Surface Retorting:
Moving Beyond the Small Size Barrier

A Road Not Taken (Yet)

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Larry M. Southwick, P.E.

Cincinnati, Ohio

Outline

- Introduction
- Challenges
- Costs vs. Oil Price
- Stops and Starts
- Size Restrictions
- Fluid Beds
- Problems
- Resolution

Synfuels Basics

- Oil shale
  - Kerogen, heating (500°C or more)
  - In situ, continued development
  - Retorting: Estonia, Brazil
- Oil sands
  - Bitumen, water wet solids, water dissolution
  - Tar sands - oil wet sands, other methods
  - New concepts (CSS, SAGD, THAI)
  - Mining - trucks, draglines (larger scale)
- Oil and gas
  - No mining required
  - Generally higher quality products


WELL YOU HEARD WRONG! WE HAVEN'T ALL PULLED OUT!
CORE SAMPLE
LONE PINE
ALSANDS
CONSORTIUM
LIKE HEAVY OIL, MAN.

Challenges

Technology

- 15% Organic carbon, 85% waste
- Small unit sizes (8-10,000 BPSD)
- Spent shale has sufficient heat content
- Dusting into product oil
- Beneficiation not real successful (grind to fine sizes, -20 µ)
- Fluid bed: inert heat carrier gets purged

Challenges

Other Areas

- Operational risks (need good demo plant, lots of tests)
- Environmental permitting/liabilities
- Uncertain public policy (Queensland moratorium)
- Lead time - design, permitting, construction
- Boom in building = boom in equipment prices
- Economics
  - Lots of iron and steel in plants
  - Ergo, oil price goes up, plant cost rises
  - Can’t get there from here
  - Except via larger sized units (6X size ~ 2T cost)

Challenges

Solids Processing Plants

- Rand studies, 1978-1981
- 40 plants, all types
- 15 solids processing plants
- Average throughput = <50% of design
- Only 2 > 85% of design
- Costs generally 2X or more
- Plant definition changes

Costs vs Oil Price

- 1960's - early 1970's
  - $2-$3/bbl oil
  - Shale plants needed $6 oil
- Late 1970's - early 1980's
  - $10-$15/bbl oil
  - Shale plants needed $20-$26 oil
- Since then
  - 1980 Iranian crises - $45 oil
  - 1985 - 2000, ~$20 oil
  - 2000 - 2004, ~$30 oil
  - 2008, $100-$150 oil

Synfuels Plant Costs

- Colony
  - $379M (1972), $583M (1973), $721M (1974), $925M (1978), $5,000M (1982)
- Occidental
  - $240M (1975), $473M (1977), $650M (1978), $800M (1978)
- Syncrude
  - $784 (1971), $1437M (1973), $2170 (‘74), $2170 (‘78)
- Shell Canada
  - $1006M (1973), $3000M (1974-8), $15,000 (1982)

Stops and Starts

- Exxon - Colony (1982)
  - Cancelled “due to falling of crude oil prices, continued escalation in costs and high interest rates”
- Shell (2007)
  - Withdrawal of permit done for economic reasons
  - Cost of underground wall of frozen water to contain melted shale have “significantly escalated”

Woulda, Shoulda, Coulda

- Pilot plants with unresolved issues
  - Fluid bed processes, large size potential
  - Exxon, Gulf (Lurgi), Amoco, Shell
  - Roadblocks to operability
- Semi commercial, effectively buried
  - Union B, ATP (shunned)
  - Availability of very large unit size not proven
- "Prospects for major increases from energy processes are not good. But longer-run benefits of having designed, constructed and operated a well-chosen set of pioneer synfuels plants could prove to be a national blessing in the 1990's" (Rand, 1981)

Size Restrictions

- Rotating vessels
  - Diameter, length, weight, location in train
  - Preheat, heat carrier heating/movement
  - Inoperable concepts
- Shaft retorts
  - Diameter, discharge mechanism,
  - Oil misting, gas sealing/bypass, heat recovery
- Other
  - Mechanical equipment design, maintenance
  - Solids flow, heat transfer, complete oil release
- Need large size demo for scaleup

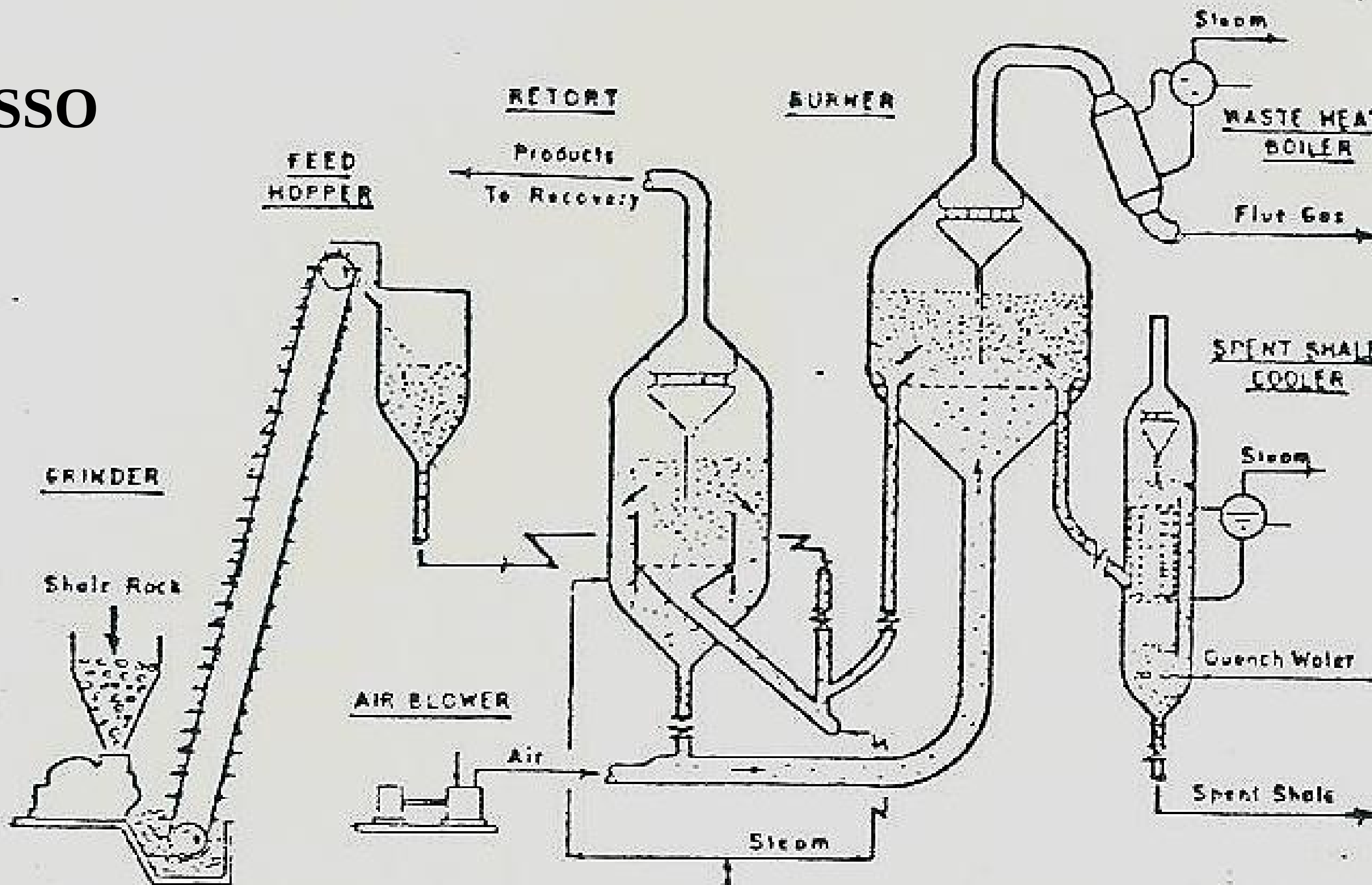
Fluid Bed Retorting

- Large commercial units with similar concept
  - Fluid catalytic cracking, fluid coking
  - Fluid hydroforming, etc. (in oil industry)
- Fluid bed benefits
  - Solids flow like water, internals can help
  - High heat transfer (solids/solids, gas/solids)
  - Well understood design concepts
- Other
  - Can borrow ideas from other industries
  - Testing for design effective on small scales

Been There, Done That

- Must have experience in design and operation
- ESSO tests (1948-9)
  - Three reports, very thorough, design info
  - Solids preparation, design/instrumentation, thorough operating data** (Jewel of the Crown)
  - Discussed and studied operating problems
- USBM (1948-50)
  - Single unit fluid bed, entrained flow
  - Relatively sparse results and discussion
- USBM (later Gas Combustion Retort, B-635)
  - Very thorough discussion of operation and mechanisms (misting)

ESSO



Fluid Shale-Oil Retorting Process
Developed by Standard Oil Development Co.

AMOCO

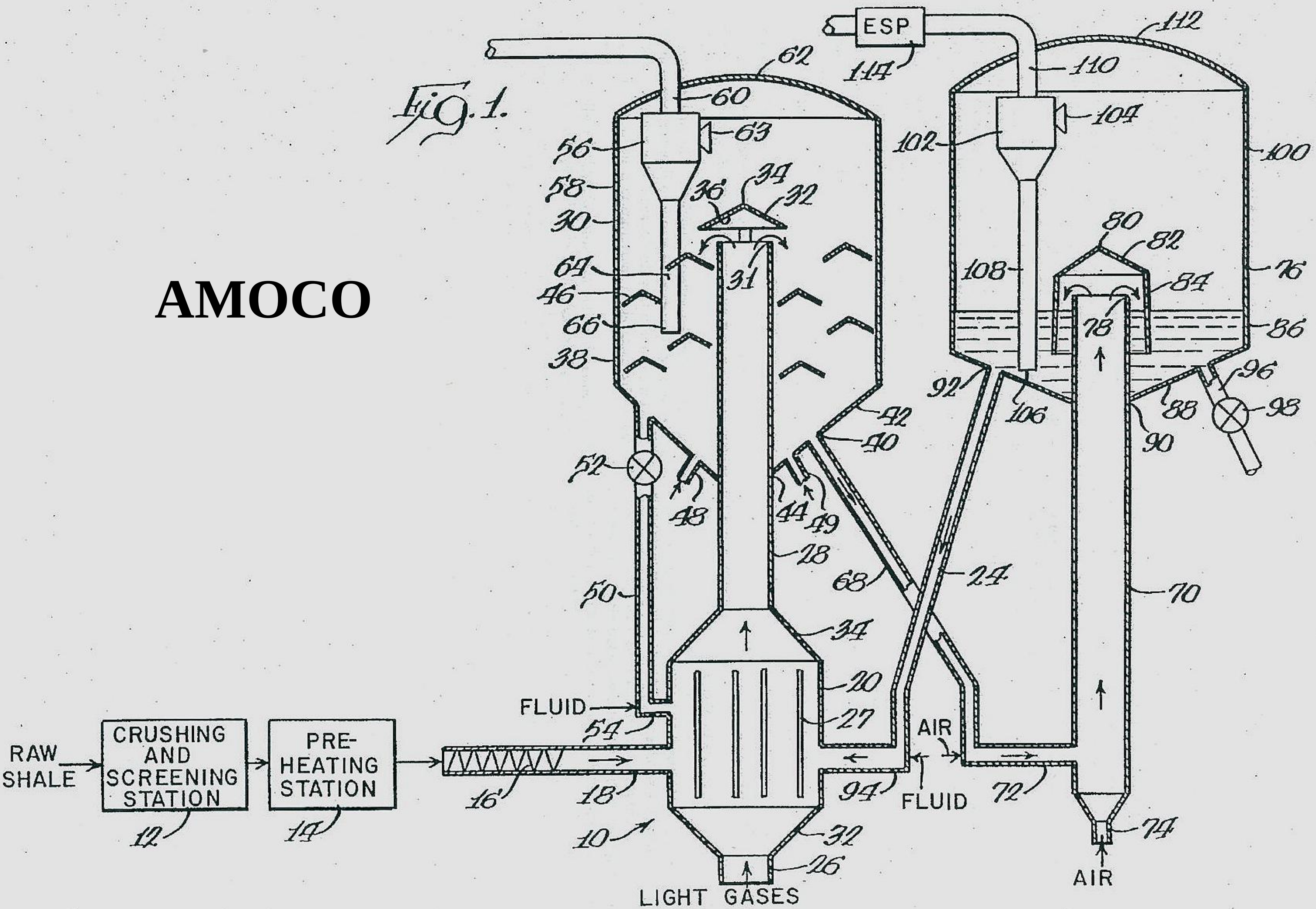


Fig. 1.
ESP
RAW SHALE
CRUSHING AND SCREENING STATION
PRE-HEATING STATION
FLUID
AIR
FLUID
LIGHT GASES
AIR

Problem Areas

- Burnt shale
  - Burning residual carbon as heat source
  - Some shales decrepitate/decompose
  - If ends up in product oil, difficult to remove
- Other heat carrier
  - “Indirect addition of heat would correct”
  - Tends to be displaced by burnt shale
  - Can be catalytic (good or bad?)
  - Higher temperature possible = less needed
- High initial heat rate can benefit yields
  - Requires much hotter carrier
- Often need “soaking time”
  - Which then requires stripping of vapors

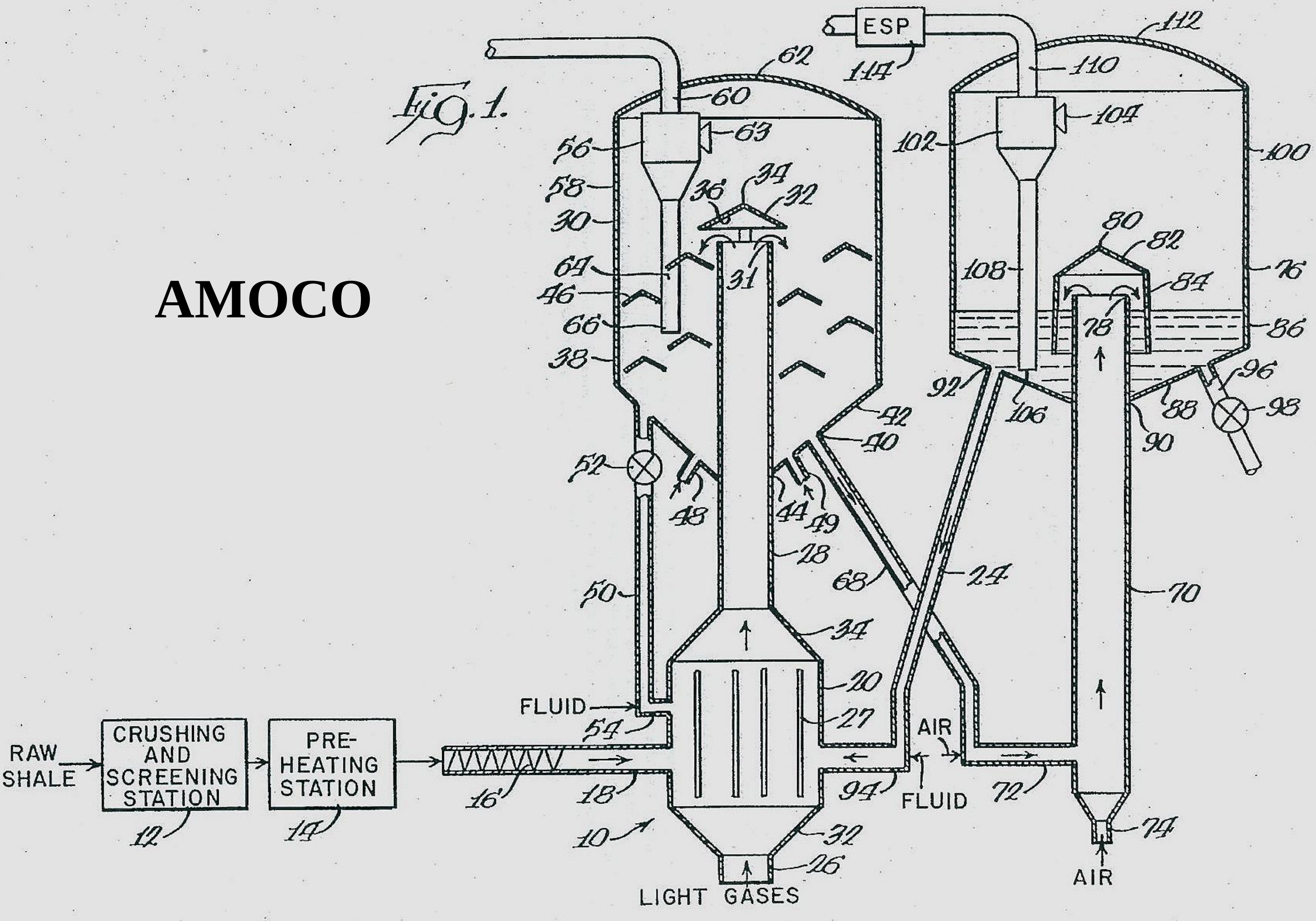
Most Thoroughly Reported Failure Ever

- ***Journal of Metals*** (Oct. 2008)
  - Peirce-Smith copper converter
  - John Hollway's work (~1876)
- One man's dead end
  - James Douglas
- Was another man's opportunity
  - Ralph M. Baggaley
  - Followed up and proved out solutions

Resolution

- Burnt shale
  - Keep burnt shale out of retort
  - May require both burning shale and gas for heat (depends on behavior of shale to high temperatures)
- Other heat carrier
  - Optimize choice, develop lift column design
  - Innovate spent/burnt shale/heat carrier separation
  - Higher temperature process design configuration
- High initial heat rate can be beneficial
  - Requires hotter carrier, higher carrier/shale ratio
- Often need “soaking time”
  - Avoid condensing vapors on retorted shale
- All are conceptually achievable, require tests

AMOCO



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Road Not Taken

- Exxon, Amoco, Gulf (Lurgi), Shell, Mobil (?)
- Problems with burnt shale recognized
- No real thoughts, studies or conclusions on answers
- Some studies by Kentort, Univ. Queensland/CSIRO
  - Made progress on understanding/quantifying benefits
- Oil companies gave up by 1985
- Answers existed by 1980, large scale/commercial
- But with other feedstocks

Conclusions

- High oil prices will not make small scale units magically become economical
- Too much iron, steel and concrete
- Need to find a larger capacity alternative
- FCCU holds considerable promise
- Think beyond Big Oil’s dead ends
  - FCCU benefited from years of improvements
- Investigate beneficiation - fines not an issue if Fl. Bed
- Oil sands has done it, oil shale can too!