UOP Integrated Approach
Production of Olefins from Coal/Petcoke

UOP MTO Integrated Complex

- Raw Syngas from Gasifier → Sour Shift → UOP Selexol Process → Methanol Synthesis → UOP/HYDRO MTO Process → C_3^+
- CO₂ → UOP Selexol Process → Claus SRU → Sulfur → TOTAL/UOP OCP Process → C_4^+
- C_2^= → UOP Selexol Process

Single Source Offering of All Process Blocks Through UOP
What is the SELEXOL Process?

- Invented by Allied Signal in the 1950’s
- Absorption/regeneration process for selective removal of H₂S, COS, & CO₂
- Physical solvent – solubility based rather than a chemical reaction

**Physical vs Chemical**

- **Chemical Solvent**
- **Physical Solvent**

*Typical Gasification Application*

*High Pressure is advantageous*
Selexol Process Flow Schemes
for Sulfur Removal Only

- Treated Gas
- Feed Gas
- Sulfur Absorber
- H₂S Concentrator
- Packinox Exchanger
- H₂S Stripper
- Lean Solution Filter
- Reflux Accumulator
- Makeup Water
- Export Water
- Stripper Reboiler
- Acid Gas
- Reflux Pump
- Export Water
Selexol Process Flow Schemes
Sulfur Removal & CO₂ Capture - Chemical Apps

- Feed Gas
- CO₂ Absorber
- Sulfur Absorber
- CO₂ Reflux
- Lean Solution Filter
- H₂S Concentrator
- Packinox Exchanger
- H₂S Stripper
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- Makeup Water
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- Acid Gas
- Treated Gas
- Makeup Water
- Export Water
- Stripper Reboiler

UOP 5670-5
Selexol Advantages for Chemical Applications

- Provides high product quality
  - Total sulfur to <1.0 ppmv (ppb guarantee with guard bed)
  - CO₂ less than 1 mol%
- Design and operational flexibility
  - Adjustable Acid Gas Composition
  - Can be designed for a range of CO₂ capture levels
  - Operate with moderate refrigeration
  - Stable operation at turndown
- Simplicity of design
  - >99% availability
  - Low CAPEX and OPEX

UOP Selexol Process is well suited for downstream Methanol/MTO applications
### Selexol Commercial Data—Coffeyville Plant Sulfur Removal

<table>
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<td>$H_2S$, ppmv</td>
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Selexol process can meet treated gas specifications of <1 ppmv total sulfur.
SELEXOL® Solvent Experience

Over 110 Operating Units
with SELEXOL solvent

- Synthesis Gas
- Natural Gas
- Landfill Gas
UOP Selexol™ Applications Worldwide

Recent Selexol Applications in Operation
- **Sarlux**: IGCC power and H₂
- **API**: IGCC power
- **Coffeyville Energy Resources**: H₂ and CO₂ capture
- **SandRidge**: Natural gas CO₂ removal for EOR
- **Nexen**: H₂, fuel and future CO₂ capture

Projects in Construction
- **Duke Energy**: IGCC power and future CO₂ capture
- **Southern Company**: IGCC power and CO₂ capture

Projects in Engineering
- **DKRW**: Methanol to gasoline and CO₂ capture
- **U.S. Transcarbon**: H₂ and CO₂ capture
- **Erora Project**: IGCC power and SNG production
- **Ketana Energy**: IGCC power and CO₂ capture
- **J-Power**: IGCC power and CO₂ capture
- **Jindal Steel & Power Limited**: DRI Reduction Gas
UOP Integrated Approach to Production of Olefins

UOP MTO Integrated Complex

- Raw Syngas from Gasifier
  - Sour Shift
  - UOP Selexol Process
  - Methanol Synthesis
  - UOP/HYDRO MTO Process

- CO₂
  - Claus SRU
  - Sulfur
  - TOTAL/UOP OCP Process
  - C₂⁺
  - C₃⁺
  - C₄⁺
Development History of UOP Advanced MTO Process

- ~1 kg/day of MeOH feed
- Multiple grades/sources of feed
- Reactor and regenerator configuration

1988

UOP Pilot Plant – Operation

- ~1,000 kg/day (maximum) of MeOH feed
- Multiple grades/sources of feed
- Reactor and regenerator configuration

1995

INEOS Demo Unit (at the time Hydro)

- ~10,000 kg/day (10t/d) of MeOH feed
- Fully integrated Advanced MTO Process Configuration

2009

Total Petrochemicals Process Demonstration Unit
UOP/HYDRO MTO Process

Similar to Refinery/FCC Equipment

Similar to Naphtha Cracker Equipment
UOP Advanced MTO Process Advantages

- Product yields as high as 90%
- Higher product purity – 98%+
  - No splitter columns required
- Operational flexibility to adjust product ratios
- Minimized production of byproducts
- Integration with Total Petrochemical/UOP OCP Process

*UOP Advanced MTO Process provides optimum performance and economics for olefin production*
Light Olefin Supply & Demand

- Rapidly growing demand - 90 million MTA of incremental light olefins needed between 2010 to 2020
- Consumption driven by:
  - Polyethylene
  - Polypropylene
  - Ethylene oxide
  - Ethylene dichloride
  - Ethylbenzene
  - Acrylonitrile
  - Propylene oxide
  - Acrylic Acid
  - Cumene

- Growing share from other sources besides steam cracking and refineries
  - Cost advantaged feedstocks
  - Propylene gap
- MTO will be the technology of choice to meet the growing demand
- If 10% of this decades incremental light olefins come from MTO it would consume 25 million MTA of methanol
**Olefin Cost of Production Comparisons**

- **Plant Capacities**: 1 million MTA

- **Light Olefins** (ethylene + propylene)

- **Technologies**
  - UOP Advanced MTO Process (MTO)
  - Steam Cracking (Cracker)

- **Feedstock Prices**
  - $50 / MT Coal (~$1.75/mm Btu)
  - $533 / MT NGL (70% Ethane/30% Propane)
  - $691 / MT Naphtha

- **Utility costs adjusted for local energy values**

- **Plant capital costs adjusted for location factors**

- **Capital Charges**
  - 10% depreciation/amortization
  - 10% return on capital

MTO costs include the production of synthesis gas, methanol, and conversion to polymer-grade ethylene & propylene

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**Solid economic drivers for utilizing cost advantaged coal/petcoke**
UOP Advanced MTO Technology

**MTO integrated with OCP**

**Significantly improved process performances and economics with combined MTO-OCP**

- Nearly 80% reduction in C₄+ by-products
- Increasing C₃=/C₂= production ratio up to 1.8 molar
- Good integration potential resulting in reduced capex: optimized conditions for MTO while C₄+ are sent to OCP section
- MTO+OCP increase yields to near 90% compared to 60-75% with conventional methods
Summary of UOP MTO Integrated Complex

- Single source offering through UOP
- UOP Selexol Process is well suited for chemical applications
  - Provides high product quality
  - Design and operational flexibility
  - Simplicity of design
- UOP Advanced MTO Process provides optimum performance and economics for olefin production
  - Lower costs of production compared to oil derived feed
  - Higher product yield and purity
  - Operational flexibility to adjust product ratios
  - Integration with Total Petrochemical/UOP OCP Process
  - First commercial Advanced MTO scheduled to startup in 2013
  - Additional MTO projects are planned for Asia and other regions