Scale-up of Iogen’s Cellulosic Ethanol Process to Raizen’s Costa Pinto Mill

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Scale-up of Iogen’s Cellulosic Ethanol Process

• Brief Introduction to Iogen
• Our Commercial Deployment at Costa Pinto
• Today’s Commercialization Challenge
• Achieving High Reliability Operations
Over thirty years in cellulosic ethanol

- $500+ million invested & 300+ patents issued or pending
- Making cellulosic ethanol since 2004 in demo plant
- Strong focus on technology validation and commercial implementation
- History with blue chip partners

Enzyme Business: Historical relationships include:
Large and experienced team in cellulosic biofuels

- 9 years developing, designing, debugging and scaling-up cellulosic ethanol technology in our integrated demo plant

- Achieved steady, reliable production operations - integrating biotech, process tech and engineering

- Projects developed in Canada, US, Germany and Brazil

- Extensive feedstock supply chain experience, with contracts totaling over 2.8 million MT/yr
At Iogen: Emphasize Design Cycles & Integrated Demo

Cycle of Process
Design Improvement
R1 to R8

- Develop
- Implement
- Operate
Cellulosic Timelines Chart: *Iogen is rich on demo experience*

Cellulosic development timelines chart

- Demo timeline in blue

Scale-up of logen’s Cellulosic Ethanol Process

- Brief Introduction to logen
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First Plant: The Costa Pinto Cellulosic Ethanol Facility
Bolt-on facility to a Brazilian Sugar Cane Ethanol Plant

Brazil’s largest cane processor, Iogen partner
- 24 sugar & ethanol mills,
- ~65 m tonnes/yr. crushing
- ~$30 billion sales
- ~40,000 employees

The Costa Pinto 2G Ethanol Project – Start-up on schedule in Q4 2014
- US ~$100 million
- 40 m litres/yr. 2G ethanol
- Bagasse as feedstock
- Residue to boiler
- Once operational, Raizen plans for 7 more plants
Processing Bagasse to Cellulosic Ethanol
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Processing Bagasse to Cellulosic Ethanol
Fuel Production already underway

Here's Second Generation Ethanol
Why Brazil? Unique Co-location Synergies

- Meets the need to get more out of existing assets
  - 50% more ethanol per acre
  - Extend the operating season

- Uses feedstock that’s already delivered on-site

- Significant cost savings
  - Opportunity to share existing equipment and facilities
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The Challenge: Achieving Highly Reliable Operation

- Over $2 billion has been invested in commercial cellulosic biofuel production
- Ten technology platforms have been scaled up (including two failures)
- Five platforms, including Iogen’s, are enzyme based cellulosic ethanol
- Expect everyone to struggle to achieve highly reliable commercial operation
The Challenge: Achieving Highly Reliable Operation

- Start with an example: Iogen’s R6 technology generation
The Challenge: Achieving Highly Reliable Operation

- Start with an example: Iogen’s R6 technology generation
The Challenge: Achieving Highly Reliable Operation

- Start with an example: Iogen’s R6 technology generation

[Graph showing Production Startup Path with Target Range and R6]
The Challenge: Achieving Highly Reliable Operation

- Significant improvement with R7

Production Startup Path

- Target Range
- R7
- R6

% Asset Utilization/Uptime

Months from Start-up
The Challenge: Achieving Highly Reliable Operation

- Significant improvement with R7
The Challenge: Achieving Highly Reliable Operation

- Further improvement with R8 – the technology generation scaled up in Brazil

![Production Startup Path](image-url)
The Challenge: Achieving Highly Reliable Operation

- Expect everyone to struggle to achieve highly reliable commercial operation
The Challenge: Achieving Highly Reliable Operation

- Expect everyone to struggle to achieve highly reliable commercial operation

[Graph showing production startup path with target range and R6, R7, R8 labels, and a box highlighting "EPA’s EMTS report of U.S. cellulosic ethanol production"]
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What Stands in the Way of Highly Reliable Operation?

• The Usual Suspects:
  • Processing a non-uniform, seasonal, low bulk density feedstock
  • Maintaining and operating equipment in a highly erosive, corrosive environment – with silica containing feedstocks that are often contaminated with sand
  • Operating biotech processes effectively without unanticipated problems – contamination, inhibiting/inactivating substrates
  • Physical properties that don’t turn out like you expect – especially for insoluble solids – filtration, foaming, deposits
  • SNAFUs everywhere

• Pretreatment is Ground Zero for issues
  • High pressure, high temperature extreme environment;
  • Very challenging sealing and feeding problems (How do you get loose packed straw into a 400 psi reactor?)
  • Highly subject to erosion and corrosion

Plant Fibre

Pretreatment

Enzymatic Hydrolysis

Separation

Ethanol Fermentation

Distillation

Cellulose Ethanol
What’s Iogen’s experience in scaling up pretreatment?

- We started with steam explosion
  - Batch process
  - Originally pioneered in the 1920s by William H. Mason for the productions of Masonite
    - Mason was a protégé of Thomas Edison and I met him
  - Iogen applied it to pretreatment in the 1970s;
  - Introduced acid to improve yield and accessibility
  - The process is run with very short residence time (5 to 50 seconds)

- What does all this mean for scale-up and erosion?
  - Erosion is an important issue
  - Many stories from the scale-up wars …..
  - Overall – good things about steam explosion, but also serious limitations
What’s Iogen’s experience in scaling up pretreatment?

• Our quest for going continuous
  • The “Stake Digester” was an early continuous pretreatment system
  • Developed by Doug Brown of Stake Technologies in the 1970s to address severe wear and erosion in conventional plug screw feeders
  • Doug’s thesis:
    • Plug screw feeders from the pulp and paper industry cannot withstand the high compression levels needed for pretreatment … too much erosion
    • Our observation was that “Stake” pretreated materials exhibited tell-tale signs of steam mass transfer limits

• The Stake experience colored Iogen’s approach to continuous pretreatment
  • Avoid high compressive forces to ensure
    • Limited opportunity for erosion – equipment troubles;
    • Uniform treatment of the substrate - technical performance
Iogen’s R8 Pretreatment System

**Features**
- Feedstock is introduced into the unit as a high pressure slurry
- It is then dewatered in low-compression feeding device before entering the primary reactor;
- The primary reactor has a precisely controlled pH and residence time - which can be kept very short;
- Integrated heat recovery system
- Multiple patents issued and in process on the system

**Benefits**
- Highly tolerant of sand and abrasives
- Uniform, consistent “short time” cooking that isn’t impaired by steam mass transfer limitations
- High xylan yields
- High level of enzyme accessibility
- Practical to have very large line sizes (e.g. 1500 tpd)

U.S. Patent 8,328,947
Iogen’s R8 Pretreatment – Operating at Costa Pinto
Thank You