

Use of Fuel Ammonia in the glass melting furnaces

The AGC logo consists of the letters 'AGC' in a bold, blue, sans-serif font. The letter 'G' is partially enclosed by a red horizontal bar.

This presentation is based on results obtained from a project, JPNP21012, commissioned by the New Energy and Industrial Technology Development Organization (NEDO).

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AGC Inc.

Toward net zero carbon emissions in 2050



Net zero carbon emissions in 2050

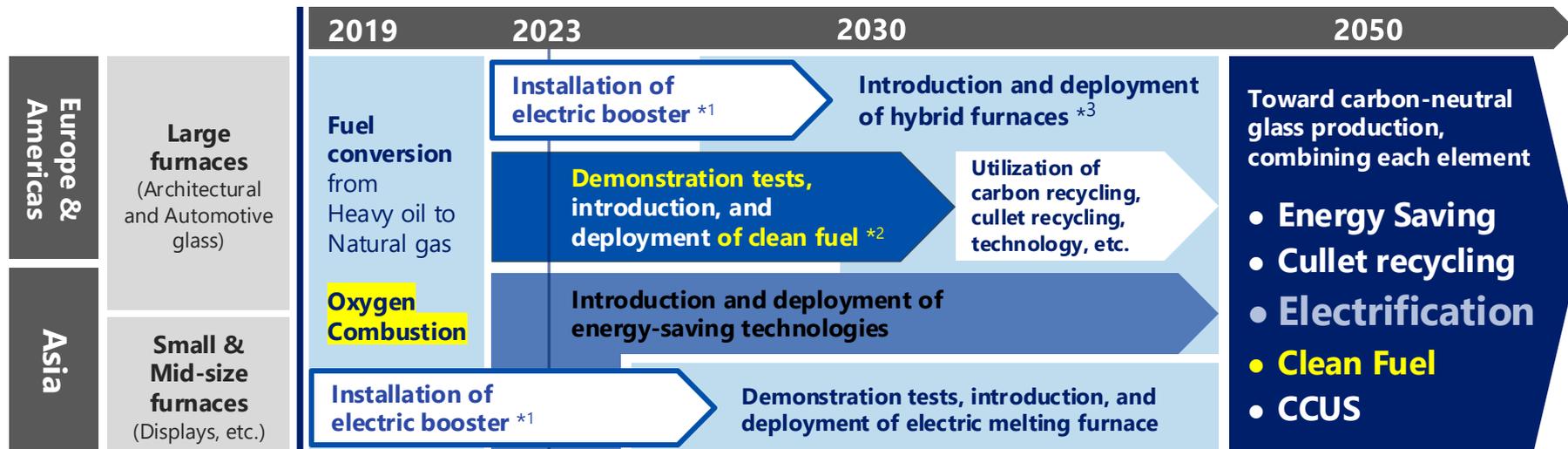
(Scope 1+2)



FY2020

FY2030

FY2050



*1 : Energized auxiliary heating *2 : Ammonia, Hydrogen etc. *3 : Energy sources are provided by a combination of electricity and fuel

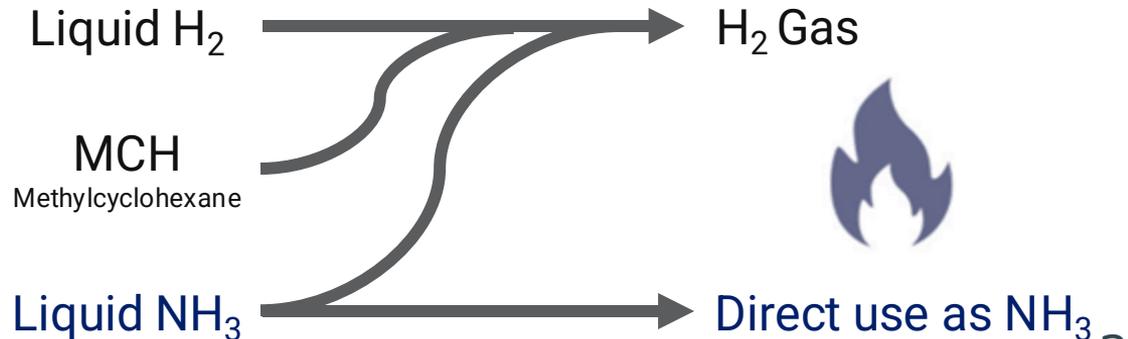
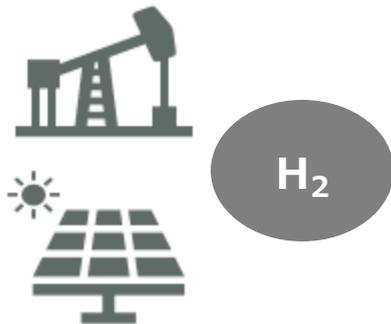
Advantages of ammonia as a hydrogen carrier

Hydrogen carrier	Liquid H ₂	MCH Methylcyclohexane	Liquid NH ₃
Boiling temp. at 1atm (°C)	-253	101	-33.4
Condensation pressure at 25°C (atm)	N/A	0.075	9.90
Hydrogen content (% by mass)	100	6.16	17.8
Hydrogen density (kg_H ₂ /m ³)	70.8	47.3	121
Energy to extract H ₂ (kJ/mol_H ₂)	0.907	67.5	30.6

Hydrogen production

Maritime transport

Industrial use



Challenges in industrial use of ammonia combustion

- The combustion speed is slow, and the flame temperature is low.
→ Oxy combustion is required instead of air combustion.
- Concerns about NOx emission, especially impact of fuel NOx.
→ Optimal design of burner need to be explored.
- The water vapor pressure in the combustion atmosphere is high.
→ Impacts on glass properties and its production process need to be quantified.

	CH ₄	H ₂	NH ₃
Low calorific value [MJ/Nm ³]	35.8	10.8	14.1
Laminar burning velocity [m/s]	0.37	2.91	0.07
Adiabatic flame temperature (°C)	Air	1970	1750
	Oxy	2778	2570

*NEDO: New Energy and Industrial Technology Development Organization

AGC has been participating NEDO project on fuel NH₃ for industrial furnaces. Attempting to introduce NH₃ fuel into glass melting furnaces through the project.

Illustration of project

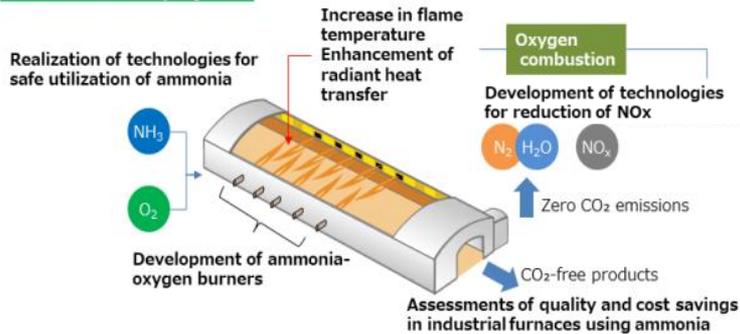


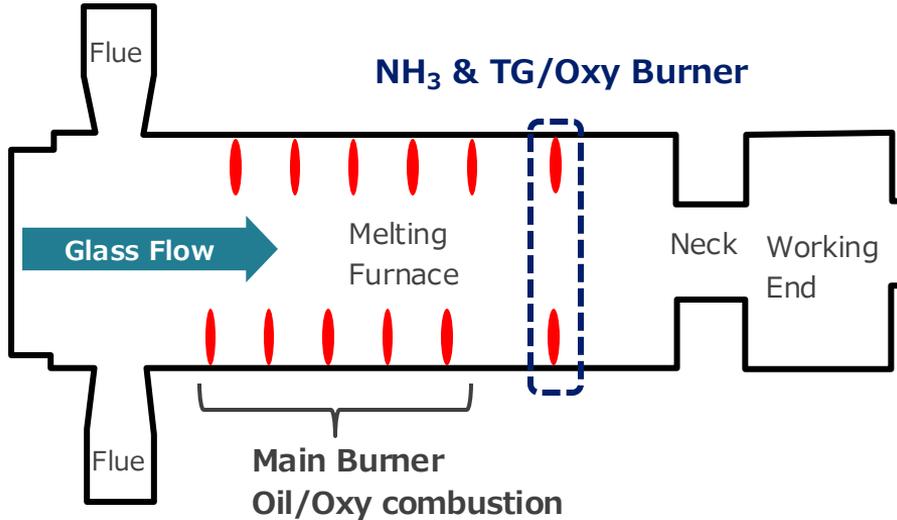
Illustration of industrial glass-melting furnace using ammonia as fuel

Organization	Responsibility
Taiyo Nippon Sanso Corp.	Development of an ammonia combustion burner for industrial furnaces
AIST (National Institute of Advanced Industrial Science and Technology)	Analysis of ammonia combustion mechanism by 50kW furnace
Tohoku University	Investigation of NOx generation and radiation heat transfer of ammonia oxy-combustion and oxygen-enriched combustion
AGC	Verification of ammonia combustion burner technology in glass melting furnace

Reference: <https://www.nedo.go.jp/>

NH₃ combustion test in a glass melting furnace

In June of 2023, AGC conducted world's first demonstration test of NH₃ combustion in a glass melting furnace that produces architectural glass.



Town gas (TG) 100%



Ammonia 100%

Inside a glass melting furnace burning with a specialized burner

Target

To verify whether NH₃ combustion technology can be applied to glass melting furnaces by evaluating ①NO_x emission, ②heat behavior and ③equipment stability.

Overview of NH₃ Combustion Test Facility (1/2)

Prepare several measures against NH₃ leakage due to its toxicity.

Equipment at NH₃ storage yard

• Install

- NH₃ leak testers
- automatic shut off valves
- emergency water spray

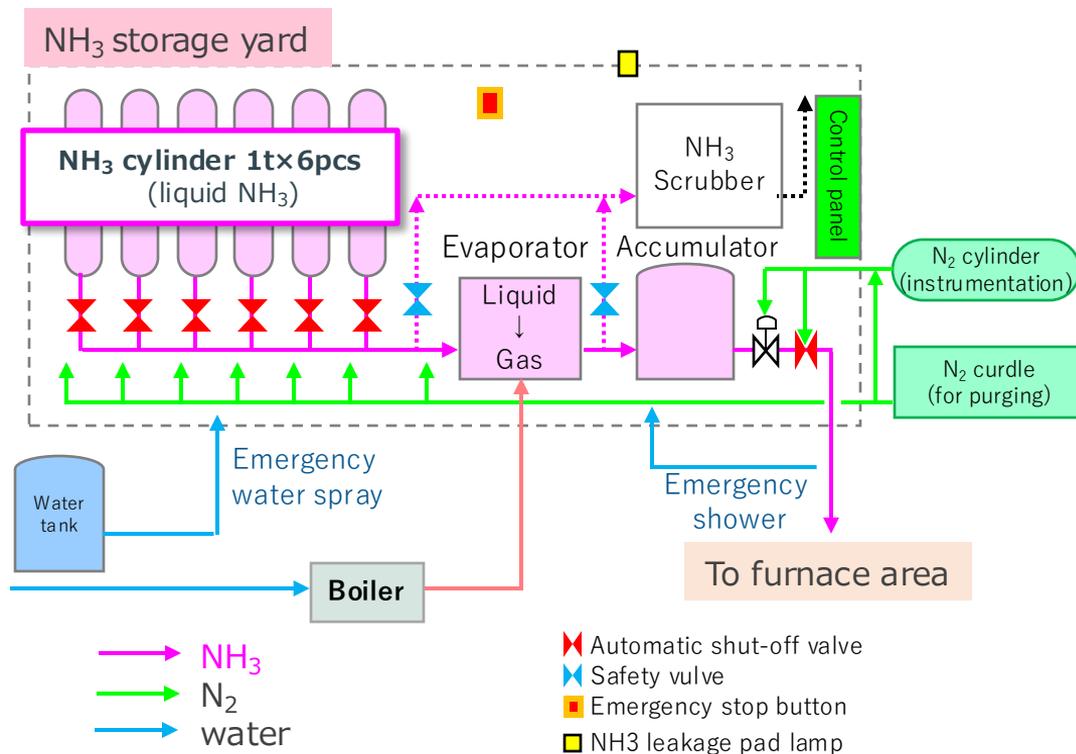
- Check leakage of pipe and valve by He, N₂.
- Wear NH₃ detectors and mask.
- Prepare O₂ tank and protective clothing for emergency.



NH₃ detector

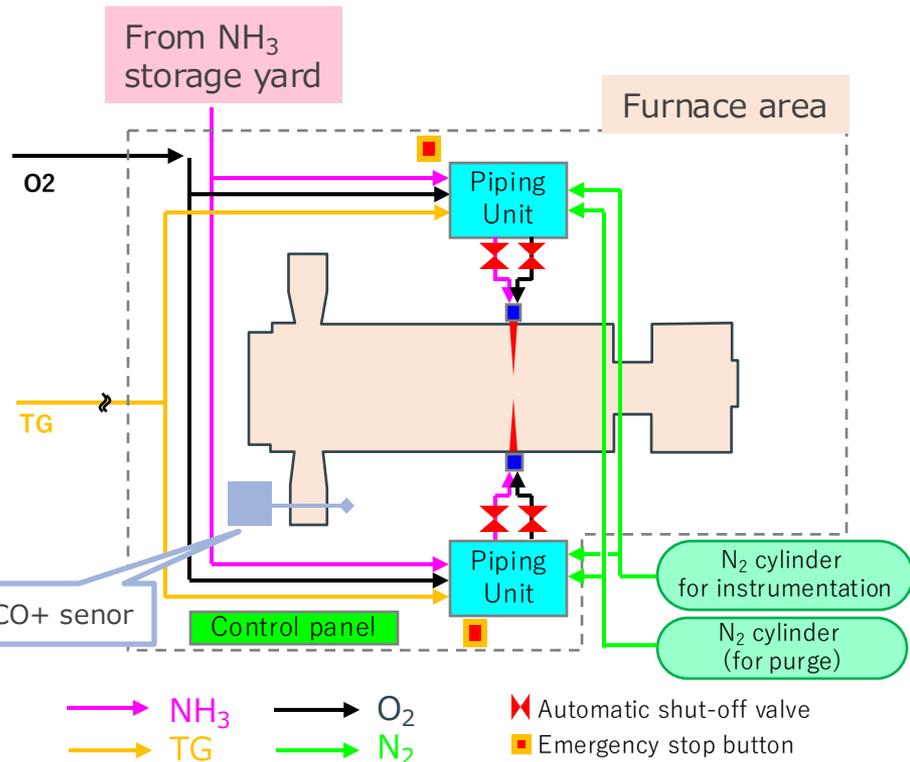


Mask



Overview of NH₃ Combustion Test Facility (2/2)

Prepare several **measures against NH₃ leakage** due to its toxicity.
→ **No NH₃ leakage** in the test.



Furnace area

- Check **leakage** at starting NH₃ combustion.
- Wear NH₃ detectors and during test.
- Wear **masks** when we **start and finish** NH₃ combustion test.
- Tested **emergency stop button** intentionally to check that comb. stop system was working correctly.



NH₃ detector



Mask

CO+ sensor

- Purchase it from CelSian Glass & Solar BV
- Measure **CO, O₂+ H₂O, temperature**



Example installed sensor

Result of NH₃ combustion tests

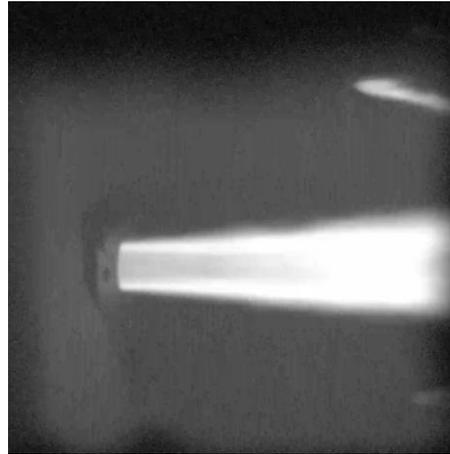
Confirmed that we could use a 0.2 to 1.0 MW ammonia burner ×1pair downstream of the glass melting furnace.

Category	Evaluation items	Comments
Combustion behavior	Local heating	No local heating on furnace refractory, especially crown was observed by thermo-viewer.
Exhaust gas	NOx	• NOx emission at chimney was under the agreement value (400ppm). • NOx near NH₃ burner is greatly reduced by O₂ staging.
Equipment	Stability	NH₃ combustion could be continued more than 24 hours.
Furnace atmosphere	Moisture	Water concentration in NH ₃ comb. was increased from that of reference:no comb.
Glass Physical properties and quality	Glass properties	Almost unchanged between ref: no comb. and NH ₃ comb.
	Defect Quality	Almost unchanged between ref: no comb. and NH ₃ comb.

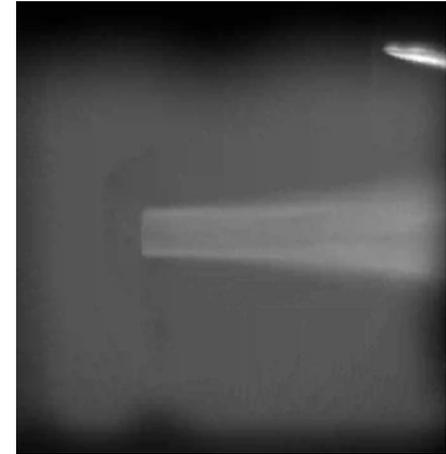
- Images captured with an ammonia flame visualization camera developed by Tohoku University and IHI.
- Successful continuous video recording of ammonia flames while preventing radiant heat from the glass melting furnace.



Photographing from the front wall



OH radical luminescence



NH radical luminescence

Confirm stable combustion without lifting or fluttering at the flame.

NOx near NH₃ burner

NOx of NH₃ comb. was significantly decreased by **staging combustion(ST)**.
NOx value of NH₃ comb. without ST was almost same as that of TG comb. without ST.

NOx measurement near NH₃ / TG burner
(LNG)

0% 20% 40% 60% 80% 100%

Ref. TG comb.
w/o O₂ staging



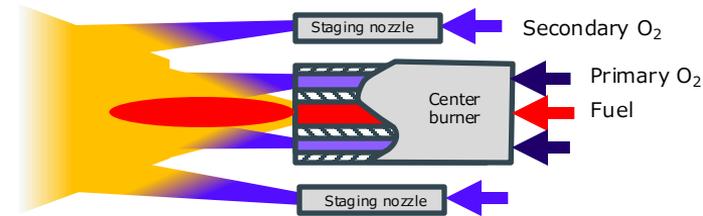
NH₃ comb.
w/o O₂ staging



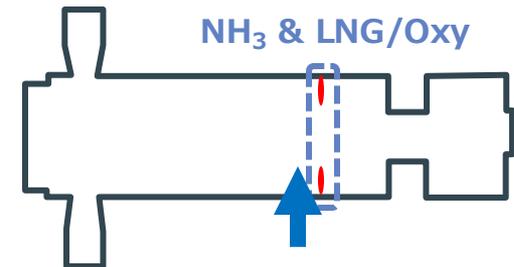
NH₃ comb.
with O₂ staging



-28%
by staging combustion

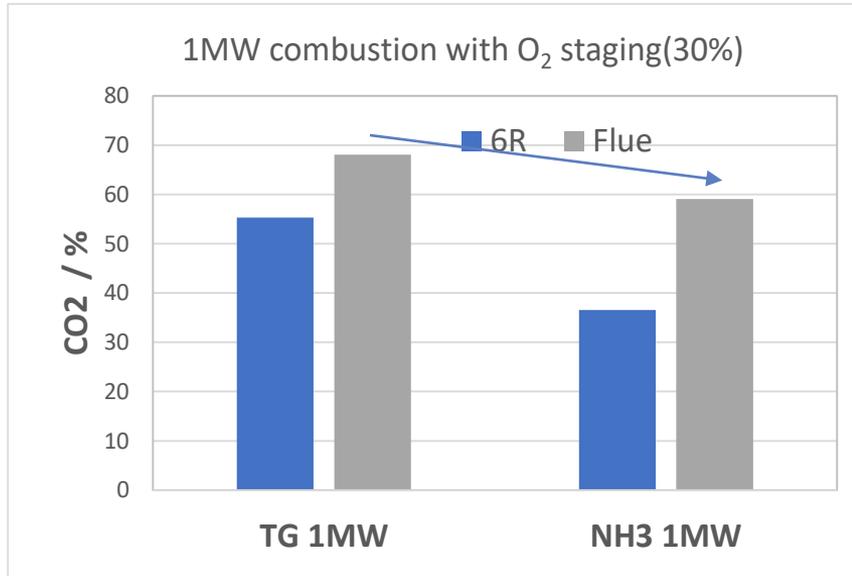


Measurement position

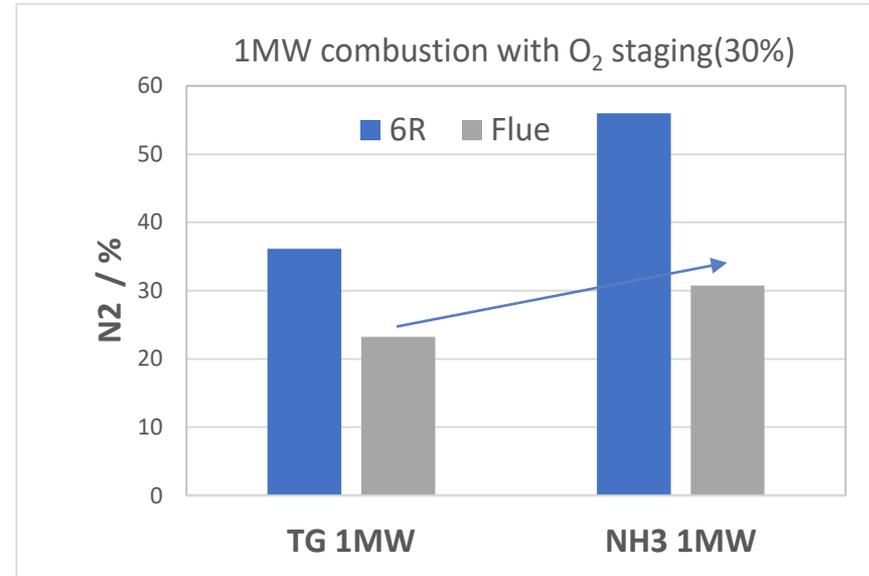


CO₂ and N₂ in the melting furnace and flue

■ CO₂

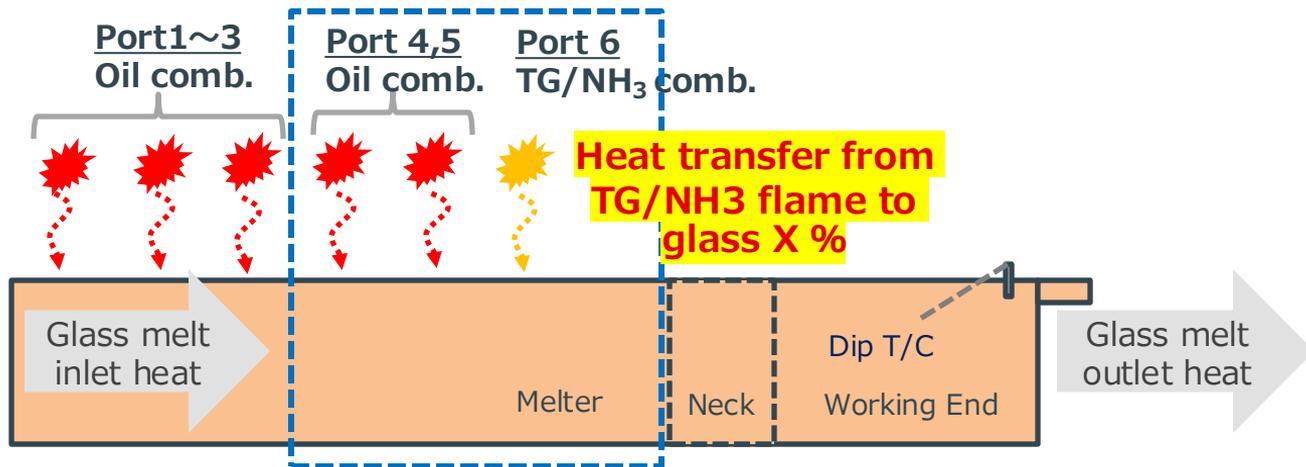


■ N₂



- 1MW_NH3 combustion clearly reduces CO₂ and increases N₂.
- During 1MW combustion, CO₂ is reduced by approximately 13% compared to TG in the flue.

Heat transfer efficiency of ammonia combustion flames



Combustion condition	Heat transfer from TG or NH ₃ flame[%]	NH ₃ /TG combustion heat transfer ratio
TG 600kW	40.3	1
NH₃ 600kW	37.5	0.93

- Achieved continuous stable combustion of approximately 7 hours for 1MW_NH₃ combustion and approximately 24 hours for 600kW_NH₃ combustion.
- Successfully continuous monitoring the NH₃ flame inside the furnace and confirmed normal NH₃ combustion behavior.
- No significant increase in NO_x emissions from the chimney during 1MW_NH₃ combustion. Maintained below 400ppm even during normal operation.
- Confirmed a significant increase in moisture concentration in the glass products after 25 hours of continuous combustion of 600kW_NH₃. However, this is at a level that does not affect characteristics or quality.
- NH₃ heat transfer efficiency is nearly equivalent to TG, under 600kW long-term combustion conditions. TG 1: NH₃ 0.93

Thank you for your attention.