Black Liquor Gasification: Development and Commercialization Update

Kevin Whitty

Institute for Combustion and Energy Studies (ICES)
The University of Utah

ACERC Annual Conference
17-18 February 2005
Provo, Utah

INSTITUTE FOR COMBUSTION & ENERGY STUDIES

THE UNIVERSITY OF UTAH

Outline

- Introduction
- History of black liquor recovery technology
- Black liquor gasification technology today
- BLG research in Utah
- Conclusions

Outline

- Introduction
  - Pulp and paper industry
  - The pulp mill
  - Black liquor
- History of black liquor recovery technology
- Black liquor gasification technology today
- BLG research in Utah
- Conclusions

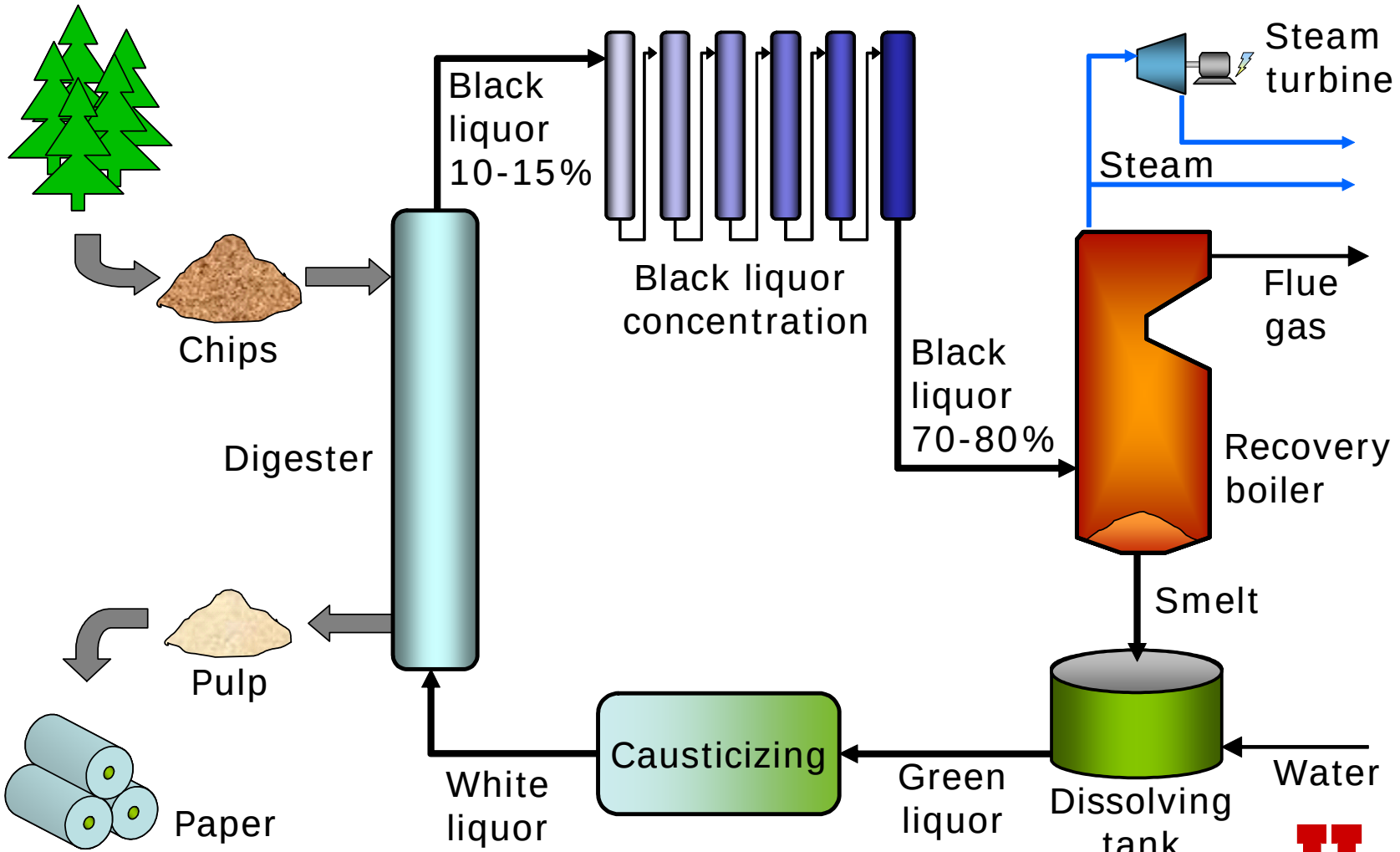
Pulp and Paper Industry Statistics

Approximate values, 2003

	U.S.	World
Paper production (10^6 ton/y)	100	340
Paper production (per capita, kg/y)	344	54
Chemical pulp mills	123	450
Chemical pulp production (10^6 ton/y)	57	167
Black liquor production (million tons ds/y)	80	200
Recovery boilers	250	700
Biomass-based fuel consumption (GW_{th})	55	192
On-site fossil fuel consumption (GW_{th})	30	94
Electricity production* (GW_{el})	7.7	24.2
Utility grid power consumption (GW_{el})	6.0	19.0

* Typically consumed on-site

Pulp Mill Chemical Cycle



Black Liquor

Approximate Composition	
1/3	Water
1/3	Organics
1/3	Inorganics

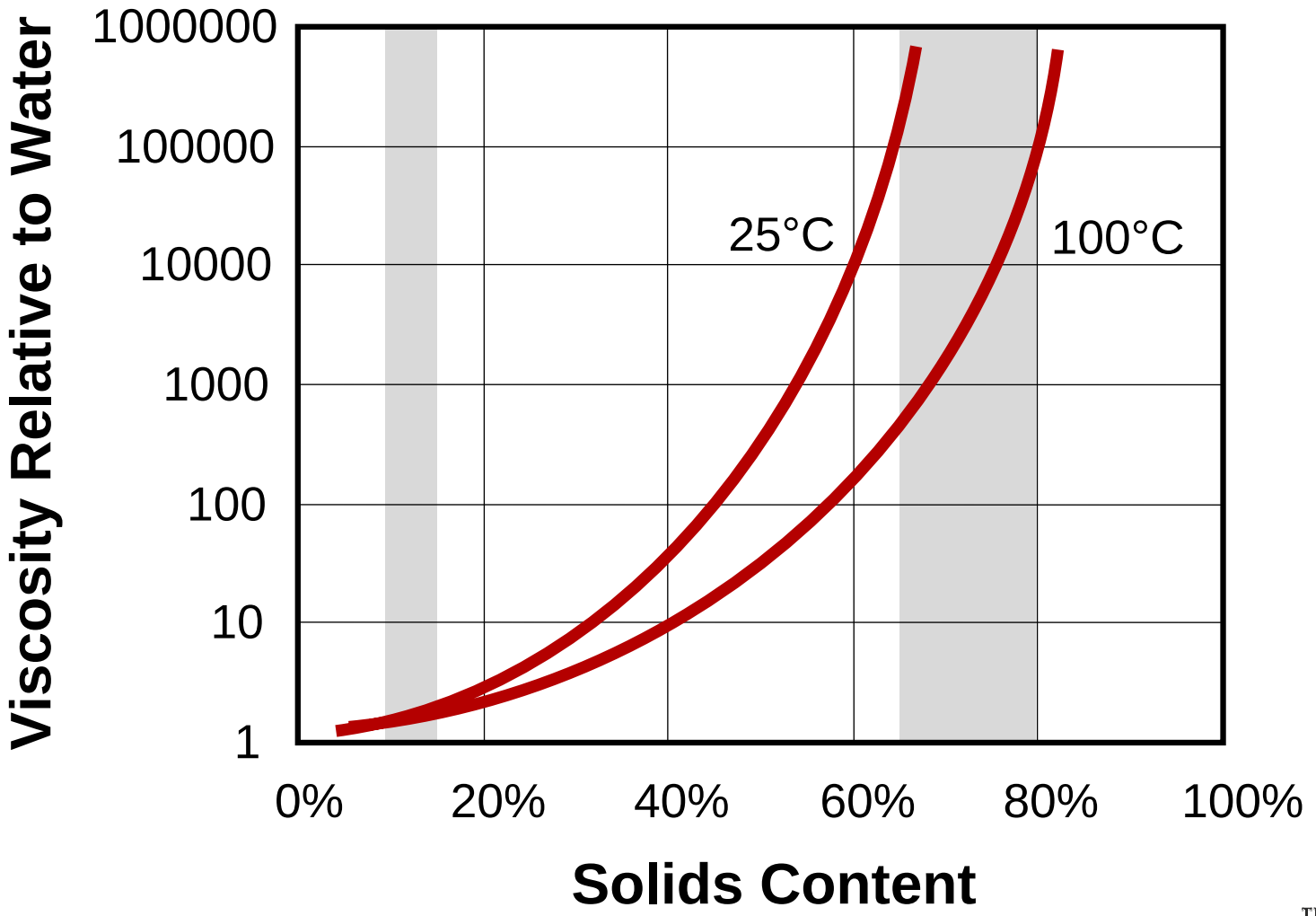
Heating Value (dry basis)	
HHV	14 MJ/kg
HHV	6000 Btu/lb

Composition (moisture-free)	
Carbon	34 %
Hydrogen	3 %
Oxygen	34 %
Sulfur	5 %
Sodium	22 %
Potassium	1 %
Chlorine	0.5 %

	U.S.	World
Black liquor production (10^6 tds/y)	80	200
Black liquor energy flow (GW_{th})	29	85

Black liquor is a *renewable* energy source

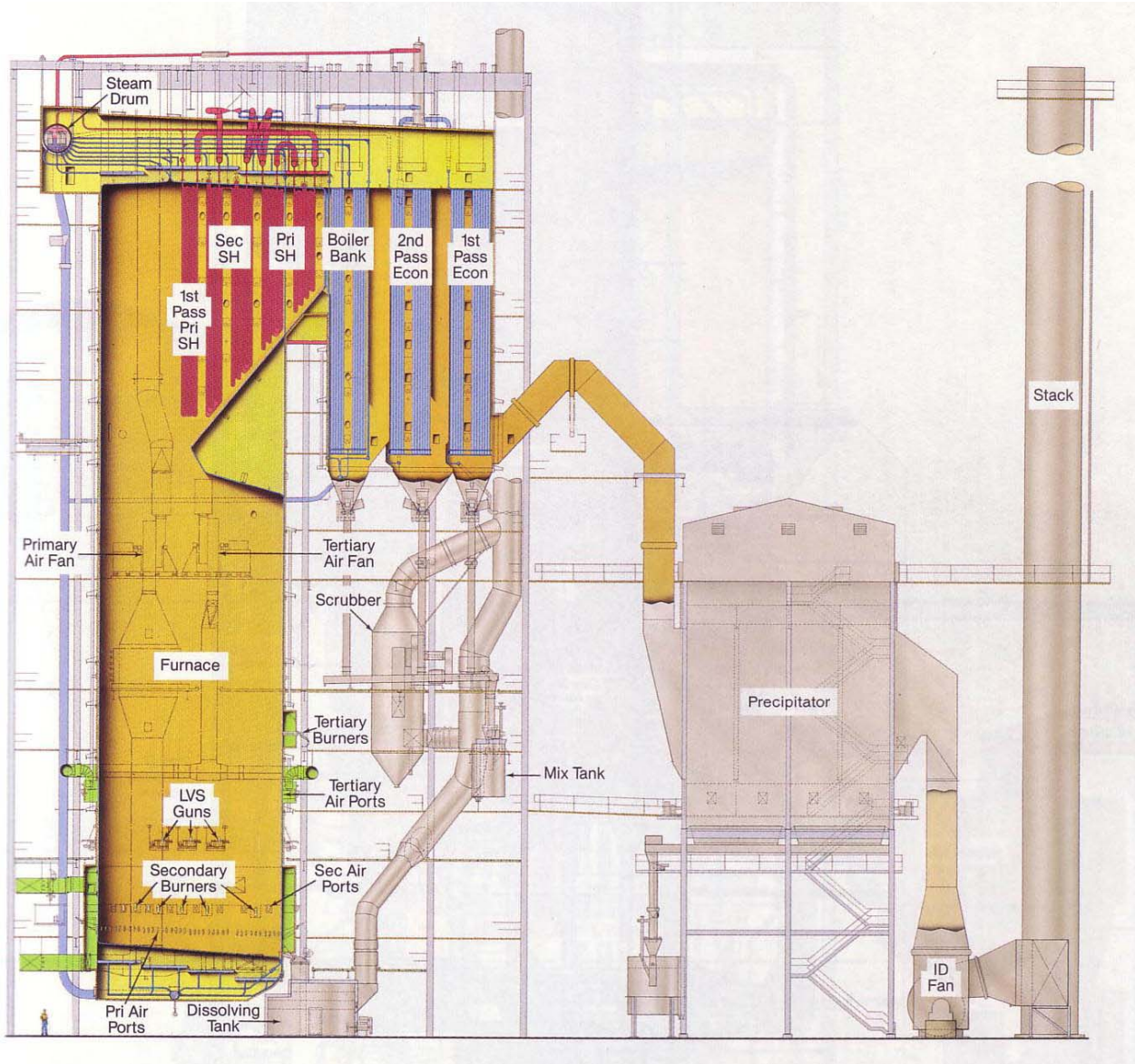
Black Liquor Viscosity



Outline

- Introduction
- History of black liquor recovery technology
  - The black liquor recovery boiler
  - Past attempts at development of alternative recovery systems
- Black liquor gasification technology today
- BLG research in Utah
- Conclusions

Black Liquor Recovery Boiler



The Recovery Boiler

- Initially developed in 1930s (Tomlinson)
- Dual purposes
  - Recover energy from black liquor
  - Recover pulping chemicals
- Power production efficiency ~12%
- Single most expensive piece of equipment in a pulp mill

Shortcomings of the Recovery Boiler

- Relatively low energy efficiency
- Relatively poor environmental performance
- Challenging boiler control
- Difficult to control mill sulfur balance
- Risk for explosion

Drivers for Black Liquor Gasification

- Energy benefits
  - More than double power production
  - Shift from net power importer to exporter
  - Potential for production of liquid fuels
- Process Benefits
  - Sulfur management
  - Opens door for advanced pulping schemes
- Environmental benefits
  - Significantly lower emissions
  - Reduced pulpwood requirements
- Economic benefits
  - Higher pulp yields
  - Lower energy costs

Alternative Black Liquor Recovery Technology Development Efforts

- Low temperature
  - St. Regis
  - Weyerhaeuser
  - Copeland
  - Owens-Illinois
  - ABB
  - KBR
  - SCA-Billerud
  - Texaco
  - DARS
  - VTT
  - B&W
  - **MTCI**
- High temperature
  - NSP
  - U. California
  - Paprican
  - Tampella
  - B&W
  - Champion/Rockwell
  - SKF
  - Ahlstrom
  - Noell
  - **Chemrec**

INSTITUTE FOR COMBUSTION & ENERGY STUDIES

THE UNIVERSITY OF UTAH

SCA-Billerud Process

- 1958-1980
- Pyrolysis process
  - Burn oil for heat
  - Product gas to boiler
- Low efficiency
  - Thermal
  - Carbon conversion
  - Used as "booster"
- Five commercial installations
- Abandoned due to technical inferiority

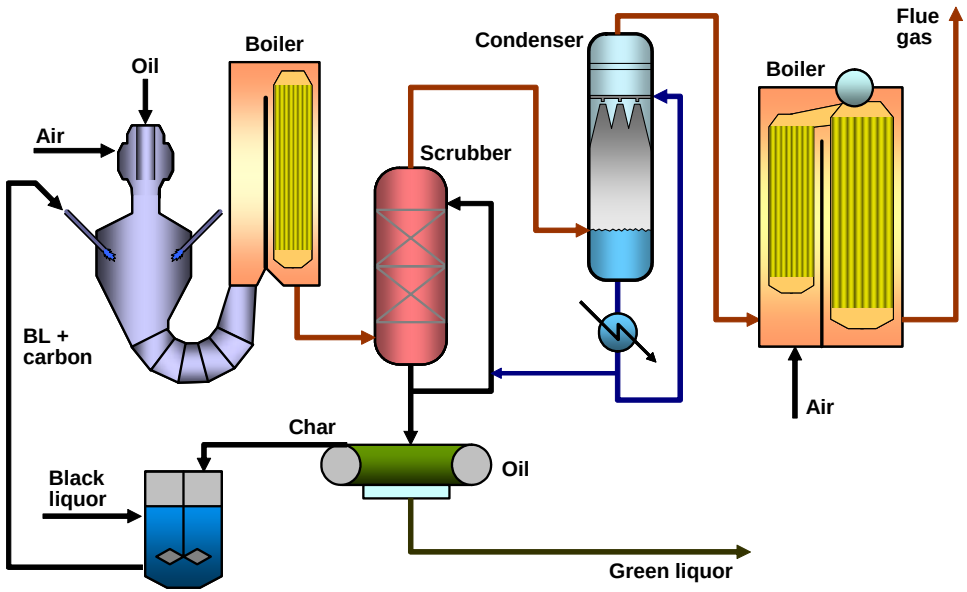
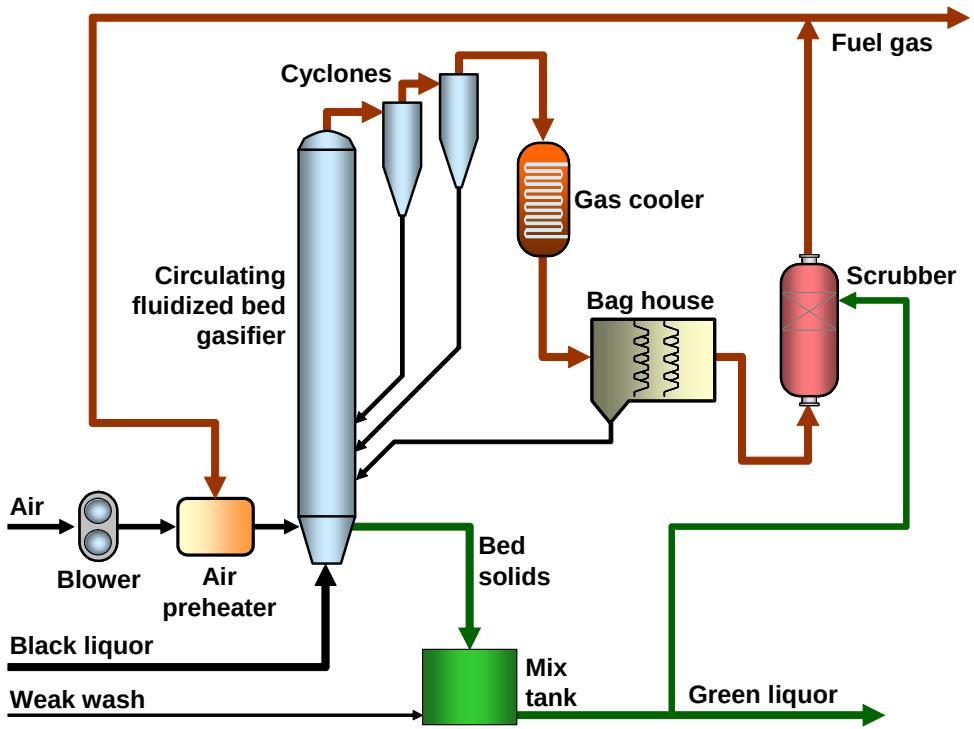


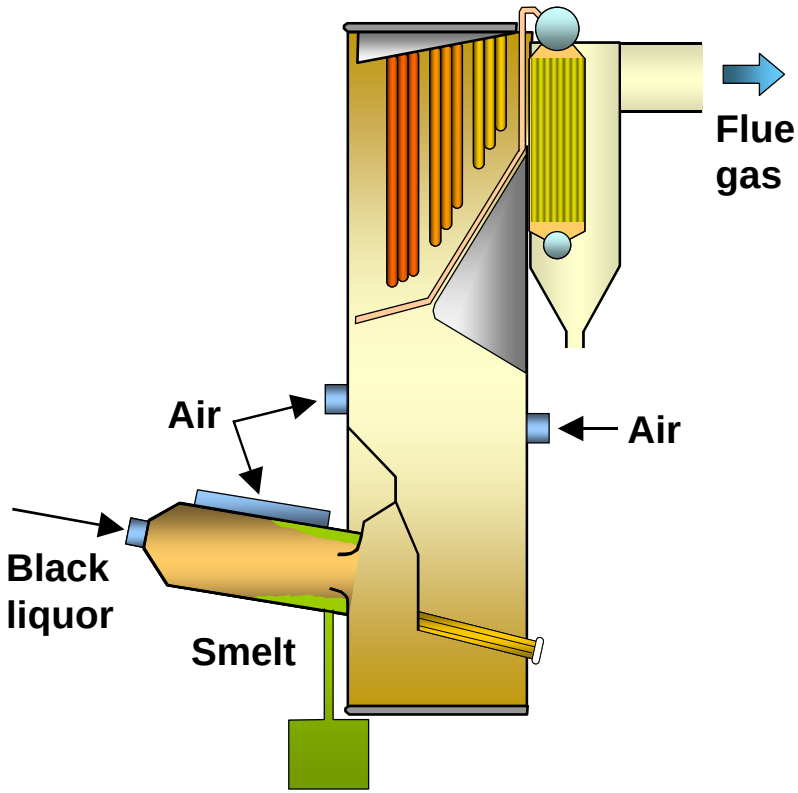
ABB CFB Gasifier

- 1989-1997
- Air or oxygen-blown
- 2.5 tds/day pilot
  - Good performance
  - Tested titanate addition
- Abandoned due to:
  - Shifting corporate priorities
  - lack of clear market in reasonable time frame



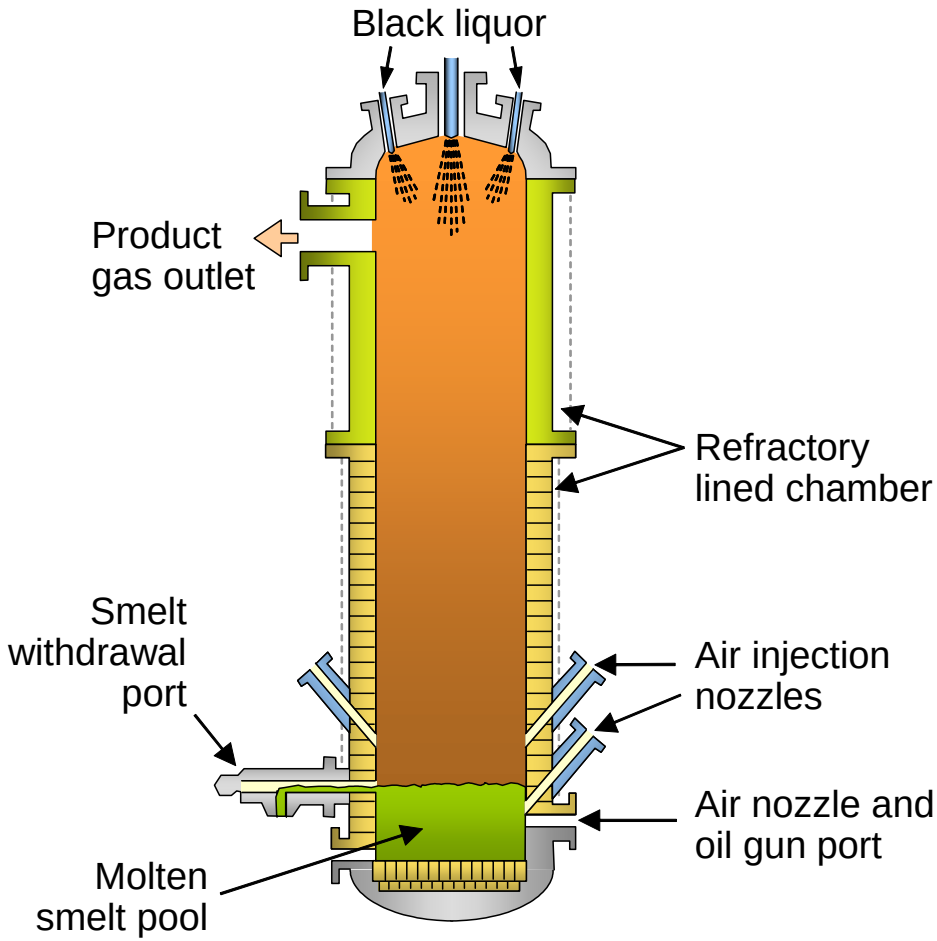
NSP Cyclone Gasifier

- “Ny Sodahus Process”
- 1973-1985
- 1100-1400°C
- Retrofit recovery boiler
- 100 tds/day pilot system
- Abandoned due to technical difficulties (corrosion) and lack of funding



Champion-Rockwell Gasifier

- Based on Rockwell molten salt gasifier for e.g. coal
- 1982-1988
- 6 tds/day pilot
- Design for larger, pressurized pilot
- Abandoned due to lack of funding

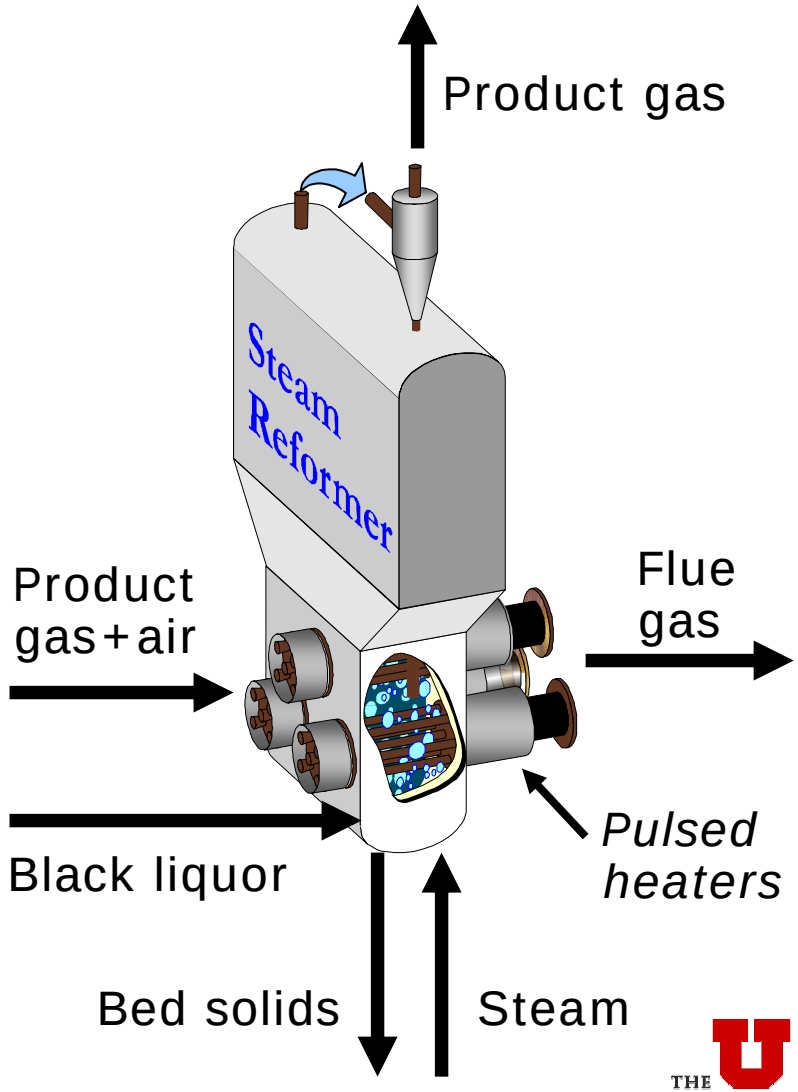


Outline

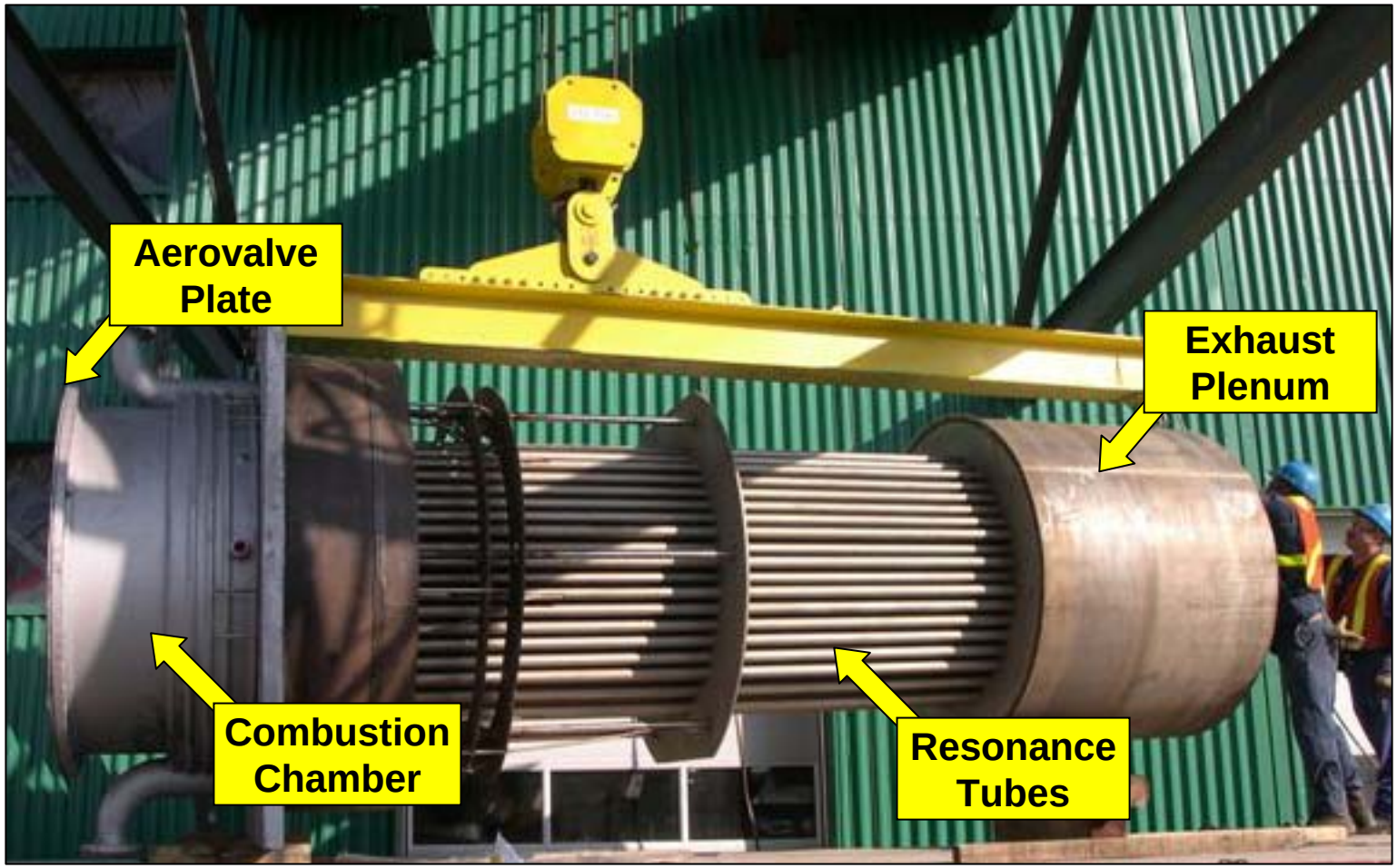
- Introduction
- History of black liquor recovery technology
- Black liquor gasification technology today
  - MTCI fluidized bed steam reforming
  - Chemrec entrained-flow gasification
- BLG research in Utah
- Conclusions

MTCI Steam Reformer

- Low temp (~600°C)
- Low pressure (~3 atm)
- Steam fluidized
- Indirectly heated by pulsed combustion heaters
- Medium HV syngas
  - 10-12 MJ/m^3
  - 50-65% H_2
- Incremental capacity or replacement technology

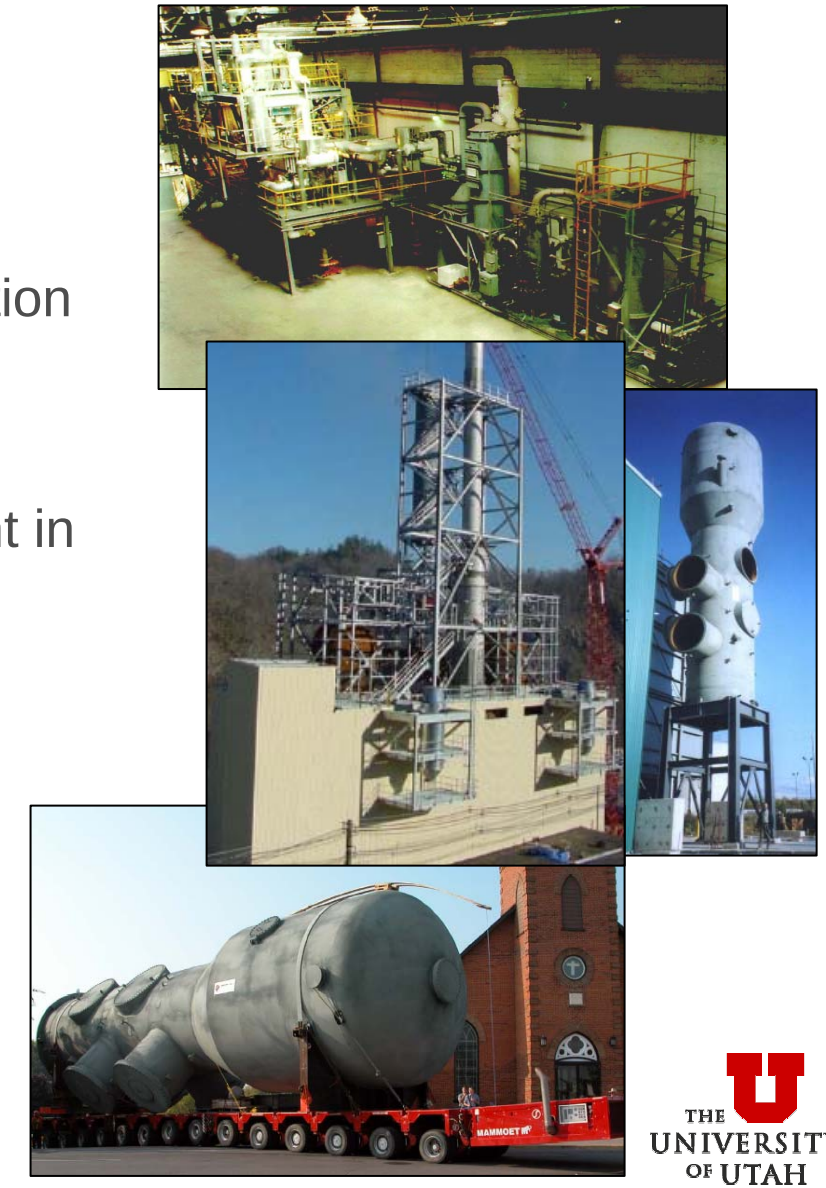


Pulsed Combustion Heater

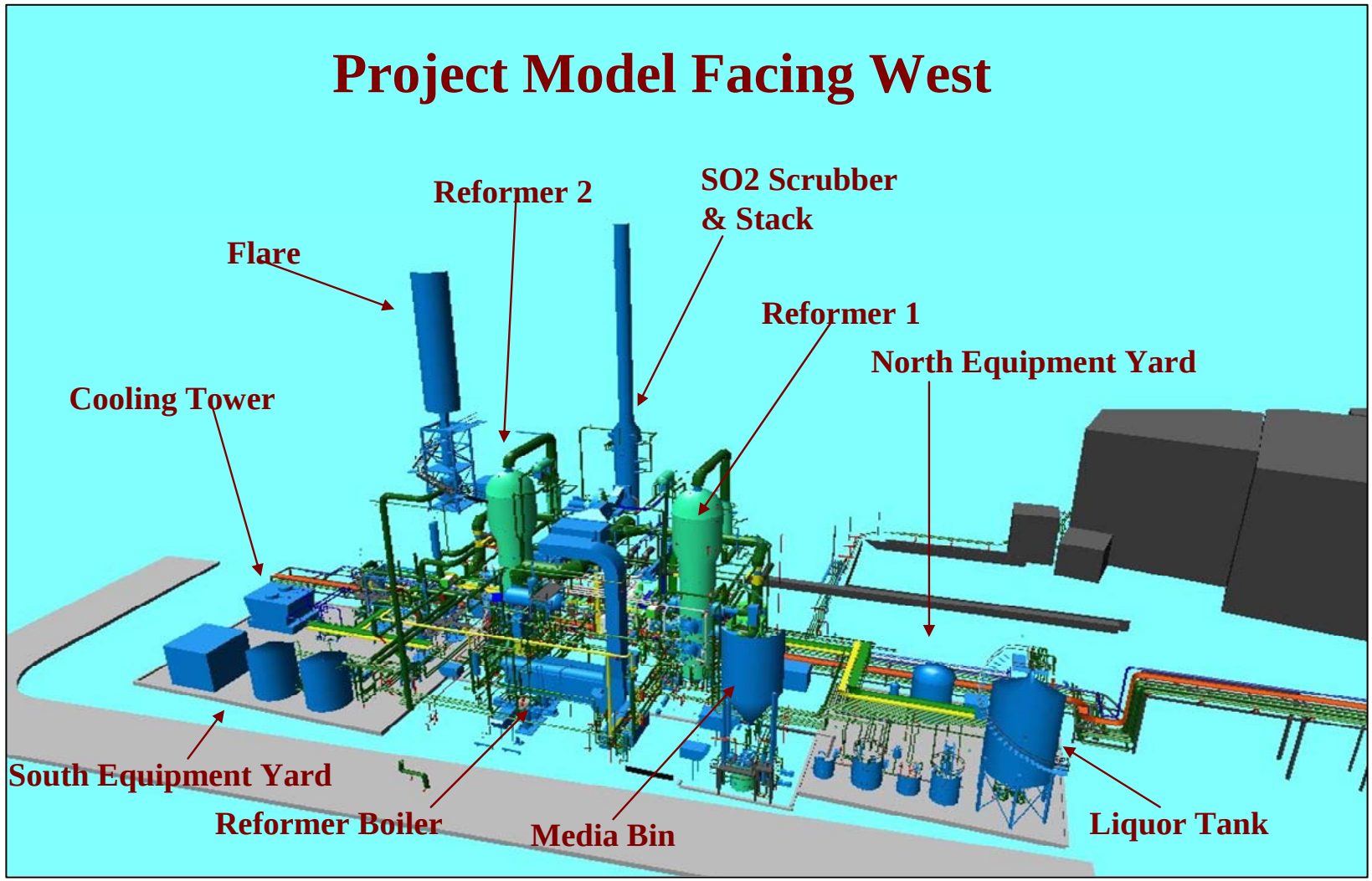


Development Status – MTCI

- PDU testing since 1990
- Two full-scale systems
  - Georgia-Pacific demonstration in Big Island, Virginia
    - 200 tds/d
    - Startup spring 2004
  - Norampac commercial plant in Trenton, ON
    - 100 tds/d
    - Startup June 2003
- Several other projects in discussion phase
- Yet to be proven on kraft liquor



G-P Big Island Demonstration



Picture courtesy of Georgia-Pacific Corporation

G-P Big Island Demonstration

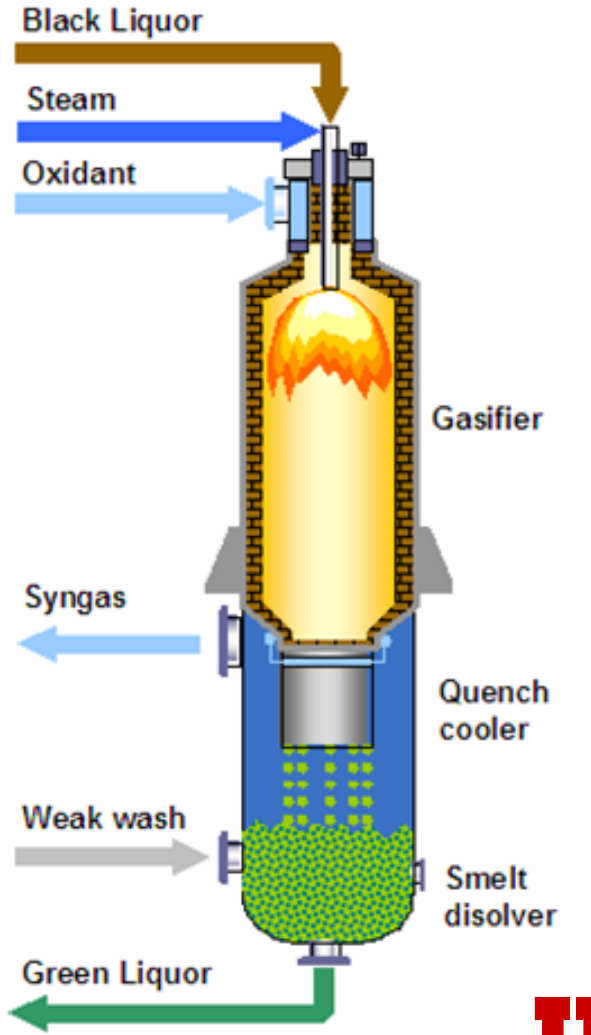
Photos courtesy of Georgia-Pacific Corporation

Norampac Steam Reformer

Photos courtesy of Norampac

Chemrec Entrained-flow Gasifier

- High temp (950°C)
- "Booster" gasifier
  - Incremental capacity
  - Low pressure
  - Air-blown
  - Low Btu syngas
  - Low thermal efficiency
- "BLGCC/BLGMF" gasifier
  - Replacement technology
  - High pressure
  - Oxygen-blown
  - Medium Btu syngas
  - High thermal efficiency



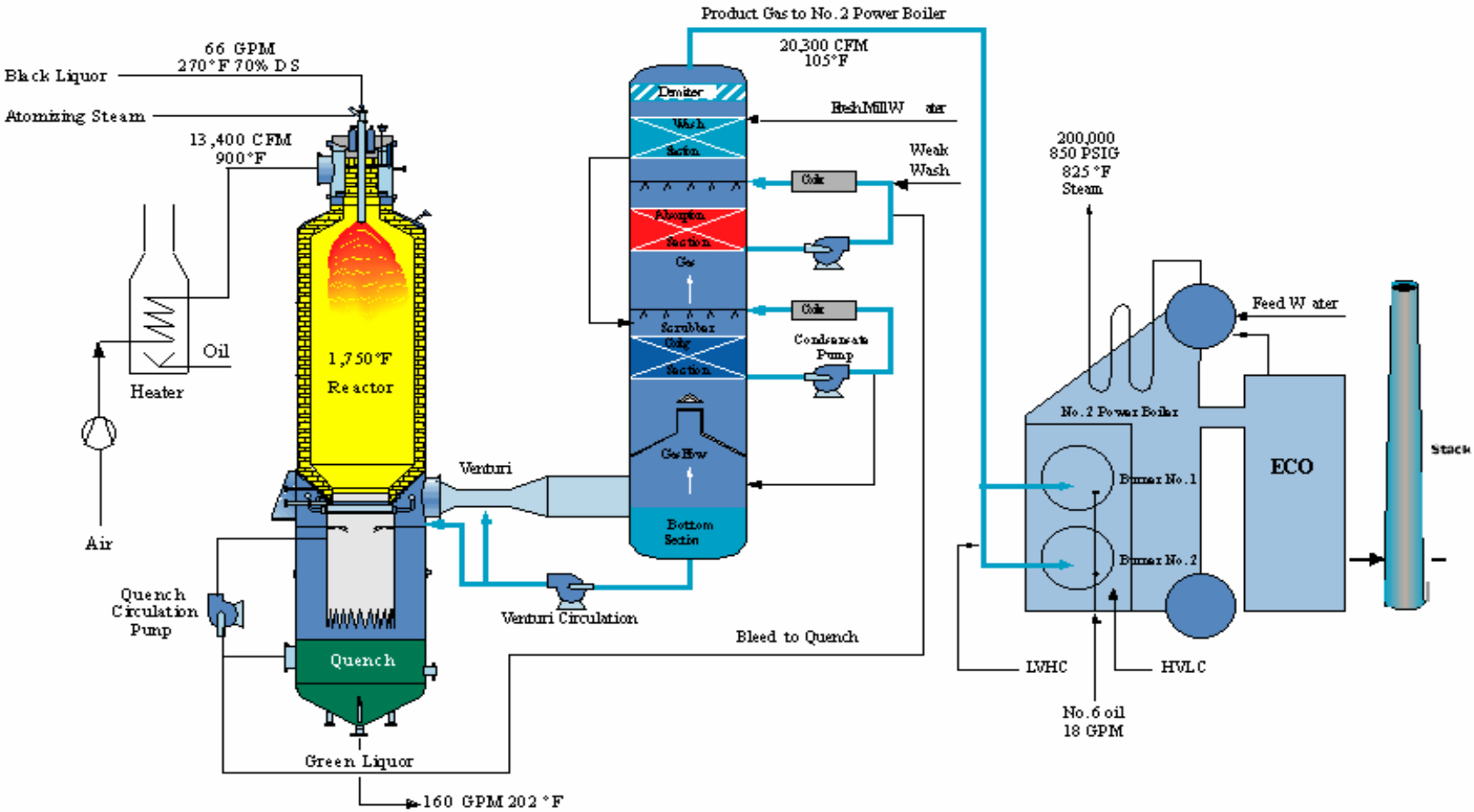
Development Status – Chemrec

- Booster System
  - Pilot system early 1990s
  - One commercial installation at Weyerhaeuser's New Bern, NC mill
- BLGCC System
  - Pressurized pilot 1994-2000
  - Larger development plant startup early 2005
  - Commercial demo targeted for startup 2008
- BLGMF System
  - Economic and technical studies in progress
  - BLG + DME production demo targeted for startup 2008

New Bern Gasifier

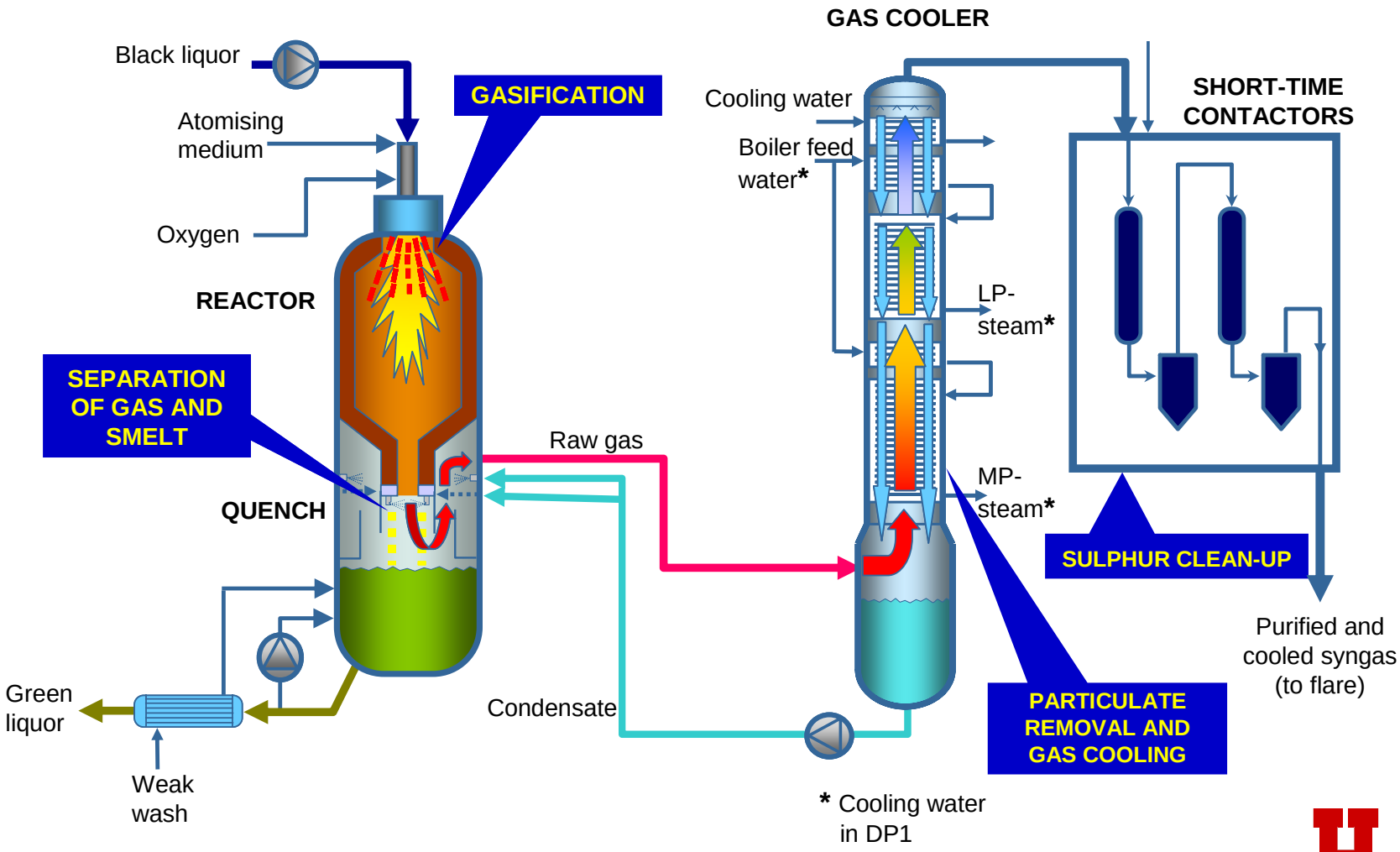
Photo courtesy of Chemrec

New Bern Booster Schematic



Picture courtesy of Chemrec

Chemrec "DP1" Plant Schematic



Picture courtesy of Chemrec

Chemrec "DP1" Pilot Plant

View from outside

Photo courtesy of Chemrec

Site of BLGMF Demonstration

Södra Cell Mörrum Mill

Photo courtesy of Chemrec

Outline

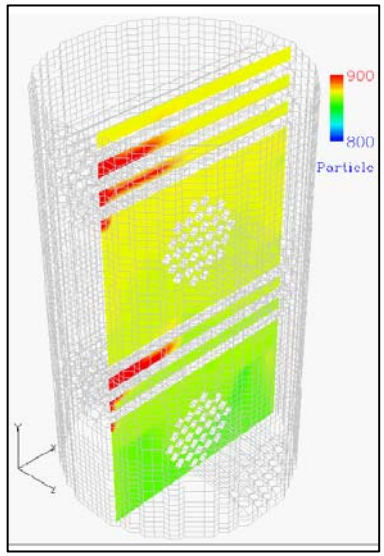
- Introduction
- History of black liquor recovery technology
- Black liquor gasification technology today
- BLG research in Utah
- Conclusions

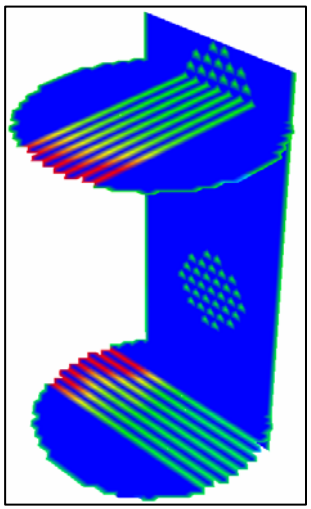
BLG Research in Utah

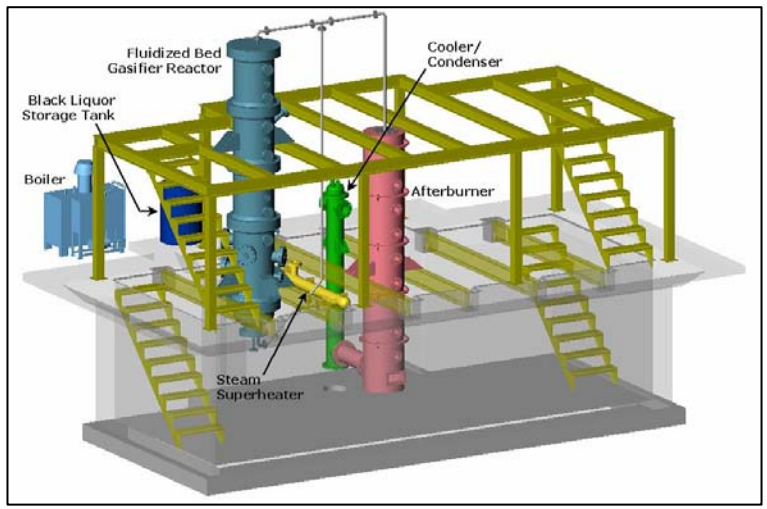
- Utah actively researching both technologies currently under development
  - University of Utah
  - Brigham Young University
  - Reaction Engineering International
- Total funding approximately $2.7 million
  - 80% from U.S. Department of Energy
  - 20% partner cost share
  - Effective $2.0 million federal funds

Fluidized Bed Steam Reforming Research

- Fuel conversion
- Bed performance
- Syngas characterization
- Tar destruction
- Computational modeling







Entrained-Flow Gasification Research

- Droplet formation and burner performance
  - Imaging studies
  - Droplet characterization
  - Computational modeling
- Fuel conversion
  - Droplet to smelt
  - Chemical properties
  - Physical properties
- Smelt characterization
  - Transport properties
  - Radiative properties
- Syngas characterization
  - Speciation
  - Tar characterization

Outline

- Introduction
- History of black liquor recovery technology
- Black liquor gasification technology today
- BLG research in Utah
- Conclusions

Conclusions

- Black liquor gasification offers significant improvements in energy efficiency and environmental performance, as well as economic benefits
- Black liquor gasification on brink of commercialization
  - Pilot-scale trials ongoing
  - Several commercial installations in place
- Utah active in black liquor gasification research

Acknowledgements

- U.S. Department of Energy
- American Forest and Paper Association (AF&PA)
- Georgia-Pacific Corporation
- Weyerhaeuser Corporation
- International Paper
- Norampac, Inc.
- MTCI / Thermochem
- Thermochem Recovery International
- Chemrec AB
- Oak Ridge National Laboratories
- University of Missouri - Rolla