Module No 3

Boil off Gas Management
What is Boil Off?

- The vapours created due to the ambient heat input (while maintaining constant pressure in the storage vessel) are called “boil-off”.
- Boil-off is inherent to the storage of a cryogenic due to the heat input from ambient.
- For LNG propelled ships, the boil-off vapours are usually fed to ship's boilers, via a compressor and heater, for use as fuel for main ship's propulsion.
Boiling Liquid Expanding Vapour Explosion (BLEVE)

BLEVE is a vapour explosion which may result from catastrophic failure of a tank structure, which was containing cargo liquid above the boiling point at nominal atmospheric pressure.
Daily Boil Off

- So far we do not have 100% perfect insulation
- There would be some heat ingress from sea and outside environment
- Latest ships with modern insulation have a boil off rate of just 0.1% per day

**LNG Carrier of 40/50 000 m³**
- Loaded: 0.23% per day
- On ballast: 0.18% per day

**LNG Carrier of 135 000 m³**
- Loaded: 0.15% per day
- On ballast: 0.08% per day
NBOG Requirement

“... means are to be provided to maintain tank pressure below MARVS by safely utilizing or disposing of NBOG at all times, while in port, while manoeuvring, while standing by ..”

“... maintain tank pressure below MARVS and not to become liquid full for a period of 15 days ...”
Bunker Station Requirement

No gas is to be discharged to air during bunkering operations.

Source: Wartsila
Bunker Station Requirement

- Sufficient natural ventilation
- Physical separation and structural protection
- Stainless steel / cryogenic drip trays
- Class A-60 protection
- Vapour return line provision
- Manifold filters
- Manual and remote ESD valves
- ESD valve closing speed
- ESD and bonding connections
- Remote control and monitoring
- Local pressure gauges
- Draining/purging/inerting provision
- Gas detection on enclosed or semi-enclosed bunker stations
- Ventilation and gas detection of enclosed bunkering lines
- Fixed fire detection and extinguishing system
Gas Combustion Unit

- Capacity to handle BOG that cannot be consumed by primary means
- Capacity should be at least = NBOR
- Need to establish capability for intended service
BOG Unit
Engine Room BOG Isolation valve
Natural Boil Off Gas

BALLAST VOYAGE

Vapour header
Spray header
Liquid header

INERT GAS
F. VAP
SEP
BOILER
LDH
LDC
HDH
HDC
VAP

CP
SP
Forced Vaporisation

LOADED VOYAGE with forced vaporisation

Vapour header

Spray header

Liquid header

INERT GAS

F. VAP

BOILER

LDH

LDC

HDH

HDC

VAP

SEP

CP

SP
SPRAYING DURING BALLAST VOYAGE

Choose the Subject Tank
- to supply the Engine Room with Boiler-off gas for the boilers.
- to the desired pressure.
- for high flow operation.
- to insulation space header to desired pressure.
  - at 0.2 kPa.
  - at 0.4 kPa.

SET LD Compressors on line
- SET Forward Mast Riser
  - to the desired pressure.

Check Nitrogen System
- for high flow operation.
- to insulation space header to desired pressure.
  - at 0.2 kPa.
  - at 0.4 kPa.

Set Nitrogen supply regulating valve

Set Exhaust regulating valve

is carried out by the following steps

Leave spray header valves open to allow the spray line to warm up to ambient temperature.

Open isolating valve further.

Increase flow rate by adjusting the spray pump discharge.

On completion of cool down:
- Once spray header is cooled down:
  - OPEN Spray discharge valve
    - to Subject tank.
  - START Spray Pump
  - PARTIALLY OPEN Isolating Valve
    - to the spray line.
  - FULLY OPEN Spray inlet valves
    - to subject tank.
    - to vapour header.
LNG BOG Pumping

Steam/Hot Water Heater

Brine Pump

HP Pump

LNG Vaporizer

Condensate from BOG RS or LNG from Cargo Tanks

Pressure: 3-5 bar
Temperature: -160°C

High Pressure Gas to Gas Engine

Pressure: Max 300 bar
Temperature: 45 ± 10°C
Boil Off Gas to Engine Room – Natural Boil Off

Exhaust Fan

#4 Vent Mast

About -130°C

+ve pressure

Exhaust Fan

Boilers

Duct

N₂ Purge

E/R Bulkhead (Safety Barrier)

Boil Off Gas to Engine Room – Natural Boil Off

Exhaust Fan

#4 Vent Mast

About -130°C

+ve pressure

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Duct

N₂ Purge

E/R Bulkhead (Safety Barrier)
LNG Intentional Curve

Need to control boil-off rate in order to use for propulsion

When vapor reduces, then adopt the “Intentional Curve”.

Start Spraying in the Morning

Stop Spraying in the evening

2 Kpi

Yet pressure increases even after stopping
BOG Utilisation Management
Diesel Electric Propulsion System for LNG

Schematic of an LNG carrier propulsion system utilising 4 dual fuel (DF) medium speed engines.
For a 138,000 m³ LNG vessel, 4 × 9L50DF engines, each 8550kW give a total 34.2MW.
Extra Delivered Cargo (Wartsila)

- Dual-fuel-electric
  - N-BOG + F-BOG
- Two-stroke diesel + reliquefaction
  - HFO
- Steam turbine
  - N-BOG + HFO
- Gas turbine-electric combined-cycle
  - N-BOG + F-BOG
- Gas turbine-electric single-cycle
  - N-BOG + F-BOG
Standby Unit?

• IGC 7.2.1
  “Unless an alternative means of controlling the pressure/temperature is provided ... ... a standby unit affording spare capacity at least equal to the largest single unit should be provided ...”

• LNG Re-liquefaction
  – Large, complex, expensive
  – No second unit practical
  – Alternative means required
Thermal Oxidiser

SAACKE Gas Combustion Unit (GCU)

- Dilution and cooling air
- Dilution and cooling air
- Primary combustion air
- Secondary Combustion air
Roll Over LNG

A. HOMOGENEOUS LNG
- Normal rate of boiloff-gas production
- Evaporation
- Convection cell

B. STRATIFIED LNG
- Reduced rate of boiloff-gas production
- Evaporation
- Lighter layer
- Heavier layer
- Convection cell

C. TANK EXPERIENCING ROLLOVER
- Rapid rate of boiloff-gas production
- Rapid flashing
- Rapid mixing of two layers
WEATHERING ROLLOVER

- A small amount of LNG boil-off is generated by heat ingress through the tank insulation.
- Liquid on the top layer evaporates, cools and becomes denser. This process is known as “Weathering”
- Heating of lower layers results in the equilibrium of densities of the two layers. When this occurs the interface between the layers breaks down resulting in rapid transfer of heat and mass within the tank.
- The two layers mix rapidly and the lower layer, which has been superheated, gives off large amounts of vapour as it rises to the surface of the tank.
- This phenomenon is “ROLLOVER”
- The large amounts of vapour generated by this, can cause a dramatic vapour expansion and rapid increase in tank pressures.
Boil off / Weathering effect