Advancing Emulsion Product Performance

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Overview

- **Velocys Technology**
  - Enabling a new process environment
- **Application to Emulsions**
  - Creating a product advantage
- **Example: Hand Lotion**
  - Tailoring properties
- **Summary**

Velocys Introduction

Formed in 2001 as a spin-out from Battelle Memorial Institute

Commercializing technology developed at Pacific Northwest National Laboratory in mid-1990s

Over $70 million invested to date

Established alliances with partners:

- **chemical producers**
- **engineering and construction**
- **equipment manufacturing**

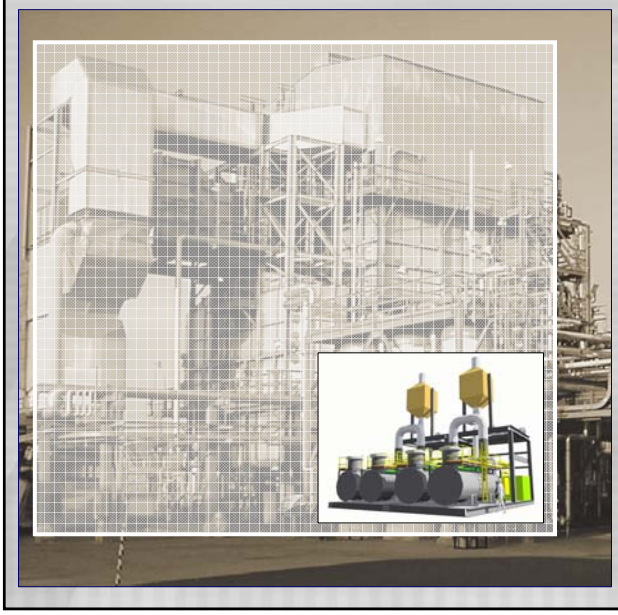
Integrated Steam Reformer for Hydrogen Production

Conventional Reactors

Conventional Technology

- Steam Methane Reformer
- 20 million standard cubic feet/day
- ~30m x ~30m x ~30m

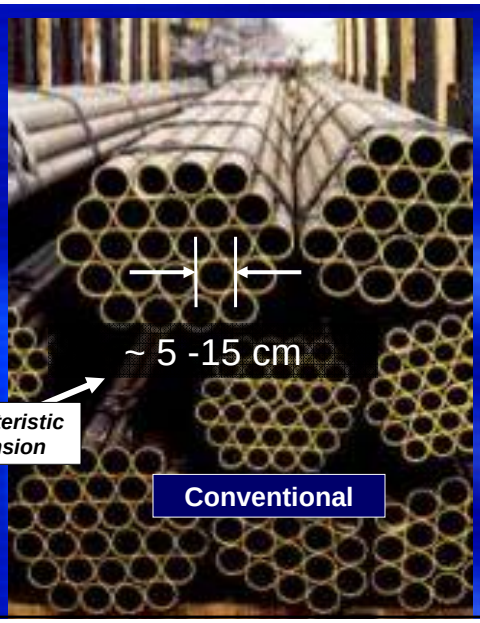
Velocys® Technology Reactors



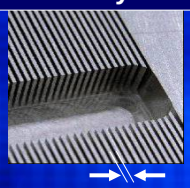
- Microchannel Steam Methane Reformer
- Same capacity
- 90% volume reduction
- ~25% reduction in overall plant costs

Technology Review

Microchannel vs Conventional Process Technology



Velocys



~ 0.1- 1 mm

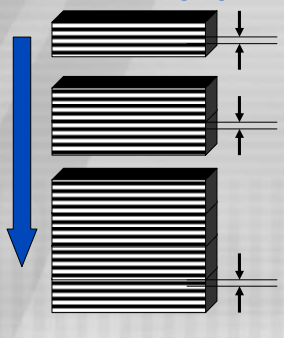
Characteristic dimension

Velocys Minimizes Time to Commercialization

Scalable process

- Velocys designs and builds massively parallel systems
- Expertise and intellectual property for flow distribution, manifolding and fabrication
- Opportunity for rapid screening formulation development, with uniform parallel processing of multiple formulations.

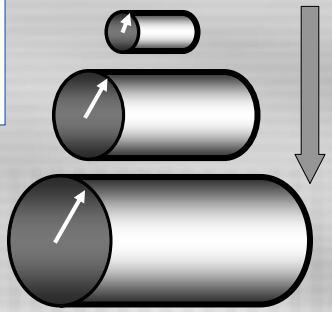
Numbering up



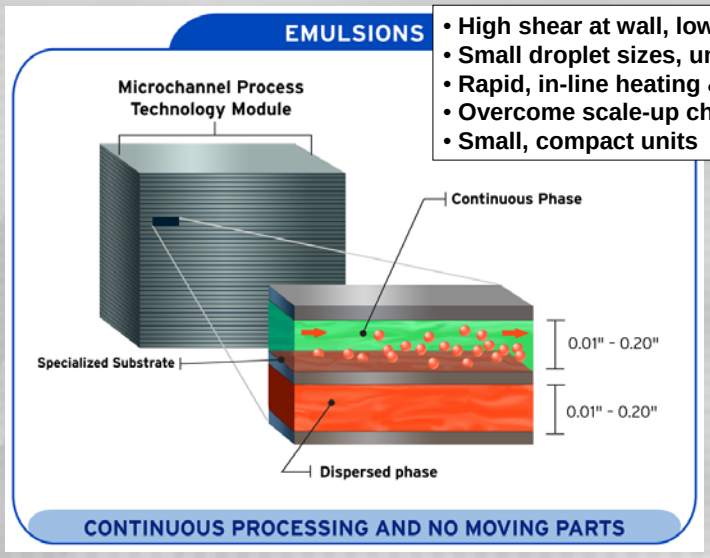
- Reduced distance for mass and energy transport
- >Surface/Volume

Velocys critical dimensions remain constant

Scale up

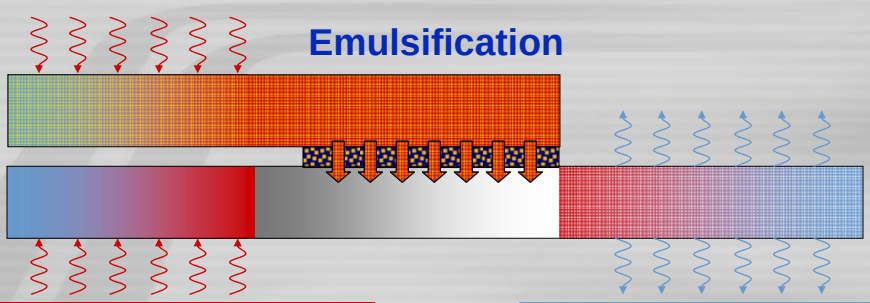


Application to Emulsions



- **High shear at wall, lower shear in bulk**
- **Small droplet sizes, uniform distribution**
- **Rapid, in-line heating & cooling**
- **Overcome scale-up challenges**
- **Small, compact units**

Integrated Heating & Cooling



Gentle Heating

- Small gradient from channel wall
- Maintains ingredient integrity
- Time at temperature minimized

Rapid Cooling

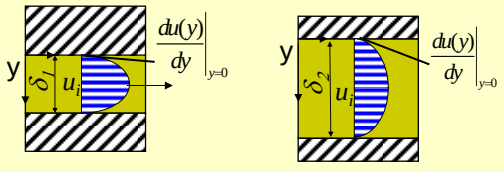
- Preserves emulsion properties
- Enhances stability
- Enables formula optimization

Technology Benchmarks

Technology	Impeller	Rotor/Stator	Velocys-wall	Velocys-bulk
Shear rate range, 1/s	10 -1,000	20,000-100,000	10,000-120,000+	0-5,000

$$\tau_1 = \mu \left.\frac{du(y)}{dy}\right|_{y=0} > \tau_2$$

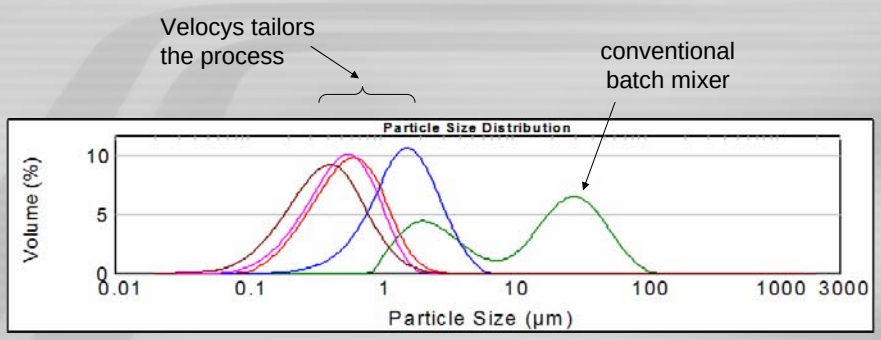
$$when \quad \delta_2 > \delta_1$$



A Few Example Process Benefits

- **Prevent over-shearing emulsion constituents**
  - Improve product formulation
  - Incorporate shear-sensitive ingredients
- **Reduce expensive surfactants**
  - Tailor amount added
- **Use precise control of process conditions**
  - Improve consistency of product
  - Exploit phase boundaries

Example: Hand Lotion



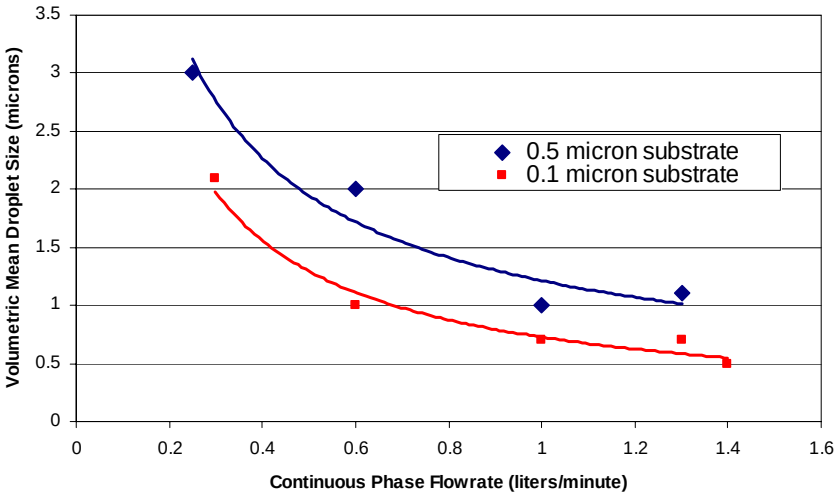
Velocys particle size distribution can be controlled by changing process and equipment parameters.

Hand Lotion Formulation

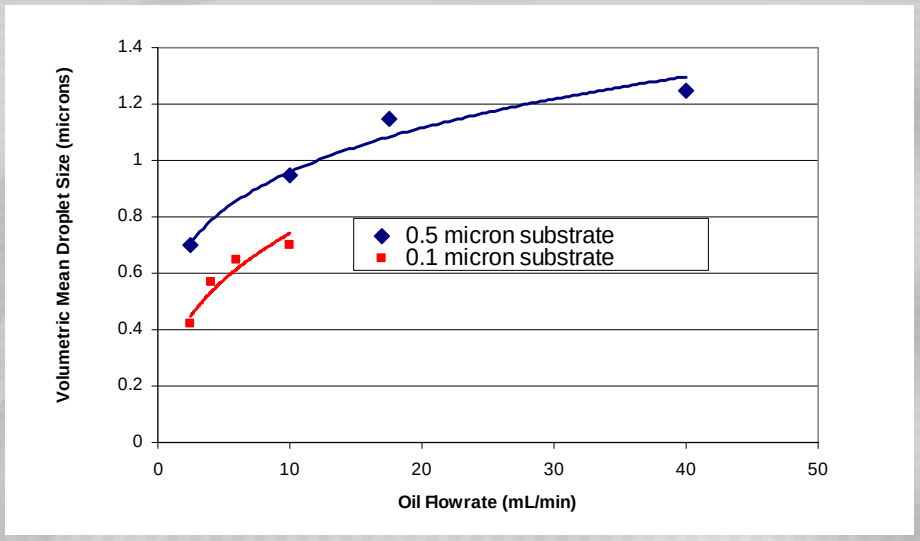
Parts by (Wt.%)	
First Liquid Continuous Phase, Aqueous	
Water	83.0
Carbopol 934	.20
Na2 EDTA	0.05
Glycerine USP	4.0

Discontinuous Phase, Oil	
Stearic Acid	2.00
Cetyl Alcohol	0.50
Glyceryl Monostearate	0.20
Ethylene Glycol Monostearate	0.30
Propylparaben	0.10
Methylparaben	0.20
Mineral Oil	7.00
Silicone Fluid DC200	1.00
Tween 20	0.50
Triethanolamine	0.90

Tailoring Process Conditions



Tailoring Process Conditions, continued



In summary, Velocys emulsion technology can

- **Enable new products / improve product performance**
  - Use novel process environment to achieve new results
- **Provide tight control of process conditions**
  - Exploit possibilities with phase diagrams
  - Standardize process technology
- **Reduce time to deployment**
  - Scale-up by numbering up channels
- **Decrease production cost**
  - Compact equipment
  - Integrate unit operations
  - Apply localized energy
  - Enable distributed production

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