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Micro Gas Turbine Firing Ammonia

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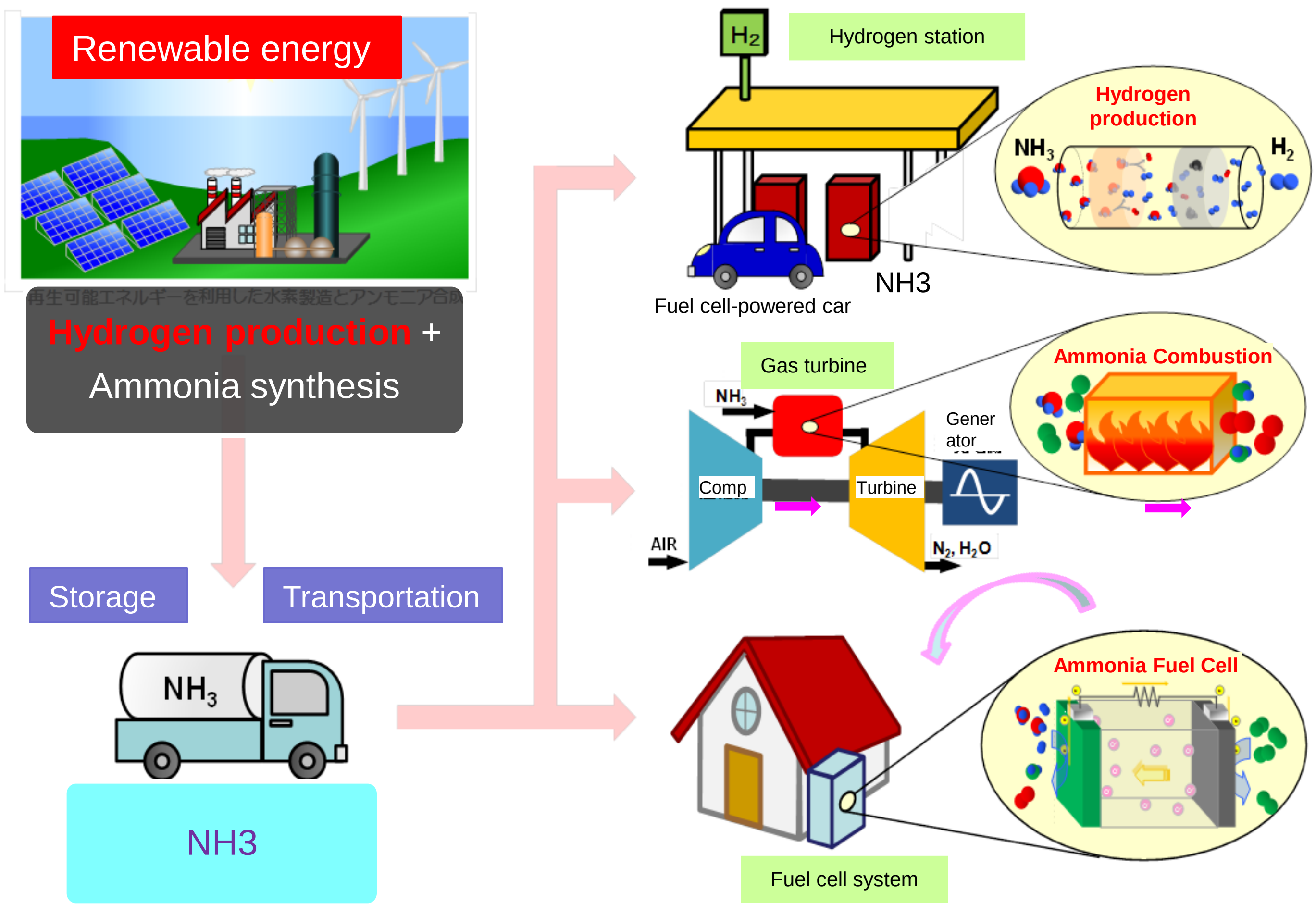
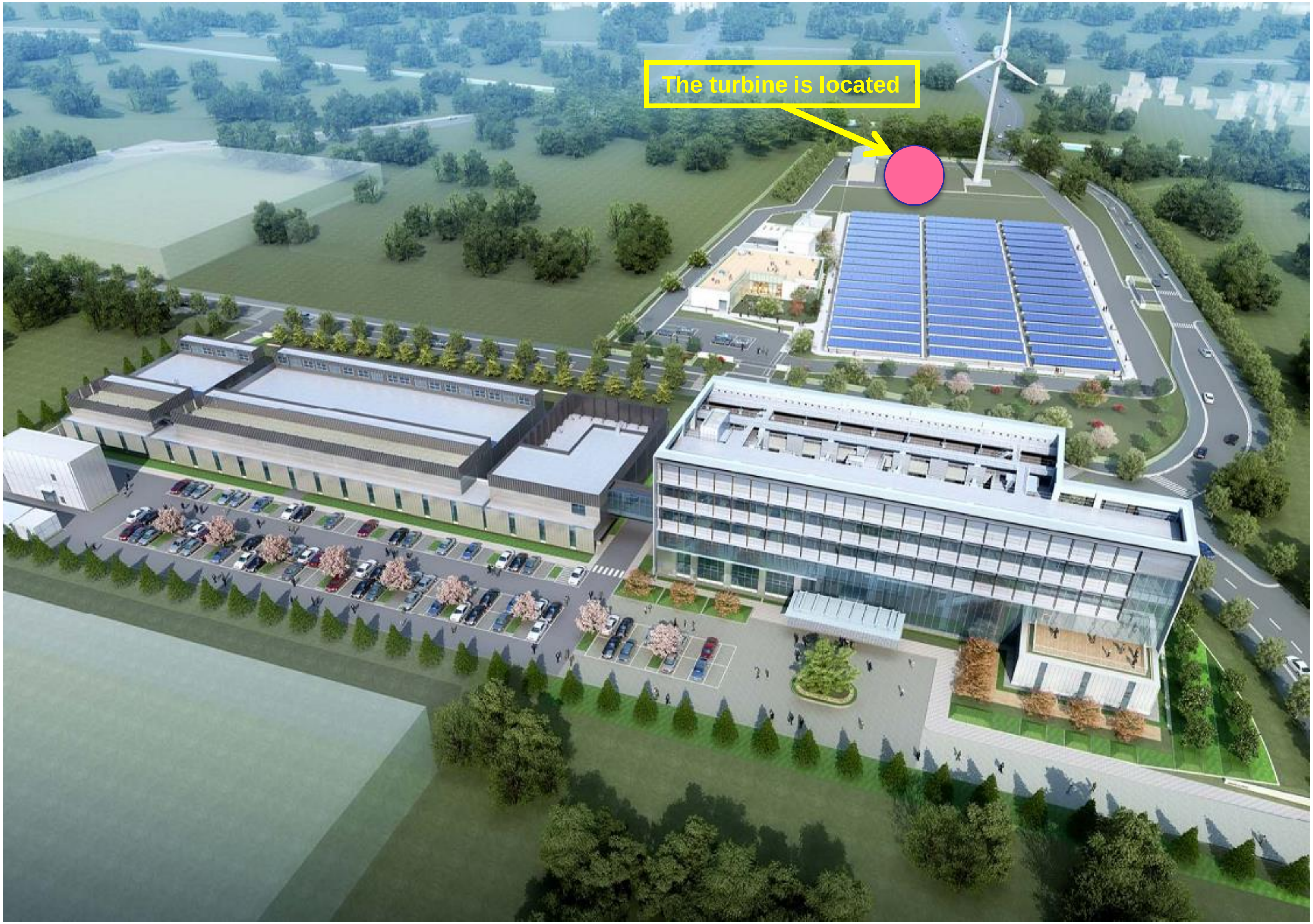
Contents

Image of NH3 Production and Use

- Japan starts the project of R&D focusing on energy carriers in 2013.
- Ammonia has become one of the attractive energy carriers.
- This project includes ammonia production and ammonia utilization.
- AIST has been responsible for the demonstration of gas turbine firing ammonia to show the potential of ammonia as a fuel.
- As the first step of the project, AIST tried to demonstrate a small gas turbine firing ammonia gas with kerosene to obtain the knowhow concerning to ammonia gas handling and combustion of ammonia.



Fukushima Renewable Energy Institute (FREA), AIST



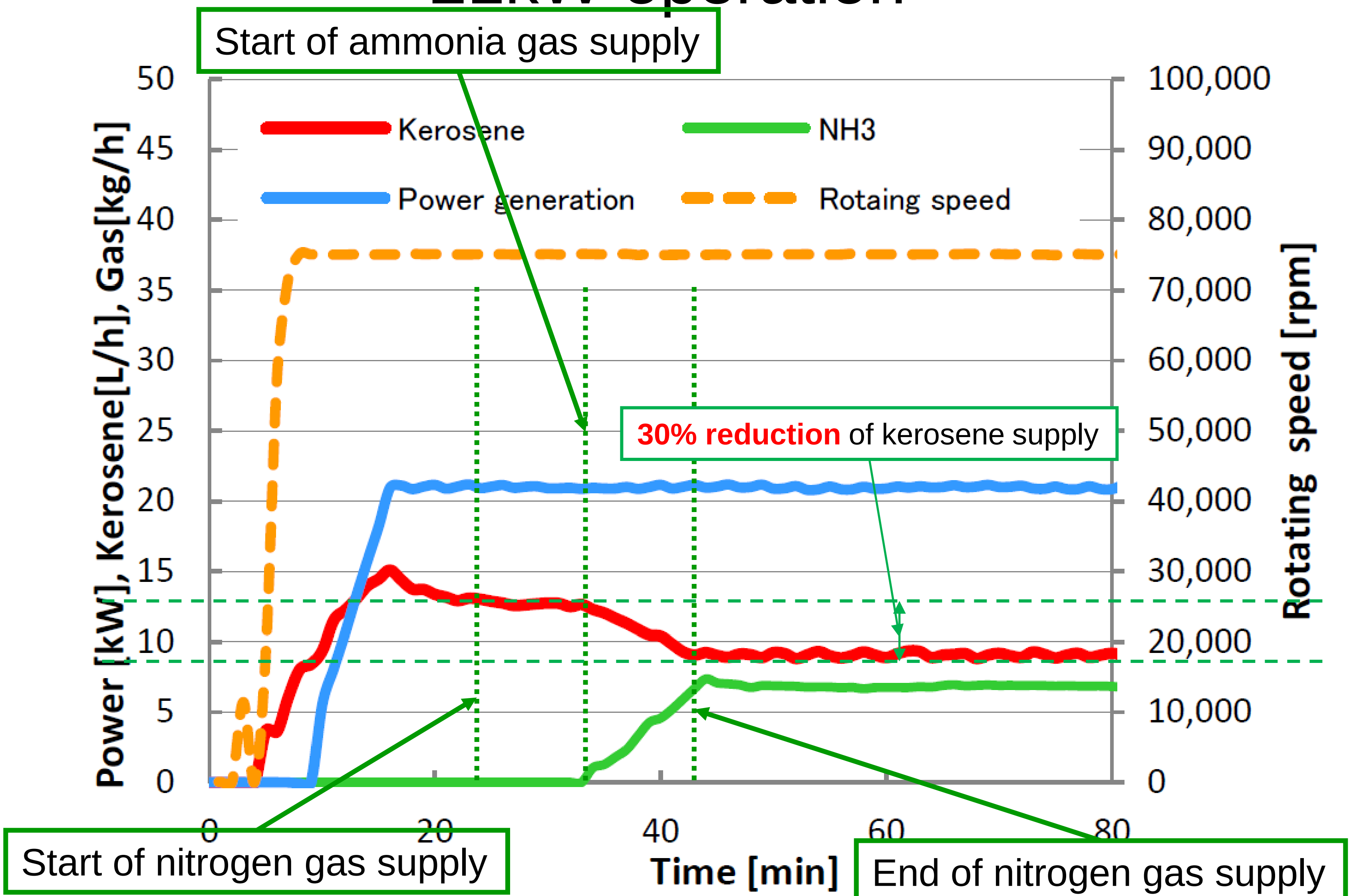
50kW class micro gas turbine set in FREA

50kW class micro gas turbine firing kerosene was remodeled for power generation firing ammonia.
A standard combustor is replaced with a prototype combustor which enables a bi-fuel supply of kerosene and ammonia gas.
Diffusion combustion is employed to the prototype combustor due to its flame stability.

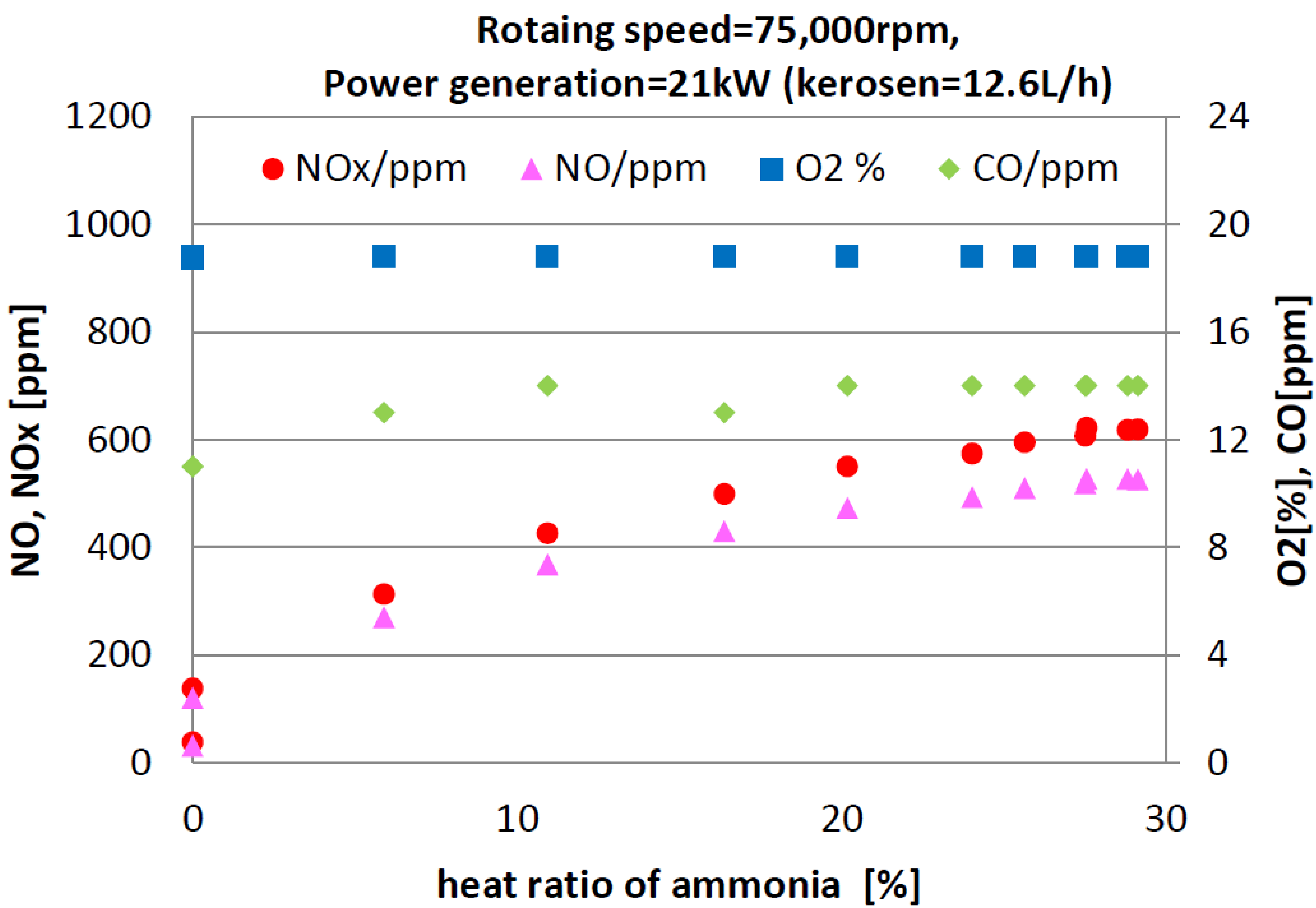
AIST previous work

- Micro gas turbine was remodeled to bi-fuel operation.
- 21kW power generation was achieved by co-firing kerosene – ammonia. 30% of kerosene supply was replaced to ammonia gas supply.
- About 600ppm of NOx is removed from exhaust gas by NOx removal equipment with proper ammonia gas supply.

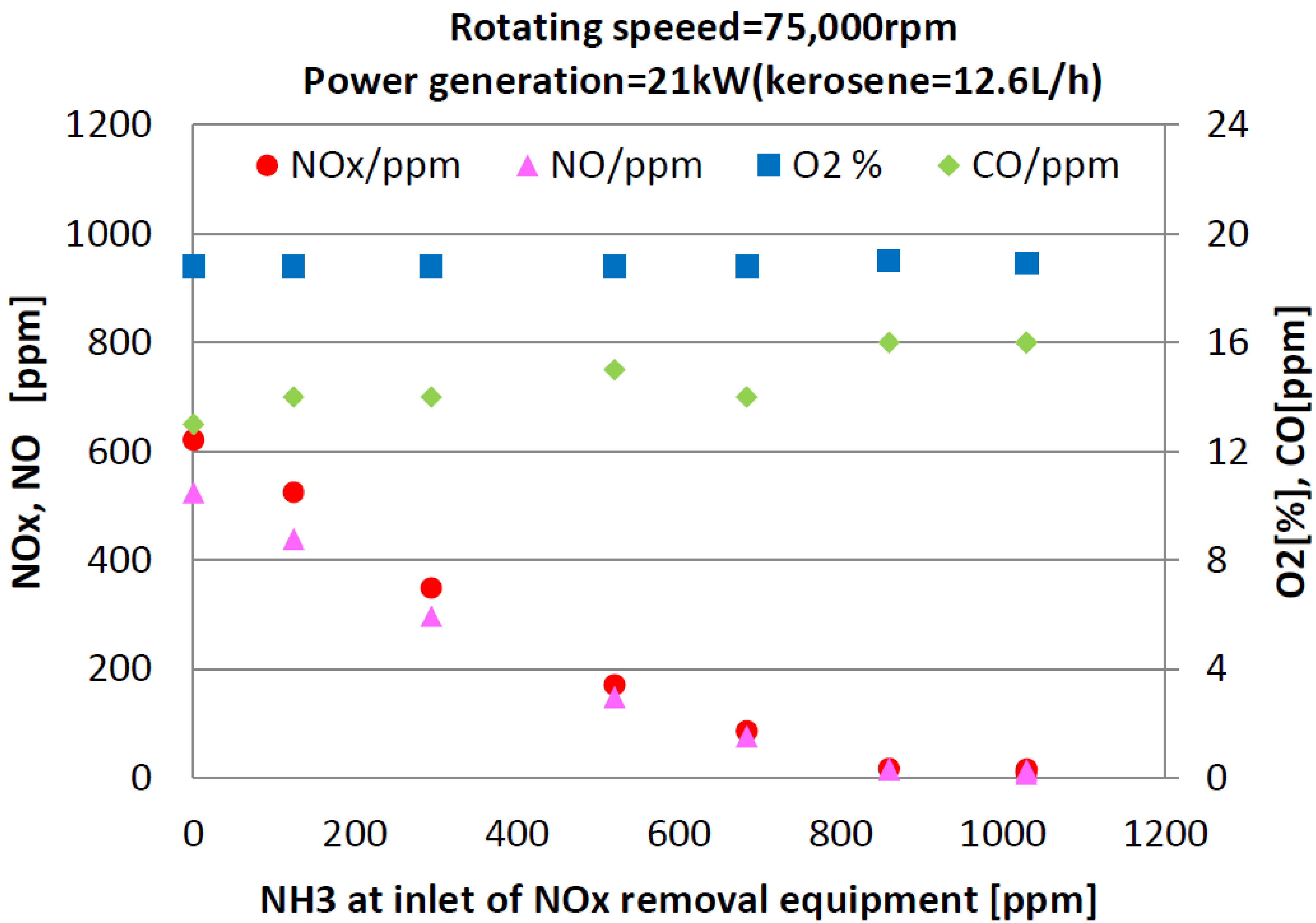
Co-firing Kerosene and Ammonia 21kW operation



Co-firing Kerosene and Ammonia Emission



Co-firing Kerosene and Ammonia NOx reduction



Present work

- Increasing the ratio of ammonia gas using small amount supply equipment of ammonia gas with 50kg cylinder.

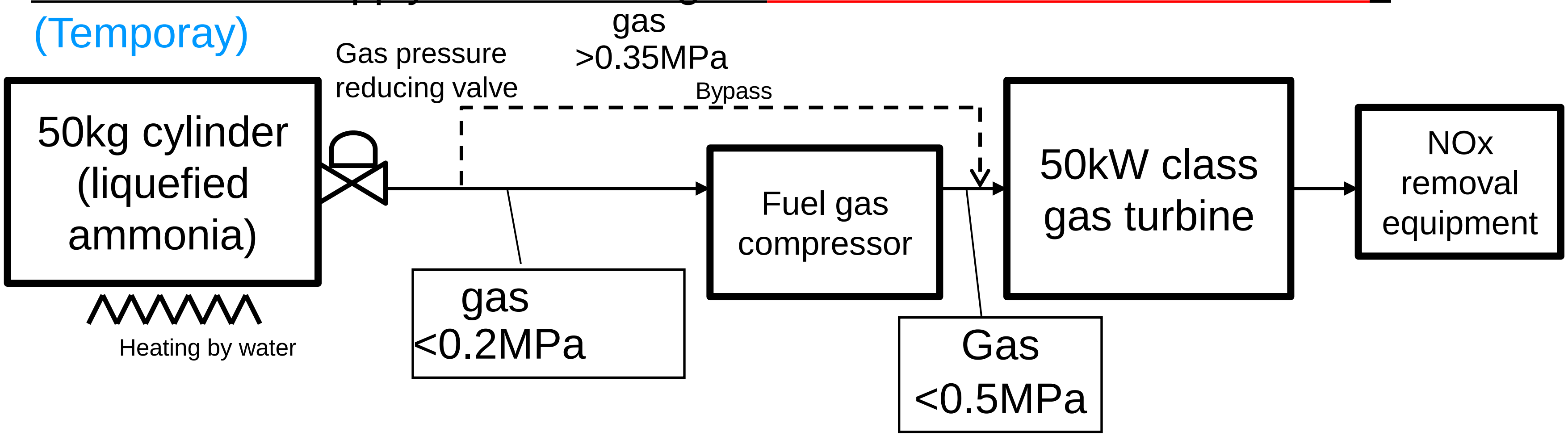
- Large amount supply equipment with 1ton cylinder is prepared.
- Methane gas supply equipment is prepared.
- Fuel control sequence was changed.

- Micro gas turbine operation firing ammonia was tried.
- Micro gas turbine operation firing methane and ammonia.

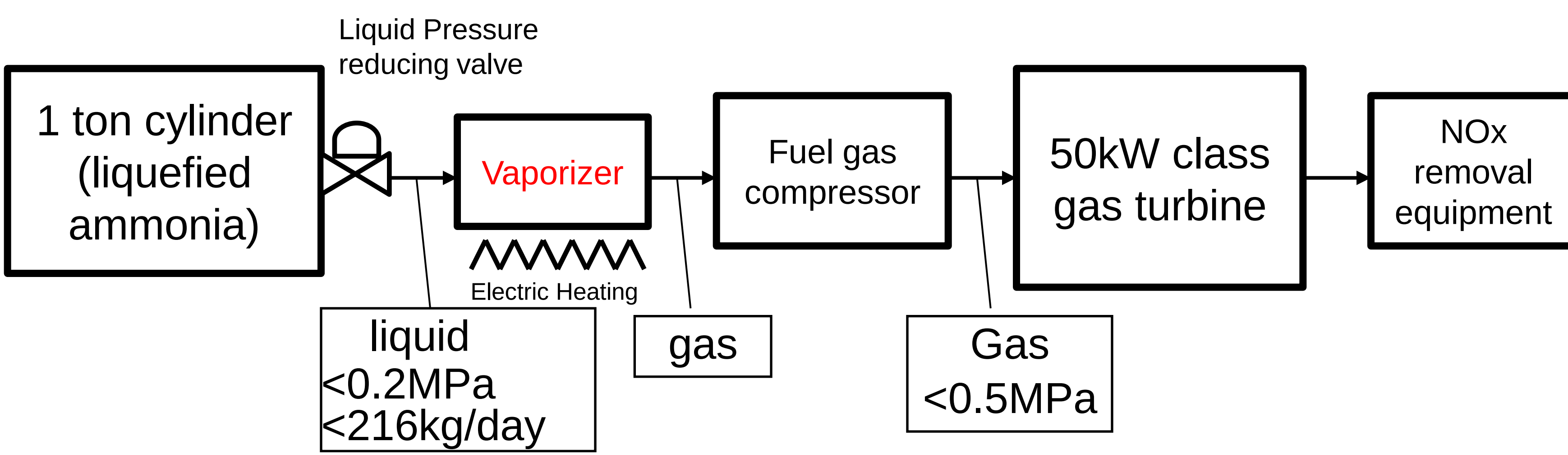
Contents

Ammonia Supply

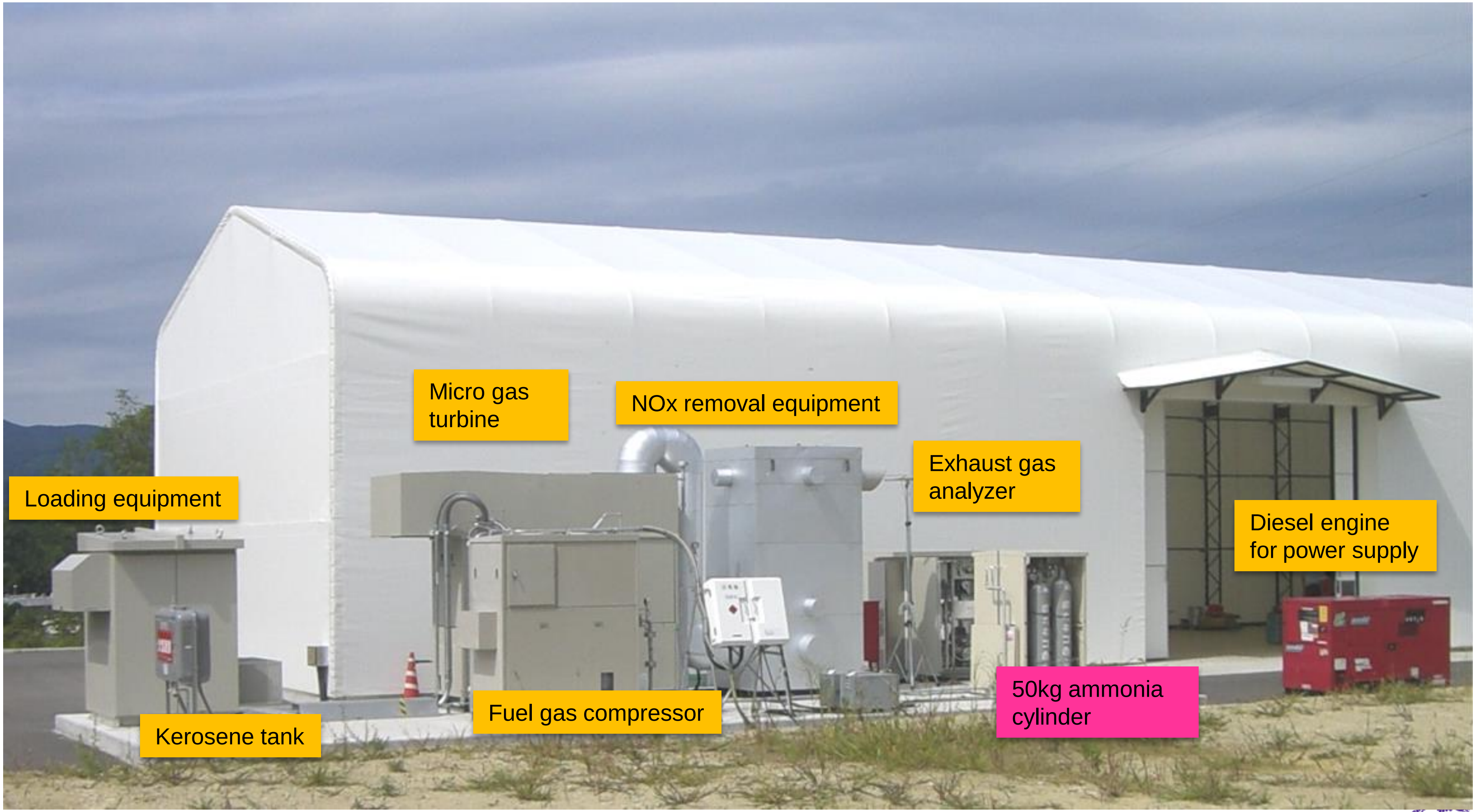
- Small amount supply of ammonia gas（Kerosene ammonia combustion）(Temporay)



- Large amount supply of ammonia liquid and vaporizer（Ammonia combustion）

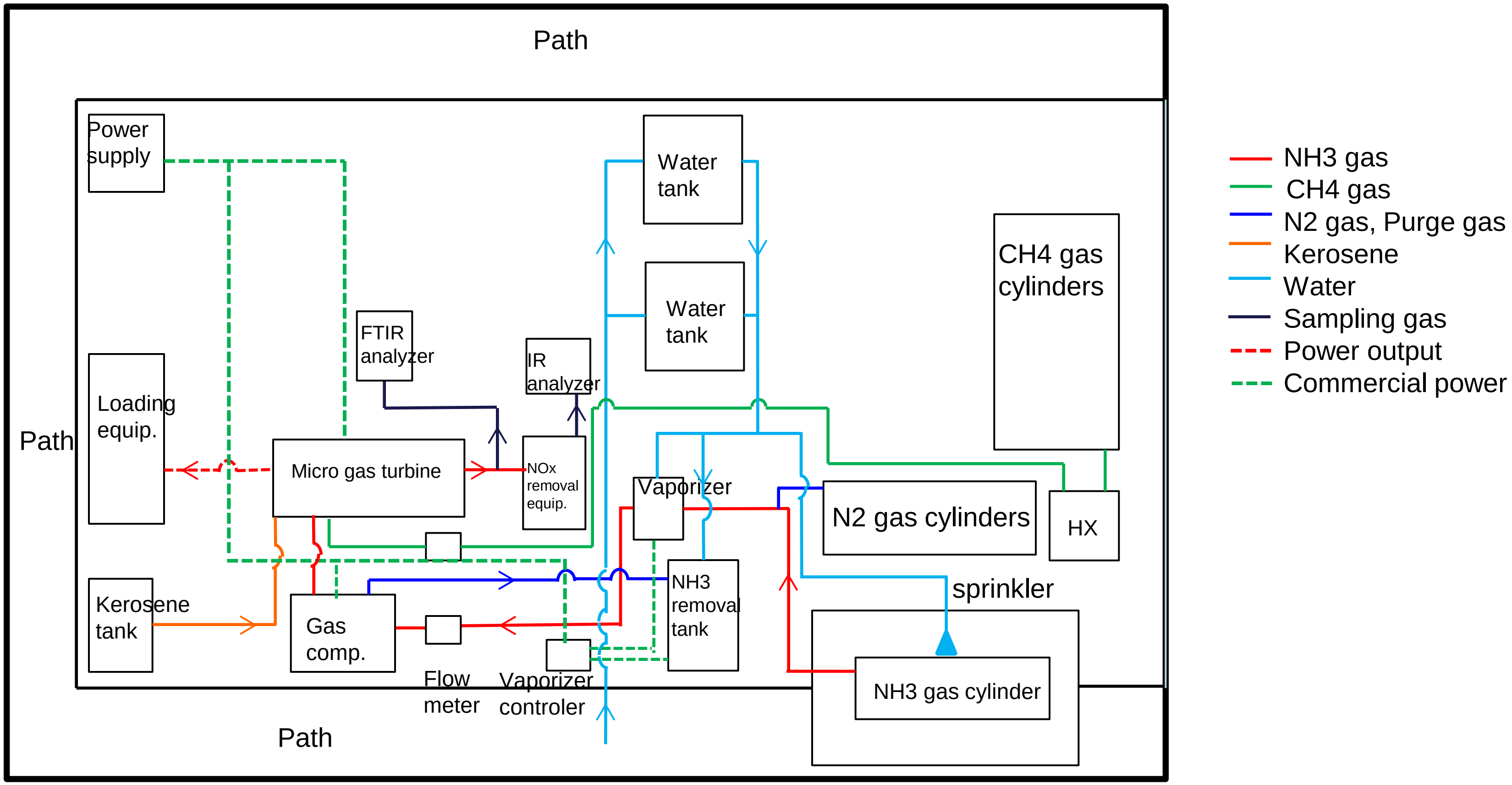


Test facilities for micro gas turbine power generation with small amount ammonia gas supply (50kg cylinder)



Test facilities for micro gas turbine power generation with large amount ammonia gas supply(1 ton cylinder)

Layout drawing of a test facilities for micro gas power generation

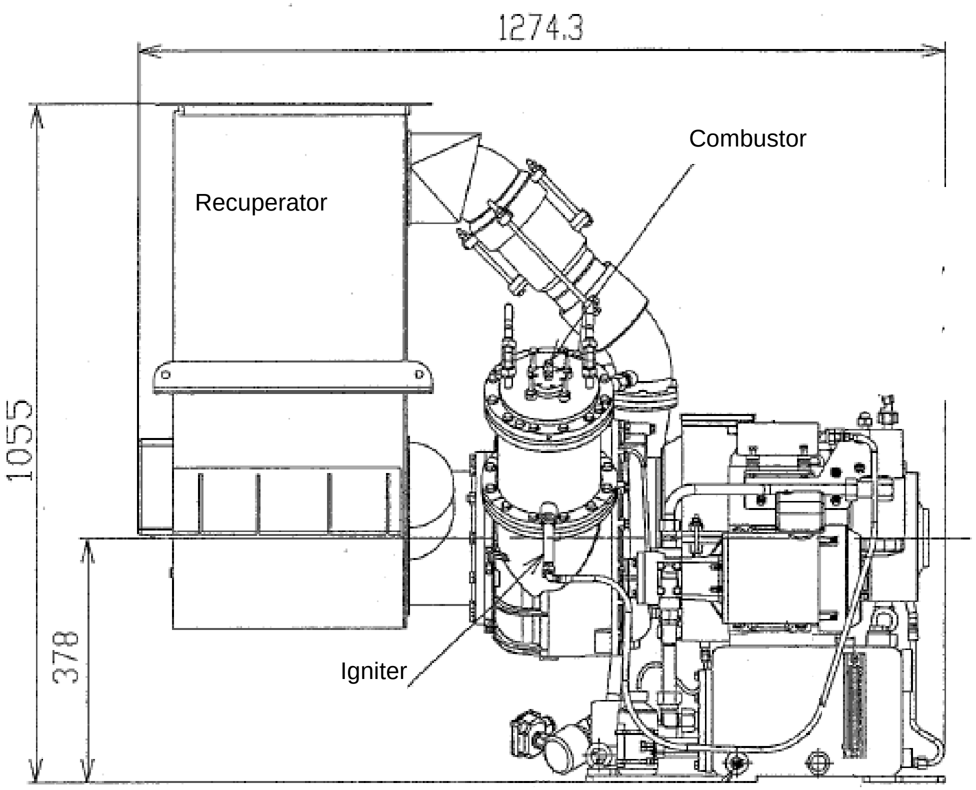


Test facilities for micro gas turbine power generation

scale —— 1000

Base Micro Gas Turbine

- A 50kW class micro gas turbine was selected as the base engine of ammonia fueled gas turbine.
- This gas turbine was made by TOYOTA TURBINE AND SYSTEMS INC (TTS).

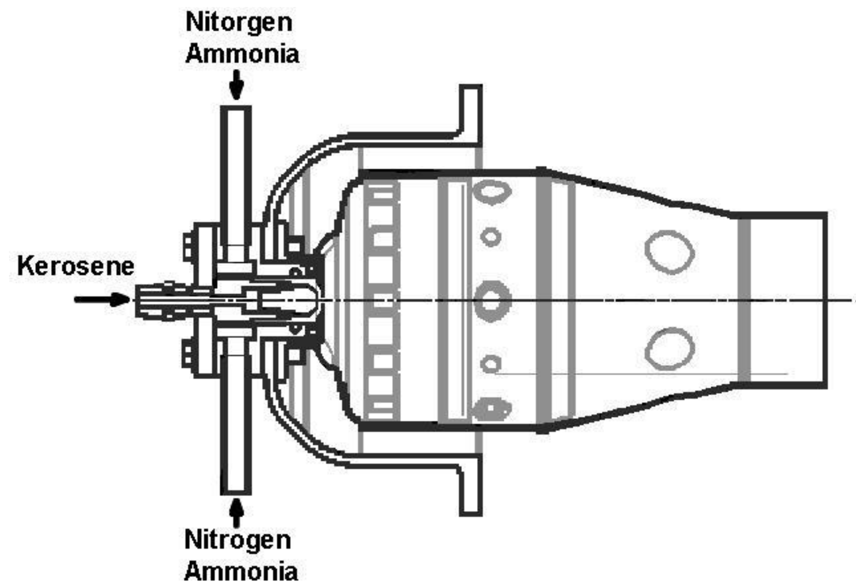


Specification of base micro gas turbine

Manufacturer	Toyota Turbine and System Inc. (TTS)
Cycle	Regenerative cycle
Shaft	Single shaft
Compressor	Centrifugal one-stage
Turbine	Radial one-stage
Rotating Speed	80,000rpm
Electric Power Output	50kW
Fuel	Kerosene
Combustor	Single can, Diffusion combustion

Micro Gas Turbine Firing Ammonia

- The standard combustor is replaced by a prototype combustor.
- Diffusion combustion is employed in the prototype combustor due to its flame stability.
- Prototype combustor is designed for bi-fuel operation of kerosene and ammonia gas fuel.
- An electric fuel controller is also remodeled.
- A conventional swirl injector for kerosene is set in the center of the combustor inlet.
- Ammonia gas is supplied from 12 holes outside of the kerosene injector.



Ammonia combustor
(prototype bi-fuel combustor)

Combustor operation sequence

Kerosene-NH_3 combustion (50kg cylinder)	
Procedure	Fuel
Start-up	Kerosene
Increasing electric output	Kerosene
Opening fuel gas valve	Kerosene (+N_2)
Starting NH_3 supply	Kerosene (+N_2)+NH_3
Stopping N_2 supply	Kerosene +NH_3

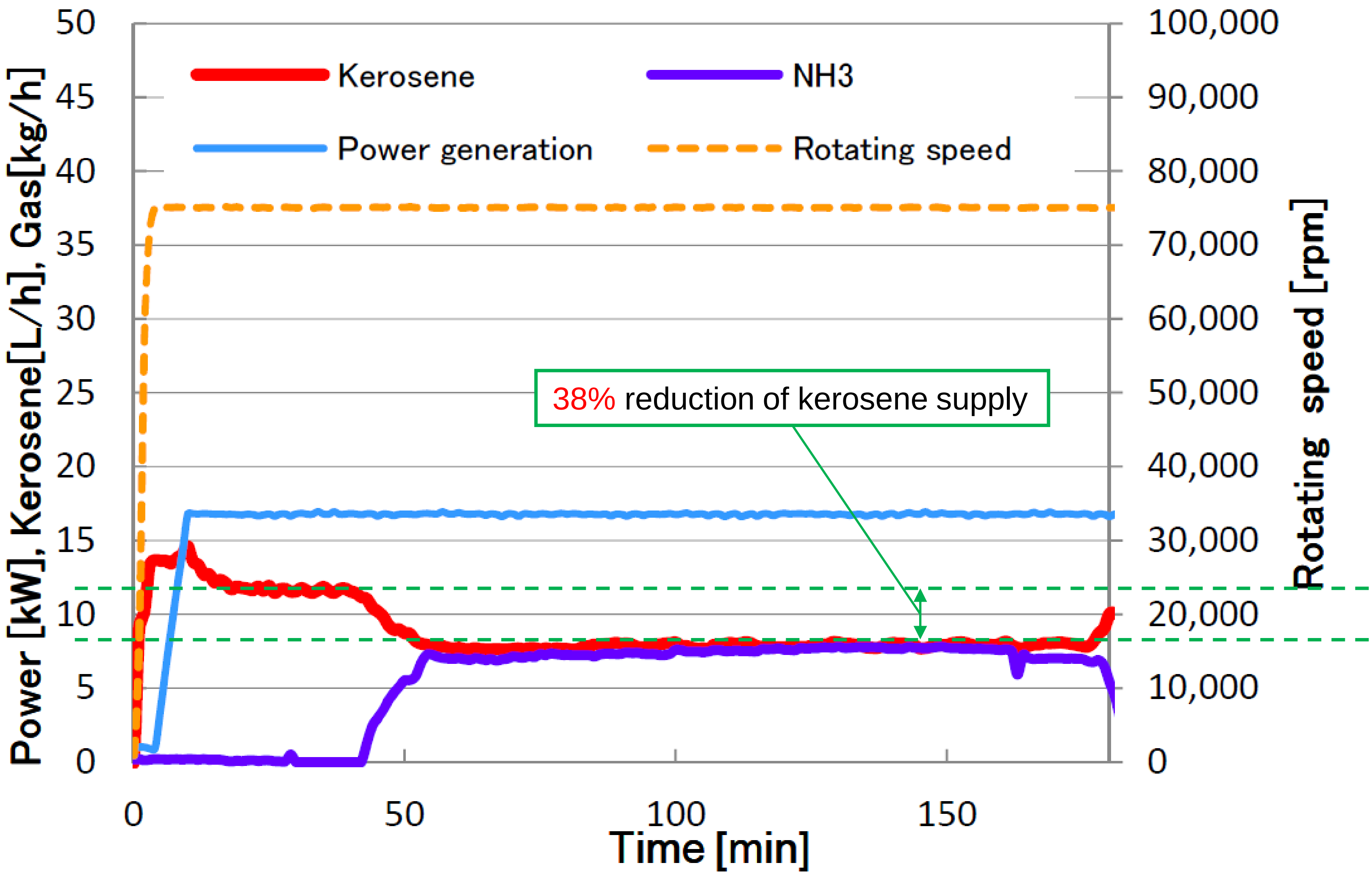
CH_4-NH_3 combustion	
Procedure	Fuel
Start-up	Kerosene
Increasing electric output	Kerosene
Opening fuel gas valve	Kerosene +CH_4
Stopping Kerosene supply	CH_4
Starting NH_3 supply	CH_4+NH_3

NH_3 combustion	
Procedure	Fuel
Start-up	Kerosene
Increasing electric output	Kerosene
Opening fuel gas valve	Kerosene +NH_3
Stopping Kerosene supply	CH_4

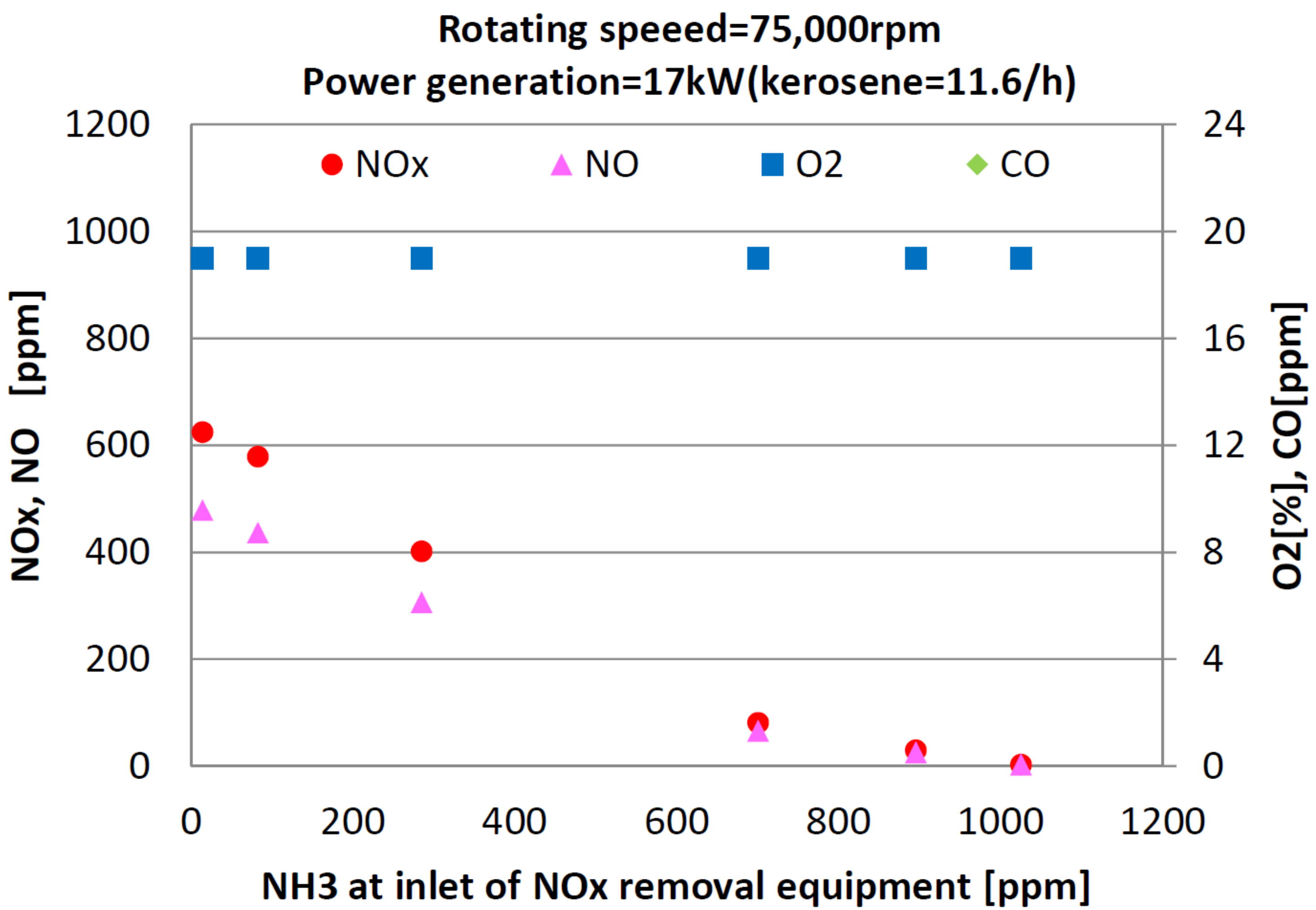
Contents

Result 1
Kerosene – Ammonia combustion with small amount ammonia gas supply (50kg cylinder)

Kerosene-Ammonia combustion (17kW operation)

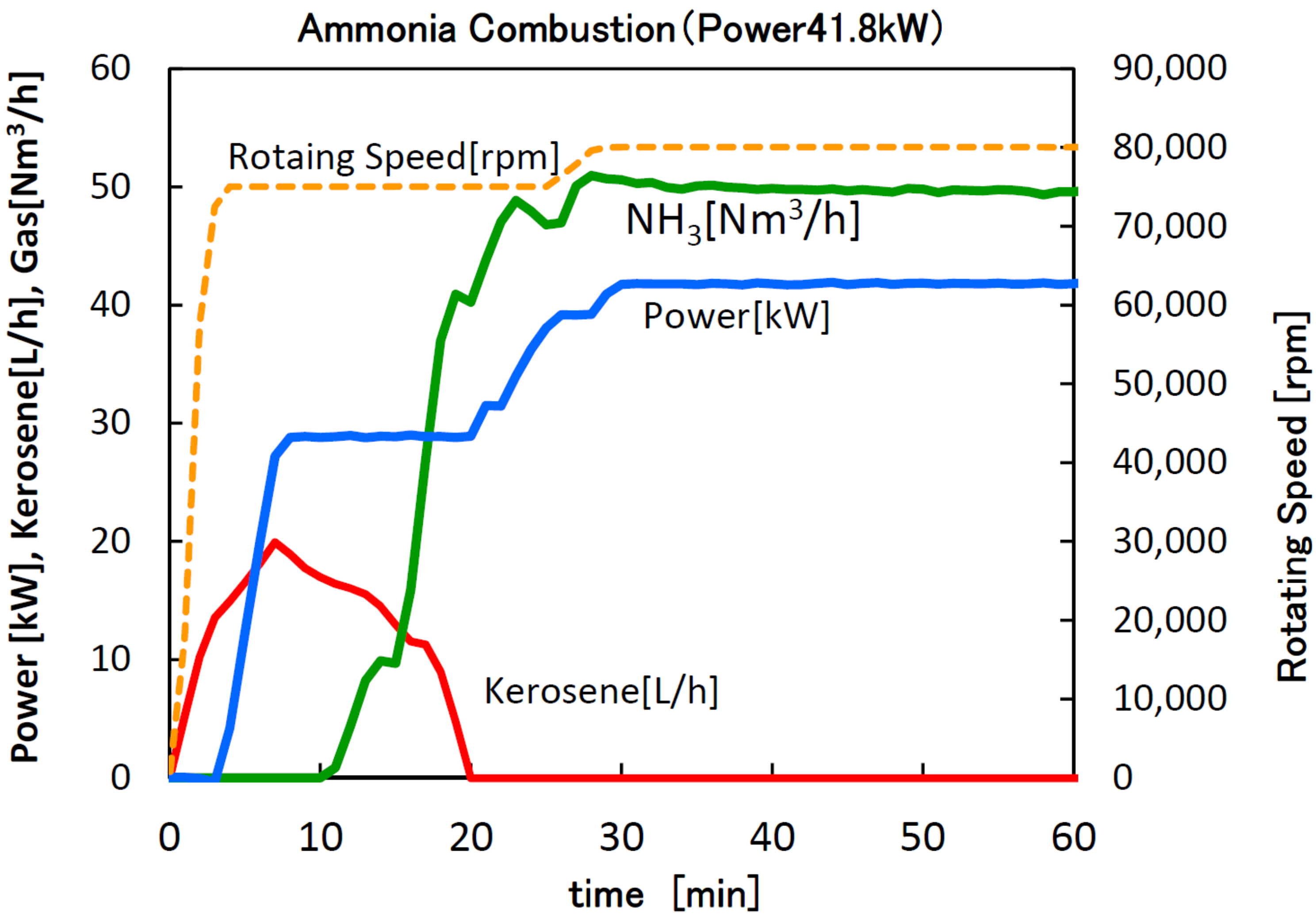


Exhaust gas concentrations after NOx reduction (Kerosene ammonia combustion)

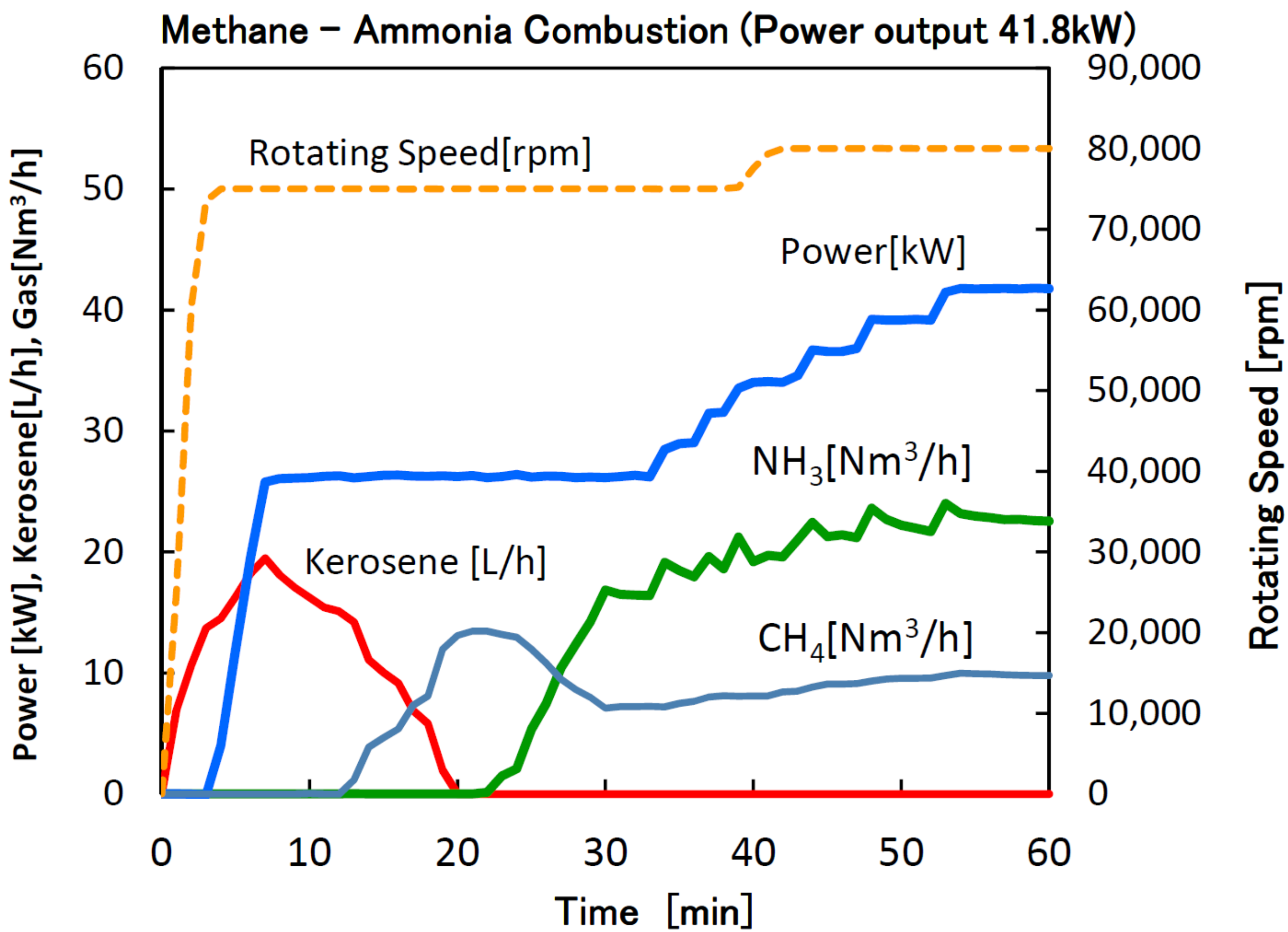


Result 2
Ammonia, Methane-Ammonia combustion with large amount ammonia gas supply (1ton cylinder)

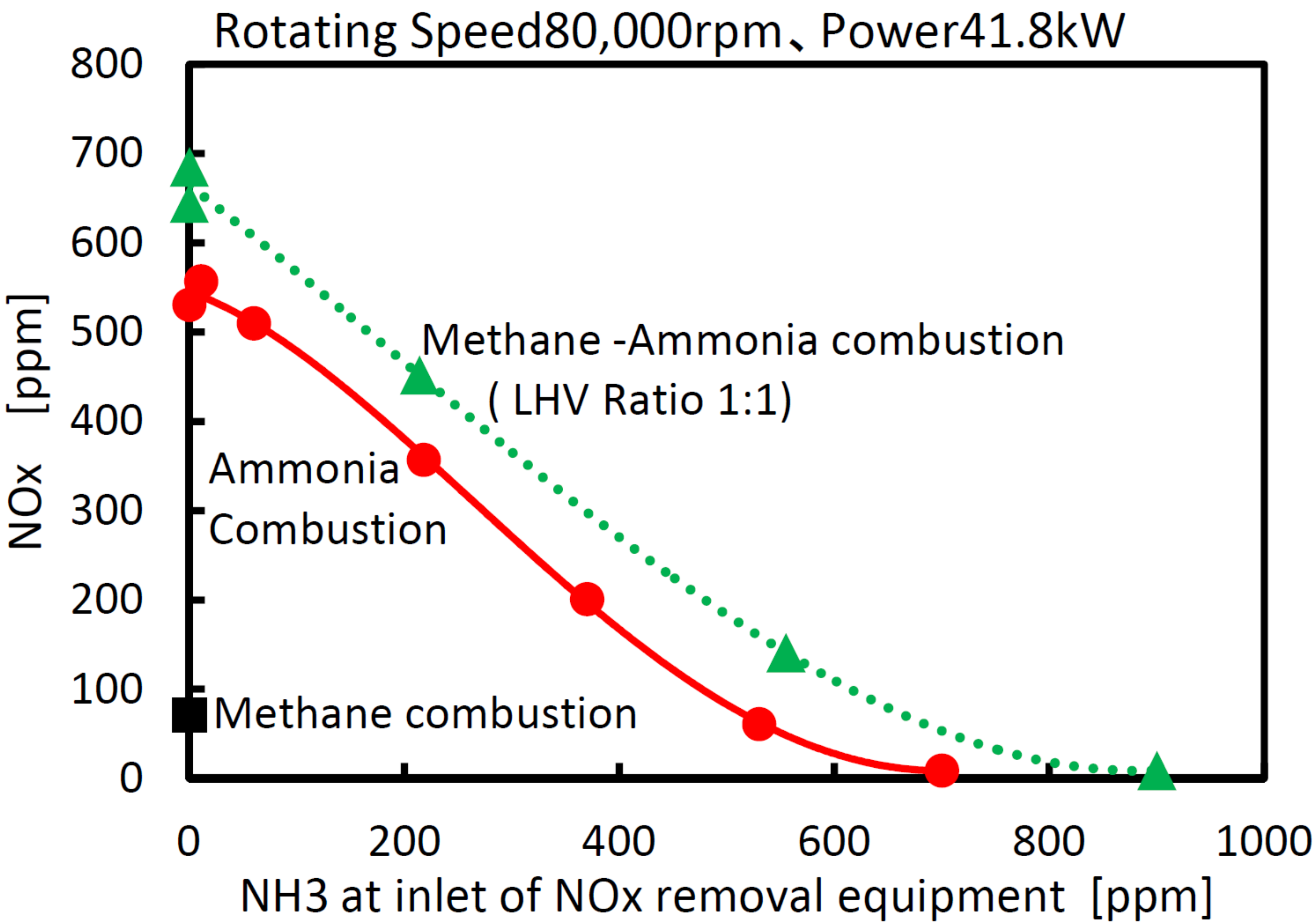
100% Ammonia Combustion



Co-firing Methane and Ammonia (LHV ratio 1:1) 41.8kW operation



NOx Emission



Contents

Future task

Near future

- Increasing of power generation
- Flame observation under the operation

Future task and under planning

- Flame observation and measurement with a combustor test rig
- Modification of combustor (fuel injector, combustor linear, etc.)
- Development of low NOx combustor
- Starting up of a gas turbine firing methane or natural gas

Contents

Summary

50kW class micro gas turbine firing kerosene was remodeled for power generation firing ammonia.

A standard combustor is replaced with a prototype combustor which enables a bi-fuel supply of kerosene and gas fuel.

[Small amount NH_3 Supply]

- 17kW power generation co-firing kerosene and ammonia was achieved with 38% reduction of kerosene supply by supplying ammonia gas.

[Large amount NH_3 Supply]

- Large amount ammonia supply was achieved with 1ton gas cylinder.
- 41.8kW power generation firing ammonia gas was achieved.
- 41.8kW power generation co-firing of methane and ammonia gas was achieved.
- Although NOx concentration in the exhaust gas of ammonia combustion exceeded 600ppm, NOx removal equipment can reduce NOx concentration below 10ppm.

Acknowledgement

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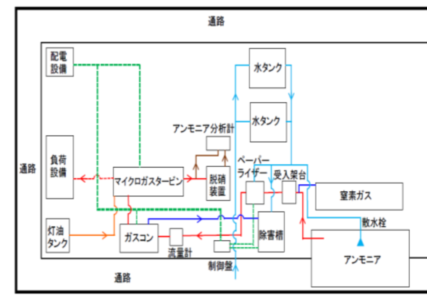
- The authors also thank to Professor Kobashashi, Tohoku University, and “Toyota Turbine and Systems Inc.” for the advice on the combustion technology and the operation of micro gas turbine.

Thank you for your attention !!

火気厳禁
TTS



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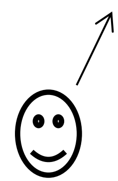
水タンク
水タンク
アンモニア分析計
通路
負荷設備
マイクロガスタービン
脱硝装置
ベーパーライザー
受入架台
窒素ガス
散水栓
灯油タンク
ガスコン
流量計
除害槽
制御盤
アンモニア
通路



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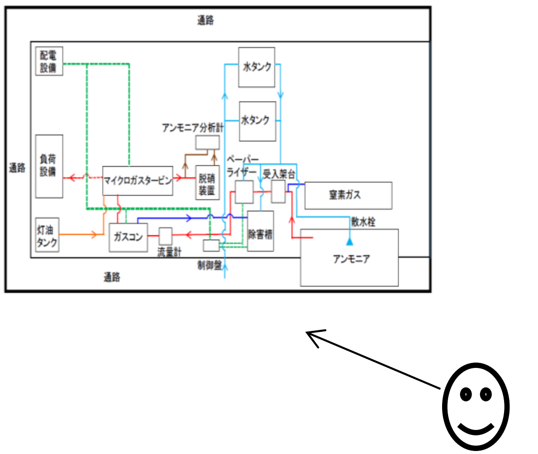
液化アンモニア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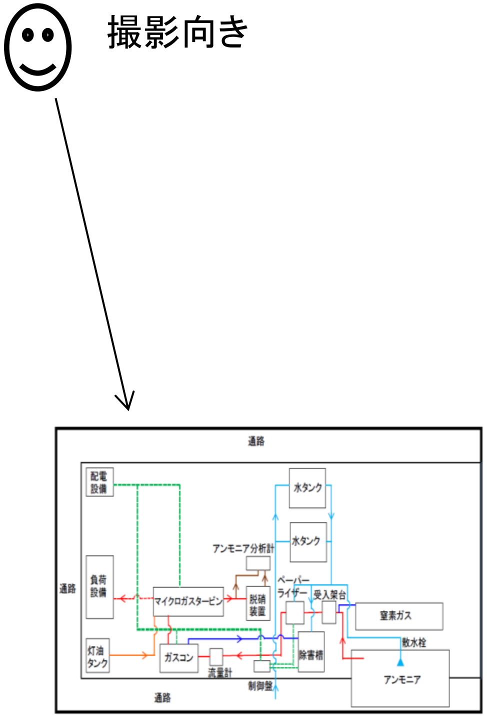
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除害槽
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アンモニア
通路

Temporary facilities for ammonia gas fuel supply

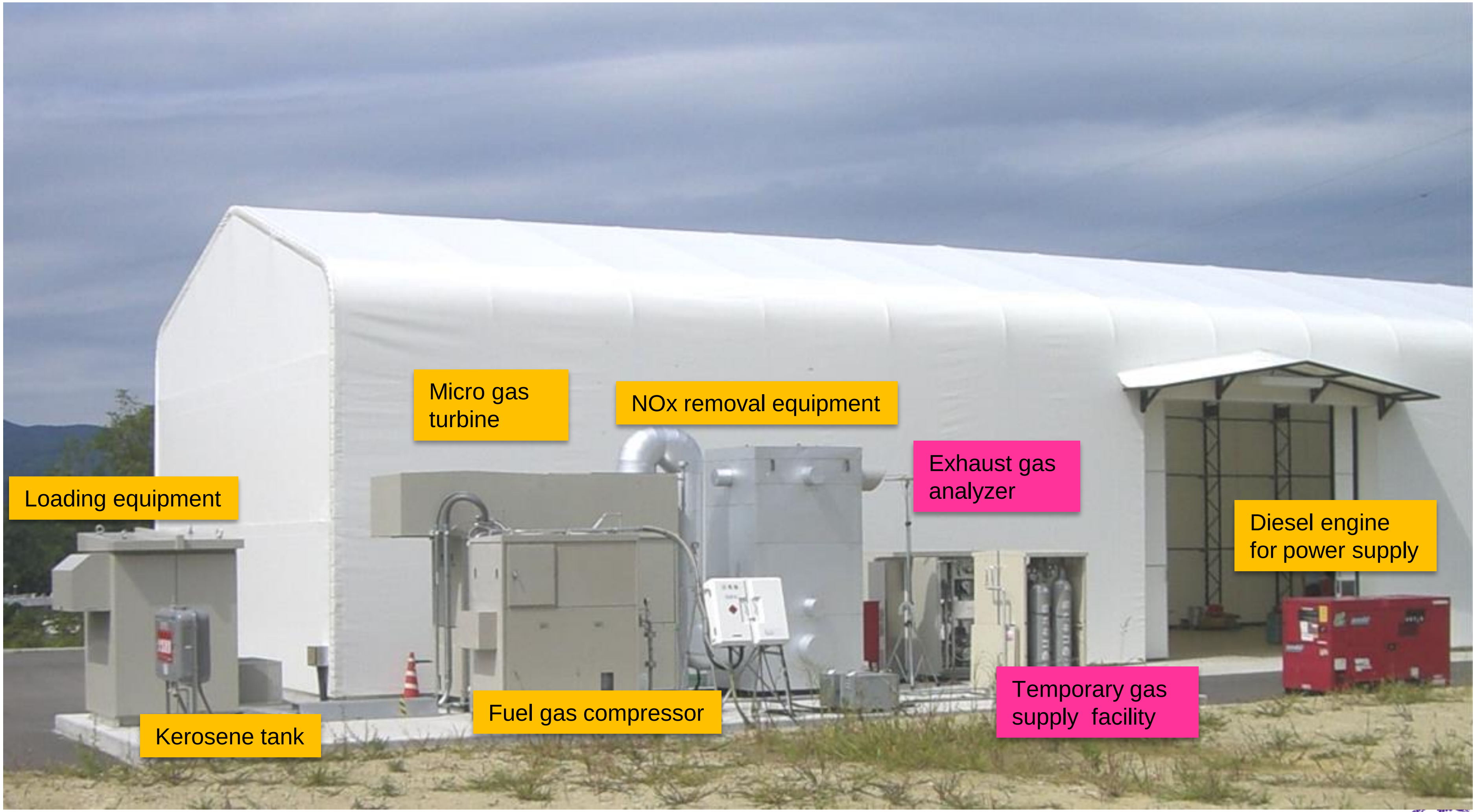
Fuel gas compressor

NOx removal equipment

Micro Gas turbine

Gas bomb storage
(Nitrogen, Ammonia)

Test facilities for micro gas turbine power generation with temporary gas supply facility



Exchange of Combustor

Micro gas turbine

Removed standard combustor
for kerosene

Installation of the prototype
combustor for ammonia

The prototype
combustor for ammonia

Co-firing Kerosene and Ammonia (1)
25kW operation