MB02 TAKE PRECAUTIONS TO PREVENT HAZARDS ON A SHIP SUBJECT TO IGF CODE
MB02 TAKE PRECAUTIONS TO PREVENT HAZARDS ON A SHIP SUBJECT TO IGF CODE

• Basic knowledge to control the risks associated with use of LNG
• Description of health, ship, equipment and environmental hazards associated with LNG operations and explanation on how to control these hazards;
BASIC KNOWLEDGE OF THE HAZARDS ASSOCIATED WITH OPERATIONS ON SHIPS SUBJECT TO THE IGF CODE

HAZARDS RELATED TO LNG CONCERN:
- HUMAN HEALTH
- SURROUNDINGS (vessel, environment)
Health hazard (cont. 1/2)

- **Methane \( CH_4 \)**
- The main hazard: **FLAMMABLE, FROSTBITE, ASPHYXIANT**

<table>
<thead>
<tr>
<th>RISK</th>
<th>EMERGENCY PROCEDURENURES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FIRE</strong></td>
<td>Stop gas supply</td>
</tr>
<tr>
<td></td>
<td>Extinguish with: Dry powder, Halon, ( CO_2 )</td>
</tr>
<tr>
<td></td>
<td>Cool surrounding area with water spray</td>
</tr>
<tr>
<td><strong>SPILLAGE</strong></td>
<td>Stop the flow</td>
</tr>
<tr>
<td></td>
<td>Avoid contact with liquid or vapour</td>
</tr>
<tr>
<td></td>
<td>Flood with large amounts of water to disperse spill</td>
</tr>
<tr>
<td><strong>VAPOUR INHALED</strong></td>
<td>Remove victim to fresh air</td>
</tr>
<tr>
<td></td>
<td>If inhalation victim is not breathing, ensure that their airways are open and administer cardiopulmonary resuscitation (CPR)</td>
</tr>
<tr>
<td></td>
<td>Render First Aid when required</td>
</tr>
<tr>
<td><strong>LIQUID ON SKIN</strong></td>
<td>Treat patient gently</td>
</tr>
<tr>
<td></td>
<td>Remove contaminated clothing</td>
</tr>
<tr>
<td></td>
<td>Immerse frostbitten area in warm water until thawed</td>
</tr>
<tr>
<td><strong>LIQUID IN EYE</strong></td>
<td>Flood eye gently with large amount of clean fresh water</td>
</tr>
<tr>
<td></td>
<td>Force eye open to allow liquid to evaporate</td>
</tr>
<tr>
<td></td>
<td>If the person cannot tolerate light, protect the eyes with a bandage or handkerchief</td>
</tr>
<tr>
<td></td>
<td>Do not introduce ointment into the eyes without medical advice</td>
</tr>
<tr>
<td><strong>EFFECT OF LIQUID</strong></td>
<td>Not absorbed through skin</td>
</tr>
<tr>
<td></td>
<td>Frostbite to skin or eyes</td>
</tr>
<tr>
<td><strong>EFFECT OF VAPOUR</strong></td>
<td>Possible damage to lungs, skin</td>
</tr>
<tr>
<td></td>
<td>Headache, dizziness, vomiting, and incoordination</td>
</tr>
</tbody>
</table>
Health hazard (cont. 2/2)

- **Nitrogen** $N_2$
- The main hazard: **FROSTBITE, ASPHYXIANT**

<table>
<thead>
<tr>
<th>RISK</th>
<th>EMERGENCY PROCERURES</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FIRE</strong></td>
<td>Non-flammable</td>
</tr>
<tr>
<td></td>
<td>Cool cargo tanks surrounding area with water spray in the event of fire near to them</td>
</tr>
<tr>
<td><strong>SPILLAGE</strong></td>
<td>Stop the flow</td>
</tr>
<tr>
<td></td>
<td>Avoid contact with liquid or vapour</td>
</tr>
<tr>
<td></td>
<td>Flood with large amounts of water to disperse spill</td>
</tr>
<tr>
<td><strong>VAPOUR INHALED</strong></td>
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<tr>
<td></td>
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<tr>
<td><strong>LIQUID ON SKIN</strong></td>
<td>Treat patient gently</td>
</tr>
<tr>
<td></td>
<td>Remove contaminated clothing</td>
</tr>
<tr>
<td></td>
<td>Immerse frostbitten area in warm water until thawed</td>
</tr>
<tr>
<td><strong>LIQUID IN EYE</strong></td>
<td>Flood eye gently with large amount of clean fresh/sea water</td>
</tr>
<tr>
<td></td>
<td>Force eye open if required</td>
</tr>
<tr>
<td><strong>EFFECT OF LIQUID</strong></td>
<td>Frostbite to skin or eyes</td>
</tr>
<tr>
<td><strong>EFFECT OF VAPOUR</strong></td>
<td>Asphyxiation. Cold vapour could cause damage</td>
</tr>
</tbody>
</table>
Environmental hazard (cont. 1/2)

• LNG rapid evaporation is expected from both land and water with no residues left behind
• LNG spills on water do not harm aquatic life or damage waterways in any way
• LNG vaporizes, the vapour cloud can ignite if there is a source of ignition, but otherwise LNG dissipates completely
Environmental hazard (cont. 2/2)

Methane:
- Not significant air pollutant
- Not considered as water pollutant
- No reactivity with water (Fresh/Salt), although may freeze to form ice or hydrates
- Dangerous reaction is possible when contacted with chlorine

Nitrogen:
- No reaction when contacted with water (Fresh/Sea).
- Insoluble
- No reaction with air or other gases/liquids
Reactivity of LNG

LNG may react with:
- Another cargo
- Its own
- Other materials
- Air
- Water to form hydrates

(cont. 1/5)
Reactivity of LNG (cont. 2/5)

Reaction with water (hydrate formation)

• Water for hydrate formation can come from:
  – Purge vapors with incorrect dew point
  – Water in the cargo system
  – Sometimes: water dissolved in the cargo
Reactivity of LNG (cont. 3/5)

Self-reaction

• Some self-react cargos (like ethylene oxide), which cannot be inhibited must be carried out under inert gas.
• Most common form is polymerization initiated by the presence of small quantities of other cargos or certain metals.
Reactivity of LNG (cont. 4/5)

Reaction with air
- Can cause explosion by forming unstable oxygen compounds
- Cargos must be either inhibited, carried under IG or N₂

Reaction with other cargos
- Consult data sheet for each cargo
- If possible, separate reliquefaction systems to be used for each cargo
- If danger of chemical reaction exist than use of completely segregated systems is required, known as positive segregation (See specification of certain cargos in IMO Gas Carrier Code)
- If there is any doubt of the reactivity or compatibility of two cargos they must be treated as incompatible and ‘positive segregation’ provided
Reactivity of LNG (cont. 5/5)

Reaction with other materials

- Consult data sheet list of materials not allowed to come into contact with cargo
- ONLY compatible materials to be used in the cargo system
### Ignition, explosion, flammability hazards (cont. 1/3)

<table>
<thead>
<tr>
<th>Liquefied Gas</th>
<th>Flash Point [°C]</th>
<th>Flammable range [%by vol. in air]</th>
<th>Auto-ignition temp [°C]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>-175</td>
<td>5.3-14.0</td>
<td>595</td>
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<tr>
<td>Ethane</td>
<td>-125</td>
<td>3.0-12.5</td>
<td>510</td>
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<tr>
<td>Propane</td>
<td>-105</td>
<td>2.1-9.5</td>
<td>468</td>
</tr>
<tr>
<td>n-Butane</td>
<td>-60</td>
<td>1.5-9.0</td>
<td>365</td>
</tr>
<tr>
<td>i-Butane</td>
<td>-76</td>
<td>1.5-9.0</td>
<td>500</td>
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<tr>
<td>Ethylene</td>
<td>-150</td>
<td>3.0-34.0</td>
<td>453</td>
</tr>
<tr>
<td>Propylene</td>
<td>-108</td>
<td>2.0-11.1</td>
<td>453</td>
</tr>
<tr>
<td>α-Butylene</td>
<td>-80</td>
<td>1.6-10.0</td>
<td>440</td>
</tr>
<tr>
<td>β-Butylene</td>
<td>-72</td>
<td>1.6-10.0</td>
<td>465</td>
</tr>
<tr>
<td>Butadiene</td>
<td>-60</td>
<td>1.1-12.5</td>
<td>418</td>
</tr>
<tr>
<td>Isoprene</td>
<td>-50</td>
<td>1.5-9.7</td>
<td>220</td>
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<tr>
<td>Vinyl Chloride</td>
<td>78</td>
<td>4.0-33.0</td>
<td>472</td>
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<tr>
<td>Ethylene Oxide</td>
<td>18</td>
<td>3.0-100.0</td>
<td>429</td>
</tr>
<tr>
<td>Propylene Oxide</td>
<td>37</td>
<td>2.1-38.5</td>
<td>465</td>
</tr>
<tr>
<td>Ammonia</td>
<td>-57</td>
<td>14.0-28.0</td>
<td>615</td>
</tr>
<tr>
<td>Chlorine</td>
<td></td>
<td>Non-flammable</td>
<td></td>
</tr>
</tbody>
</table>
Ignition, explosion, flammability hazards (cont. 2/4)

- LNG when exposed to air, it evaporates extremely rapidly, producing explosive gas vapor

- Pools of LNG can burn for burns with a visible flame

- Flammability limits are narrow

- Combusting in air-to-fuel proportions of 5-15% ONLY

- Below 5% the mix is too lean to burn and above 15% the mix is too rich to burn
Ignition, explosion, flammability hazards (cont. 4/4)

Flammability of Methane, O\textsubscript{2} and N\textsubscript{2} mixtures

- Not capable of forming flammable mixture with air
- Capable of forming flammable mixtures with air, but not explode - too much methane
- Flammable mixture with air
- Mixtures of air and methane cannot be produced above this line
Sources of ignition:

• Smoking & naked lights
• Spontaneous ignition waste
• Hot work, Cold work
• Safety tools
• Aluminum
• Portable Electrical Equipment & air driven lamps
• Mobile phones
• Radio transmitter, Radar, VHF
• Insulation flanges & ship shore bonding cables
• Cargo handling equipment such as cranes, railroad cars, trains, cryogenic tanker trucks
• Cooking stove in galley, Electric heaters in pantries, etc.
Electrostatic hazards (cont. 1/3)

- Static electricity can cause sparks capable of ignition a flammable gas
- Some routine operations can cause electrostatic charging
Electrostatic hazards (cont. 2/3)

- No CO₂ to be released to flammable mixture
- Metal reinforcement bounded to the cargo flanges
- No steam injection to system with flammable mixture
- Anti-electrostatic clothes and shoes
- Electrostatic discharge plate
- Grounded handle

Precautions to minimize the hazard of static electricity
Electrostatic Generation

• Some materials (solid, liquid or vapor) can generate and retain a static charge depends on their electrical resistance. If the resistance is high, a charge can be built up.

• The cargo system of a gas carrier is electrically bonded to the ship’s hull via various bonding connections. This is provided to prevent charge build-up.

Cargo hoses are bonded to their **flanges by the metal reinforcement**. Thanks to this solution it provides a continuous path to earth though the ship’s manifold and the hull.
Toxity hazards

• The principal constituents of natural gas, methane, ethane, and propane, are not considered to be toxic
• Those gases are considered as simple asphyxiants (they are health risk as they can displace oxygen in a close environment)
• threshold limit value (TLV) for an average natural gas composition is about 10,500 ppm
• LNG become toxic by adding odour substances
Vapor leaks and clouds (cont. 1/4)

- LNG has no natural odor of its own
- Difficult for personnel to detect leaks unless the leak is sufficiently large to create a visible condensation cloud or localized frost formation
- Methane gas detectors has to be placed in any area where LNG is being transferred or stored
- LNG transfer and fuel system itself need to be closely monitored due to constant warming of the LNG
Vapor leaks and clouds (cont. 2/4)

HOW to detect gas leak in a system?

MIX couple of tablespoons of typical dish soap into container with water
When system is pressurized wet down suspected area with soap solution

IF THERE IS AN LEAK YOU WILL SEE BUBBLES FORM ON THE LEAKAGE AREA
Vapor leaks and clouds (cont. 3/4)

Situation of flammability within vapor cloud

Wind direction

Too lean

Flammable

Too reach

LNG spill
Vapor leaks and clouds (cont. 4/4)

- VAPOR CLOUD may form when LNG spill
- Lack of breathable atmosphere
- Vapor cloud will gradually disperse downwind
- Vapor cloud is long, thin, cigar shaped
- Vapor initially ‘hugs the surface’
- The major danger from an LNG vapor cloud occurs when it is ignited
Extremely low temperatures (cont.1/2)

- Low cargo temperatures can freeze water in the system leading to blockage of, and damage to pumps, valves, sensor lines, spray lines etc.

- All the temperature sensing equipment must be well maintained and calibrated minimum as per manufacturer requirements
Extremely low temperatures
(cont.2/2)

• LNG spillage on the vessel can result in the brittle fracture of the steel

• Stainless steel drip tray are necessary

• Water curtain must be provided

• Liquid domes must have laid down fire hoses

• Water spray ready for use
Pressure hazards

- To minimize danger of damage to the system, the pressure of the cargo should be maintained between the specified minimum and maximum.

- Avoid liquid hammers (shock pressures) by SLOW opening or closing valve actions as the pressure can be sufficient to cause hose or pipeline failure.

- Suitable means shall be provided to relieve the pressure.
## Fuel batch differences (cont. 1/6)

<table>
<thead>
<tr>
<th>Origin</th>
<th>Nitrogen N₂ [%]</th>
<th>Methane C₁ [%]</th>
<th>Ethane C₂ [%]</th>
<th>Propane C₃ [%]</th>
<th>C₄ [%]</th>
<th>Total [%]</th>
<th>LNG Density [kg/m³]</th>
<th>Gas Density [kg/m³ (n)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia - NWS</td>
<td>0.0</td>
<td>87.3</td>
<td>8.3</td>
<td>3.3</td>
<td>1.0</td>
<td>100</td>
<td>467</td>
<td>0.831</td>
</tr>
<tr>
<td>Australia - Darwin</td>
<td>0.1</td>
<td>87.6</td>
<td>10.0</td>
<td>2.0</td>
<td>0.3</td>
<td>100</td>
<td>461</td>
<td>0.812</td>
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<tr>
<td>Algeria - Skikda</td>
<td>0.6</td>
<td>90.4</td>
<td>7.4</td>
<td>0.6</td>
<td>0.1</td>
<td>100</td>
<td>447</td>
<td>0.776</td>
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<tr>
<td>Algeria - Bethioua</td>
<td>0.6</td>
<td>89.5</td>
<td>8.2</td>
<td>1.3</td>
<td>0.3</td>
<td>100</td>
<td>455</td>
<td>0.795</td>
</tr>
<tr>
<td>Algeria - Arzew</td>
<td>0.7</td>
<td>88.9</td>
<td>8.4</td>
<td>1.6</td>
<td>0.4</td>
<td>100</td>
<td>457</td>
<td>0.801</td>
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<td>Brunei</td>
<td>0.0</td>
<td>90.1</td>
<td>5.3</td>
<td>3.0</td>
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<td>100</td>
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<td>0.818</td>
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<tr>
<td>Egypt - Idku</td>
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<td>Egypt - Damietta</td>
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<td>97.3</td>
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<td>0.1</td>
<td>0.1</td>
<td>100</td>
<td>429</td>
<td>0.737</td>
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<td>Equatorial Guinea</td>
<td>0.0</td>
<td>93.4</td>
<td>6.5</td>
<td>0.1</td>
<td>0.0</td>
<td>100</td>
<td>440</td>
<td>0.760</td>
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<tr>
<td>Indonesia - Arun</td>
<td>0.1</td>
<td>91.9</td>
<td>5.7</td>
<td>1.6</td>
<td>0.8</td>
<td>100</td>
<td>451</td>
<td>0.789</td>
</tr>
<tr>
<td>Indonesia - Badak</td>
<td>0.0</td>
<td>90.1</td>
<td>5.5</td>
<td>3.0</td>
<td>1.4</td>
<td>100</td>
<td>461</td>
<td>0.816</td>
</tr>
</tbody>
</table>
## Fuel batch differences (cont. 2/6)

<table>
<thead>
<tr>
<th>Origin</th>
<th>Nitrogen</th>
<th>Methane</th>
<th>Ethane</th>
<th>Propane</th>
<th>C4</th>
<th>Total</th>
<th>LNG Density [kg/m³]</th>
<th>Gas Density [kg/m³ (n)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Indonesia - Tangguh</td>
<td>0.1</td>
<td>96.9</td>
<td>2.4</td>
<td>0.4</td>
<td>0.2</td>
<td>100</td>
<td>431</td>
<td>0.742</td>
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<td>Libya</td>
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<td>82.6</td>
<td>12.6</td>
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<td>Nigeria</td>
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<td>5.5</td>
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<td>100</td>
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<td>457</td>
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<td>10.3</td>
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<td>0.7</td>
<td>100</td>
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<td>0.795</td>
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<tr>
<td>Russia - Sakhalin</td>
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<td>4.5</td>
<td>2.0</td>
<td>1.0</td>
<td>100</td>
<td>451</td>
<td>0.789</td>
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<tr>
<td>USA - Alaska</td>
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<td>Yemen</td>
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<td>100</td>
<td>442</td>
<td>0.767</td>
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</tbody>
</table>
Rollover is a rapid transfer of heat and mass within the storage tank due to superheating of lower layers in a large storage tank.
Fuel batch differences (cont. 4/6)

Rollover is a rapid transfer of heat and mass within the storage tank due to superheating of lower layers in a large storage tank.
Fuel batch differences (cont. 6/6)

To help prevent rollover:

• Store liquids of differing density in separate shore tanks
• Promote mixing by filling shore tanks with liquefied gas what should be made via nozzles or jets
• Avoid prolonged stoppages during LNG transfer to ships
• Close eye shall be kept for unusual data in cargo conditions and boil-off rates
• Transfer cargo to other tanks or recirculate within the affected shore tank
Emptying, inerting, drying and monitoring techniques

EMPTYING (cont. 1/3)

Regular LNG operation procedures (LNG tanker)

EMPTYING / DISCHARGE

On arrival at discharge port:
• tank pressures and temperatures should be set as per terminal requirements

Before discharge operation starts:
• the pre-operational ship/shore procedures should be carried out
• suitable cargo plan for both ship and shore side must be draw up
• safety issues connected with planned cargo discharge should be raised up
The method of discharging the ship depends on:

- Cargo specification
- Terminal storage
- Type of ship
EMPTYING (cont. 3/3)

Discharge methods

- Discharge by pressurising the vapor space
- Discharge via centrifugal pumps alone or with booster pumps
- Discharge via booster pump and cargo heater
Inerting cargo tanks, cargo machinery and pipelines is undertaken primarily to ensure a nonflammable condition during subsequent gassing-up with cargo.

To archive nonflammable conditions oxygen concentration must be reduced from 21% to a maximum of 5% by volume (lower values are preferred).

Inert gas is supplied from the inert gas generator on board.
INERTING (cont. 2/2)

Procedures used for inverting cargo tanks

- Displacement
- Dilution
Drying means that water vapor and free water must all be removed from the system prior loading.

If this is not done, the residual moisture can cause problems with icing and hydrate formation within the cargo system.
Tank atmosphere drying can be accomplished in several ways:

- Drying using inert gas from the shore
- Drying using inert gas from ship's plant
- On board air-drying systems
MONITORING TECHNIQUES

MONITORING TECHNIQUES while EMPTYING, INERTING, DRYING operations:

1. Observing manifold pressures on liquid/vapor line
2. Observing tank pressures and levels
3. Monitoring pressures at the insulating spaces
4. Monitoring the temperatures in the tanks via temperature sensors provided at different tank levels
5. Watch for any abnormalities
Measures to prevent ignition, fire and explosion (cont. 1/6)

ALL SOURCES OF IGNITION SHALL BE EXCLUDED FROM SPACES WHERE FLAMMABLE VAPOR MAY BE PRESENT !!!

Three things are needed to support a fire:

1. Source of fuel (e.g., flammable gas or vapor)
2. Air (oxygen)
3. Source of ignition (e.g., spark, open flame, or high-temperature surface)
Measures to prevent ignition, fire and explosion
(cont. 2/6)

Fire Triangle
Measures to prevent ignition, fire and explosion (cont. 3/6)

“FLAMMABLE RANGE” is the range of a concentration of a gas or vapor that will burn if an ignition source is introduced.

The limits are commonly called:
- Lower Flammable Limit (LFL)
- Upper Flammable Limit (UFL)

Flammability range for methane:
- Will not burn
  - Upper flammability limit: 15%
  - Lower flammability limit: 5%
- Too lean
Measures to prevent ignition, fire and explosion (cont. 4/6)

<table>
<thead>
<tr>
<th>Fuel</th>
<th>LFL</th>
<th>UFL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>5.0</td>
<td>15.0</td>
</tr>
<tr>
<td>Butane</td>
<td>1.86</td>
<td>7.6</td>
</tr>
<tr>
<td>Kerosene</td>
<td>0.7</td>
<td>5.0</td>
</tr>
<tr>
<td>Propane</td>
<td>2.1</td>
<td>10.1</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>4.0</td>
<td>75.0</td>
</tr>
<tr>
<td>Acetylene</td>
<td>2.5</td>
<td>&gt;82.0</td>
</tr>
</tbody>
</table>

Flammability limits of hydrocarbon fuels
Measures to prevent ignition, fire and explosion (cont. 5/6)

• All LNG terminals use several types of equipment on and around the storage tanks and piping throughout the facility to detect any unlikely leakages and combustible gas mixtures.

• The IGNITION TEMPERATURE, also known as auto-ignition temperature, is the lowest temperature at which a gas or vapor in air (e.g., natural gas) will ignite spontaneously without a spark or flame being present.
Measures to prevent ignition, fire and explosion (cont. 6/6)

- Temperatures higher than the auto ignition temperature will cause ignition after a shorter exposure time to the high temperature.

<table>
<thead>
<tr>
<th></th>
<th>Natural Gas</th>
<th>Diesel Oil</th>
<th>Gasoline</th>
</tr>
</thead>
<tbody>
<tr>
<td>Auto-ignition temperature</td>
<td>599°C</td>
<td>260-371°C</td>
<td>226-471°C</td>
</tr>
</tbody>
</table>

Auto-ignition temperature of some fuels at standard conditions
Gas carriers must be fitted with fixed gas detection system with audible and visual alarms.

These must be fitted in:

- the wheelhouse
- the cargo control room
- the gas detector readout location
Detector heads are normally provided in the following spaces:

- Cargo compressor room
- Electric motor room
- Cargo control room (unless classified as gas-safe)
- Enclosed spaces such as hold spaces and inter barrier spaces
- Airlocks
- Burner platform vent hoods and engine room gas supply pipelines
Gas testing

Each vessel will however carry instruments capable of measuring Oxygen, Hydrogen Sulphide, Methane, Carbon Monoxide, Carbon Dioxide and also the lower explosive limit.

Instruments carried onboard must measure:

- Oxygen
- Hydrogen Sulphide
- Methane
- Carbon Monoxide
- Carbon Dioxide
- LEL (lower explosive limit)
Gas testing

- COMBINED FUNCTION METRES

Gas Detector Riken RX415
[source: http://www.equipcoservices.com]
Portable combination gas detector Riken Reiki 515
[source: Model RX-515 operation manual]
PERSONAL MONITORING METERS

• Some can be carried in a pocket
• Intended only as a personal monitor
• Used for enclosed space entry
• Audible and visual alarm if the Oxygen content falls below its preset level
• NOT designed for testing the atmosphere for oxygen or other gases
Gas testing

- Draeger PAC5000: this instrument measures O2, CO and H2S
Thank you for your attention