The Technology of Ammonia Fuel Supply System for Two-stroke Engine

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***Abstract*—The goal of the Ammonia Fuel Supply System (AFSS) is to provide the ammonia fuel to the engine as required. It must be achieved during engine operation and bunkering. The ammonia fuel must be delivered to the engine within a specific range of temperature, pressure and purity. It is achieved by means of supply pumps, heat exchanger and filters.**

***Keywords*—ammonia fuel, supply system, engine**

I. Overview

Marine ammonia fuel supply system is a power system that uses ammonia (NH_3) as fuel and ammonia is mainly used in ships to replace traditional fossil fuels such as diesel. Ammonia fuel can achieve zero carbon emissions. After combustion, it only produces nitrogen and water, fundamentally eliminating carbon dioxide emissions. Ammonia fuel has a high energy density . The energy density of liquid ammonia is three times that of liquid hydrogen, and a fuel tank of the same volume can provide a longer range. Ammonia fuel is easy to store. It can be liquefied at room temperature under pressure or cooled to −34 ℃, without the extremely low-temperature storage conditions required for hydrogen.

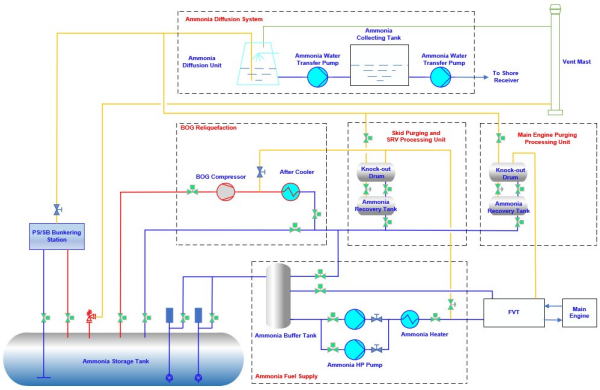

Fig. 1. The flow diagram of ammonia fuel supply system.

II. General

Ammonia Fuel Supply System (AFSS) is equipped to supply ammonia fuel for dual-fuel main engine. Redundancy of propulsion and power supply is ensured by fuel oil in case of fuel supply shutdown. The Ammonia system shall consist of bellows.

A. Bunkering Station

Bunkering station in open space and is a semi-enclosed system. Ammonia bunkering station is designed referred to SGMF [1], and other relevant regulations. The material of bunkering lines shall be SS316L. The material of valves and the drip tray shall be SS304.

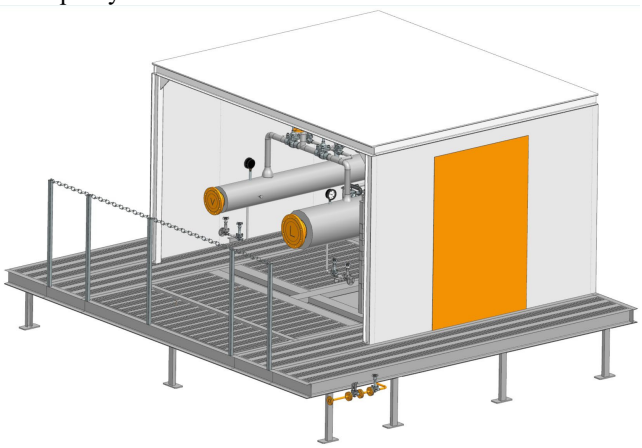

Fig. 2. Open-deck bunker station (side view).

Two Ammonia bunkering stations (port side and starboard side) shall be provided as a skid in accordance with IGF code [2] configuration.

Air tightness steel cover with forced ventilation fan, which are equipped with flow switch and remote isolation valve. In order to prevent the diffusion of ammonia gas during leakage, automatic water spray system for inside the top of bunkering station and outer area, this could also provide coverage for exposed area for fire protection.

Bunker (NH3) and vapour pipelines on the main deck shall be well protected. Distance of the manifold from the accommodation, entry to control space and air intakes is more than 90 meters [3].

B. Ammonia Storage Tank

From the bunkering station, ammonia is transferred to the ammonia storage tank(s). Ammonia storage tank shall contain two support saddles, one of which is fixed and the other is sliding. The saddles shall be welded to deck of the hull and designed according to the hull structure drawing which shipyard provide in later steps. Anti-floating device shall be designed according to ship deformation. The roll and pitch requirements of ship are fully considered for the Tank interface layout.

The Ammonia storage tanks shall be equipped with necessary instruments, internal pipes, connections, manhole, internal access ladder, stiffening rings, and swash plates.

One (1) set tank connection space for each tank have been designed as a gastight steel enclosure, which shall be fixed on top of the tank and contain tank dome nozzles, associated valves and instruments, etc.

Safety guard devices shall be supplied, such as below:

- Closed-Circuit TeleVision
- Gas detectors

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- Fire detectors
- Ex-proof junction box (SS316L, IP56)
- Solenoid valve plate (Ex-proof solenoid valves, IP56)
- Water spray system
- Water screens system
- Ex-proof Light
- Forced ventilation fan

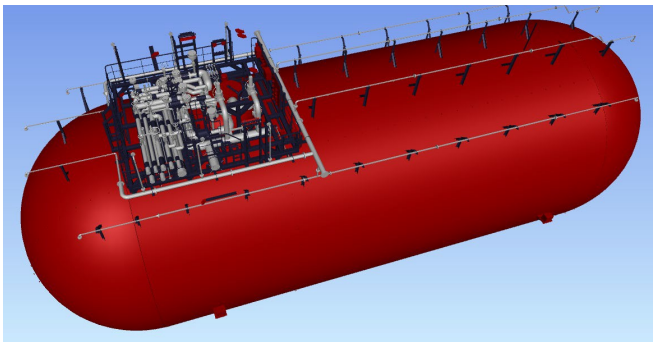

Fig. 3. Ammonia storage tank.

The polyurethane foam material shall be used for insulation of tank. The insulation shall be designed according to the BOR and holding time of tank [4].

After application of spray foam, a polyurea coating or glass fiber reinforced plastics shall be applied on the foam surface as a homogeneous continuous protective layer.

Peelable lacquer shall be provided to protect the tank surface before delivery.

C. Low Pressure (LP) Ammonia Supply Pump

LP ammonia supply pump shall be installed in each ammonia storage tank. The LP ammonia supply pump shall be used for supplying ammonia to the High Pressure (HP) ammonia supply pump. Meanwhile, LP ammonia supply pump shall meet the pressure and flow requirements of HP ammonia supply pump, and engine's recirculation flow. The ammonia supply pumps shall be controlled by variable-frequency drive. The pump design shall meet zero gas leakage.

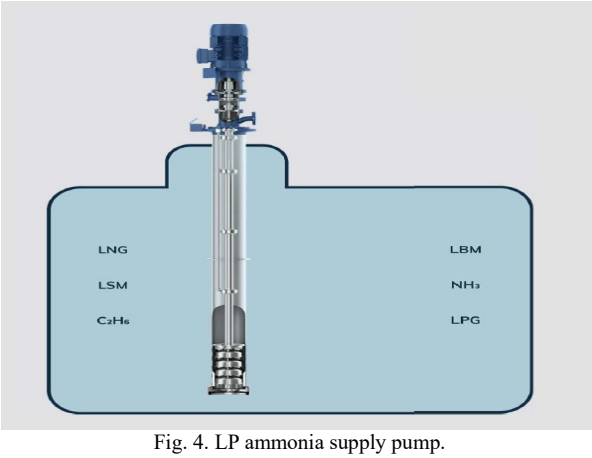

Fig. 4. LP ammonia supply pump.

D. High Pressure (HP) Ammonia Supply Pump

HP ammonia supply pump shall be installed at downstream of LP ammonia supply pump to pressurize ammonia to certain pressure suited for main engine requirement.

E. BOG Re-liquefaction Unit

BOG re-liquefaction unit to be installed for ammonia liquid sub-cooling from storage tank, then super cooled liquid will send back to storage tank for BOG condensing, avoiding the tank overpressure and BOG management, ammonia sub-cooled.

Two sets of refrigerant compressor shall be equipped in the safety area, which is close to the AFHR. The compressor is driven by electrical motor, and the capacity of which is controlled by a slide valve. Re-condenser heat exchanger to be installed on downstream of refrigerant compressor to sub-cooling ammonia liquid from storage tank.

F. Ammonia Gas Diffusion Unit

Ammonia diffusion unit mainly to ensure the ammonia gas relief via vent mast is satisfied with the classification requirement [5]. One set of Ammonia diffusion unit is equipped with Ammonia aqueous detector to control the liquid auto drain and water circulation. Water should be not lower than 8 liters for each kilogram of ammonia to be dissolved, the specific volume could be determined according to the installation plan of the ship's equipment.

The ammonia absorption unit process constitutes a one-stage high-efficiency ammonia absorber and a three-stage packing tower absorption system.

The absorbing water for the high-efficiency ammonia absorber and the primary and secondary packing towers are circulated through the circulating pump.

The tertiary packing tower is supplied with clean water, and the amount of water injected is regulated by the ammonia detector and the water regulating valve [6]. Under normal circumstances, the water requirement is low.

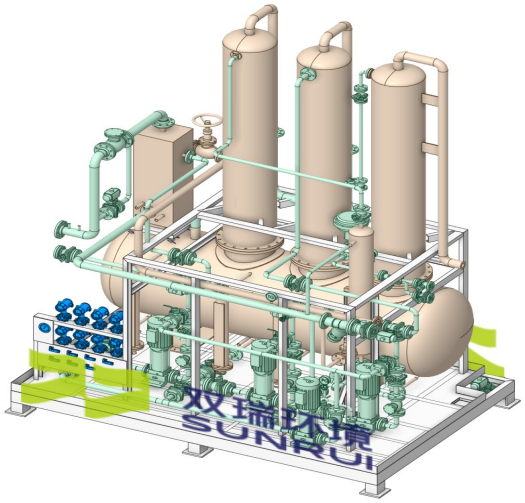

Fig. 5. Example of ammonia gas diffusion unit.

G. Nitrogen Generating System

One set of membrane nitrogen generator unit shall be supplied to purge ammonia pipeline after bunkering and fuel supplying.

The following pipes and equipment shall be purged:

- Ammonia bunkering pipes
- Tank dome pipes
- Fuel supply pipes
- High pressure ammonia pump unit
- Inner pipe of double-walled pipe for main engine
- Main engine fuel pipes
- The nitrogen generator unit contains the following

parts:

- Air compressor
- Oil-injected screw compressor
- Cooling: air-cooled
- Refrigeration dryer
- Insulation grade: F
- With space heater
- Membrane nitrogen generator
- Discharge pressure 10 bar G
- Dew point: −40 °C
- Integrated coalescing filter, oil vapor filter and dry dust filter
- PDP (pressure dew point) and purity (oxygen) sensor with alarm
- Control module
- Compressor status indications
- Pressure, temperature indications
- Compressor control
- Meters (running hours, loading hours)
- Safety-warning indications
- Safety-shutdown indications
- Output for remote monitoring

The nitrogen plant shall be started and stopped manually or automatically by the pressure transmitter in the Nitrogen receiver. The pressure of nitrogen receiver shall be indicated at local and control system.

Main control panel shall be provided near the generator unit. The generators shall be started/stopped locally from the main control panel.

Heater for feed air temperature control according to manufacturer's recommendation

Valves, instruments, controls, and panels for safe and automatic unattended operation

Nitrogen booster shall be installed, one nitrogen booster (with flexible hose for inlet, outlet) unit including the relevant high pressure nitrogen distribution valves, safety valve. Meet the requirements of main engine. Another one nitrogen booster unit is designed for Ammonia gas processing unit.

Two (2) oxygen sensors to be positioned at appropriate locations in the space containing the nitrogen generator [7]. If the oxygen level falls below 19%, these sensors to trigger alarms, which shall be both visible and audible inside and outside the space.

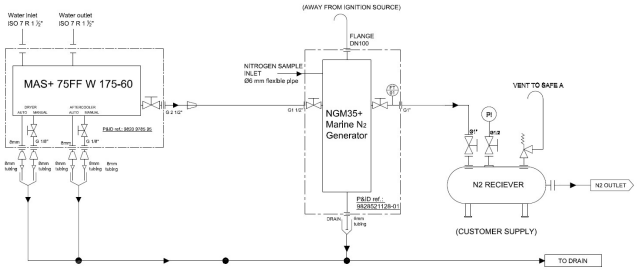

Fig. 6 Nitrogen system flow-chart.

H. Emergency Shutdown (ESD) System

The emergency shutdown system shall be designed according to the IGF code and Class requirements to ensure the security of ammonia supply system in case of emergency.

The physical ESD push buttons shall be arranged for manual shutdown of relevant ESD valves and electrical equipment during relevant operation process. Emergency shutdown push buttons shall be equipped in the following locations:

- Bunkering stations
- Tank connection spaces
- Ammonia fuel handling room
- Engine control room
- Escape way of engine room
- Outside of the engine room
- Bridge
- Firefighting room
- Deck office

I. Ship Shore/Ship Link System

Ship shore/ship link shall be supplied for Ammonia bunkering operation, it shall meet recommendations and guidelines of SIGTTO [8]. A ship-shore/ship-ship link with main (Fibre optic) and back-up (Electric) systems for automatic ESD communication shall be fitted.

The system shall include the following equipment:

- Main control cabinet
- A hot phone to provide commutations with shore/ship, 1 set
- Shipside boxes with 2 pin fibre optic connector and 5pin SIGTTO electric connector
- Fibre optic link system with 2 cores uses standard digital SONET data transmission, with 2 cores connector to transfer ESD and digital data
- Fibre optic and electric test unit
- In-built system test & diagnostics
- Operator Hand-Carry Umbilical Reel

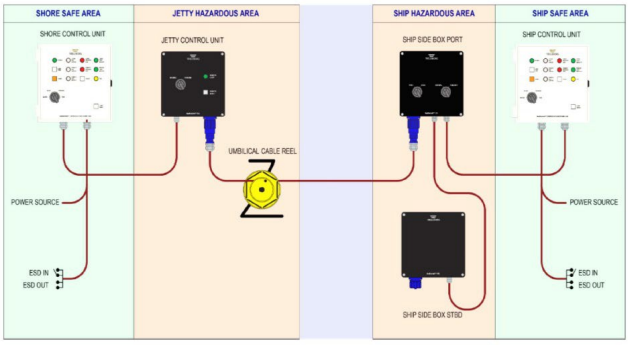

Fig. 7. Example of an electric pneumatic system.

J. Vent Mast

One vent mast shall be supplied according to Classification society, except the safety relief valve of the ammonia storage tank is directly connected with the vent mast, other piping of AFSS that may contains ammonia discharge are connected with the vent mast through the ammonia gas processing unit.

One flame arrested vent head (SS316L) shall be provided and equipped with rain defector on the top of vent mast.

The interior of the vent mast is equipped with sea water spray line for the reabsorption of ammonia vapor in the released gas.

The discharge capacity calculation and back-pressure calculation of safety valves of the ammonia storage tank shall be needed.

K. Water Screens System

The water screens system shall be provided for bunkering stations, tank connection spaces and ammonia fuel handling room, the system shall be operable manually from outside the compartment and automatically in the event of gas detection or emergency shutdown.

Drip tray to be installed and designed with a dedicated volume according to classification requirement to contain liquid ammonia or ammonia containing mixture. Ammonia drain pump to be equipped for transfer liquid to ammonia aqueous collecting tank.

L. Water Spray System

Water spray system shall provide coverage for exposed safety related equipment both for fire and toxicity protection. The water spray capacity, coverage area, and spray nozzle selection shall meet the requirement of IGF code and classification society [9].

Manual activation points shall be readily accessible in non-hazardous and non-toxic areas. To ensure the smooth access of personnel to the area covered by the water spray system, safe transit (such as secure walkways, gratings, non-slip surfaces) should be considered.

M. Ammonia Fuel Piping

Butt welded joints shall be generally used for AFSS piping [10]. The pipe joints shall be kept to a minimum. The system, including any bellows, shall be welded as far as practicable but with sufficient flanges to allow maintenance and removal of equipment.

Screwed connections shall be used for accessory lines and instrumentation lines with external diameters of 1 inch or less in general in accordance with the requirements of the Rules and Regulations.

The cryogenic Ammonia pipes (single wall) shall be covered insulation by PU foam. The insulation to be covered with water and vapor tight barrier. The High-temperature line with temperature over 60℃ shall be insulated.

N. Electrical System

The electrical components of AFSS are shown as follows:

- Motor starter unit
- Control and monitor unit
- IS signal panel
- Safety and shutdown unit
- Control station
- Monitor station
- ESD buttons for safety system
- Junction boxes
- Motor local start box

Motor starter unit shall include several inverters and motor protect circles. The speed of LP Ammonia supply pump shall be regulated by variable-frequency drive to keep the flow and pressure requirement of HP Ammonia supply pump inlet.

Signal interface:

- Integrated Automation System: Interface ModBus-RTU RS485 to Integrated Automation System
- Fire and gas detector system: Dry contact for Safety/ESD system
- Fuel Valve Train: Hard-wired signals (including necessary hard-wired signals) as interface to Fuel Valve Train
- Ventilation system: Alarm signals to be connected to AFSS safety system via hard-wired

AFSS control and safety system together with the interface components is installed in an enclosed main control cabinet in engine control room. This main control cabinet can be operated manually and consist of UPS cabinet.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Ding Ding conducted the research; Chenyang Ma analyzed the rule; Luyi Chen wrote the paper; all authors had approved the final version.

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