OTM Technology: Process Intensification and Modularization

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Modular might be a solution if...

The technology is inherently small, but it needs to scale larger.

and/or

The process is large, but it practically needs to be smaller.

A strategy of integration and disintegration
### Modular Construction
- Well-known, available option
- Drastic reduction in field costs
- Scale is logistically limited
- Traditional process scaling rules apply
- **Large system → small modules**

### Modular Process
- Replicate over and over
- Massive parallel processing
- Linear process scale-up
- High volume manufacturing scaling rules apply
- **Small modules → large system**

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**Why modular?** Reduced cost and increased flexibility

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What is a “Module”?  

**Integrated Process Units**  
- The “new” technology  
- Smallest unit of process  
- Numbered-up to achieve scale with lower risk  
- Packaged into modules  
- Maximize productivity and manufacturing efficiency

**Modules**  
- Packaged process units  
- Parallel operating unit in process  
- Numbered-up to achieve scale with lower risk  
- **Minimize** number for economy

Modular systems are comprised of process units in modules
The economies of scale.....

This curve always wins in consumer goods
“The right product at the right price”

This curve always wins in the process industry
“The most for the money, period.”

What value for mass production in the process industry?
The economies of scale.....

“New technology” must enable process intensification
- Combine processes
- Eliminate processes
- Smaller boxes
- More productive boxes
- Smarter, less labor input

Integration of process intensified units shifts this curve to the left
Enables economics at smaller scale

Process intensification and mass produce to enable improved economics
OTM – A “New” Technology:

Oxygen Transport Membrane (OTM)

Porous support  Active layers

Oxy-combustion Product

High Pressure Fuel

Electrons

Low Pressure Air

950-1000°C

Pure Oxygen

Oxy-combustion Product

Process Intensification: Solid-state, pure air separation
Ceramic Membrane—Mass Produce 1,000’s for a System

Substrate extrusion → Coating → High temperature firing

Finished Multi-tube Assemblies

Seal assembly
A process intensified, modular process utilizing modular construction
Lessons Learned

Modular Construction

- Size module for low total freight costs
- Maximize fab shop scope, build & check out
- Don’t forget about serviceability / maintenance access

Modular Process

- Drive manufacturing efficiency/volume
- Fault-tolerant parallel units
- Largest module size → reduce parallel trains
- Small plants low risk but always capital cost challenged
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Thank you!