DEVELOPMENT OF CELLULOSIC ETHANOL TECHNOLOGY USING FLORIDA SUGARCANE BAGASSE

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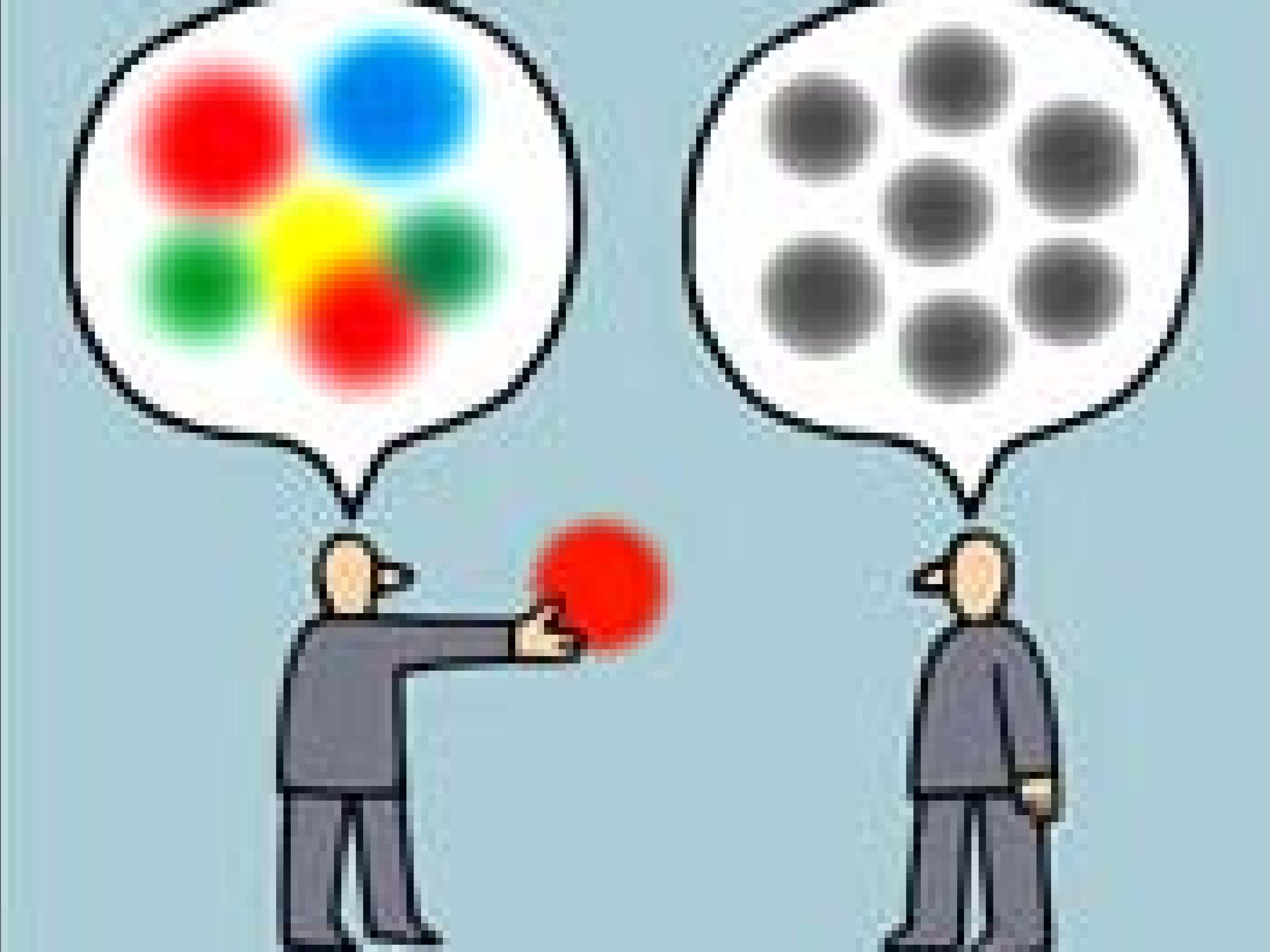
ASSESSMENT AND DEVELOPMENT OF PRETREATMENT FOR SUGARCANE BAGASSE TO COMMERCIALIZE CELLULOSIC ETHANOL TECHNOLOGY

- Funded by Florida Department of Environmental Protection
- State funds - $990,532
- FCC Cost match - $927,774
- Duration – April 2007 through March 2010
- Location – primarily at the Okeelanta facility of FCC

OKEELANTA CORPORATION

BAGASSE STORAGE AND COGENERATION FACILITY



PROJECT RATIONALE

- Bagasse availability and condition
- Technology developed for bagasse should also apply to other grassy biomass materials
- Two basic approaches
  - Biochemical: a wet process that requires the raw material be converted to an "enzyme ready" condition for hydrolysis of the complex polysaccharides, primarily cellulose and hemi-cellulose; lignin not converted. Ethanol produced by fermentation and distillation.
  - Thermochemical: a dry process that requires the raw material by converted to a "gasifier ready" condition of low moisture and increased bulk density; potential for conversion of all carbon in biomass, minus that required to generate process temperatures by combustion. Liquid fuels produced by catalytic conversion of syngas.

CHOICE OF BIOCHEMICAL APPROACH

- Advantages –
  - More suitable for high moisture raw materials;
  - Available free sugars utilized, along with complex carbohydrates;
  - Specificity of fermentation process for ethanol.
- Disadvantages –
  - Intractable characteristics of polysaccharides, especially cellulose. **HENCE THE NEED FOR PRETREATMENT**.
  - High cost of enzymes;
  - Lignin residue must be recovered and used (for fuel?);
  - Waste streams, especially water.

PROCESS OUTLINE

RAW **BIOMASS** (BAGASSE)

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PRETREATMENT – combination of -

size reduction;
acid or alkali treatment;
elevated temperature.

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ENZYMATIC AND/OR ACID HYDROLYSIS
TO LIBERATE FERMENTABLE SUGARS

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FERMENTATION OF MIXED SUGARS
WITH SELECTED MICROORGANISMS

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DISTILLATION TO RECOVER **ETHANOL**

FUTURE PROCESSES SHOULD COMBINE THESE

NECESSITY AND GOALS OF PRETREATMENT

- Lignocellulosic material is inherently stable under ambient conditions; evolved to become the structural components of plant material.
- Biomass degraded by enzymes in fungal systems but much too slowly for industrial application.
- Pretreatment therefore required to –
  - Enhance biomass susceptibility to enzymatic hydrolysis to simple sugars by enzyme cocktail; this may include both natural and engineered enzymes.
  - Improve the process characteristics of biomass slurries in terms of pumping and mixing, pH and temperature control, achieving high solids concentration and therefore good soluble sugar levels for fermentation, etc.

CONSTRAINTS ON COMMERCIALLY VIABLE PROCESSES - 1

- Capital costs –
  - Related to process conditions (temperature, pressure, corrosion, etc);
  - Need to avoid exotic materials and custom equipment.
- Operating costs –
  - Chemicals and enzymes (latter more critical though cost reduction anticipated as improved enzyme systems are developed); chemical costs very erratic.
  - Energy (trade-off between chemical and energy inputs?).
- Environmental –
  - Chemicals added to process do not disappear; recycling?
  - Potential for high BOD/COD wastewater.

CONSTRAINTS ON COMMERCIALLY VIABLE PROCESSES - 2

- Important to set limits on process options to minimize costs.

ASSUME	80 gal Ethanol / ton dry biomass
	Maximum total processing cost $1.00 / gal Ethanol
	Chemical costs not to exceed $0.10 / gal Ethanol
THEN	$0.10 for chemicals per 25 lb dry bagasse

- Goal of >10% (w/v) fermentable sugars in solution after hydrolysis with acid and/or enzymes.

- **CHALLENGE TO DEVEVOP A COMMERCIALLY VIABLE PROCESS WITH SUFFICIENT DETAILED DATA FOR REAL-WORLD EVALUATION**

EXPERIMENTAL APPROACH

- Laboratory work performed to set range of conditions for design of pilot plant –
  - Minimum temperature and pressure, even if this requires harsher mechanical treatment;
  - Avoid corrosive conditions that require special alloys, etc;
  - Minimize chemical use and waste; avoid excessive pH excursions and recycle chemicals if practical;
  - Use degree of enzymatic hydrolysis to monitor pre-treatment efficiency.

- Requirements for pilot plant design –
  - Throughput equivalent to ~ 1000 kg bagasse (dry) / day;
  - Maximize the solids concentration at each process stage;
  - Use of off-the-shelf equipment.

SUMMARY OF RESULTS TO DATE

- Pilot scale pre-treatment at 100ºC under various conditions, followed by enzymatic hydrolysis using “cocktail” of commercial enzymes –
  - Glucose release typically 75-80%; maximum achieved 91%
  - Xylose release typically 70-80%; maximum achieved 90%
  - Best combined results for glucose or xylose when both cellulase and xylanase used together in “cocktail”.
- Ongoing process development concerns –
  - Enzyme cost and performance;
  - Possibility of cellulose (and xylan) “retrogradation” after the initial pretreatment;
  - Chemical recycling and re-use.

CURRENT PROCESS DESIGN SUMMARY

STAGE 1

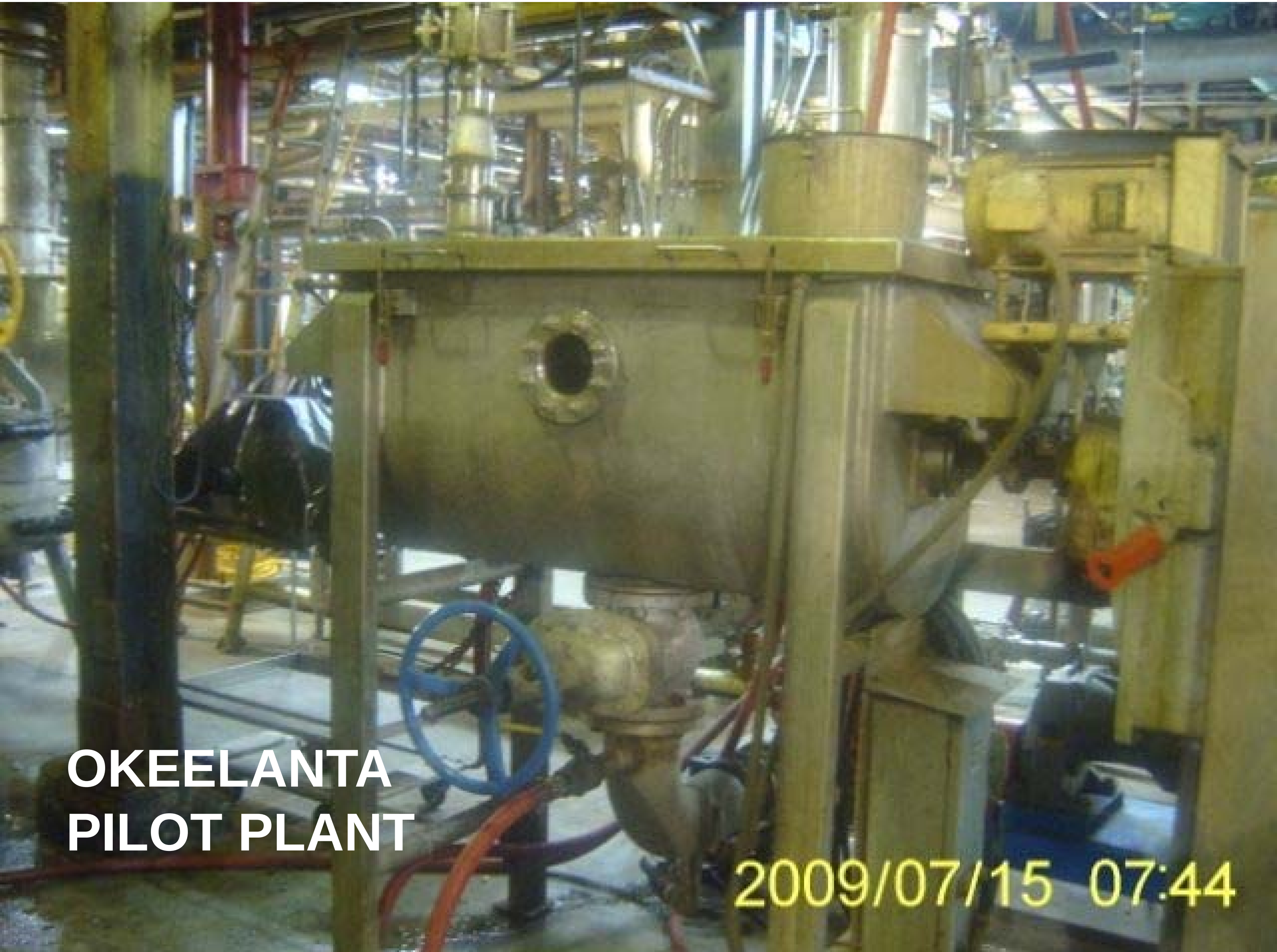
- Mixing of bagasse (or other biomass) and water, addition of chemicals, size reduction and heating of slurry to 100ºC.
- Maximization of solids content of slurry prior to pumping to –

STAGE 2

- Pumping of slurry through heat exchanger under pressure to raise to higher temperature.
- Discharge, with flash, into collection tank prior to –

STAGE 3

- Cooling, filtration and washing to remove and recycle chemicals, thickening to increase slurry concentration, pH adjustment and enzyme treatment.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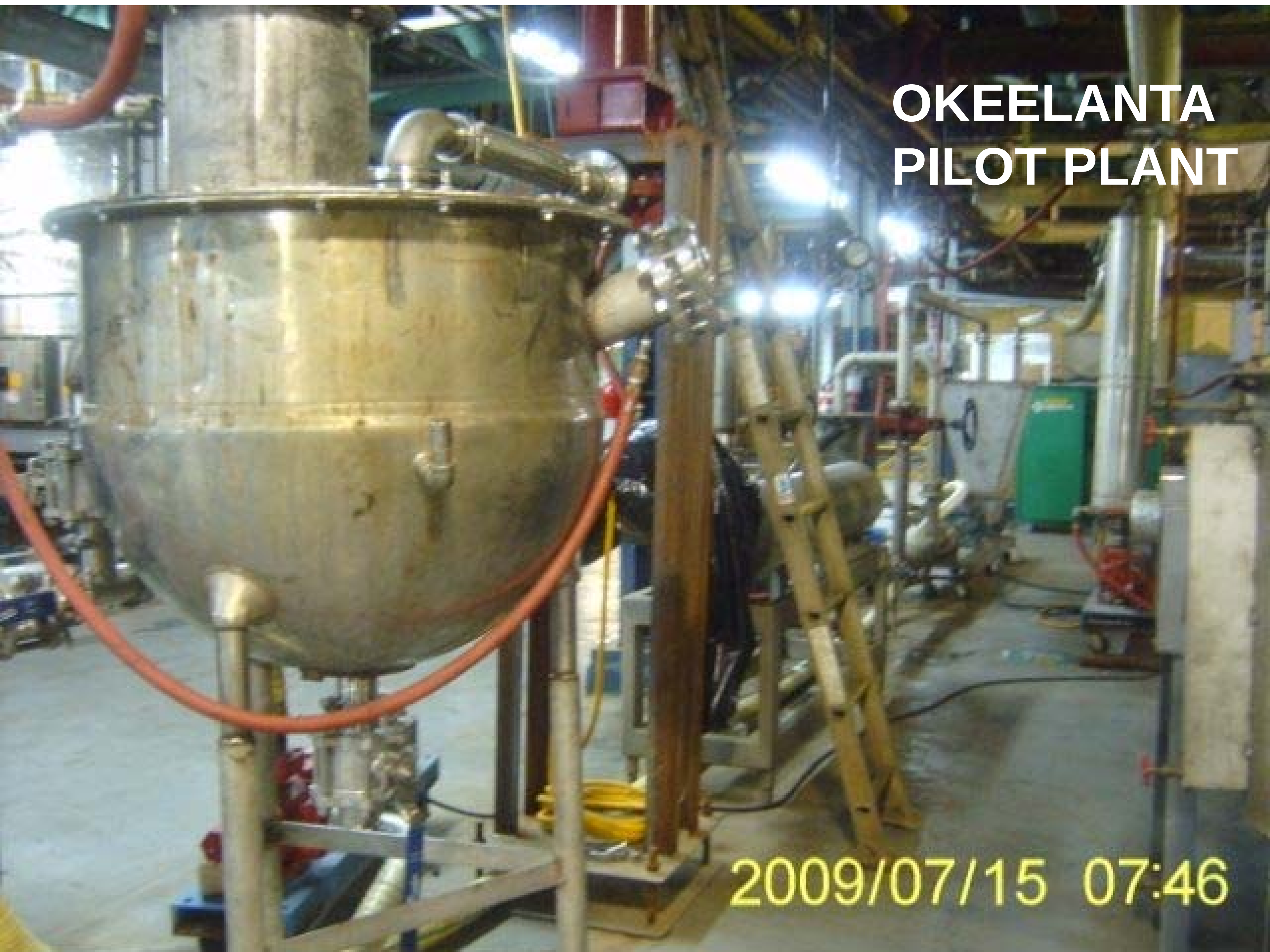
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