MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP

Ammonia Fuel Firing Technology Development Update

2024 Ammonia Energy Association Conference

MITSUBISHI POWER

1. Ammonia Fueled Gas Turbines

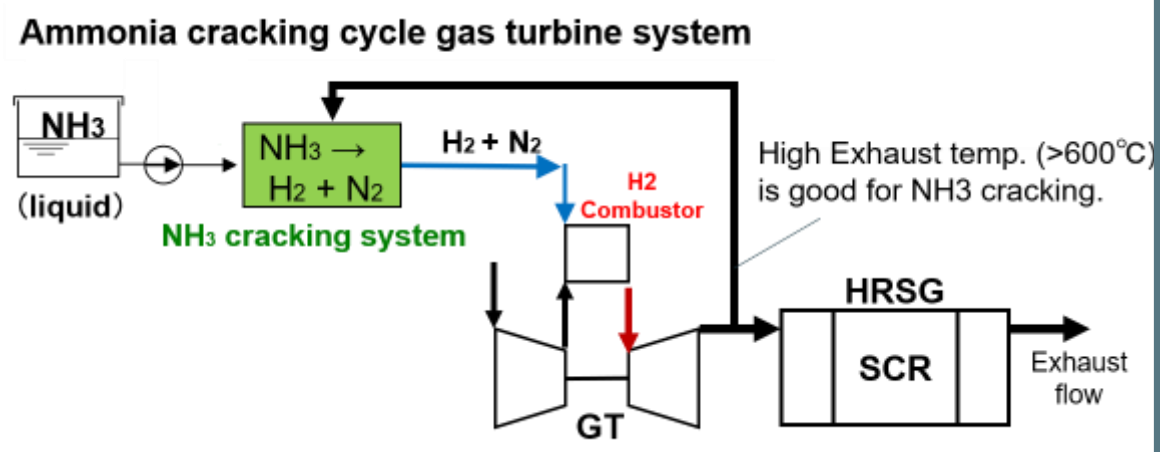
2. Ammonia System Safety Measures

Ammonia Fuel Applications for Gas Turbines

Ammonia(NH3)

- Hydrogen can be efficiently transported long distances and be stored as ammonia
- Ammonia can then be used as a carbon free source of energy
- Direct firing of Ammonia results in high N0x generation (Fuel N0x)

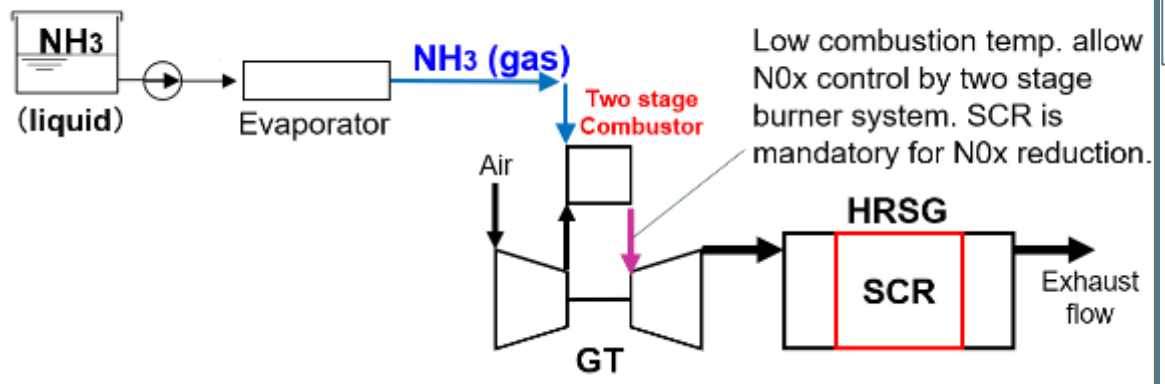
High efficiency large frame GT



Cracking System
Standalone
Verification Test : 2025～

GTCC Combination

Middle&Small Frame GT



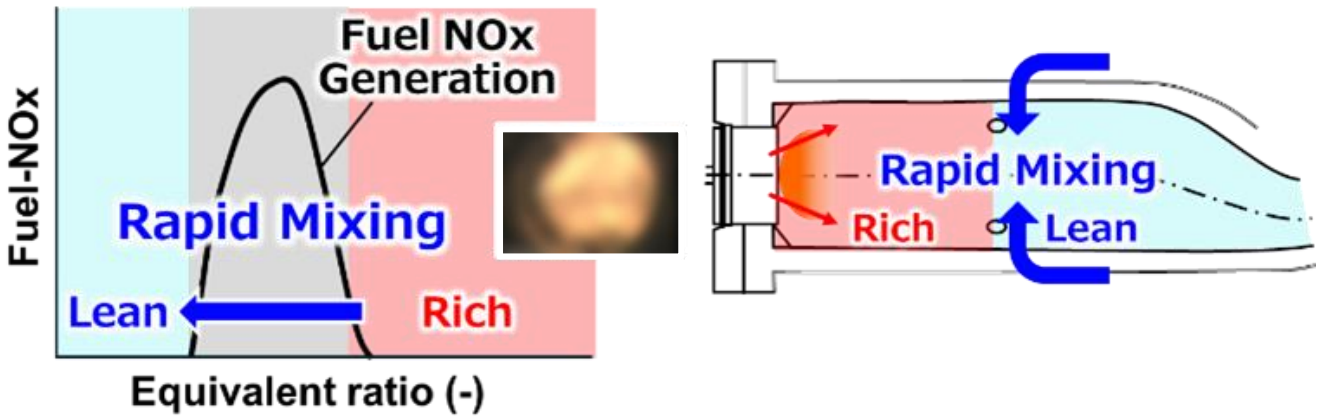
Small Frame
Combustor Test : 2023～
Engine Verification: 2025～

Large Frame GT combustor development

Direct Ammonia Firing Gas Turbine

Key challenges of Ammonia combustion
Optimization of NOx emission control (due to high fuel bound nitrogen) and flame stability

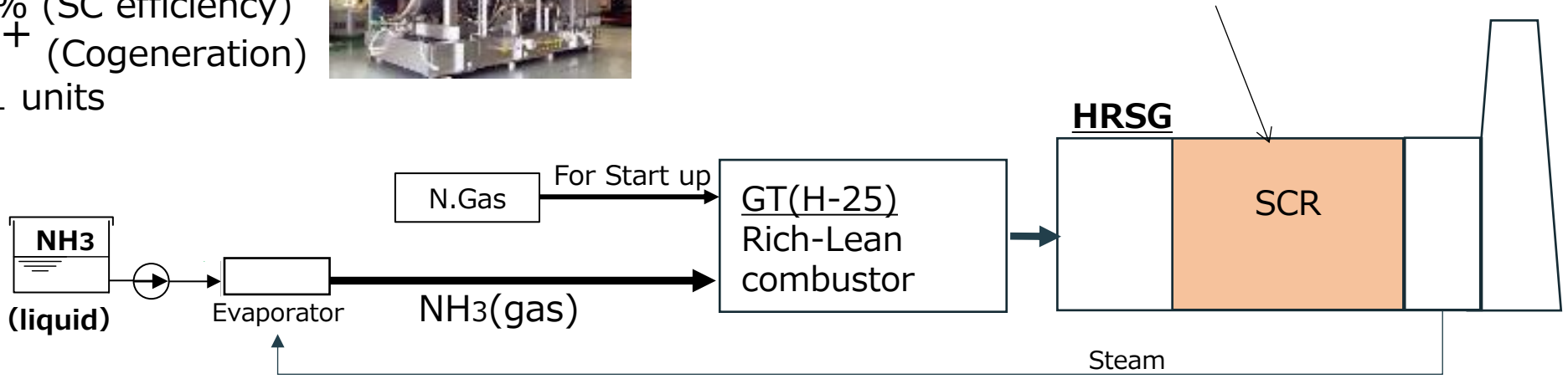
Solution
Rich/Lean Combustion



H25 Gas Turbine

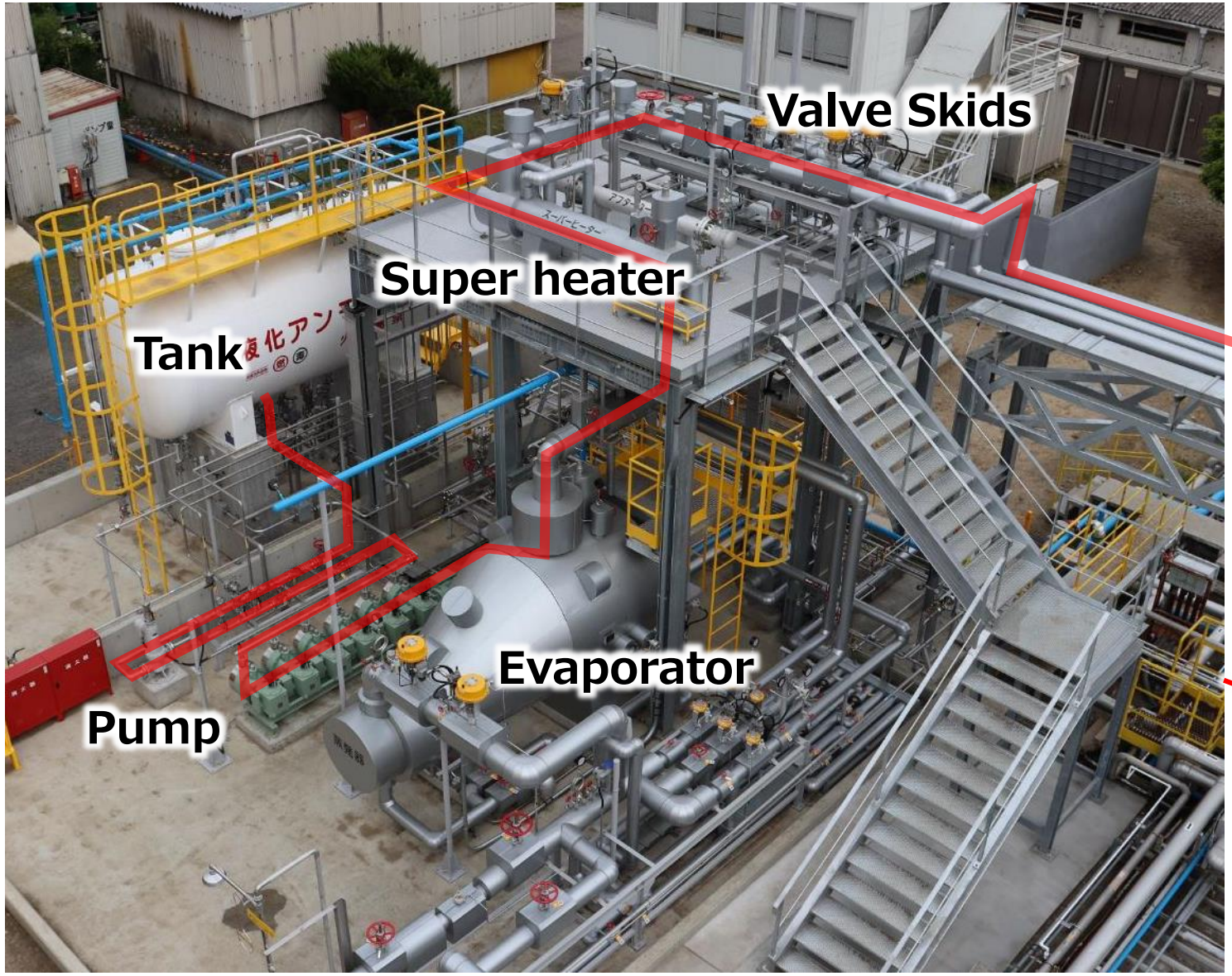
- 41MW (Output)
- 36.2% (SC efficiency)
  80%+ (Cogeneration)
- ~191 units

Ultra High efficiency SCR (Selective Catalytic Reduction) Required

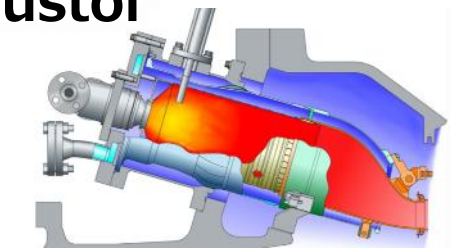


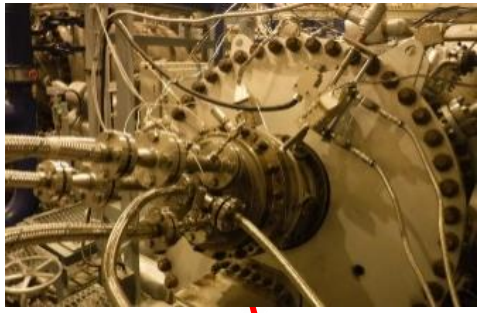
*This presentation is based on results obtained from a project commissioned by NEDO that is a government organization in Japan. (NEDO: New Energy and Industrial Technology Development Organization)

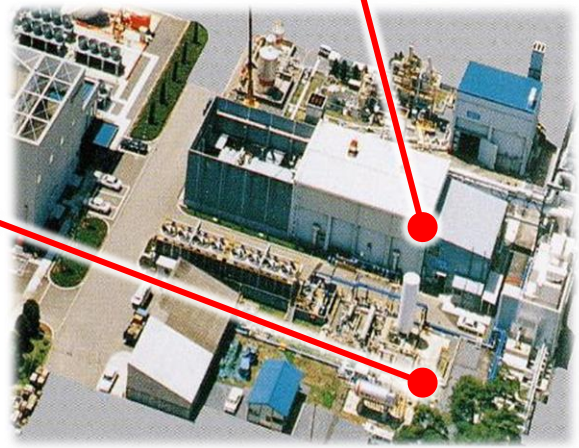
Overview of High-Pressure Ammonia Combustion Test Facility



Combustor







Katsuta GTD Overview

*; Gas Turbine Demonstration Facility

High Pressure Ammonia Combustion Facility at Katsuta

- Three hours continuous operation is possible with actual engine condition.
- 3 ton/h / 3.5MPa / 100ºC gas ammonia is supplied from 10 ton liquified ammonia tank through evaporator and heaters.

Liquid NH3 Tank (10ton)

100ºC/3.5MPa

N2

N2 Heater

Super Heater

100ºC/3.5MPa 3ton/h

Three Way Valve

Steam for piping heat tracing

H-25

Air Comp.

N.Gas

SCR

Safety Valves

H2O

Combustor

Stack

NH3 Redundant Removal Tank / Scrubber

NH3(Gas)

74ºC/3.5MPa

After Cooler

Steam

Transfer Pump

NH3 Evaporator

40ºC/2.1MPa

NH3(L)

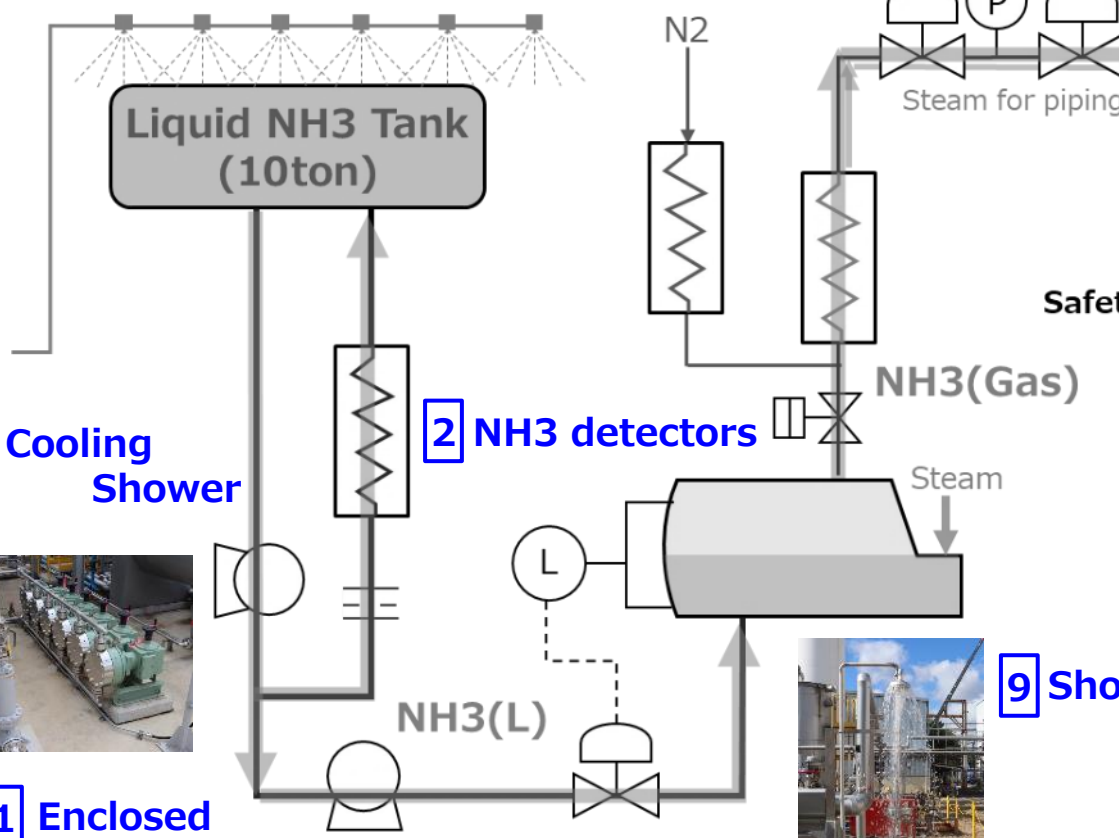
HP Pump

40ºC/3.8MPa

NH3 System Overview

Safety Measures for Ammonia

- Low leak risk devices, leak detection, removal equipment and catalyst applied in the system.
- Detail analysis of ground level NH3 concentration in entire cases of operation such as Lean Blow Out.
- Safety shower and suits



4 Leak Check Tube

5 Three Way Valve

7 SCR

6 NH3 Redundant Removal Tank / Scrubbers

3 Cooling Shower

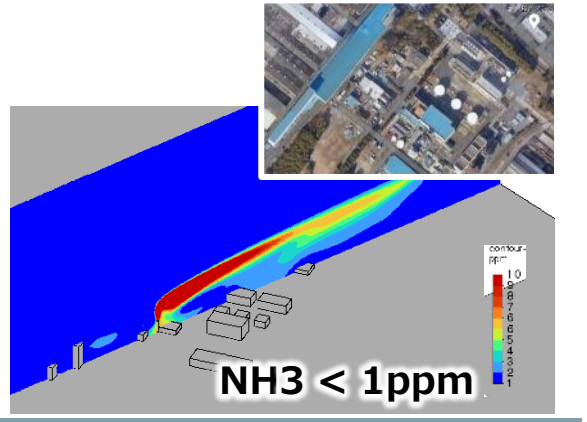
2 NH3 detectors

1 Enclosed Leakproof Pump

9 Shower / Eye Washer

10 Safety Suits

8 Detail CFD of Ground level NH3



Safety Consideration Summary

- Sensitivity to Ammonia by humans (*Source: National Laboratory of Medicine*):
  - 5 ppm – Odor detection
  - >30 ppm – Irritation to nose, eyes and throat
  - >80 ppm – Moderate to high intensity irritation
- The Katsuta Test Facility is located in an industrial complex with others working within close proximity and with residential properties within 1 km of the test rig
- **Objective:** Limit Ammonia emissions to < **1 ppm** at the test facility boundaries
- Safety provisions were enhanced during the testing sequences to control ammonia releases.

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