Safety Issues Within Topsides Design

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Contents

- Risk Analysis and Quantitative Risk Analysis (QRA)
- Fire Analysis
- Explosion pressure impact on design
- Plated vs Grated Deck
- Accommodation Location
- Gas and fire detection
- Active fire protection and fire mitigation
- Passive fire protection on structures and process equipment
- Escape analysis
- HVAC analysis
- Flare analysis
- Dispersion of exhaust from power supply and auxiliary systems
- Wind chill in case of harsh metocean conditions
- Green water
- Analysis of helicopter operations

Risk Analysis and Quantitative Risk Assessment

Why is Risk Analysis necessary

- Major Accident Events will continue to occur.

Ship Collision Followed by Major Fire

Cargo Tank Explosion

Riser Fire Engulfing Platform

- Our work during design can minimise the frequency of accidents and minimise the consequences of an accident.

Risk Analysis and Quantitative Risk Assessment

How is it Performed?

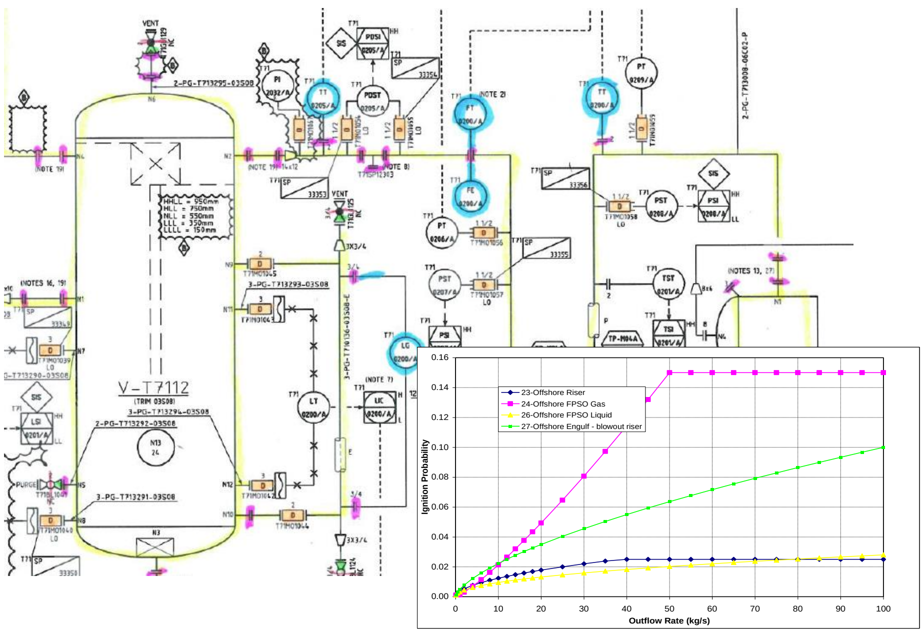
- **Risk** = **Frequency** x **Consequence**

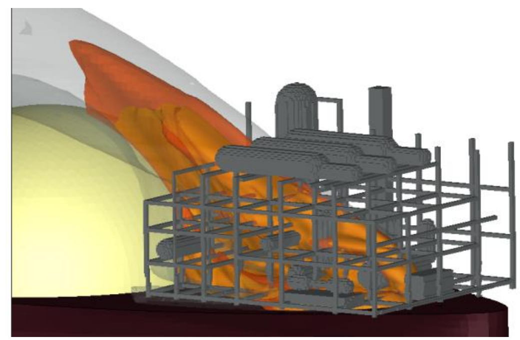
Likelihood of event occurring

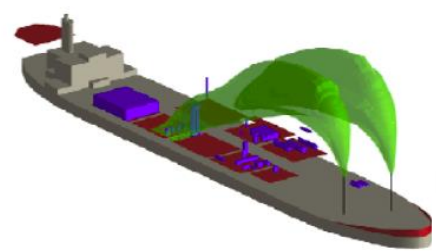
What are the effects on Personnel, Environment, FPSO, Reputation

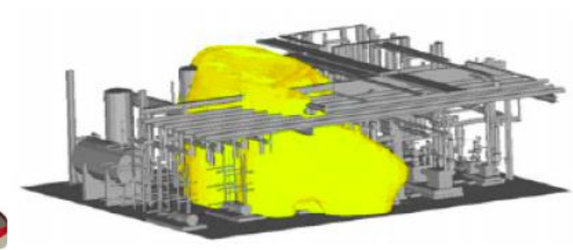
Where from?
Databases, Equipment Counts

Where from?
Fire Sizes, Explosion Overpressures, Escalation



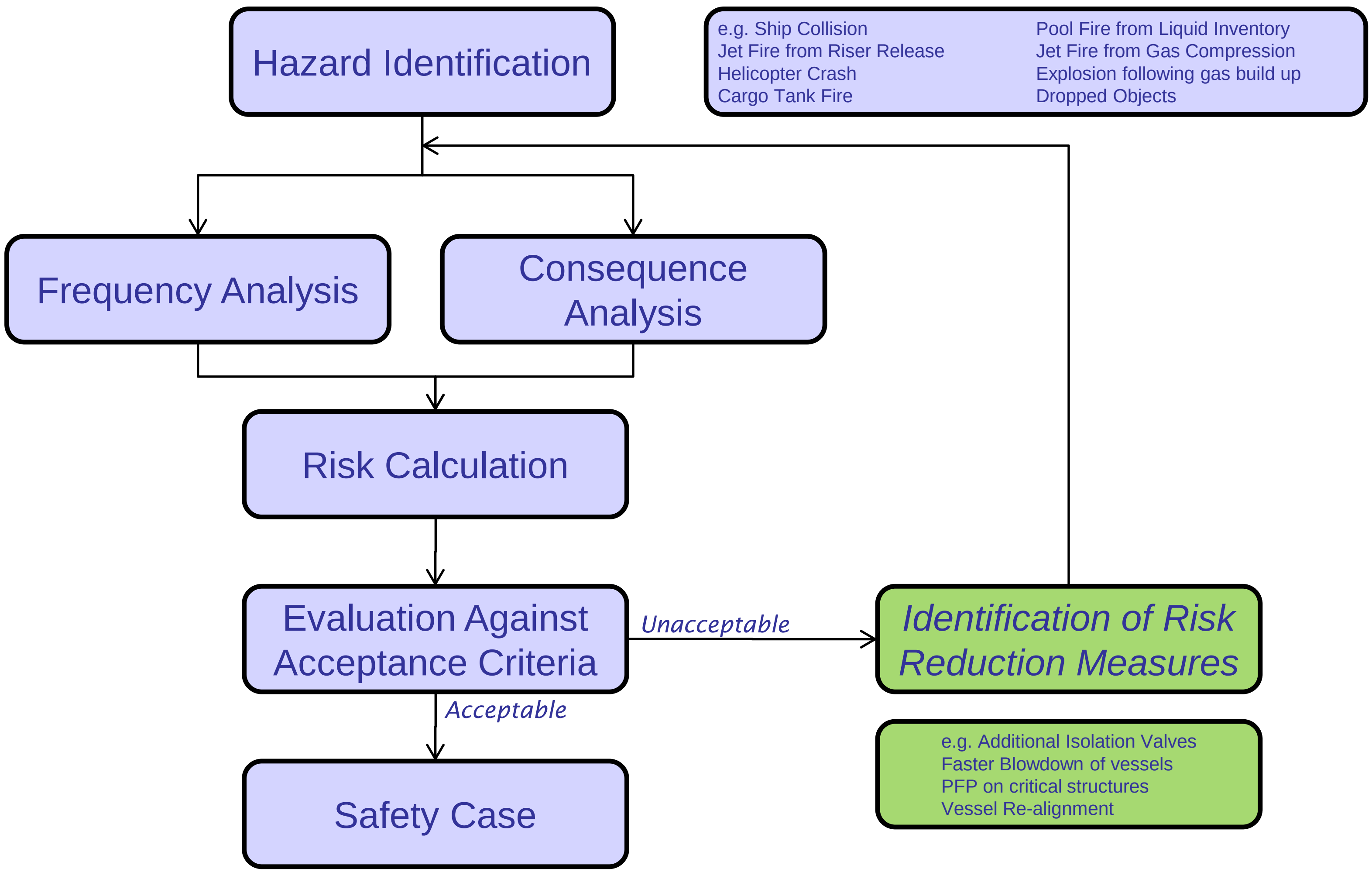






Risk Analysis and Quantitative Risk Assessment

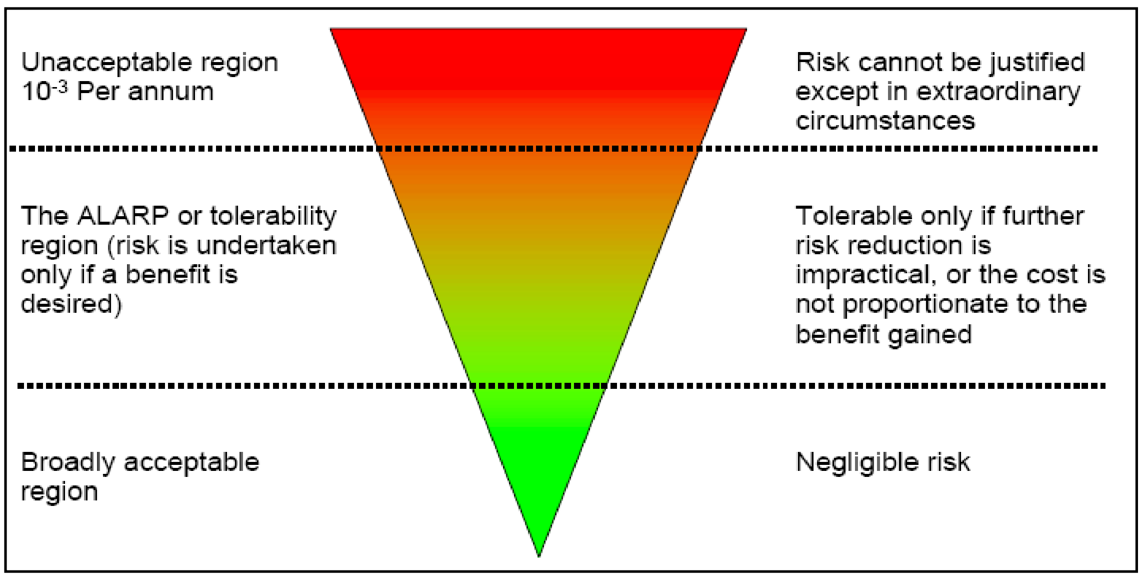
What is the Process?



Risk Acceptability

How do we decide we have done enough?

- A regulator would expect to see the following approach for risks:
  - Risks are below maximum tolerable level;
  - That the nature and level of the risks are properly assessed and the results used to determine control measures;
  - That residual risks are not unduly high and have been kept ALARP;
  - That the risks are periodically reviewed to ensure that they still meet the ALARP criteria.



Fire Analysis

How do we model Jet Fires and Pool Fires?

- ❑ Jet Fires
  - ➢ A burning jet of gas or spray of atomised liquid released from high-pressure equipment
  - ➢ Long and narrow flames
  - ➢ High momentum
  - ➢ High surface emissive power
  - ➢ Limited effectiveness of fire fighting

- ❑ Pool Fires
  - ➢ Burning pool from low pressure liquid releases (<4bar)
  - ➢ Potential for running into areas below
  - ➢ Greater potential for smoke

- ❑ Commercially available software (PHAST, etc) available to model the effects on personnel, structures, adjacent process equipment.

Example Videos

From recent Spadeadam Testing

- ❑ Flange Fire
- ❑ Large Jet Fire

Explosion Pressure Impact on Design

What Affects Explosion Overpressure?

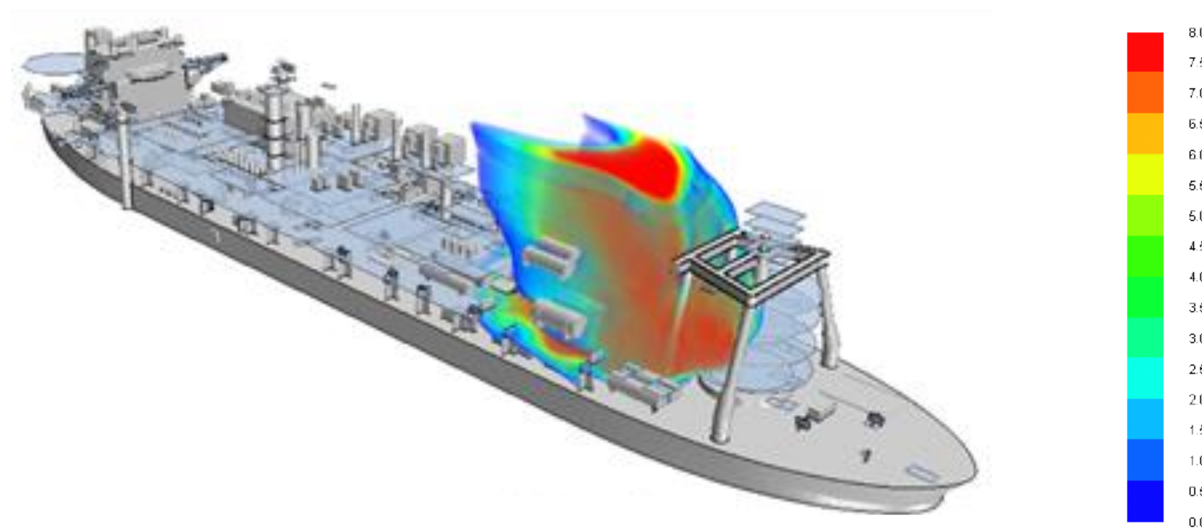
- Size of ignitable gas cloud
- Type of gas
- Equipment congestion
- Confinement of module
- Sharpness of obstacles
- Ventilation rate
- Ignition location
- Module Size / Flame Path length

Spadeadam Video

Explosion Pressure Impact on Design

How do we model Explosions?

- ❑ Typically requires CFD modelling to determine gas cloud sizes and explosion overpressures. This is typically based on the 3D model built of the facility.
- ❑ Some simpler tools may be effective for very open, single level decks
- ❑ Need to perform lots of runs to understand the threats from all parts of the process, different hole sizes, different release directions, different wind conditions, etc.
- ❑ Calculate the overpressures at key points (e.g. accommodation block, TEMPSC, escape ways, adjacent process equipment)
- ❑ Link each overpressure with a frequency
- ❑ Calculate Design Accident Loads for key elements



Explosion Pressure Impact on Design

What can we do to reduce the threat?

- Reduce the **Frequency** of explosion
  - Reduce likelihood of release (Remove flanges, improved inspection)
  - Remove ignition sources
  - Enhanced gas detection to isolate ignition sources
- Reduce the **Consequence** of Release
  - Reduce congestion in the area
  - Align equipment to provide less resistance to flame front movement
  - Enhanced blowdown (more gas to flare – less in gas cloud)
  - More isolation (less inventory to feed gas cloud)
  - Activate deluge on gas detection
- **Mitigate** against the release
  - Blast rated Decks and Walls

- **FPSO Areas of Concern:** Plated Process Deck, Pump Room, Moonpool, Weathervaning
- **Conclusion:** This needs to be understood very early in the design, otherwise costs of mitigation can overwhelm a project

Plated or Grated Decks?

What are the Influencing Factors

Factor	Grated	Plated
Spill Containment	All spills drop down onto hull deck. ✗	Spills can be contained at process deck level. ✓
Gas Dispersion	Greater airflow reduces potential for gas build up ✓	Plated decks may cause stagnant areas ✗
Gas Cloud Size	Gas can spread between levels ✗	Solid decks may restrict gas movement ✓
Overpressures	Less confinement ✓	More confinement, particularly at hull deck level ✗

- No 'one size fits all' solution

Accommodation Location

ibc Energy Academy

Global Producer III

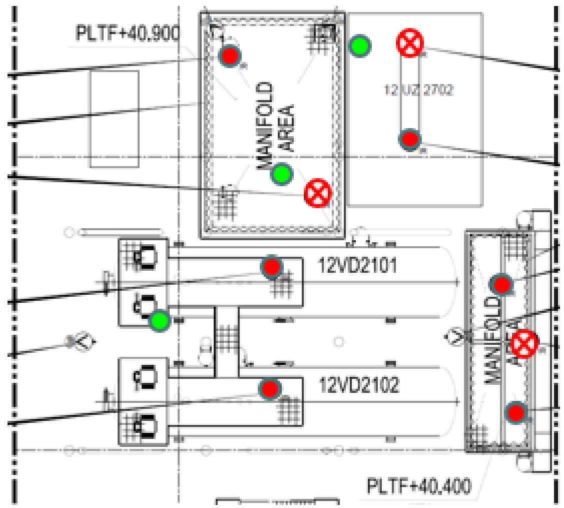
Marlim Sul

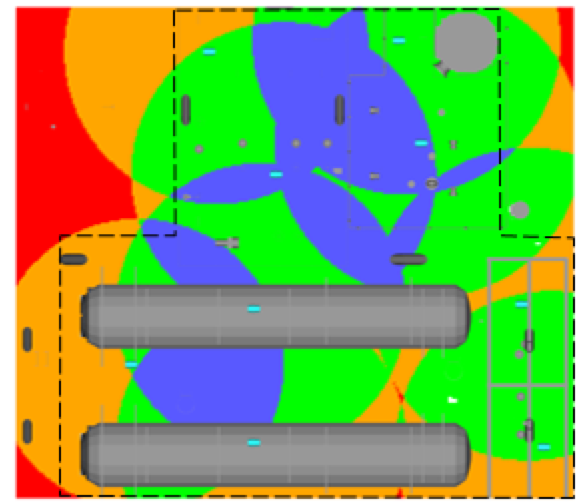
Hazard / Factor	**Forward Accommodation**	**Aft Accommodation**
Turret Fires		Better
Smoke from Process / Turret	Better	
Cargo Tank Fires	Better	
Pump Room Hazards	Better	
Helideck		
Green Water		Better
Shuttle Tanker	Better	
Wellbeing		Better
H_2S	Better	

Gas and Fire Detection

Why do we have it?

- ❑ Fire and Gas Detection systems provide a continuous automatic monitoring of the facility to alert personnel
- ❑ Normally ties into ESD, Blowdown and Fire Fighting systems to allow automatic control of escalation (requires voting logic)
- ❑ Fire Detectors
  - ➢ Infrared Flame Detection
  - ➢ Smoke (including VESDA)
  - ➢ Heat Rate of Rise, Fusible loops
- ❑ Gas Detectors
  - ➢ Point
  - ➢ Line of Sight
  - ➢ Acoustic
- ❑ Oil Mist Detection





- ❑ **Detector Analysis** is normally required to optimise the number and location of detectors.
- ❑ This would require an understanding of how big the gas clouds/fires would be and how far the effects would extend.
- ❑ Need to balance probability of detection against the potential for spurious alarms (e.g. Due to IG vents)

Gas and Fire Detection

Typical Applications

Fire & Gas system				
Hazard	**Type of detector**		**Typical application**	**Typical actions**
Fire	Heat	pneumatic	Process, wellhead, utilities	Alarm, ESD, EDP, closure of the SSSV, active fire protection
		electric	Turbine hoods, workshops, stores, engine rooms, process, wellhead, utilities	Alarm, ESD, EDP, active fire protection
	Flame		Process, wellhead utilities, generators, gas turbines	Alarm, ESD, EDP, active fire protection
	Smoke		Control rooms, electrical rooms, computer rooms, accommodation	Alarm, isolate power, active fire protection (if present)
			Air intakes to TR and control stations	Alarm, isolate ventilation
Flammable gas			Process, wellhead utilities areas [a], engine rooms [a]	Alarm, ESD, EDP, isolate power
			Air intakes	Alarm, ESD, EDP, isolate power, ESD ventilation system
Oil mist			Enclosed areas handling low GOR liquid hydrocarbons	Alarm, ESD, EDP, isolate power
	Manual call point		All areas, escape routes, muster points, TRs	Alarm, start of fire pumps

Active Fire Protection and Fire Mitigation

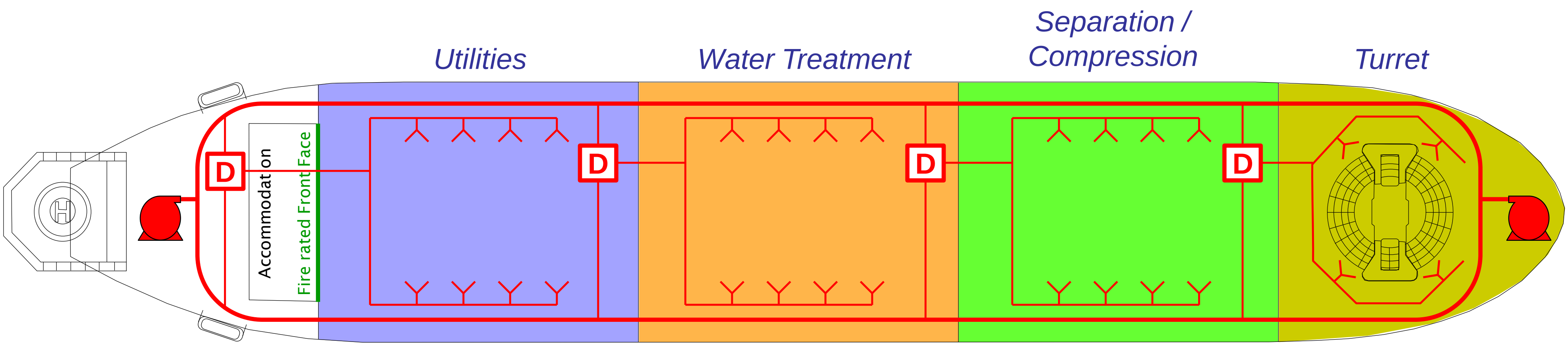
Uses and Components

- Objectives:
  - To control fires and limit escalation;
  - To reduce the effects of a fire to allow personnel to undertake emergency response activities or to evacuate;
  - To extinguish the fire where it is considered safe to do so;
  - To limit damage to structures and equipment.
- Includes
  - Fire and gas detection systems
  - Firewater Lift Pumps
  - Fire pumps
  - Fire ring main
  - Fire water consumers (deluge, monitors, hose reels, mist, sprinkler systems)
  - Foam system (for liquid or alcohol fires)
  - Dry chemical or gaseous agents
  - Mobile and portable fire fighting equipment

Active Fire Protection and Fire Mitigation

Typical FPSO Arrangement

- FPSO divided into fire zones for firewater demand calculations
- Redundant fire water supply
- Firewater ring main to provide two possible paths for supply of water to consumer
- Deluge panels located in areas outside the zone they protect
- Foam normally supplied to fire zones where liquid fires are the most credible scenarios



Active Fire Protection and Fire Mitigation

Typical AFP requirements (from ISO 13702)

Area/room	Type of protection in addition to portable	Typical minimum water application rates l/min/m²	Comments
Wellhead/manifold area	Deluge/foam/dry chemical	10 (or 400 l/min/well)	
Process areas	Deluge/foam/dry chemical	10	
Pumps/compressors	Deluge/foam	20	
Gas treatment area	Deluge/dry chemical	10	Foam if area contains significant flammable liquids
Methanol area	Alcohol-resistant foam or deluge	10	Portable foam units, if the methanol area is small
Water-injection treatment area	None, if no HC risk		
Central control room (CCR) / LER	None		To be confirmed in developing FES
Turbine hood	CO2 , gaseous or water-mist		Interlock access to hood, if gaseous
Emergency generator room	Water-mist/foam/deluge	10	Effect of water on equipment in the room should be evaluated
Fire pump room	Water-mist/foam/deluge	10	Effect of water on equipment in the room should be evaluated
Mechanical workshop	Sprinkler	6	
Instrument workshop	Sprinkler	6	
Storage of gas bottles	None		Provided stored externally and not exposed to radiant heat
Paint store	Sprinkler		
Vent extract from galley	Gaseous		Operated local in galley
General galley area	None		
Galley cooking appliances and range	Proprietary systems		According to supplier recommendation
Helideck	Foam/dry chemical	6	
Chain locker	Water	60	
Turret area	Deluge/foam	10	
Vertical and horizontal structures	Deluge	10 (4 l/min/m² for horizontal)	
Escape and evacuation routes	Water curtain	15 l/min/m to 45 l/min/m	

PFP on Structures and Process Equipment

Why and where is it required?

- A common Risk Reduction measure is to fit PFP to reduce the potential for escalation.
- The idea is to protect the structures against the worst credible threat (or to protect against a certain frequency of threat – DAL)
- Protect Areas where personnel muster
- The location and rating (typically J15, H120, A60) required will come from the QRA

Critical Valves / Exposed Risers

Process Vessels and Saddles

Process Module Supports

Flare Tower Base

Escape Analysis

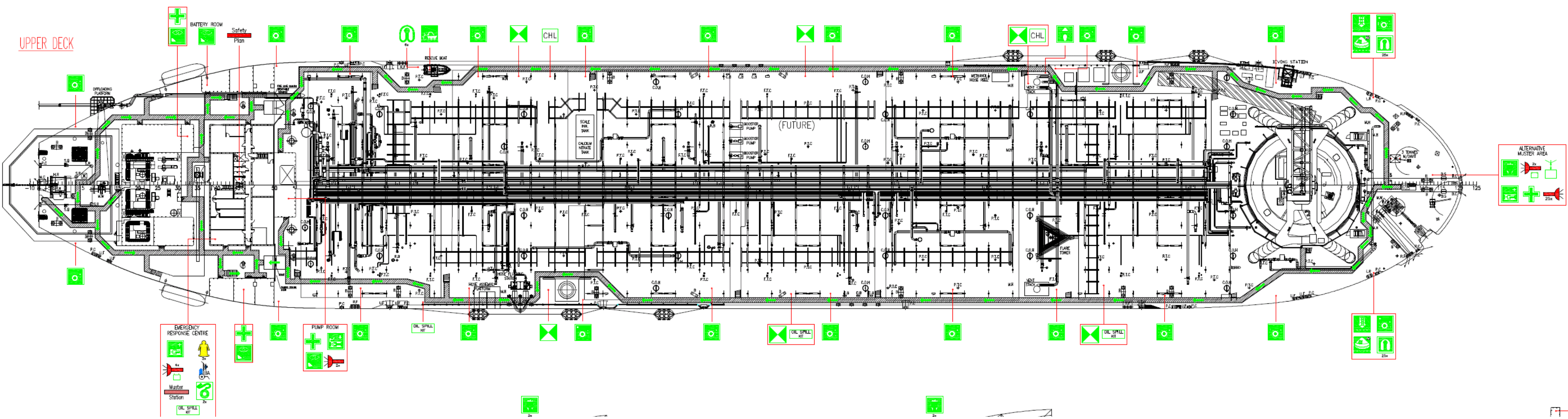
- ❑ Objective
  - ➢ To maintain the safety of all personnel when they move to another location to avoid the effects of a hazardous event
  - ➢ To provide a refuge on the installation for as long as required for a controlled evacuation of the installation;
  - ➢ To facilitate rescue of injured personnel;
  - ➢ To ensure safe abandonment of the installation.

- ❑ Means
  - ➢ **Escape routes** (to enable all personnel to leave an area when they are directly affected by an incident.)
  - ➢ **Temporary Refuge** (A place where personnel can muster while investigations, emergency response and evacuation pre-planning are undertaken.)
  - ➢ **Evacuation means** (lifeboats, rafts)

- ❑ Evacuation, Escape and Rescue Analysis normally required to calculate potential for entrapment, escape route timings, TR survival time, etc.

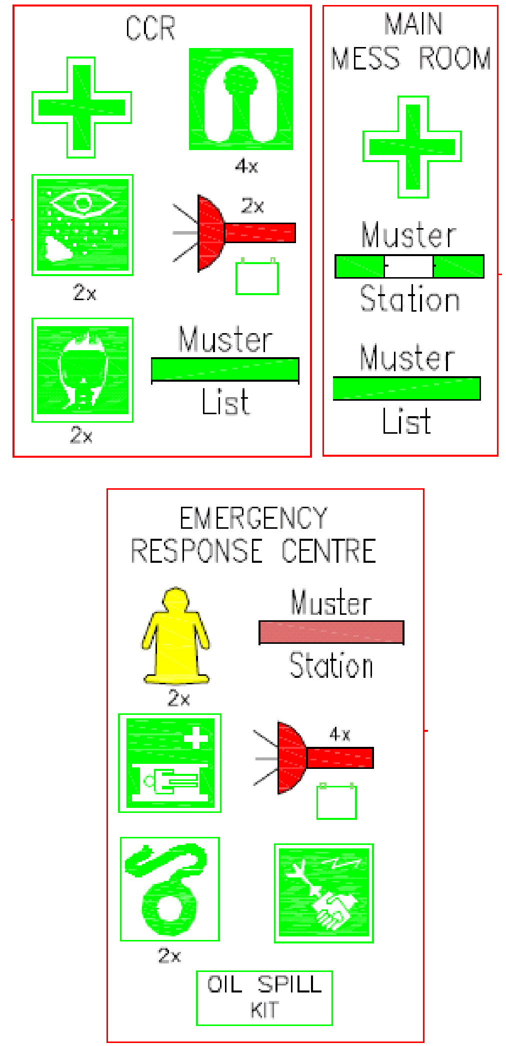
Escape Routes

- General requirements
  - Escape routes from all manned areas should be marked and lit
  - Signs should be provided to allow personnel to identify escape routes
  - Alternate evacuation routes should be provided from any normally manned location
  - Dimensioning of evacuation routes should be sufficient (number of people, stretcher)
- FPSO
  - Main escape routes typically located along the edge of process deck and main deck
  - Escape from elevated modules provided through a combination of stairs and ladders
  - Some FPSOs are provided with an escape tunnel (Blast/fire rated and pressurized)



Temporary Refuge

- The TR is a place where people can muster whilst investigations, emergency response and evacuation pre-planning are undertaken.
  - The TR should have sufficient capacity to protect the maximum POB for the time required to:
  - Complete full muster at the TR.
  - Account for personnel not reporting to their assigned muster stations.
  - Evaluate the situation and make decisions.
  - Initiate responses to minimize the consequences and control the emergency
  - Complete the evacuation (if required)
  - Contingency time to allow for the unforeseen
- The installation should be designed such that a condition which could impair the TR does not arise while people are still at or in the TR
- FPSO
  - TR normally located within the Accommodation block
  - Alternate muster area in some cases provided in the opposite end of the installation (requires the same endurance time as the primary muster area)



HVAC Analysis

Are Personnel Safe in the Muster Areas during an Emergency?

- During an emergency, the personnel in the muster area may be in an isolated environment:
  - HVAC (external ventilation) shut down
  - Fire Dampers closed
  - HVAC (cooling) on recirculation
- Does the environment inside become intolerable?
  - Oxygen Depletion
  - Heat Stress
  - Carbon Dioxide Accumulation
- Typical Criteria:

Impairment Mechanism	Criteria
Oxygen Depletion	17% or less by volume in breathing air – onset of muscular coordination disturbance
Carbon Dioxide Accumulation	5.5% or more by volume in breathing air
Heat Stress	1. Exceedance of $50 Wh/m^2$ maximum permissible body heat storage 2. Exceedance of 2600g maximum body water loss 3. Room temperature exceeds 40ºC, onset of impairment (equipment and people) 4. Room temperature exceeds 70ºC (danger level for people)

Evacuation

- Preferred methods of evacuating the installation:
  1. Helicopter
  2. Lifeboats (davit launched, free fall)
  3. Life rafts (Chutes, scramble nets, rope ladders, etc)
- Number, size and location of evacuation means should be sufficient for 100% of POB plus redundancy
- If an alternate muster area is provided this needs to be provided with means for evacuation

Freefall TEMPSC

- Ensure water entry height and angle are correct - taking into account wave conditions and variable draught of FPSO

What happens next?

- Lifeboat makes a perfect entry.
- Lifeboat gets stuck on the rails.
- Lifeboat sinks.
- Lifeboat does a somersault and sails away.

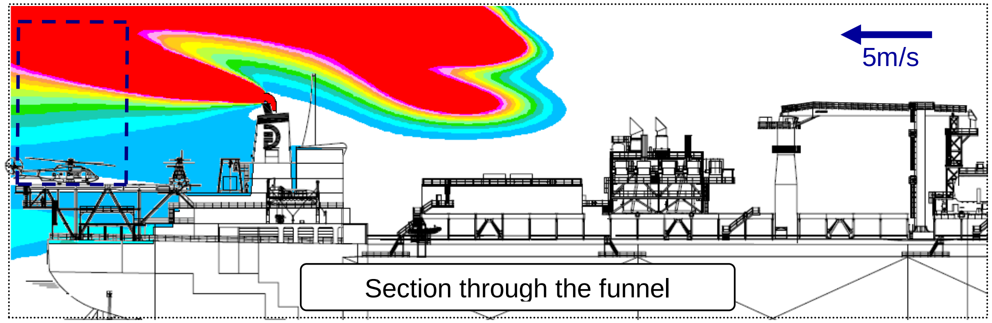
Flare Analysis

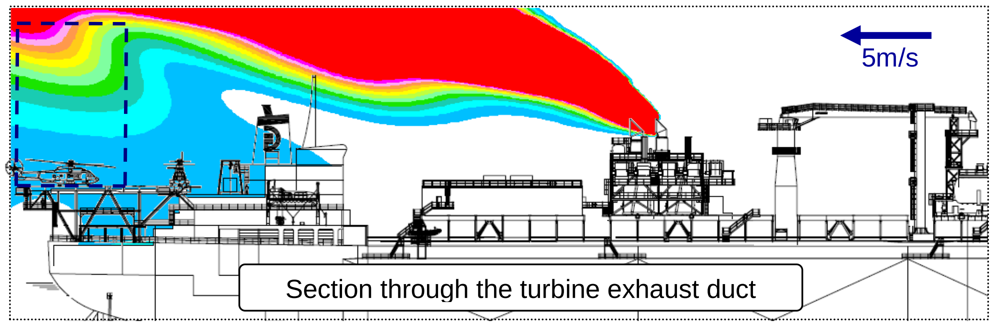
- Concerns
  - Radiation levels prevent personnel access
  - Noise
  - Liquid rain-out
  - Flammable gas cloud size on flame-out
  - Toxic products of combustion
  - Smoke effects
- Solution
  - Use commercially available software (e.g. FLARESIM) to perform detailed calculations of thermal and noise threats for continuous and emergency flaring.
  - Cost benefit analysis may be required to balance flare height versus blowdown rate and cost of additional heat shielding.
  - HAZOP for flare system operation and flare drum sizing

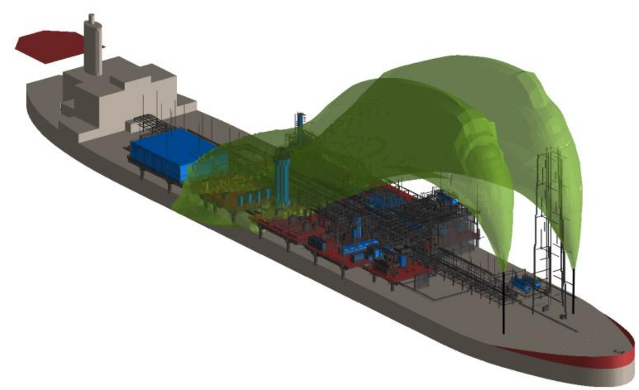
Dispersion of Vents & Exhausts

What effects do we need to Consider?

- ❑ Turbulent air around helideck
- ❑ High temperatures in working areas
- ❑ Effect of NOx, SOx, CO_2 on working areas (e.g. crane cabs)
- ❑ Hydrocarbons from IG vents
- ❑ This will probably require the use of CFD to adequately model these complex flow environments



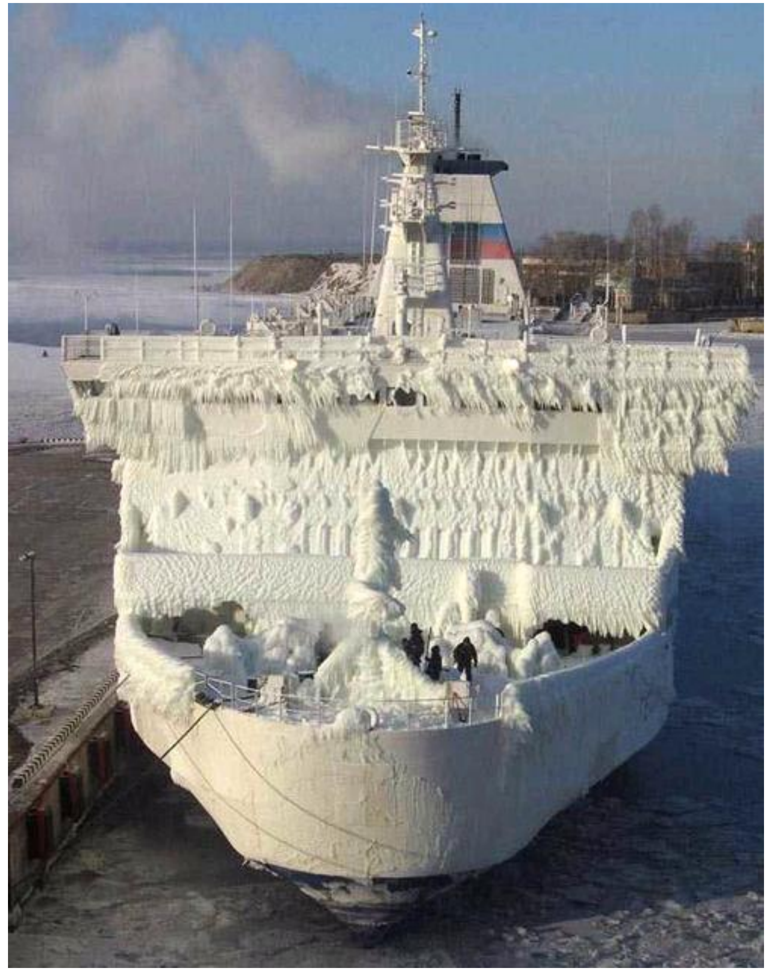




Wind Chill in Harsh Metocean Conditions

General Considerations

- Installations traditionally built as open structures:
  - Improve Natural Ventilation
  - Dilute potential gas released in area
  - Reduce blast pressures in the event of an explosion
- Harsh environmental conditions with potential sub-zero temperatures and wind:
  - Deteriorating working environment
  - Medical problems and reduced work capabilities
  - People more prone to make take wrong actions
  - Icing of equipment
- Mitigation:
  - Weather limitations for specific work activities
  - Enclosed modules
  - Weather walls
- Enclosed Modules – explosions need careful management



Wind Chill in Harsh Metocean Conditions

Specific Threat from Wind-Chill

- The percentage of time that the individual employee is exposed to a Wind Chill Index (WCI) above 1000 W/m^2 shall be reduced insofar as reasonably practicable for workplaces where there is frequent work with a duration of 10 min or more. The unavailability shall be less than 2 % on a yearly basis.

- For evaluations of the acceptability of a WCI above 1000 W/m^2, the following operational restrictions should be assumed to prevent harmful effects of wind chill on unprotected skin:
  - WCI > 1600 W/m^2: No outdoor work to be performed;
  - 1600 W/m^2 > WCI > 1500 W/m^2: The available working time per hour and person increases from 0 % to 33 % linearly;
  - 1500 W/m^2 > WCI > 1000 W/m^2: The available working time per hour and person increases from 33 % to 100 % linearly.

Windspeed in		Temperature in degC														
[km/hr]	[m/s]	10	7.5	5	2.5	0	-2.5	-5	-7.5	-10	-13	-15	-18	-20	-23	-25
3	0.8	500	554	609	663	718	772	826	881	935	989	1044	1098	1152	1207	1261
5	1.4	556	617	677	738	798	858	919	979	1040	1100	1161	1221	1282	1342	1403
10	2.8	649	720	791	861	932	1002	1073	1143	1214	1285	1355	1426	1496	1567	1638
15	4.2	712	790	867	944	1022	1099	1177	1254	1332	1409	1486	1564	1641	1719	1796
20	5.6	759	842	925	1007	1090	1172	1255	1337	1420	1502	1585	1667	1750	1833	1915
25	6.9	797	883	970	1056	1143	1230	1316	1403	1489	1576	1662	1749	1836	1922	2009
30	8.3	827	917	1006	1096	1186	1276	1366	1456	1545	1635	1725	1815	1905	1995	2085
35	9.7	851	944	1036	1129	1221	1314	1407	1499	1592	1684	1777	1869	1962	2054	2147
40	11.1	872	966	1061	1156	1251	1345	1440	1535	1630	1724	1819	1914	2009	2103	2198
45	12.5	889	985	1082	1178	1275	1372	1468	1565	1661	1758	1854	1951	2048	2144	2241
50	13.9	903	1001	1099	1197	1295	1393	1491	1589	1687	1785	1884	1982	2080	2178	2276
55	15.3	914	1013	1113	1212	1311	1411	1510	1609	1709	1808	1908	2007	2106	2206	2305
60	16.7	923	1024	1124	1224	1325	1425	1526	1626	1726	1827	1927	2027	2128	2228	2328
65	18.1	931	1032	1133	1234	1335	1437	1538	1639	1740	1841	1942	2044	2145	2246	2347
70	19.4	937	1038	1140	1242	1344	1445	1547	1649	1751	1853	1954	2056	2158	2260	2362
75	20.8	941	1043	1145	1248	1350	1452	1554	1657	1759	1861	1963	2066	2168	2270	2372
80	22.2	944	1046	1149	1251	1354	1456	1559	1662	1764	1867	1969	2072	2174	2277	2380
85	23.6	945	1048	1151	1254	1356	1459	1562	1665	1767	1870	1973	2075	2178	2281	2384
90	25.0	946	1049	1151	1254	1357	1460	1563	1665	1768	1871	1974	2077	2179	2282	2385
95	26.4	945	1048	1151	1254	1356	1459	1562	1665	1767	1870	1973	2076	2178	2281	2384
100	27.8	944	1046	1149	1252	1354	1457	1559	1662	1765	1867	1970	2072	2175	2278	2380

- No limitations (green)
- Worktime reduce between 0% and 33% (yellow)
- Worktime reduce between 33% and 100% (purple)
- No outdoor work performed (red)

Green Water

- Hazards
  - Threat to personnel working outside
  - Threat to living quarters and personnel inside
  - Structural damage
  - Production Shutdowns
- Physical Actions:
  - Bow protection structures such as breakwaters and higher bulwarks
  - Raising equipment / piping to reduce the loading
  - Protection of process, deck equipment, cable trays, hydrants and evacuation equipment
  - Redesign of structural details to resist wave loads
  - Assessment of green water using mathematical or physical models
- Operational Actions:
  - Restriction of draught (storage) particularly in winter conditions
  - Operation of the FPSO/FSU with stern trim where bow green water is more likely than elsewhere
  - Heading control to reduce wave incidence angles and side green water
  - Restriction of personnel access in green water zones

Analysis of Helicopter Operations

Accommodation Forward:

- Pros
  - Helideck advantage of clean air
  - no vessel induced turbulence
- Cons
  - Potential for misaligned approach
  - No forward visual reference point
  - Increased vertical movement

Accommodation Aft:

- Pros
  - Limited Vertical Movement
  - Forward visual reference point
- Cons
  - Turbulent air coming over the accommodation block
  - Turbine/boiler exhausts may cause additional turbulence