

## 6.3 Radio Frequency Heating

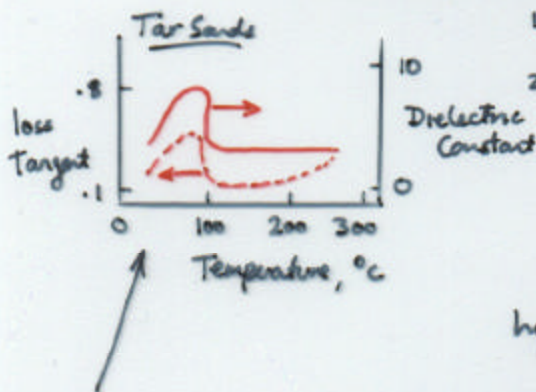
Electro magnetic energy  $\rightarrow$  heating:

1. Vaporizes low b.p. liquids  $bp < 100^\circ C$
2.  $\uparrow$  Evaporation rates for high bp liquids  $bp > 100^\circ C$
3. Displacement by propagating steam front  
+  $\uparrow k$  and  $\downarrow \mu$

Analogous to CEOR

Microwaves distort physical (molecular) structure of polar compounds (water)  $\rightarrow$  kinetic energy  $\rightarrow$  heating.

Important parameters:



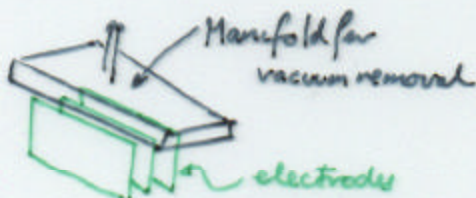
1. Dielectric constant (porous medium)
2. Loss tangent (ratio of apparent conductivity to change in frequency)

High loss of energy and low penetration in high  $\epsilon$  soils. Water saturated  $\rightarrow \epsilon_r \sim 80$   
 $\therefore$  low penetration of saturated soil

$\epsilon_{NAPL} < 5$  } tar sand @ low  
 $\epsilon_{water} \sim 80$  } water saturates

As fluid boils off the  $\epsilon$  magnitude  $\downarrow$   
 and coupling is more effective

### Field Implementation



- o Shield RF from humans (harmful) navigation etc.
- o Triplate design
- o Also used in EOR

Subsurface heating  $\rightarrow$  vapors to perforated electrode - "vacuum" manifold  
- removal to manifold  
- produces natural draft

If soil temp  $< 100^\circ\text{C}$  then hot water propagation front.

### Level of Demonstration

Bitumen recovery from tar sands

20' long electrodes as triplate

Daily power 40-70 kW. Soil temp  $200^\circ\text{C}$  for 20d.

336 gals bitumen or 36% recovery

1 environmental application. Volk Field Air Nat. Guard Base, WI

Sandy soils. Hydrocarbons to 4000 ppm

6-8' deep triplate array

12' to water table

12d.

temp to  $150^\circ\text{C}$

Removal of volatiles (bp  $< 120^\circ\text{C}$ ) 99%

semi volatiles (bp  $120-300^\circ\text{C}$ ) 95%

### Applicability

o Low or high boiling point materials

o Applicable in unsat. zone

Not obvious if useful in saturated zone, or advantageous over SCS

Not greatly affected by presence of clays

Likely sterilizes soil for bioremediation

### Cost/Availability

Patent to IIT  $\rightarrow$  Licensed to Roy F. Wacker

\$40-100/ton soil