Special Purpose Reservoir Simulators

4-Thermal Recovery Simulators

Thermal Recovery Simulators

- **Thermal recovery processes are designed to raise the temperature of reservoir oil, thereby decreasing its viscosity and enhancing its flow characteristics.**
- **The primary differences among various thermal recovery methods are in the heat sources used to raise oil temperature.**
- **The two most popular methods are steamflooding and in-situ combustion.**
- **There are two basic types of steamflooding simulators: compositional and non-compositional.**

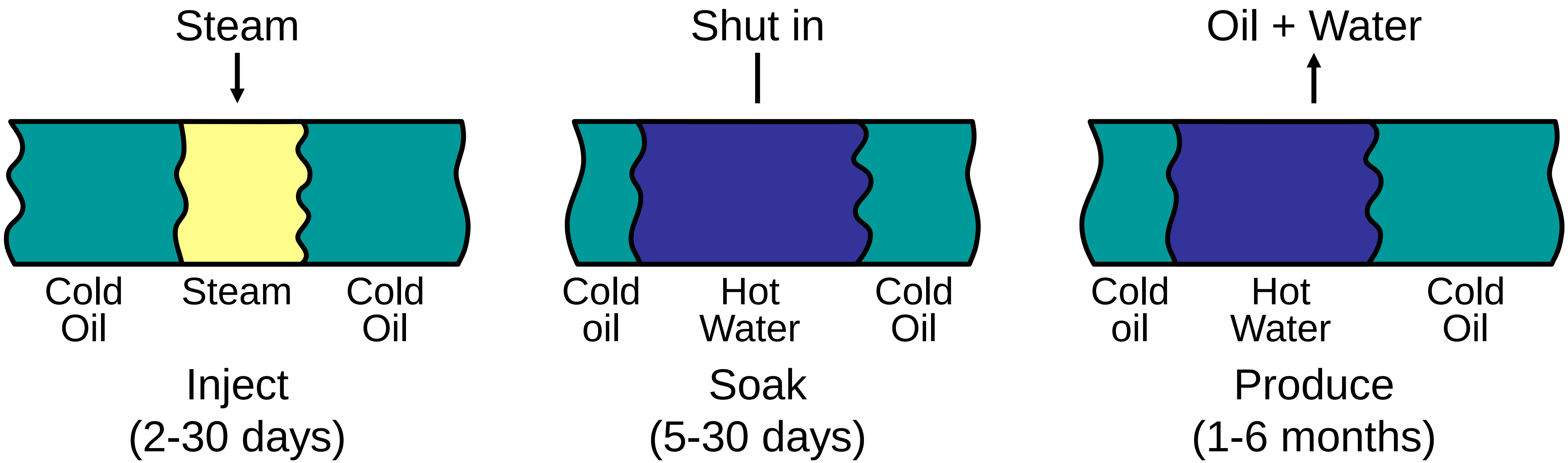
- **The major difference between thermal recovery simulators and other types of models is the need for the energy balance equation.**
- **Temperature distribution is the main driving factor in thermal recovery, and so must be adequately predicted--especially since viscosity is a strong function of temperature.**
- **The energy equations are usually highly nonlinear and strongly related to the mass balance equations.**
- **One other feature of thermal simulators is the need to calculate the heat loss to the surrounding formations.**

Thermal Process Variations...

- **Steam soaks (aka huff'n'puff, push-pull)**
- **Drives…**
  - **Hot water**
  - **Steam (plus additives)**
- **Gravity drainage (SAGD) processes**
- **In situ combustion**
- **Electromagnetic heating**
- **Cold heavy oil production (CHOP)- foamy**

Steaming a Well...

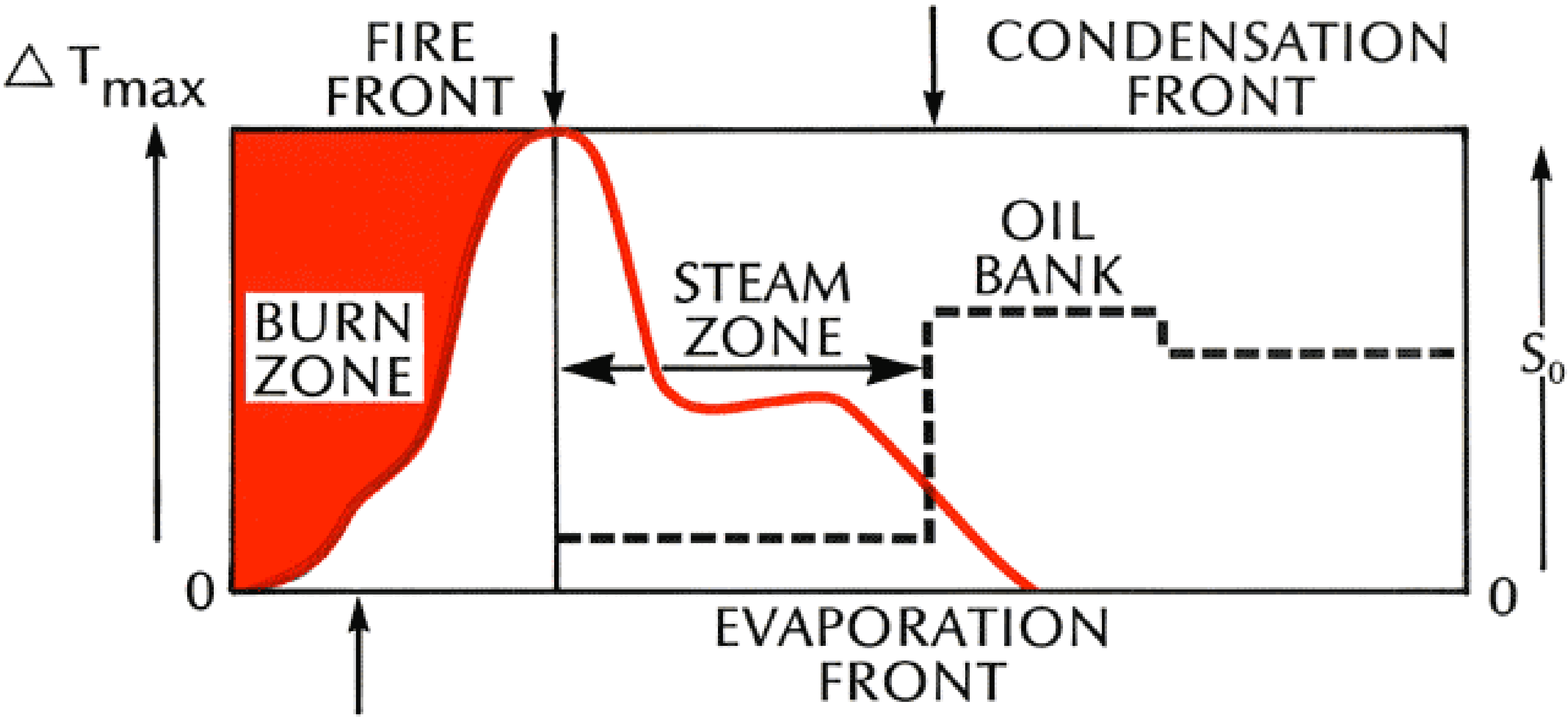
Steam Soak (Huff and Puff)



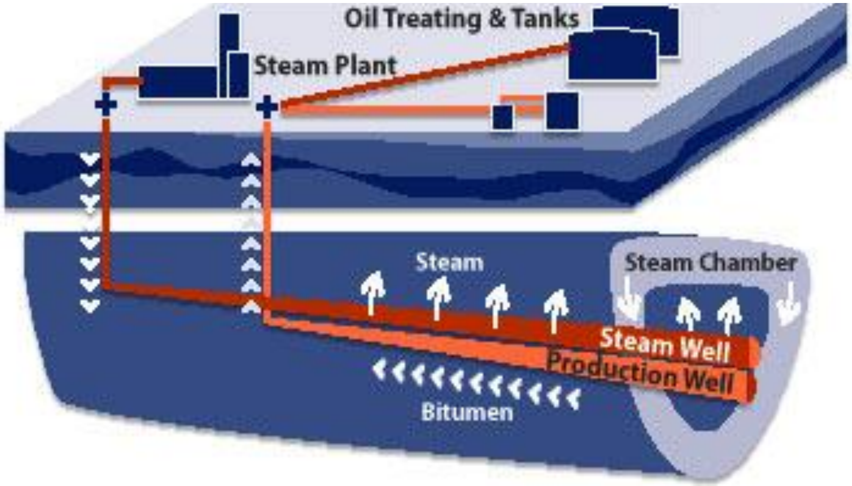
Driving the Oil...

Steam Drive

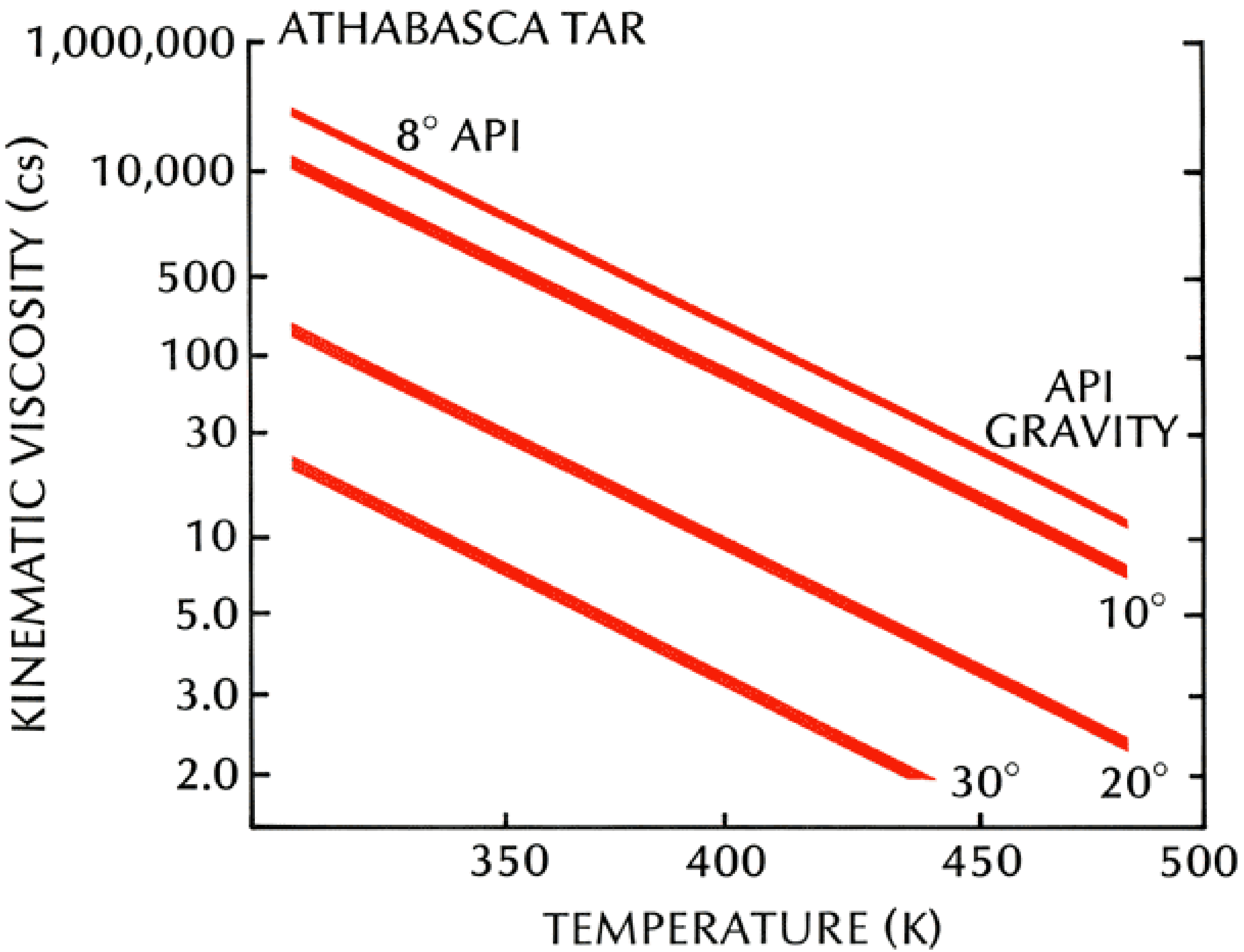
Burning the Oil...



Steam-Assisted Gravity Drainage (SAGD)…

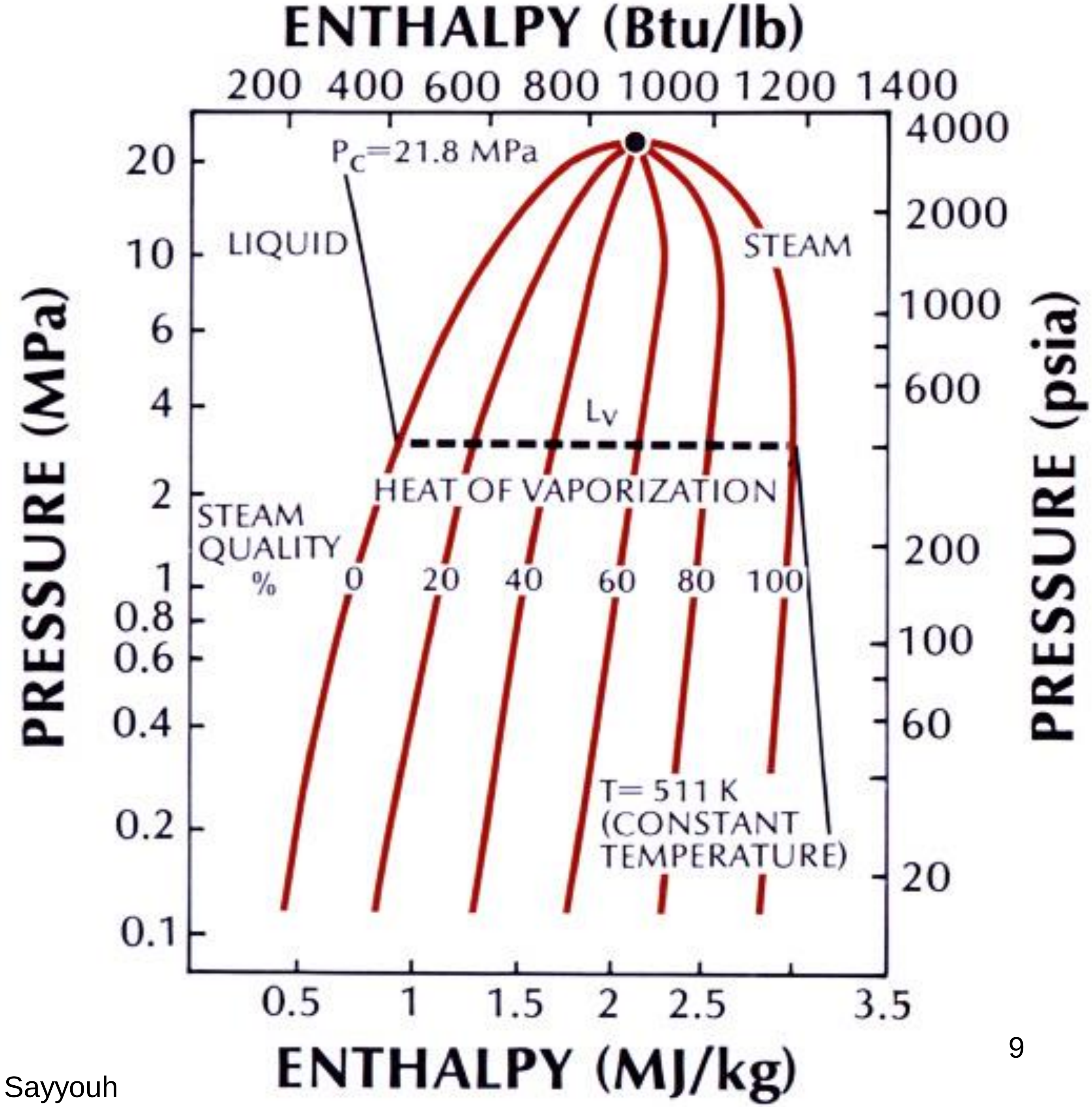


Increasing Temperature Lowers Viscosity...



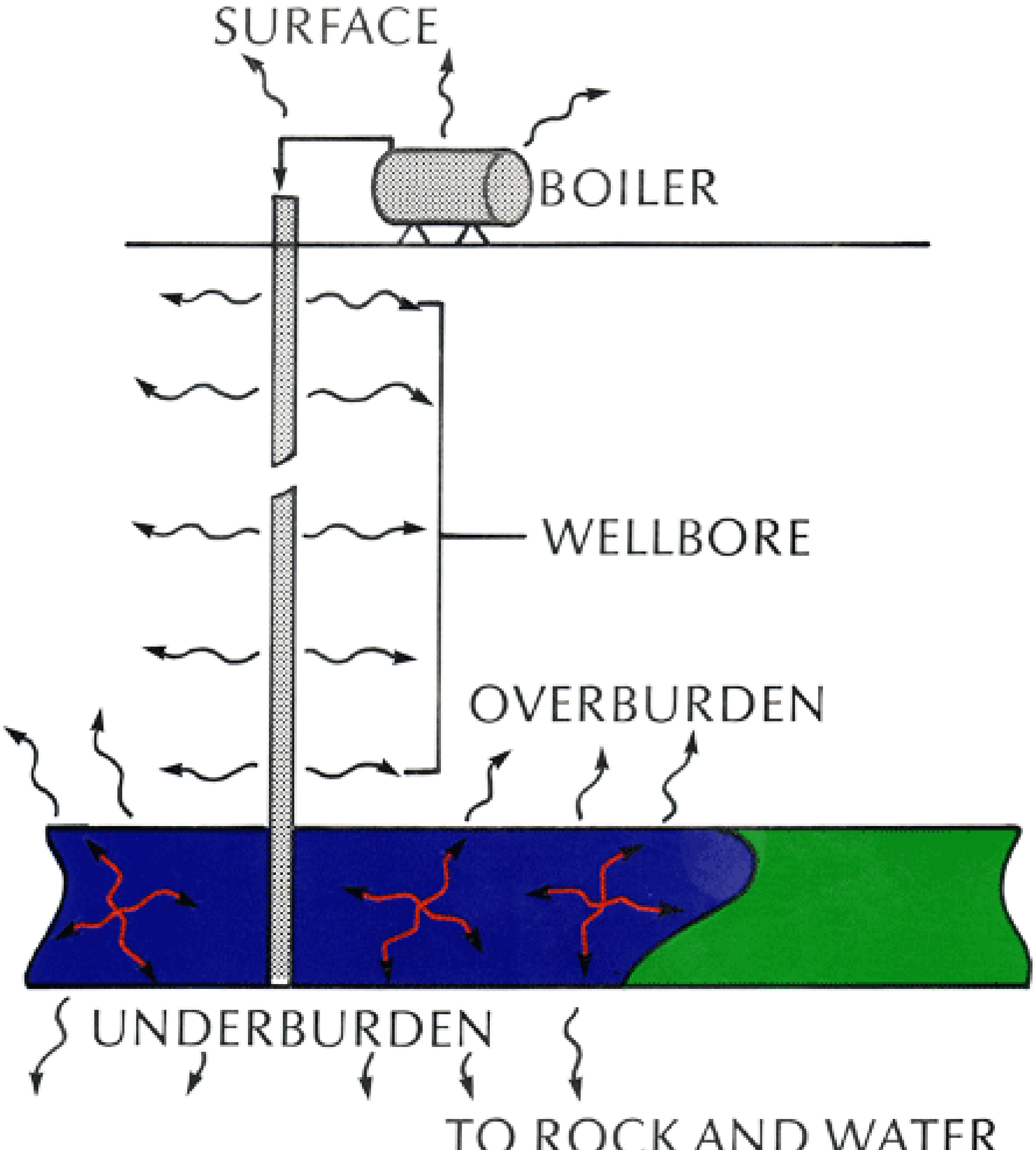
Enthalpy of Water...

Steam quality is the amount of vapor as a fraction of the liquid and vapor mass.



How Heat is Lost...

- Surface equipment
- Rock and water in formation
- From wellbore
- To adjacent strata

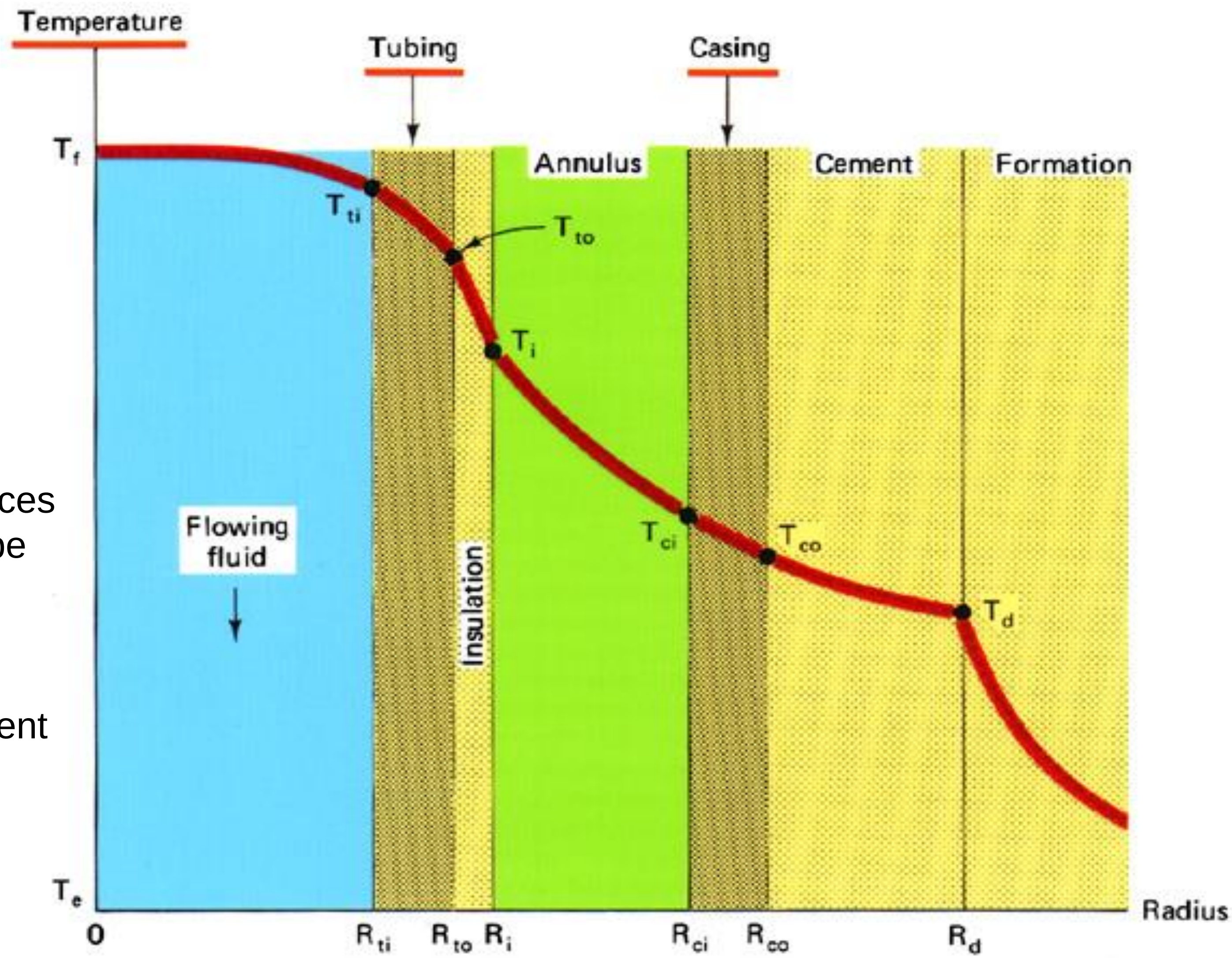


Schematic Temperature Profile in Drill Hole

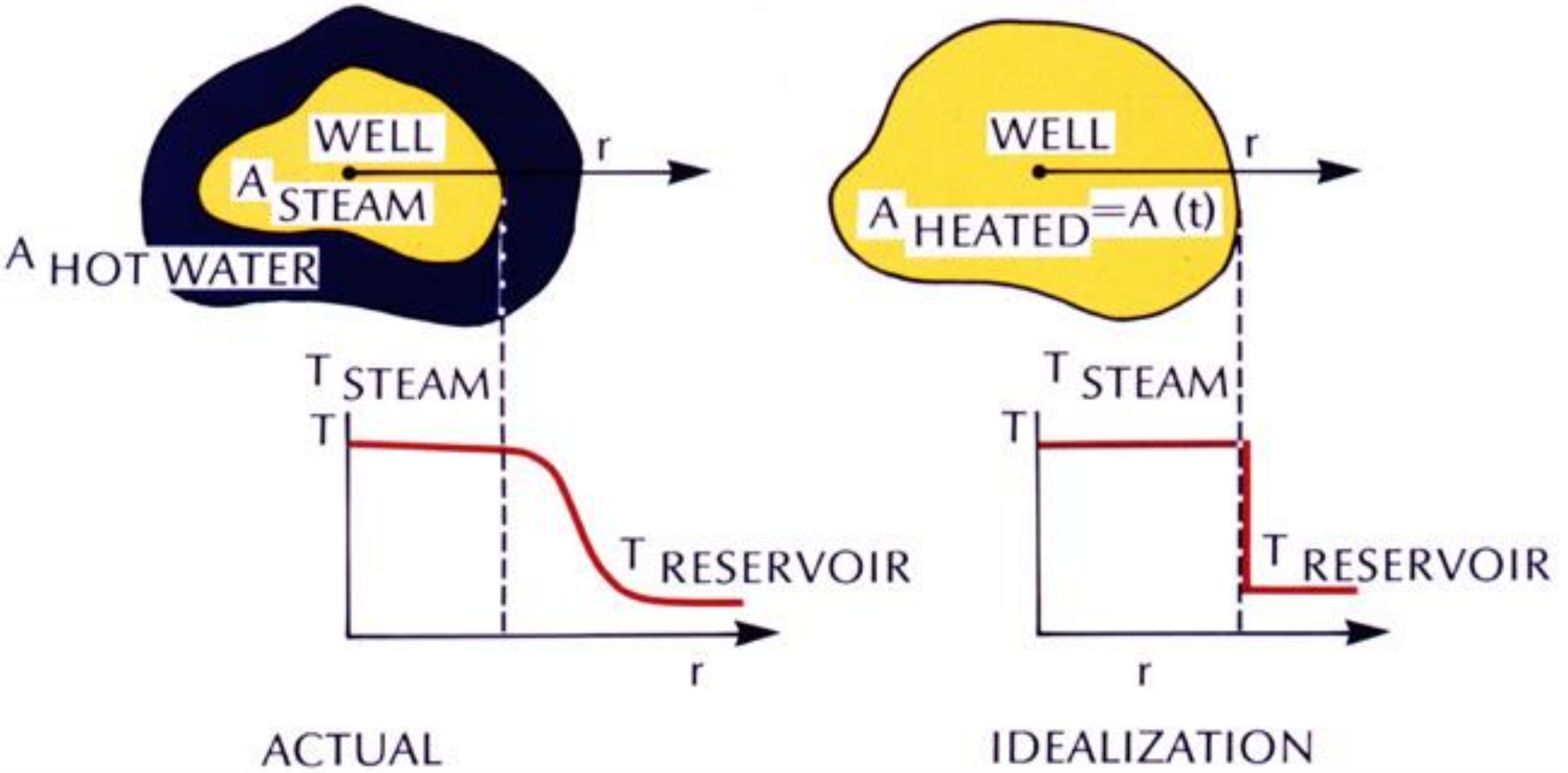
Heat transfer from a flowing fluid is by conduction and convection

Temperature differences between zones can be estimated if heat transfer is known

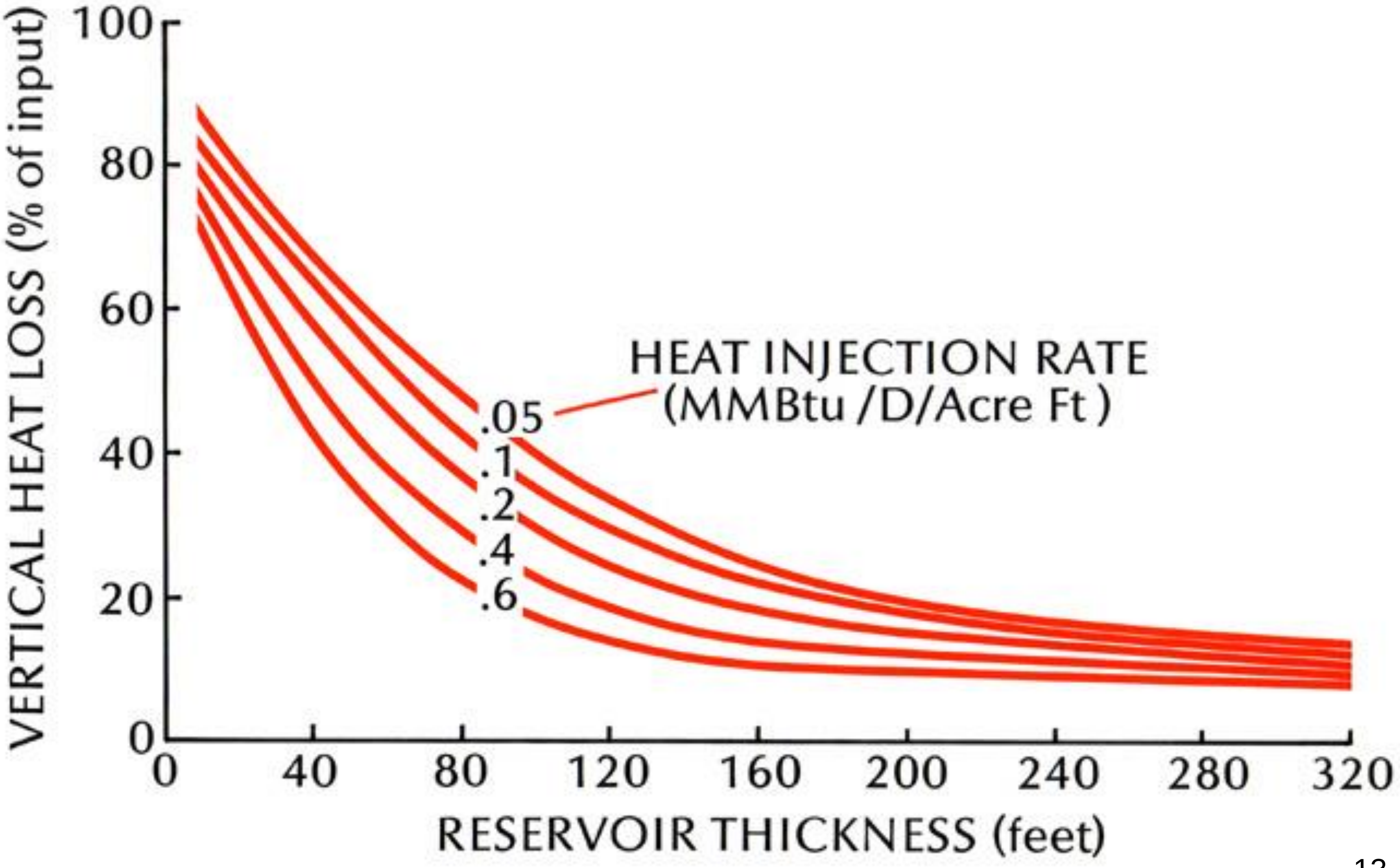
Heat transfer coefficient can be estimated



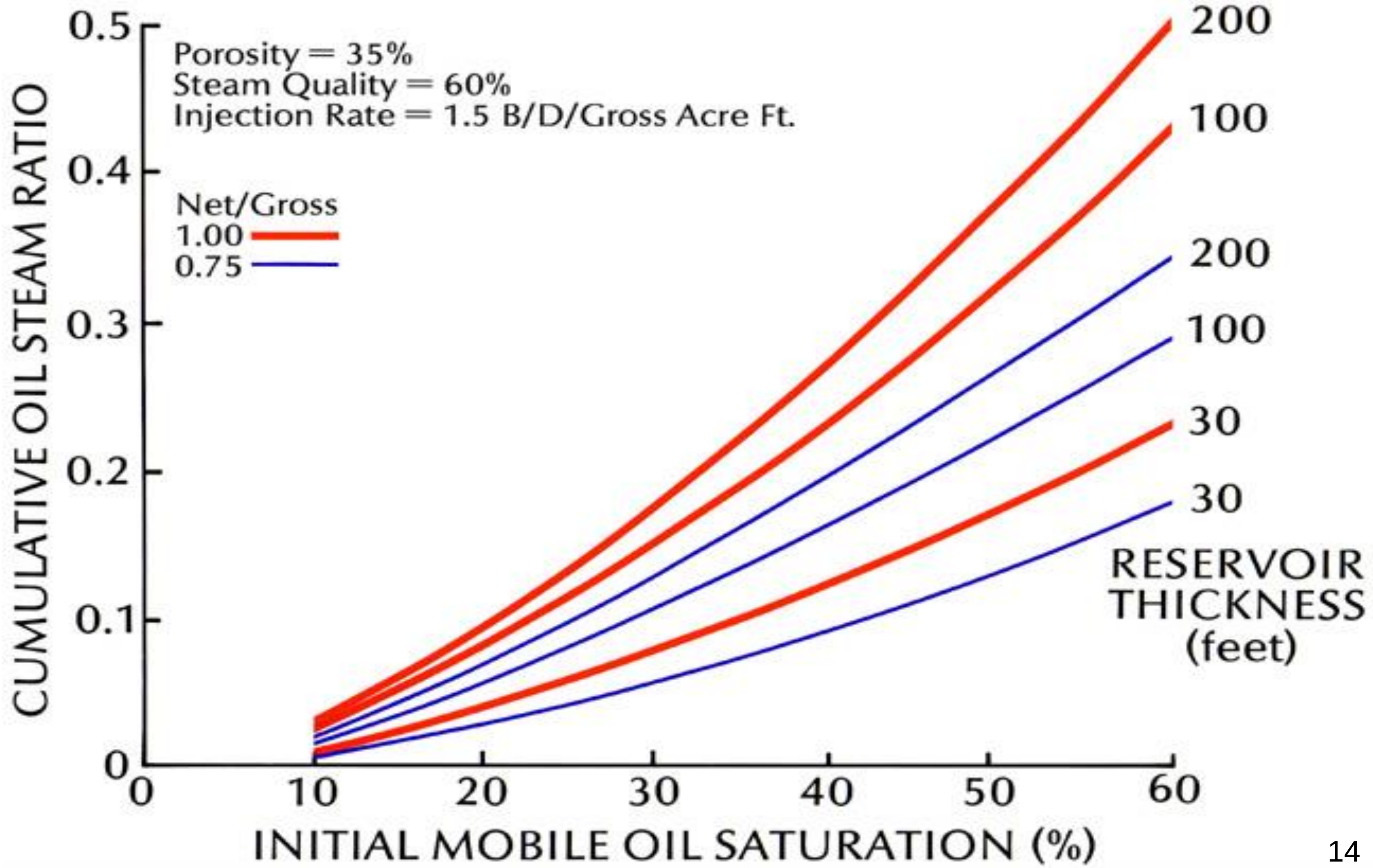
Losses to Adjacent Strata...



Thin Reservoirs Lose Heat



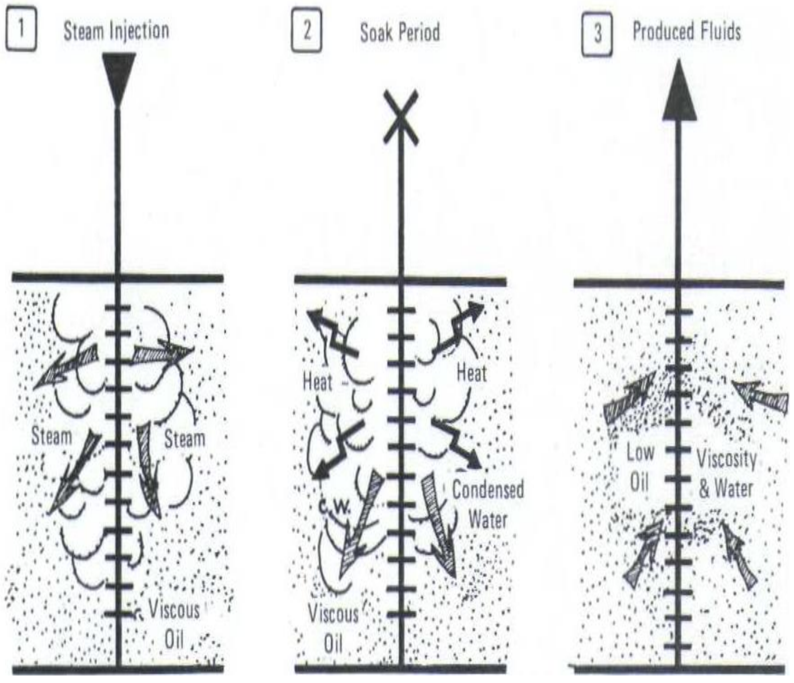
Effect of Oil Saturation, Reservoir Thickness, and Net/Gross Ratio



Steam Cycling Process

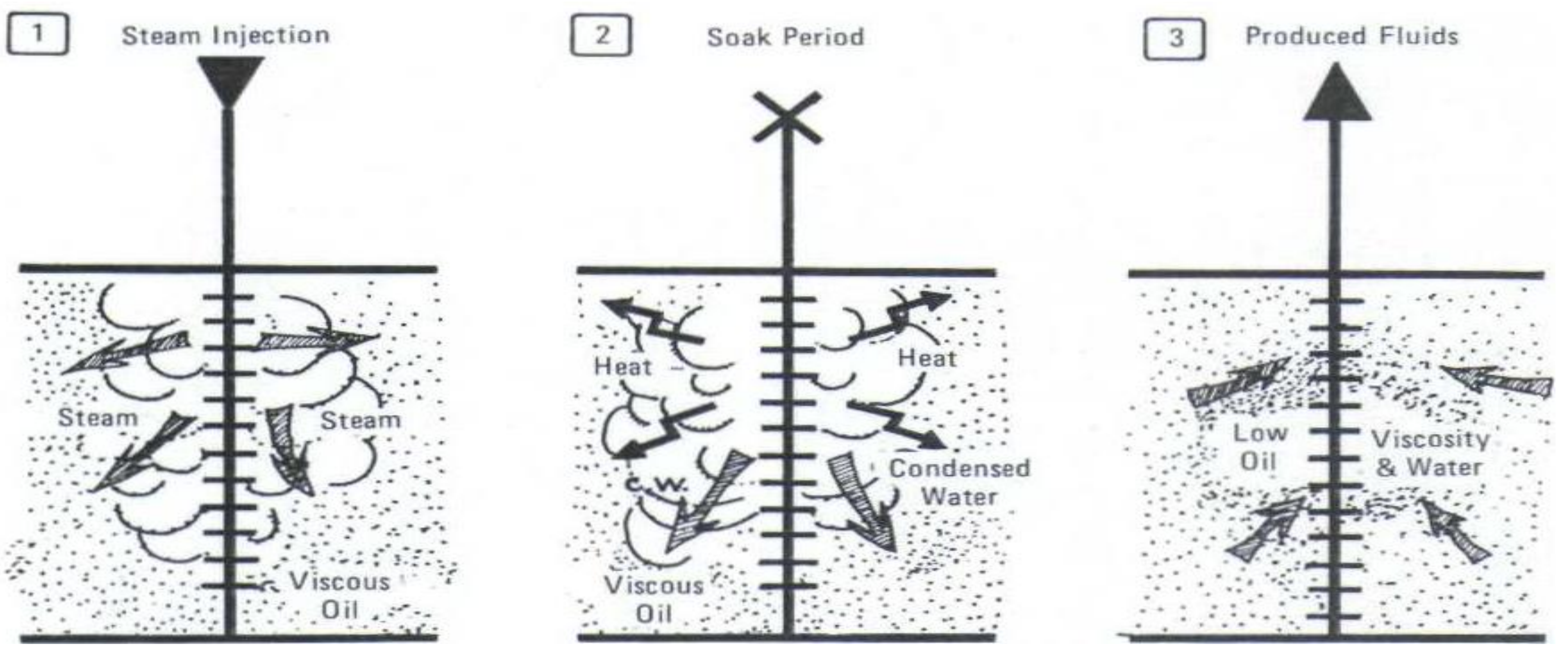
Injection Phase: High quality steam is injected into a producer.

Injection is achieved at the highest practical injection rate, to minimize heat loss.



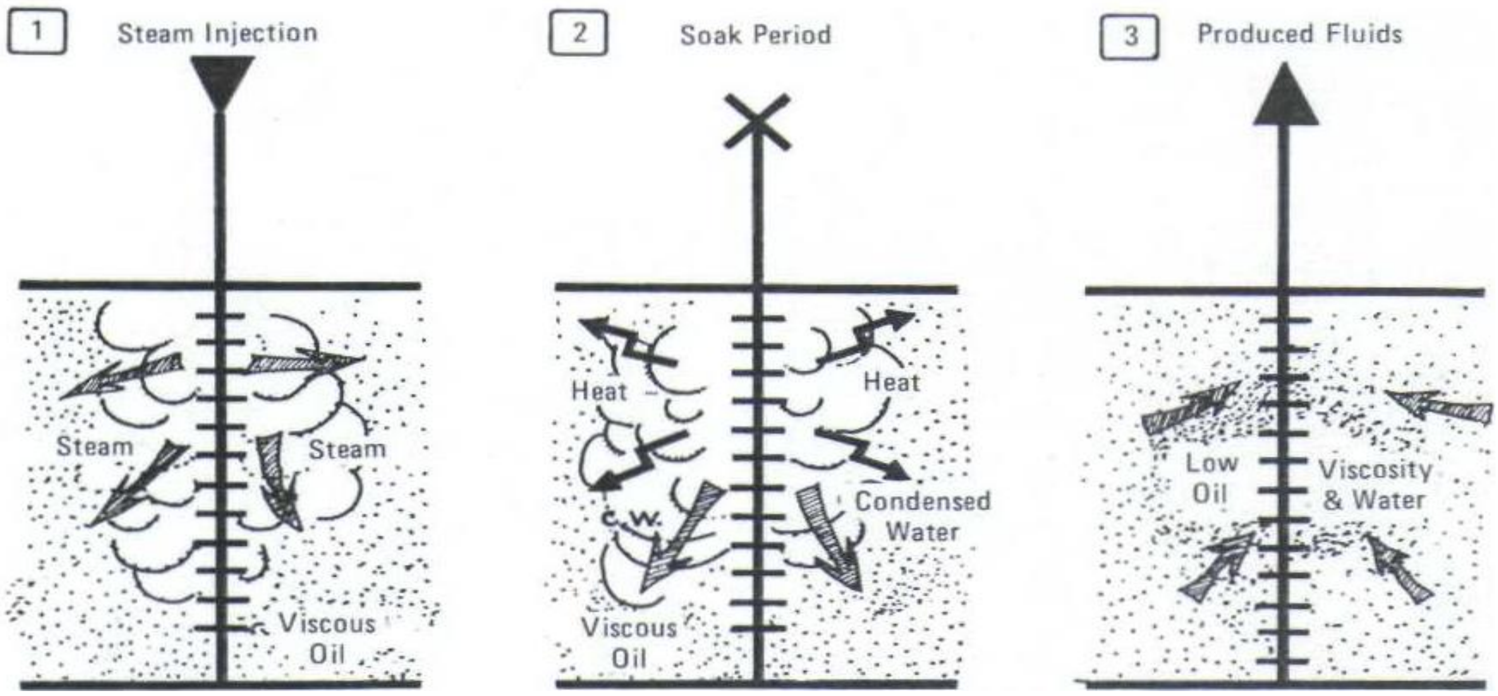
Soaking Phase

Well is shut-in for some time allowing steam to heat the region. Optimum soaking duration is programmed to achieve a balance between maximizing the heated volume around the well and minimizing the loss of heat to the formations above and below.



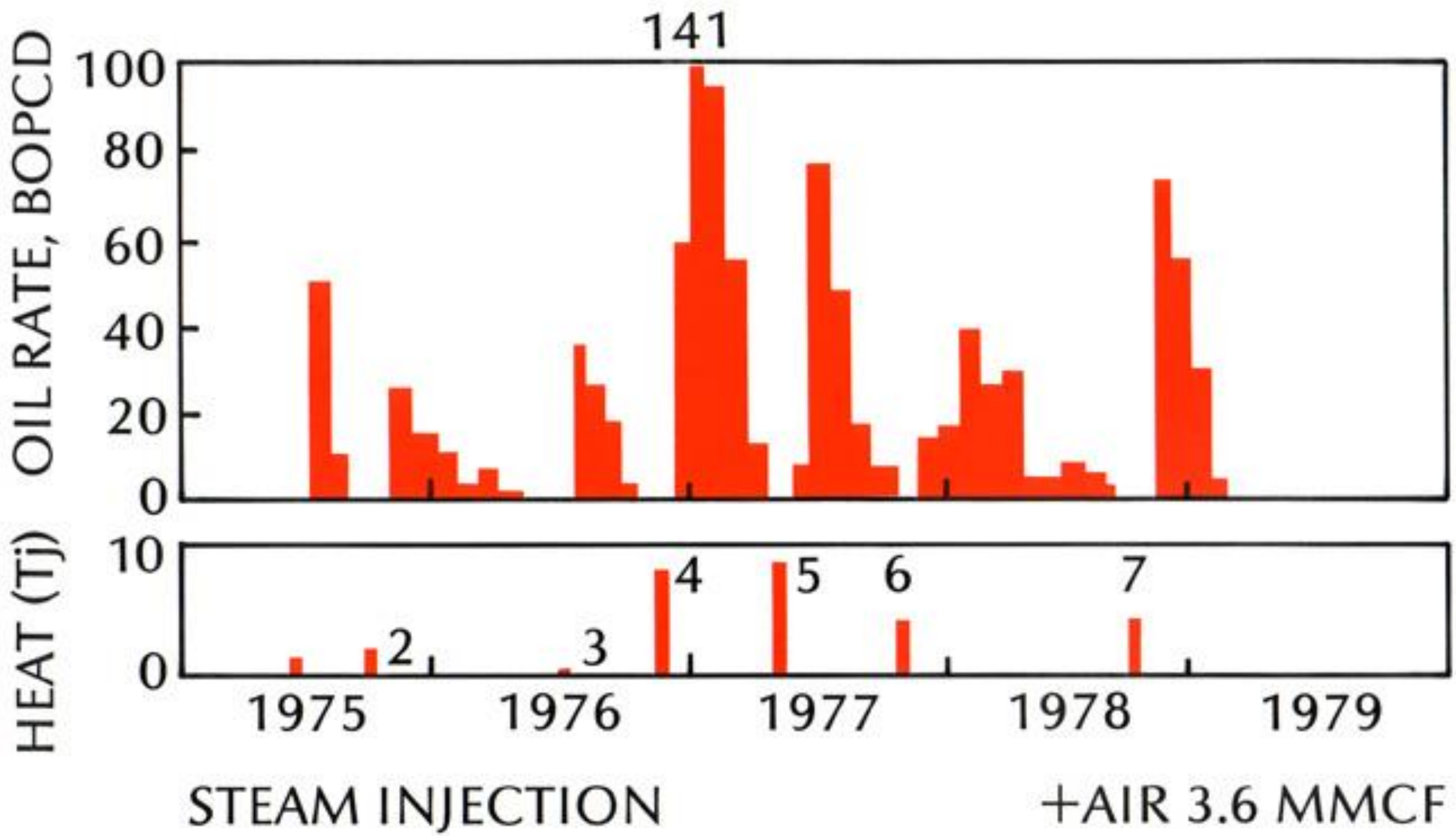
Production Phase

producer is put back on production until the oil rate declines to the economic limit. The above cycle is repeated (two to three times, in general) until oil rate response becomes uneconomical.

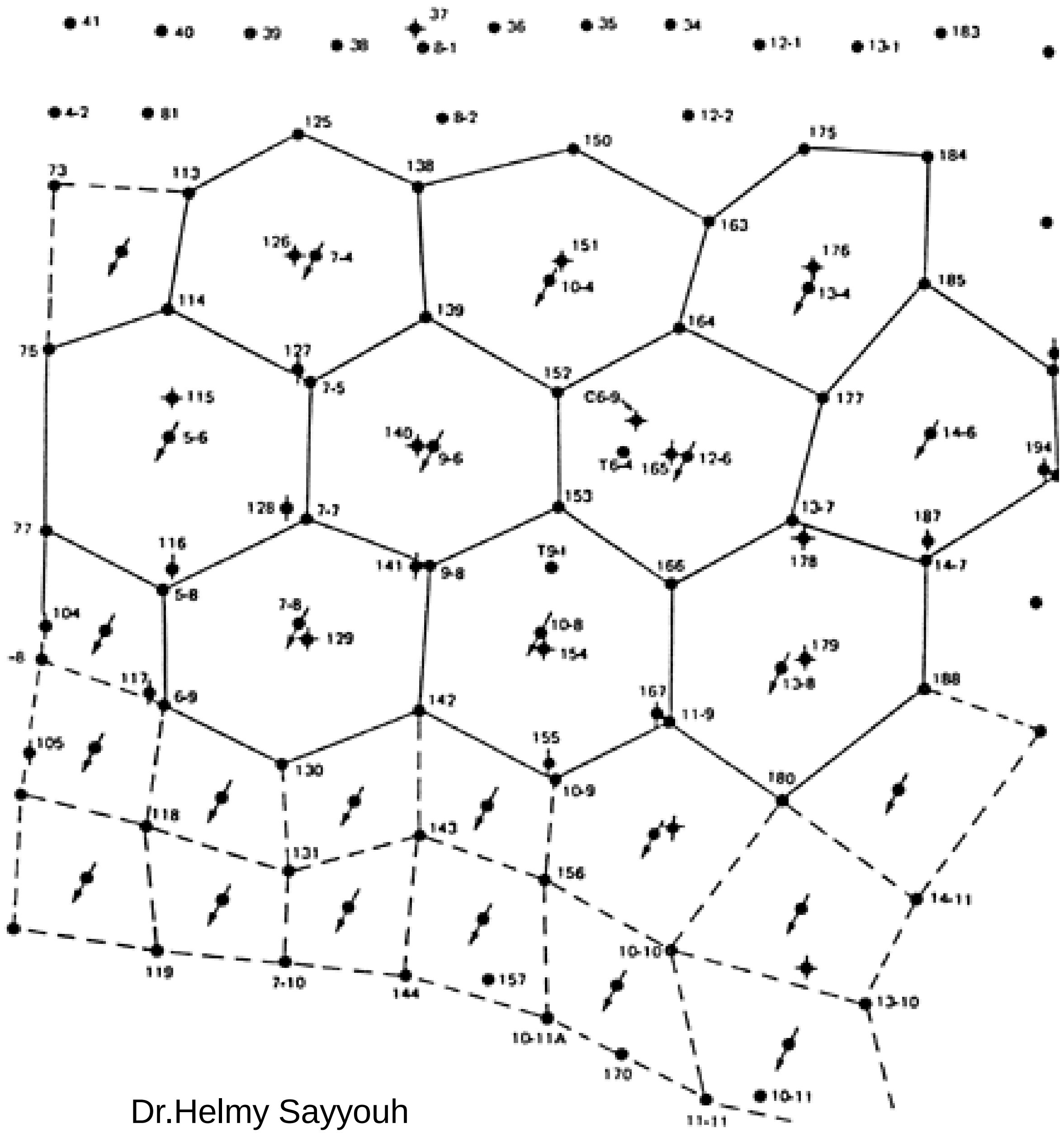


Example...

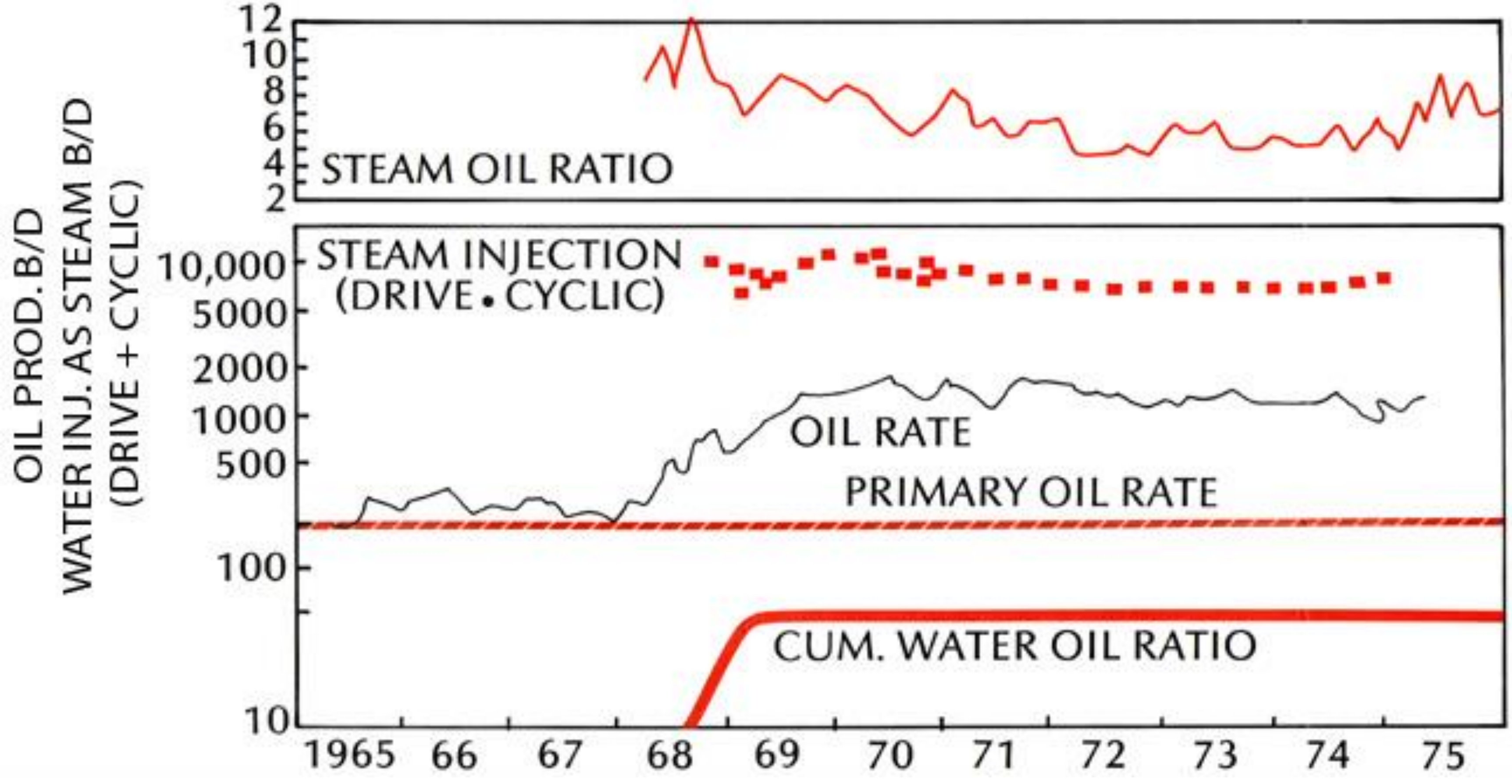
Steam Soak - Paris Valley Field



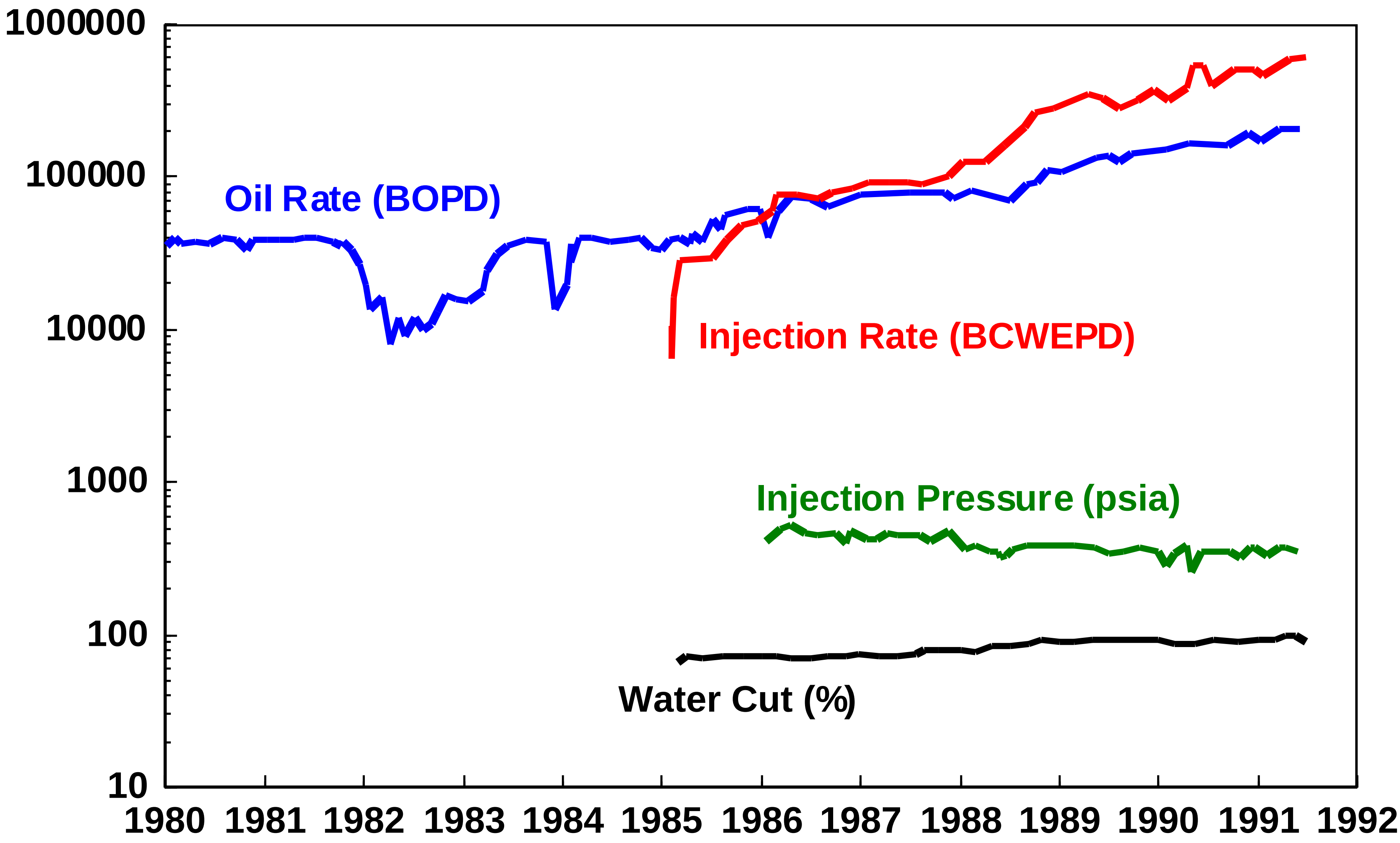
Kern River 10 Pattern



Ten-Pattern Performance Well...

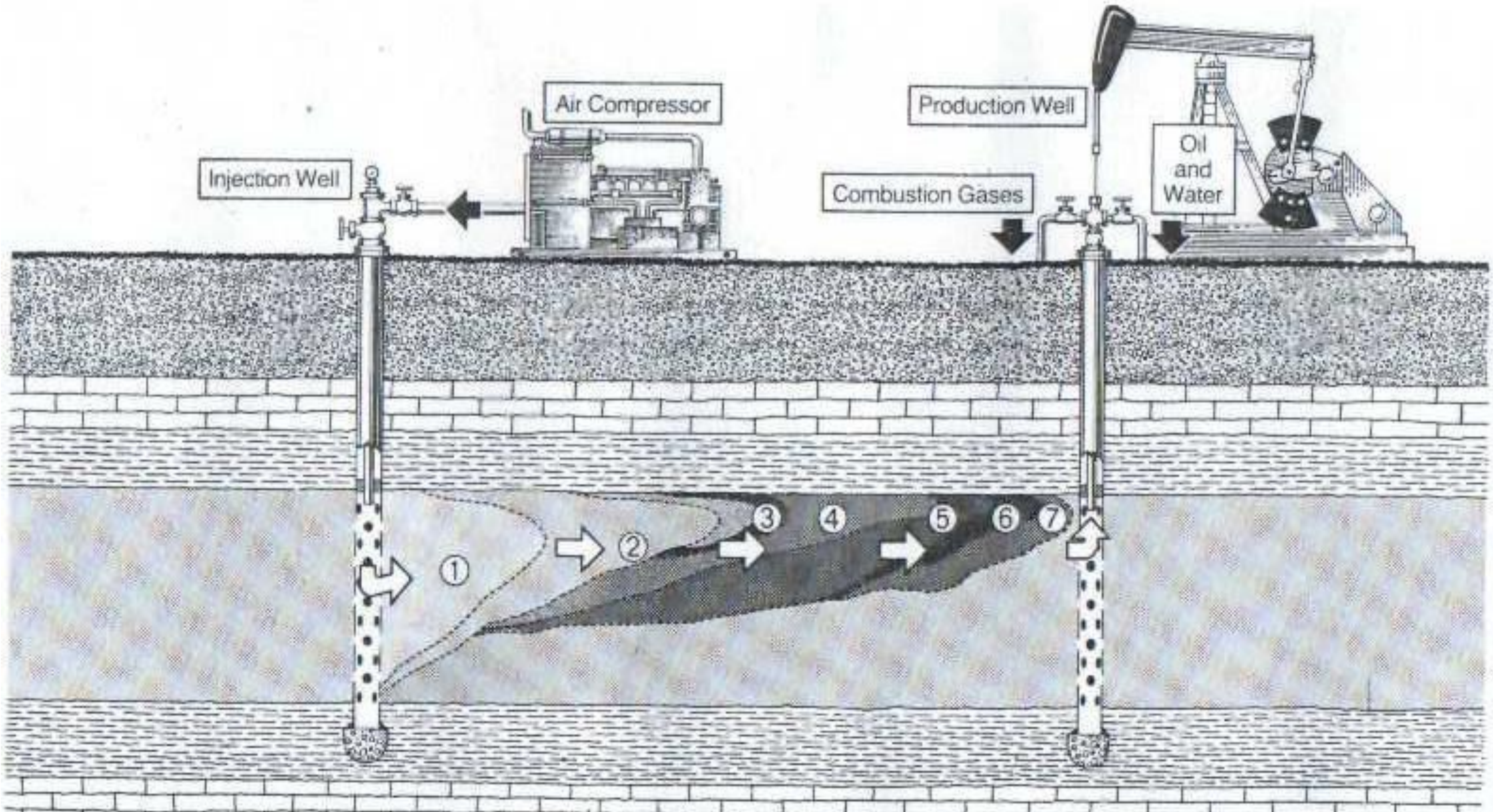


Duri Field, Phase 1



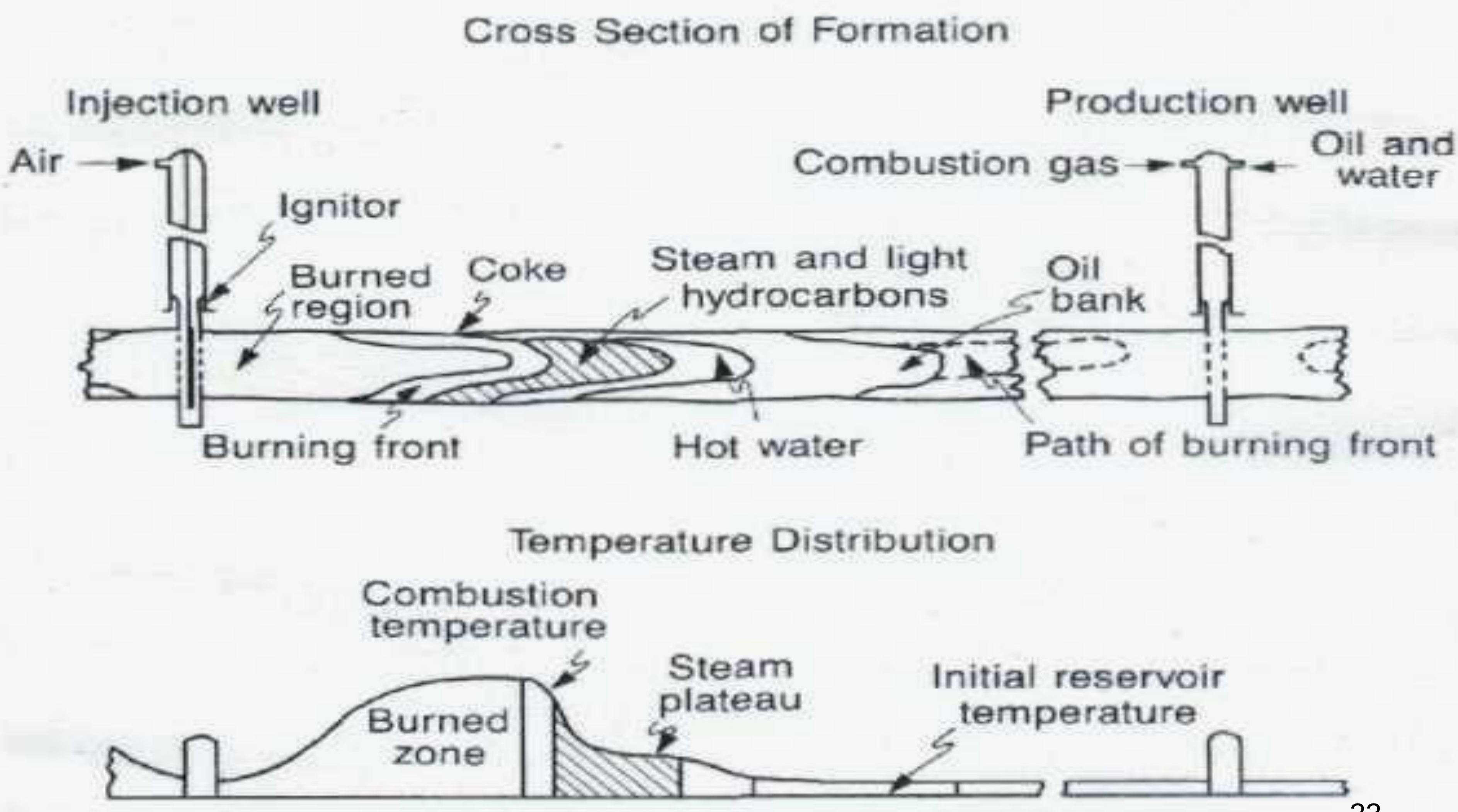
From Enhanced Oil Recovery Field Reports, SPE

In Situ Combustion



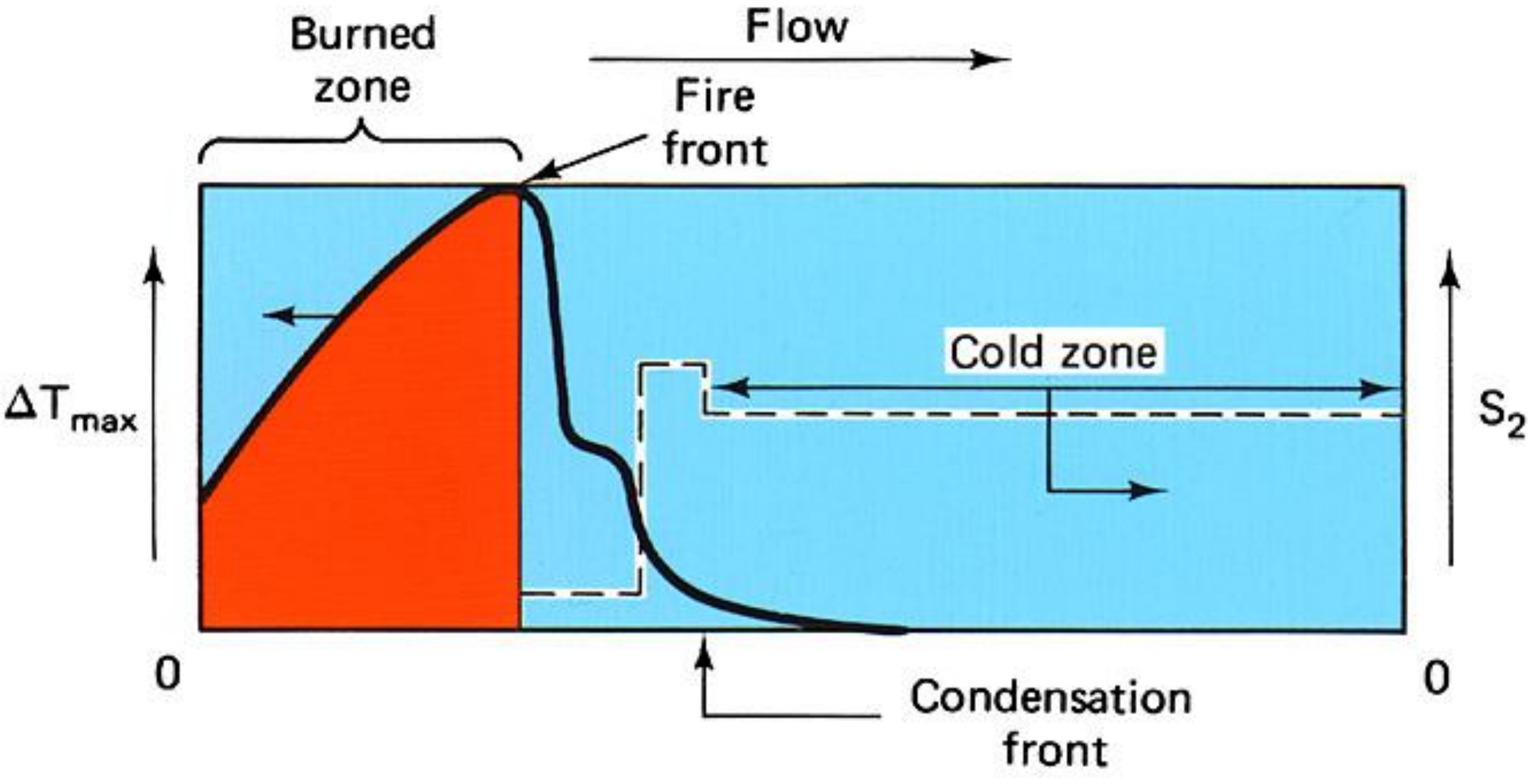
1. Injected Air and Water Zone (Burned Out)
2. Air and Vaporized Water Zone
3. Burning Front and Combustion Zone (600° - 1200°F)
4. Steam or Vaporizing Zone (Approx. 400°F)
5. Condensing or Hot Water Zone (50° - 200°F Above Initial Temperature)
6. Oil Bank (Near Initial Temperature)
7. Cold Combustion Gases

A burning front and combustion zone is propagated to the producing well by air injection into a well (forward combustion).



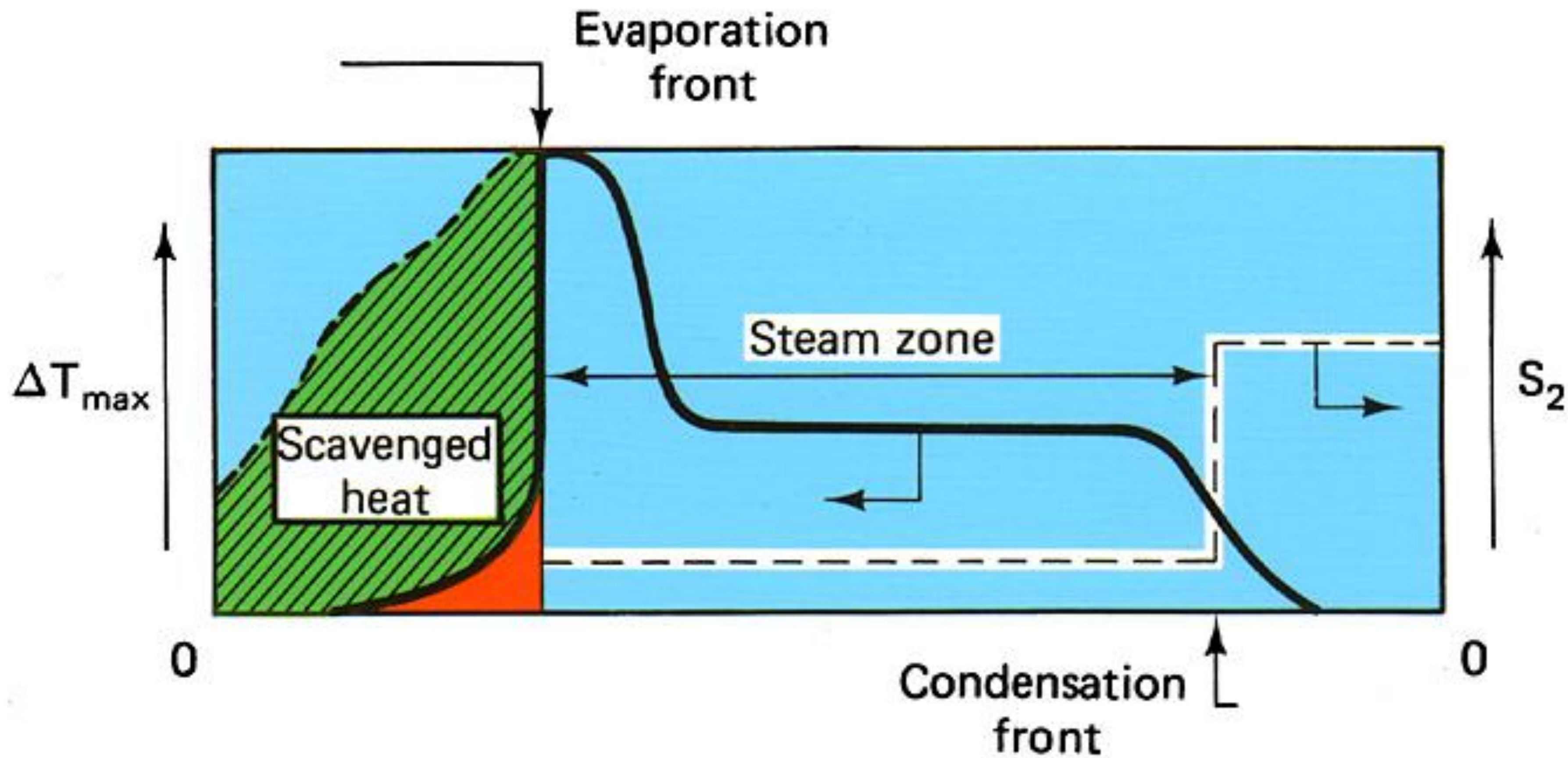
Dr.Helmy Sayyouh

Dry Combustion Schematic



Optimal Wet Combustion Schematic

$0.47 < f_{13} < 0.95$



West Buffalo Red River Unit