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Regulatory and Technical Considerations for the Treatment of AMMONIA-CONTAINING EFFLUENTS from Ammonia-Fuelled Ships

From gas-release control to a defined and verifiable final destination

Generation & Characterization • Environmental Risk • Management Pathways • Shipboard Integration

KIM Joonghun | Korean Register

IMO Technical Seminar on the Use of Ammonia as Marine Fuel

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Contents

A five-part technical story following ammonia-containing liquid from generation to a defined and verifiable final destination.

From technical discussion to practical solutions for cleaner oceans.

Regulation, technology and collaboration for a sustainable maritime future.

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01

CHAPTER 01

Problem & Work Context

Why are we discussing this issue now?

Why the liquid issue arises · formal IMO PPR work · Korean and international technical coordination

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Why the Ammonia-Containing Liquid Issue Arises

Water is used to control gaseous ammonia releases for safety — and this creates a new management challenge.

1 Global decarbonization

Shift to zero/near-zero greenhouse gas emissions

2 Adoption of ammonia as a marine fuel

Use of ammonia in engines and fuel systems

3 Gaseous ammonia releases

From purging, venting, pressure relief or depressurization

4 Water-based release control

Absorption / scrubbing using water for safety

MSC.1/Circ.1687 · MSC.1/Circ.1702

5 Ammonia-containing liquid is generated

Absorbed ammonia remains in the water as NH_3 / NH_4^+

6 Subject of PPR discussion

Draft guidelines for ammonia effluent generated from ammonia-fuelled ships

- **MEPC 83** Development agreed
- **PPR 13** First considered
- **PPR 14** Further consideration
- **2028** Target completion

Key questions to be addressed

To complete the management pathway, several technical and regulatory questions need to be answered.

1 Scope & regulatory criteria

- Which streams are covered?
- What parameters and discharge criteria are needed?

2 Technology & environmental performance

- What does the route achieve and what are all outputs?
- How do we verify environmental acceptability?

3 Shipboard integration

- How will the liquid be segregated, contained and routed on board?
- What design and monitoring measures are required?

4 Operation & fallback

- What if the liquid is off-spec?
- What if the preferred route is unavailable?
- How do we safely retain, manage and reassess?

Controlling gaseous releases serves a safety function — the resulting liquid also requires a defined and verifiable management pathway.

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How Korea and International Experts Are Organizing the Technical Work

Korean technical inputs and wider international experience help structure questions for future PPR discussion.

1 KOREAN CONSULTATIVE GROUP

Regulatory, scientific and shipbuilding expertise

Government

Ministry of Oceans and Fisheries

Class + science

KR Korean Register

KTR 한국화학융합시험연구원 Korea Testing & Research Institute

Shipbuilders

HD KSOE
HD Hyundai Heavy Industries
HD Hyundai Samho
Samsung Heavy Industries
Hanwha Ocean

Technical inputs

Treatment studies · Design inputs
Environmental questions
Shipboard application

2 INTERNATIONAL INFORMAL TECHNICAL EXCHANGE

Open and voluntary · Wider international experience

- Member States
- NGOs
- Class
- Industry
- Academia
- Technical Experts

How the exchange works

Focused papers · Technical briefings
Written input
Different and unresolved views are preserved.

Role and boundary

Not an IMO decision-making body.
Not technology approval or a vote.

3 QUESTIONS FOR FUTURE PPR DISCUSSION

Evidence-based · Reflecting diverse views

Source streams and operating scenarios

Which streams are covered, and under which operating conditions?

Treatment and environmental questions

What does the route improve, and where do all outputs go?

Shipboard arrangements and fallback

How is the liquid managed on board?
What if the selected route is unavailable?

Supporting informed PPR discussion

Bringing different expertise together for informed PPR discussion.

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02

CHAPTER 02

Define the Stream & Management Scope

What liquid are we actually managing?

Chemistry · Quantity · Generation Pathways · Scenario-based Scope

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What Makes Ammonia Effluent Different?

Identify the chemistry before selecting a management route.

TAN alone does not define the hazard or the management route.

TAN = total ammonia nitrogen

1 WHAT EXISTS IN THE LIQUID?

TOTAL AMMONIA

$NH_3 + NH_4^+$

Free ammonia (NH_3)

- Un-ionized
- More volatile
- Acute toxicity + vapour risk

Ammonium (NH_4^+)

- Ionized
- Less volatile
- Reactive nitrogen remains

REPORTING BASIS

State whether values are expressed as N or as NH_3.

2 WHAT SHIFTS THE BALANCE?

$$NH_4^+ \rightleftharpoons NH_3$$

Higher pH / temperature → more un-ionized NH_3

pH	Temperature	Salinity + co-contaminants
DOMINANT DRIVER	IMPORTANT MODIFIER	CASE-DEPENDENT

ILLUSTRATIVE RESEARCH EXAMPLE

pH 11.9–12.7

Research conducted by KTR

3 WHY DOES IT MATTER?

IMMEDIATE HAZARD

Free NH_3

Aquatic toxicity · re-vaporization
Crew exposure

NITROGEN INVENTORY

TAN / T-N

Cumulative loading · nitrogen remains after neutralization

ROUTE SUITABILITY

pH · salts · oil · solids · chemicals

Materials · scaling / fouling
Treatment or recovery feasibility

Characterize the chemistry first.
It determines the hazard and which management routes remain feasible.

Where and How Much Ammonia-Containing Liquid Is Generated

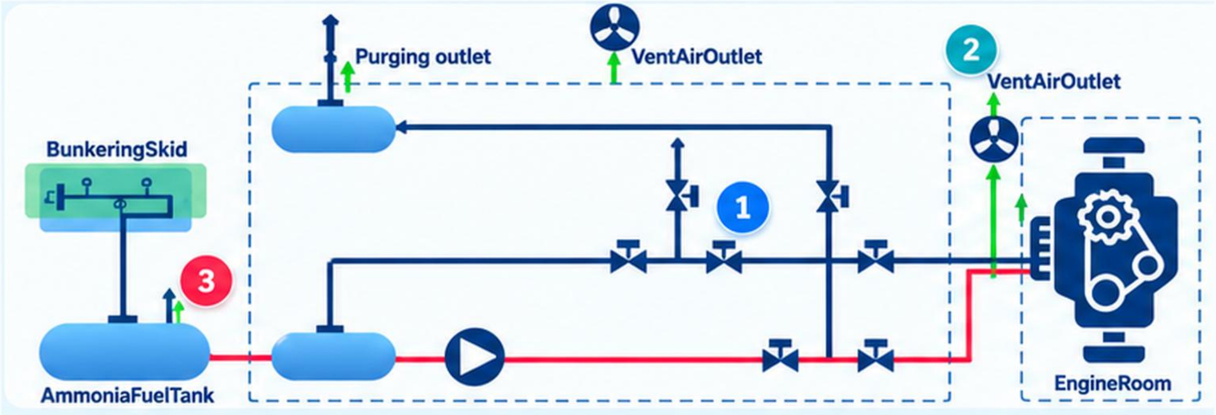
Indicative quantities are meaningful only when the ship, fuel system, operating profile and ARMS basis are stated.

1 WHERE CAN THE LIQUID ORIGINATE?

1 Planned operations

2 Routed abnormal

3 Response water



Operation / event → NH_3 release or contaminated area → water-based control / collection → liquid inventory

2 WHAT SETS THE VOLUME?

NH_3 load + water / collection basis + duration = liquid inventory

1 SYSTEM INVENTORY

pipe hold-up · consumer arrangement

2 PURGE SEQUENCE

depressurization · target residual

3 WATER BALANCE

water-to-gas ratio · target concentration

4 DURATION

valve lift · spray / firewater demand

ENGINE MW IS AN INDIRECT DRIVER — NOT A SIZING VALUE BY ITSELF

3 INDICATIVE EXAMPLES — EACH VALUE DEPENDS ON ITS STATED BASIS

A · PLANNED OPERATIONAL STREAMS

change-over · shutdown · routine drain

0.5–2 m^3/change-over · 2–4 m^3/shutdown
≈0.01 m^3/h drain

B · FORESEEABLE ROUTED EVENTS

PRV / TSV · piping overpressure routed to ARMS

0.5–5 m^3/event + upstream-inventory / duration effects

C · RESPONSE-GENERATED WATER

leakage mitigation · decontamination · firewater

several m^3, case-dependent
emergency: 15–20 m^3 in ≈8 min; >20 m^3 possible

ILLUSTRATIVE BASIS: VLAC · 10 MW reciprocating engine · NH_3 ≈3,600 kg/h (≈86 t/day)
20–30 d profile · water-absorption ARMS 600 kg/h

NOT UNIVERSAL RANGES

The source and event define the stream; inventory, water balance and duration define the volume.

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03

CHAPTER 03

Management Pathways & Final Endpoints

Where can technology intervene—and where does the nitrogen finally go?

Upstream prevention and recovery · Stabilization · Reuse · Conversion · Conditional discharge · Shore transfer

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From Pollution-Prevention Principles to Management Pathways

Managing ammonia-containing effluents to reduce marine pollution — from generation to a defined **and verifiable final destination.**

1 PREVENT & MINIMIZE
Reduce the pollutant load at source, where feasible, without compromising safety.

2 CONTROL ALL OUTPUTS
Do not simply transfer pollution between phases — manage every output.

3 VERIFY BEFORE RELEASE
Demonstrate environmental acceptability and compliance with applicable requirements.

Upstream Prevention & Recovery
Can we avoid or reduce the liquid?

Engine / Process
Ammonia-containing gas (e.g. from safety release)

- **Recover** → To fuel tank or reuse
- or
- **Absorb** → Water-based release control (Safety function) → Ammonia-containing liquid (effluent)

If Liquid Exists ...
How can it be managed on board?

- **Stabilize** — Neutralization, pH control, etc. → Transformed liquid with reduced free ammonia (Total nitrogen remains)
- or
- **Reuse / Recover** — Use in suitable processes or recover useful materials → Product / Recovered substance (With quality control) + remaining liquid (if any)

Final Destinations
Where does the nitrogen finally go?

To Air
- Ammonia slip, NO_x, N_2O, etc.
- Verify with applicable requirements

To Sea
- Policy-dependent — not current authorization
- Final discharge criteria under IMO PPR consideration

To Shore
- Transfer to an adequate reception facility
- Confirm subsequent treatment

A management route must address the overall pollution burden — not only the ammonia concentration in one stream.

This figure shows a management framework, not a fixed sequence or a ranking of technologies.

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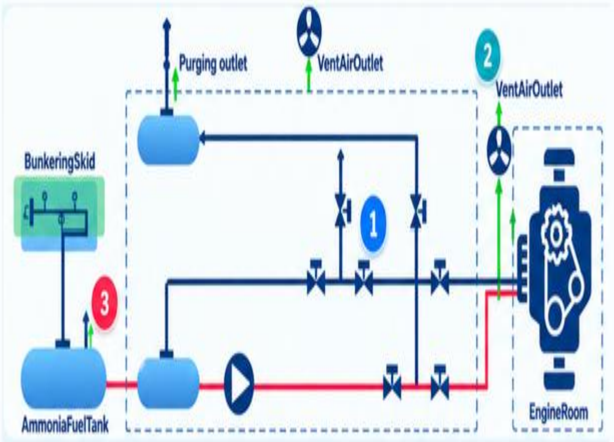
Prevent and Recover Before Water Capture

Can we recover ammonia before it becomes part of the effluent?

1 Ammonia-containing gas release

From purging, venting, pressure relief or depressurization



2 Check feasibility for recovery

Recovery depends on gas composition, condenser capacity and operating conditions.

Gas composition
Ammonia concentration, other components

Condenser capacity and availability
Size, redundancy, operating status

Header pressure
Pressure and temperature conditions

Feasible

3A Recover ammonia (preferred where feasible)

Condense and recover the ammonia for fuel or reuse.

Condense / Recover → NH_3 → To fuel tank or other reuse

- Reduces ammonia load to the effluent
- No new ammonia-containing liquid stream from this route

Not feasible or impractical

3B Route to water-based release control (when recovery is not feasible)

Absorb the gas in water through scrubbing or a water seal.

Water absorption →

Controlled vent gas
Verify outlet NH_3 with applicable requirements

Ammonia-containing liquid (effluent)
Manage through downstream pathways

- Performs a safety function by controlling gaseous releases
- Creates an ammonia-containing liquid, which requires further management

Recover before water capture where feasible, without compromising safety. | The choice depends on project-specific design and operating conditions.

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Manage the Liquid: What Changes, What Remains?

Different options can reduce risk or create value, but the nitrogen remains and must be accounted for.

1 Stabilize the Liquid

Reduce free ammonia and handling risk.

Acid dosing (e.g. H_2SO_4)

Ammonia-containing liquid (characterized) → Measure & Control pH → Shift to ammonium (NH_4^+) → Recirculation / bleed

pH

$NH_3 + H^+ \rightarrow NH_4^+$

What changes?

- Free ammonia decreases
- Re-vaporization risk decreases

What remains?

- Total nitrogen remains
- Ammonium salts and additives
- Bleed and residual streams

! Project-specific pH conditions; not a universal standard.
Stabilization does not, by itself, demonstrate discharge eligibility.

2 Reuse the Liquid or Recover a Useful Product

Turn the liquid into a resource where appropriate.

- **Qualified stream** — Characterized quality
- **Defined user or product** — Compatible process or product specification
- **Closed residual mass balance** — Account for what remains

A Direct process reuse

Use the qualified liquid as a process feed.

Qualified liquid → Compatible receiving process → Useful process feed

B Selective recovery

Recover ammonia or a defined ammonium product.

Characterized liquid → Separate / concentrate / condition → Defined product (e.g. NH_3 or NH_4^+ salts) → Residual stream (to further management)

Each option changes the form and use of the liquid — but every remaining stream needs a controlled destination.

The objective is not to move ammonia between phases, but to minimize the overall environmental burden.

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Final Endpoints: Verify Every Output

Treatment is not the endpoint — each gas, liquid and solid output needs a verified destination.

Outputs from management options

After prevention, stabilization, reuse or recovery, residual streams remain.

Gaseous outputs
e.g. NH_3 slip, NO_x, N_2O, vent gas

Liquid outputs
e.g. stabilized effluent, concentrate, process water

Solid outputs
e.g. salts, sludge, spent media

Optional onboard conversion (where appropriate)

Further treatment may convert the streams into different forms.

Residual streams

- Treated gas
- Treated liquid
- Treated solid

Final destinations and key considerations

Discharge or transfer is not assumed to be acceptable.
Environmental acceptability and compliance with applicable requirements must be demonstrated.

AIR
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Verified atmospheric output
- Verify ammonia slip, NO_x and N_2O
- Comply with applicable air emission requirements

SEA
PROTECT MARINE ENVIRONMENT

Conditional marine discharge
- Only where policy and regulatory requirements allow
- Demonstrate environmental acceptability
- Not a current authorization

SHORE
RESPONSIBLE FINAL TREATMENT

Retain and shore transfer
- Closed and safe transfer
- Accepted facility with actual final treatment
- Traceability and documentation

No verified, authorized and available endpoint?
Isolate • Retain • Reassess

A management route must address the entire pollution burden — not only one stream.

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04

CHAPTER 04

Shipboard Integration & Failure-Safe Operation

How does a treatment concept become a safe ship system?

Stream segregation · installation engineering · monitoring · off-spec and fallback

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Shipboard Routing: When to Proceed, When to Hold

Keep ammonia-containing liquids identifiable, verify their suitability, and route them to the most appropriate pathway.

1 Keep streams identifiable

Know where the liquid comes from.

Engine & machinery
e.g. safety release, purging, depressurization

Fuel system
e.g. draining, maintenance

Process / auxiliary systems
e.g. equipment drains, wash water

Response and contingency
e.g. leakage mitigation, firewater (if applicable)

Maintain segregation and traceability (e.g. dedicated lines/labels, sampling).

2 Check the liquid and the route

Is the liquid suitable, and is the pathway available?

A. Check liquid characteristics

Composition
Total ammonia (TAN), pH, salts, other components

Physical condition
Temperature, phase, volatile fraction

Compatibility
With selected treatment/ reuse process

B. Confirm route availability

Technical feasibility
Capacity, operating conditions, redundancy

Final destination
Reuse process, discharge (when authorized), or shore facility

Regulatory & operational readiness
Applicable requirements, monitoring and evidence

Within the operating window and route available?
- YES → Proceed with the selected pathway
- NO → Hold, verify and reassess

3 Proceed or hold

Take the appropriate action based on the assessment.

Proceed with the selected pathway

- Send to stabilization
- Send to reuse / recovery
- Send to further conversion
- Send to conditional discharge (when authorized)
- Send to shore facility

Hold, verify and reassess

- Store in a dedicated tank
- Keep under controlled conditions
- Reassess composition, route availability and regulatory status

Genuine emergency: respond first

- Ensure safety of people, ship and environment
- Manage residuals afterward, where practicable

Verify both the liquid and the route before proceeding. | Prevent uncontrolled releases — keep the option to manage safely.

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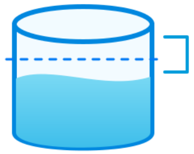
Make the Selected Route Work on Board

Design for normal operation—and when the preferred route is unavailable.

DESIGN CHECK Liquid continues to accumulate while the selected treatment route is unavailable.

1 SIZE

How long can we retain the liquid if the route is unavailable?



- Accumulation and repeated events
- Treatment downtime, endpoint delays and operating margin

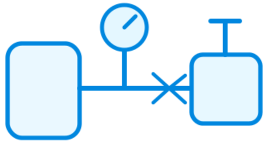
2 CONTAIN

Can we safely contain the liquid and its vapour?

- Vapour / relief routing and secondary containment
- Materials for pH, salts and contaminants

3 CONNECT

How is the route physically connected and verified?



- Utilities, sampling, monitoring and interlocks
- Closed shore transfer; authorized sea interface where applicable

4 MAINTAIN

Can we isolate, empty and service the system safely?

- Isolation and safe emptying
- Purging, gas testing and maintenance access

DESIGN OUTPUTS | **Design inventory** | **P&ID** | **Cause-and-effect logic**

Design the ship to manage the liquid even when the preferred route is unavailable.

Functional design framework—not a universal sizing formula or prescribed arrangement.

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05

CHAPTER 05

Conclusions

What must ultimately be demonstrated?

Complete pathway · defined and verifiable final destination

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Closing the Ammonia Pathway

From generation to a defined and verifiable final destination — for pollution prevention.

TREATMENT PERFORMANCE ALONE IS NOT ENOUGH.
We must demonstrate the complete pathway, with defined and verifiable final destinations for all nitrogen-containing outputs.

1 DEFINE THE STREAM

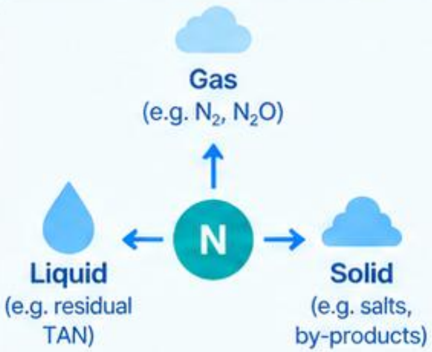
Know what we are managing.

- Identify the source and operating scenario
- Estimate quantity and chemical characteristics (e.g. TAN, pH, salts)
- Prevent or minimize the ammonia load where feasible, without compromising safety

Clear characterization enables appropriate management and regulatory compliance.

2 FOLLOW THE NITROGEN

Account for what happens after treatment.

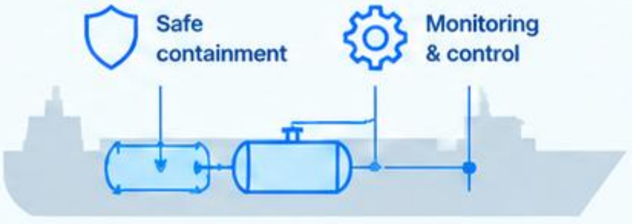


- Account for all nitrogen-containing outputs (gas, liquid, solid, residuals)
- Verify environmental acceptability
- Confirm a defined and feasible final destination for each output (discharge, reuse, further conversion, or shore transfer)

Track the nitrogen — and ensure every output has a verifiable and environmentally acceptable destination.

3 PROVE THE SHIP SYSTEM

Make it work safely on board.



- Verify the liquid and the selected route
- Provide sufficient retention and safe management when the preferred route is unavailable
- Enable isolation, maintenance and safe recovery
- Demonstrate compliance under normal and foreseeable failure conditions

From a treatment concept to a verifiable, robust and failure-safe ship system.

Demonstrate pollution prevention across the complete pathway — not just treatment performance.

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