ITN ENERGY SYSTEMS

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Contract: DE-SC0010151

A Cost-Effective Oxygen Separation System Based on Open Gradient Magnetic Field by Polymer Beads

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August 10, 2015

Technology

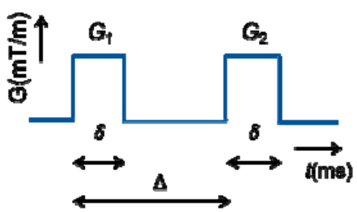
Description

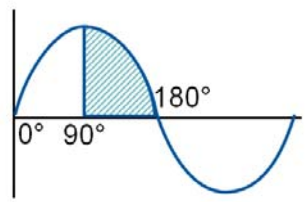
- Cost effective system for oxygen separation from air using a precise application of pulsed magnetic fields under multiple gradients on ambient air flowing through a chamber of polymer coated magnetic beads
- Magnet activates oxygen's paramagnetic properties to retain oxygen while other gases are released, allowing oxygen to be captured by timed valve system

- Target Improvements
  - Lower cost than currently-used cryogenic separation systems (12% COE and $11-13/ton reduction)
  - Continuous high yield oxygen separation from air (99% pure O_2) for feeding a coal gasification system for production of Syngas for industry applications.

Technology

- Magnetic field gradient interaction creates body force on oxygen
- Traps oxygen while allowing nitrogen to continue freely
- Square wave field switching enhances the interaction
- Enriched O_2 is drawn (vacuum pump) from the domain during off state
- Duty cycle reduces output relative to flow rate, but improves enrichment rate





Gradient pulses can be simply turned **on** and **off** like high-power RF pulses (rectangular pulses) or they can be shaped so that they turn **on and off** more gradually.

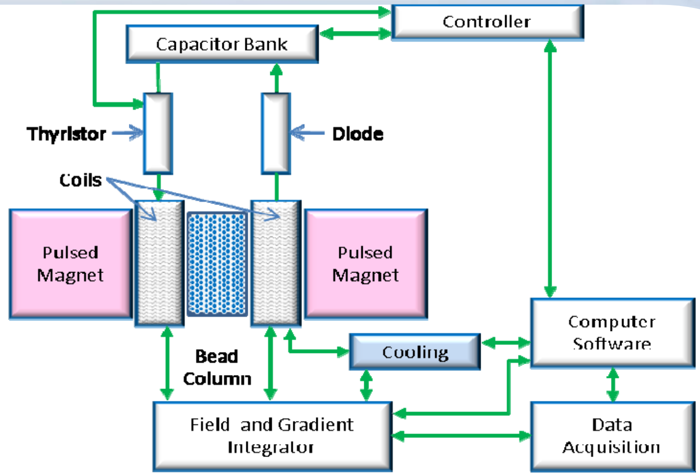
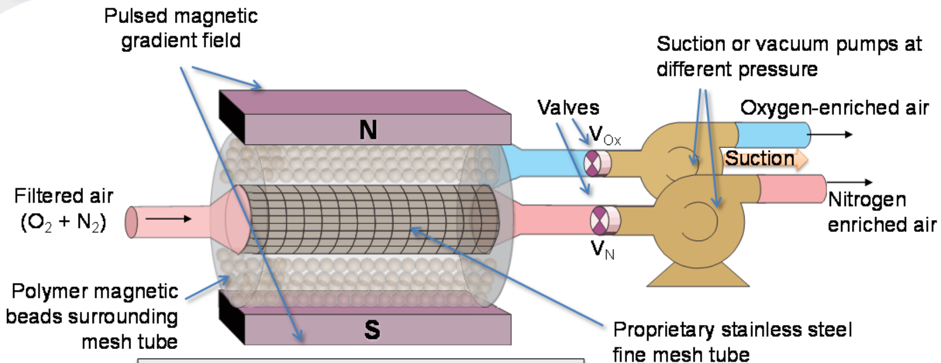


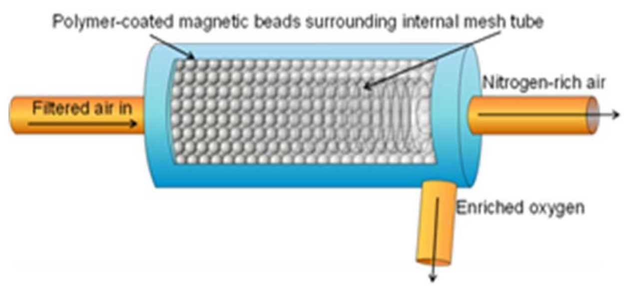
Diagram of Pulsed-Magnetic Field Gradient

Domain Coordinate System

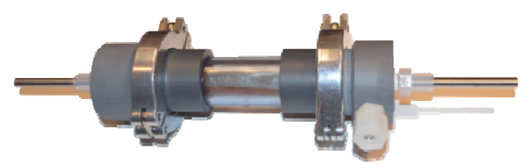
Technology



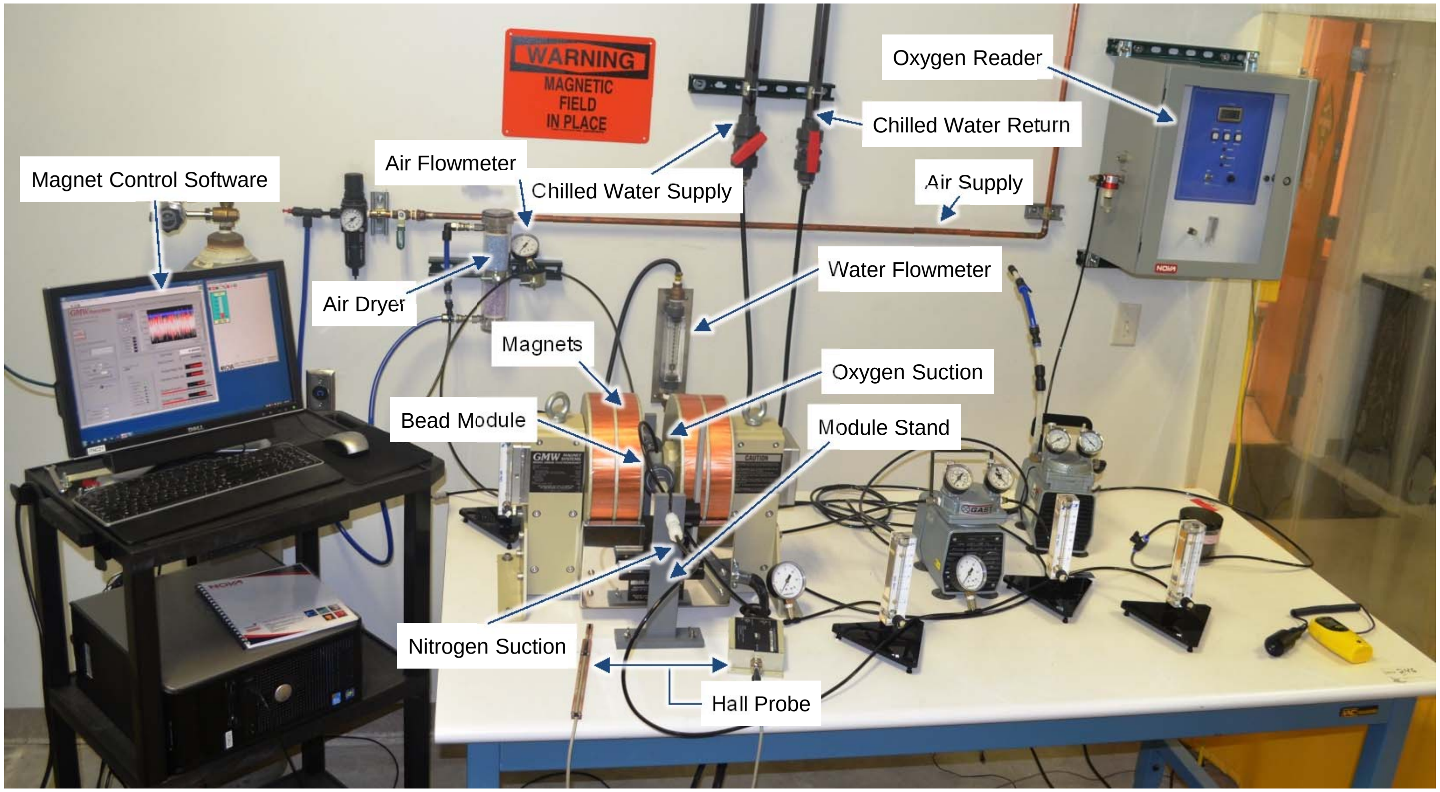
- VOx is open when magnetic field is OFF, and closed when it is ON.
- VN is open continuously at a fixed pressure.



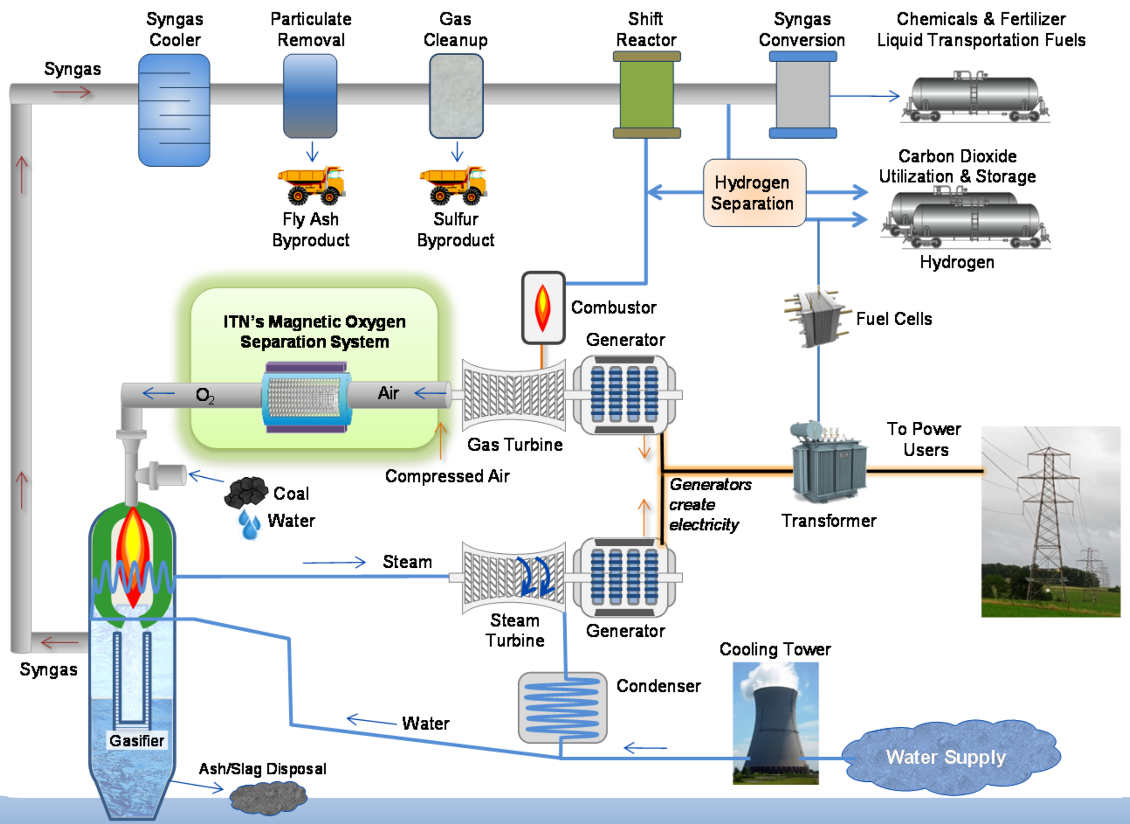
- Beads module is placed between the magnet's poles with magnetic field (B_0), and the magnetic moments of these beads align with the direction of the field
- Computer controls on/off pulses to change magnetic field on pre-defined intervals
- When field is on, the magnetized beads *hold* oxygen and alter their alignment towards the column
- When the field is off, beads return to the original alignment, and *release* oxygen



Project Configuration



Integration with Gasification Plant



ITN's magnetic oxygen separation system goes inline with air feed to provide pure oxygen to gasifier, dramatically increasing process efficiency

Ancillary R and D Needed

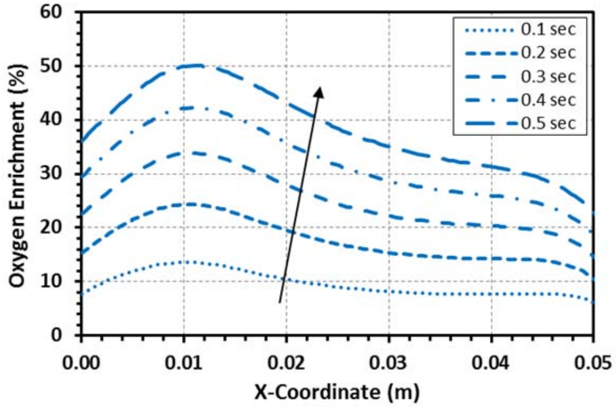
- Additional work to scale up technology from lab to industrial size
- Increase magnet pulse gradient power
- Cheaper magnet technology would lower system cost
- Minor engineering required to integrate system into gasification plant air intake

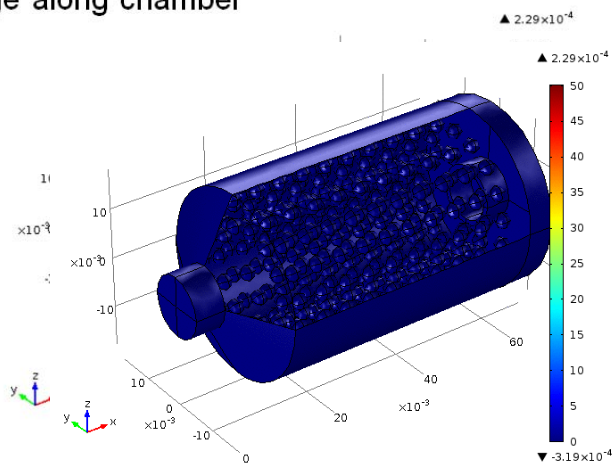
Goals for Commercial Viability

- Work with industry leaders in commercial gas production to establish marketing and logistical pipelines
- Obtain funding for development of large-scale devices and infrastructure for pilot production
- Collaborate with Industrial Partner to obtain funding for volume production and distribution
- Targeted cost-effective oxygen production

Maturity & Development Remaining

Pulse enrichment – Charging
Span-wise average along chamber





Peak Oxygen Enrichment (%)

	0.1 LPM			0.5 LPM			1.0 LPM		
	1.0 ATM	1.5 ATM	2.0 ATM	1.0 ATM	1.5 ATM	2.0 ATM	1.0 ATM	1.5 ATM	2.0 ATM
1.0 T	5.3	12.1	16.7	2.6	6.0	8.2	1.1	2.5	3.4
2.0 T	10.5	24.2	33.3	5.2	12.0	16.5	2.1	4.9	6.8
3.0 T	15.8	36.3	50.0	7.8	18.0	24.7	3.2	7.4	10.2

↑Frequency, ↓%   ↑Flow Rate, ↓%

↑Mag Field, ↑%   ↑Pressure, ↑%

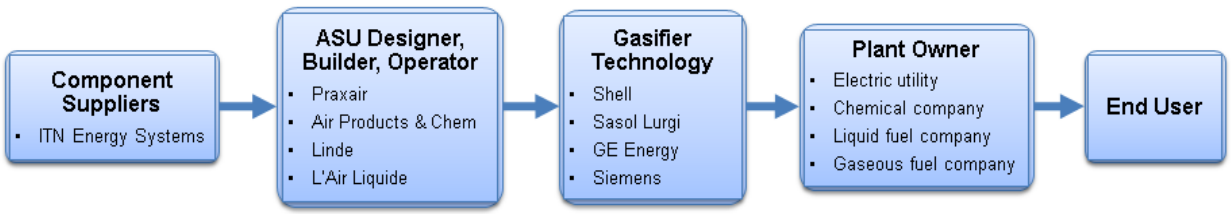
Commercial Benefits

- Replace expensive cryogenic oxygen production processes throughout multiple industries
- Save energy by increasing efficiency of coal plants
- Less complex
- Compact system
- Field deployable

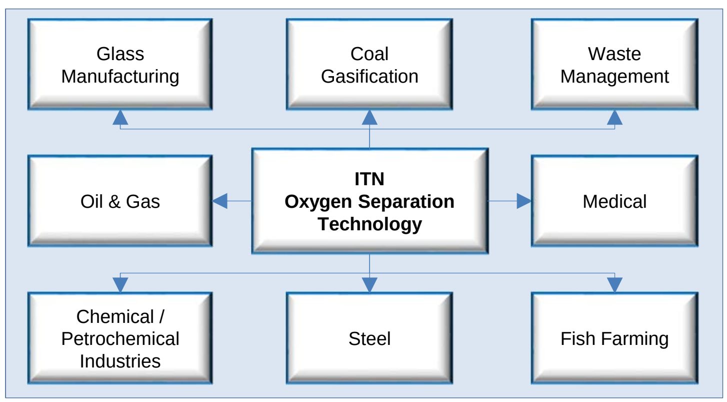
Technology	Status	Eco. Range (sTPD)	Purity limit (vol.%)	Byproduct Capability	Start-up Time
Cryogenic	mature	>20	99+	excellent	Hours
Membrane	Semi-mature	<20	~40	poor	minutes
ITM	developing	unknown	99+	poor	hours
Adsorption	Semi-mature	<150	95	poor	minutes
ITN's Magnetic	developing	undetermined	>99	good	seconds

Commercial Benefits

Air Separation Value Chain



Huge potential application for use of oxygen in primary metals production, chemicals, and clay, glass, rocket fuel, and concrete products, petroleum refineries, welding, and other industries.



Magnetic Air Separation Cost Analysis

- Magnetic power consumption is significantly more energy efficient than Cryogenic and VSA technologies
- 95% of operational costs of cryogenic ASUs come from compressor work
- Capital costs of magnetic ASU design are relatively small
- Maintenance cost is lower, fewer moving parts
- Goal is to operate magnetic air separating unit close to atmospheric pressure to reduce compressor costs.

Initial Calculations

	Magnetic	VSA	Cryogenic
Operating Pressure (atm)	1.00	1.00	8.0
Nominal O_2 Gen (mTPD)	1.00	10	100
Compressor/Blower Work (kW)	0.04	280	1230
Electromagnet Power (kW)	1.65	-	-
Specific Energy (kWh/ton)	40.7	672	295

Oxgen Separation Project Team

ITN Energy Systems

- Raghuvir Singh, Ph.D. (Principal Investigator)
- Scott Kato
- James Mickle
- B.J. Green

Texas A&M University

- Prof. Partha Mukherjee, Energy and Transport Science Laboratory, Department of Mechanical Engineering

Other Contacts

- Potential Industry Partners: Praxair, Air Liquide
- Commercialization Support: Dawnbreaker