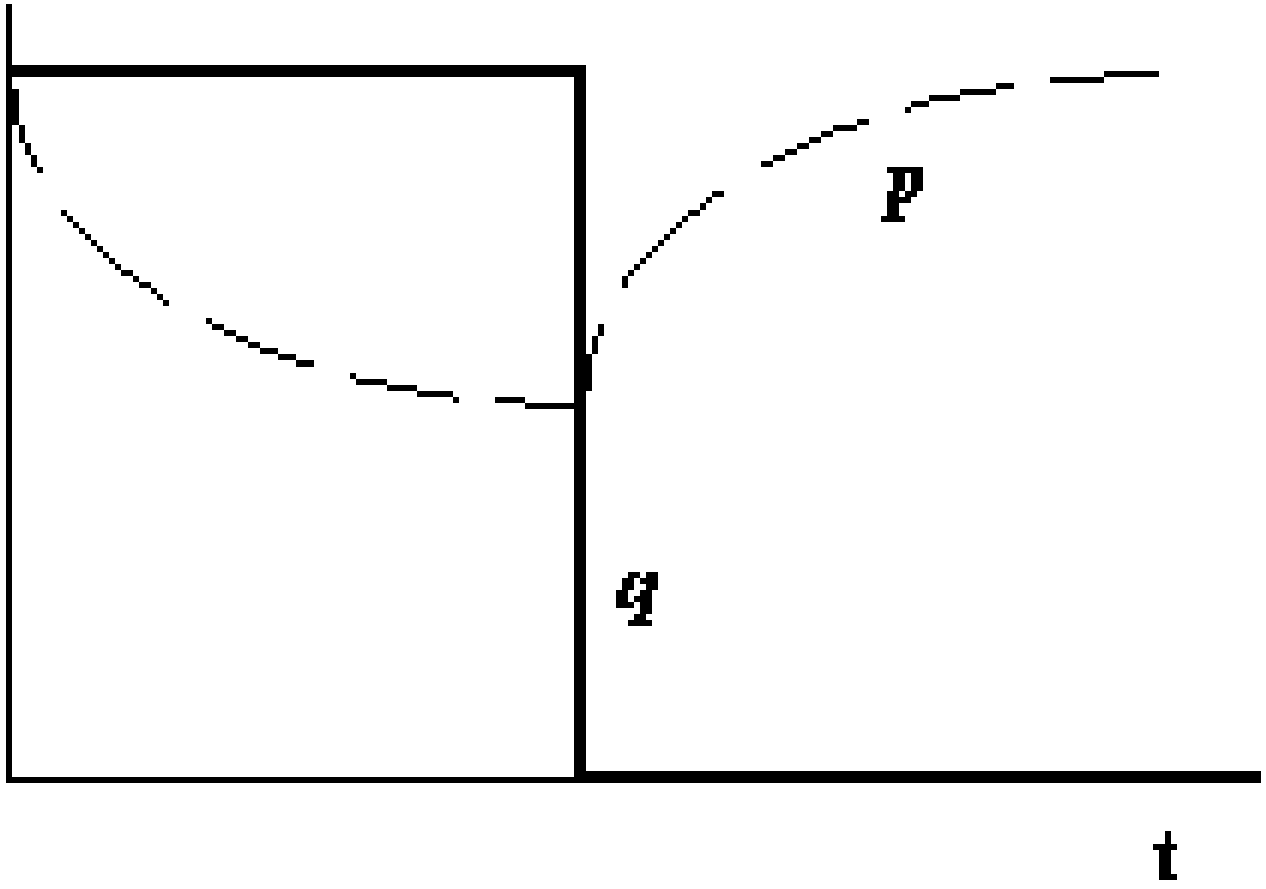
Buildup Test

- In a buildup test, a well which is already flowing (ideally at constant rate) is shut in, and the downhole pressure measured as the pressure builds up.
- Analysis of a buildup test often requires only slight modification of the techniques used to interpret constant rate drawdown test.
- The practical advantage of a buildup test is that the constant flow rate condition is more easily achieved (since the flow rate is zero).

Buildup Test.../2

- Buildup tests also have disadvantages:
  - It may be difficult to achieve the constant rate production prior to the shut in. In particular, it may be necessary to close the well briefly to run the pressure tool into the hole.
  - Production is lost while the well is shut in.

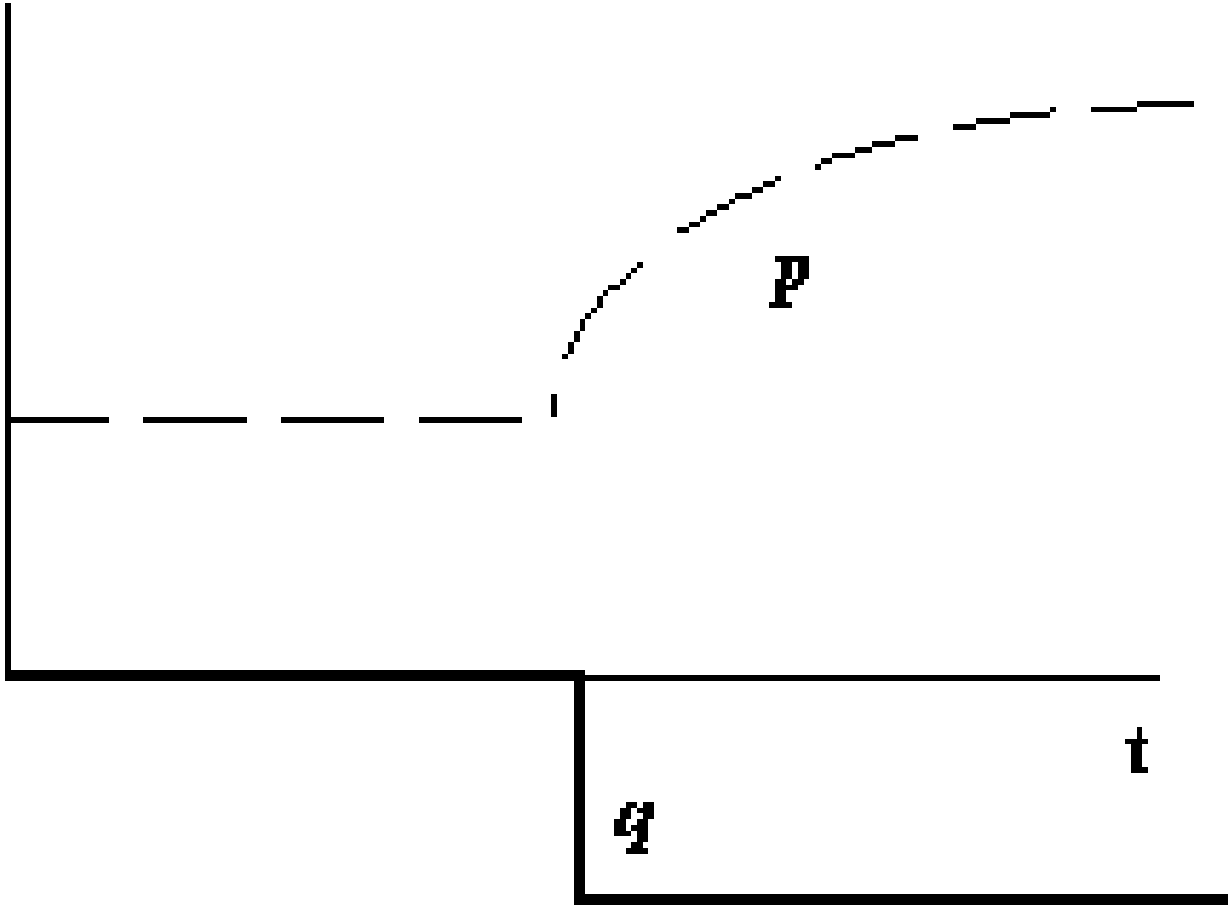
Buildup Test.../3



Injection Test

- An injection test is conceptually identical to a drawdown test, except that flow is into the well rather than out of it.
- Injection rates can often be controlled more easily than production rates, however analysis of the test results can be complicated by multiphase effects unless the injected fluid is the same as the original reservoir fluid.

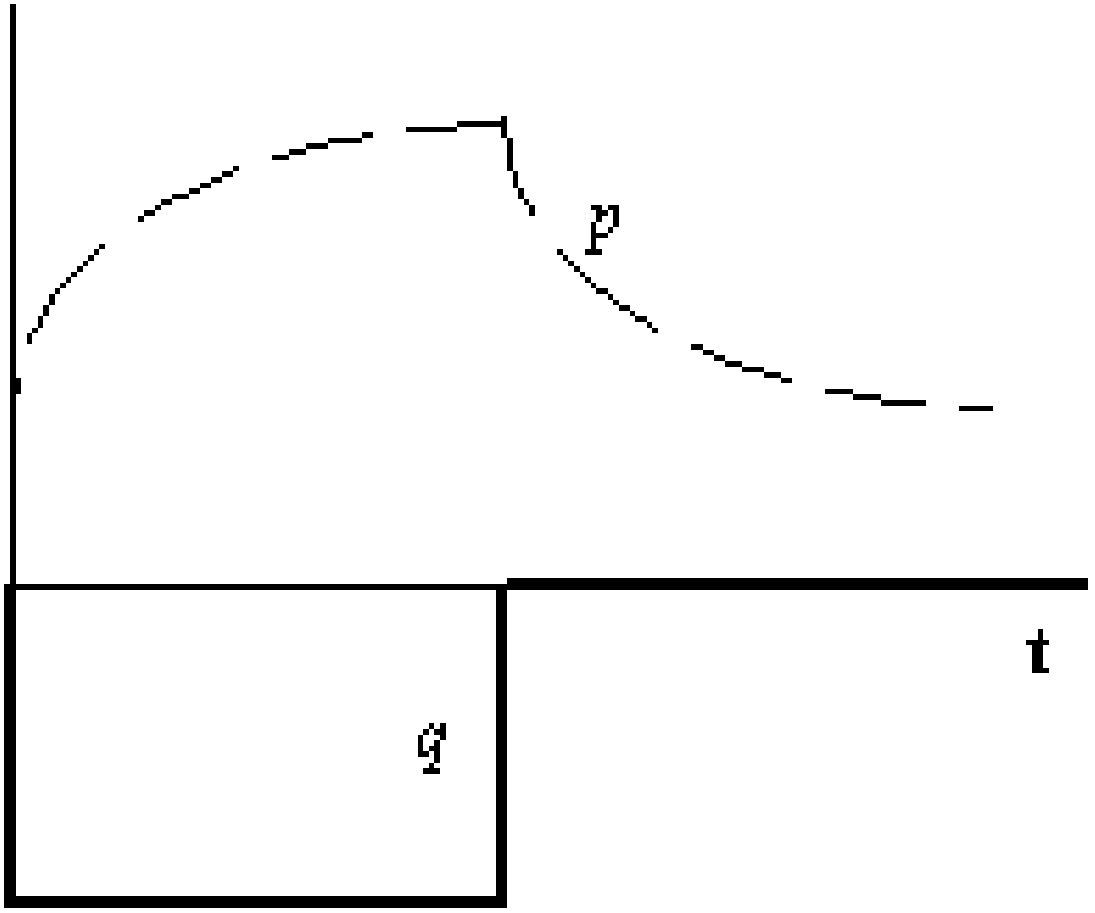
Injection Test…/2



Falloff Test

- A falloff test measures the pressure decline subsequent to the closure of an injection. It is conceptually identical to a buildup test.
- As with injection tests, falloff test interpretation is more difficult if the injected fluid is different from the original reservoir fluid.

Falloff Test…/2



Interference Test

- In an interference test, one well is produced and pressure is observed in a different well (or wells).
- An interference test monitors pressure changes out in the reservoir, at a distance from the original producing well.
- Thus an interference test may be useful to characterize reservoir properties over a greater length scale than single-well tests.

Interference Test.../2

- Pressure changes at a distance from the producer are very much smaller than in the producing well itself, so interference tests require sensitive pressure recorders and may take a long time to carry out.
- Interference tests can be used regardless of the type of pressure change induced at the active well (drawdown, buildup, injection or falloff).

Drill Stem Test (DST)

- A drill stem test is a test which uses a special tool mounted on the end of the drill string. It is a test commonly used to test a newly drilled well, since it can only be carried out while a rig is over the hole.
- In a DST, the well is opened to flow by a valve at the base of the test tool, and reservoir fluid flows up the drill string (which is usually empty to start with).
- A common test sequence is to produce, shut in, produce again and shut in again.

Drill Stem Test (DST)…/2

- Drill stem tests can be quite short, since the positive closure of the downhole valve avoids wellbore storage effects.
- Analysis of the DST requires special techniques, since the flow rate is not constant as the fluid level rises in the drill string.
- Complications may also arise due to momentum and friction effects, and the fact that the well condition is affected by recent drilling and completion operations may influence the results.

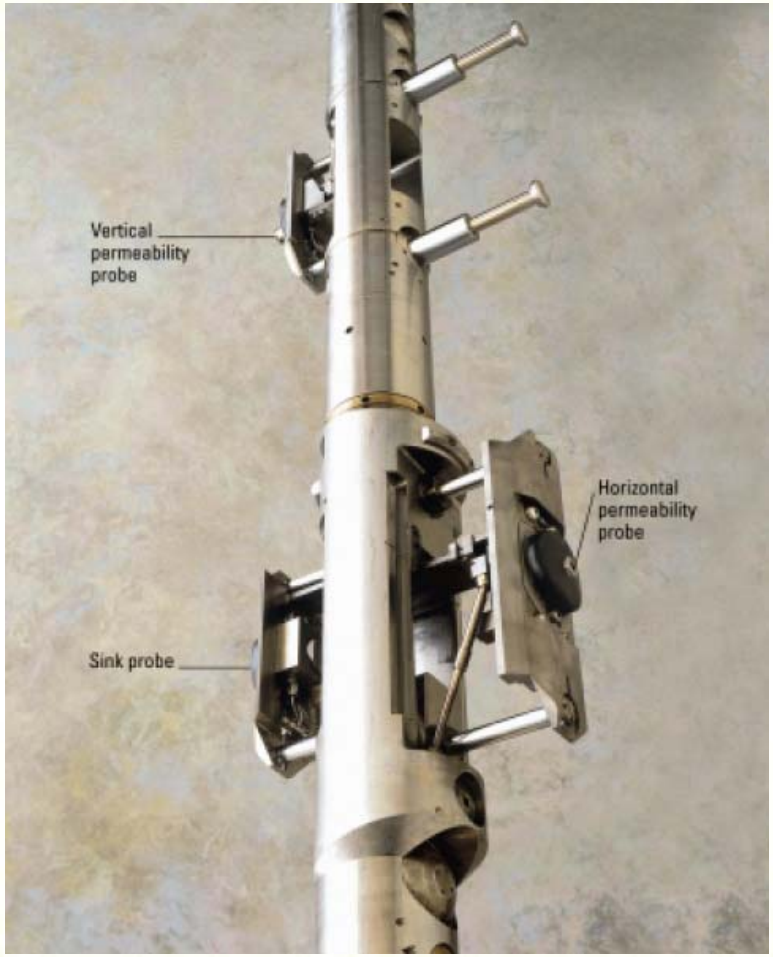
Well Test Equipment

- Formation Tester (FT), 1950s
- Repeat Formation Tester (RFT), 1970s
- Modular Formation Dynamics Tester (MDT), 1990s
- Drill Stem Test (DST)
- Surface Test Equipment

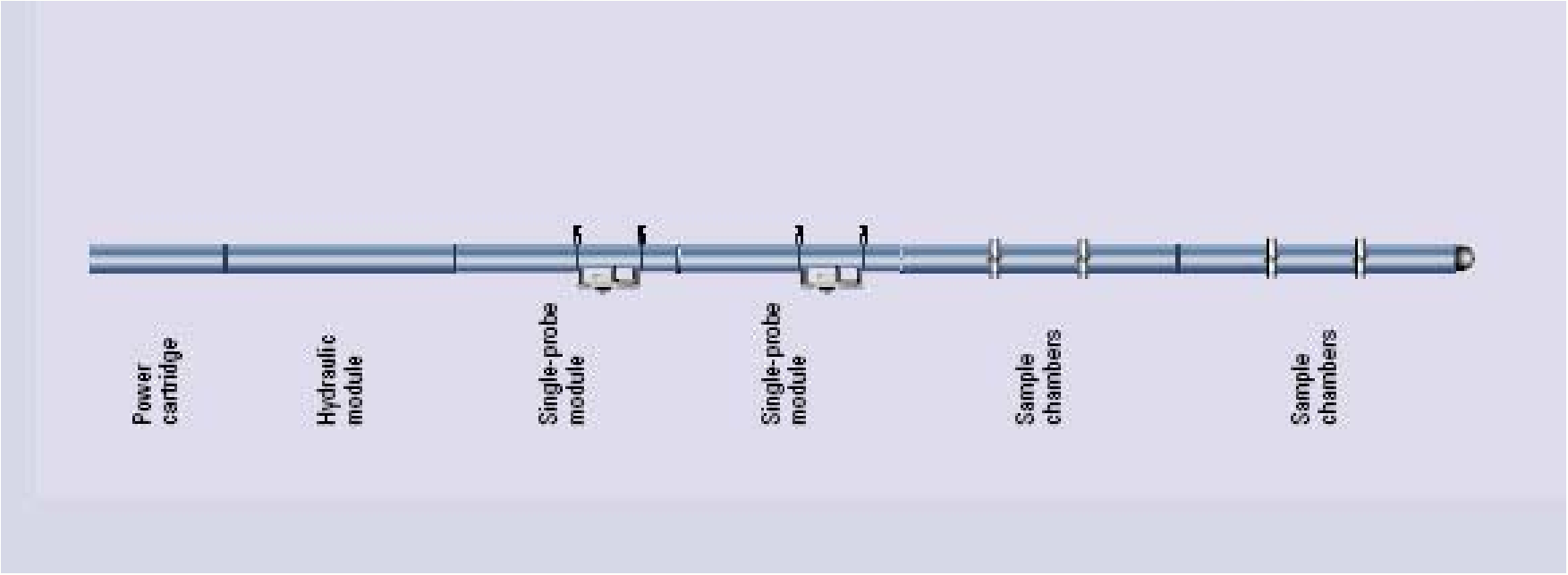
MDT

- The Modular Formation Dynamics Tester (MDT) measures reservoir pressure, collects representative fluid samples from multiple layers, and provides permeability and anisotropy data through a variety of interval pressure transient tests.
- The MDT tool can also be used to conduct a mini-frac test to obtain the minimum in situ horizontal stress in several layers.

MDT…/2



Basic MDT Configuration



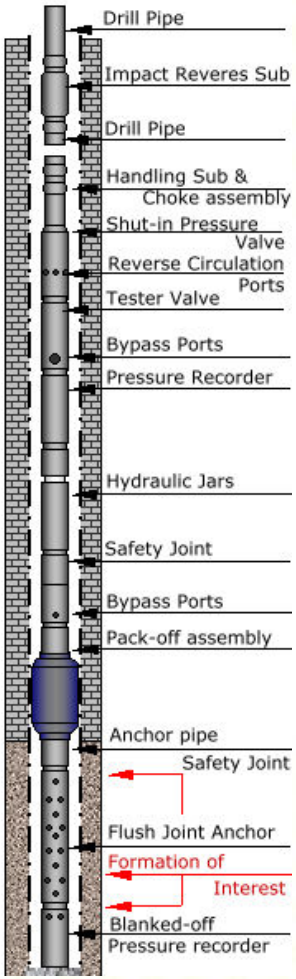
MDT Applications

- Formation pressure measurement and fluid gradient estimation.
- Formation fluid sampling and downhole fluid analysis.
- Pretest drawdown mobility values (permeability/viscosity).
- Permeability and permeability anisotropy determination away from the well.
- In situ stress determination.

Drill Stem Test (DST)

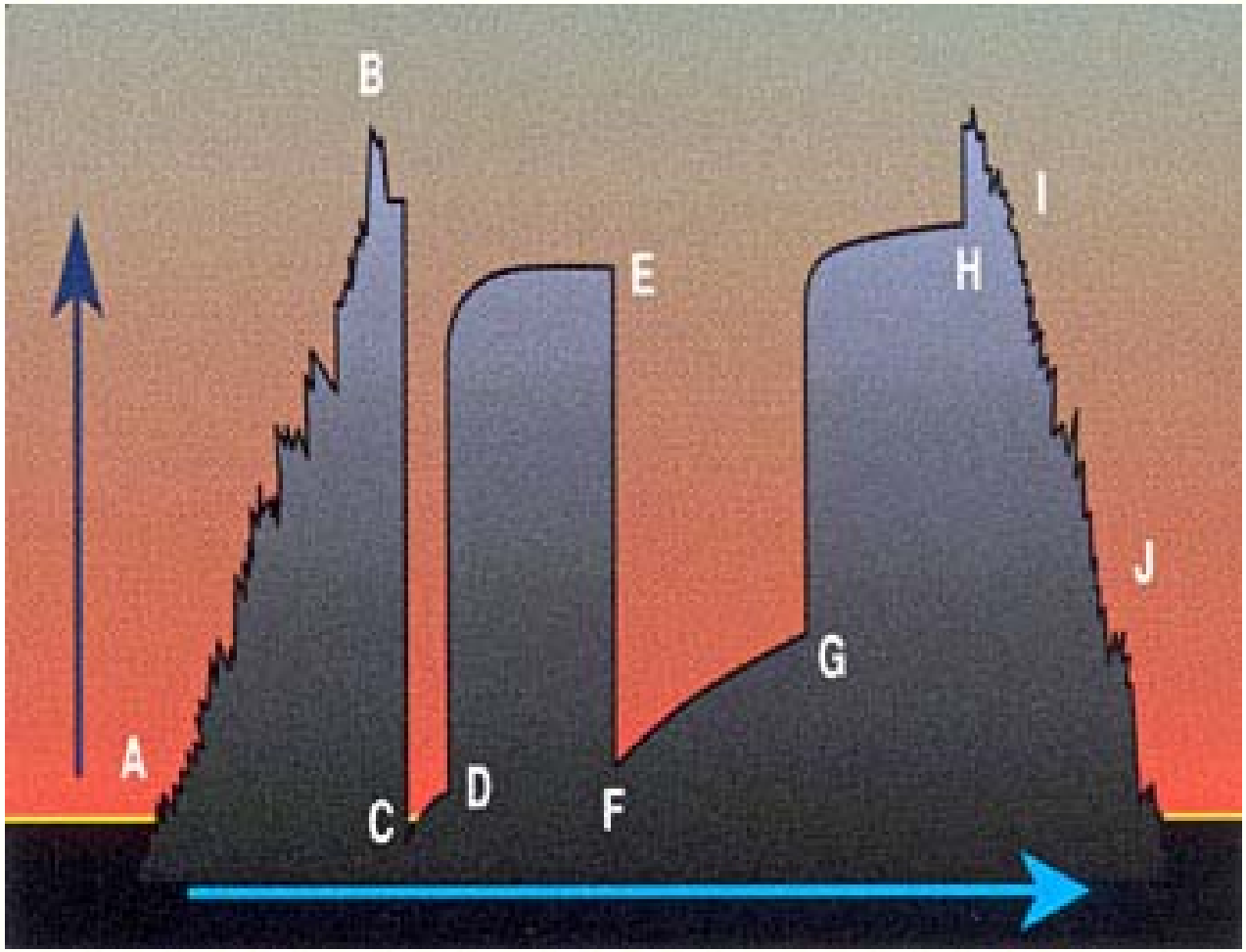
- In oil and natural gas extraction, the drill stem includes the drill pipe, drill collars, bottomhole assembly, and drill bit.
- A **drill stem test (DST)** is a procedure for testing the surrounding geological formation through the drill pipe.
- During normal drilling, fluid is pumped through the drill stem and out the drill bit. Instead, in a drill stem test, fluid from the formation is recovered through the drill stem, while several measurements of pressure are being made.

Drill Stem Test (DST).../2

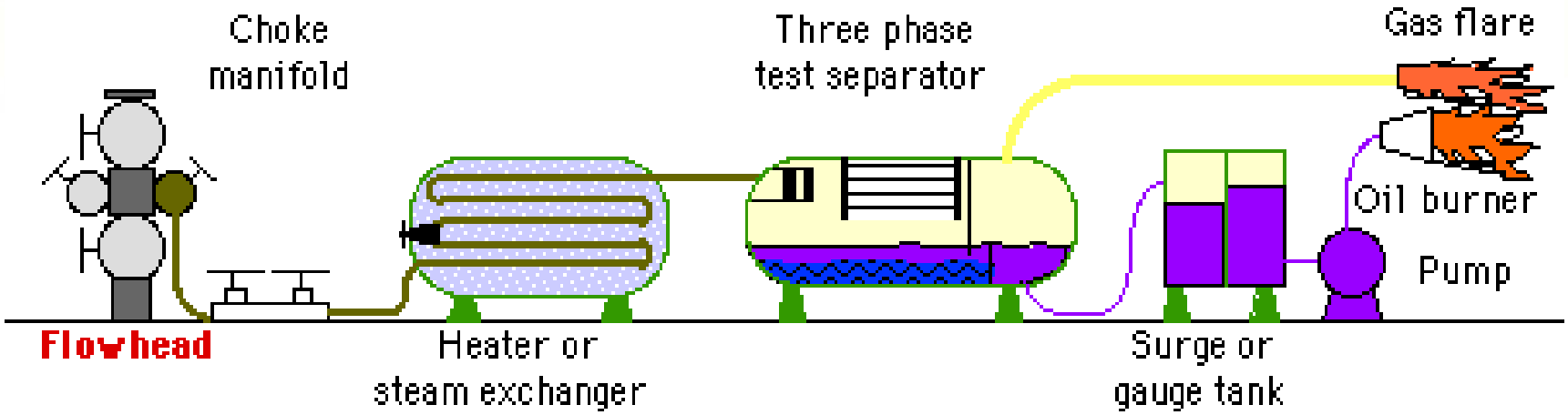


- The basic drill stem test tool consists of a packer or packers, valves or ports that may be opened and closed from the surface, and two or more pressure-recording devices.
- A packer is an expanding plug which can be used to seal off sections of the open well, here to isolate them for testing.
- The tool is lowered on the drill pipe to the zone to be tested.
- The packer or packers are set to isolate the zone from the drilling fluid column, and testing measurement begins.

DST Pressure Profile

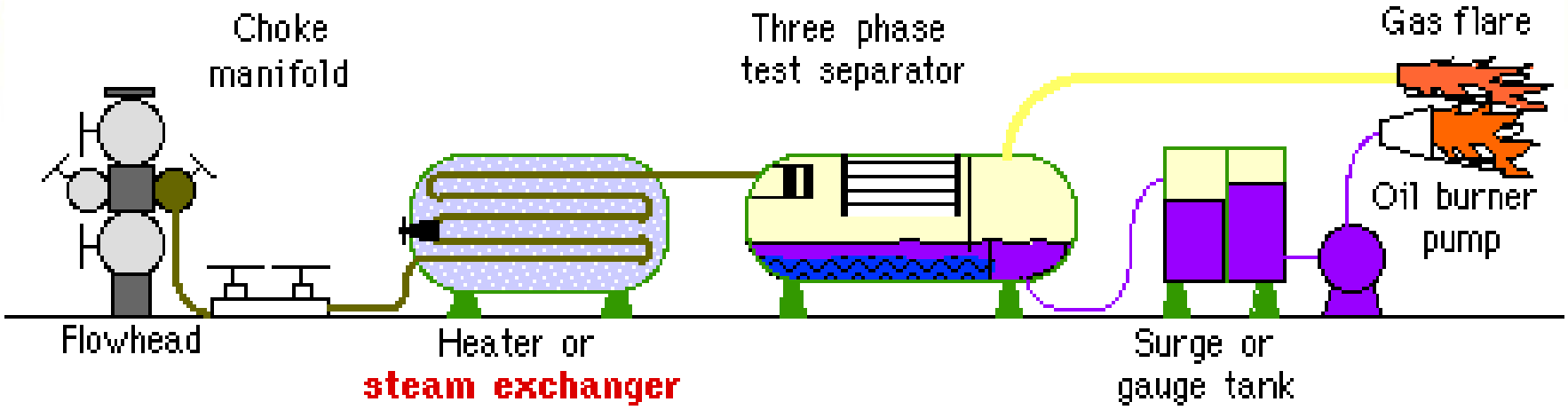


Surface Test Equipment



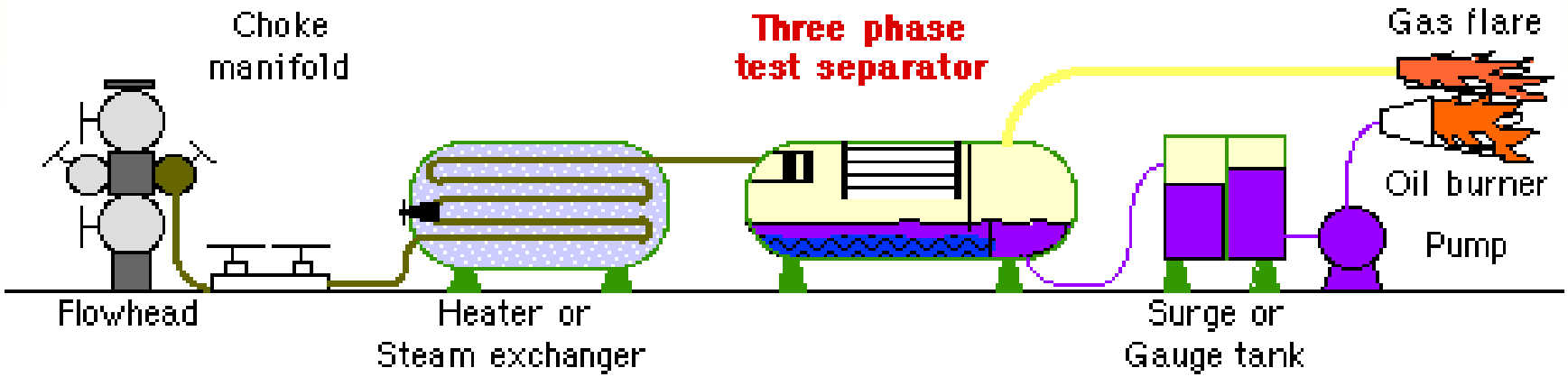
The FLOWHEAD is the primary well pressure control equipment

Surface Test Equipment



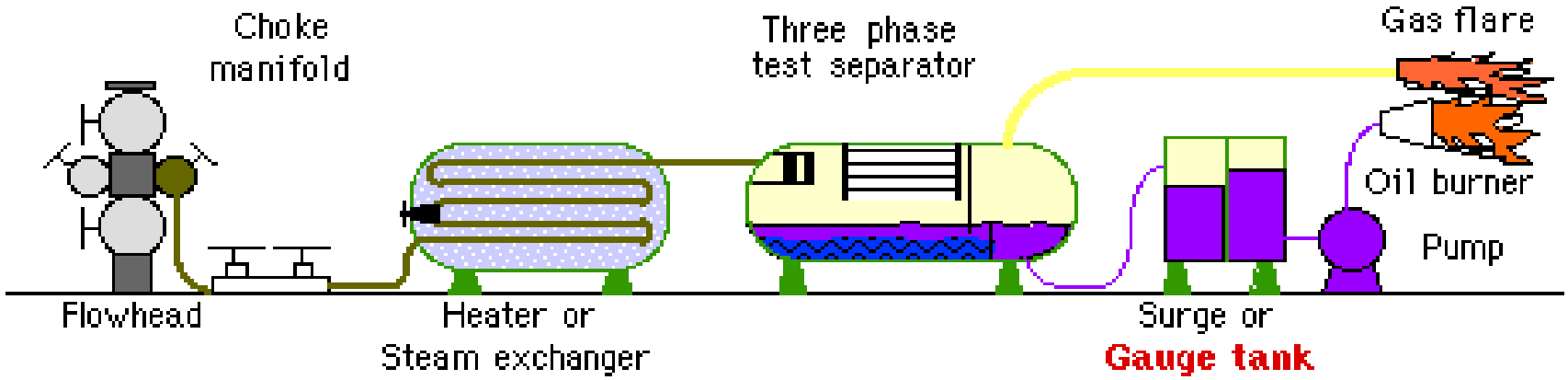
The HEATER (or STEAM EXCHANGER) is used to raise the effluent temperature above hydrate formation point, to reduce viscosity (heavy crude oil) or to break the emulsion.

Surface Test Equipment



The SEPARATOR is the main surface testing piece of equipment. It separates the three phases of the effluent which can then be metered and sampled individually.

Surface Test Equipment



The ATMOSPHERIC GAUGE TANK and the SURGE TANK are used to calibrate the separator liquid flow measurement, and to measure the flow in case of low oil flow rates.

Surface Burner

Computer-aided design of the EverGreen oil burner.

Courtesy of Schlumberger

Surface Burner

References

1. Horne, Roland N. : Modern Well Test Analysis : A Computer Aided Approach, Petroway Inc., 1995.
2. Internet.