U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

WBS 1.2.3.3 Biomass Feedstock User Facility

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Goal Statement

- The goal of this project is to engage industry collaborators in the scale-up of biomass preprocessing systems.
- The project advances the BETO goal of growing a bioeconomy by developing robust biomass preprocessing technologies to overcome variability and feed handling challenges faced by the biofuel and bioproduct industries.
- The Biomass Feedstock National User Facility (BFNUF) is available to industry and other users.

Process Demonstration Unit (PDU)

Quad Chart Overview

1.2.3.3 PDU Budget

Project start date: 10/01/15
Project end date: 09/30/18
Go/No Go milestone: Mar 31/17
(20-ton demonstration run)
Percent Complete: ~42%
On-going

	FY 16 Costs	Total Planned Funding (FY 17-Project End Date)
DOE Funded	$1.93M	$3.4M

Barriers

FT-E: Variable properties of biomass material

IT-A: Lack of accurate in-line sensors

IT-B: Availability of suitable preprocessing equipment

Partners

- AdvanceBio
- Bliss
- Bulk Handling System
- DuPont Industrial Biosciences
- Forest Concepts
- Rotex
- Vermeer
- Virginia Commonwealth Univ.
- Vortex Processing
- NREL, PNNL, LBL

1 – Project Overview

Objective of the Control Project

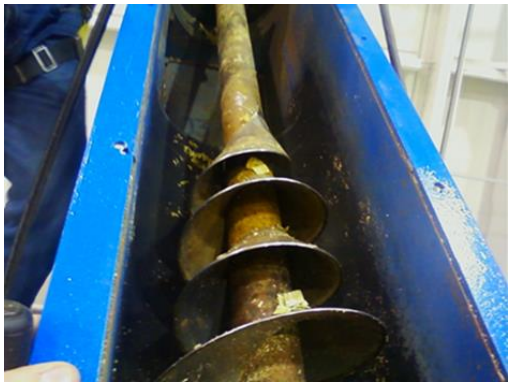
To solve industrial biomass feed handling problems associated with variability in biomass properties by developing an integrated preprocessing system that can reliably produce consistent feedstocks

Background

Technology	Throughput (T)	Quality(Q)	Reliability (R)	TQR Score
Conventional Feedstock Preprocessing	Low T, frequent plugging, lacking process control	Composition & particle size not meeting specs	Low R, high maintenance, low on-stream time	Low
Advanced Feedstock Preprocessing	High flowability & throughput, adv. process control	Feedstock meeting conversion specs	Low maintenance, high on-stream time, high R	High

Conventional feedstock preprocessing results in:

Plugging of hammer mill screen



Bent Screw Conveyor Flights

2 – Approach (Management)

- Project Scope for the User Facility
  - Single unit operation or integrated testing
  - Proprietary projects pay 100%
  - Non-proprietary projects require 50% cost share
- Management Tools
  - BETO-sponsored and competitively awarded projects have priority
  - DOE review & approval of external projects
  - Industry Advisory Board (established May 2016):

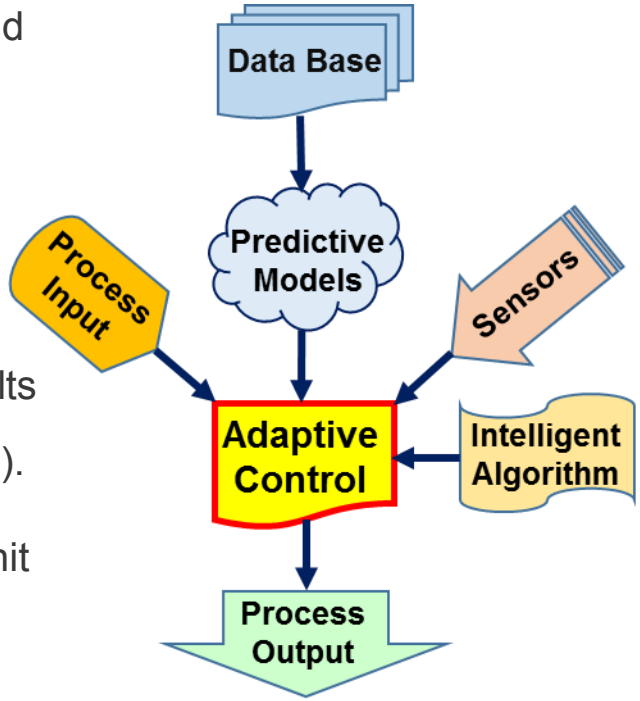
  Tim Bell – DuPont, Darwin Krause – formerly with Iogen, Abraham Haspel – Cogent Energy Systems, prior COO of EERE, Jordon Solomon – Ecostrat
  - Marketing/trade shows for networking
- Success Factors:
  - Number of projects, users, publications
  - Knowledge gained and improved technologies for the customers
  - Advancements to industrial control systems, and significant improvement in the reliability of biomass preprocessing systems.
- Challenges:
  - Meeting feedstock specifications for different conversion pathways
  - Getting enough business to be self-sustaining

2 – Approach (Technical)

- **Approach**
  - Engage industry to identify major issues of handling corn stover
  - Develop an advanced preprocessing system that can reliably produce consistent feedstocks from variable and diverse biomass materials
- **Methodology for Control System**
  - Develop an adaptive control system (feedforward & feedback) using the PDU as the testbed and PDU data as the basis for control system development
- **Projected Outcome (FY18)**
  - Demonstration of an artificial intelligence-based control system in a 20-ton 2-stage grinding operation that results in >90% reliability and >50% capability in industrially relevant conditions (corn stover with 10-30% moistures).

  Note: the inter-stage conveyors are capacity-limited
  - This control strategy is applicable to other integrated unit operations (e.g., reactor feeding, separation, etc.)

  Definitions:
  - Reliability = % on-stream
  - Capability = % design throughput (limiting factors: Full-load Amp of motor, bulk density of feedstock)



3 – Technical Accomplishments: PDU Utilization

PDU Operation History

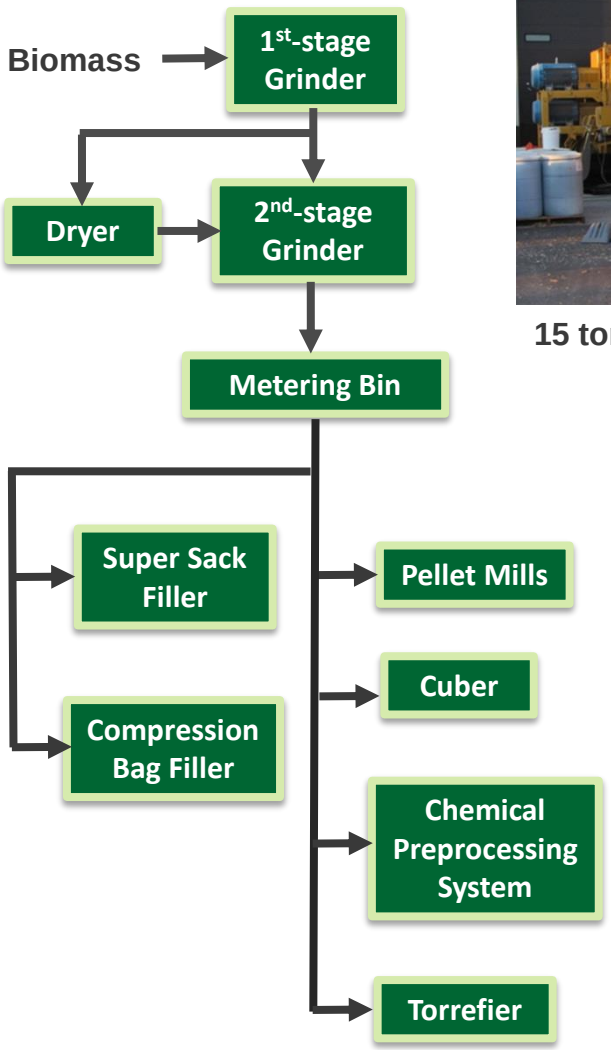
- More than 1,000 tons of herbaceous and woody feedstock processed to a wide variety of conversion pathway specifications
- Extensive material characterization and data collection
- Helped customers validate equipment performance and generate engineering design data for:
  - Size reduction & classification. Challenge: meeting particle size distribution
  - Densification
  - Drying
  - Torrefaction
- Knowledge gained from equipment operation and maintenance

Customers/Users:

- BETO-sponsored projects,
- Industry, national labs, universities, farmers, and state government

3 – Technical Results: PDU Process Development

Block Flow Diagram of the Feedstock Preprocessing System

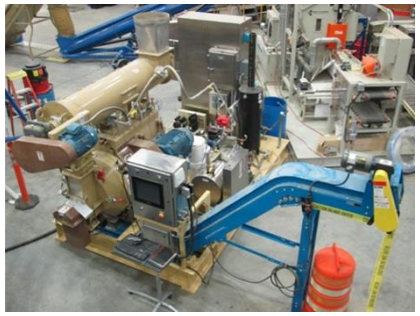


15 ton/hr 1st-Stage Grinder

5 ton/hr 2nd-Stage Grinder

Metering Bin

Rotary Dryer



1 ton/hr Pelleting Mill

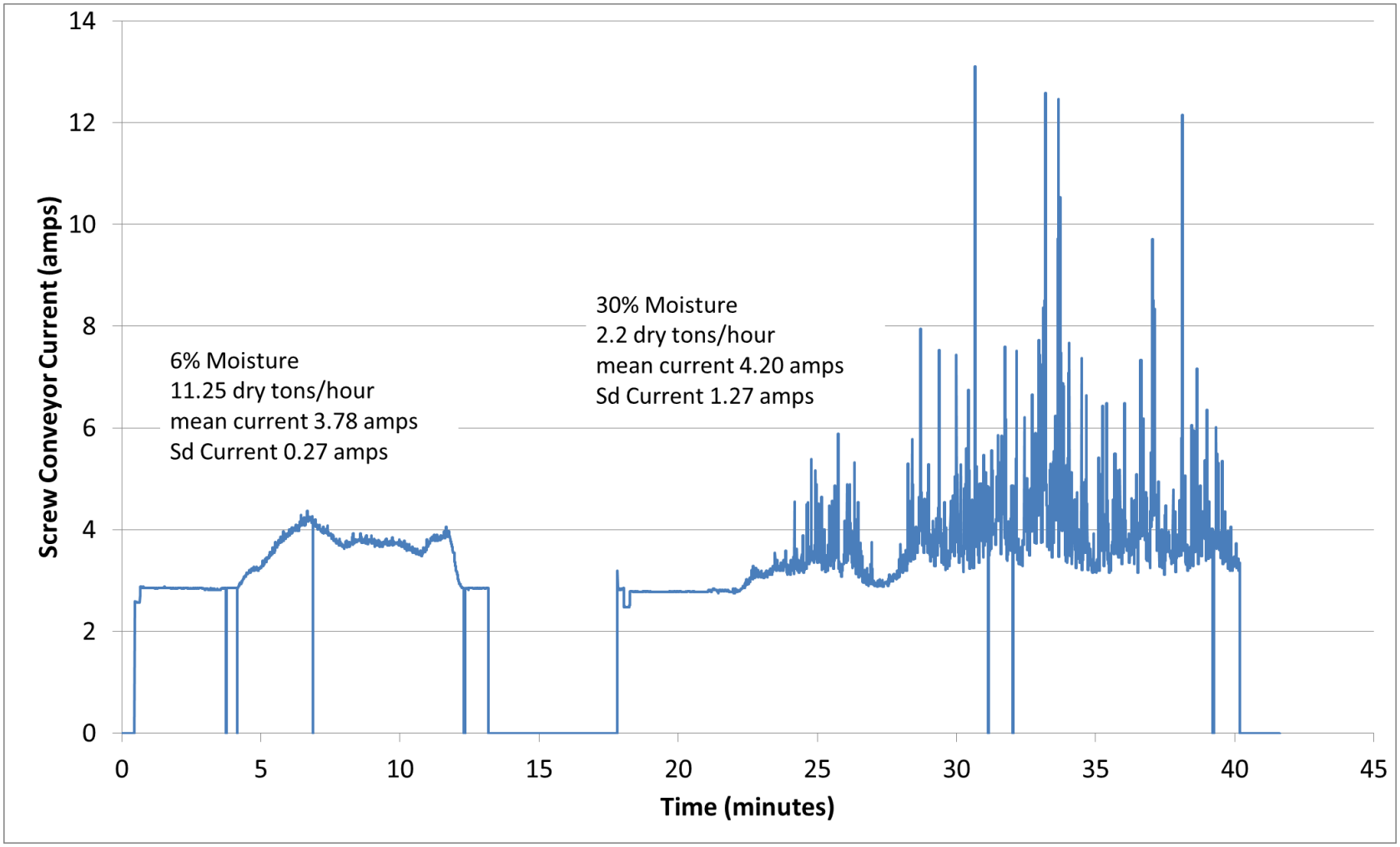
5 ton/hr Pelleting Mill

15 ton/hr Cuber

3 – Technical Results: PDU Process Development

Effect of corn stover moisture content (MC) on screw conveyor performance

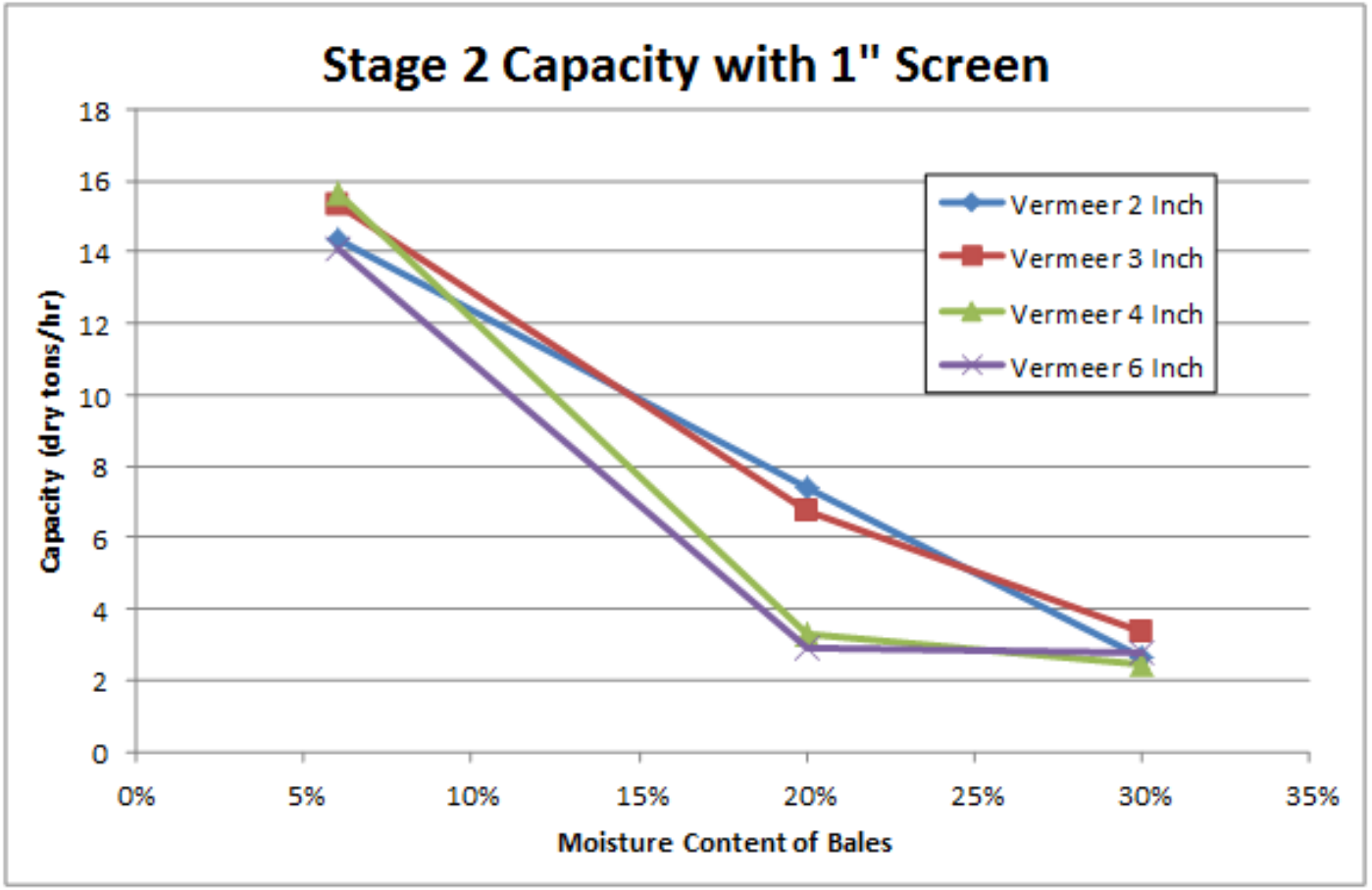
Capacity at 30% MC = 20% Capacity at 6% MC



3 – Technical Results: PDU Process Development

Effect of corn stover MC on stage-2 grinder performance

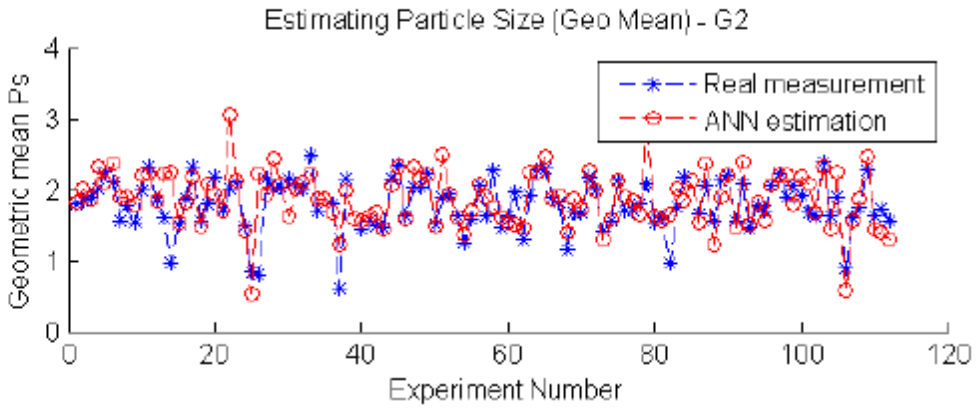
Capacity at 30% MC = 22% Capacity at 6% MC



3 – Technical Results: PDU Process Control

- Virginia Commonwealth University (Richmond, VA) is researching how predictive modeling, data driven monitoring and expert knowledge can maximize throughput and reliability of the PDU.

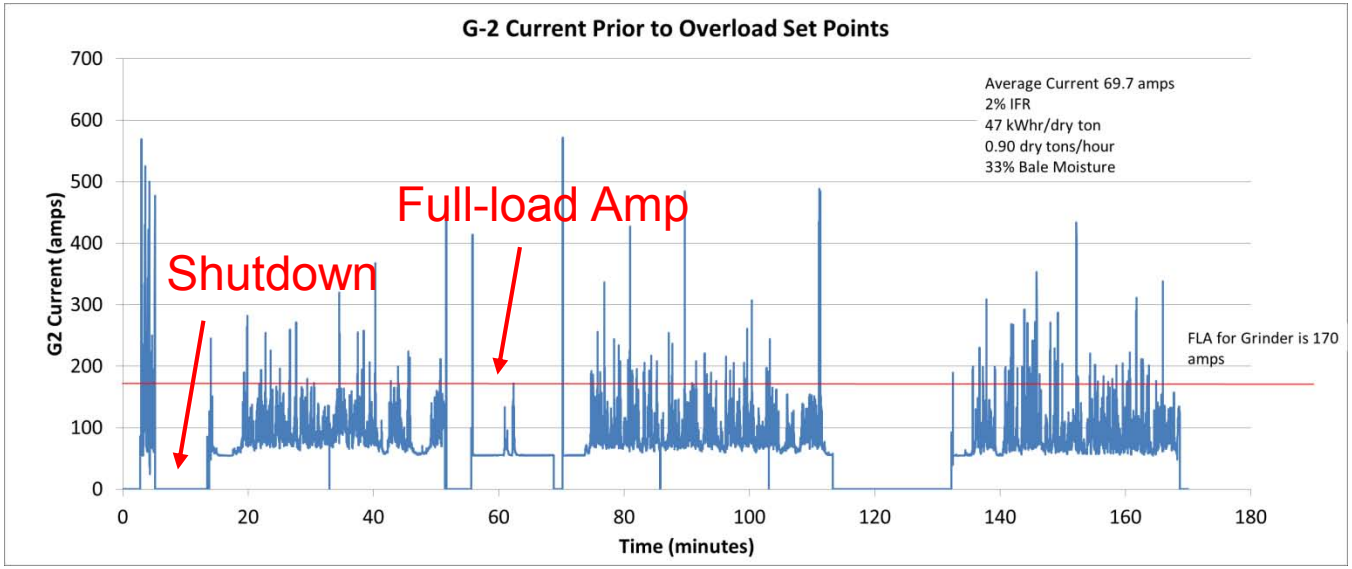
Estimating Particle Size of Stage-2 Grinder using predictive modeling



ANN: Artificial Neural Network

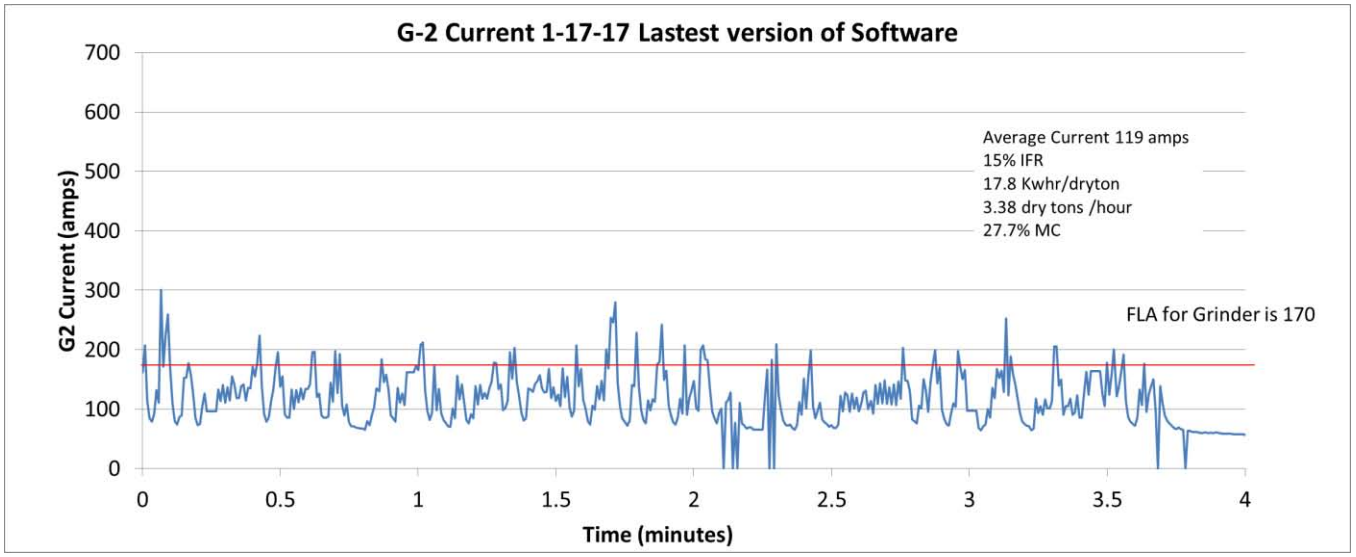
3 – Technical Results: PDU Process Control

Adaptive control improves hammer mill throughput



Original setup
- 0.9 t/h
- 47 kWh/t
- 33%MC
- 4 shutdowns

(2 bales in 170 min)



Adaptive control
- 3.4 t/h
- 18 kWh/t
- 28%MC
- No shutdown

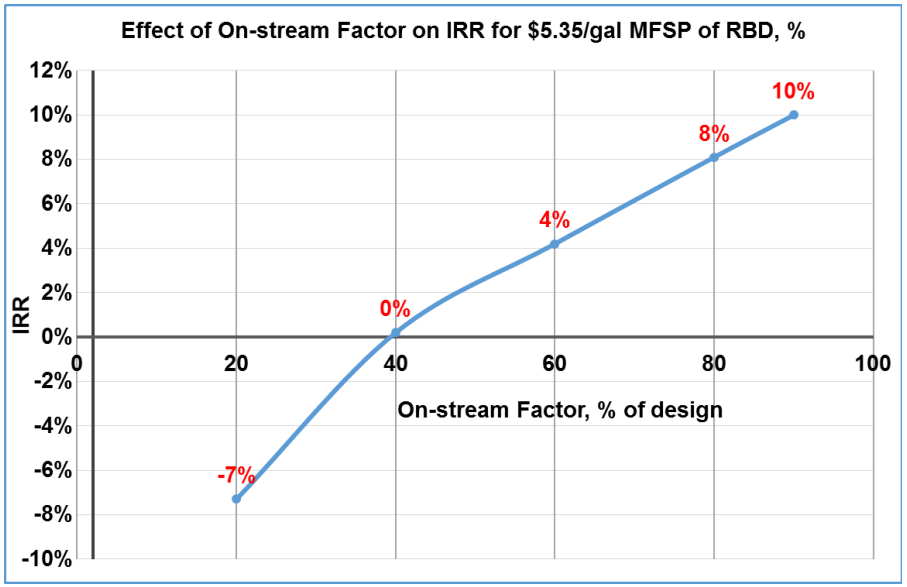
(1 bale in 4 min)

IFR = Infeed Rate of Stage 1 Grinder

4 – Relevance

Biomass feed handling problems pose barriers to the cellulosic ethanol industry

- In 2015, 2.0 million RINS generated from cellulosic ethanol
  - ~3% of installed biorefinery production capacity
- "Biomass handling" problems blamed for slow start-up of biorefineries
  - Grinding
  - Conveyance
  - Feeding
  - Solids handling up to and through conversion
- Integrating Feedstock Preprocessing with Conversion complicates operation



RDB = Renewable Diesel Blendstock

Source : Ryan Davis, NREL

4 - Relevance

- Rand Corporation study (Merrow, 1984) showed that plants that process bulk solids typically operate at less than 50% of design capacity the first year of operation
  - Performance of 37 new plants using data provided by 25 companies
- Problems generally relate to an inadequate understanding of the behavior of elastic & compressible particle systems (Bell, 2005). This observation is still true today.

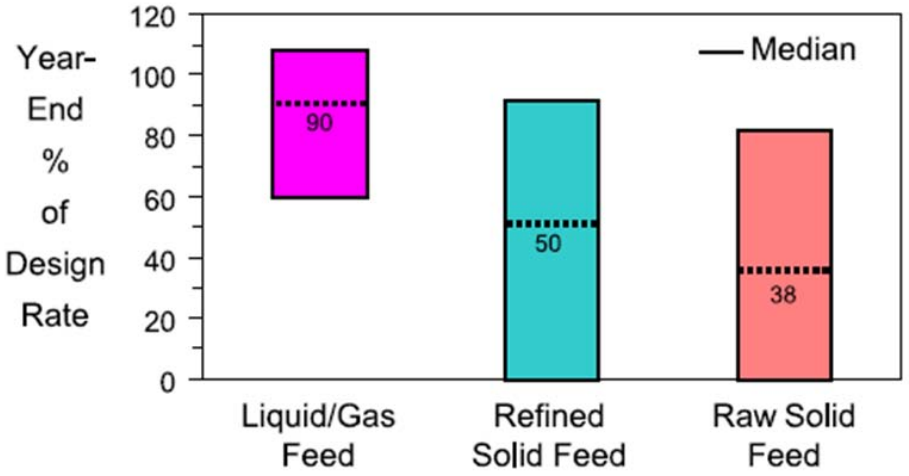


Image source: Merrow, 1984 (Rand Corp. P-7034)

4 - Relevance

- The PDU project is dependent on collaborations to provide solutions to real world feedstock handling problems

- User Facility projects are helping INL and BETO
  - Understand range of feedstock specifications for different conversion pathways
  - Understand the gap between specifications and what is achievable at an industrial scale
  - Identify innovative solutions to industrial preprocessing needs (closing the gap)
  - Supply data to support BETO techno-economic assessments and state of technology reports

- Collaborations are helping our partners (users)
  - Develop robust feedstock preprocessing technologies that enhance the reliability of integrated biorefineries

5 – Future Work

- Go/No-Go Milestone (Q2 FY17): demonstrate an adaptive Control Logic to improve throughput of a two-stage grinding operation
- Development of a control system for integrated preprocessing
  - Test new on-line sensors for measuring dirt and moisture content
  - Integrate grinding, drying, and pelleting process models
  - Develop predictive control system to improve reliable operation, optimize energy consumption, throughput, and product quality
- Expand user facility capabilities
  - Add screening system to facilitate fractional milling and improve particle size distribution of feedstock
  - Improve modularity to simplify adding third-party equipment modules
- Business tools – working internally to
  - Reduce project development time
  - Streamline contracting reviews and approvals
- Become self-sustaining. Challenges: capability and market conditions

Summary

Overview

- The User Facility provides a unique and critical capability for projects that require an integrated system too large or too complex for industry test laboratories

- **Approach**
  - Active industry engagement and project development to ensure relevance to BOTH industry and DOE-BETO
- **Technical Accomplishments**
  - Relating characteristics of biomass to equipment performance
  - Adaptive control systems will accelerate scale-up and integration of robust biomass preprocessing technologies
- **Relevance**
  - Developing robust feedstock preprocessing technologies will help accelerate the expansion of a bioeconomy
  - Characterization of biomass and feedstock properties will help manufacturers design and build better instrumentation & equipment to improve throughput and obtain target feedstock specifications

Questions ?