Enhancing Recovery from Mature Fields: Air Injection Potential

I. Yucel Akkutlu

School of Mining & Petroleum Engineering

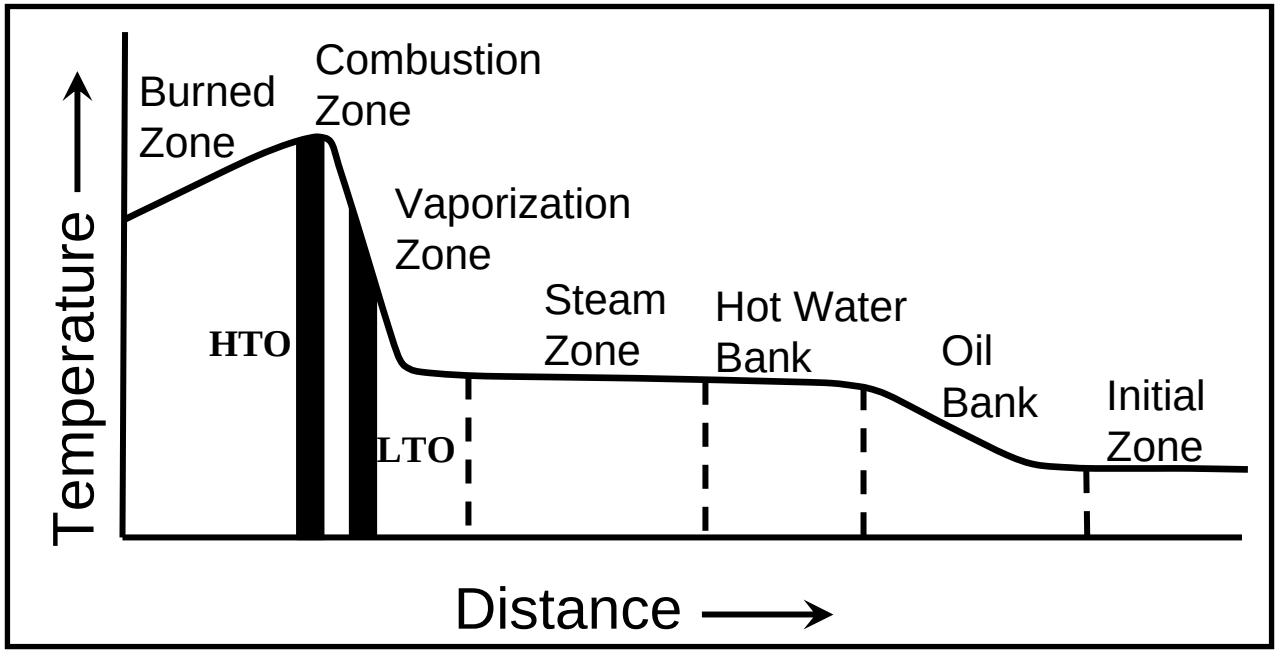
University of Alberta

Edmonton, Canada

Current Status

- Air injection processes
  - Heavy oil reservoirs (thermal recovery)
  - Light oil reservoirs (gravity-stabilized gas displacement)
- They have not been widely accepted as risk-free recovery techniques due to
  - High initial cost of air compression facilities
  - Perceived safety problems during operations
  - Unfavorable thermal projects in the past
  - Complexities of the reaction phenomena

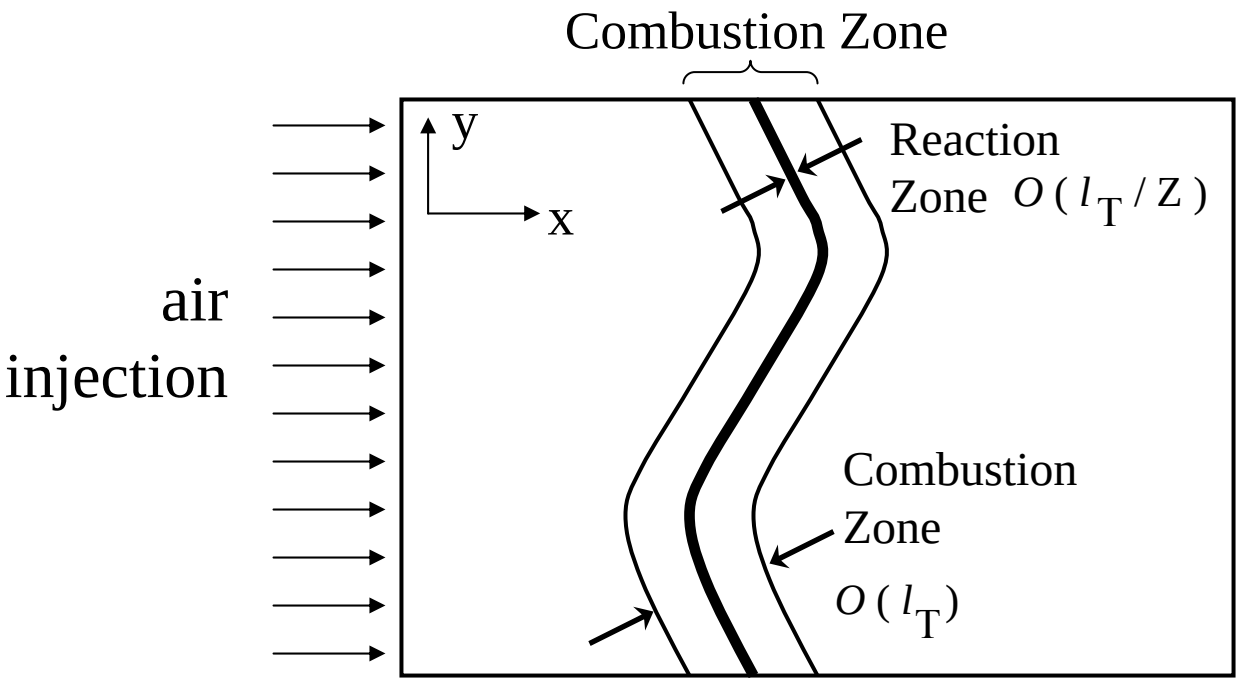
1-D ISC Temperature Profile



How to predict the occurrence and behavior of HTO/LTO regions under reservoir conditions

HTO Frontal Structure

(Large Activation Energy Asymptotics)



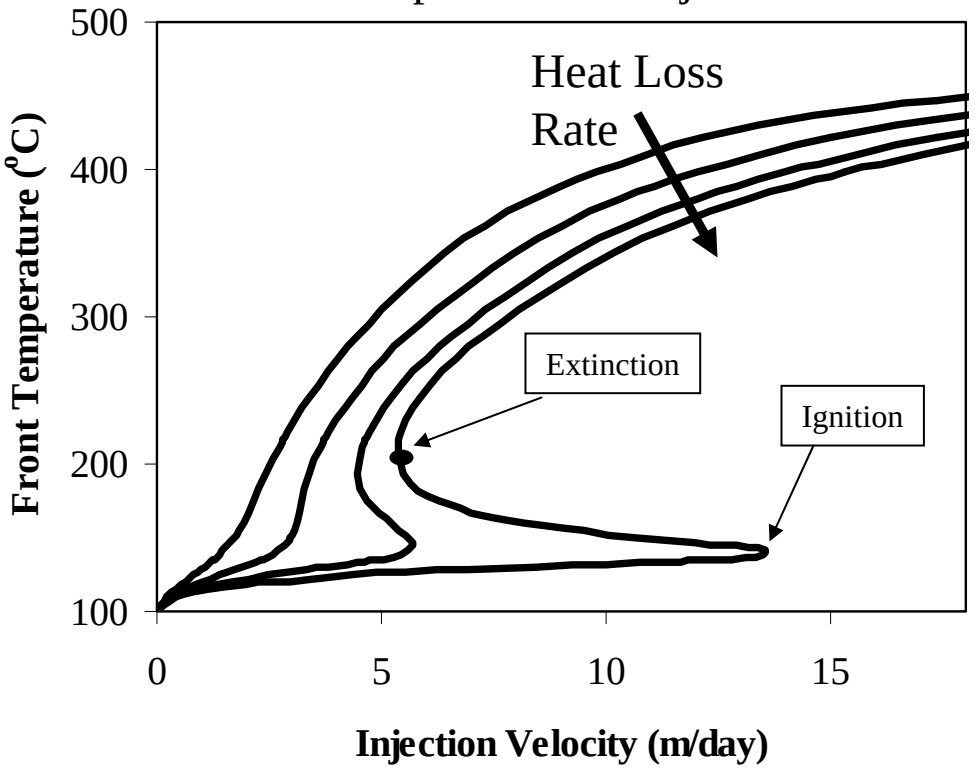
Area of HTO reaction is a place of discontinuities

(Akkutlu & Yortsos, *Combustion and Flame* 2003)

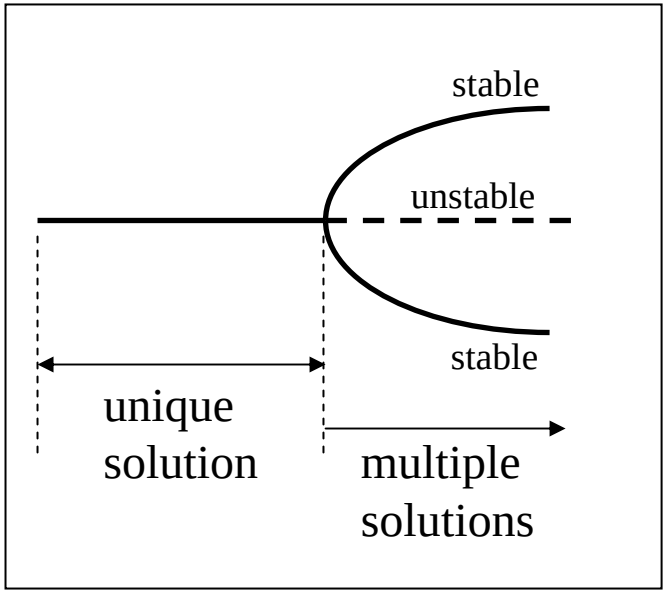
Non-adiabatic HTO Fronts

(Appearance of Bistability and Hysteresis)

Front Temperature V. Injection Rate



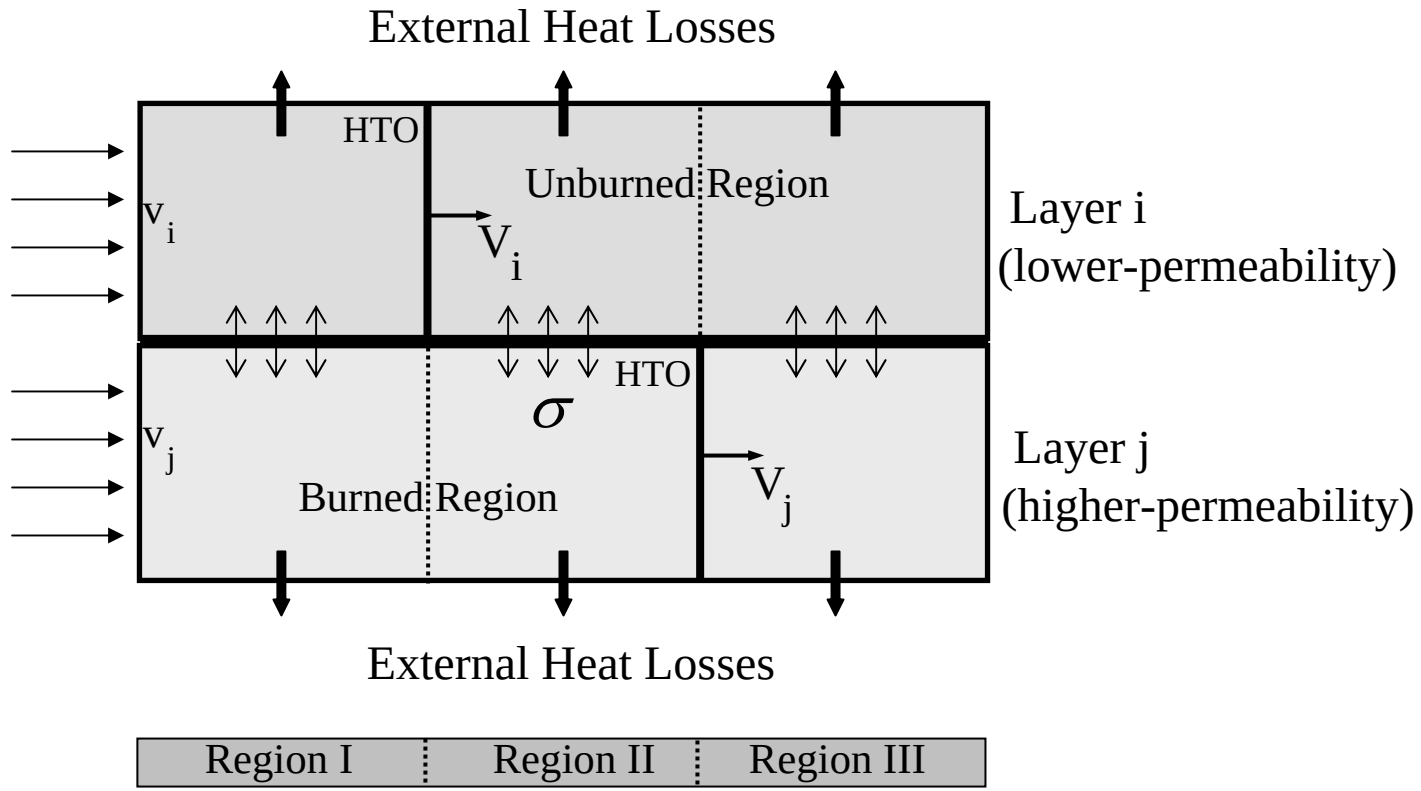
Bifurcation Diagram



Multiplicity character appears and becomes more pronounced with the increasing heat loss rate

Layered Reservoir Model

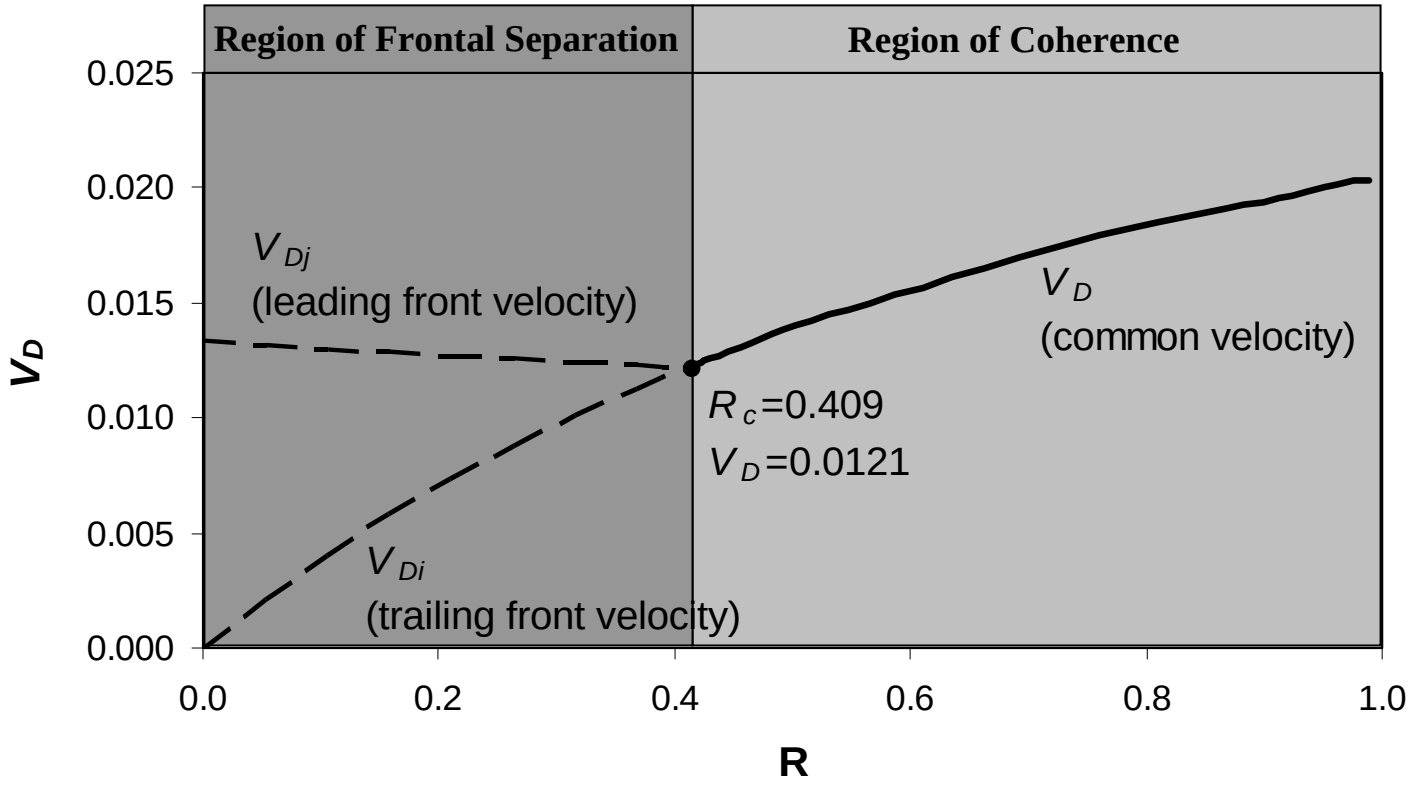
$$R = \frac{k_i H_i}{k_j H_j}$$



Traveling-wave solution exists: coherent HTO front

(Akkutlu & Yortsos, *SPEJ*, December 2005)

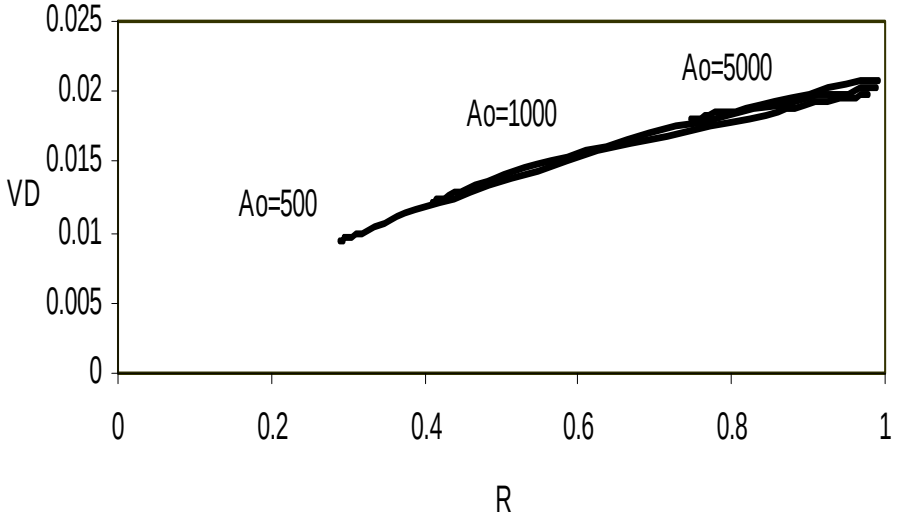
HTO Front Propagation Velocity in Layered System



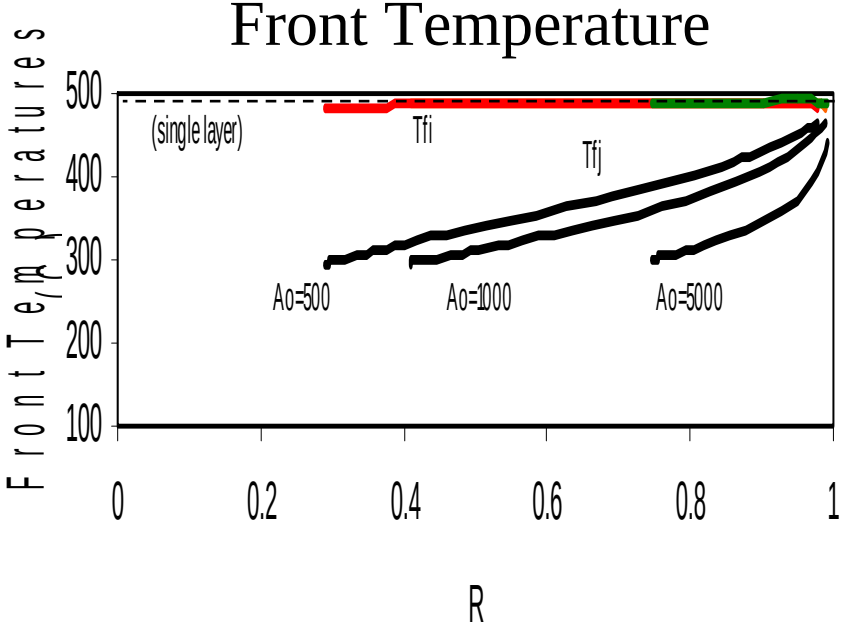
As the contrast reaches a critical value R_c,
HTO front becomes de-coupled and fully separated in the layers

HTO Front Properties in Layered System

Front Velocity



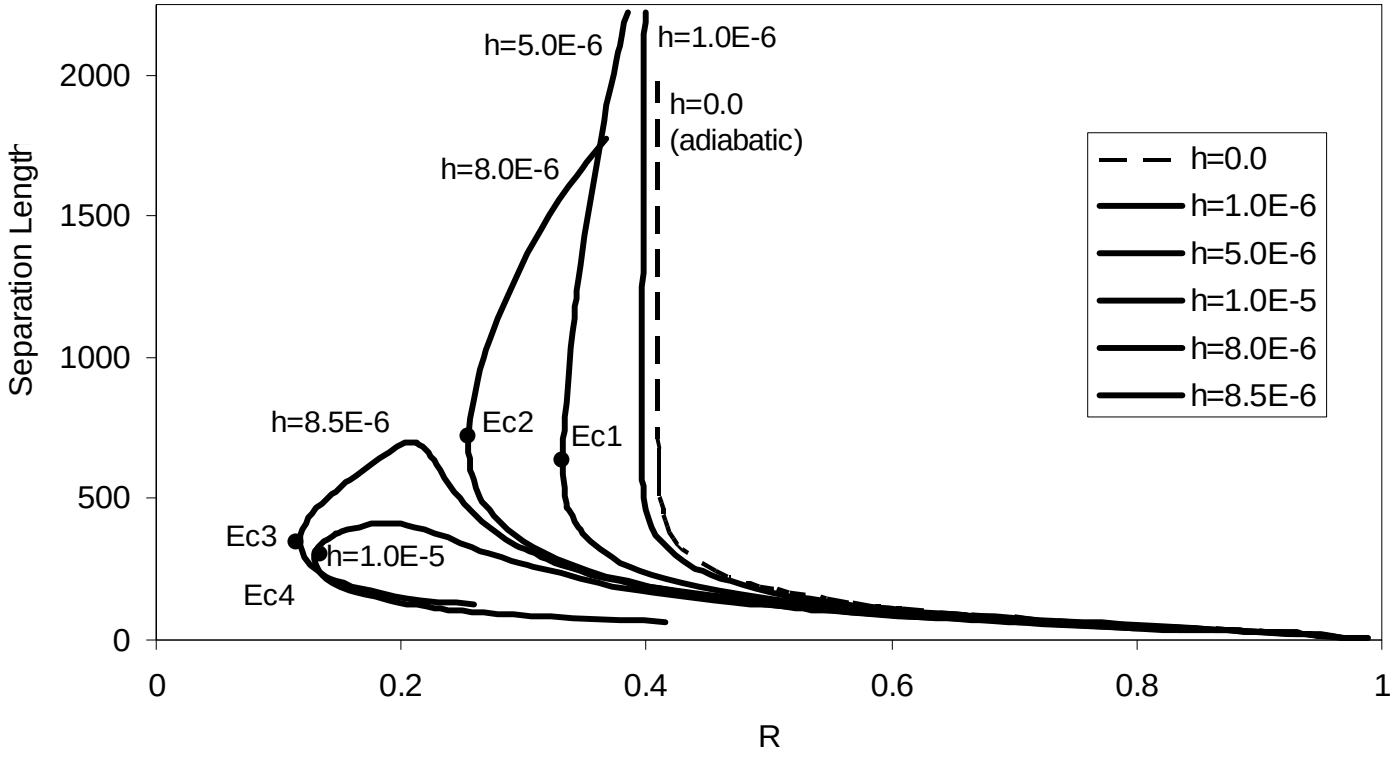
Front Temperature



Thermal coupling retards the leading front significantly; whereas, it accelerates only slightly the trailing front

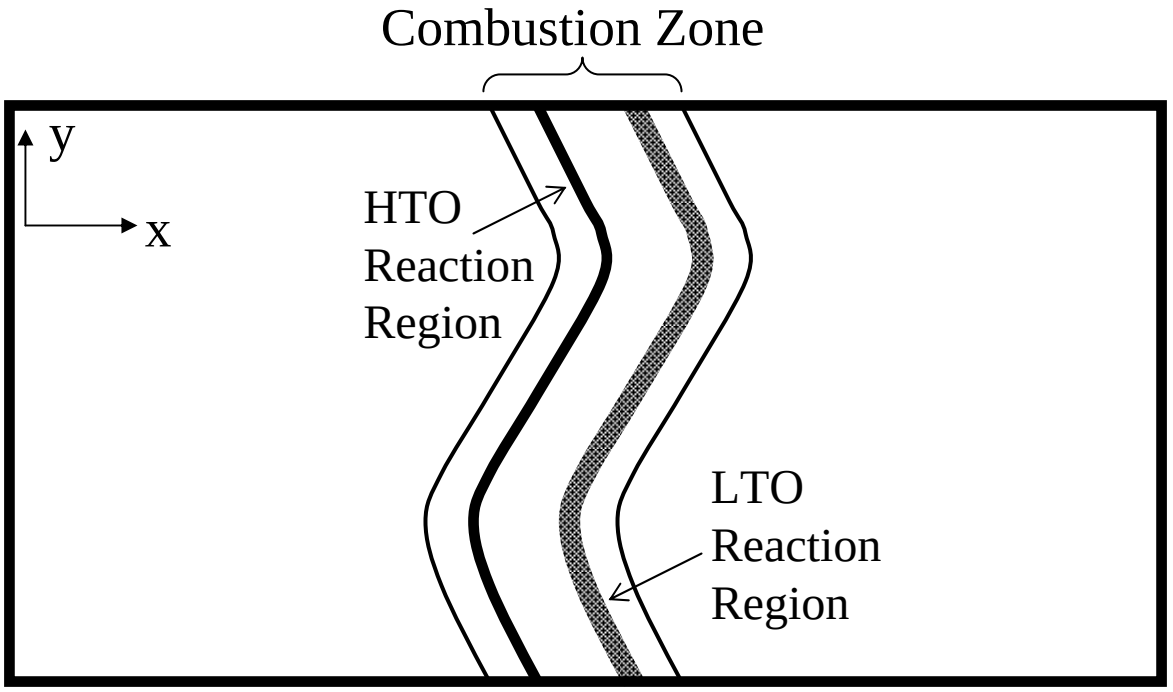
Leading front temperature drops significantly

HTO Front Coherence in Layered System



In the presence of reservoir heat losses, coherent propagation yield two bifurcating solutions: Frontal separation & extinction

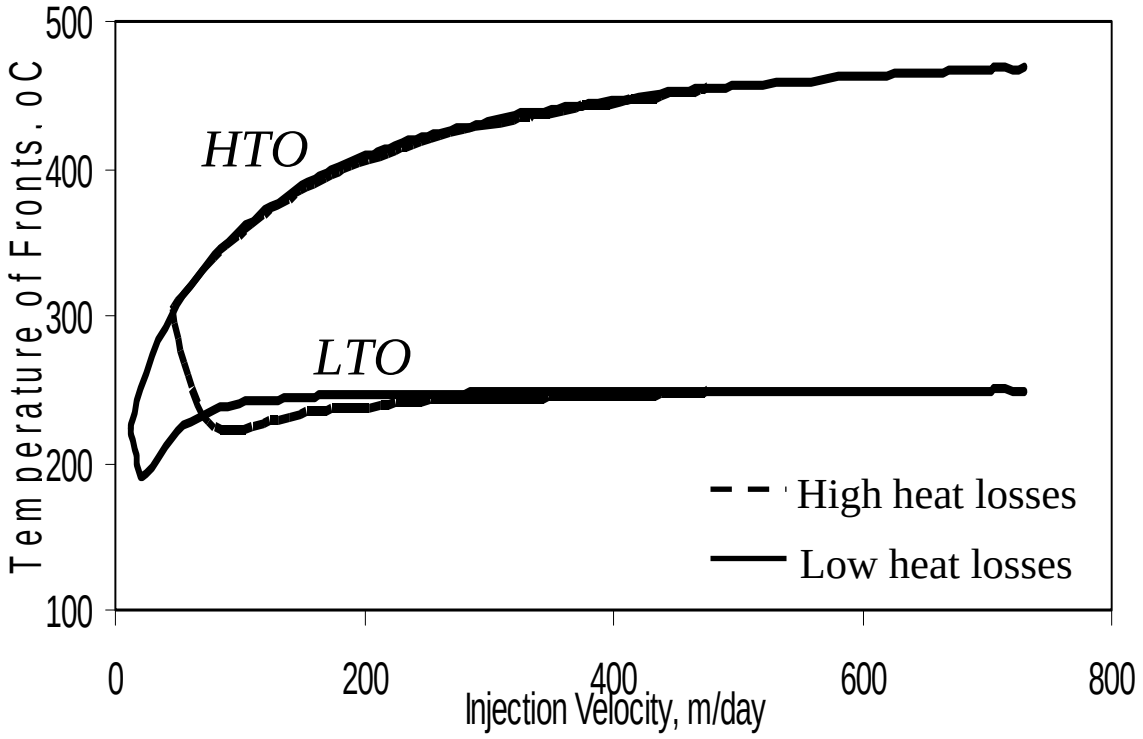
Sequential Reaction
HTO/LTO Frontal Structure



Traveling-wave solution exists: coupled fuel generating/ consuming reactions with a finite separation distance

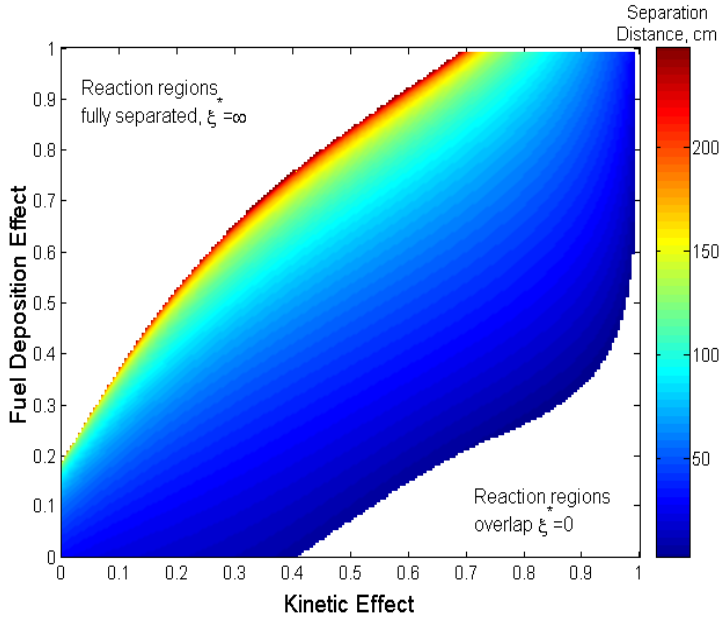
Non-adiabatic HTO/LTO Propagation

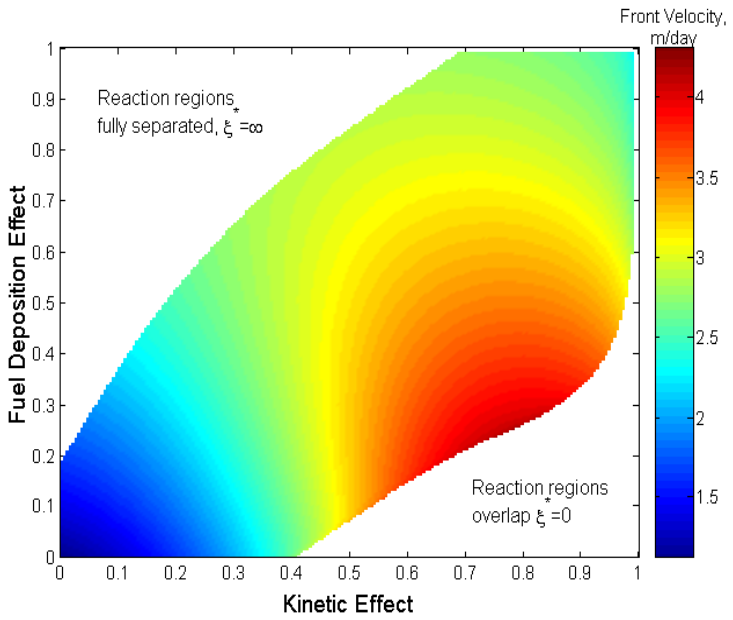
(Temperature Vs. Injection Velocity)



Change in heat loss rate does not have significantly effect on the HTO and LTO region temperatures

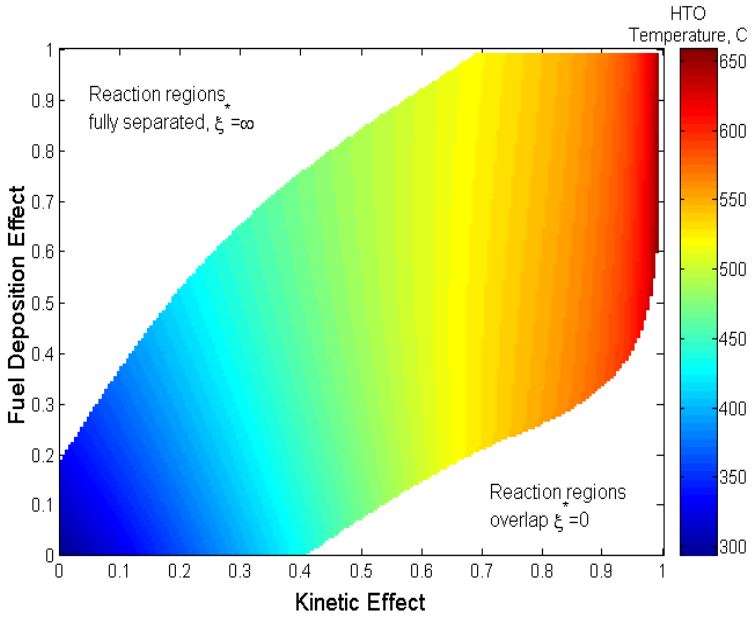
Dual Effects of Catalytic Agents
(Separation Distance and Propagation Velocity)

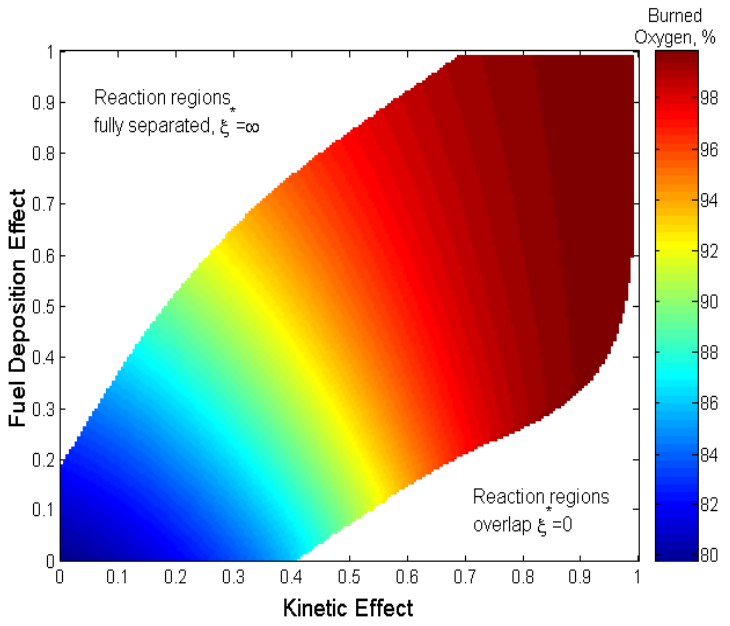




Frontal coherence possible
only when both fuel deposition and kinetics effects present
(Adagulu, Akkutlu, Yortsos, *J. Canadian Pet. Tech*, 2006)

Dual Effects of Catalytic Agents
(Peak Temperature and Oxygen Consumption Efficiency)





Peak temperature and oxygen consumption efficiency increases in the presence of catalytic agents