



Hydrogen Production with Integrated CO₂ Capture

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78-year History of Turning Raw Technology into Practical Energy Solutions

FOR A BETTER ECONOMY AND A BETTER ENVIRONMENT

SUPPLY



CONVERSION



DELIVERY



UTILIZATION



RESEARCH & DEVELOPMENT



PROGRAM MANAGEMENT



TECHNICAL/ ANALYTICAL



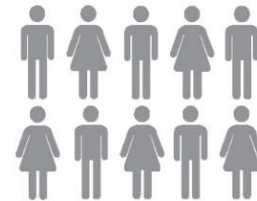
CONSULTING



TRAINING



COMMERCIALIZATION



EMPLOYEES



World-class piloting facilities headquartered in Chicago area

Product Summary: Hydrogen Production with CO₂ Capture

Product

- System for large-scale H₂ production from natural gas
- Replaces Steam Methane reformer

Benefits

- Steam Neutral
- Substantially lower equipment costs compared to SMR
- Increased H₂ efficiency
- Concentrated CO₂ byproduct

Markets

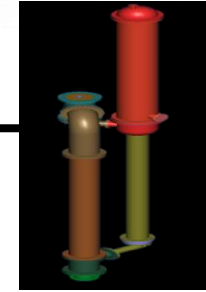
- H₂ for refineries, bio-refineries and chemicals
- Hydrogen for distribution through pipeline infrastructure
- Power Generation

Status

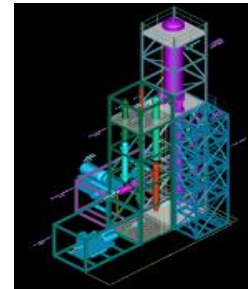
- Initial pilot test completed.
- Pilot system modification underway for extended testing.
- Demo plant defined at 5.0 MMSCFD (2-20 Feasible)



Current Technology



Hydrogen Generator



Demo Plant

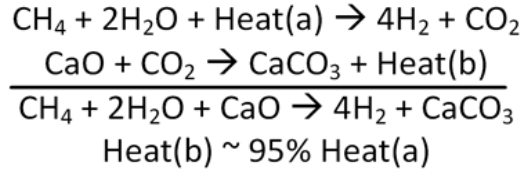


Pilot Plant



Process Schematic

Sorption Enhanced Steam Methane Reforming



700°C, 20-35 psig

Catalyst:

Commercially Available
Ni on Alumina
2mm diameter

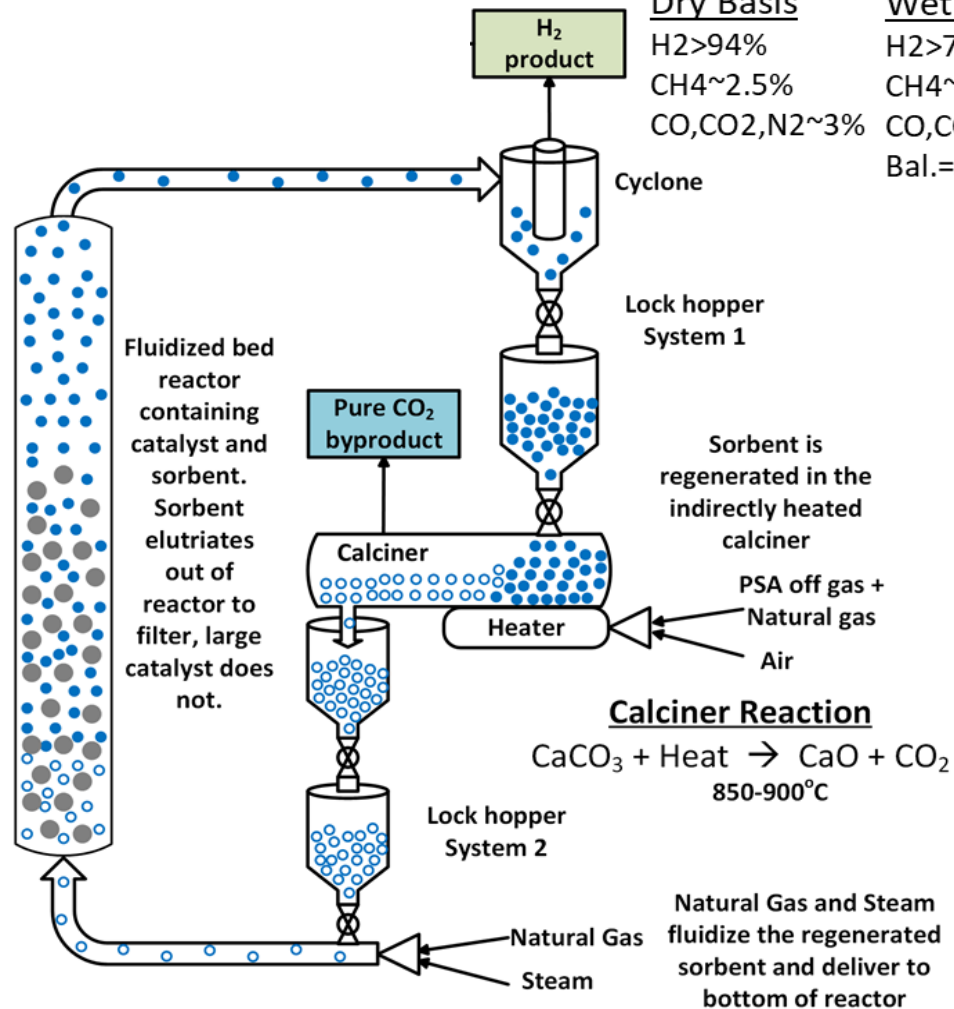
Sorbent:

Natural Solid Sorbent:
Limestone or Dolomite
<0.2mm diameter

- Catalyst
- Sorbent
- Sorbent with CO₂

H₂ Product Composition

	Dry Basis	Wet Basis
H ₂	>94%	>75%
CH ₄	~2.5%	~2%
CO, CO ₂ , N ₂	~3%	~2.8%
Bal.		=Steam for NO _x Control



Process Development

- > GTI has performed a systematic development of the CHG process, demonstrating each of the key system elements. This has culminated in a pilot plant which is operational and currently being tested.

Fixed Bed Tests

Demonstrated chemistry with commercial catalyst for wide range of operating conditions.



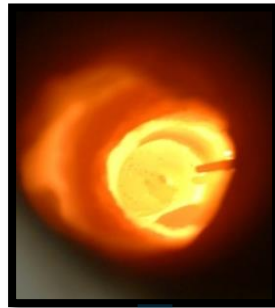
Cold Flow Tests

Defined component designs, demonstrated solids handling under wide range of operating conditions.



Flash Calciner Tests

Validated calcination rate models. Demonstrated operation of short-residence-time calciner.



20 MSCFD Pilot

Accumulated 88+ hours of SER-mode and >200 hours of solids handling operation. Achieved up to 92% H₂ purity



Test Article Skid



Complete Pilot Facility

Design Data and Operating Experience

Pilot Successes

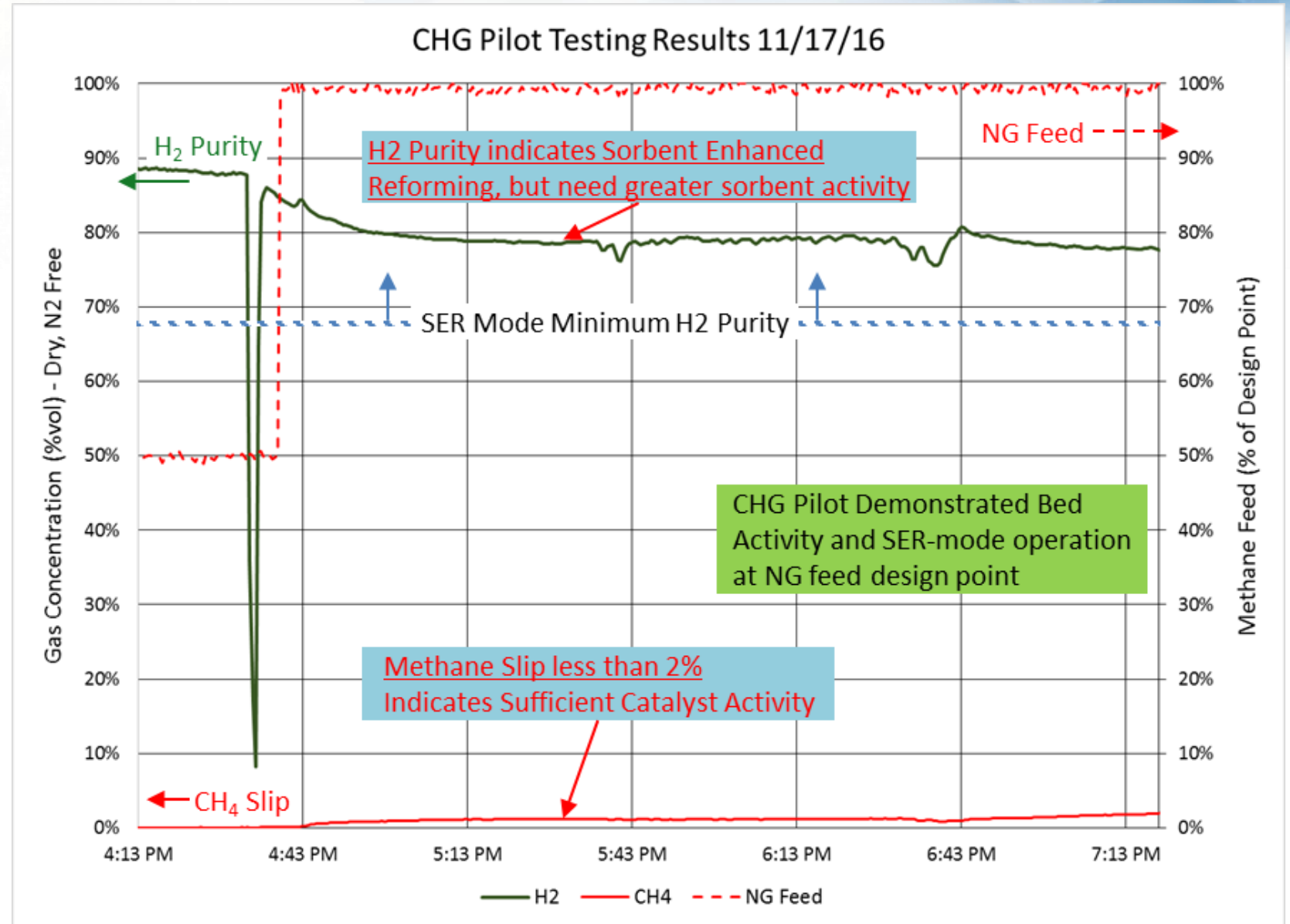
- Improved Sorbent flow via changing to larger particle size achieved three-fold increase in overall activity
- Key risk of catalyst deactivation was resolved via improved operating conditions and substrate changes
- Demonstrated bed reactivity at design feed rate. Identified sorbent activity as limiter.
 - Need greater sorbent feed rate



Pilot Testing

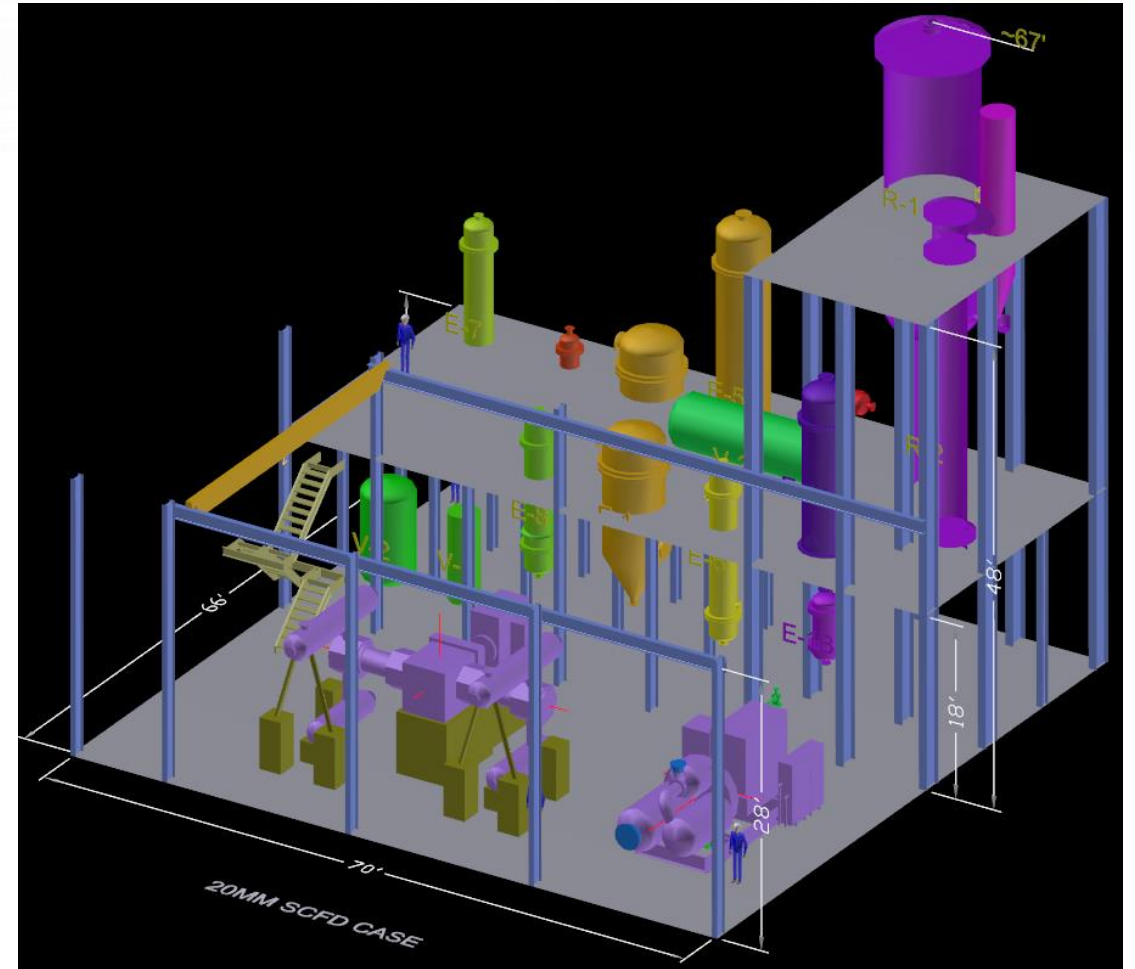
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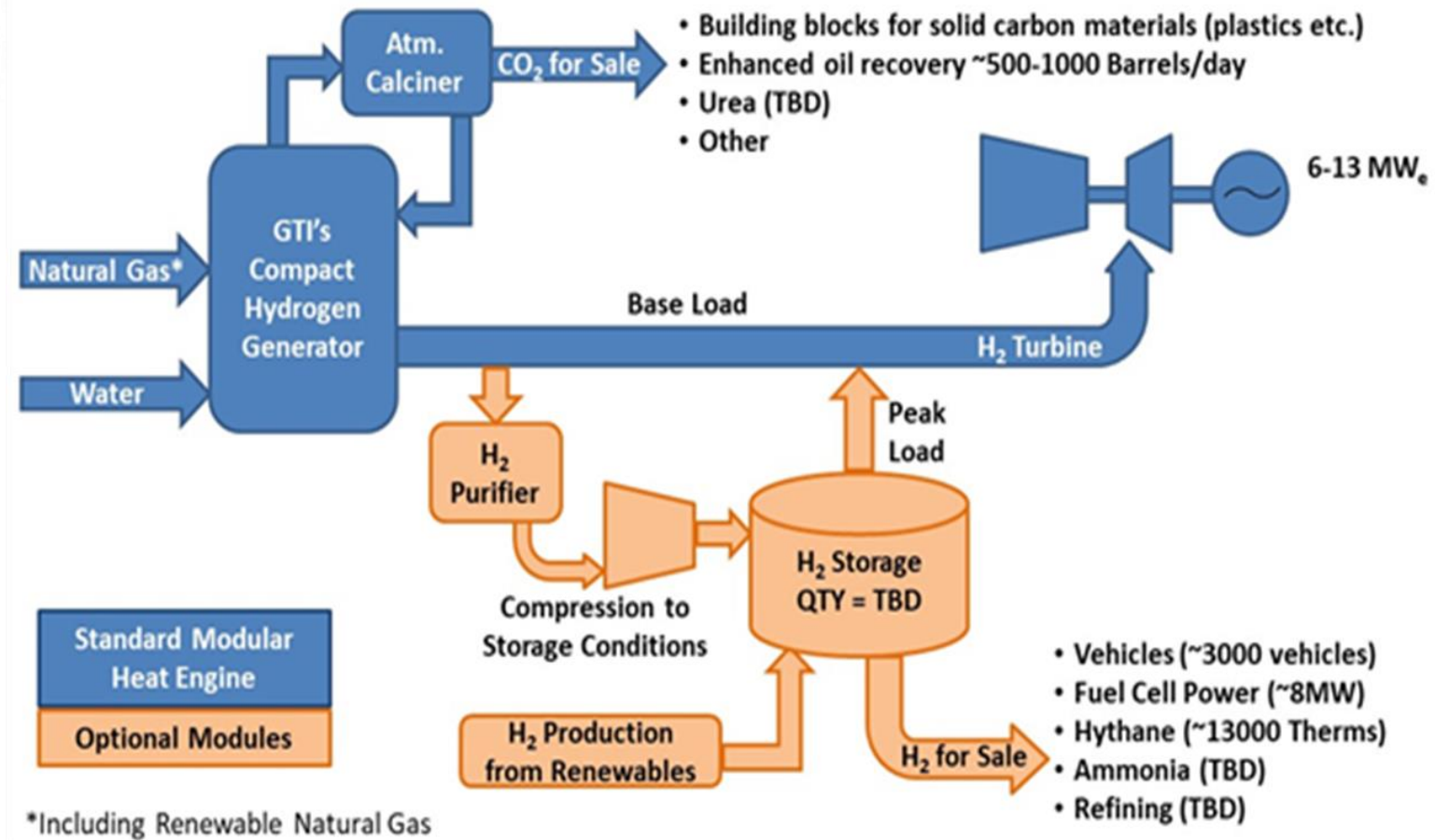


Modular Design Layout

- Worked with EPC firm to assess cost and sizing of small-medium sized plants
- Preliminary design of both a 5MMSCFD and 20MMSCFD demonstration plant performed
- Compactness lends to modularization (>60 MMSCFD) and factory built construction (<60 MMSCFD)
 - Enables lower Installed costs



H₂-Power System Concept (U.S. DOE)



H₂-Power Phase I Status

- Partnering with Turbine OEM's to define hydrogen requirements for gas turbines
- Developing ~ 30 - 40 MW case
- Developing U.S. site candidate (suitable site identified)
- DOE-NETL is validating Aspen models

Case specific optimization required to determine system efficiency vs. CO₂ capture

Phase II Risk Mitigation Scope

- GTI Technology Testing
 - Expanded pilot operation (>1000h)
 - Elevated pressure testing
- H₂ Purification, Compression and Storage
 - Functional testing & safety systems
- H₂-fired turbine development (OEM)
- Demonstration Plant Concept Definition
 - System Architecture
 - Final Sizing & Preliminary Design
 - Site preliminary design, permitting
 - Level 4 cost estimate & project schedule

Natural Gas Decarbonization for H₂ Production & Power

- GTI's CHG process has inherent CO₂ capture, ideal for low carbon H₂ production.
 - One-step conversion of natural gas to H₂
 - Lower product cost vs. current technology
 - Lower CO₂ capture cost vs. current technology
 - Expecting substantially lower CAPEX compared to SMR
 - Carbon capture from conventional SMR flue gas requires amine unit (additional CAPEX).
 - Other option includes autothermal reforming (ATR) but requires air separation plant
- GTI's process also attractive for low carbon power production
 - Pre-Combustion carbon capture solution for natural gas fired power plant
 - Lower cost of electricity compared to post-combustion capture

Application for Norway

- GTI's CHG process has inherent CO₂ capture, ideal for low carbon H₂ production.
- Expected to be very suitable for application in Norway
- GTI is proposing a feasibility study for demonstration project for H₂ production with integrated CO₂ capture
 - Assess potential sites for H₂/CO₂ process applications
 - Prepare scope and preliminary engineering package for demo project
 - Cooperation between GTI and other stakeholders
 - Looking for interested partners

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