THE CHESS PROCESS: Environment Friendly, Low-cost Shale Oil Recovery

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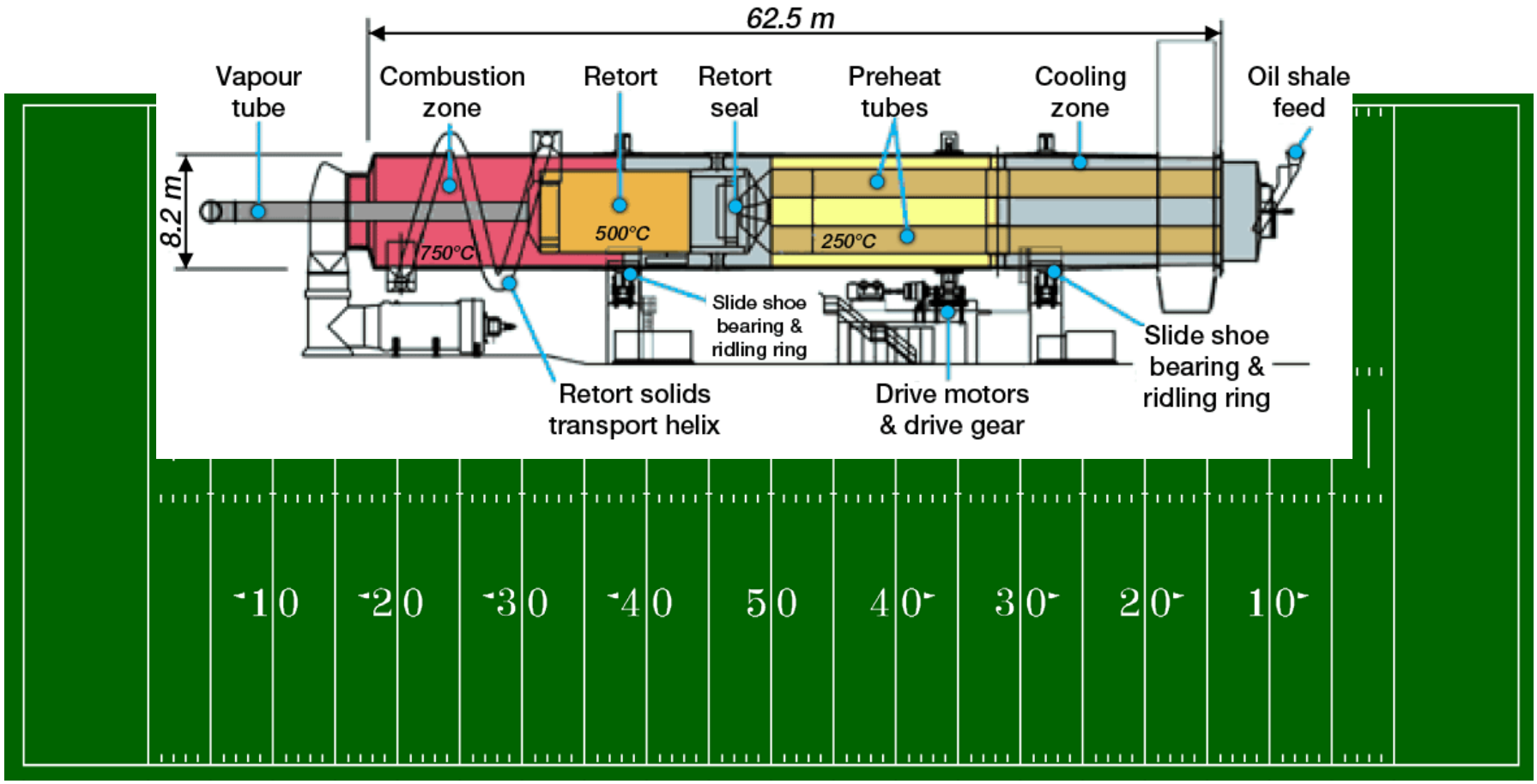
35th Oil Shale Symposium

Salt Lake City, UT

October 5-6, 2015

Need for Improved Oil Recovery

1. Size cost of current units



Alberta Taciuk Processor retort

Need for Improved Oil Recovery

2. Grade of ore that is economical

Comparative Oil Reserves

Grade (gpt)	% Org. Matter	Billion Barrels Oil
> 25	> 15	600
10 – 25	6 – 15	1,400
5 – 10	3 – 6	2,000
Total Green River Deposit *		**4,000**
World Crude Oil Reserves†		**1,000**

*Synthetic Fuels Data Handbook, Cameron Engineers
†Worldwide Pet. Ind. Outlook, 15th Edition, 1999-2003

Challenges with Green River Oil Shale Processing

- For Green River Oil Shale 10% organic (17 gpt), results in 8% liquid, 90% inorganic mineral
- 20% of organic material converts to char or coke
- Inorganic mineral is 33% dolomite, calcines above 1000˚F
  - $CaMg(CO_3)_2 \rightarrow CaCO_3 + MgO + CO_2$
  - Energy cost of 380 Btu/lb (880 J/g)

Objective

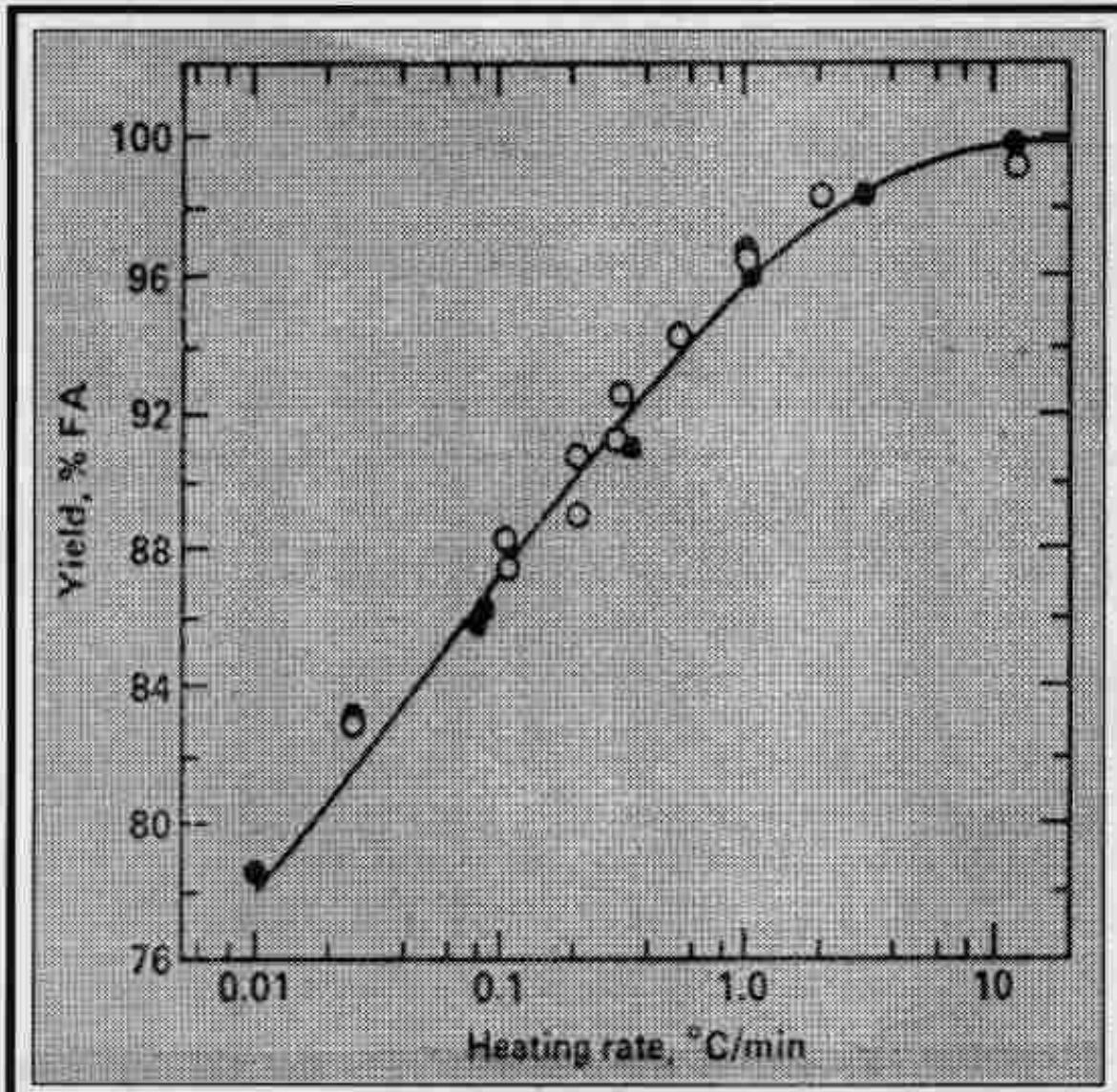
Develop efficient process to

- **Maximize oil yield**
- **Use residual char**
- **Keep ash temperature < 1000°F**
- **Minimize heat requirement & cost**

Wanted:

MODERATE HEATUP

- **Minimum heating rate should be > 10 K/min**
- **High heating rate (1000K/min), as in ash recycle systems:**
  - **NOT NECESSARY**
  - **UNDESIRABLE**



EFFECT OF HEATING RATE ON OIL YIELD

LOW HEATING RATES RESULT IN OIL LOSS DUE TO COKING. DATA POINTS ARE FROM TWO DIFFERENT SOURCES. (After J. H. Campbell et al. IN Situ, 2(1), 1978).

MINIMIZE COKING REACTIONS

SURFACE COKING*

1200F, 0.2 SEC. = 14% LOSS
1200F, 1.2 SEC. = 40% LOSS
932F, 3 SEC. = 7% LOSS

METAL OXIDE SORBPTION† (OF OIL ON FINE ASH THEN THE SORBED OIL BURNS IN THE COMBUSTOR)

HYDROGEN ABSTRACTORS‡, S, O (present in recycle ash as Sulfates and as O2 in fine particle interstices)

*Bissel, et al., Shale Oil Cracking Kinetics, Ind. Eng. Chem. Process Des. Dev., 1985, 24, 383.
†Barney & Calson, US Patent #3,691,056
‡Lewis, LLNL Oil Shale Qtr. Report, UCID-16986-85-2

NO OXYGEN!

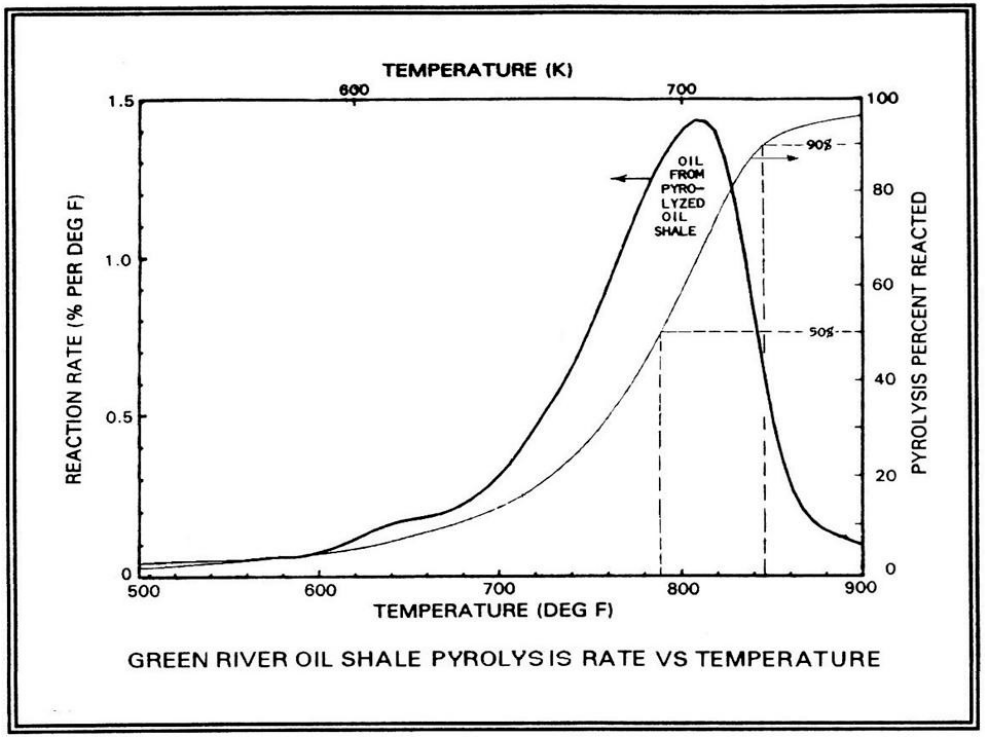
ROBINSON & HUBBARD:

- When oil shale retorted after preheat in gas with > 0.1% O_2, oil yield reduced by up to 16%
  - Equivalent increase in coke and water

(USBM RI-4787)

Oil shale pyrolysis and vapor formation occur at a relatively low temperature:

- 50% below 785°F
- 90% below 845°F
- 100% as T $\rightarrow$ 950°F



GREEN RIVER OIL SHALE PYROLYSIS RATE VS TEMPERATURE

Idea:

- Quickly withdraw at the formation temperature and cool the vapor immediately after it forms to avoid coking or cracking
- Heat residue to a relatively high T (950°F) thus providing the best of both effects
  - low temperature pyrolysis (minimal coking/cracking) and
  - high temperature (thorough) pyrolysis.

Challenge

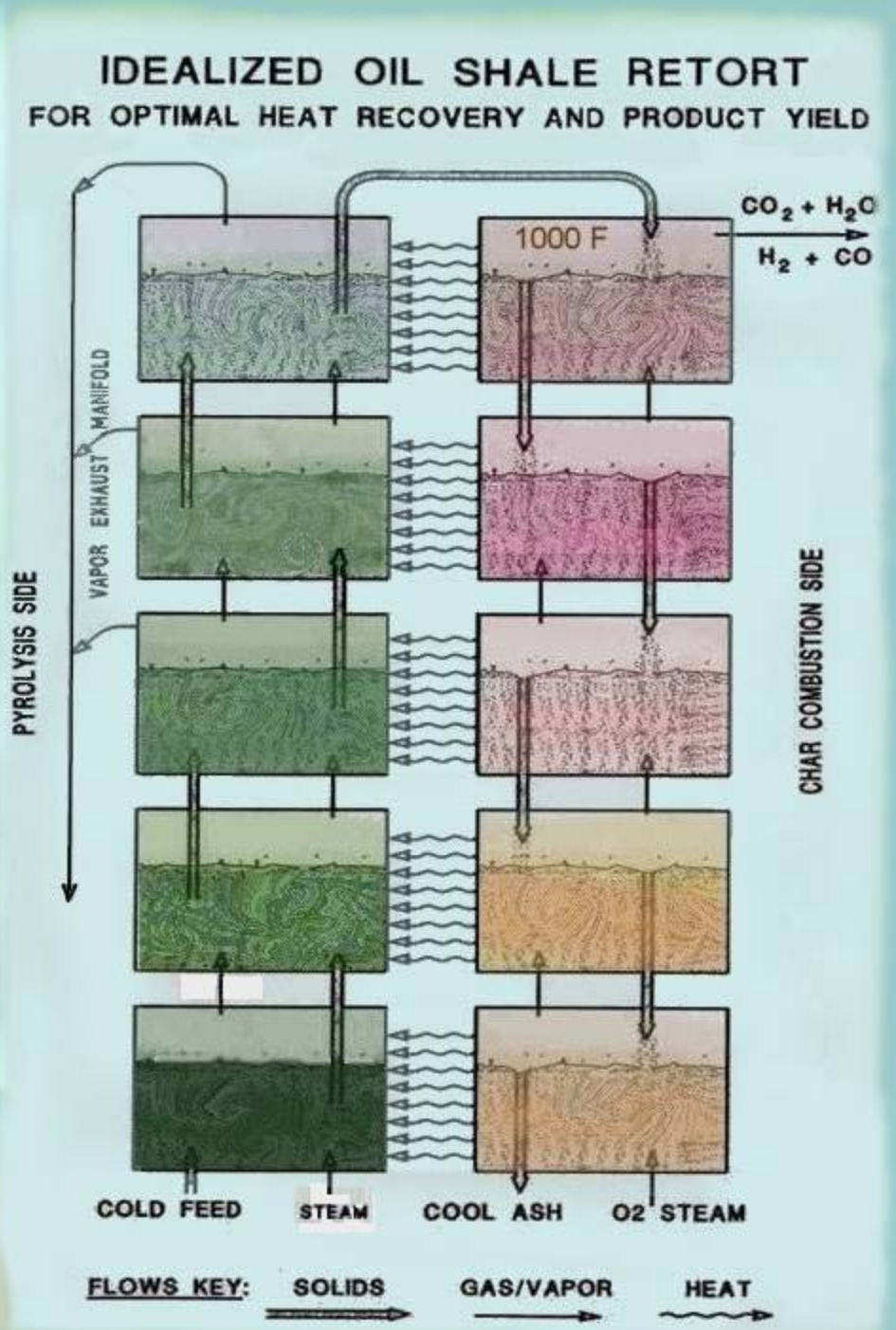
- How do you efficiently heat the oil shale at ~ 10 K/min with no Sulfates or O_2 present?
  - Difficult when ash is recycled

- Most efficient heat exchange is counter-current (vs co-current).

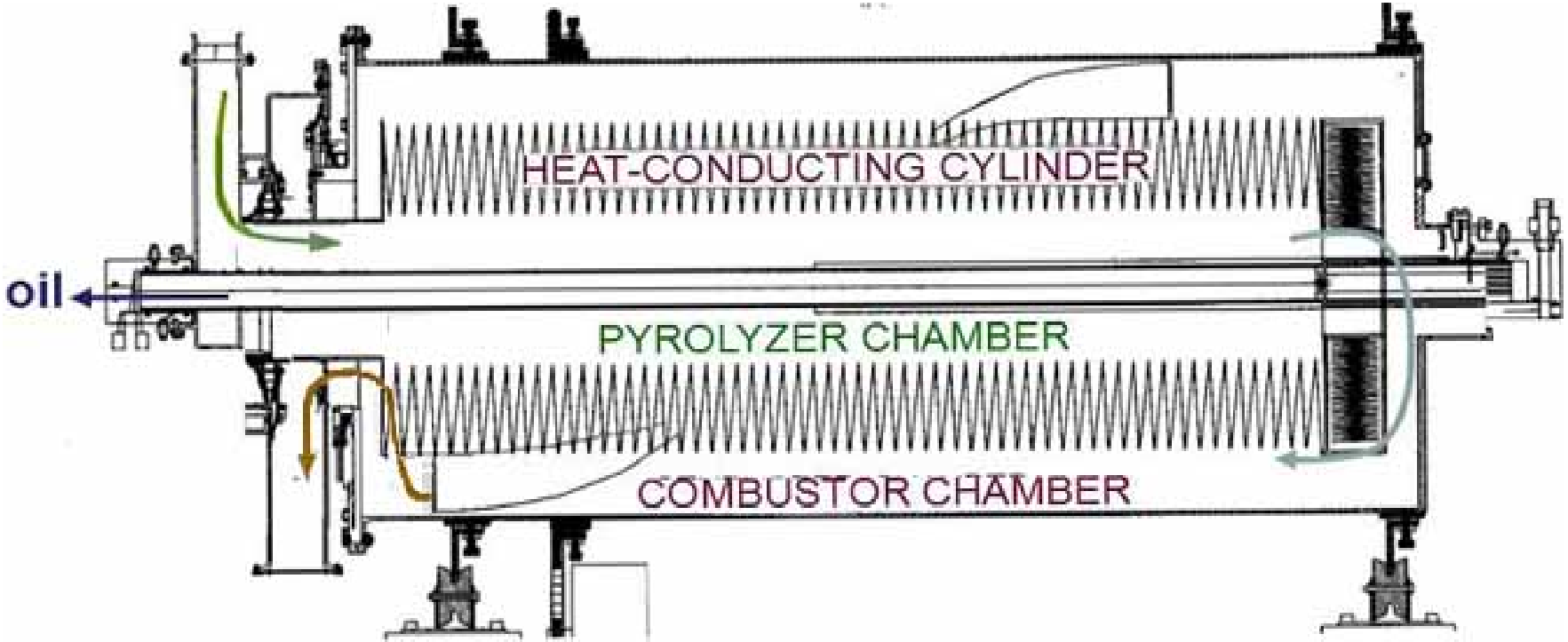
EFFICIENT OIL RECOVERY

- Numerous stages for countercurrent heat exchange
- Low T vapor removal to reduce coking
- Optimal heating rate
- Optimal gas/solid fluid bed contacting
- Countercurrent oxidation of char to provide heat

- **Heat Transfer Problem!**

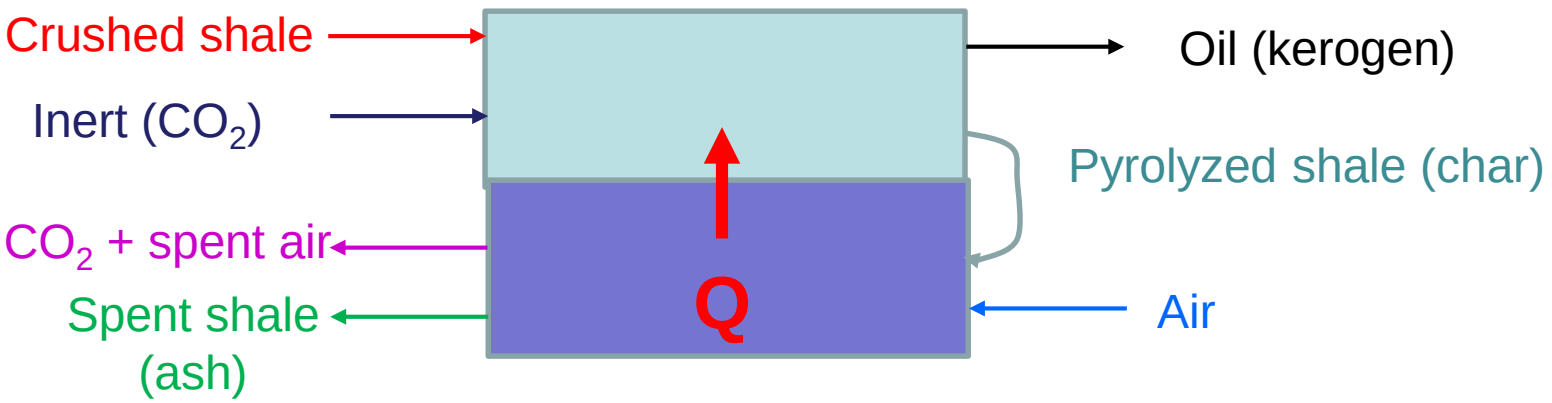


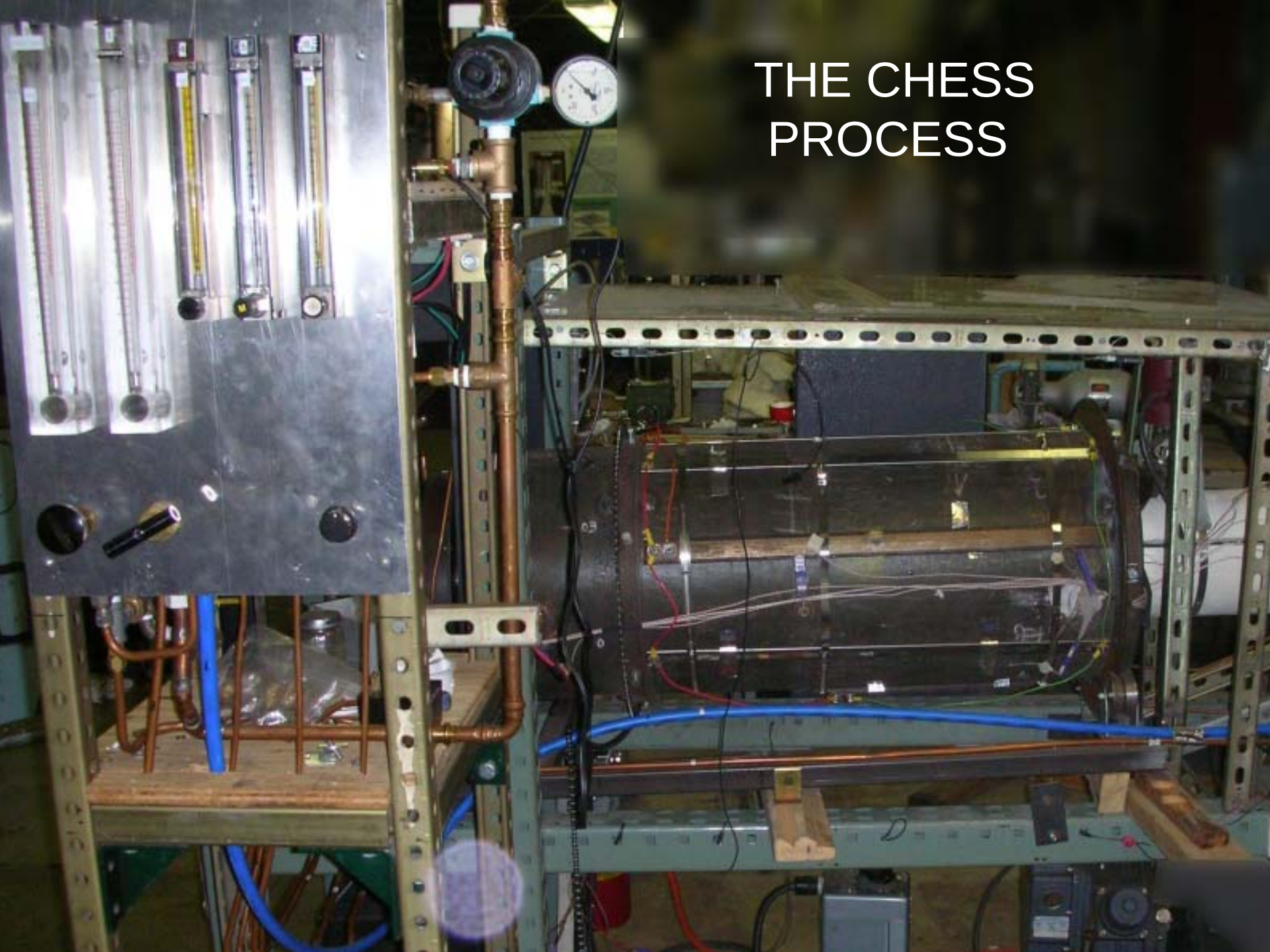
CHESS Process
(Counterflow Heat Exchange Retort)



Counterflow Heat Exchange in Solid Streams

Process Diagram

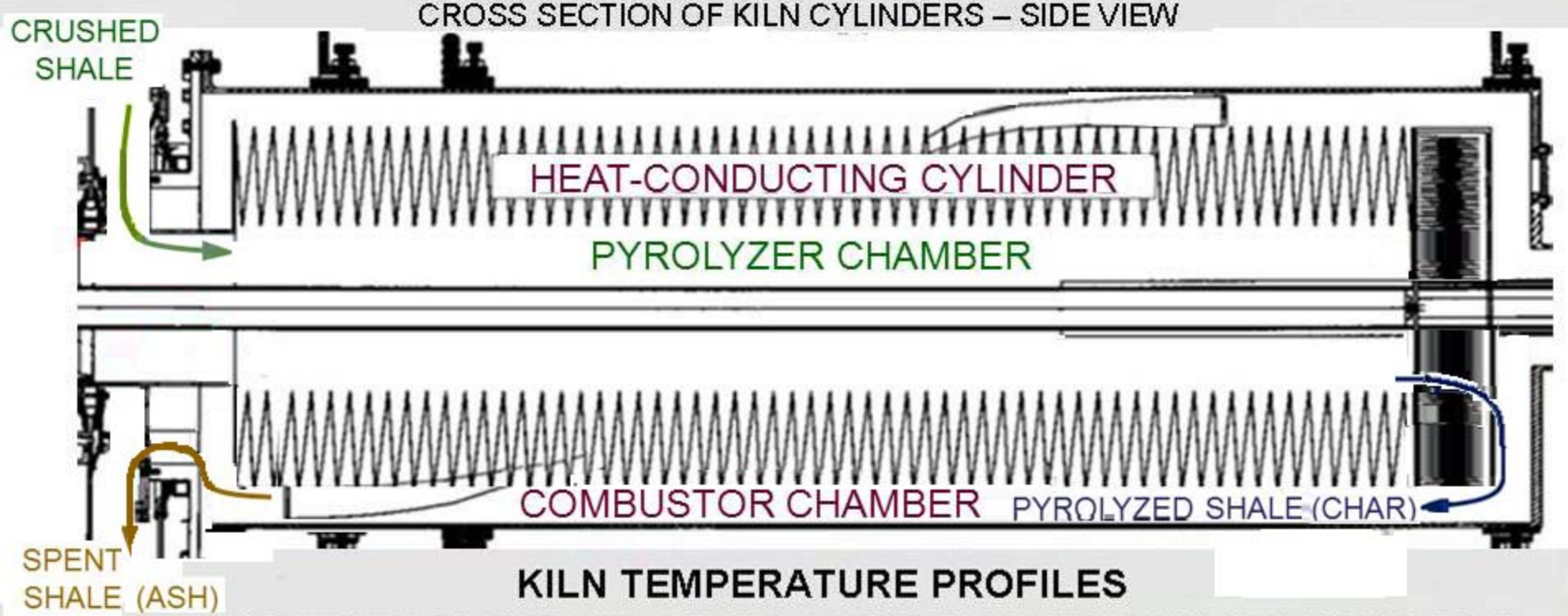



THE CHESS
PROCESS

CHESS ROTARY KILN

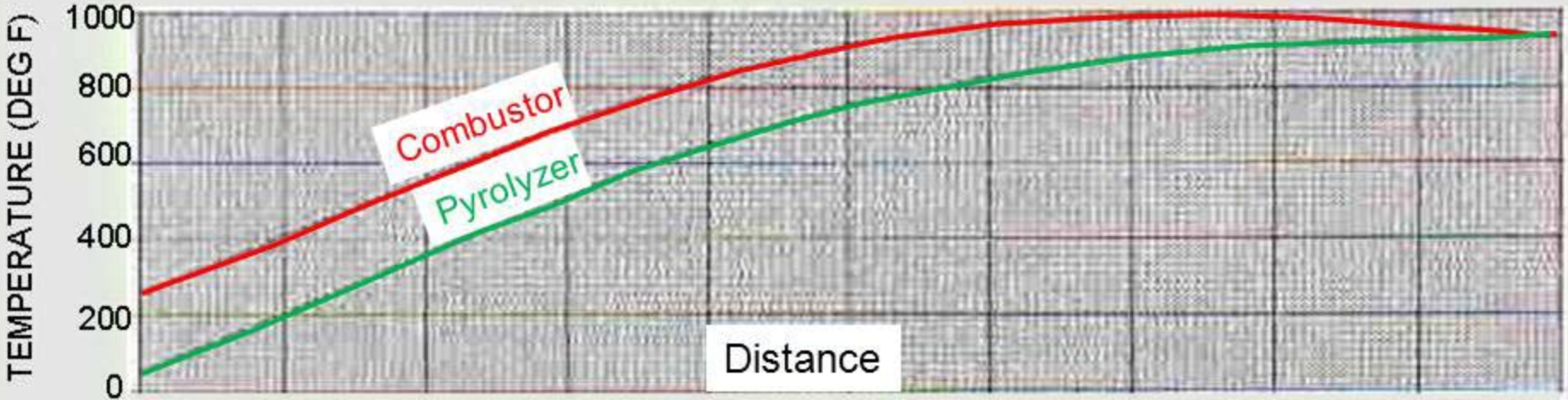
COUNTER-CURRENT SOLID-SOLID HEAT EXCHANGE

CROSS SECTION OF KILN CYLINDERS – SIDE VIEW

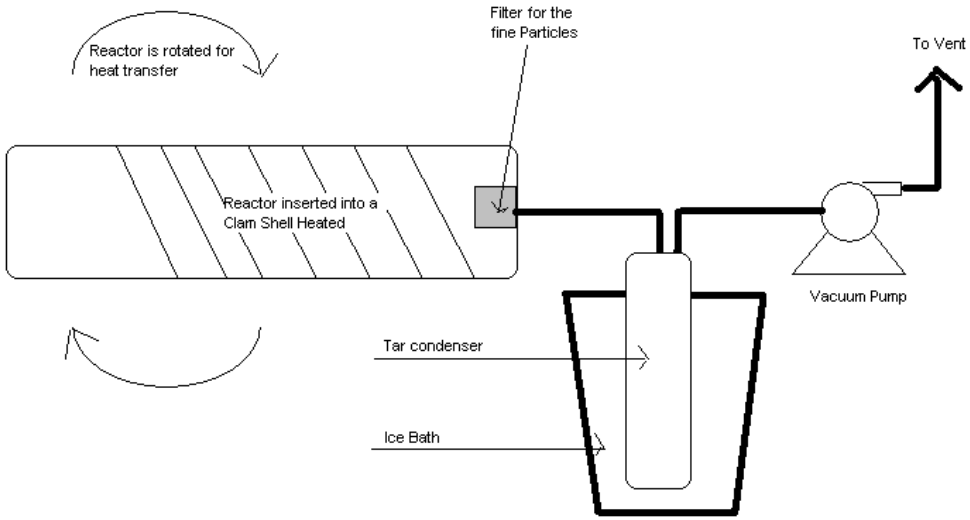


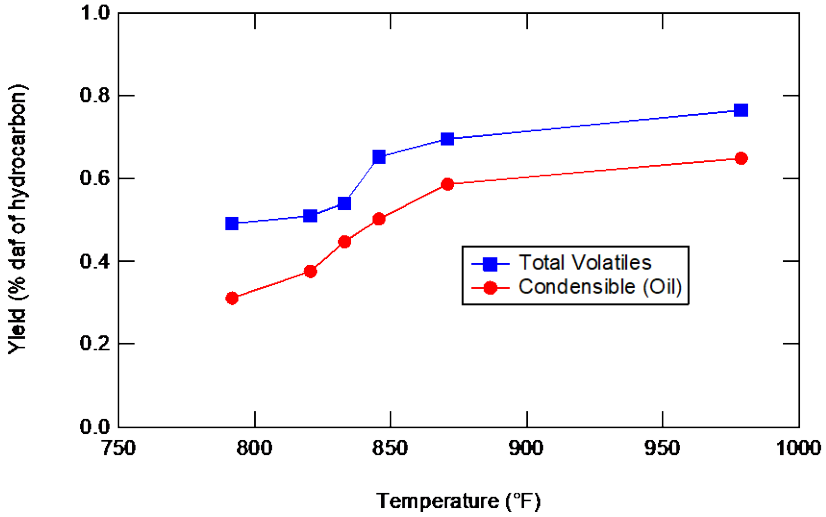
KILN TEMPERATURE PROFILES

NOTE MAXIMUM COMBUSTOR TEMPERATURE EXCEEDS PYROLYZER MAX BY ONLY ABOUT 50 DEG.F



Demonstration: Batch Retort Data





- Colorado Green River Oil Shale
- 10 K/min heating rate
  - Electric heaters
- Crushed to ~1/8 inch diameter
- Rotated in batch retort at rate similar to CHESS process
- 65% oil yield
  - (i.e., % of initial organic mass)
  - 103% of Fischer Assay

CHESS High Efficiency Features

- Recovers 80 to 90% of sensible heat
- Burns residual char for process heat
- Operates without recycling hot ash
- Burns coke at or below 1000°F to prevent calcination

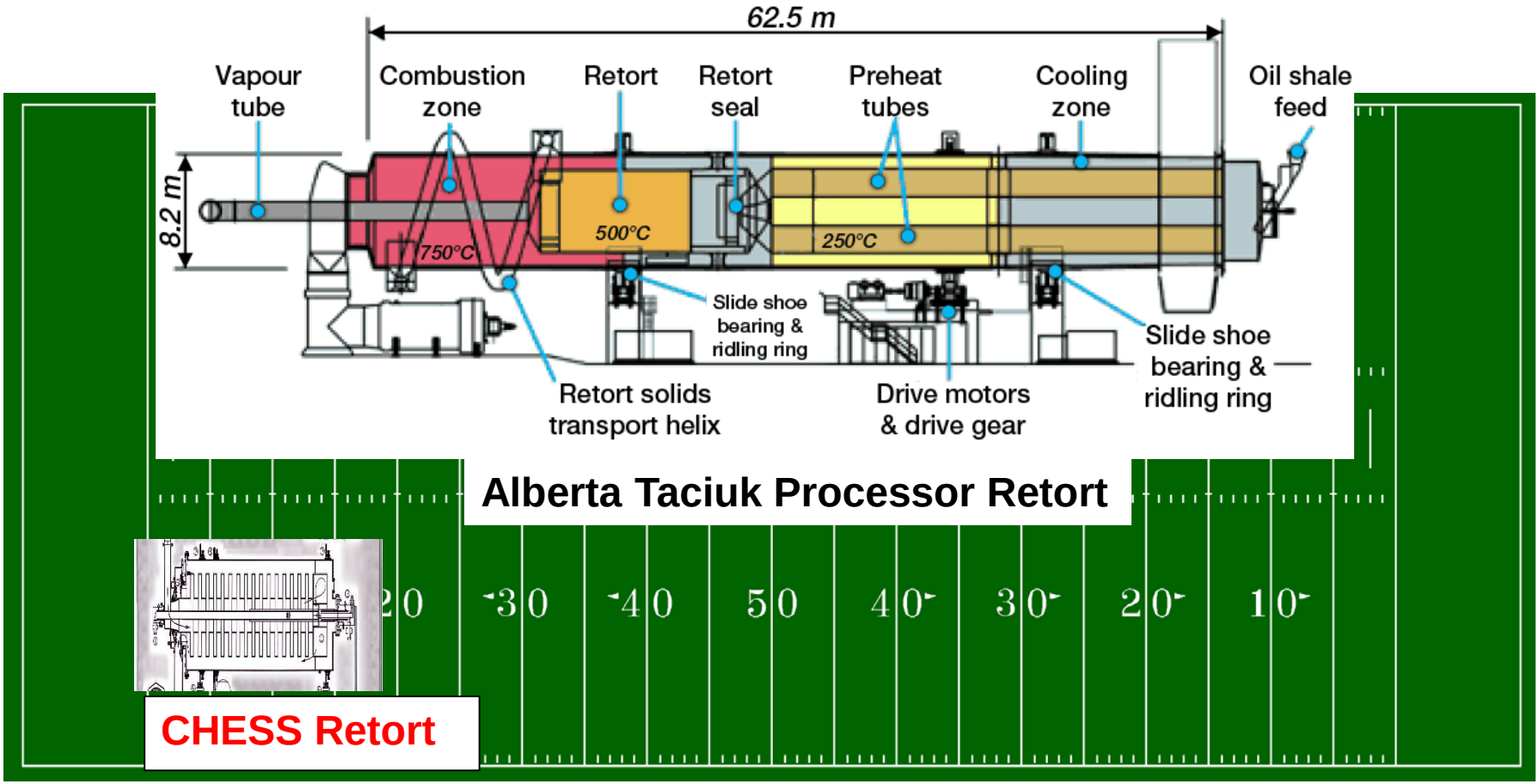
Advantages to the CHESS Process

- **High oil yield**: 103% OF Fisher Assay – 15% above that anticipated (90% of FA) for other processes, plus 13.5% saved by burning coke rather than oil = 25% more oil
- **Reactive coke** (Low temperature retorting of shale provides for reactive coke and optimal coke use)
- **High Volume Specific Capacity** (VSC, ton/ft^3) achieved from the high heat exchange and high fill fraction of the CHESS system

Equipment Advantages

- Low vertical profile (saves $$)
- Compact single vessel multi-operation
  - 30% of kiln volume required by other processes
  - 30% of capital cost
- Simple design, easy scale-up
- 85% reduction in pollutant gases
- Minimal water use
- Ash is clean
  - Not leachable
  - Free of PAH
  - pH neutral

Comparative Size



Cost Estimate for Oil Production

- Cost estimates include
  - Mining & handling
  - Retorting
  - Refining of oil product
  - Environmental remediation
- Ore grades > 5 gallons/ton
- $30/barrel
- Reviewed by DOE, NIST

Status

- Batch trials succesful
- 400 lb/hr continuous unit built and being debugged at BYU
  - Only 6 ft long

Thank you