HIGH EFFICIENCY SHALE OIL RECOVERY

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Reserves

Recent History & Problems

CHESS Process: Resolving the Problems

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

Oil Shale is a huge resource, exceeding the entire world reserve of petroleum. But the significance of this data is that if we can recover the lean end of the oil shale, which we anticipate the CHESS process can economically do, it will increase the resource some 6 or 7 times the size of what most processes envision as the recoverable resource.

SHALE OIL RECOVERY

Simple process: pyrolysis – heat to about 950ºF

Condense & collect the oil.

Problems:

1. For Green River Oil Shale 10% organic (17 gpt), results in 8% liquid, 90% inorganic mineral.
2. 20% of organic (2%) converts to char or coke.
3. Inorganic mineral, 1/3 dolomite, $CaMg(CO_3)_2$, calcines above 1000˚F to $CaCO_3 + MgO + CO_2$ using 380 Btu’s / lb (880 J/g).

Objective: find efficient process

1. Maximize oil yield
2. Use residual char
3. Minimize heat requirement & cost

Recent History

Since 1970’s, commercialization efforts have been directed around two process approaches:

1) In-Situ retorts (MIS): *Object was* to recover oil with minimal effort and cost, shale oil on-the-cheap. This was a bad approach with a history of numerous problems.

Recent History

2) Above-ground retorts:

a. UNOCAL's Rock Pump retort

b. Advanced methods: recycled ash heat carriers

e.g. Lurgi, Taciuk, LLNL HRS

Processing Cost

What does it cost to produce a barrel of shale oil?

Processing Cost

Oil cost climbed to $40 / bbl in 1981 (about $80 in today's dollars). Considering the difficulties, everyone naturally assumed shale oil would cost all of the $40. Then the petroleum price dropped under $10 / bbl and everyone lost interest in shale oil.

These negative reports were a disservice to the industry, as they provided an overly-harsh view of the problems and cost estimates that were only based on those failed processes.

Currently no one knows what shale oil will cost as it has never been successfully commercialized. But if a simple, reliable process were used, then the 1981 WRSP estimate would be reasonable.

WRSP: Eastern Utah White River Shale Project estimated $15 / bbl in 1981. That would be the equivalent of about $30 per bbl inflated to current dollars. The CHESS process would reduce that cost by approximately 50% as shown below.

Southern Pacific Petroleum estimated shale oil cost at $10.70 (1983 $US) for the Condor (Australia) deposit. This estimate was based on the use of Lurgi technology. Their subsequent use of the Taciuk technology would undoubtedly improve the economics still further.

(Maeda & Poole, The Condor Oil Shale Project, Australia, 11/2/1984, Proc. 4th World Synfuels Conf., n 6)

Principles of Efficient Oil Recovery

1. Minimize coking reactions to achieve high oil yield

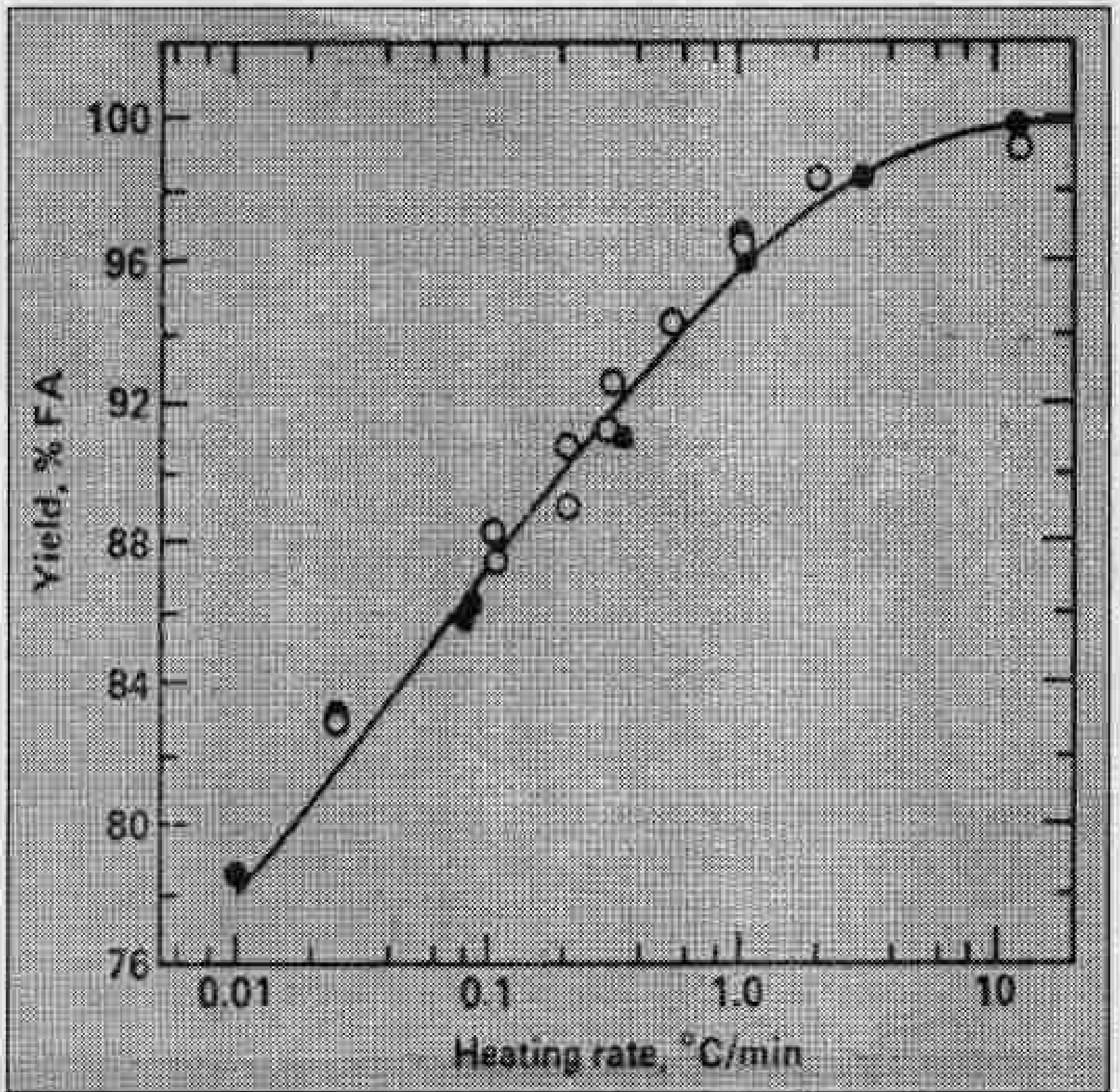
2. Efficient heat recovery

3. Avoid dolomite calcination: < 1000˚F (for GROS)

MODERATE HEATUP

MINIMUM HEATING RATE SHOULD BE ABOVE 10 DEG PER MIN.

THOUSANDS DEG. PER MIN., AS IN RECYCLE ASH SYSTEMS, UNECESSARY, UNDESIREABLE.



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 CALCINATION ASH THEN THE SORBED OIL BURNS IN THE COMBUSTOR)

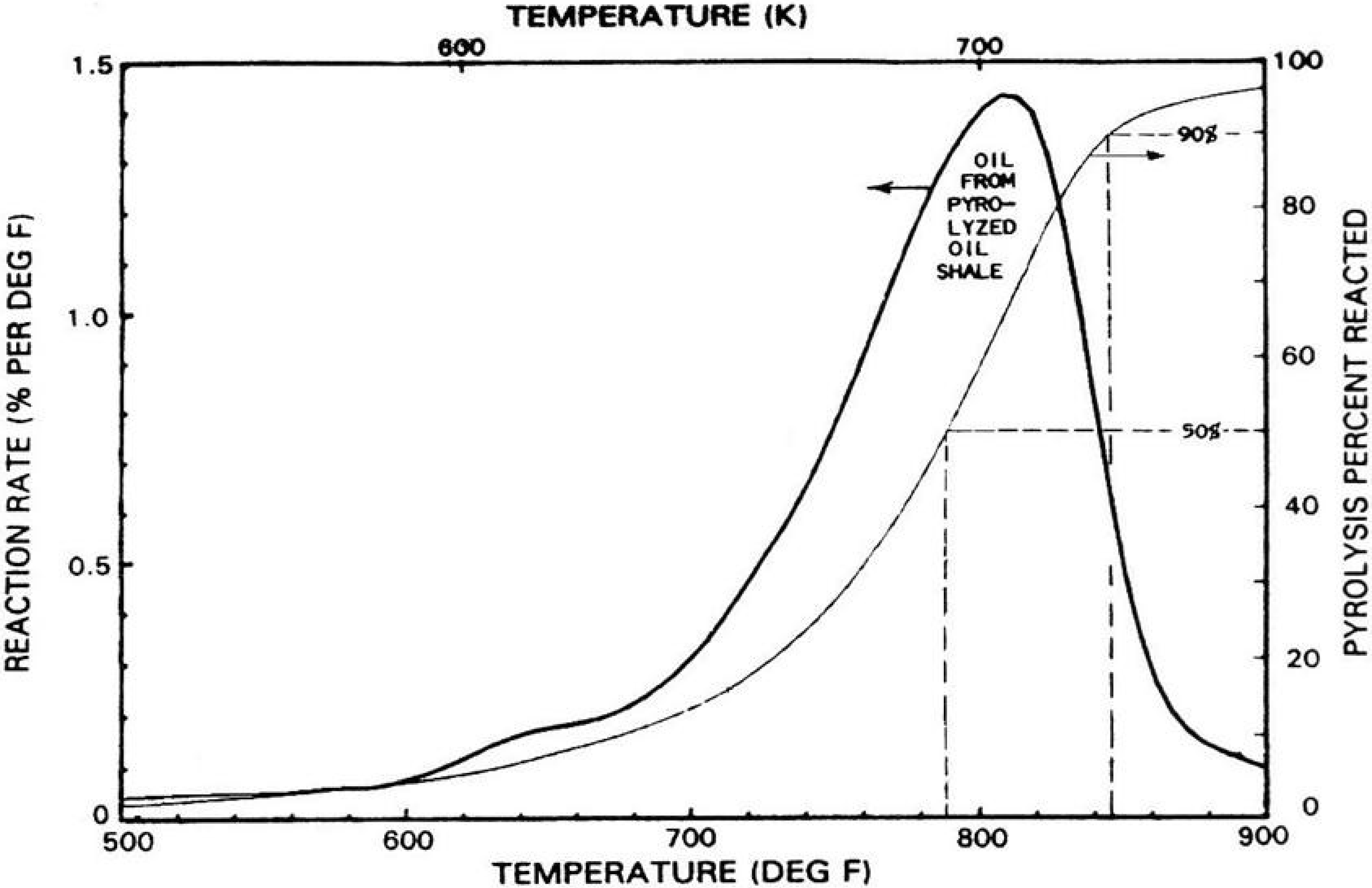
HYDROGEN ABSTRACTORS‡, S, O (present in recycle ash as Sulfates and as O2 in fine particle interstices)

*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 FOUND WHEN OIL SHALE WAS RETORTED AFTER IT WAS PREHEATED IN GAS WITH AS LITTLE AS 0.1% OXYGEN PRESENT, THE OIL YIELD WAS REDUCED BY UP TO 16% WITH EQUIVALENT INCREASE IN COKE AND WATER.

(USBM RI-4787)



GREEN RIVER OIL SHALE PYROLYSIS RATE VS TEMPERATURE

EFFICIENT OIL RECOVERY

NUMEROUS STAGES FOR COUNTERCURRENT HEAT EXCHANGE & LOW TEMP VAPOR REMOVAL

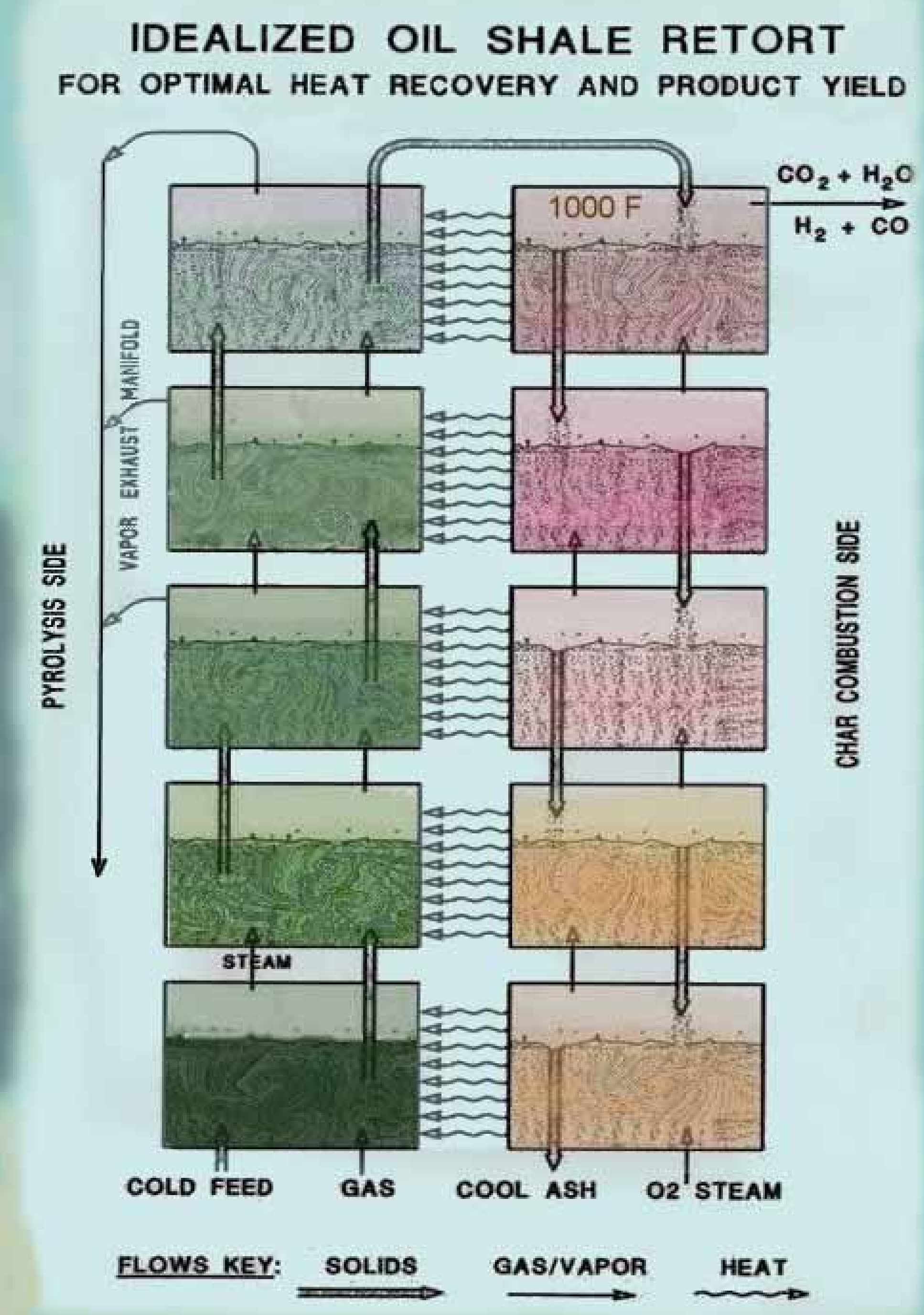
OPTIMUM OIL RECOVERY

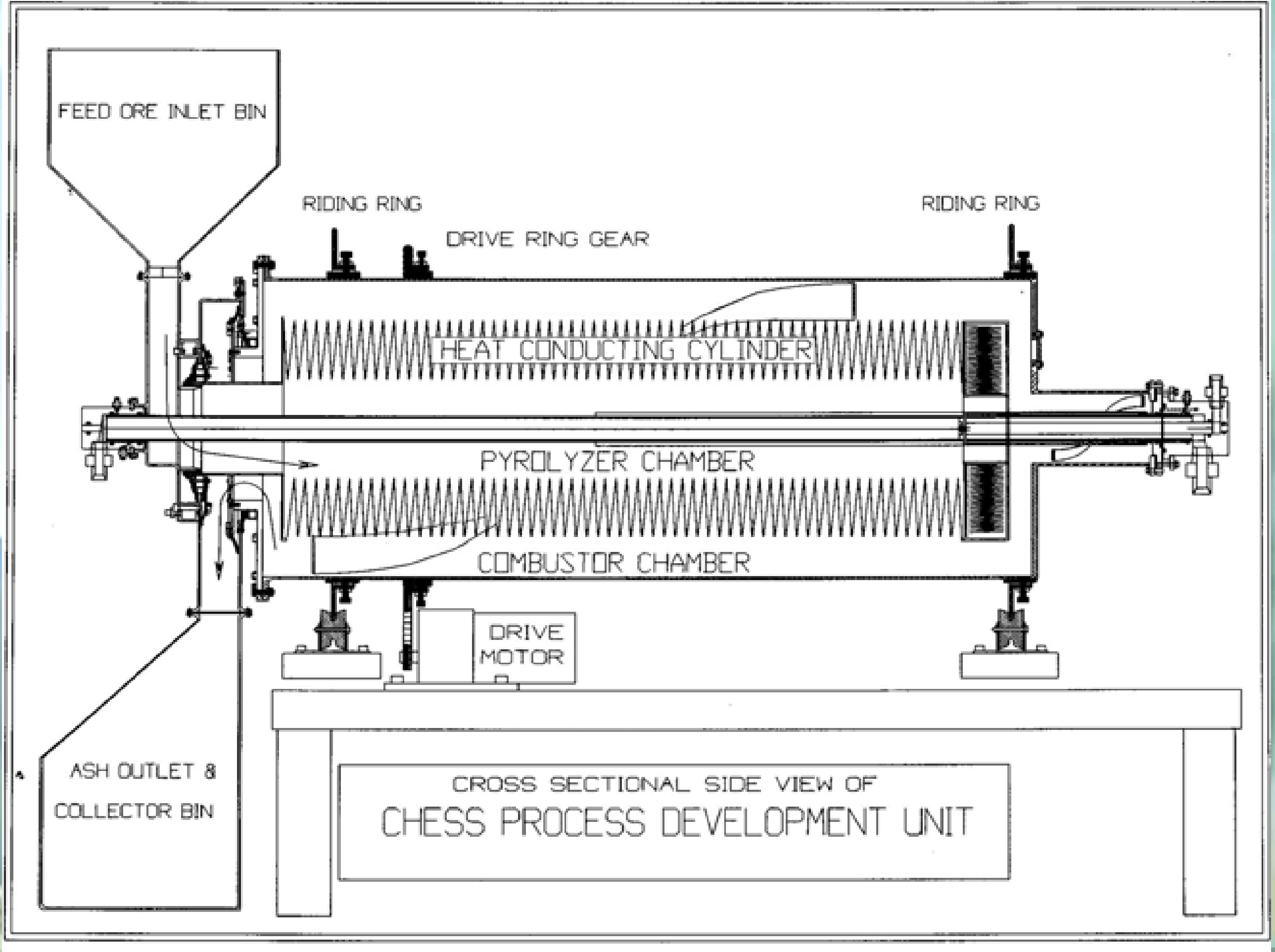
MINIMUM COKING (no recycle ash, O or S)

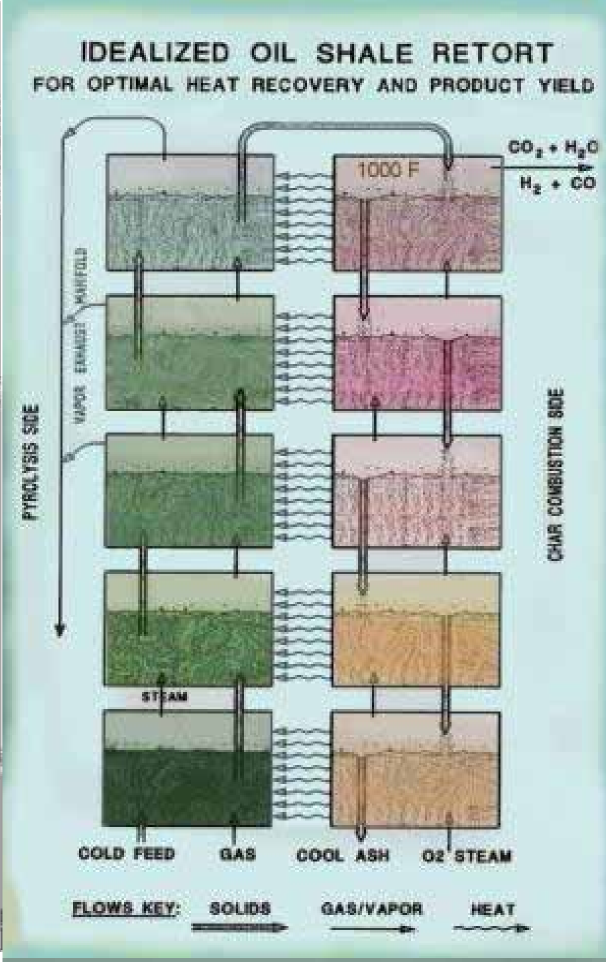
THOROUGH RETORTING

OPTIMUM GAS/SOLID FLUID-BED CONTACTING WITH COUNTERCURRENT OXIDATION OF CHAR

HEAT TRANSFER PROBLEM







CASCADE FLUIDIZATION – OPTIMUM GAS/SOLID CONTACTING

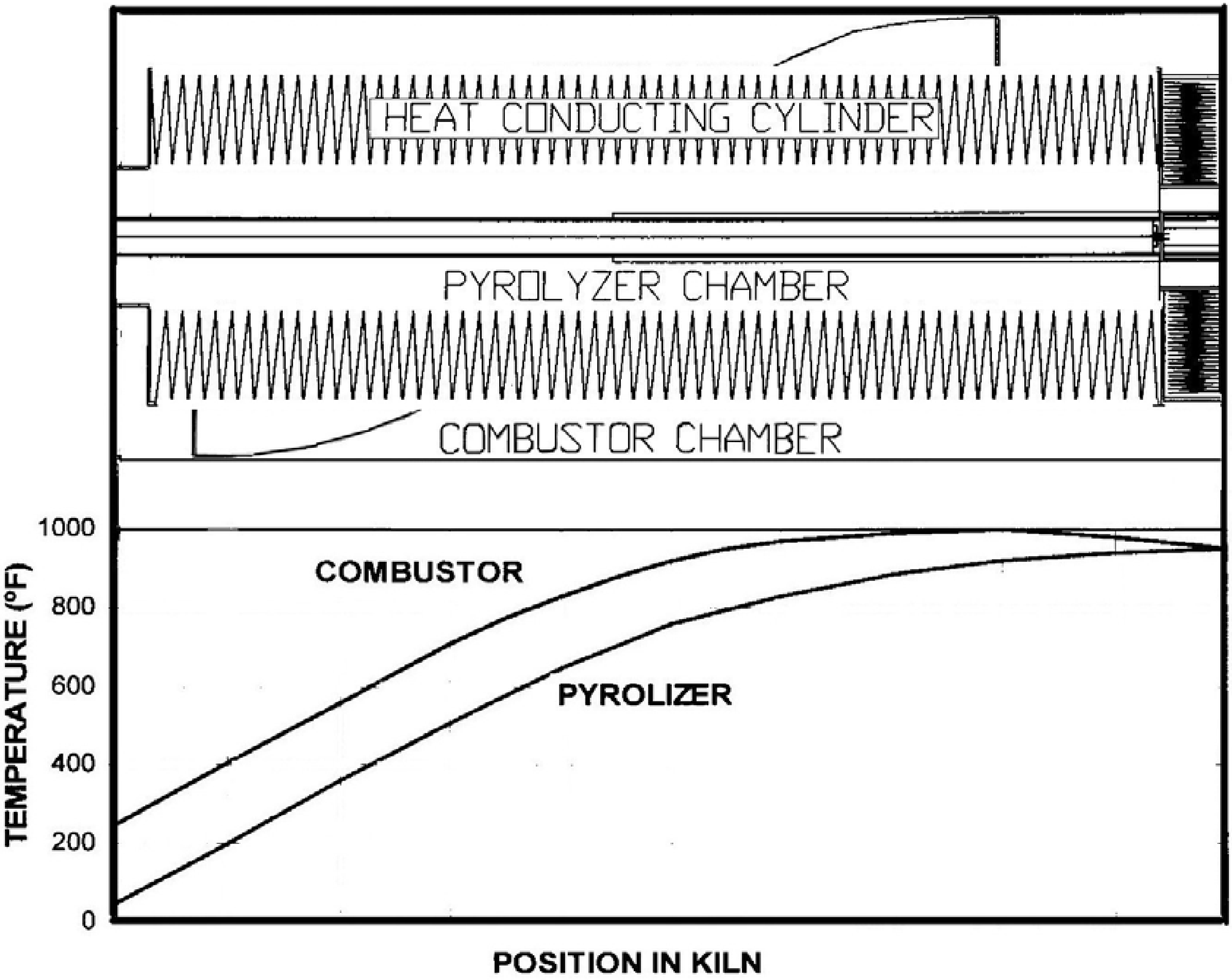
NUMEROUS STAGES FOR EFFICIENT COUNTERCURRENT HEAT EXCHANGE

MINIMAL COKING WITH THOROUGH RETORTING

MODERATE HEATUP, NO RECYCLE ASH NOR GAS,

HCC SOLVES HEAT TRANSFER PROBLEM

TEMPERATURE PROFILES IN KILN



THREE HIGH EFFICIENCY FEATURES

CHESS (Counter-current Heat Exchange in Solid Streams) is a unique retorting approach that :

1. Recovers about 80 to 90% of sensible heat energy.
2. Burns residual char for process heat.
3. Operates below the calcination temperature of the mineral carbonates.

CHESS ACHIEVES THE FOLLOWING NUMEROUS ADVANTAGES

HIGH OIL YIELD: 109% OF Fisher Assay – 20% above that anticipated (90% of FA) for other processes.

REACTIVE COKE (Low temperature retorting of shale provides for reactive coke and optimal coke use.)

HIGH VSC (ton/ft^3/day) achieved from the high heat exchange and high fill fraction of the CHESS system.

ADVANTAGES

LOW VERTICAL PROFILE

COMPACT SINGLE VESSEL MULTI-OPERATION

LOW CAPITAL COST - 30% OF WRSP

SIMPLE EQUIPMENT, EASY SCALE-UP

ADVANTAGES

LOW TEMPERATURE COMBUSTION

MINIMAL ENVIRONMENTAL COST

MANY ADDITIONAL ADVANTAGES

CHESS EXPECTED TO BENEFIT THREE OF FOUR PROCESSING AREAS

1. MINING & HANDLING
2. RETORTING

– REFINING

3. ENVIRONMENTAL REMEDIATION

MINING & HANDLING

BY PROMOTING SURFACE MINING

MINING RULE OF THUMB IS $10 / TON UNDERGROUND vs $1 / TON FOR SURFACE

BY REMOTELY LOCATING RETORT MODULES

FOR MINIMAL SOLIDS HANDLING

RETORTING

70% CAPITAL EQUIPMENT COST REDUCTION

85% LESS POLLUTION GAS TREATMENT EQUIPMENT

ENVIRONMENTAL REMEDIATION 8 BENEFITS

ASH THAT IS pH NEUTRAL

ASH THAT IS COOL

ASH THAT IS CLEAN OF PAH

RELATIVELY SMALL FINE ASH FRACTION

NO CALCINATION CO2

NO CALCINATION HEAT REQUIREMENT

MINIMAL WATER USE

85% REDUCTION IN POLLUTION GASES

WHAT ARE LIKELY PROBLEMS

1. SCALE UP? NOT A PROBLEM: SINGLE SHORT HORIZONTAL VESSEL, CAPACITY PROPORTIONAL TO VOLUME.

2. DUST CONTROL? CHESS KILN HANDLES DUST

3. FUNDING? A LOW COST OPPORTUNITY

Retort costs (1988 $)	Capacity	WRSP/Lurgi	CHESS
PDU	5 tpd	$29 million	$0.3 million
Commercial	177,000 tpd	$1,200 million	$350 million