



Gasification at Elevation ASU Design Impact

Workshop on Gasification Technologies

Denver, CO, March 14th, 2007

Gasification at Elevation – ASU Design Impact

- Air Liquide Overview
- Basic ASU Process
- ASU Equipment Affected
- Conclusion



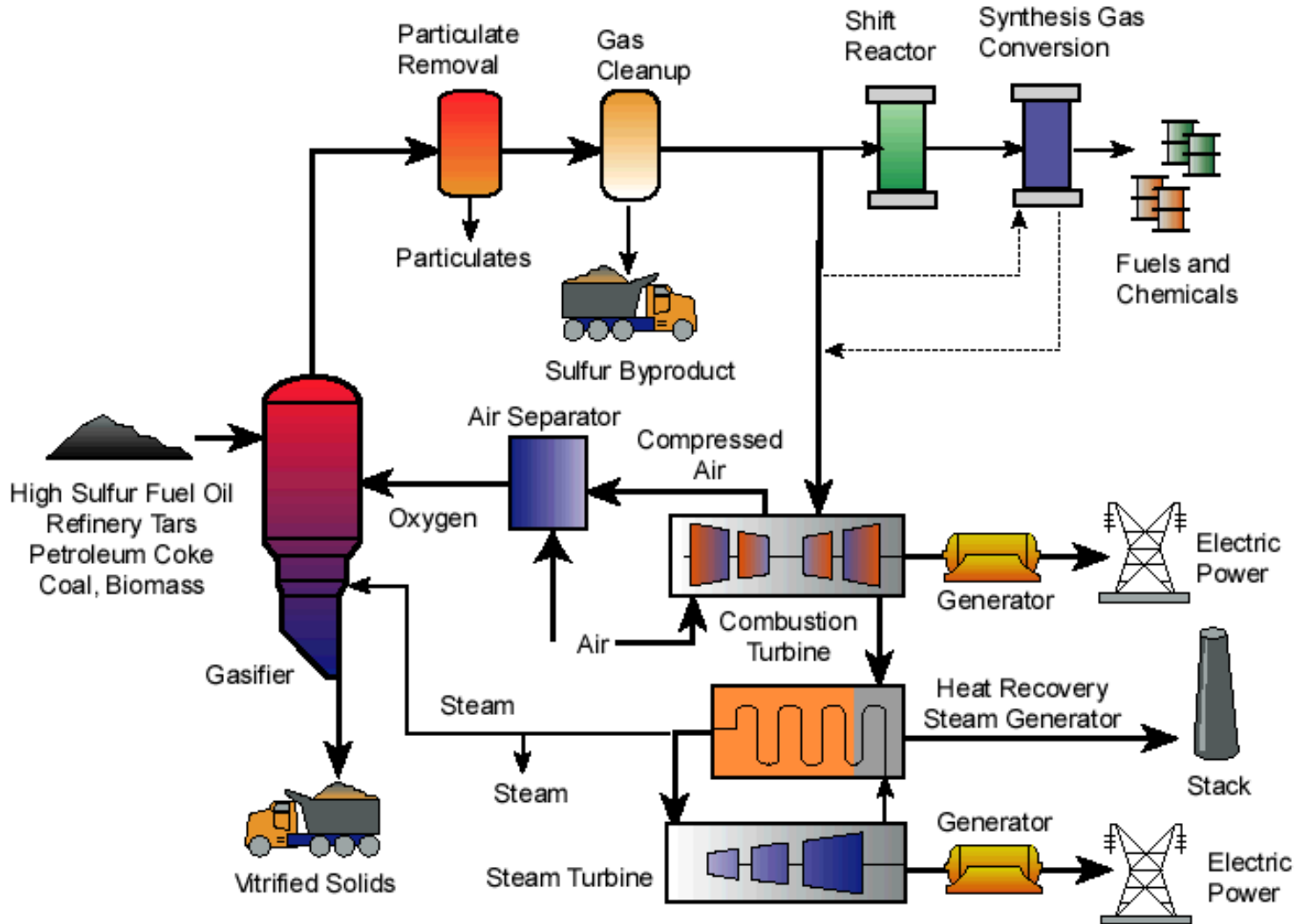
Air Liquide Overview

- World Leader in Industrial Gas Supply with 18% Market Share
- Formed in 1902: Headquartered in Paris
- Over \$14 Billion in Sales in 2006
- Employs Approximately 37,000 People
- 130 Subsidiaries in More than 70 Countries
 - ✓ Japan – 1907
 - ✓ Canada – 1911
 - ✓ USA & China – 1916
 - ✓ Kuwait – 2006
- Technology Driven Company
 - ✓ 6,300 Patents and 1,800 Inventions
 - ✓ Largest supplier of ASUs over 2000 TPD
- #1 Plant Operator in the World
 - ✓ Over 350 Air Separation Units
 - ✓ Approximately 5,000 miles of Pipelines
 - ✓ 125,000 TPD of O₂ and 95,000 TPD of N₂ Delivered
 - ✓ 50 Syngas Generation Plants – Units up to 100 MMSCFD H₂
 - ✓ 23 Power and Steam Cogeneration Units – Total of 1,550 MW

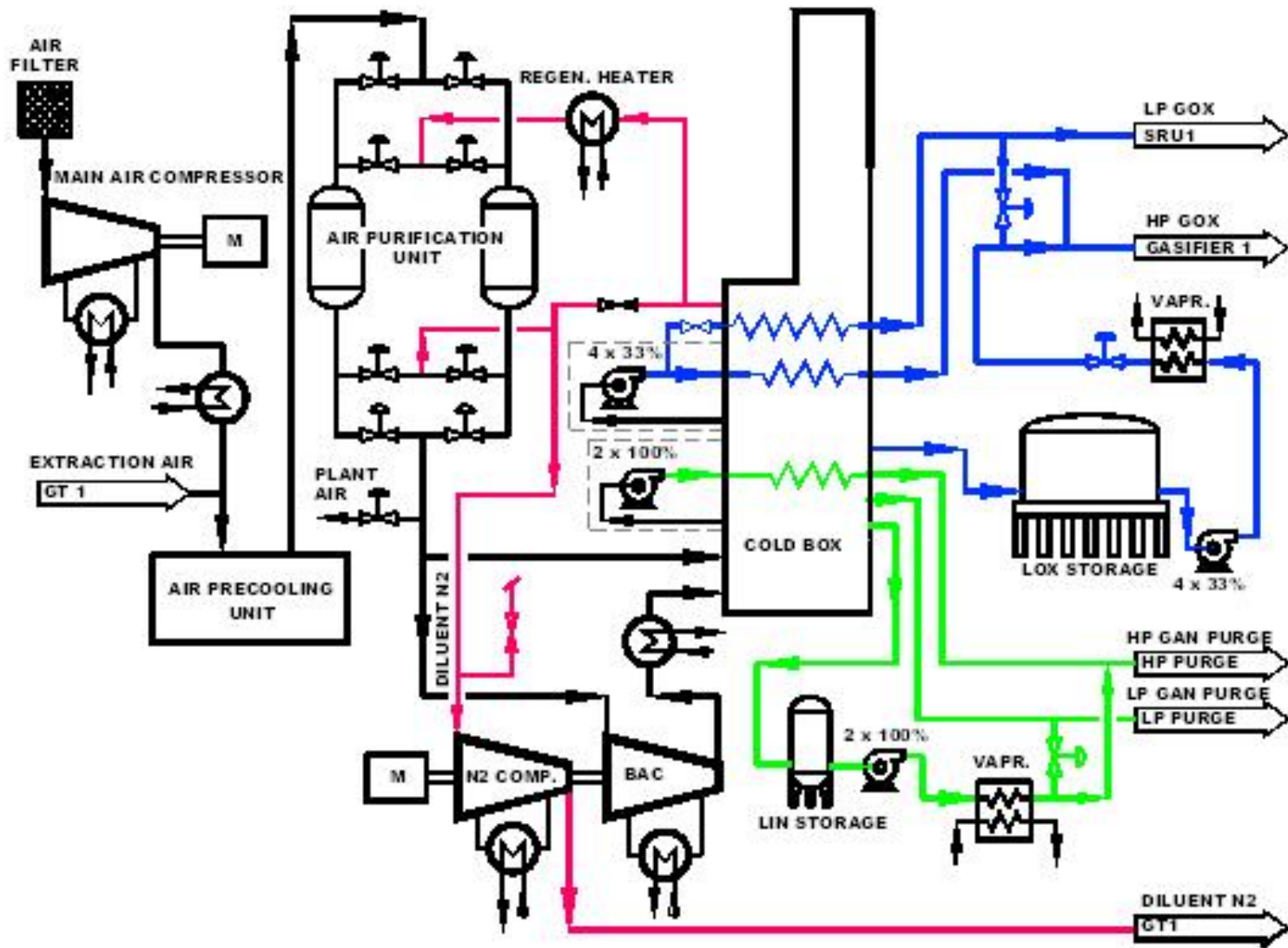


Safety first

Typical IGCC

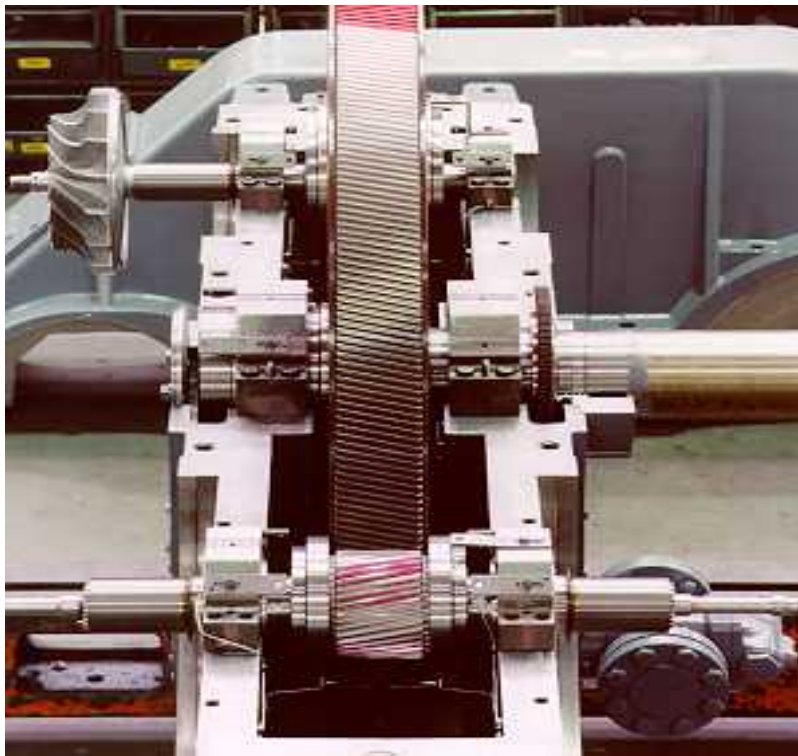


One Typical ASU for IGCC



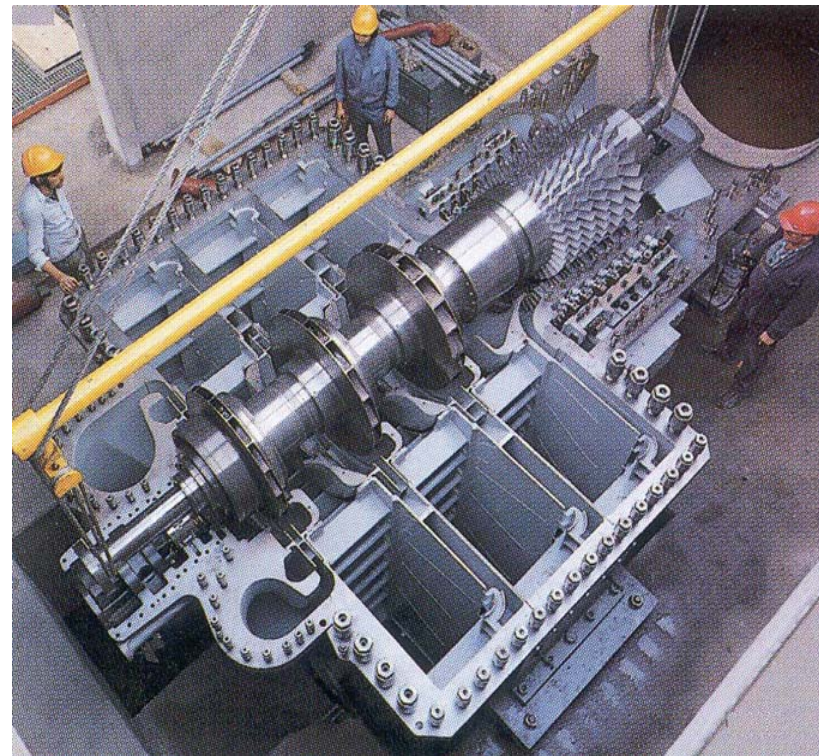
■ Integrally Geared Compressors

- ✓ Optimized for process requirements
- ✓ Improved efficiency
- ✓ Reduced capital costs



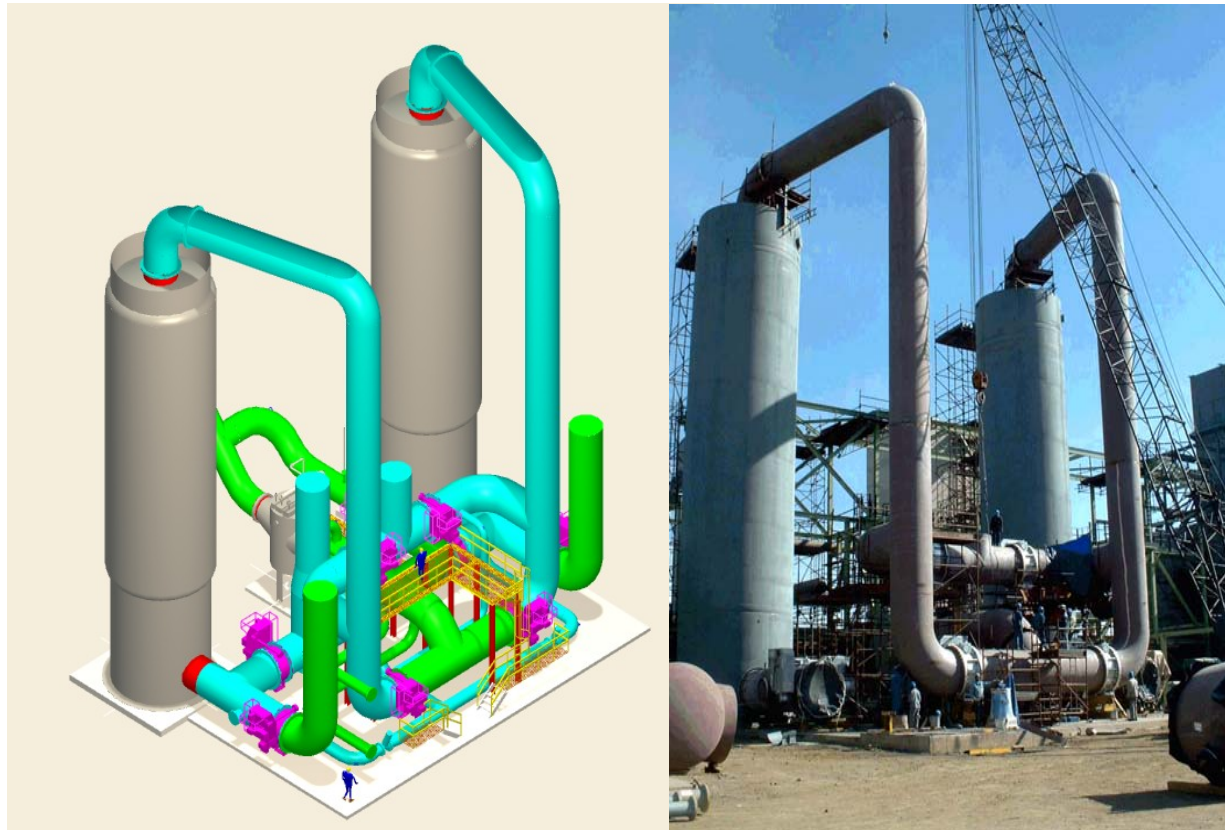
■ Single Shaft Compressors

- ✓ Compact
- ✓ Easy installation
- ✓ Simple mechanical design



ASU Process – Air Purification

- Desiccant beds designed to purify air by removing
 - ✓ Moisture
 - ✓ Carbon dioxide
 - ✓ Some hydrocarbons

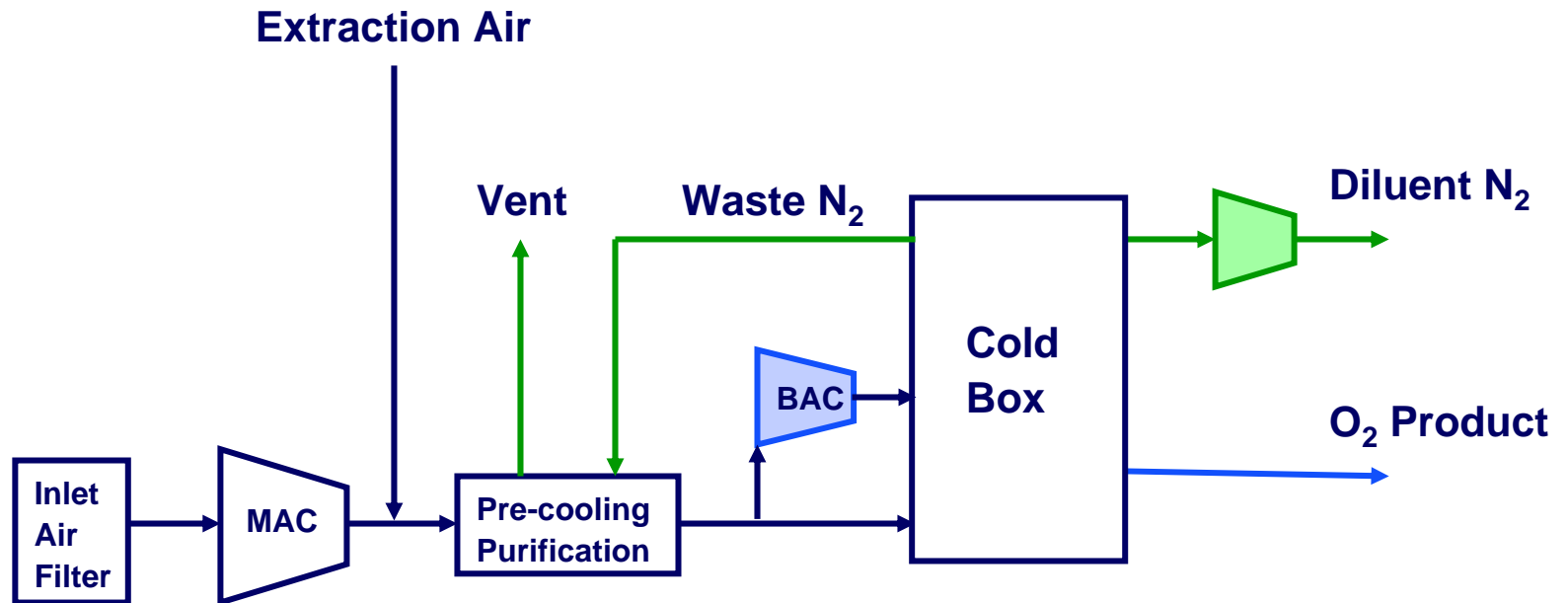


ASU Process – Cold Box

- Insulated enclosure containing cryogenic distillation columns, heat exchangers, valves and piping



Basic ASU Block Flow Diagram



- Air compression consumes approximately 90% of the energy needed for an ASU.

ASU Design Impact – Main Air Compressor

- For a given mass flow rate, the volumetric flow rate varies by the ratio of the change in inlet pressures. Example:
 - ✓ A flow of 10,000 lbs/min of air at sea level (14.7 psia) is equal to approximately 131,000 acfm (dry, at 60 degrees F.).
 - ✓ At 5,000 feet elevation, atmospheric pressure drops to 12.2 psia. Therefore, the same 10,000 lb/min of mass flow becomes 158,000 acfm, an increase of more than 20%.
 - ✓ The Main Air Compressor must be sized for the larger flow rate of 158,000 acfm. In most instances, this may be achieved by:
 - Running the compressor a higher speed
 - Use larger, more expensive, compressor frame size, since a Main Air Compressor typically must have a certain amount of margin to allow for off-design operating points



ASU Design Impact – Main Air Compressor

- At sea level, a Main Air Compressor sized for 100 psig discharge pressure must deliver a compression ratio of 7.8 (114.7 / 14.7)
- At 5,000 feet altitude, a Main Air Compressor must work harder to deliver the same 100 psig discharge pressure, since the delivered compression ratio becomes 9.2 (112.2 / 12.2)
- This may be achieved by:
 - ✓ Increasing the compressor operating speed
 - ✓ Increasing the impeller diameters
 - ✓ Adding an additional impeller, resulting in a longer, more expensive rotor



ASU Design Impact – Main Air Compressor Motor

- Most electric motors are designed to operate normally at altitudes up to 3300 feet (at constant temperature).
- Above 3300 feet most motors are de-rated due to the reduced heat dissipation of the thin air:
 - ✓ 3300 – 5500 feet approximately 3%
 - ✓ 5500 – 6600 feet approximately 6%
 - ✓ 6600 – 8300 feet approximately 10%



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ASU Design Impact – Exchangers and Columns

- All equipment subject to a flow of gas affected by atmospheric pressure is impacted by altitude due to increase in volumetric flow:
 - ✓ Distillation columns
 - ✓ Heat exchangers
 - ✓ Adsorbers
 - ✓ Piping
 - ✓ Others
- To mitigate the impact on pressure drop, the size (or cross sectional area) of the equipment affected must be increased



Conclusion

- Manufacturers give performance ratings on equipment at specified temperature and pressure (for example STP: 68°F at sea level or 14.7 PSI_{abs}). This is important because air (and other gases) expands and contracts significantly at higher and lower temperatures and pressures. For instance, a one cubic foot balloon at sea level will expand to about 1.2 cubic feet at 5,000 feet (1,500 meters) altitude.
- When an air compressor is operated at altitude, it takes in less air because the air is less dense. It must turn more revolutions or do more work to move the same amount of air it does at sea level.
- Equipment subject to gas flows affected by atmospheric pressure must be enlarged to minimize pressure drop
- Motors are de-rated

Gasification & Air Liquide

■ Sasol T-15 (CTL application)

- ✓ Production capacity in excess of 4000 tons O₂/day (currently the largest operating oxygen plant)
- ✓ Site altitude approximately 5000 feet, which translates into an atmospheric pressure of 12.5 psia
- ✓ Plant designed to mitigate effects of altitude, resulting difference in energy compared to sea level about 7.5%

■ IGCC/Gasification references:

- ✓ Wabash River: 2050 t O₂/day
- ✓ Elcogas: 2400 t O₂/day
- ✓ ISAB: 2 x 1850 t O₂/day
- ✓ Sarlux: 2 x 2300 t O₂/day
- ✓ Negishi: 2400 t O₂/day
- ✓ IPG Singapore: 1600 t O₂/day
- ✓ ENI - Sannazzaro: 1540 t O₂/day



Questions?