

This photo shows Dedini's delegation receiving the Best Paper Award – Factory Commission at the XXVII ISSCT Congress



# Ethanol Dehydration

## System by Siftek™ Polymeric Membrane



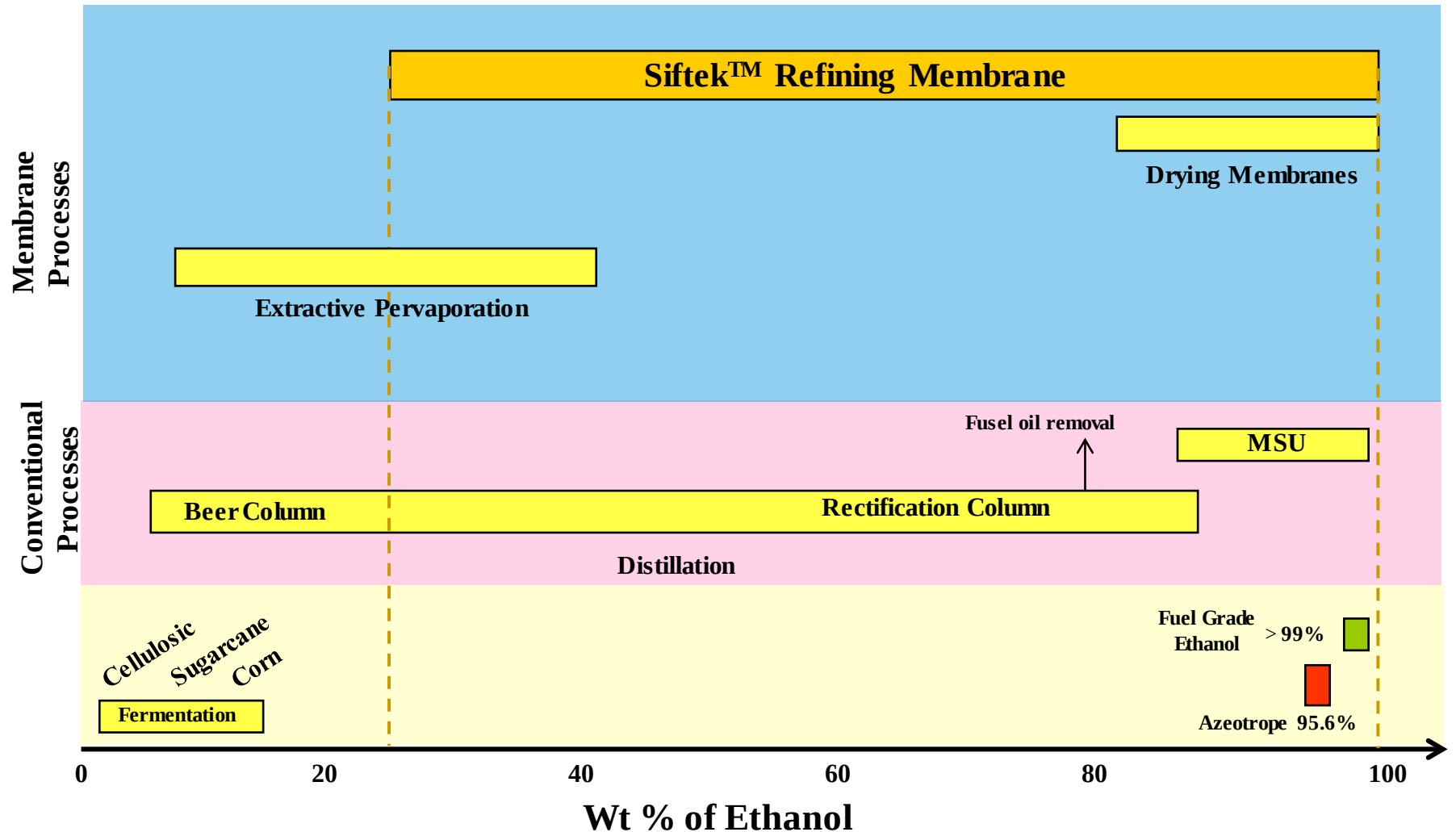
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# Introduction

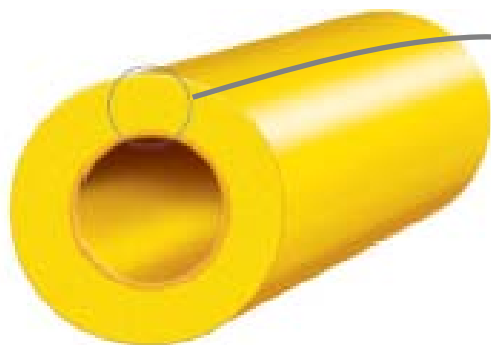
- Recently, polymeric membranes have received much attention because of their excellent performance in gas and vapour separation, especially in separation of water from organic vapour mixtures in industrial processes, which include water-ethanol systems (Huang et al., 2003a).
- The Siftek<sup>TM</sup> polymeric membrane has these properties and was designed specifically for ethanol-water separation with a higher selectivity for water over ethanol.
- Distillation and dehydration are responsible for the largest fraction of energy use in ethanol production. The technology has the potential to reduce this energy consumption between 35 and 70% when compared with conventional technology, like molecular sieve or extractive dehydration with cyclohexane (Côté et al., 2007).

# Siftek™ Membrane Technology



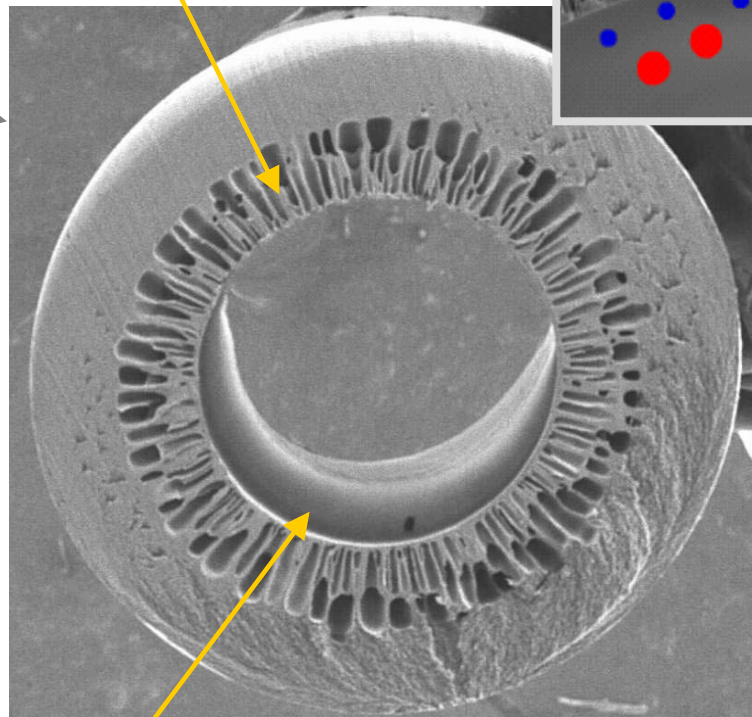
# Siftek™ Membrane Technology

## Doble layer hollow fiber membrane

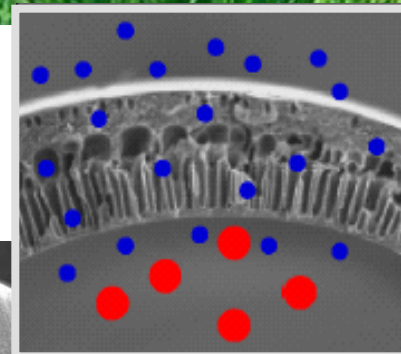


- Hydrophilic Polymer
- Thermo resistant
- Solvent resistant
- **Vaperma Patent**

Micro-porous  
sublayer 0.2 mm



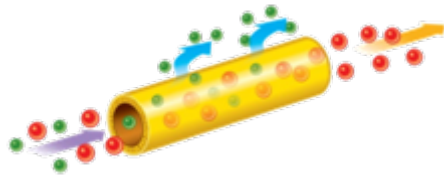
Integrally skinned  
membrane  
100 – 200 nm



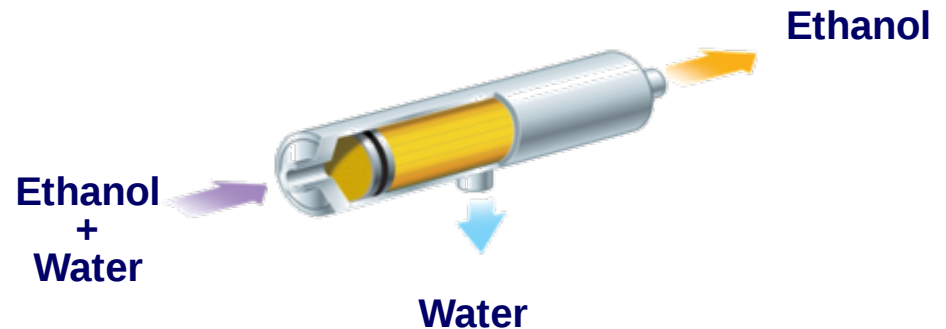
- Ethanol Molecule (0,43nm)
- Water Molecule (0,30nm)

# Membrane Cartridge

Hollow Fiber

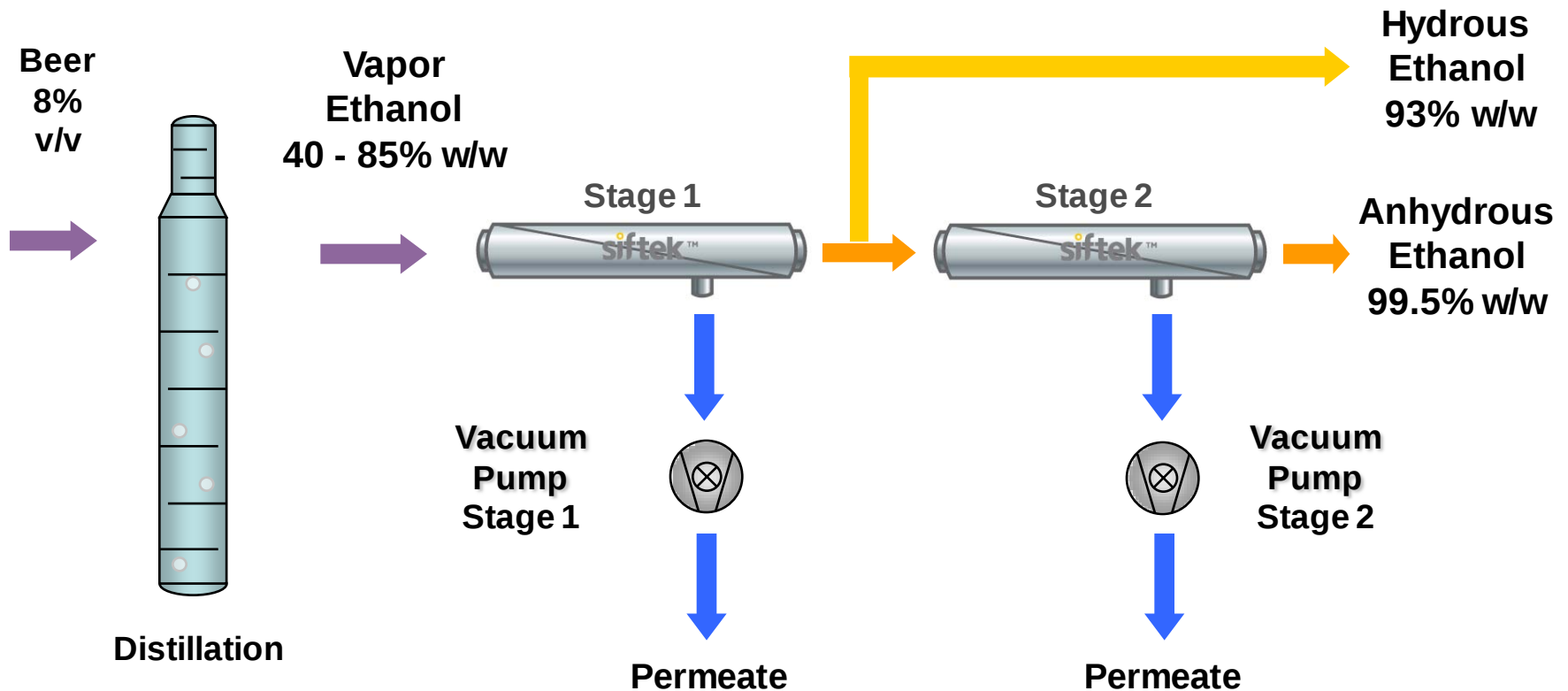


Cartridge



- Hollow fibers housed in a stainless steel cartridge
- Feed in vapour form under pressure
- Water removed continuously under vacuum

# Components of the Siftek Membrane System



# Tiverton Field Pilot Unit

*Phase 1: Pilot (Q3/2006 – today)*



## 1.0 m<sup>3</sup>/d Pilot Unit at GreenField Ethanol Plant in Tiverton (Ontario, Canada)

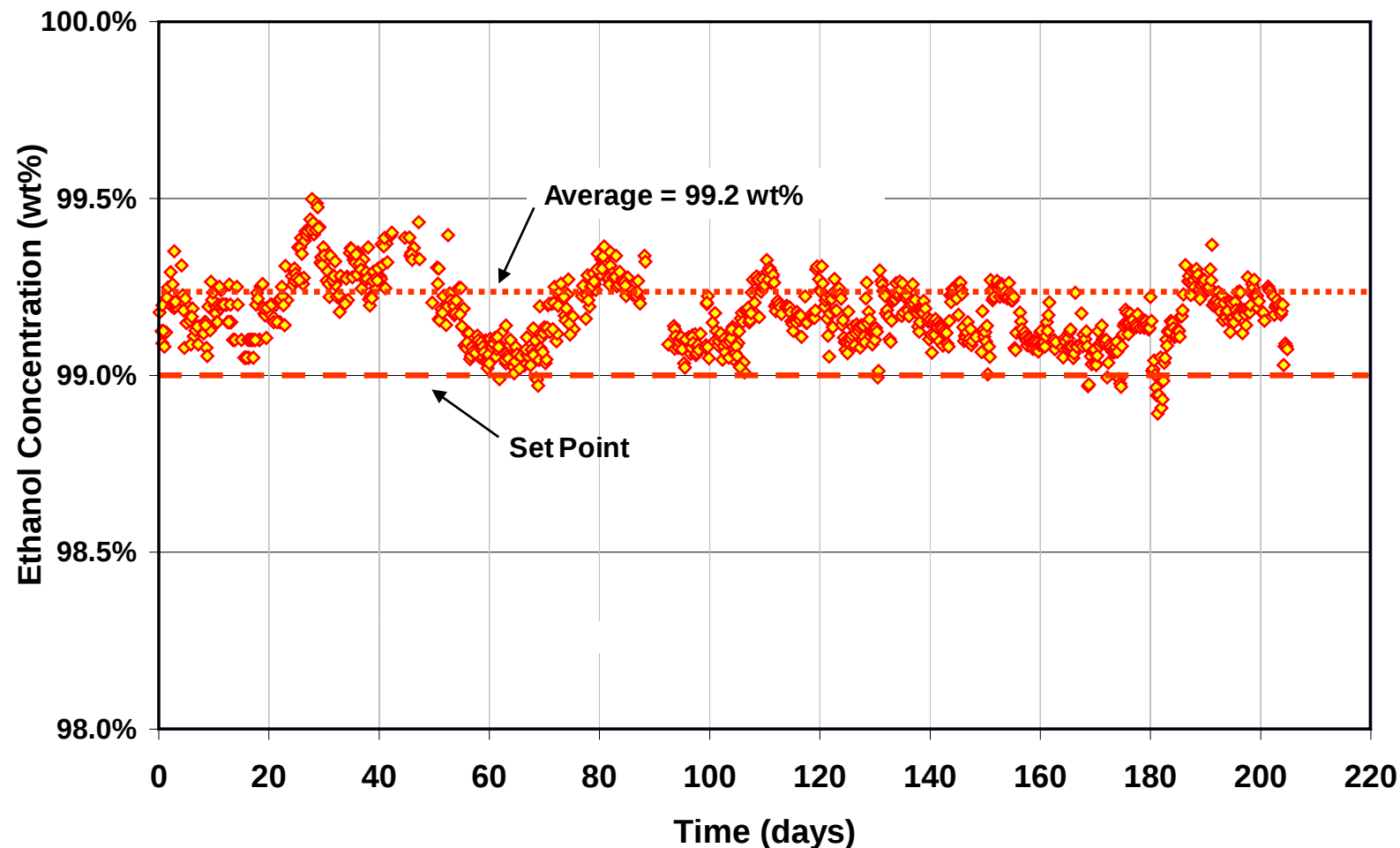


- Single membrane module testing unit
- Vapor feed is a split stream of the rectification column
- Feed pressure: 120-140 kPa (3-6 psig)
- Temperature: 105-115 °C
- 75-90 wt% ethanol feed
- 99.2 wt% fuel grade ethanol product

# Tiverton Field Pilot Unit

*Long Term Test: 200 days at >99% up-time*

ETHANOL  
GREENFIELD



# Chatham Field Demonstration Unit

*Phase 2: Demonstration Unit (Start-up Q3/2008)*



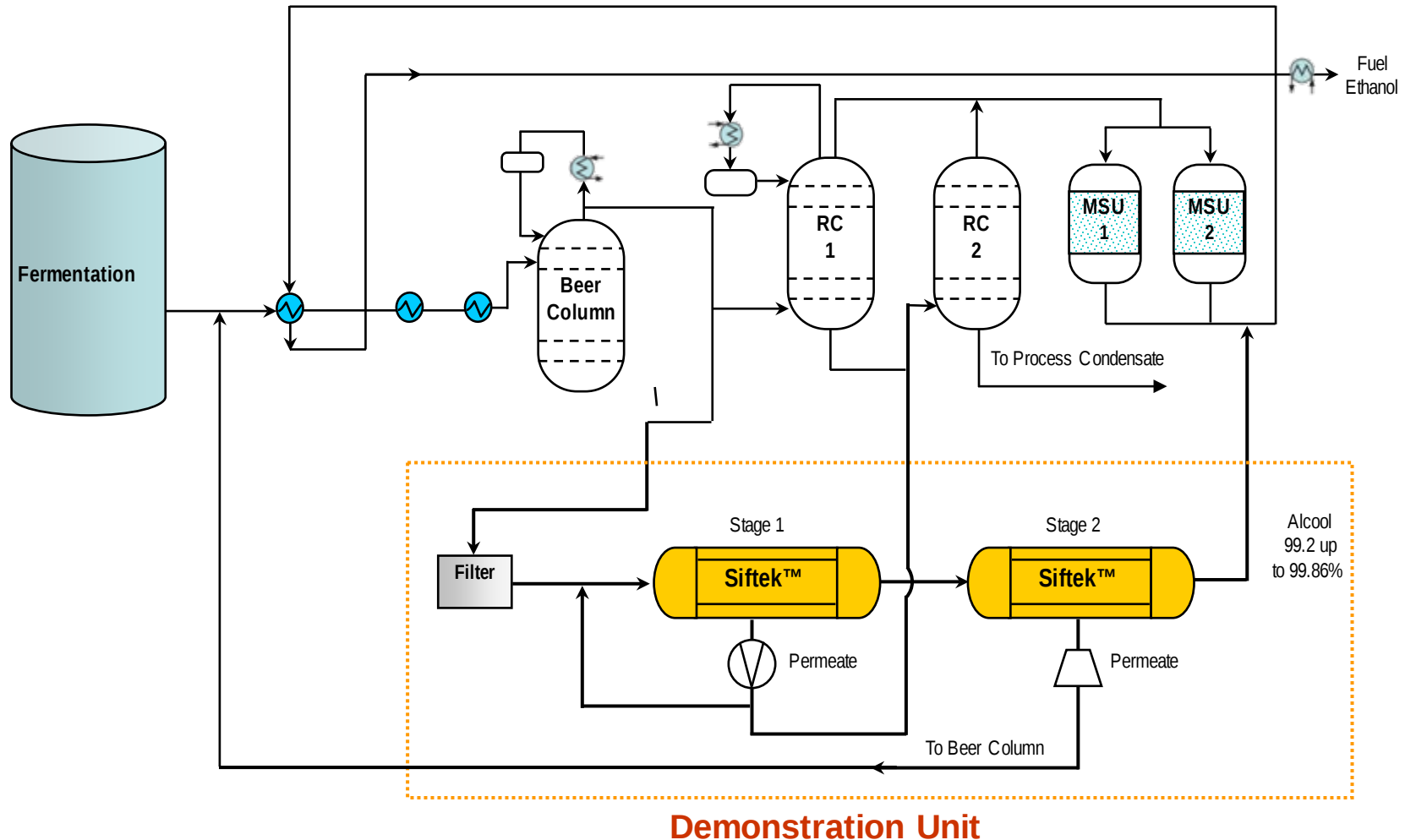
## 8 m<sup>3</sup>/day Demonstration Unit at GreenField Ethanol Plant in Chatham (Ontario, Canada)

- Two-stages / 8 modules
- Vapor feed from beer column with 40-60 wt% ethanol feed
- Feed pressure: 160 kPa
- Temperature: 105 -110 °C
- 99.2 – 99.86 wt% fuel grade ethanol product
- Heat recovery integrated with full-scale plant
- The Siftek™ demo unit is equipped with real-time monitoring, ethanol, heat integration and carbon footprints.



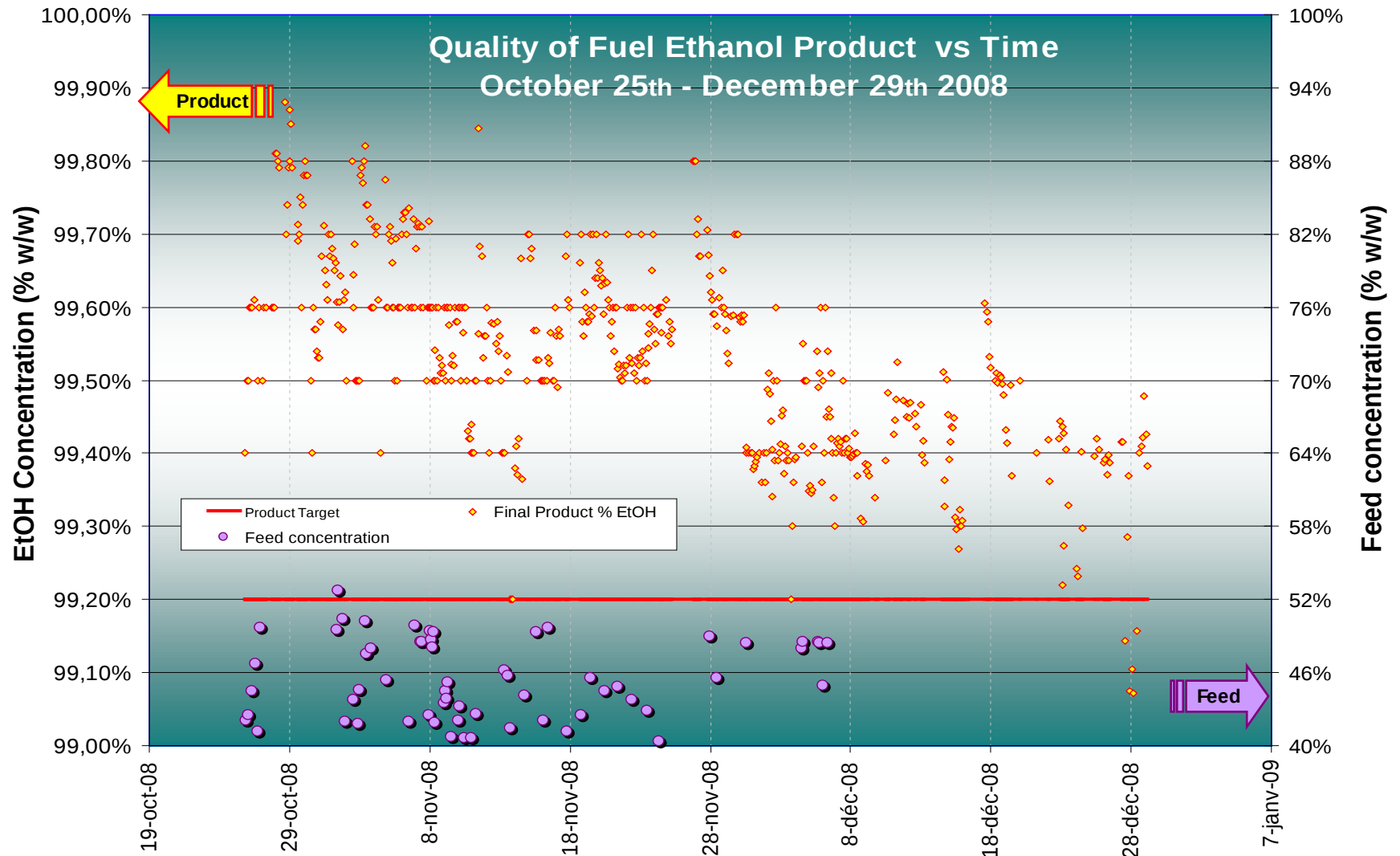
# Chatham Field Demonstration Unit

## Connection with industrial plant



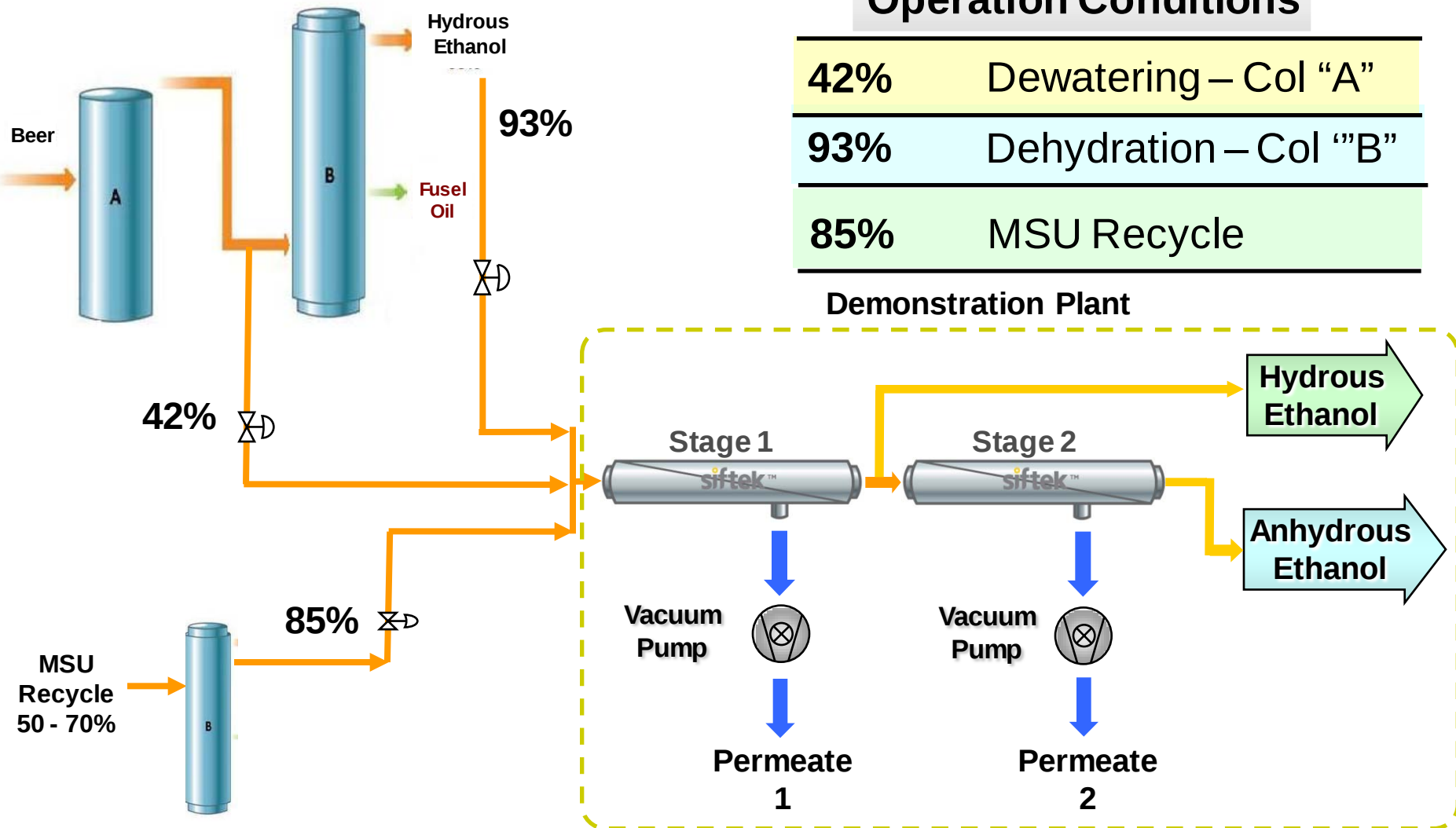
# Chatham Field Demonstration Unit

## Results



# DEDINI Demonstration Unit - Brazil

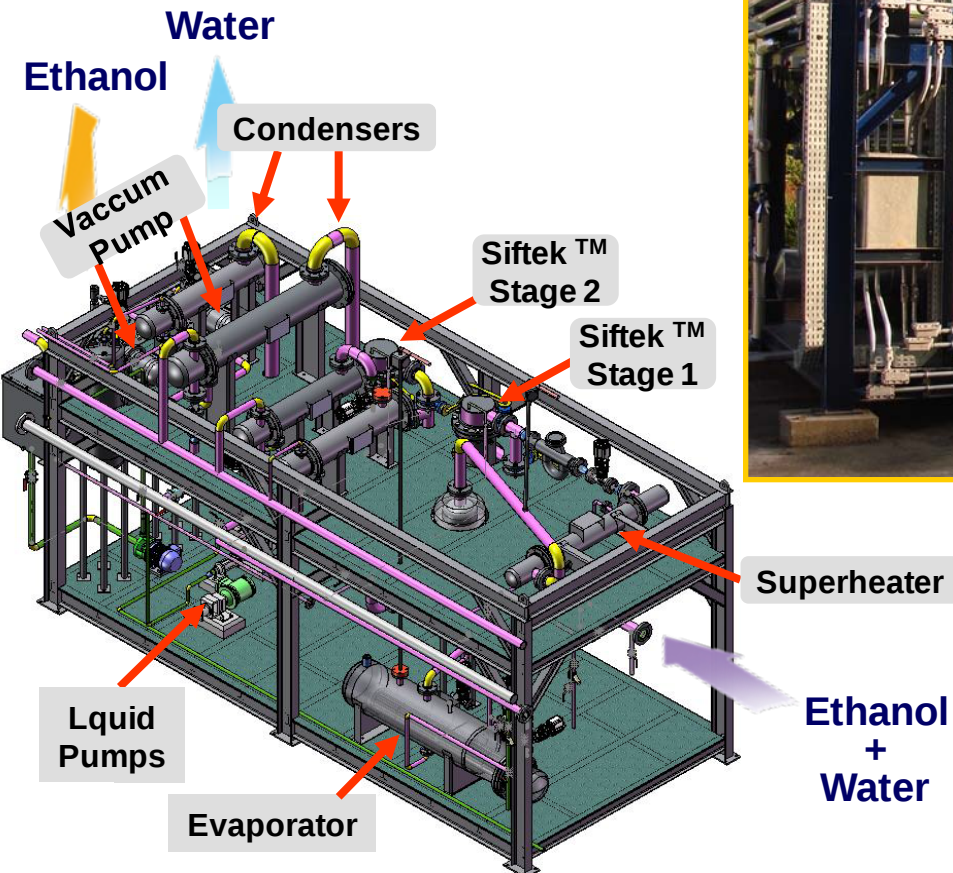
## Process and Operation Conditions



# DEDINI Demonstration Unit - Brazil

## Skid Unit

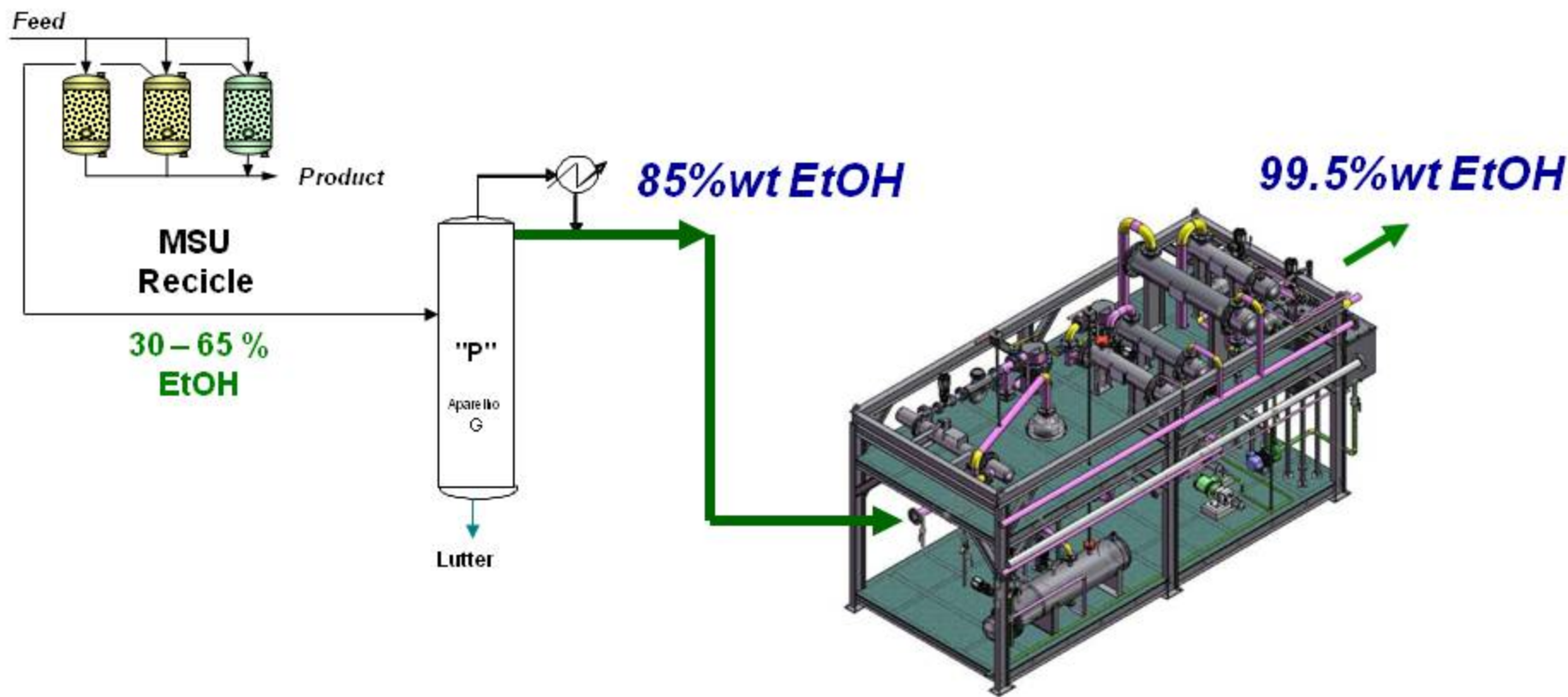
Capacity 4.500 liters/day



Feed Pressure: 160 - 190 kPa  
Temperature: 112 °C  
100 % Automatic

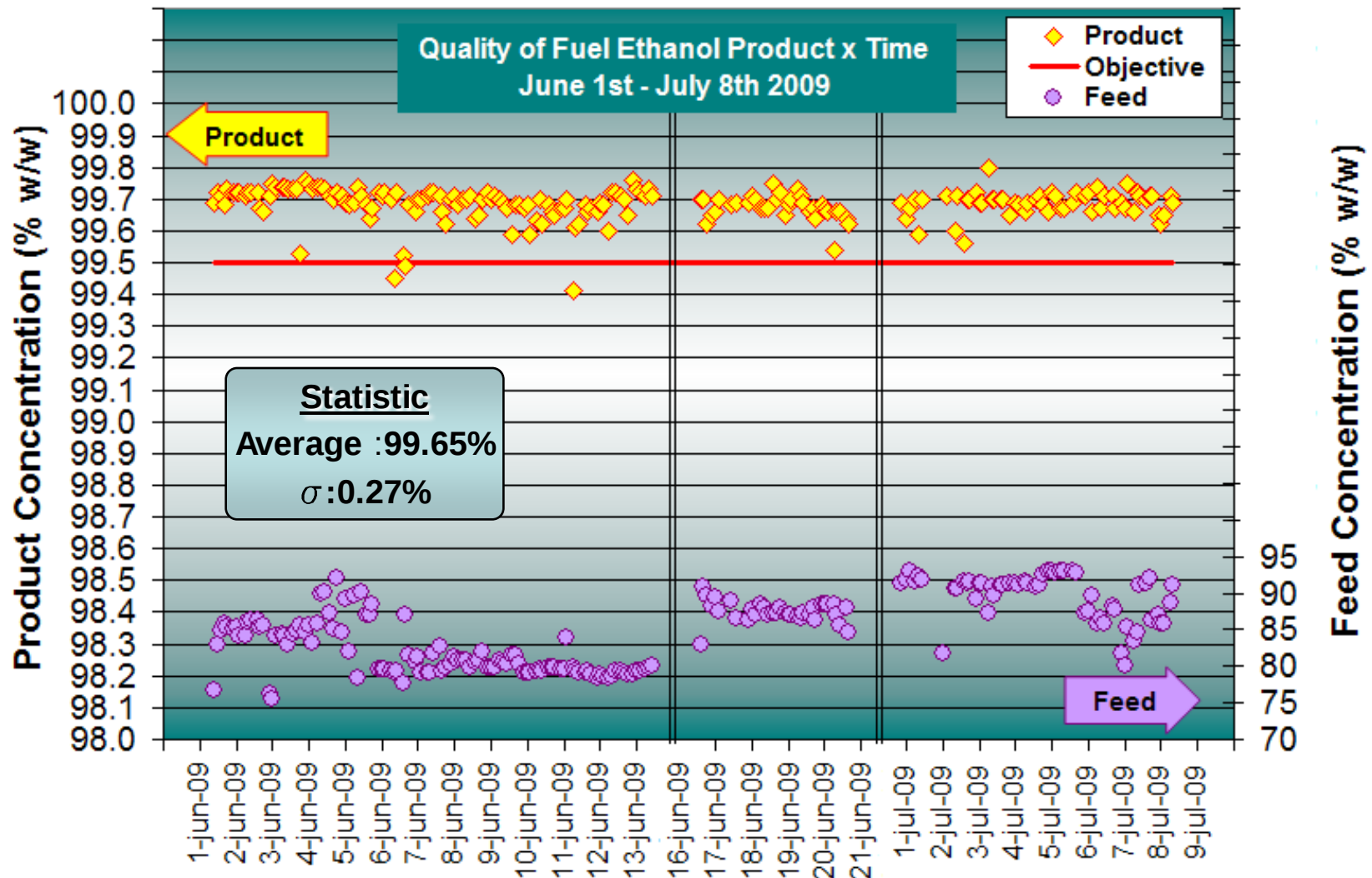
# DEDINI Demonstration Unit - Brazil

## Results Test 1: MSU Recycle (85%) to 99.5% wt EtOH



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Results Test 1: MSU Recycle (85%) to 99.5% wt EtOH

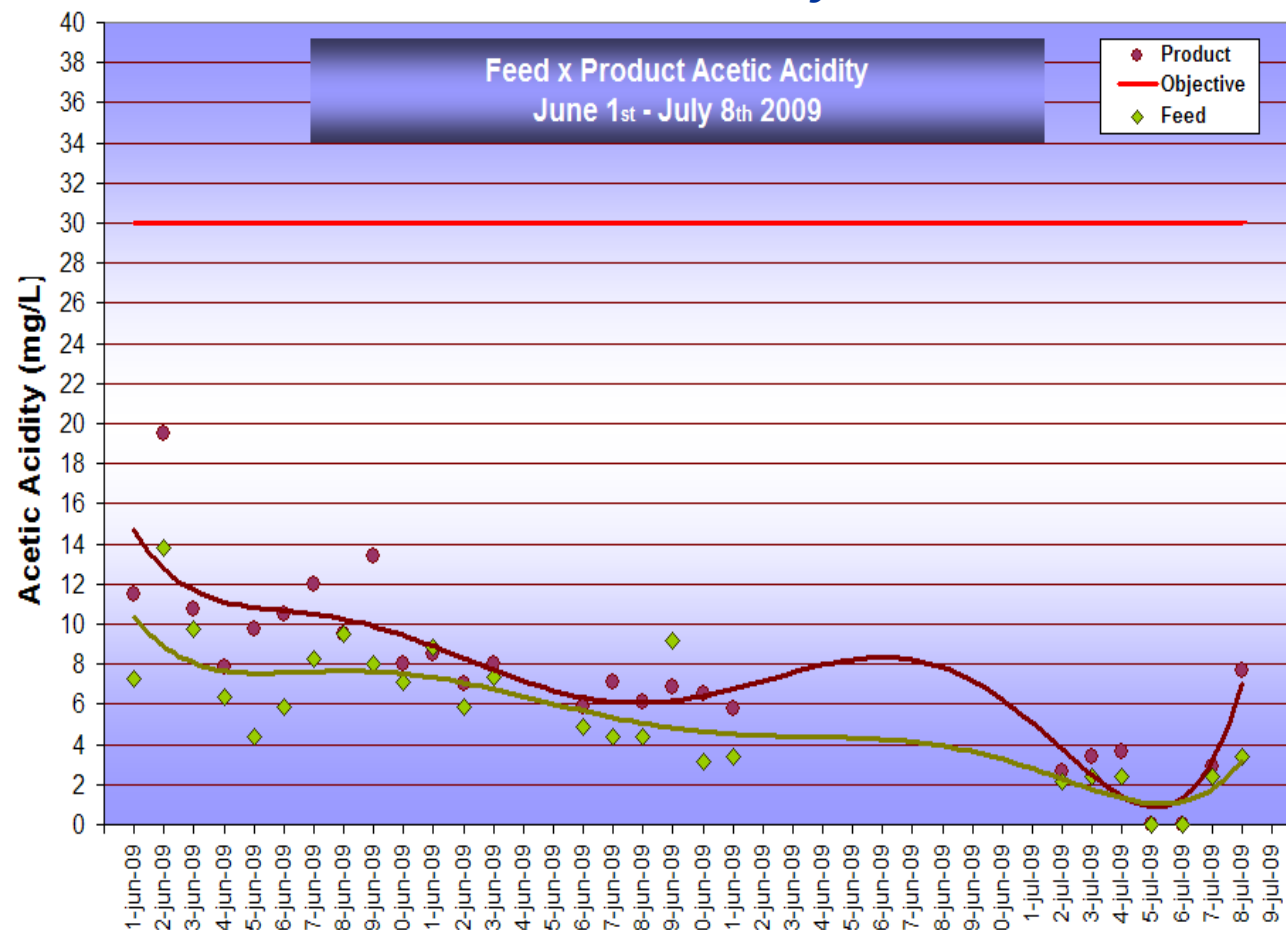


# DEDINI Demonstration Unit - Brazil

Results Test 1: MSU Recycle (85%) to 99.5% wt EtOH



## Acetic Acidity



## FEATURES

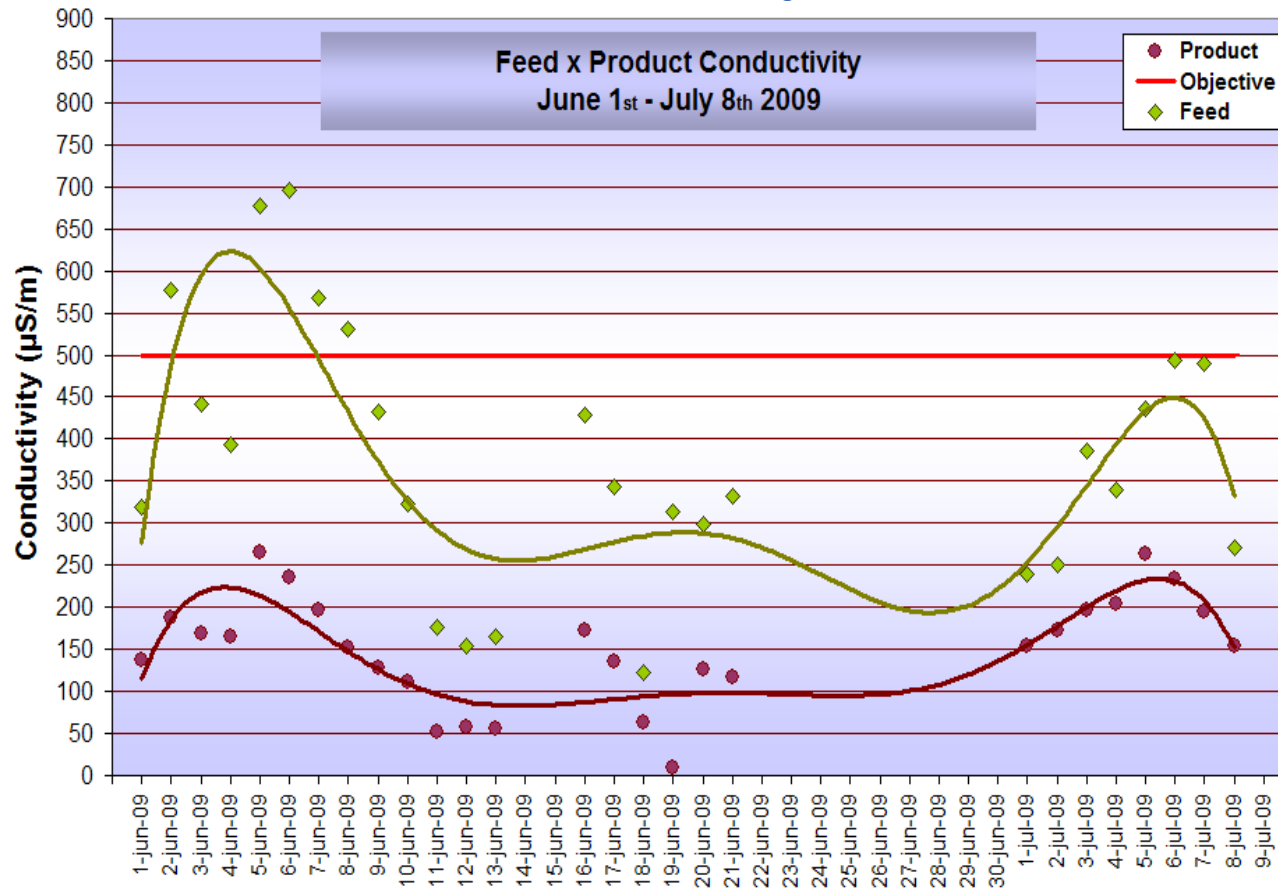
- Increase of 2 mg/l (lower than specification)
- Water removal and organics concentration
- Organics stay in the product
- High water selectivity

# DEDINI Demonstration Unit - Brazil

Results Test 1: MSU Recycle (85%) to 99.5% wt EtOH



## Conductivity

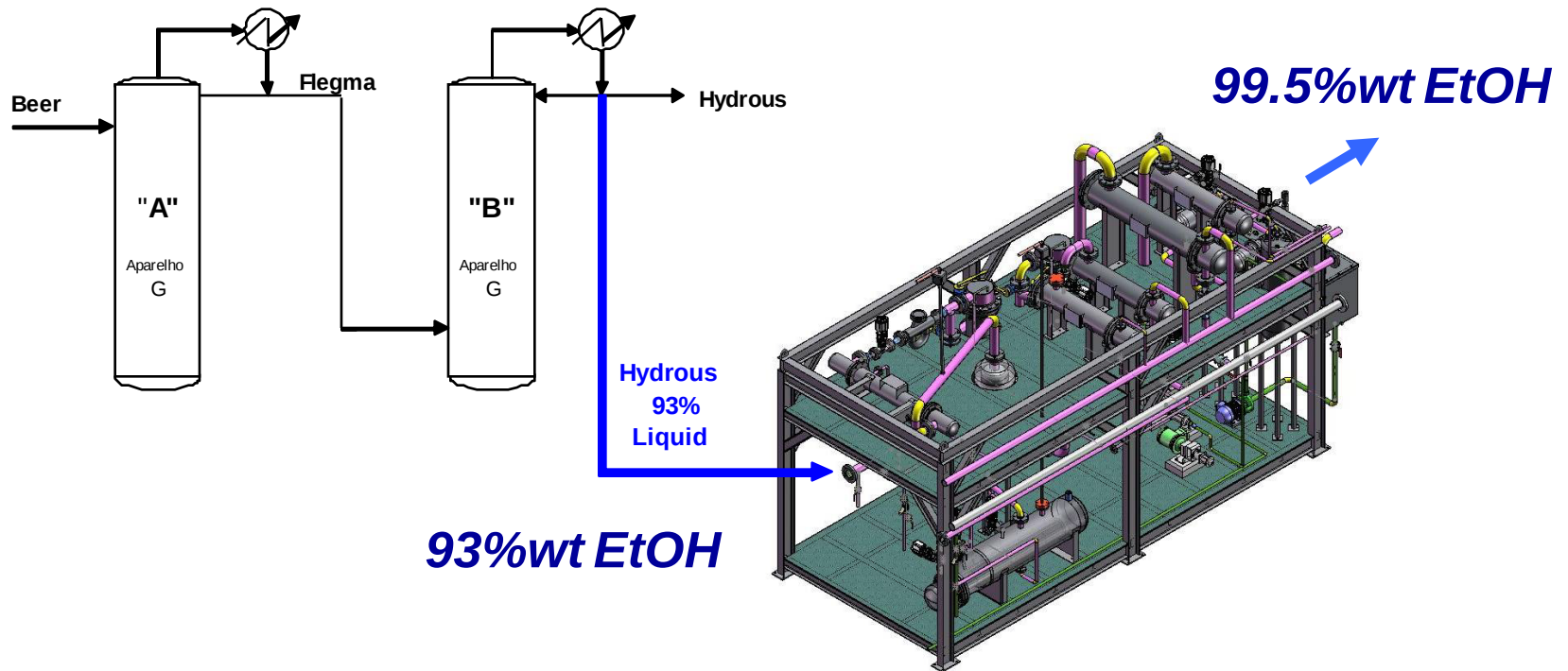


## FEATURES

- Water (+ dissolved salts) removed
- Reducing of 55%
- Help to reach the specification

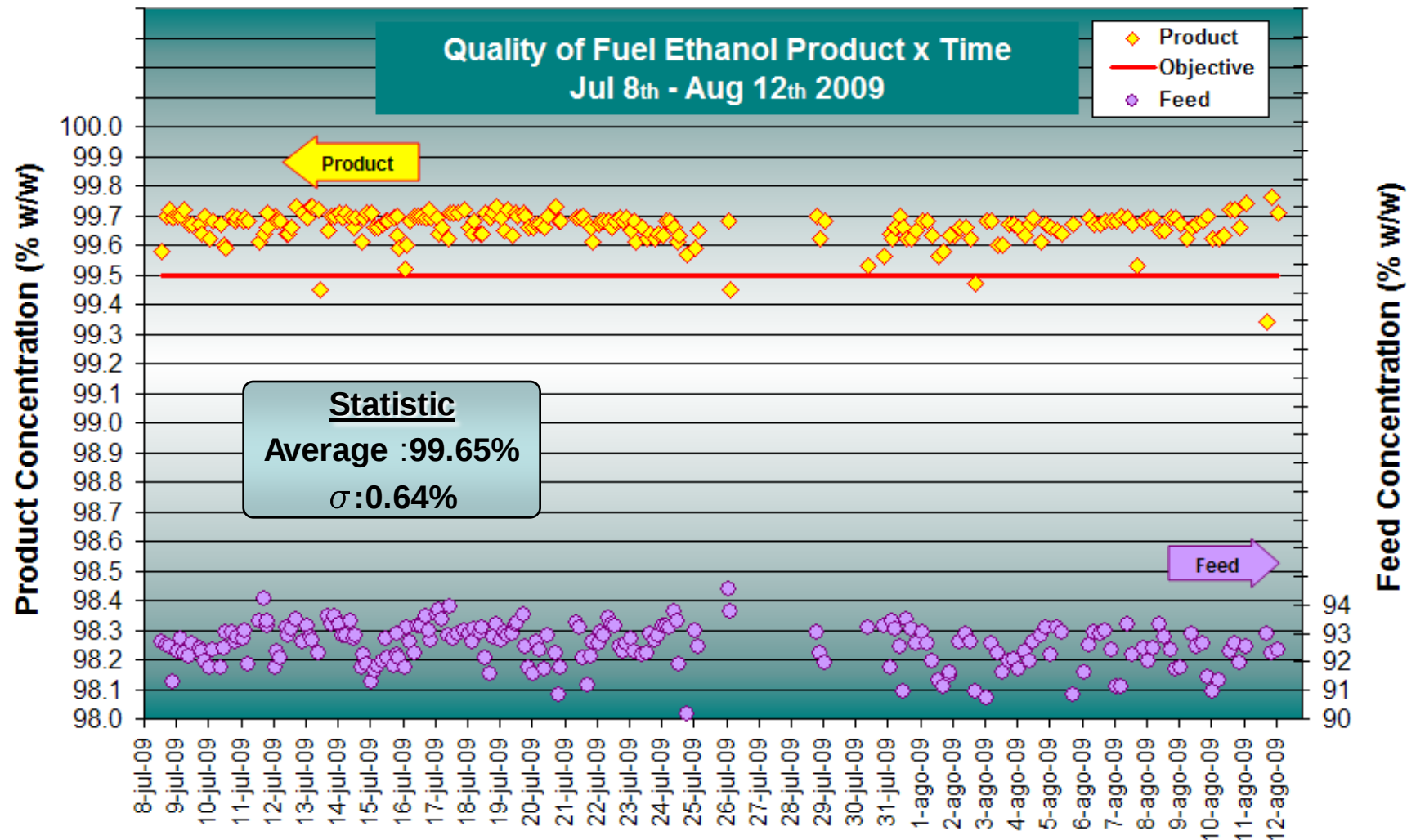
# DEDINI Demonstration Unit - Brazil

## Results Test 2: Hydrous (93% to 99.5% wt)



# DEDINI Demonstration Unit - Brazil

Results Test 2: Hydrous (93% to 99.5% wt)

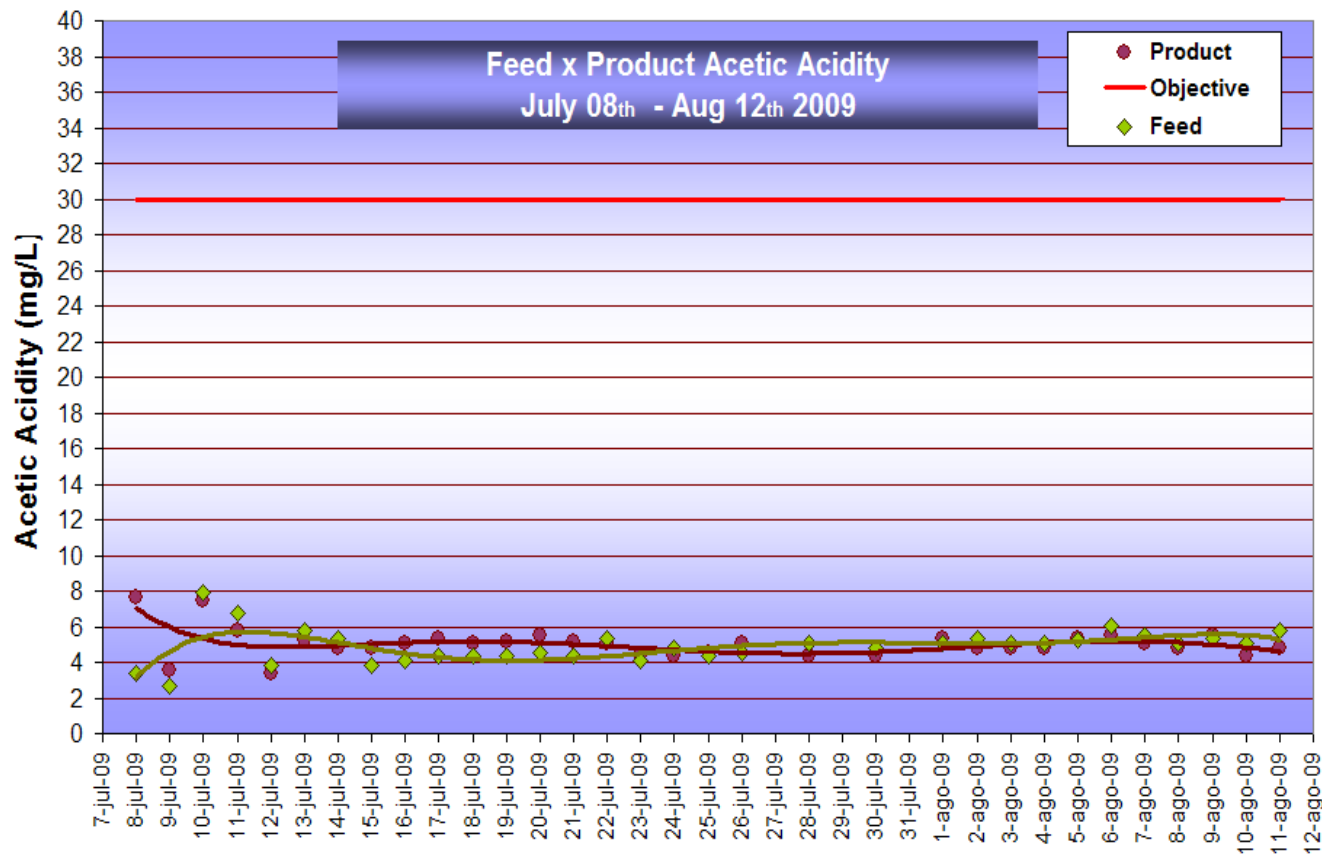


# DEDINI Demonstration Unit - Brazil

Results Test 2: Hydrous (93% to 99.5% wt)



## Acetic Acidity



## FEATURES

- No change
- Became lower than specification
- High water selectivity

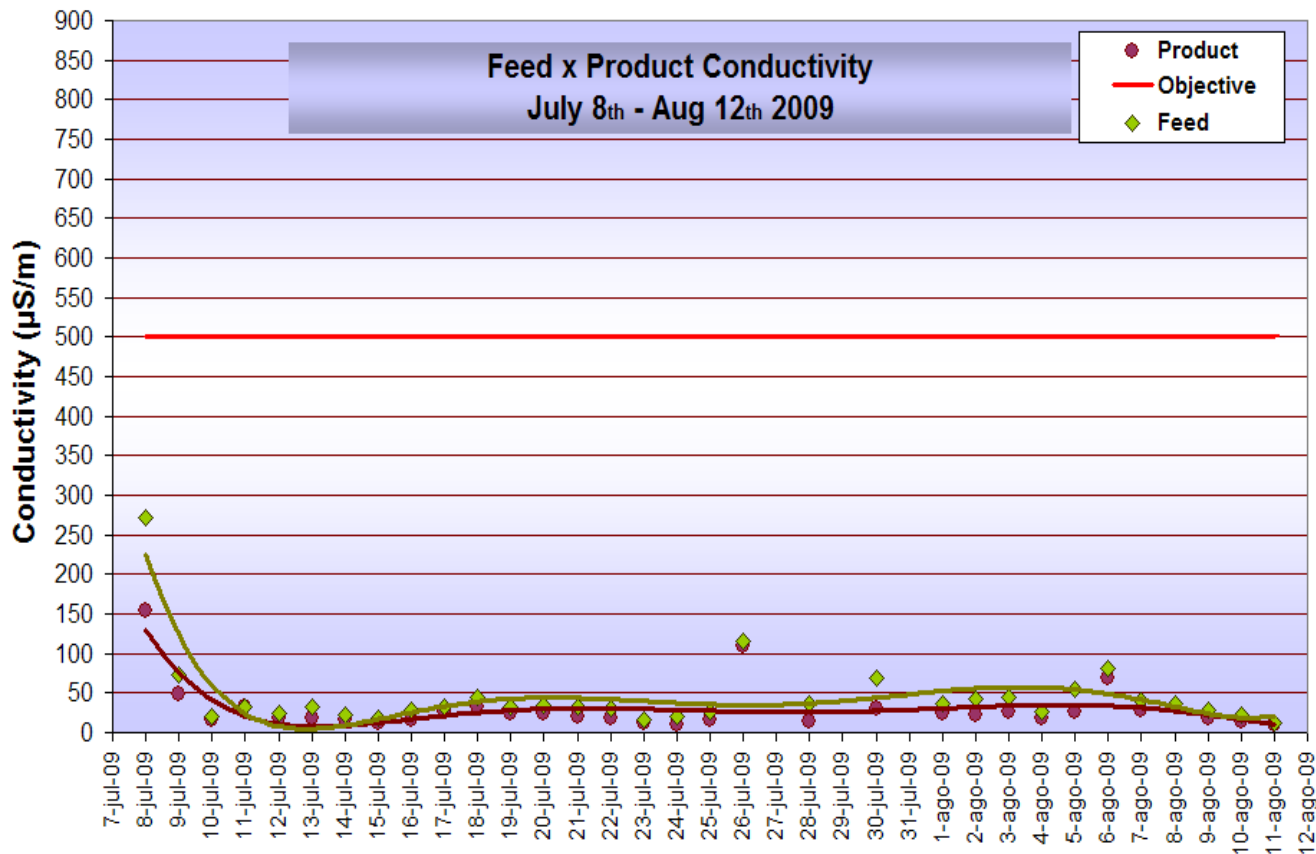
# DEDINI Demonstration Unit - Brazil

## Results Test 2: Hydrous (93% to 99.5% wt)

### Conductivity

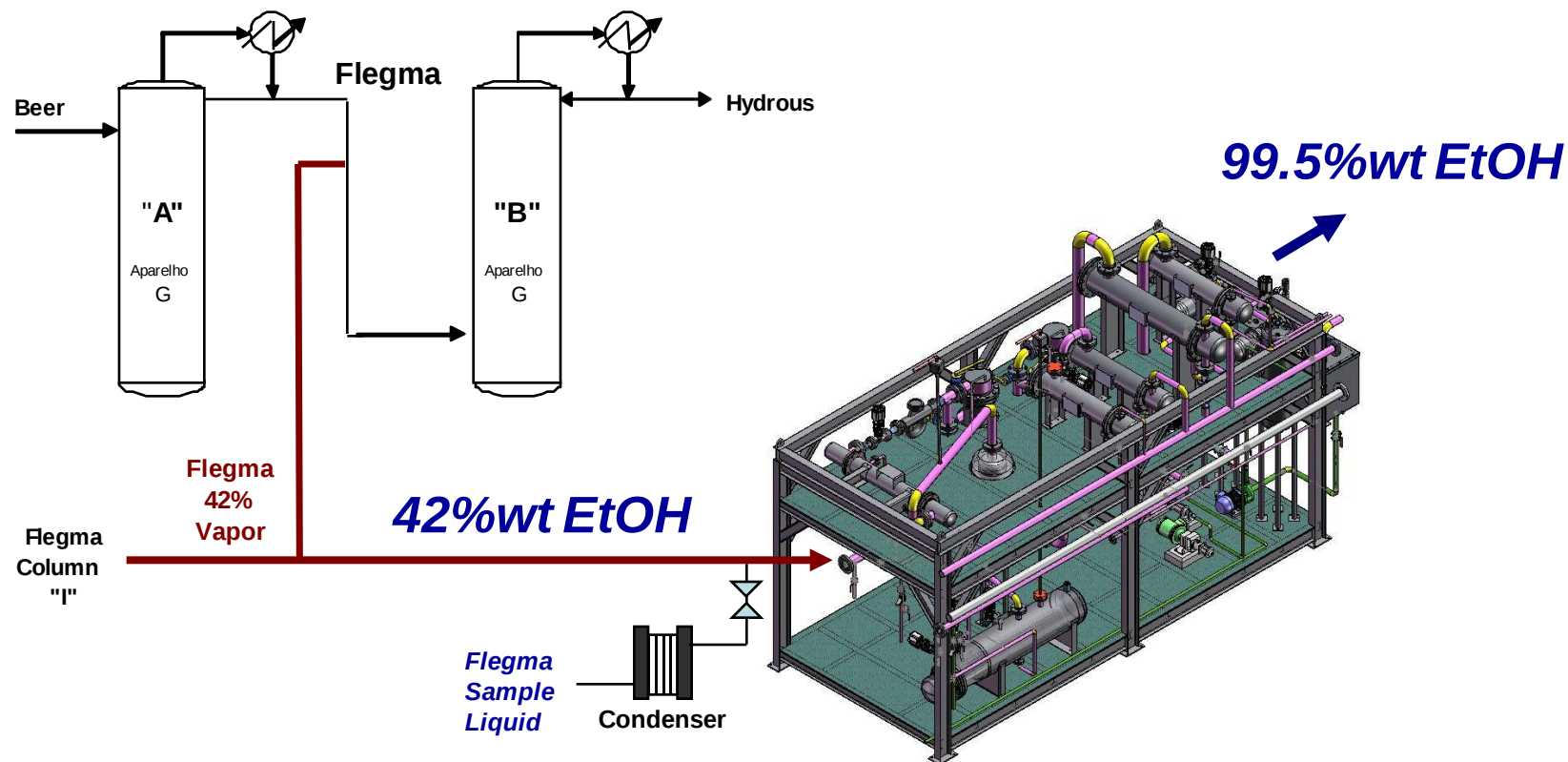
### FEATURES

- No change
- Lower than specification



# DEDINI Demonstration Unit - Brazil

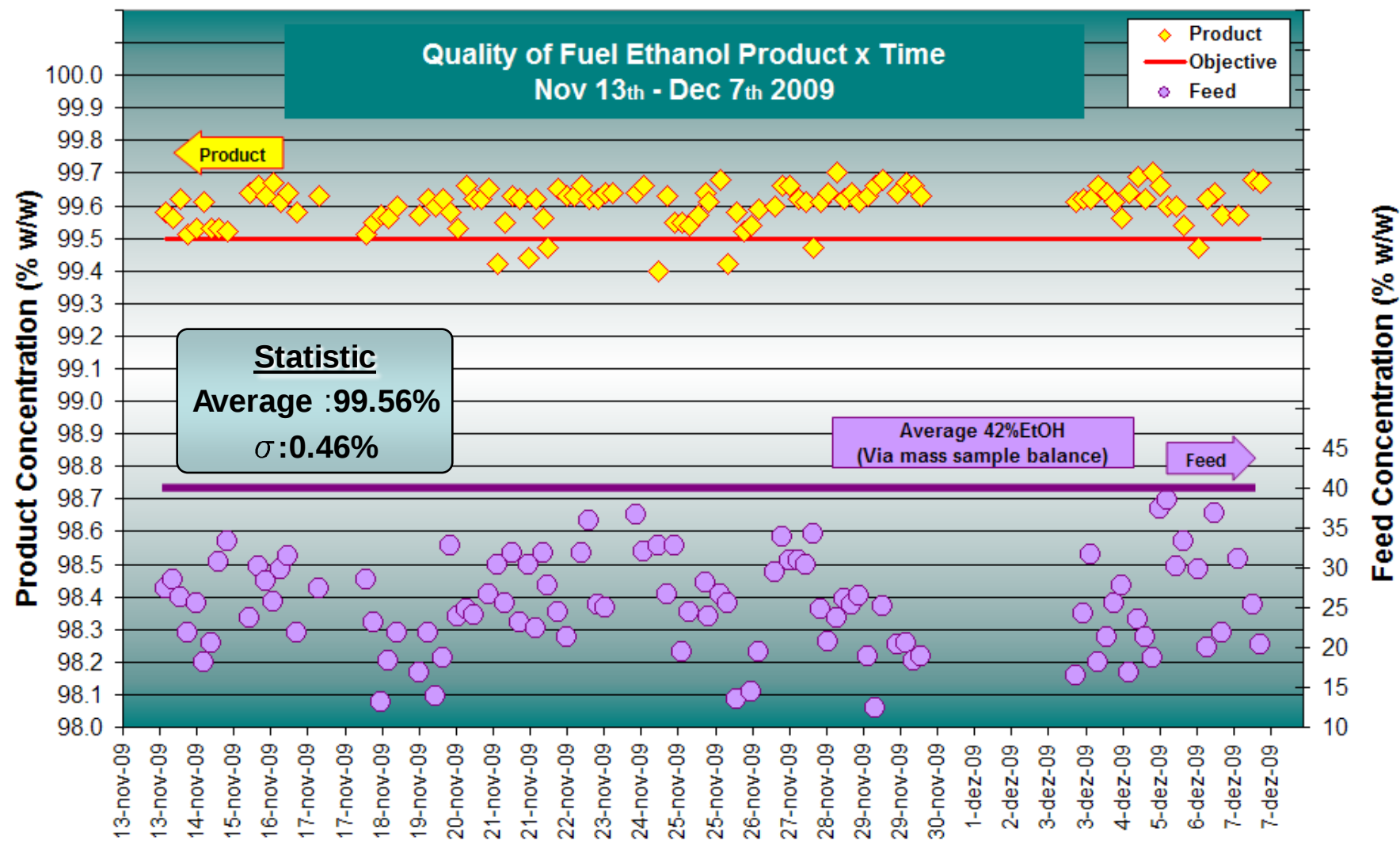
Results Test 3: Flegma "A" Column (42%) to 99.5% wt EtOH



➤ The feed sample was condensated to be analyzed, but because of partial condensation this values was not thrust. Then product and permeate samples were collected and a mass balance done. Was fond 42% EtOH in the feed.

# DEDINI Demonstration Unit - Brazil

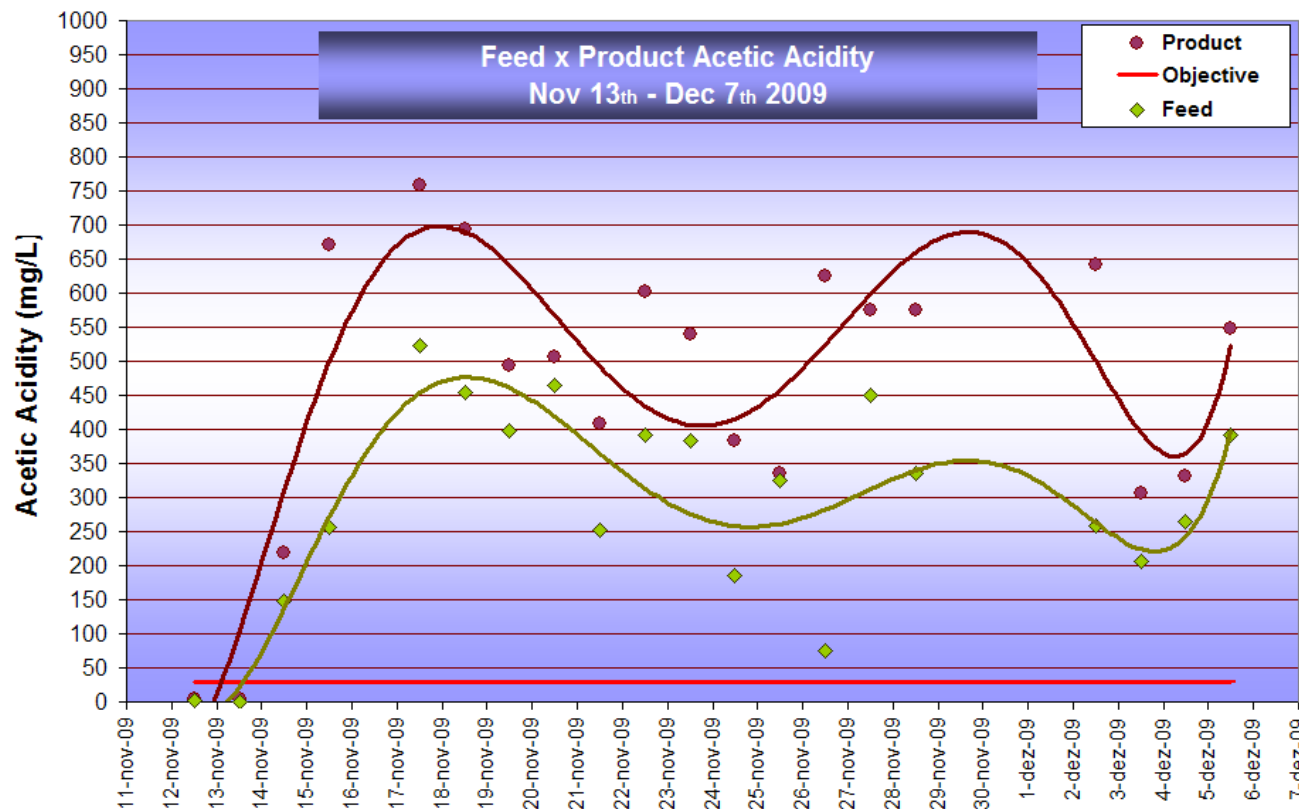
Results Test 3: Flegma "A" Column (42%) to 99.5% wt EtOH



# DEDINI Demonstration Unit - Brazil

Results Test 3: Flegma "A" Column (42%) to 99.5% wt EtOH

## Acetic Acidity



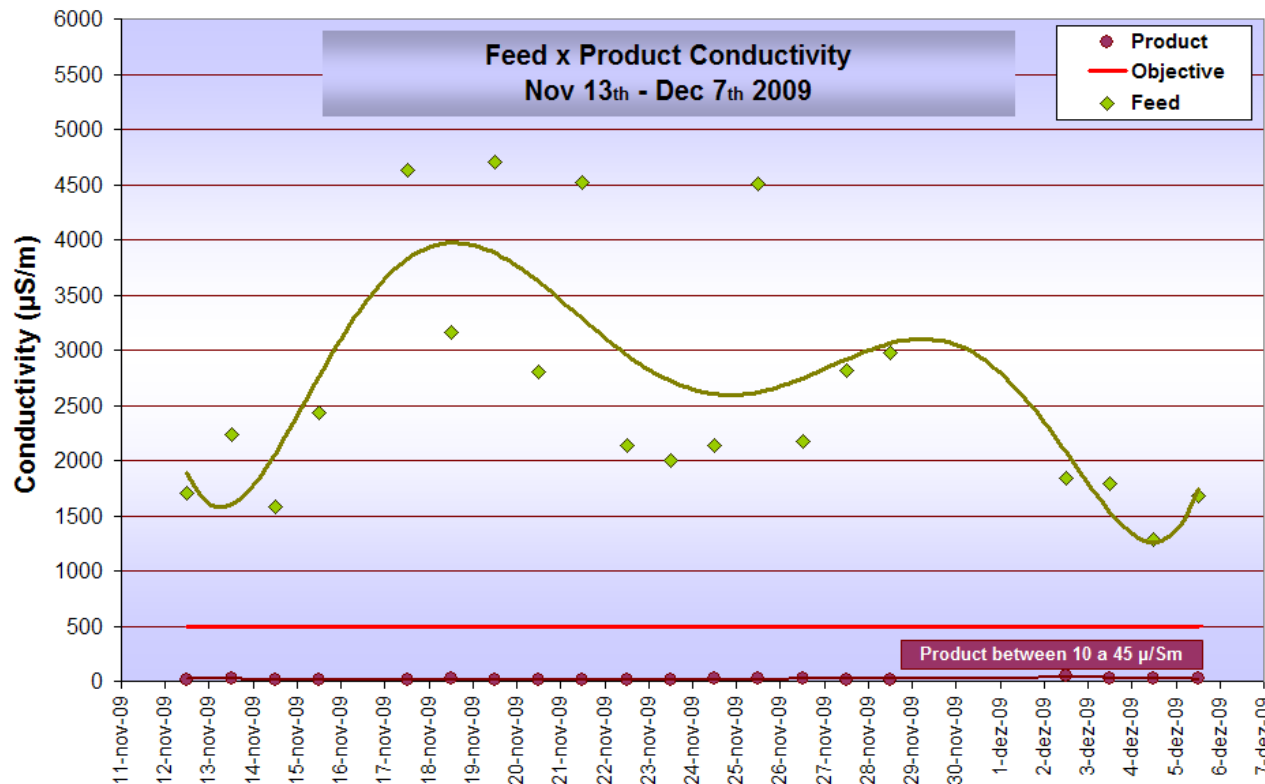
## FEATURES

- Feed Acidity is high
- A lot water removed
- Increase Acidity
- Organics stay in the product
- High water selectivity
- Acidity usually is corrected in the reservoir tank

# DEDINI Demonstration Unit - Brazil

## Results Test 3: Flegma "A" Column (42%) to 99.5% wt EtOH

### Conductivity

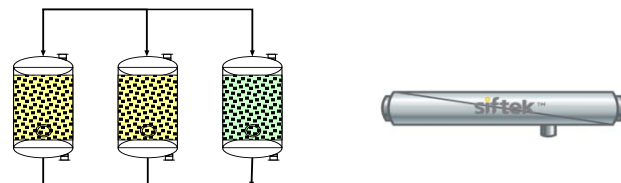


### FEATURES

- A lot water (+ dissolved salts) removed
- Drastic reducing
- Help the specification

# DEDINI Demonstration Unit - Brazil

## Color Aspects: Test 2 (93% - 99.5%wt EtOH)



**Feed**

**Product**



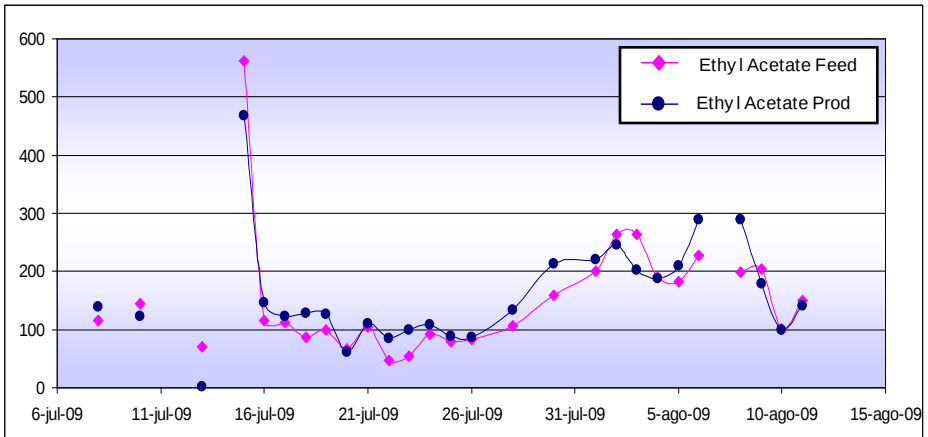
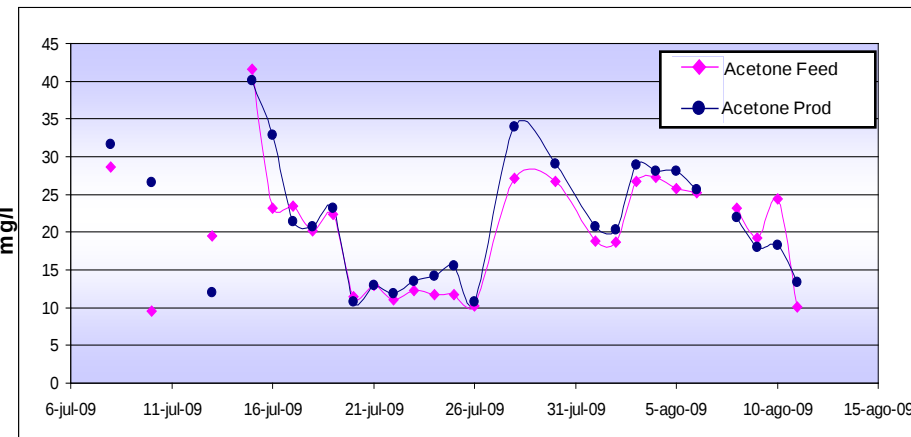
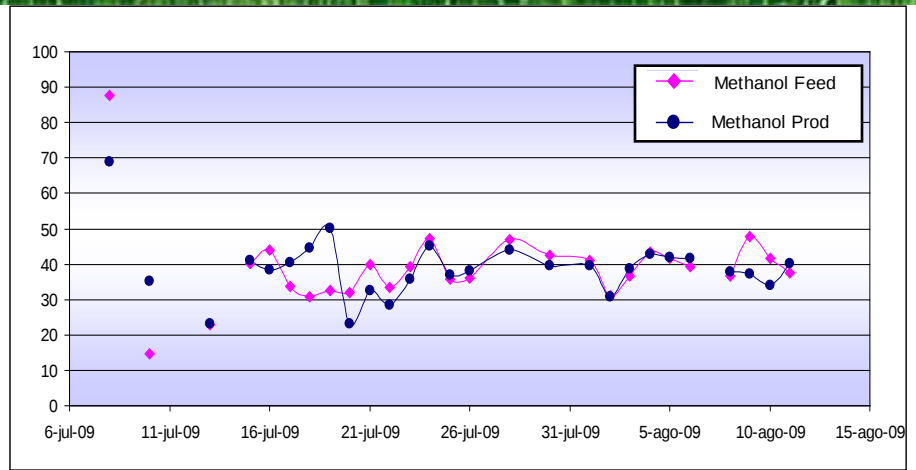
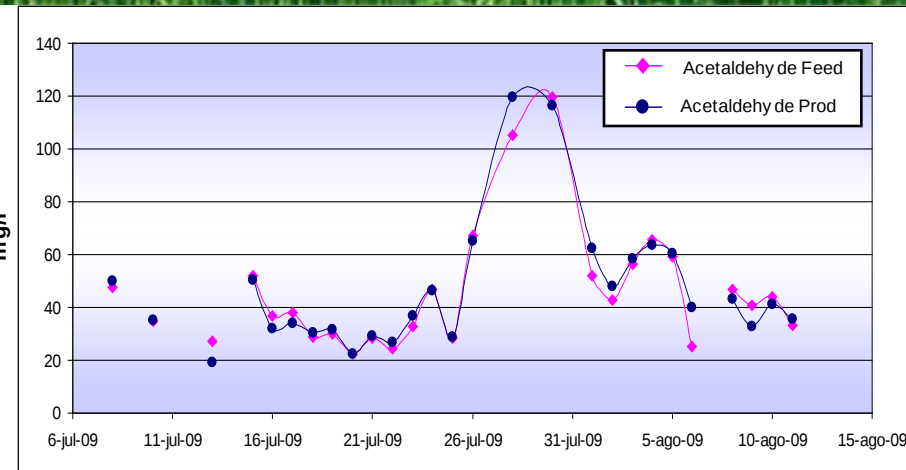
**Product  
MSU**

**Product  
Siftek**

**No Color Change**

# DEDINI Demonstration Unit - Brazil

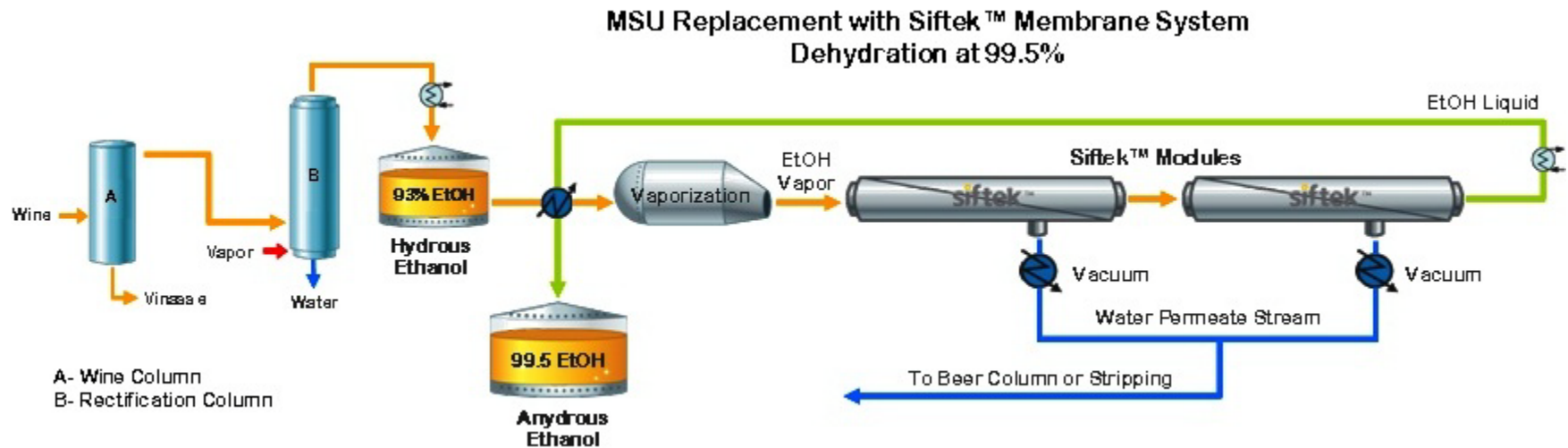
## Chromatograph Results: Test 2 (93% to 99.5%wt EtOH)



- Organics stay in the product
- High water selectivity

# Application of the Membrane Technology

## Dehydration Plant



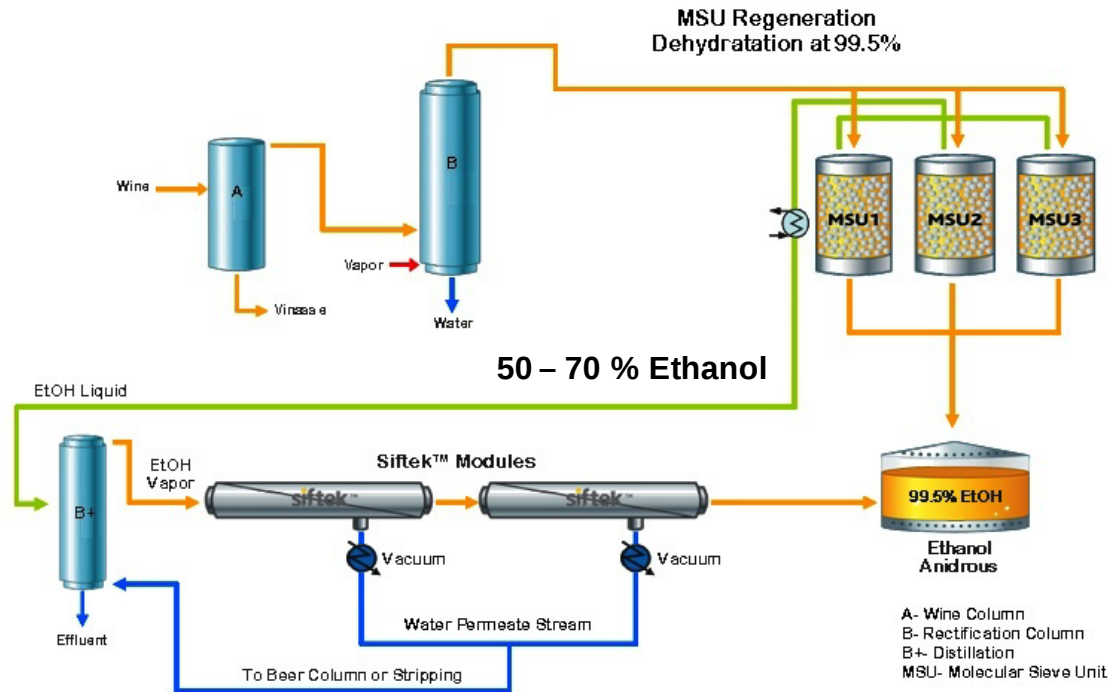
|                      | Cyclohexane | Molecular Sieve | Siftek™ Membrane |
|----------------------|-------------|-----------------|------------------|
| Steam (kg/L ethanol) | 1.55        | 0.65            | 0.41             |

Save 70%

Save 35%

# Application of the Membrane Technology

## Treatment of the MSU Recycle Stream



**Increase Capacity**  
**20%**

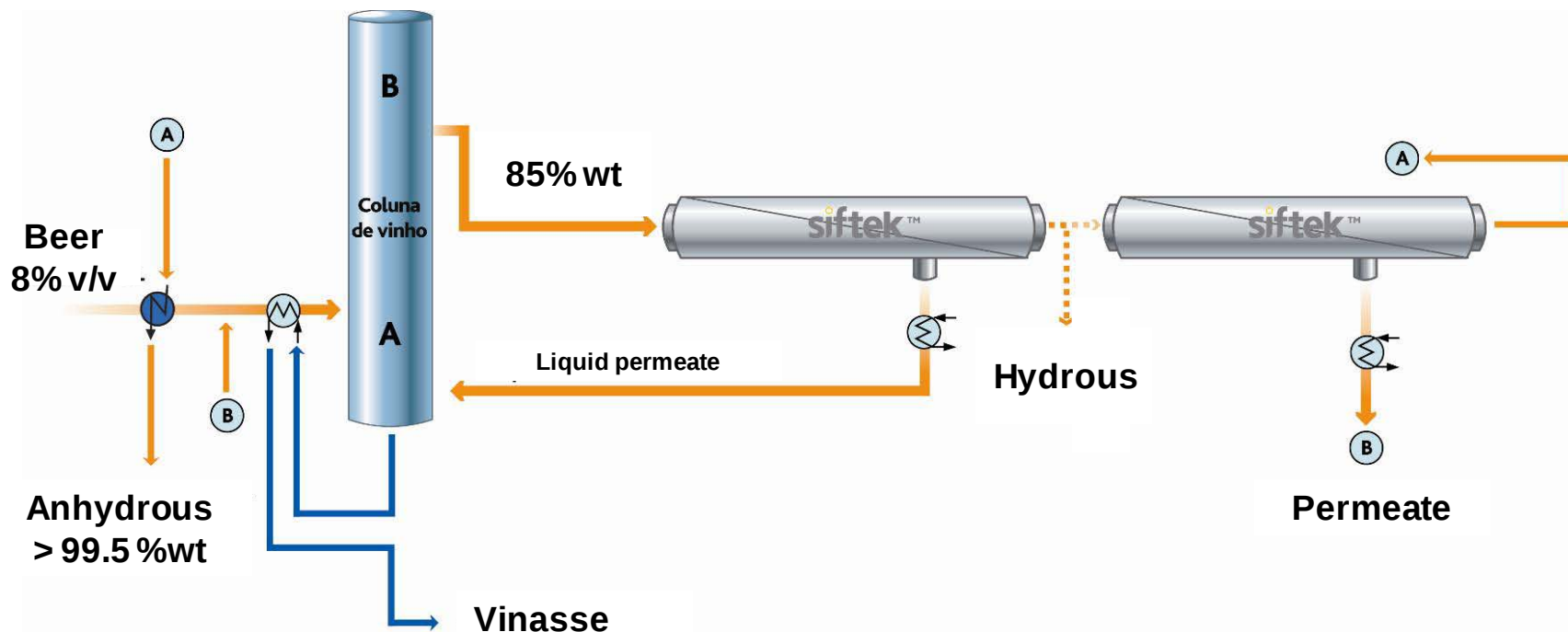
500 → 600 m<sup>3</sup>/day

600 → 720 m<sup>3</sup>/day

|                                   | Molecular Sieve | Siftek™ Membrane      |
|-----------------------------------|-----------------|-----------------------|
| Steam (kg/l ethanol)              | 0.65            | 0.55                  |
| Electricity (kWh/L)               | 0.007           | 0.007                 |
| Additional Electricity Generation |                 | 24 kWh/m <sup>3</sup> |

# Application of the Membrane Technology

## *MSU Recycle + Partial B Column Replacement*



|                                   | Distillation & MSU | Siftek™ Membrane        |
|-----------------------------------|--------------------|-------------------------|
| Steam (kg/l ethanol)              | 3.4                | 1.9                     |
| Electricity (kWh/L)               | 0.0078             | 0.014                   |
| Additional Electricity Generation |                    | 60.4 kWh/m <sup>3</sup> |

# Conclusion

## *Demonstration Results*

- The results showed a high membrane performance in water removal, **producing ethanol in a continuous process** with concentration higher than **99.5 wt% ethanol**.
- The Dedini system showed a high **stability in quality product** ethanol > 99.5wt% ethanol, with a system flexibility to **assimilate variation in the feed concentration** (test 1).
- The acidity and conductivity became lower then the needed parameters.
- The Siftek™ has **high selectivity of water over ethanol**, with benefits of no contamination in the product.
- **Recirculation of ethanol is minimized.**
- The product has the **same quality** as the one from MSU.

# Conclusion

## *Industrial Application*

- **Additional revenue** with energy **co-generation**;
- **Green House Gases reduction** and potential to carbon credits generation;
- **Continuous Process**;
- **Flexible and modular system** that allow **Hydrous and Anhydrous** production;
- **Several application:**
  - **New Plants:** Dehydration plant annex the distillery.
  - **Existent Plants: Capacity Increase** by dehydration of **molecular sieve recycle** or hydrous from B Column.
  - Molecular Sieve replacement.
  - Cyclohexane replacement.



# *Thank You!*

## ***Ethanol Dehydration System by Siftek Polymeric Membrane***

### **CONTACT**

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