Novel Ethanol-Water Separation by SpaCeR™ **S**hort **P**ath **C**ondensation **R**ecovery Operational Update

WIA PRESENTATION – BOSTON – ALAN RAE, ROSHAN JACHUCK

September 2011

Rensselaer Technology Park, 405 Jordan Road, Troy, NY-12180   www.r3fusion.com

Previously…

- We introduced the SpaCeR ™ technology at the Dayton WIA meeting
- We were just installing the first commercial system at an ethanol plant in Western New York
- We had pilot but not commercial operating experience
- We couldn't talk much about it as our patent hadn't been published

January 2010

Pilot

January 2011

Full Scale Fabrication

March 2011

Installation – Ethanol Recovery

THE TECHNOLOGY

Short **Pa**th **C**ondensat**e** **R**ecovery

SPaCeR™

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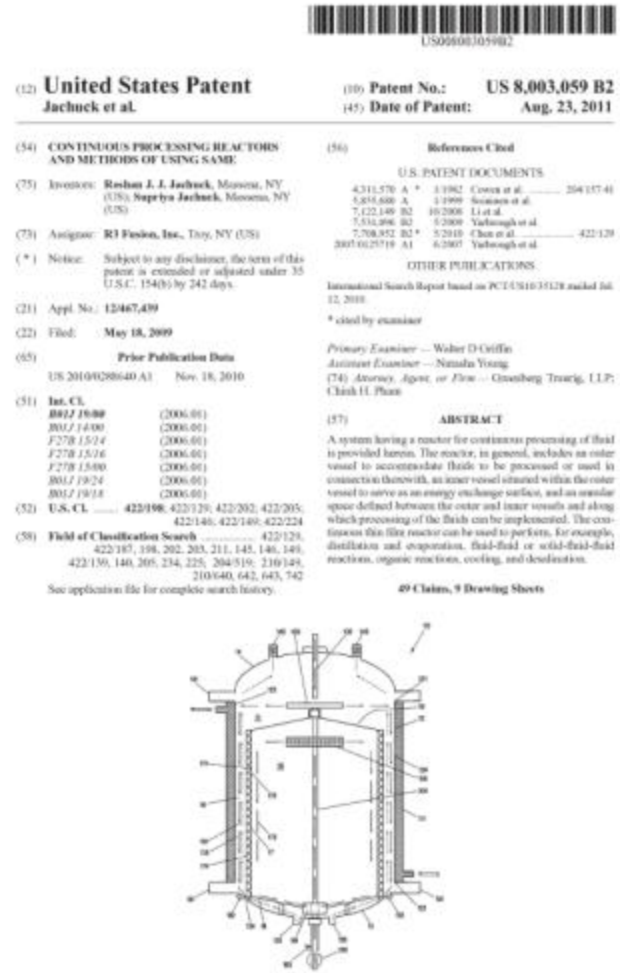
- 50 gpm Unit Installed
  - Running continuously
  - Meeting objectives
- Patent Granted
- New Initiatives
  - Li Brine
  - Completion fluids
  - Frac water



(12) **United States Patent**
Jachuck et al.

(10) **Patent No.:** **US 8,003,059 B2**
(45) **Date of Patent:** **Aug. 23, 2011**

(54) **CONTINUOUS PROCESSING REACTORS AND METHODS OF USING SAME**

(75) Inventors: **Roshan J. J. Jachuck**, Massena, NY (US); **Supriya Jachuck**, Massena, NY (US)

(73) Assignee: **R3 Fusion, Inc.**, Troy, NY (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 242 days.

(21) Appl. No.: **12/467,439**

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(51) **Int. Cl.**

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B01J 14/00	(2006.01)
F27B 15/14	(2006.01)
F27B 15/16	(2006.01)
F27B 15/00	(2006.01)
B01J 19/24	(2006.01)
B01J 19/18	(2006.01)

(52) **U.S. Cl.** **422/198**; 422/129; 422/202; 422/205; 422/146; 422/149; 422/224

(58) **Field of Classification Search** 422/129, 422/187, 198, 202, 203, 211, 145, 146, 149, 422/139, 140, 205, 234, 225; 204/519; 210/149, 210/640, 642, 643, 742

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

4,311,570 A *	1/1982	Cowan et al.	....	204/157.41
5,855,600 A	1/1999	Sciamanna et al.		
7,122,149 B2	10/2006	Li et al.		
7,531,096 B2	5/2009	Yarbrough et al.		
7,708,952 B2 *	5/2010	Chen et al.	....	422/129
2007/0125719 A1	6/2007	Yarbrough et al.		

OTHER PUBLICATIONS

International Search Report based on PCT/US10/35128 mailed Jul. 12, 2010.

* cited by examiner

Primary Examiner — Walter D Griffin
Assistant Examiner — Natasha Young
(74) *Attorney, Agent, or Firm* — Greenberg Traurig, LLP; Chinh H. Pham

(57) **ABSTRACT**

A system having a reactor for continuous processing of fluid is provided herein. The reactor, in general, includes an outer vessel to accommodate fluids to be processed or used in connection therewith, an inner vessel situated within the outer vessel to serve as an energy exchange surface, and an annular space defined between the outer and inner vessels and along which processing of the fluids can be implemented. The continuous thin film reactor can be used to perform, for example, distillation and evaporation, fluid-fluid or solid-fluid-fluid reactions, organic reactions, cooling, and desalination.

49 Claims, 9 Drawing Sheets

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Technique	Challenge
Distillation	Energy cost
Bed treatment	Volume, disposal, regeneration, flexibility
Reverse osmosis	Fouling, energy cost
Biological	Volume, speed, flexibility

Our question – how could we design a simple and robust system that combined

- Low energy consumption (preferably using waste heat)
- Compact footprint
- Ease of use
- Ionic / nonpolar / organic / inorganic compatibility

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We Like Distillation - <u>But</u>

•Distillation is a low thermal efficiency unit operation that currently consumes 4.8 quadrillion BTUs of energy—40% of the processing energy used in refining and continuous chemical processes.

•The multiphase gas/liquid flow patterns in distillation columns are complex, making them difficult to predict and control.

•Lack of understanding of the mass transfer and flow dynamics occurring between phases inside these devices is the primary barrier to improving their energy and process efficiencies.

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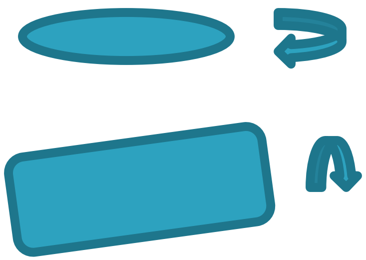
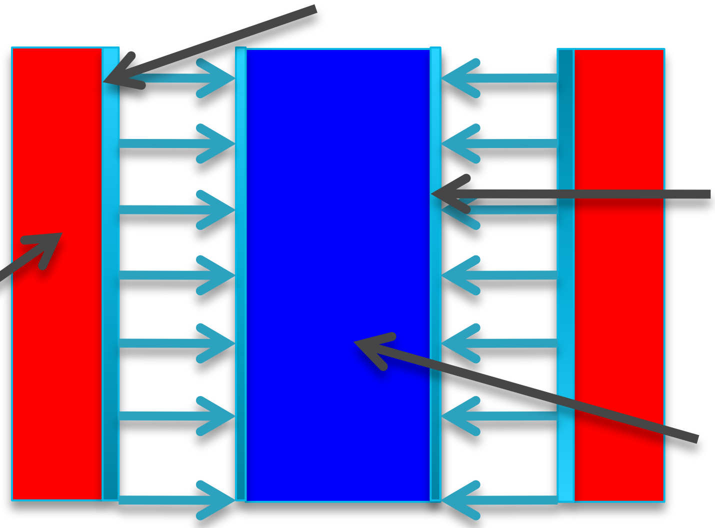
Process Intensification

- Using ultra thin films of liquid for highly effective processing
  - Gas-liquid
  - Liquid-liquid
- Reactive thin films can be generated in a number of ways
  - Spinning discs, rotating cylinders
    - Effective but can be mechanically challenging
  - The new SPaCeR configuration
    - Novel but mechanically simple and robust construction



Dr. Roshan Jachuck

SPaCeR™



•Negligible vapor pressure build-up – due to short condensation path length

•Thin film heat transfer on evaporation & condensation surfaces gives a high heat transfer coefficient

•Unique distribution system for maintaining the thin film on both the heating and cooling side allows uniform temperature distribution and minimizes scaling

•High surface area density due to the use of tailored / profiled heat transfer surface and jacket design; heat transfer material can be tailored to enhance chemical resistance

•High thermal conductivity material with thin sections used for reducing the resistance offered by the heat transfer surface.

•Vacuum capability to achieve high overall heat transfer coefficient.

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Comparison to Other Technologies

Description	Distillation	Reverse osmosis	SPaCeR
Energy kWh/m^3	17	5	<5
Energy source	Heat	Electrical pumps	Flexible
Maintenance	High	Moderate	Low
Water TDS mg/l	0.5-50	50-500	50
Modularity	No	Yes	Yes
Best application	Seawater / cogen / industrial	Flexible	Flexible
Cost ratio	1.9X	1.8X	1X (desalination)

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TARGET MARKET - ETHANOL YIELD ENHANCEMENT

Ethanol plants utilize millions of gallons of water to clean their carbon dioxide by-product (waste scrubber water) which contains~ 1-4% ethanol.

Separating water/ethanol from the scrubber water is a significant and valuable yield enhancement for each and every ethanol plant in the world.

12 billion gallons of ethanol in the US = 6 billion gallons of scrubber water at 4% average ethanol or 240 million gal ($500 MM + accessible market.

Recovery of Ethanol from Scrubber Water

Scrubber water contains between 1% and 4% ethanol by volume. Research has demonstrated that not all ethanol is reclaimed when the scrubber water is recycled through the plant.

Lost Ethanol is Lost $$

•**Overall ethanol flow through CO_2 scrubber bottoms** (for a 50 MM gal per year plant) can be as much as 120 Gal/hr or about 1.1 MM Gal per year. At $2.50 per gallon estimated value of ethanol that is lost is in excess of $2.5 MM per year.

•**Cook water tank bacteria** could consume as much as 48 Gal/hr. This means about $1MM worth of ethanol will not be shipped per year.

•Ethanol **recycled through Cook Water Tank** – Even if this ethanol is not consumed or burned, ethanol recycled through cook water tank (hence displacing slurry make-up) can be as much as 72 Gal/hr worth more than $1.5 MM per (1 full fermenter per year)

•Loss through **slurry tank venting** is about 2.5 Gal/hr, about $50,000 per year.

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PROMISE vs. PERFORMANCE

PROMISE VS. PERFORMANCE

Commissioning Issues

- Piping
- Pumps
- Sensors
- Software
- NO issues with the evaporation modules

Performance

- Ethanol yield as predicted @50gpm
- Energy use as predicted (uses plant waste heat)
- Electricity <5kW

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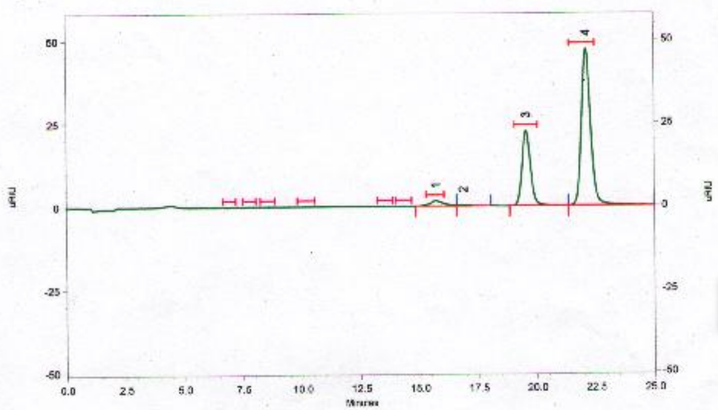
Installed Performance

Scrubber Water Ethanol Concentration.

Fermentation Product Analysis

Sample ID: SA L.C
File Name: C:\Class-VP\Enterprise\Projects\HPLC\Data\MAY11\SA L.C5-23-2011 6-31-40 PM.dat
Method: C:\Class-VP\Enterprise\Projects\HPLC\Method\Fermenter.met
Acquired: 5/23/2011 6:34:12 PM Vial#: 14 Injected Vol.: 50



RID-10A Results

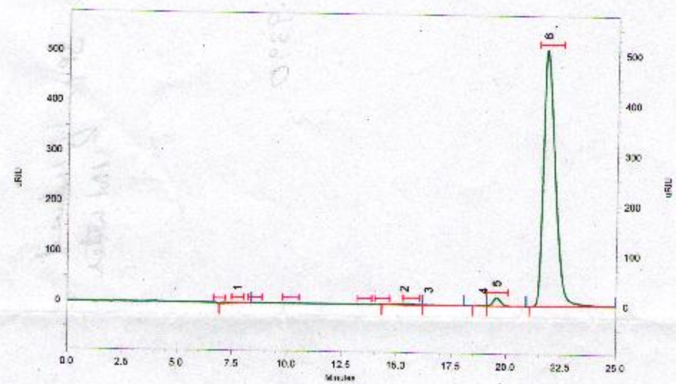
Pk #	Name	Ret. Time	Area	Conc.	Units
	DP4+			0.00 BDL	Wt%
	DP3			0.00 BDL	Wt%
	Maltose			0.00 BDL	Wt%
	Glucose			0.00 BDL	Wt%
	Lactic Acid			0.00 BDL	Wt%
	Glycerol			0.00 BDL	Wt%
1	Acetic Acid	15.71	66404	0.09	Wt%
3	Methanol (System)	19.56	565684	1.17	Wt%
4	Ethanol	22.12	1283663	2.03	Wt%
Totals			1915751	3.29	

Ethanol 2.03 wt%

Ethanol Concentration from SPaCeR

Fermentation Product Analysis

Sample ID: R3 FUSION 1400
File Name: C:\Class-VP\Enterprise\Projects\HPLC\Data\MAY11\R3 FUSION 14005-31-2011 2-12-34 PM.dat
Method: C:\Class-VP\Enterprise\Projects\HPLC\Method\Fermenter.met
Acquired: 5/31/2011 2:15:07 PM Vial#: 5 Injected Vol.: 50



RID-10A Results

Pk #	Name	Ret. Time	Area	Conc.	Units
	DP4+			0.00 BDL	Wt%
1	DP3	7.77	109079	0.07	Wt%
	Maltose			0.00 BDL	Wt%
	Glucose			0.00 BDL	Wt%
	Lactic Acid			0.00 BDL	Wt%
	Glycerol			0.00 BDL	Wt%
2	Acetic Acid	15.35	113341	0.16	Wt%
5	Methanol (System)	19.57	403589	0.83	Wt%
6	Ethanol	21.78	19311017	30.66	Wt%
Totals			19937026	31.72	

Ethanol 30.66

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Client Fulfillment

Business challenge – ethanol plants have limited ongoing capital budgets.

Our business Model is NOT to sell equipment but to provide systems on-site in exchange for share of value creation or cost avoidance.

Partnerships outside the United States & Canada will provide base monthly lease payments to incentivize partners plus percentage of profits.

This model can work for other markets also.

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Other Markets

There are significant markets where a robust containerized / trailerable water purification method is attractive

(www.wikimapia.com)

Removal of water from product

- **Li brines**

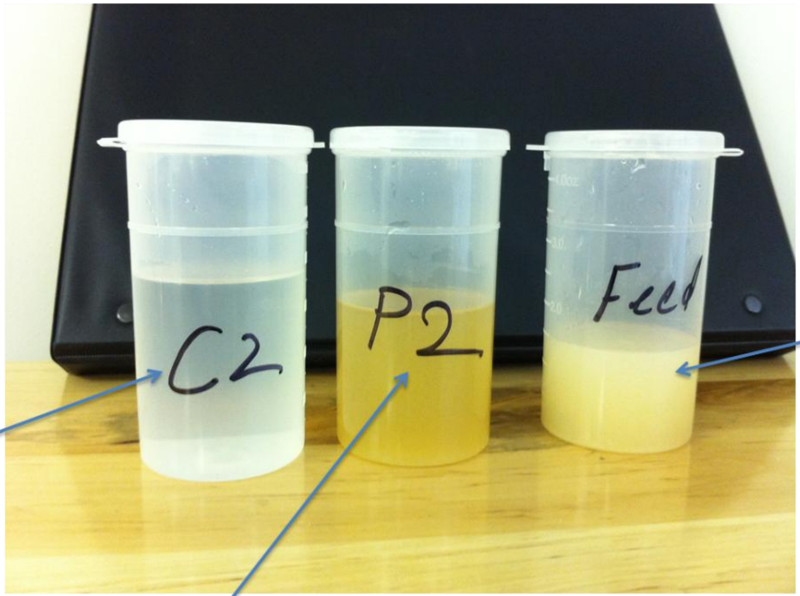
Removal of impurities from water

- **Oil and gas E&P**
- **Brackish / salt water**
- **Food processing**
- **Industrial cleaning residues**

ENERGY MARKETS: Frac Water, Slop Water, Completion Fluids, Produced Water

APPLICATION

Completion Fluids Trial
Zinc Bromide



Recovered Water

Product

Feed

Frac water remediation ~ $700 MM annually

Marcellus shale alone estimated at 7 billion gallons per year of water @ $4 per barrel ($0.10 per gallon)

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In Summary

We have a new water purification process with significant operational advantages over existing technologies.

We have operated the process successfully at industrial scale on ethanol separation from water.

We have demonstrated it at lab/pilot scale on brines, oilfield fluids and industrial wastes.

Next steps – deployment in the ethanol industry, development for other industries

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THANK YOU

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