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RISKS ASSOCIATED WITH THE MARINE ASPECTS OF LNG FPSOs (FLOATING PRODUCTION, STORAGE AND OFFLOAD) UNITS

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The intent of today's presentation is to address
The Marine risks associated with LNG FPSOs
and as such the presentation does not address
The aspects of gas production and processing.
Production risks will vary field to field similarly
gas processes will vary field to field depending
on specific gas make up.



What is LNG (Liquidified Natural Gas)

LNG is primary liquid methane (CH_4) at a temperature of -163°C at atmospheric pressure.

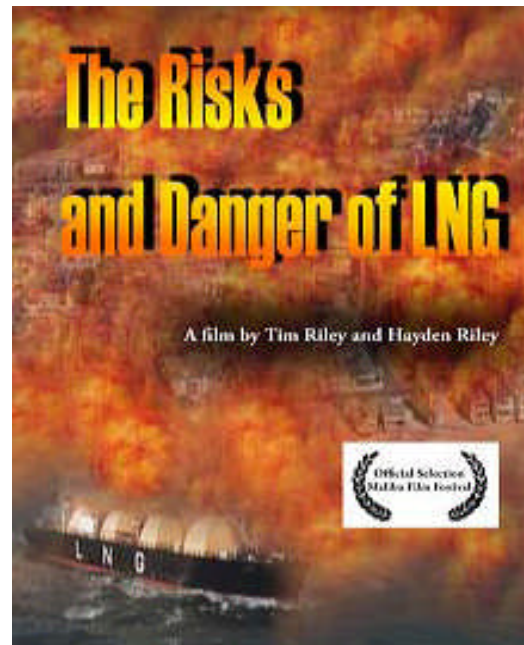
It is a hydrocarbon fuel.

It is lighter than air, it is colourless and odourless.



What LNG is not

Myth 1. LNG and LNG Carriers are floating bombs!!





Fact: LNG is a hydrocarbon and will burn BUT it is only combustible in free air at between **5 – 15%** by volume.

By comparison motor gasoline is combustible in free air between **1.4 – 7.6%** by volume!



Myth 2. Leaking LNG will vaporise to form a vapour cloud that can become a BLEVE (Boiling Liquid Expanding Vapour Explosion) which will can ignite causing a major explosion.



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Exploding Vapour Cloud



Fact: Leaking LNG will form a vapour cloud that will disperse rapidly BUT throughout the vapour cloud fuel to air ratio will vary considerably.

Ignition is only possible at between 5-15% in free air so that rapid combustion across the cloud (explosion) is extremely unlikely!!



Myth 3: Leaking LNG vapour cloud will ignite and burn as it disperses causing a large fire in city areas potentially causing huge damage!!



Fact: Vapour will disperse rapidly and move down wind. As it moves down wind it will dilute and as such we once again have a situation where vapour density varies considerably.

Some areas of the cloud will pass through the 5-15% flammability range as they do it is possible that, with a source of ignition, they could ignite but once out of this range fire will go out.



Fact: tests carried out to either develop an LNG vapour cloud explosion or fire in free air have all failed?!

In summary LNG is a hydrocarbon fuel and needs to be treated with respect having said this is no more of a risk than any other fuel.

In the marine industry LNG carriers have the best safety record of any vessel type bar none.

LNG has been transported by sea for over 40years.



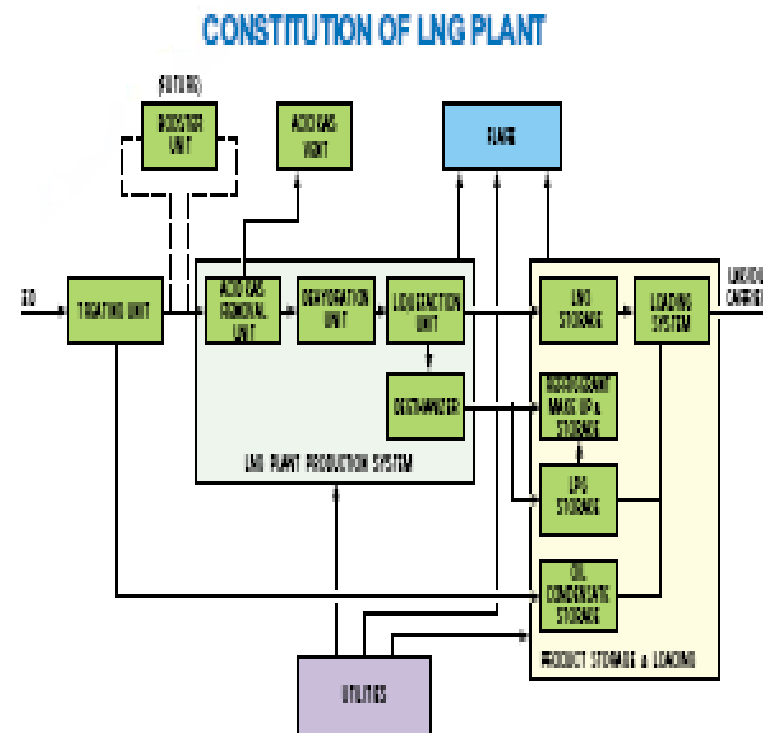


LNG FPSOs

An LNG FPSO is a Floating Production Storage and Off-load Units so the unit is permanently moored over a gas well(s), gas is brought on board through a series of sea bed connections and risers to the vessel.

Once on board the gas is processed, dehydrated and liquefied for storage within the vessel. LNG is then transferred from the FPSO to LNG carriers for delivery to terminals around the World.

The basic principle is identical to that for Oil and LPG FPSOs,





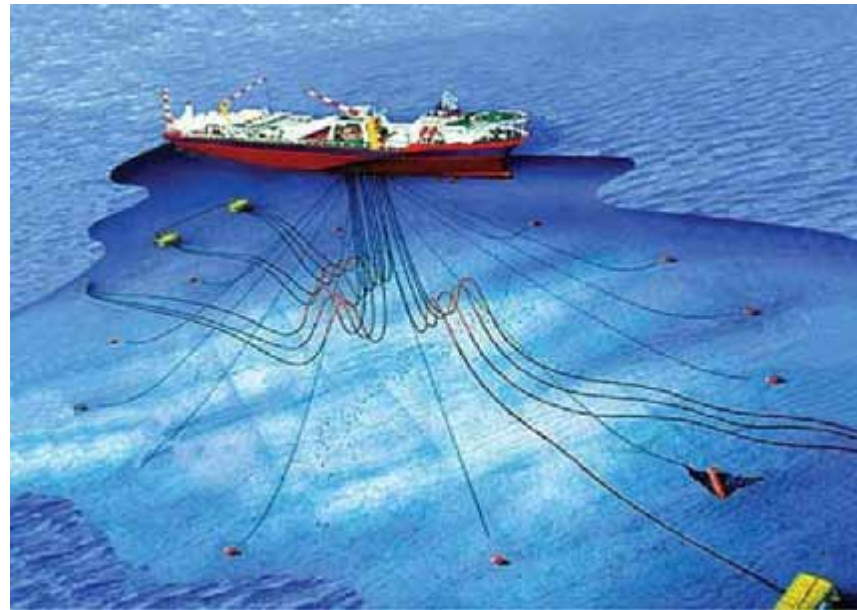
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Typical Oil FPSO



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Schematic indicating FPSO mooring and production lines



The Catch - while Oil FPSOs are fairly common and there are LPG FPSOs in service there are **NO** LNG FPSOs currently in service!!



What do we have now?

Today we have a number of concepts that have been developed to one degree or another.

There are two cases where there are designs in place and letters of intent have been placed with ship yards to construct such units.



What are designs based on?

Currently the FPSO hull designs are based on experience gained in FPSOs and Offshore structures built over the last 30 years and marine LNG carrier experience over the last 40 years.



So where are the risks?

Common sense says that with 30 years structural experience offshore and 40 years marine transport experience most aspects of risk must have been addressed?

Sadly we do not believe that to be the full story.

The experience we have in the marine sector is not the same as the conditions we will find offshore, we look at those aspects shortly.



What we see as the major aspect of risk centres on the cryogenic nature of LNG, remember we are dealing with a liquid at - 163°C.

To deal with liquids at these temperatures we need to address two major areas:-

1. LNG stored within the FPSO structure:-

The main concerns in this area are:-

- a) Steel structures must be isolated from these low temperatures as they will not withstand them.
- b) We need to be able to store liquids such that there is the minimum of heat ingress to reduce liquid boil off.
- c) Tanks need to be operable at any level of fill between empty and full

2. Transfer of LNG from FPSO to LNG Carrier



1. LNG stored within the FPSO structure

If we look at points 1a) and 1b) how do we solve these problems in the marine industry now?

We use what are called “**containment systems**”.

So what are containment systems and how do they work?

Simply put they are insulated tank systems within a ship that isolates LNG from ship structures.



Current Containment Systems.

There are three different types of containment systems currently in use:-

Moss

**Membrane – GTT MK III
GTT No. 96
CS 1**

IHI SPB



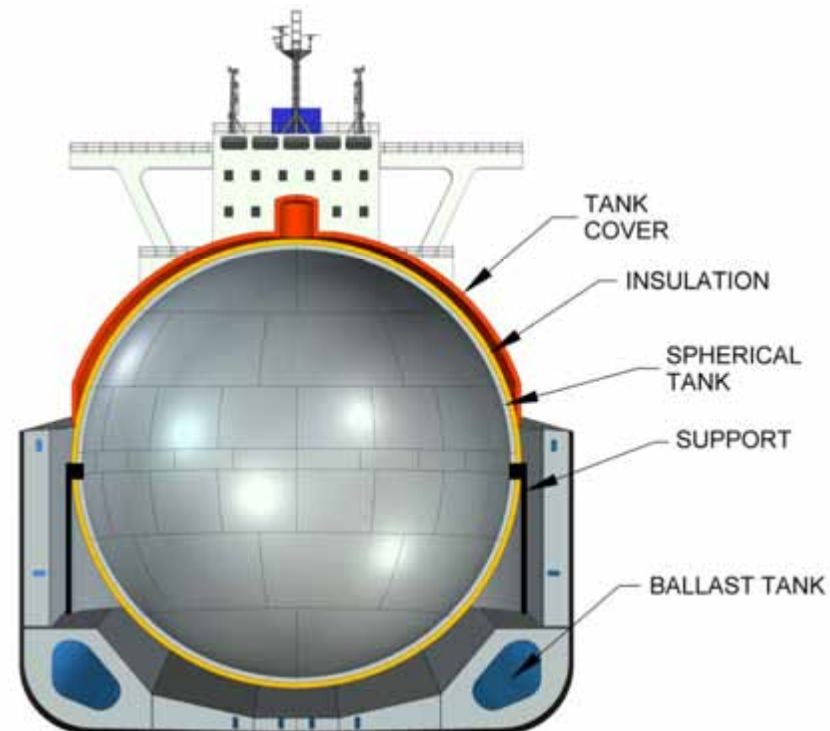
The Moss system is, in essence, a spherical, aluminium tank supported within the vessel structure but isolated from it.

The aluminium tank is insulated and then protected from the weather by a steel cover.





MOSS SYSTEM



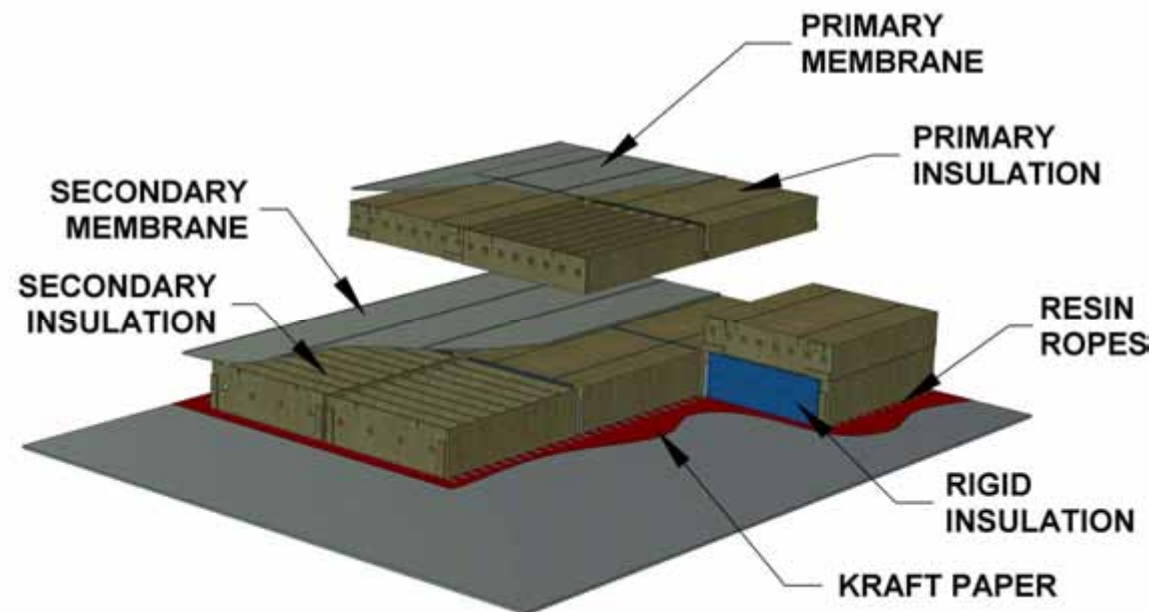


Membrane Systems – While there are three (3) different membrane systems in use, all designed and licensed by GTT, all 3 follow the same basic principle in that they provide two liquid tight layers, membranes, and two layers of insulation which line an LNG carriers hold spaces.





No. 96 Membrane system





IHI SPB System – the IHI system is a self supporting (S), prismatic (P), Type B (B) tank.

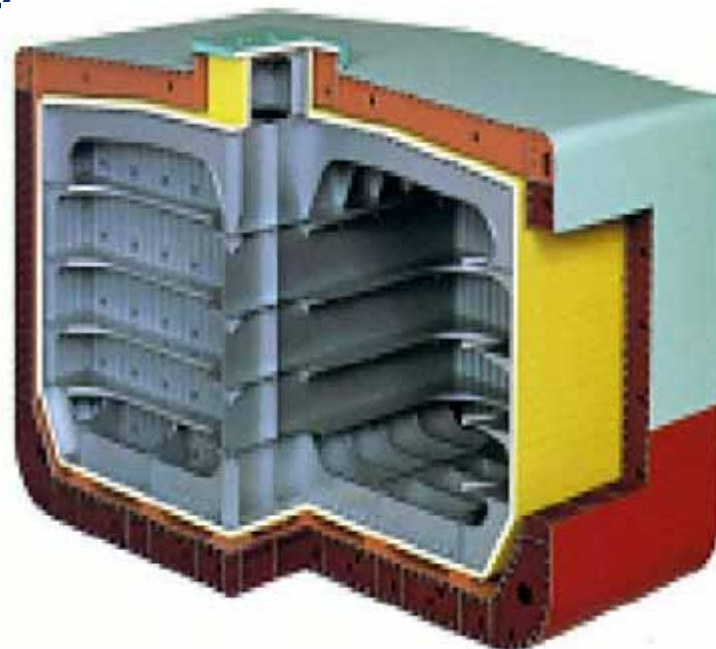
Essentially it is a separate, insulated aluminium tank within a ships hold supported on blocks top, bottom and side to prevent movement of the tank.





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IHI SPB Containment System





From this it is clear that in the marine sector we have successfully dealt with the issues in regard of liquid temperature and tank insulation.

What we haven't dealt with entirely is the aspect of partial fill, the sloshing loads generated at partial fill and how this translates in to FPSO use. Traditionally LNG carriers have been constructed for a specific trade and have been designed to operate either fully laden or empty. They rarely, if ever, operate in the partial fill condition.

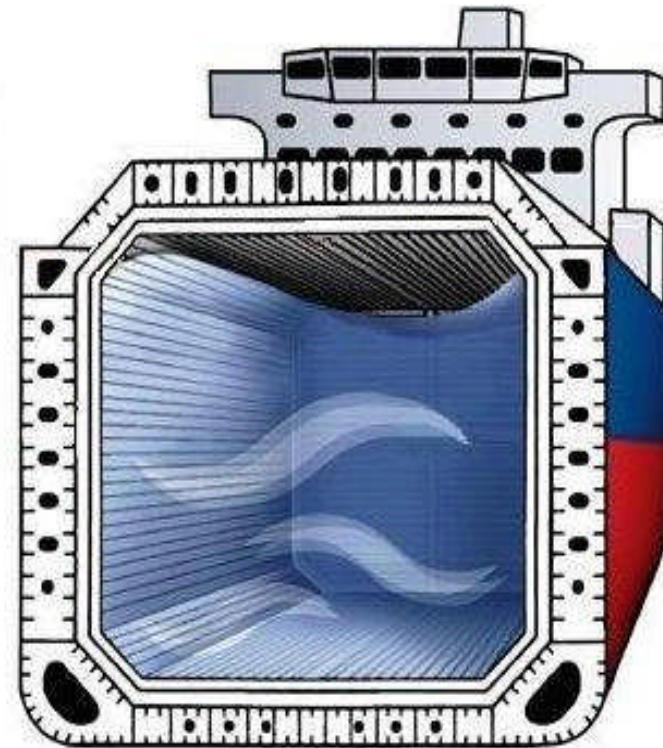
An FPSO will spend the vast majority of it's working life in the partial fill condition as it produces LNG then off loads to an LNG Carrier and as such this, and the sloshing loads, becomes a critical issue.



What is sloshing?

Sloshing is liquid movement within the cargo tanks caused by vessel motions.

Liquid movement takes the form of “waves” within the cargo tank.





Each of the containment systems described above have different issues when it comes to sloshing and partial fill.

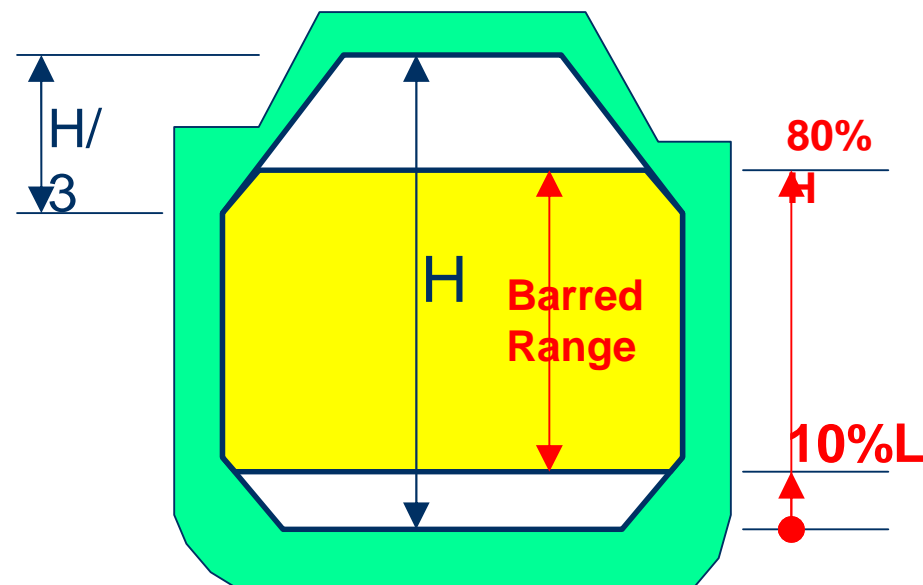
Moss System

– will allow partial fill to any level BUT has problems re deck space to fit process and liquefaction equipment.



Membrane Systems –
Operating requirements for
membrane systems are
generally that tanks are
Operated with liquid levels
below 10% of tank depth and
above 80% of tank depth.

**NB work is ongoing on to
address this.**





IHI SPB

— Will allow partial fill to any level and provides a relatively flat deck to allow fitting of process and liquefaction equipment **BUT** only two ships have ever been built with this system, a total of 8 tanks!

Largest tank built size has been around 23,000 cu.m.

Typical LNG FPSO will require cargo tanks of around 45,000 cu.m



2. Transfer of LNG from FPSO to LNG Carrier

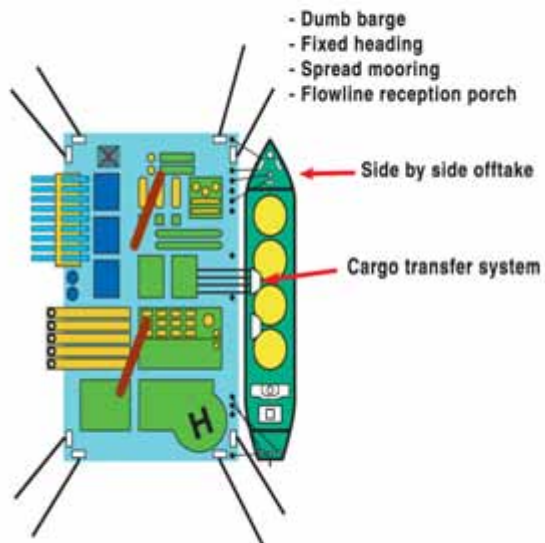
Currently there are two means of transferring LNG from LNG FPSO to LNG Carrier being discussed.

- a) Side by side**
- b) Tandem Systems**



Side By Side Off Loading Systems

LNG production, storage and offtake barge



Connecting Loading Arms





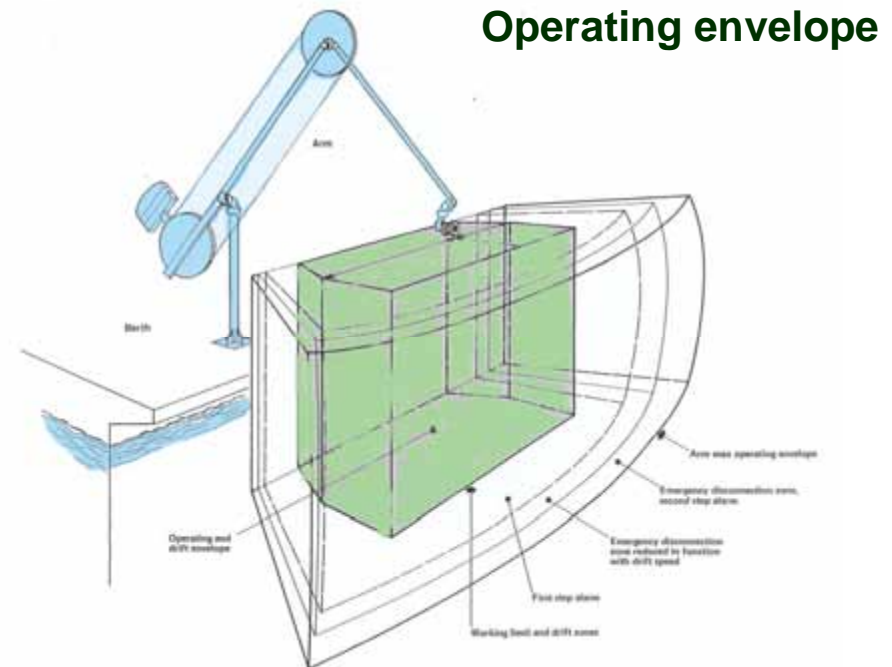
Side By Side Off Loading Systems

Advantages:-

- Well tried, well proven in land based operations.

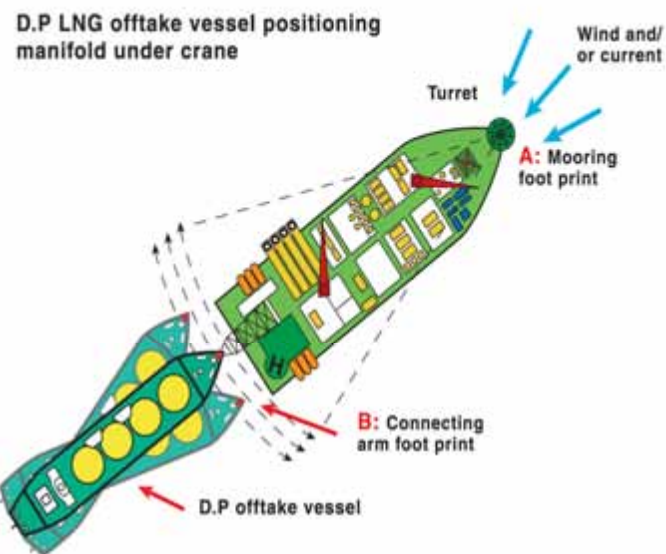
Disadvantages:-

- Limited operating range limits use in some sea states.
- Not used offshore



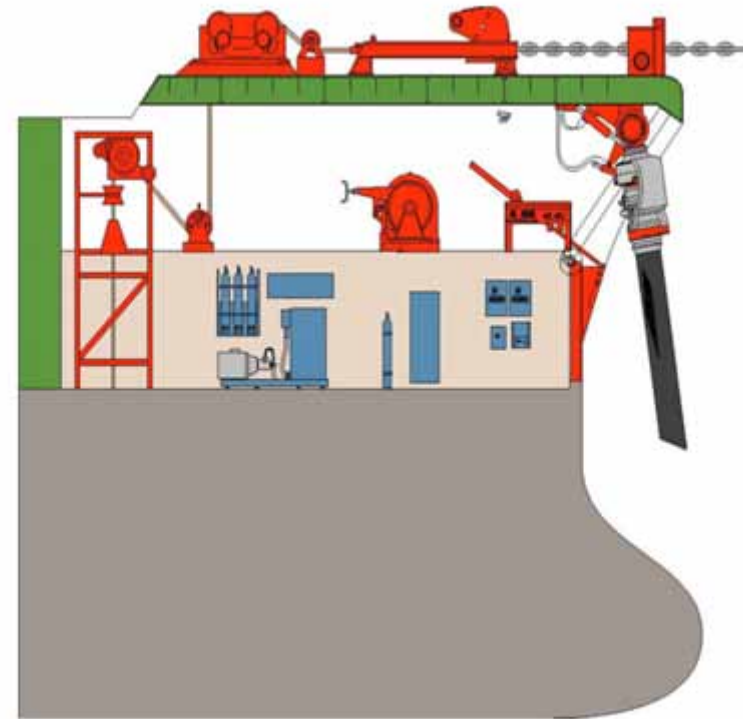
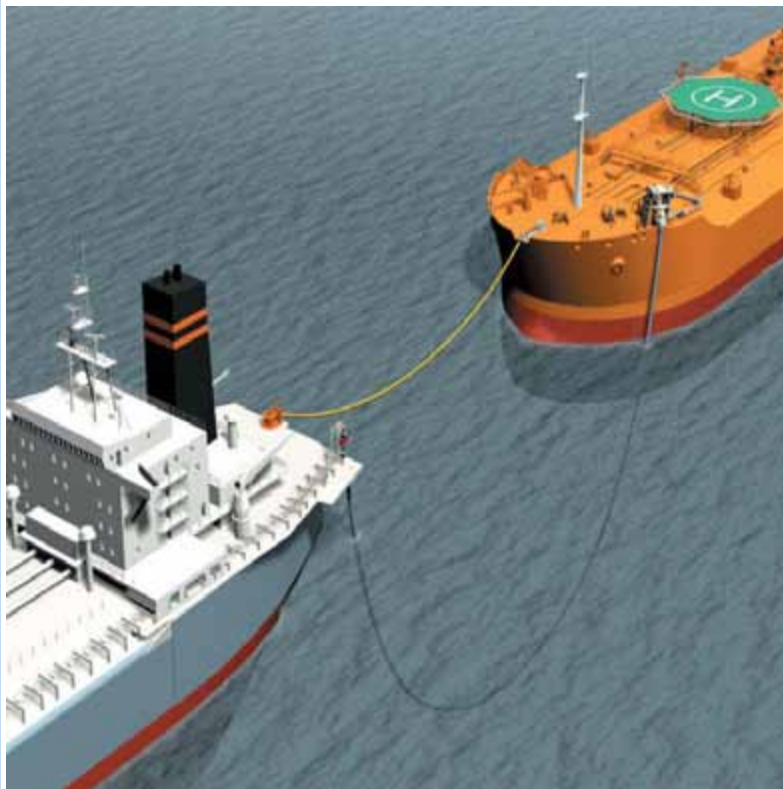


Tandem Off - Loading Systems





Tandem Off - Loading Systems





Tandem Off Loading Systems

Advantages:-

- Well tried, well proven in offshore oil and LPG operations.

Disadvantages:-

- Not used extensively offshore LNG



Summary

While there are areas that require further study and, in this context these can be considered risks, we feel that LNG FPSOs are a technology that will happen provided the economic drivers remain in place.

We also feel that to each LNG FPSO must be looked at in its totality and that detailed risk assessment studies must be undertaken for each project. These must include detailed review of wave and weather data in conjunction with assessments of proposed containment system and off load systems.



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