2050 IERE-TPC Taipei Net-Zero Workshop

Development status of ammonia combustion technology for thermal power generation facilities

27th May. 2025

IHI Corporation

Carbon Solution Business Unit
Resources, Energy & Environment Business Area

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1.(1) Purpose of Demonstration Test

- To understand the overall plant characteristics and constraints etc. under 20% ammonia firing, and to identify issues for commercialization.
- To establish ammonia combustion technology.

NEDO Subsidized Project【JPNP16002】

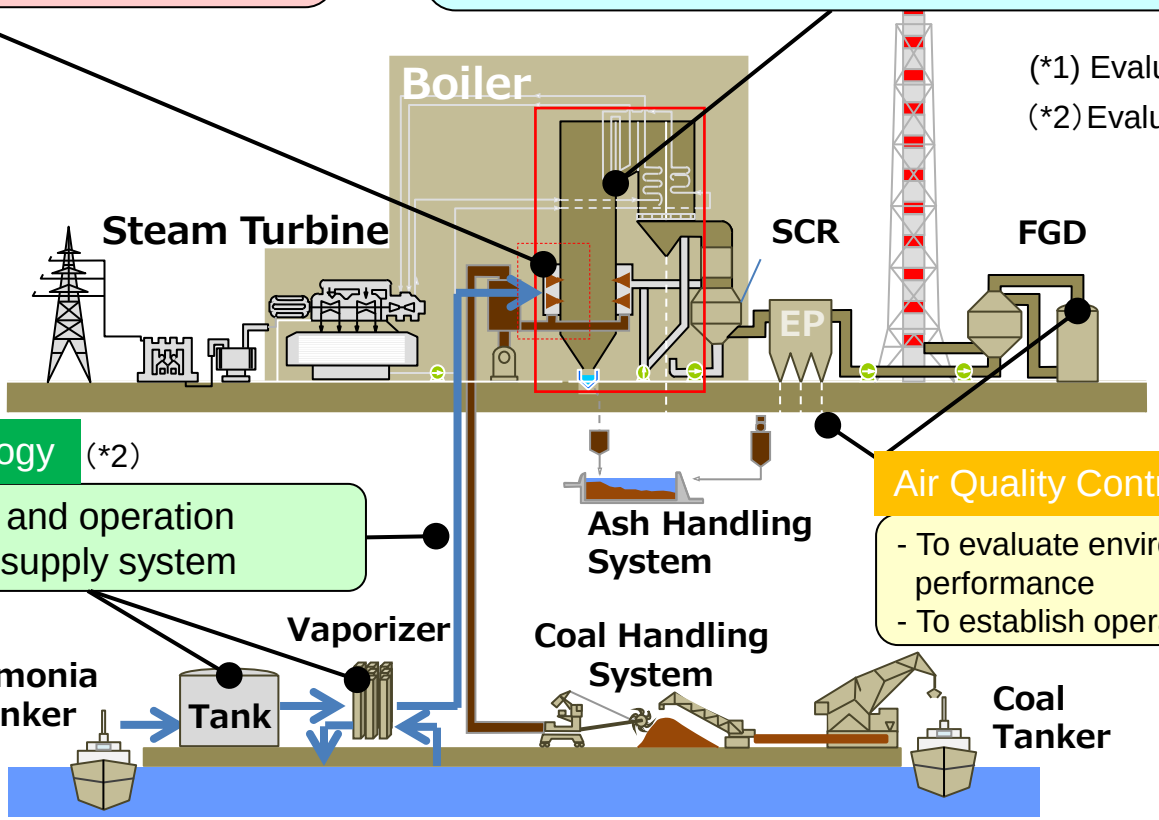
Combustion Technology (*1)

- To establish specifications and operation procedure for burners and related equipment
- To understand combustion characteristics

Plant Performance (*1)

- To evaluate boiler performance
- To evaluate auxiliary equipment performance
- To establish operation procedure

(*1) Evaluated by IHI/JERA
(*2) Evaluated by JERA



Supply Equipment Technology (*2)

- To establish specifications and operation procedure for the ammonia supply system

Air Quality Control System (*2)

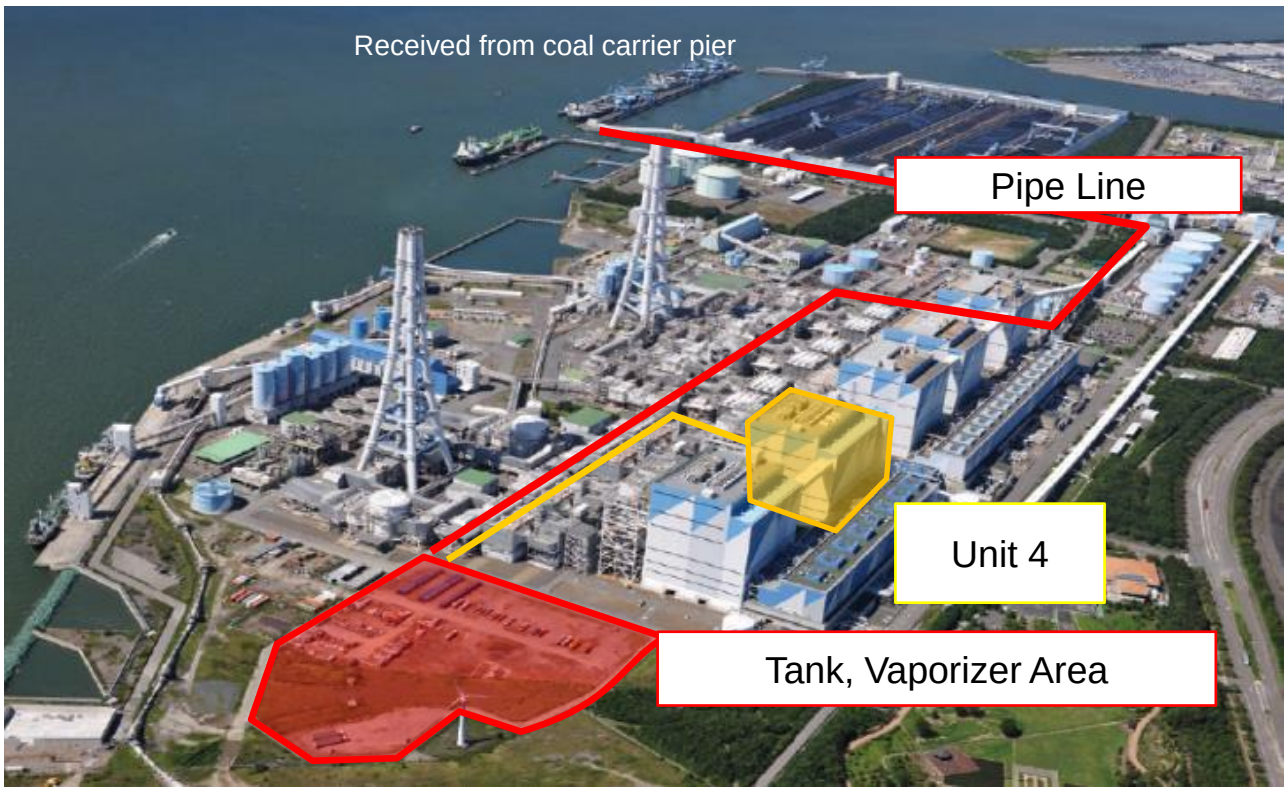
- To evaluate environmental equipment performance
- To establish operation procedure

1.(2) Demonstration Test Equipment

■ Demonstration Test Organization and Test Equipment

- Conductors： JERA Co., Inc., IHI Corporation
- Test Unit： Hekinan Thermal Power Station, Unit 4 (1,000 MW)
- Test Period： From April 1 to June 26, 2024

  Stable operation of 20% ammonia firing had been achieved on April 10

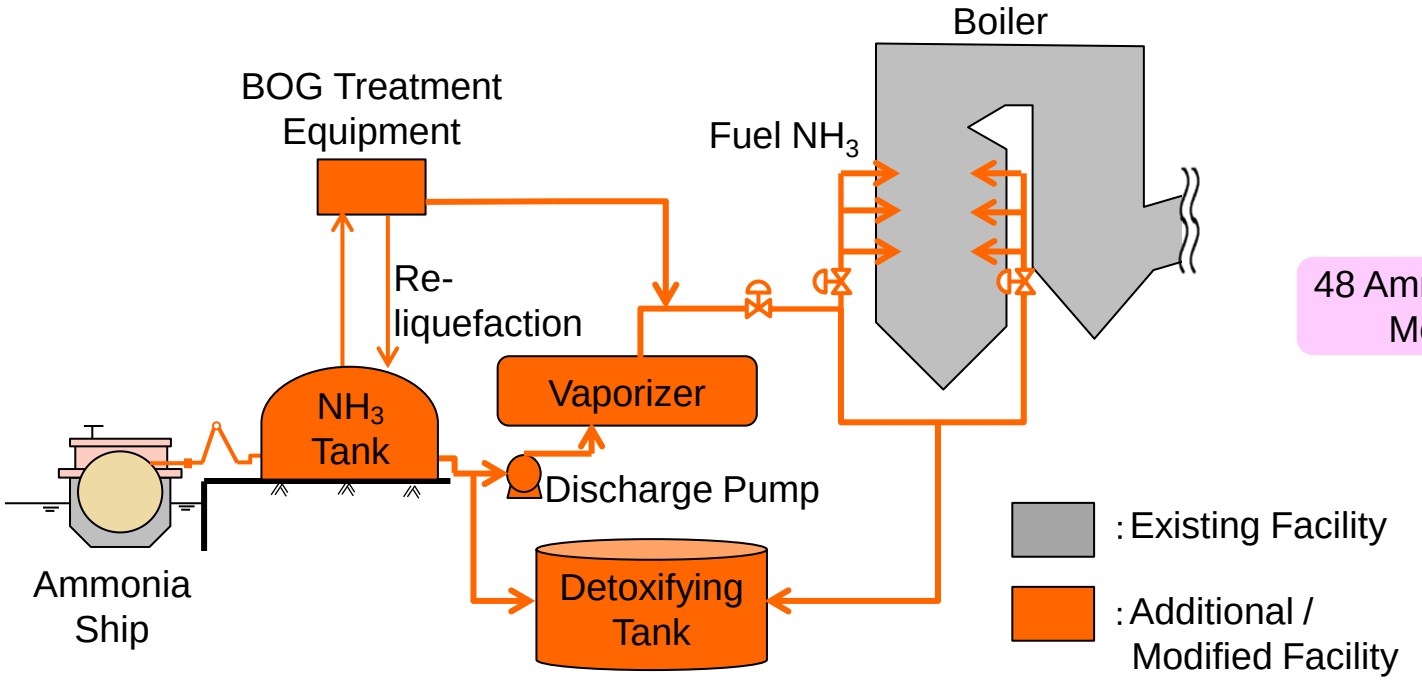


Overview of Hekinan Thermal Power Station and Schematic Diagram of Ammonia Supply System
(Provided by JERA Co., Inc.)

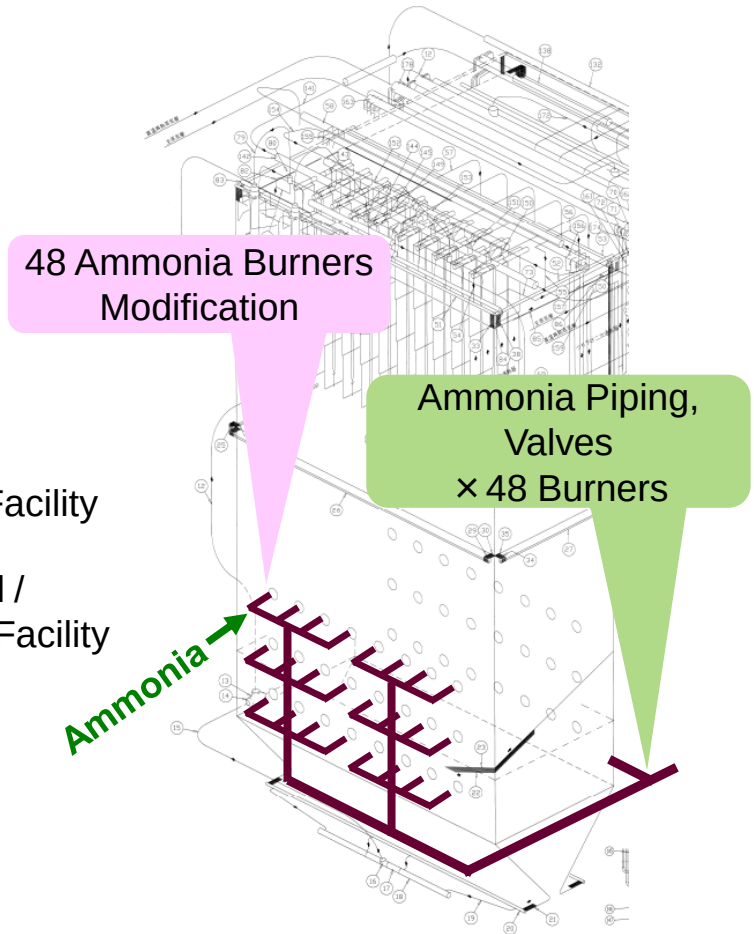
1.(3) Ammonia Firing Demonstration Facility

■ Overview of Demonstration Test Equipment

【 Ammonia Receiving and Supply Equipment (JERA Scope) 】



【 Boiler Modification (IHI Scope)】



Overview of Ammonia Supply System
(Provided by JERA Co., Inc.)

1.(3) Ammonia Firing Demonstration Facility

■ 20% Ammonia Firing Burner

NH_3 Burner Nozzle： **Inject ammonia into reducing and high temperature zone in the flame**

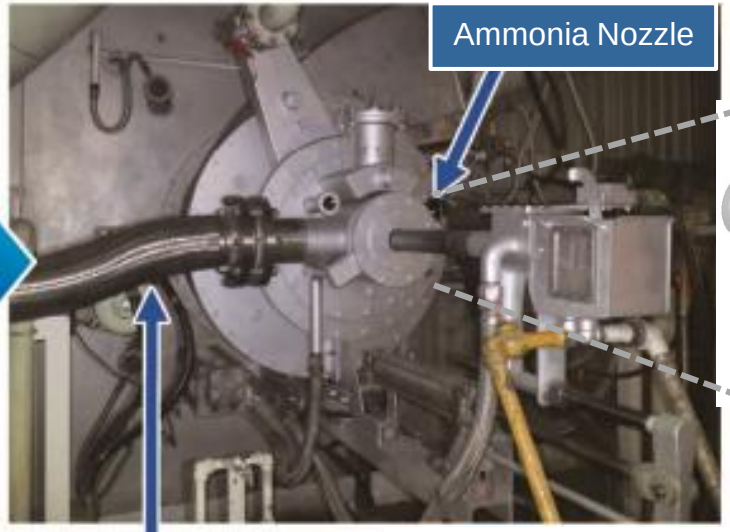
⇒ Suppress NOx generation

NH_3 Supply Pipe： **Adopt a "lip seal flange" at the piping connection**

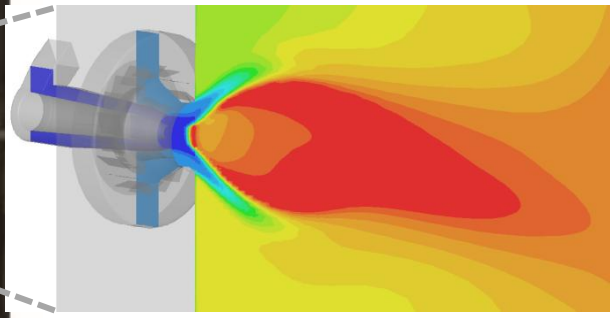
⇒ Prevent NH_3 leakage through welded structures

Before Ammonia Nozzle Installation

After Ammonia Nozzle Installation



Numerical analysis and combustion testing for burner development



Patented technology applied
(Patent no.7049773)

1.(4) Safety Measures Overview

Implementation safety measures against ammonia leakage inside the boiler building and successfully completed the demonstration test without any accidents.

Leakage Prevention Structure

The pipe connections fundamentally consists of welding joint.
Also, when applying flanges for maintenance purpose, “Lip Seal Welding” is adopted. (Fig. 1)

Ammonia Detector/Alarm Device

Gas detectors are installed on each burner floor.
When a leak is detected by the gas detectors, an alarm is issued at the site and the Control Center Room, allowing for the identification of the leak source and ensuring that the gas leak is effectively communicated.

Local Ventilation System

To prepare for leakage from the gland part of the valve, the valve is enclosed with a cover and a local ventilation facility is adopted. (Fig.2)
The fan is used to forcibly exhaust to the outside.

Interlock

In case of critical deviation from normal operation conditions,
the fuel ammonia shut-off is occurred.
The conditions of fuel ammonia shut-off are:
① Ammonia Gas Pressure LL or HH at Burner Inlet
② MFT (Master Fuel Trip) Occurred
and so on.

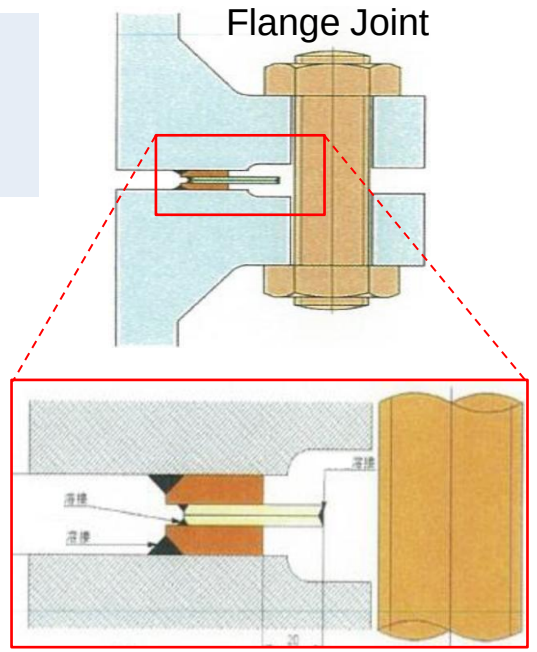


Fig.1 Lip Seal Welding Structure of the Flange Part

Fig.2 Valve Cover

1. Project Overview
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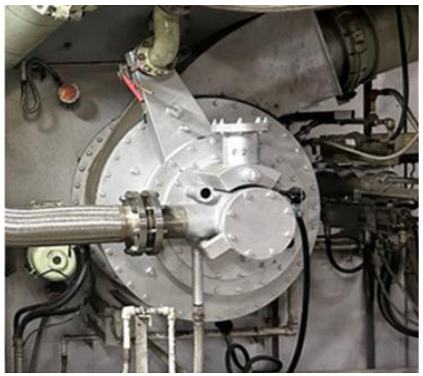
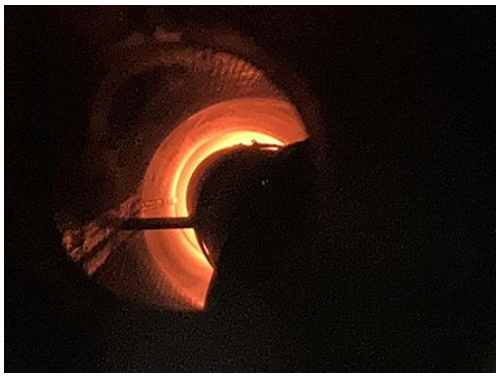
2.(1) Overall Summary of Test Results

■ The progress and completion of the demonstration test

Published on May 16, 2024

IHI and JERA launched this initiative on April 1 with the New Energy and Industrial Technology Development Organization (NEDO). On April 10, ammonia substitution reached 20% at a 1GW unit.
This effort has yielded favorable environmental outcomes. Carbon dioxide emissions at the unit have fallen around 20%, nitrogen oxide emissions are equal to or less than before ammonia substitution, and sulfur oxide emissions are down about 20%. Emissions of powerful greenhouse gas nitrous oxide have been undetectable.





https://www.ihi.co.jp/en/all_news/2024/resources_energy_environment/1200850_13691.html

The result of the demonstration test with 20% ammonia firing (compared to coal firing)

【Combustion Performance】
- NOx：Equivalent to coal firing
- SOx：Approximately 20% reduction
- N_2O：Below the quantitation limit

【Operability】
- Equivalent to coal firing

Published on June 26, 2024

In this demonstration test, 20% substitution of fuel ammonia for operation of rated output of 1GW has been achieved successfully on April 10, 2024.This effort yielded favorable environmental outcomes. It is confirmed that carbon dioxide emissions at theunit fell around 20%, nitrogen oxide(NOx) emissions were equal to or less than when mono-firing coal before ammonia substitution, and sulfur oxide(SOx) emissions were down about 20%. Emissions of the potential greenhouse gas nitrous oxide(N2O) were undetectable. IHI and JERA also confirmed that operability was equivalent to that before the conversion to fuel ammonia .

https://www.ihi.co.jp/en/all_news/2024/resources_energy_environment/1200954_13691.html

2.(1) Overall Summary of Test Results

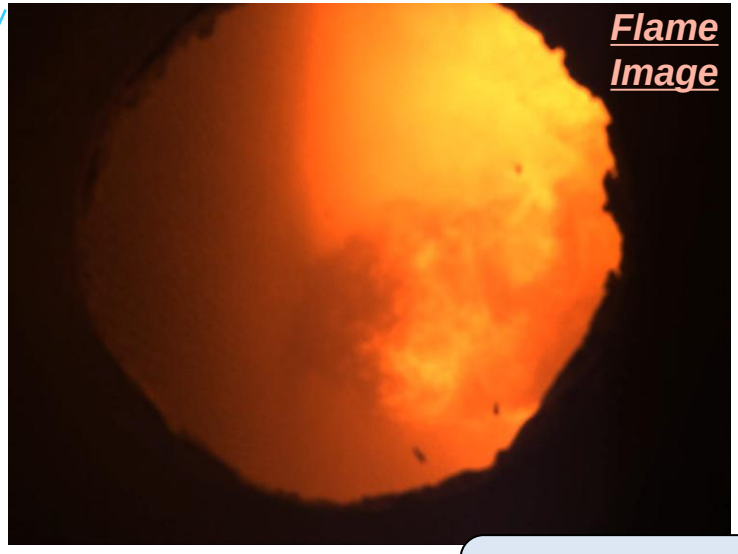
■ The results of the major evaluation items

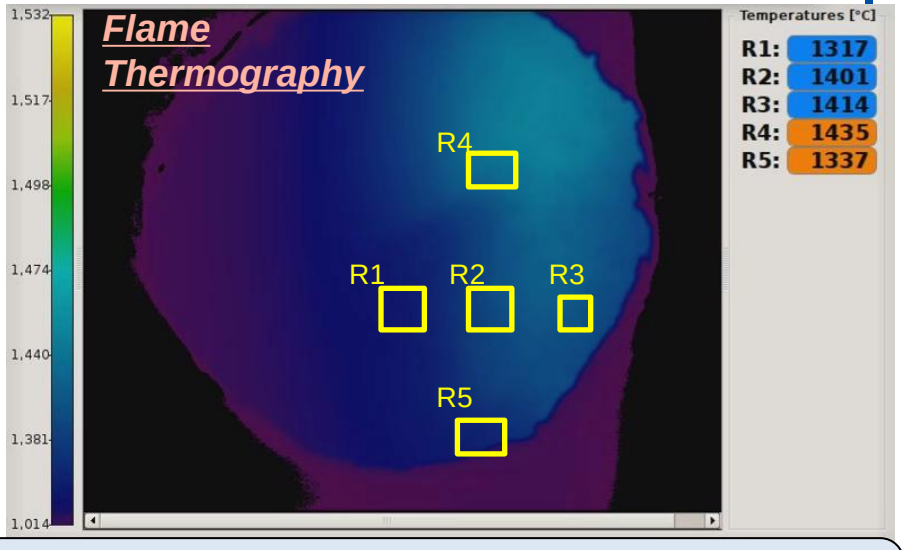
The major items have all met the targets.

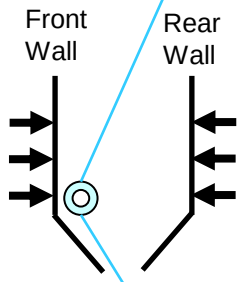
No.	Item	Target	Result	Evaluation of 20% Ammonia Firing
1	Main Steam/Reheat Steam Temperature	Equivalent to Coal Firing	Achieved	Steam conditions have been maintained
2	Boiler Capability Steam Generation Capacity	Equivalent to Coal Firing	Achieved	Steam generation rate have been maintained
3	Ammonia Firing Ratio	20%	Achieved	Achieved firing ratio of 20%
4	NOx	Equivalent to Coal Firing	Achieved	Achievable equivalent to Coal firing
5	Unburned Carbon in Ash	Equivalent to Coal Firing	Achieved	Can maintain the same level as Coal firing
6	N_2O	Not detected	Achieved	Below the quantitation limit
7	Unburned NH_3	Not detected	Achieved	Below the quantitation limit

2.(2) Flame Appearance

Coal Firing



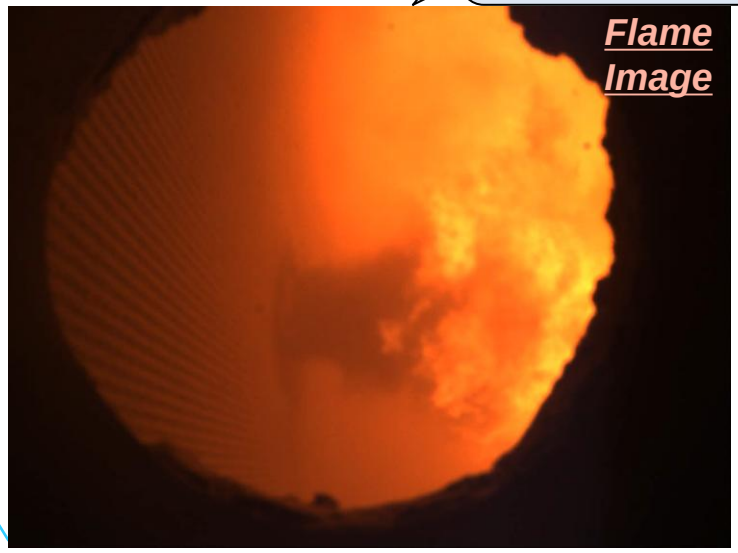


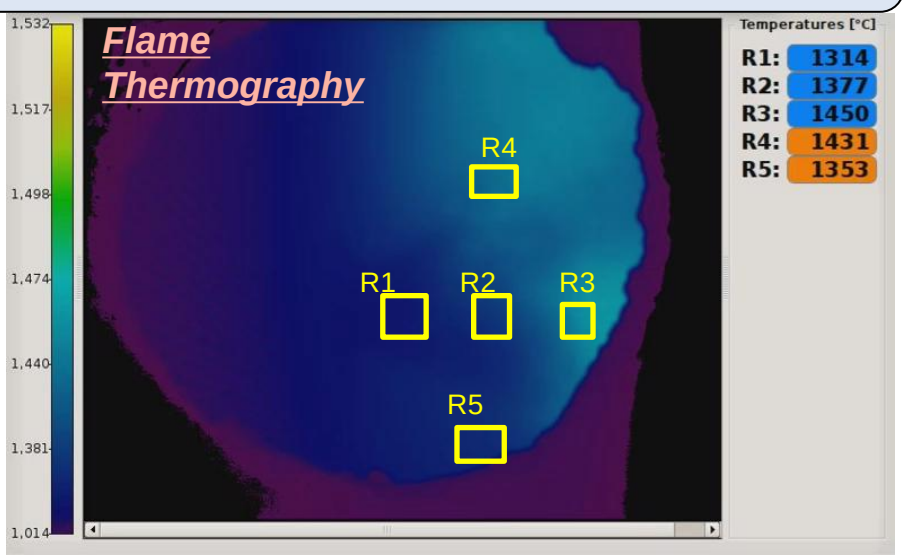


Shooting Location
Lower burner
Right side wall
Front side observation window

As expected from the combustion test and numerical analysis, the ignition point moves away from the furnace wall, and the flame becomes elongated.

20% Ammonia Firing





2.(3) Combustion Characteristics

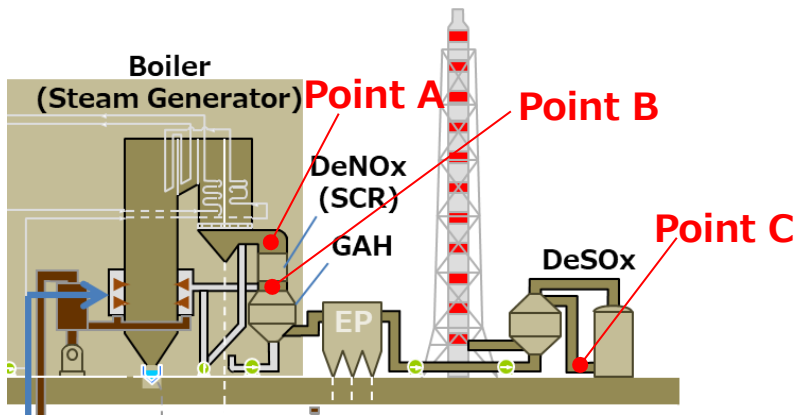
1) Emission (NOx, SOx) and combustibility

- ✓ Combustion characteristics and static characteristics of the boiler with 20% ammonia firing were generally equivalent to coal-only combustion
- ✓ Operation could be managed within the control range of the existing equipment.
- ✓ Boiler efficiency with 20% ammonia firing was as initially expected
- ✓ No significant changes in unburned components were observed.

NOx		
Ammonia Firing Ratio	Coal Firing	20%
Measurement Location	DeNOx (SCR) Inlet (Point A)	
Result	134 ppm [Dry, 6%O_2basis]	106 ppm [Dry, 6%O_2basis]

Unburned Carbon in Fly Ash		
Ammonia Firing Ratio	Coal Firing	20%
Measurement Location	DeNOx (SCR) Inlet (Point A)	
Result	1.6 %	1.8 %

SOx		
Ammonia Firing Ratio	Coal Firing	20%
Measurement Location	DeSOx (FGD) Inlet (Point C)	
Result	502 ppm [Wet]	397 ppm [Wet]



※The above values are based on measurements during steady load operation at 1000MW.

2.(3) Combustion Characteristics

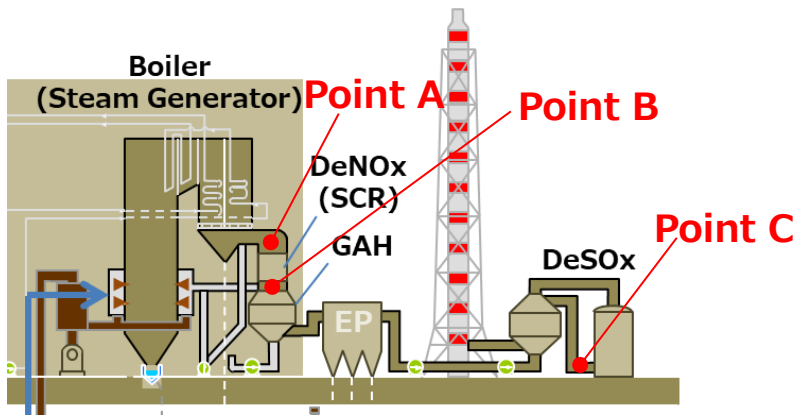
2) GHG (CO_2 , N_2O), Unburned NH_3

- ✓ CO_2 emissions were reduced by approximately 20% through 20% ammonia co-firing
- ✓ Flue gas properties were good condition in terms of emission

CO_2		
Ammonia Firing Ratio	Coal Firing	20%
Measurement Location	GAH Inlet (Point B)	
Result	13.4 % [Dry, 6%O_2basis]	10.8 % [Dry, 6%O_2basis]

N_2O		
Ammonia Firing Ratio	Coal Firing	20%
Measurement Location	DeNOx (SCR) Inlet (Point A)	
Result	Below Limit of Quantitation (1 ppm)	Below Limit of Quantitation (1 ppm)

Unburned NH_3		
Ammonia Firing Ratio	Coal Firing	20%
Measurement Location	DeNOx (SCR) Inlet (Point A)	
Result	Below Limit of Quantitation (0.3 ppm)	Below Limit of Quantitation (0.3 ppm)



※The above values are based on measurements during steady load operation at 1000MW.

2.(4) Boiler Characteristics

1) Operability
Operability was fine even when 20% ammonia firing.

Ammonia Injection Balance for DeNOx (SCR)

It was not significant change in NOx distribution. Therefore, ammonia injection balance tuning is not required.

Load Change Test

Load changes were performed stably for both increases and decreases for actual operation range.

Ammonia Emergency Shut-off

Even during the ammonia emergency shut-off operation, the boiler could succeed safety runback to the target load. And after reaching the target load, it was confirmed that the unit was stable. Also, it was confirmed that the process value fluctuations associated with the ammonia shut-off operation were within the design range, and that the shut-off could be safely carried out without any leaks or other issues.

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3(1). IHI's target for Commercialization of ammonia firing

■ Roadmap for Ammonia Combustion Technology Development

IHI's Target

Pilot Test (Small Scale Combustion Test) → Large Scale Combustion Test → Demonstration Test → Commercialization

Numerical Analysis

Ammonia Firing Ratio

100%

Pilot Test

Large Scale Test

Demo. Test (under planning)

Over 50%

Pilot Test

Pilot Test

Large Scale Test

FS

Retrofit for Demonstration Hekinan Unit 5

Demo. Test

CM (Target)

20%

Large Scale Test

Large Scale Test

FS

Retrofit for Demonstration Hekinan Unit 4

Demo. Test

Commercialization (IHI's Target)

2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030

3(2). Deployment of Ammonia Firing in Social Implementation

Success of HEKINAN Demonstration Project

- The ammonia combustion was achieved by only adding ammonia burner nozzles and related piping to the boiler, without any modifications to the main body of the boiler, flue gas ducts, or environmental equipment.
- The specified performance and operability were achieved.
- The demonstration test was carried out without any accidents or incidents.

1) Commercialization of Hekinan and expansion to other projects

- **We will convey the message that commercialization of ammonia combustion is feasible to customers considering its introduction.**
- **We will disclose detailed results at industry association presentations (such as this presentation) to support the decision-making of customers considering ammonia firing introduction.**

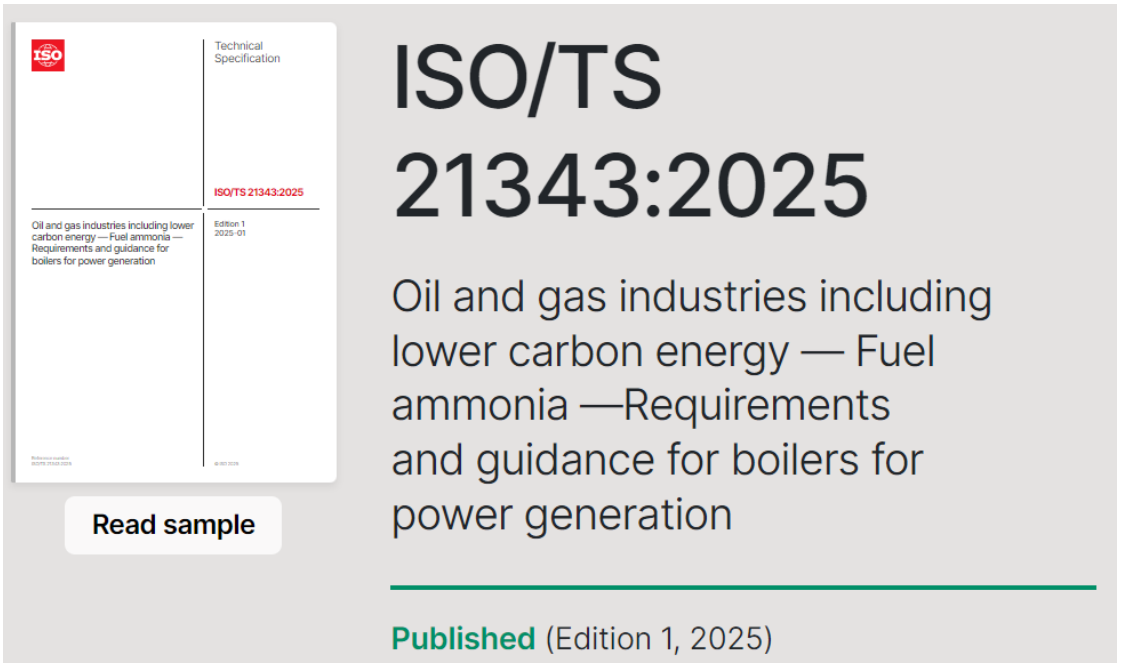
2) Establishment of the ammonia supply chain

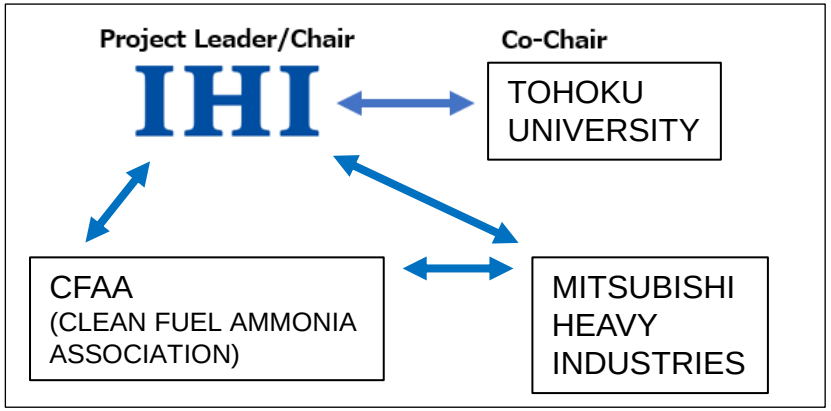
- **We will further promote specific initiatives in the consideration of supply chain construction in cooperation with various countries and companies around the world.**

3(3). International standardization for ammonia utilization

- International Standardization Activities for Fuel Ammonia: Technical Specification (ISO/TS 21343) to be issued on January 14, 2025.

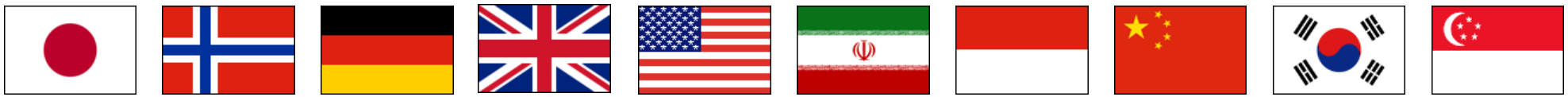
出典：ISO/TS 21343:2025 - Oil and gas industries including lower carbon energy — Fuel ammonia —Requirements and guidance for boilers for power generation





Japanese Organization

Participating Expert (Country)



Next Action

Reflecting the results of the Hekinan, switch from TS to IS.

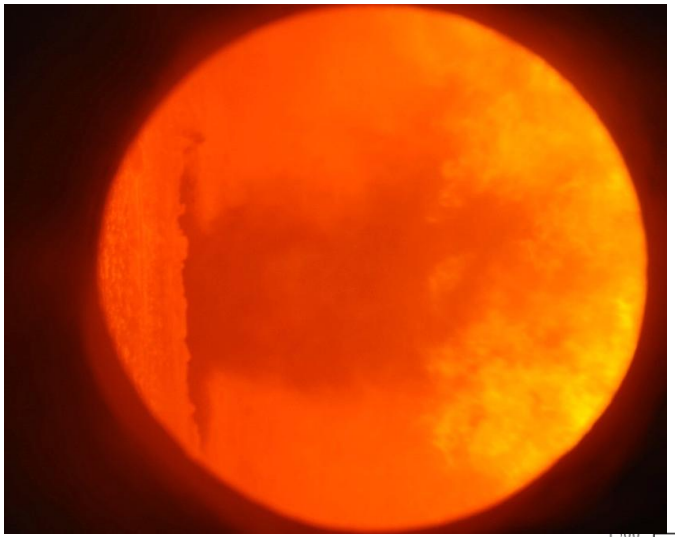
（Remark：TS（Technical Standard／IS（International Standard）

3(4). 60% Ammonia firing : Development completion

+The development of the burner is mostly completed.
⇒Additional studies are being conducted for detailed design.

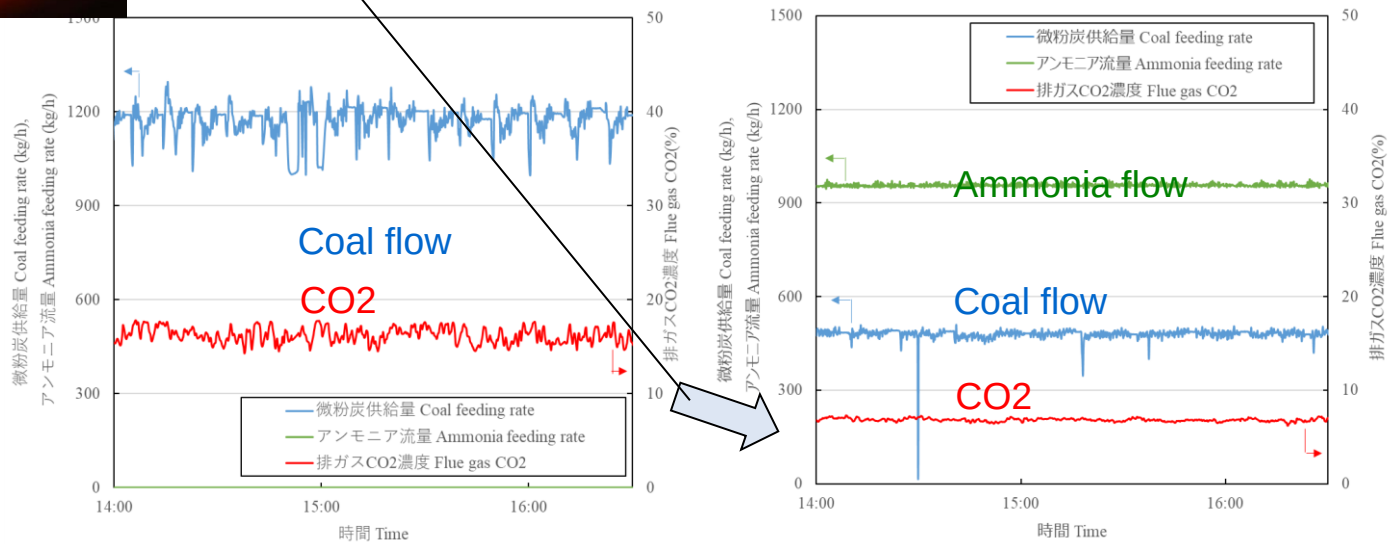
+FS based on actual operation has been completed.

NEDO Subsidized Project【JPNP21020】



Flame picture of 60% Ammonia firing

CO2 was reduced from 17% to 6.5% by to 60% ammonia firing.
It indicates 60% ammonia firing can reduce 60% of CO2.

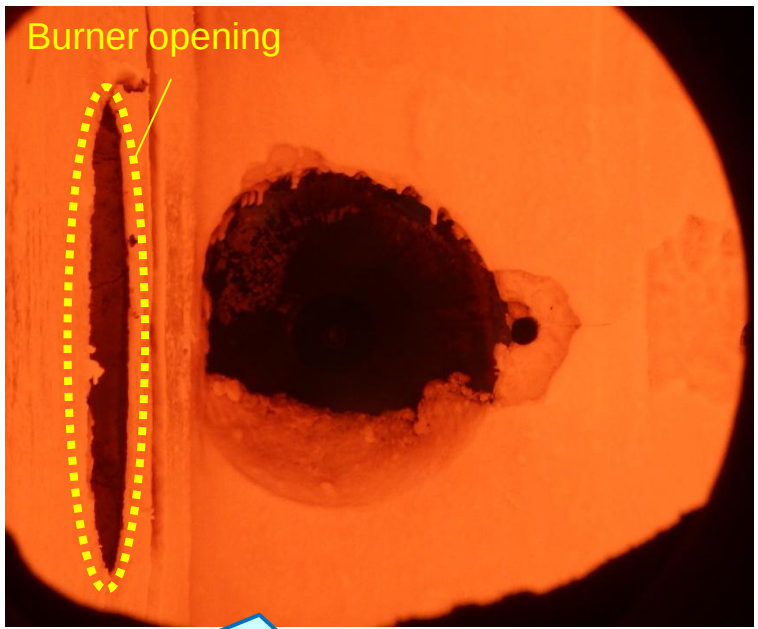


3(5). 100% Ammonia firing : Just before development completion

+Topics --- Visualization of Flame shape of 100% Ammonia firing

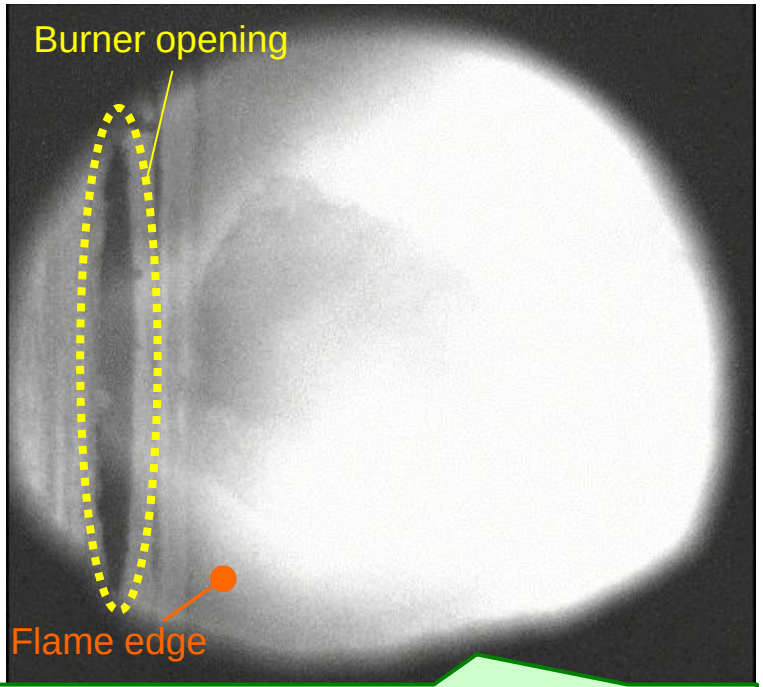
+Development would be completed by end of fiscal year FY2023.

By normal camera / visual



It is not visibly by normal camera and visual contact

By Special camera and filter



It can be visible clearly by special camera and filter

+to be verified flue gas measurement result in furnace

+to be available to make advance combustion technology and combustion tuning

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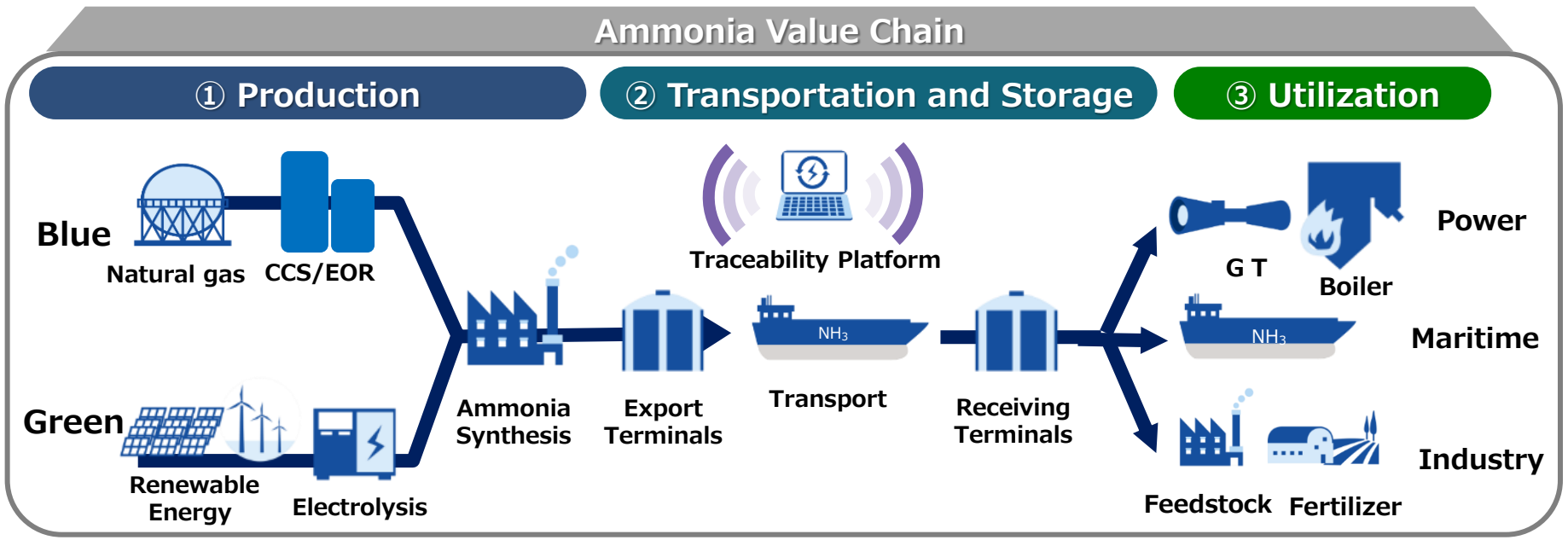
- IHI is actively advancing the development of ammonia combustion technology, which is a promising carbon-neutral fuel for thermal power generation facilities. Regarding burners, we are working on establishing a lineup that includes 20% ammonia firing burners, 60% ammonia firing burners, and 100% ammonia firing burners.
- The demonstration test at Hekinan for 20% ammonia firing achieved successful results, indicating that social implementation is realistic. Furthermore, the successful development of high ammonia firing ratio burners and 100% ammonia burners in the future also looks promising.

IHI is not only developing ammonia combustion technology but also participating in ammonia production, transportation/receiving and storage. By realizing a supply chain for carbon-free ammonia fuel, we aim to contribute to the achievement of a carbon-neutral society.



IHI

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