KISH P & I LOSS PREVENTION CIRCULAR KPI-LP-12-2012
(LNG Basic Knowhow)

Properties of LNG :

Natural gas is a mixture of hydrocarbons which, when liquefied, form a clear colourless and odourless liquid; this LNG is usually transported and stored at a temperature very close to its boiling point at atmospheric pressure (approximately – 160 degree C).LNG is very cold liquid form of natural gas - the fuel that is used in gas stoves, home heaters, and electric power plants. When it warms back up, LNG becomes natural gas again. It is not possible to liquefy natural gas without cooling it. Many countries export and many others import LNG by ships.

		Ras Laffan	Das Islands	Standard
Methane	CH_4	90.28%	84.5%	89.63%
Ethane	C_2H_6	6.33%	12.9%	6.32%
Propane	$n\text{-}C_3H_8$	2.49%	1.5%	2.16%
Butane	$n\text{-}C_4H_{10}$	0.49%	0.5%	1.20%
Iso-Butane	$i\text{-}C_4H_{10}$	0.00%	0.00%	0.00%
Pentane	$n\text{-}C_5H_{12}$	0.02%	0.00%	0.00%
Iso-Pentane	$i\text{-}C_5H_{12}$	0.00%	0.00%	0.00%
Nitrogen	N_2	0.41%	0.6%	0.69%
Average Mol. Weight		17.88	18.56	18.12
Boiling Point at Atmospheric Pressure		-160.8	-161.0	-160.9
Density kg/m^3		461.8	456.8	459.4
Higher Specific Energy kJ/kg		54.414	54.031	54.090

Composition of sample LNGs

LNG does not burn itself .LNG needs to be in vapour form and mixed with air to burn .It is combustible in the range of 5% to 15% volume concentrations in air .Combustible mixtures in confined space will burn with an explosion .

LNG is a cryogenic substance (i.e. associated with very low temperatures) and physical contact or spillage constitutes a personnel and equipment hazard. Natural gas presents an asphyxiation hazard. Its main component is *methane*. It turns into gas form violently when directly introduced into a cargo tank at ambient temperature, rapidly increases the internal pressure of the cargo tank and makes the atmosphere into a highly flammable condition.

In addition, the cargo tank is rapidly cooled, resulting tremendous thermal stress on cargo tank skins and cargo piping systems. To avoid such damages, the preparatory work for cargo loading after dry-docking or any period without cargo must be followed. During dry dock all the compartments of an LNG carrier are kept gas free.

After leaving the dry dock the vessel has to be prepared to load cargo, for that the following points to be considered with priority:

1-Liquefied natural gas (LNG) compresses to a small fraction of its original volume (approximately 1/600) under liquefaction. Liquefaction reduces the volume of natural gas making it much more economical to transport. With the amount of flammable material that LNG contains, it has the potential to be an extremely dangerous chemical, if handled improperly.

2-LNG is not as dense as petroleum, requiring between double and triple the space for the tank. For ships using the LNG as their fuel; to alleviate the loss of space, some designers locate the tanks under accommodation spaces, building protective coffers to hold the tanks. Others have placed tanks on deck where they can vent into the atmosphere should a spill occur. IMO guidelines do not prohibit placement of LNG tanks under accommodation, however, the USCG feels the decision requires careful analysis.

3-The actual composition of LNG will vary depending on its source and on the liquefaction process, but in all cases the major constituent will be *methane* with small percentages of the heavier hydrocarbons such as ethane, propane, butane and pentane. In addition, small quantities of nitrogen may be present.

4-However for custody transfer purposes when accurate calculation of the heating value and density is required the specific properties based on actual component analysis must be used. During a normal sea voyage, heat is transferred to the LNG cargo through the cargo tank insulation, causing vaporization of part of the cargo, i.e. boil-off.

5-The composition of the LNG is changed by this boil-off because the lighter components, having lower boiling points at atmospheric pressure, vaporize first. *Therefore the discharged LNG has a lower percentage content of Nitrogen and Methane than the LNG as loaded, and a slightly higher percentage of Ethane, Propane and Butane, due to Methane and Nitrogen boiling off in preference of the heavier gases.*

6-The flammability range of Methane in air (21% Oxygen) is approximately 5.3 to 14% (by volume). To reduce this range, the air is diluted with Nitrogen until the Oxygen content is reduced to 2% prior to loading after dry-dock. In theory, an explosion cannot occur if the O2 content of the mixture is below 13% regardless of the percentage of *Methane*, but for practical safety reasons, purging is continued until the O2 is below 2%.

7-The boil-off vapour from LNG is lighter than air at vapour temperature above –110 degree C or higher depending on LNG composition & Variation of Density with Temperature, therefore when vapour is vented to atmosphere, the vapour will tend to rise above the vent outlet and will rapidly disperse. When cold vapour is mixed with ambient air the vapour air mixture will appear as a readily visible white cloud due to the condensation of the moisture in the air. It is normally safe to assume that the flammable range to vapour-air mixture does not extend significantly beyond the perimeter of the white cloud.

8- The auto-ignition temperature of Methane, i.e. the lowest temperature to which the gas needs to be heated to cause self-sustained combustion without ignition by spark or flame is 595 degree C.

		Methane	Ethane	Propane	Butane	Pentane	Nitrogen
		CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}	N_2
Molecular Weight		16.042	30.068	44.094	58.120	72.150	28.016
Boiling Point at 1 bar absolute	°C	-161.5	-88.6	-42.5	-5	36.1	-196
Liquid Density at Boiling Point	Kg/m^3	426.0	544.1	580.7	601.8	610.2	808.6
Vapour SG at 15°C and 1 bar absolute		0.554	1.046	1.540	2.07	2.49	0.97
Gas Volume/liquid volume Ratio at Boiling Point and 1 bar absolute			619	413	311	311	205
Flammable Limits in air by Volume	%	5.3 to 14	3 to 12.5	2.1 to 9.5	2 to 9.5	3 to 12.4	Non-flammable
Auto – Ignition Temperature	°C	595	510	510/583	510/583		
Gross Heating Value at 15°C *Normal* – *Iso* -	KJ/kg	55559	51916	50367	49530 49404	49069 48944	
Vaporization Heat at Boiling Point	KJ/kg	510.4	489.9	426.2	385.2	357.5	199.3

Physical properties of LNG

If LNG spilled on water the following critical facts are to be considered:

- **LNG pool vaporizes rapidly (faster than an equal sized pool on land)**
- **LNG spill on or within hull can cause brittle fracture (carbon & low alloy steel fracture)**
- **LNG can undergo "rapid phase transition", a physical vapour explosion (not combustion)**
- **LNG pool formation accompanied by ignition**
- **Natural gas cloud formation with subsequent burn back**

KPI LOSS PREVENTION TEAM
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