Moving the Scale on Hydrogen Production
Modular solutions for any capacity

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Linde Engineering
139 Years of Innovation

World's first air liquefaction plant on a pilot plant scale, commercial scale, production scale

World's first air separation plant for the production of oxygen

World's first recovery of rare gases on a commercial scale

Foundation of the "Gesellschaft für Linde's Eismaschinen" in Wiesbaden
Linde Engineering North America
Technology, Engineering, Procurement & Construction

Houston, TX - Headquarters
— Synthesis gas, air separation, LNG, adsorption, petrochemical plants, & refinery technologies
— PLANTSERV™— revamps, rebuilds and spare parts
— Located in the Houston Energy Corridor
— Global Procurement Center for the Americas

Selas Linde North America Division in Blue Bell, PA
— Process fired equipment – furnaces for hydrogen reforming and synthesis gas, chemicals, refineries, and petrochemicals; oxidation equipment for environmental emissions treatment

Hydro-Chem Division in Holly Springs, GA
— Engineering, design, fabrication & modularization for modular and skid-mounted hydrogen plants

Natural Gas Division in Tulsa, OK
— Gas processing and natural gas liquids (NGL) plants & refinery technologies
— Linde Cryogenics – helium and hydrogen cryogenic liquefiers
— Fabrication, modularization and structural shop at Port of Catoosa
LE’s Hydrogen & Syngas Technology Portfolio

Hydrocarbon Reforming
- Steam Reforming
- Autothermal Reforming
- Partial Oxidation

Isothermal Shift Conversion

Gas Separation

Gas Conditioning
Industrial H$_2$ Users
Wide Range of Markets and Applications

- **Refineries 30%**
  - Hydrocracking
  - Hydrotreating

- **Chemical Industry 63%**
  - Ammonia (Urea, Fertilizers)
  - Methanol
  - Polymers
  - Polyurethanes

- **Metal & Glass Processing 6%**
  - DRI of Iron Ore
  - Forming & Blanketing Gas
  - Float Glass Production

- **Other 1%**
  - Rocket Fuel
  - Semiconductor Industry
  - Food Processing
  - Generator Cooling
Increasing Use of Hydrogen as an Energy Carrier

Many New Opportunities in Mobility, Power & Heat
The Importance of Scale

Many factors affect the cost of $\text{H}_2$ production:

- Feedstock type, price and availability
- Utility prices, availability and reliability (electricity, water, etc)
- Local infrastructure for transportation (pipelines, trucks, rail, etc)
- Local construction costs (labor availability, productivity and skill set, bulk material availability, etc)
- Competition
- Environmental regulations & restrictions
- Governmental policies
- Technology accessibility
- Capital investment
- Demand load variation
Meeting Small H₂ Demand – Hydro-Chem
Standardized and Modularized H₂-Plants

Hydro-Chem
A Division of Linde Engineering North America Inc.

HYDROPRIME® Min

- New line of innovative on-site hydrogen generators
- Compact single module H₂ generator
- Capacities up to 300 Nm³/hr of H₂
- Efficient and flexible alternative to other hydrogen supplies
- Lower operator cost & high reliability
- Greater availability & supply security
- Fully automatic with fail-safe controls
- Remote start-up and monitoring
- Max dimensions (14m x 3m x 4m) – easy transportation
- Easy site installation
- Global fabrication capabilities
- Modular open skid design with space for maintenance
- Designed for outdoor installation
HYDROPRIME® Mid

— Cylindrical “can-type”, up-fired furnace with excellent heat transfer characteristics
— Cost-effective design; easy to manufacture and transport
— Standard Plant Sizes: 1, 3, 5 and 8 kNm³/hr capacities; reduce cost & schedule

— Capacity up to – 8,000 Nm³/hr \( \text{H}_2 \)
— Less than 10 modules
— Off-skid items
  – Reformer
  – PSA vessels & Tail Gas Drum

— Capacity up to – 16,000 Nm³/hr \( \text{H}_2 \)
— Less than 20 modules
— Off-skid items
— Hydrotreater, Desulfurizer(s), Shift Converter
  – Reformers
  – PSA vessels & Tail Gas Drum
HYDROPRIME® Max
Modularized, Standardized Box Reformer

Standardization:
- 1-row layout concept due to modularization
- Fixed diameter & length of reformer tubes
- Fixed reformer tube pitch
- Fixed burner configuration (2 burners / 4 reformer tubes)
- Variable number of tubes (48/60/72)
- Variable tube wall thickness

Modularization:
- 4 horizontal box and 2 penthouse modules
- Harped reformer tubes installed at site
- Cold header installed in two pieces
- 10 self-supporting modules incl. structural steel
- Castable refractory preinstalled
- Maintenance platforms dressed at site
- Customized Convection Section
- Retractable bundles (optional)

- All skid modules of same size
- Procurement & fabrication harmonized and optimized
- Maximize degree of pre-assembly
- 5 or 6 bed PSA design
- High-recovery PSA with low pressure TGD
HYDROPRIME® Max
Modularized, Standardized Box Reformer

— First HYDROPRIME® Max installation (Europe)
— 16,000-28,000 Nm³/hr capacity
— June to October 2018 progress
— Second plant in design (US)
Going Big
Benefiting from Modularization at Global Scale

Even at world scale, modularization proves beneficial to overall project cost, lowers execution risk, and improves quality control.

Stick built design

Module design
HYCOMP™
Modularization at World Scale

— Compact hydrogen plant design concept
— Maximum modularization with minimal footprint
— Expandable design for capacity
— Options on WHR: vertical, omega, horizontal
— Vertical deaerator
— World-scale plant in design phase – 196,000 Nm³/hr H₂
Collaborate. Innovate. Deliver.
Thanks for your attention.