MOBIL'S FLOATING LNG PLANT

L'USINE FLOTTANTE DE GNL DE MOBIL

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ABSTRACT

Mobil has developed a unique floating LNG plant design. It will improve the profitability of large fields and will allow small marginal fields to become viable, because it is reusable and can be moved when the field is depleted. The facility will be located on a large square concrete barge with a central moonpool. It will have a capacity of 6 million tonnes per year (MMTA) of LNG combined with up to 8750 m^3/d (55,000 B/D) of condensate produced from some 27 MM m^3/d (1BCFD) of feed gas.

Storage will be provided for 250,000 m^3 of LNG and 103,000 m^3 (650,000 Bbls) of condensate with both products offloaded from the barge. The level of safety and reliability currently provided by existing onshore plants will be met or exceeded with this new design. The plant, which is capable of operating in a variety of maritime environments, will pave the way for significant capital savings in grassroots offshore developments.

RESUME

Mobil a développé une conception unique d'usine flottante de GNL. Cette conception améliorera la rentabilité des grands champs et permettra aux petits champs marginaux de devenir viables, car elle est réutilisable et peut être déplacée lorsque le champ est épuisé. L'installation sera placée sur une grande barge carrée en béton avec réservoir central. Elle aura une capacité de 6 millions de tonnes par an (MMTA) de GNL combinée à un maximum de 8750 m^3/d (55 000 B/D) de condensat produit à partir de 27 MM m^3/d (1 BCFD) de gaz d'alimentation.

Le stockage sera assuré pour 250 000 m^3 de GNL et 103 000 m^3 (650 000 Bbls) de condensat, les deux produits étant déchargés de la barge. Le niveau de sécurité et de fiabilité actuellement fourni par les installations existantes au large du littoral sera atteint ou dépassé grâce à cette nouvelle conception. L'usine, qui est capable de fonctionner dans des environnements maritimes variés, permettra des économies importantes de capitaux pour les développements de base au large des côtes.

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INTRODUCTION

Floating LNG holds much appeal for any company interested in monetising small gas fields or improving the economics of large fields. When the gas reserves are offshore, the traditional onshore plant project usually includes an offshore platform for dehydration and compression, large pipelines to shore, an onshore liquefaction plant, and a harbor to accommodate the purpose-built LNG carriers. By contrast, a floating LNG plant eliminates the platform, pipelines, harbor site preparation, and greatly reduces the infrastructure requirements (Figure 1). The savings can be significant depending on the length of the pipeline and the cost of a harbor.

Even if the gas field is located onshore, floating LNG may be considerably cheaper if site preparation is extensive and there is no local infrastructure or natural harbor. And floating LNG may have considerably less environmental impact, particularly if the potential onshore plant is located near populated areas. Depending on the reservoir, floating LNG may allow a higher recovery of gas reserves, since the abandonment pressure can be lower with the plant sitting right above the field.

Construction time can be 25% faster, partly because work on individual components can proceed in parallel. There is no delay for site preparation. Worldwide sourcing of modular components that can be linked together in protected waters also hastens the process, as well as reducing costs. And the plant can be precommissioned in transit.

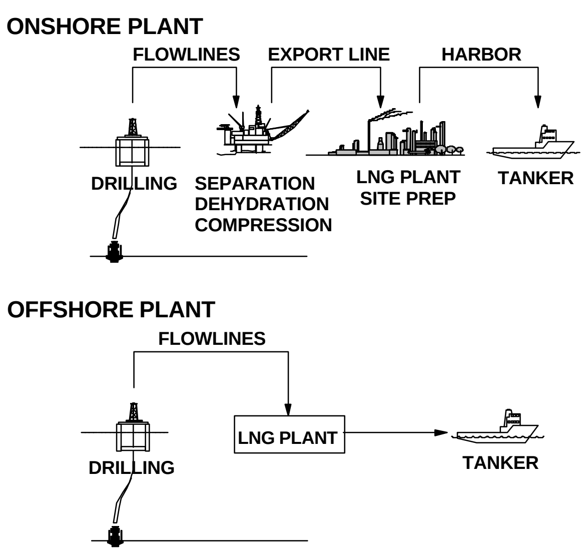

Figure 1. Advantages of Floating LNG

Given these many advantages, why has a floating LNG plant never been built? Certainly floating production offloading storage (FPSO) systems have been accepted by the industry for years. Since the 1970's, there have been many references to floating LNG in the public domain. Can a floating LNG plant be designed which could meet the same high reliability and safety criteria as an onshore LNG plant?

About two years ago, Mobil surveyed the information in the public domain to determine if floating LNG was technically and economically feasible, as well as safe and reliable. Finding no comprehensive evaluation which addressed these questions, Mobil formed a multi-discipline team to investigate the problem. In the process, Mobil designed a unique large-scale floating LNG plant, which will meet or exceed the reliability and safety performance of any existing onshore grassroots LNG plant.

CONCLUSIONS

Mobil's floating LNG design involves a square, concrete hull design capable of processing up to 6 MMTA LNG and 8750m^3/d (55,000 B/D) of condensate production. The unique hull shape allows for continuous operation during typhoon conditions. Model testing verified predicted motions, showing 6^o roll amplitude during 100-year offshore Australia typhoon conditions. Normal sea states will result in movements of less than 1^o roll amplitude.

The generic plant design can handle up to 15% CO_2, 100 ppm H_2S and 55 Bbl/MMSCF condensate yield. The floating facility was designed for water depths of 200m (650 feet), but can be modified to handle deeper water (depths up to 1200m) and harsher environments. Stringent base case design parameters exceed those found in most Pacific Rim locations, thus allowing the concept to be applied to most locations with little or no modifications.

LNG storage is provided for 250,000m^3 and condensate storage for 103,000m^3 (650,000 Bbl). Both products are offloaded from the barge. Stable barge motions allow offloading reliability equal to that of onshore. The hull supports topside facilities totalling 100,000 tons.

Four cases were developed: A 3 MMTA and a 6 MMTA propane precooled, spiral-wound liquefaction case, and a 4 MMTA and a 6 MMTA single refrigerant, plate-fin liquefaction case. Enhanced process flow diagrams, equipment lists, electrical load lists, two-dimensional layouts, and a three-dimensional computer model were developed for the cases.

The feasibility study was completed in early 1997. Significant R&D funds have been spent in 1997-98 to optimize the design and firm up developmental areas. Programs include hull model testing, offloading, shipping, hull materials, flare design, safety studies, constructability studies, and topsides optimization to efficiently meet generic requirements. In addition, P&IDs were completed, and 2-D layouts were optimized. Mobil is working with DNV on precertification.

The result is a design which takes advantage of economy-of-scale and meets topsides, hull, and storage requirements in a cost effective manner. The development is integrated from the wellheads through the process, through storage, to the tankers, building on the synergy between the hull and the topsides.

The plant will be among the safest and most reliable in the industry. And all technical challenges have been met with proven technology. The design FEED package is about 80% complete. If a project were approved tomorrow, the constructability study predicts a 40-month project schedule, including detailed engineering, construction, hookup, and commissioning. The future of floating LNG is now.

DISCUSSION

Early on, the team discovered that traditional approaches either would not work or were not efficient for a floating LNG plant. Although the team started with a ship-shape weathervaning FPSO, demands from the various engineering disciplines caused the design to evolve to a square concrete barge with a moonpool in the middle (Figure 2).

The design was greatly impacted by safety, reliability, thermal efficiency, and cost considerations.

Hull Design

Mobil's marine engineers performed hydrodynamic/motion analysis using the WAMIT program (developed by MIT). A sizing program was written using MATHCAD to optimize the shape for a variety of sea conditions.

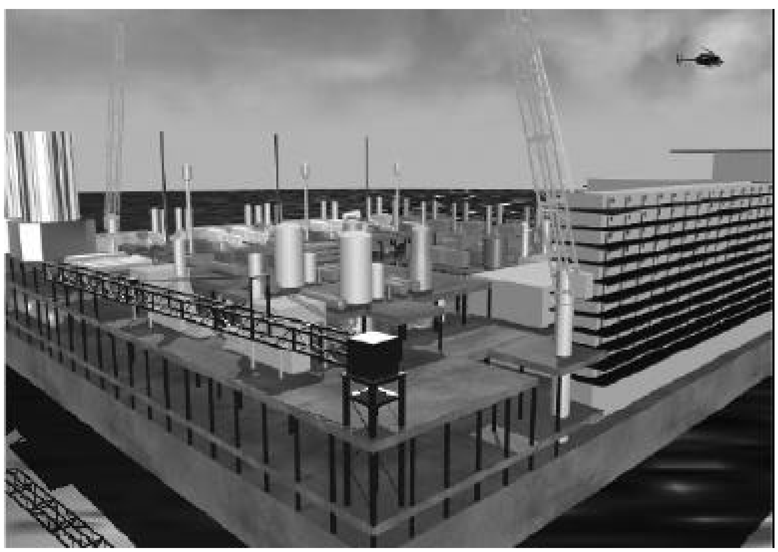

Figure 2 Mobil's Floating LNG Plant

Model motion tests of the 540-ft. square concrete hull conducted at Texas A&M University's Offshore Technology Research Center indicated an extremely stable platform. Motion on the barge will range from less than 1^o amplitude in normal conditions, to 3^o in a rough storm, to 6^o in a 100-year typhoon, allowing for production to continue even during rough seas.

Two phases of model testing have been performed. The hull shape, moonpool size, motion dampers, and other fixtures have been optimized with regard to motion, construction efficiency, and safety. Towing and offloading testing have also been performed.

Table 1. Model Test Results

Seastate		100 Year Return Period	1 Year Return Period
Max Wave Height (m)		22.4	9.5
Heave (m)	Predicted	4.5	0.4
	Measured	4.2	0.3
Pitch & Roll (°)	Predicted	8.0	0.8
	Measured	6.2	0.7

Table 1 describes the resulting motion parameters, both predicted and measured. H_s = significant wave height, T_p = peak period, and H_{max} = maximum wave height. Figures 3 and 4 show photographs illustrating an 11.8m significant wave height with the waves at 0^o angle to the spread-moored barge. This is the most stringent alignment during a 100-year Northwest Australia typhoon. The tests verified the barge to be extremely stable.

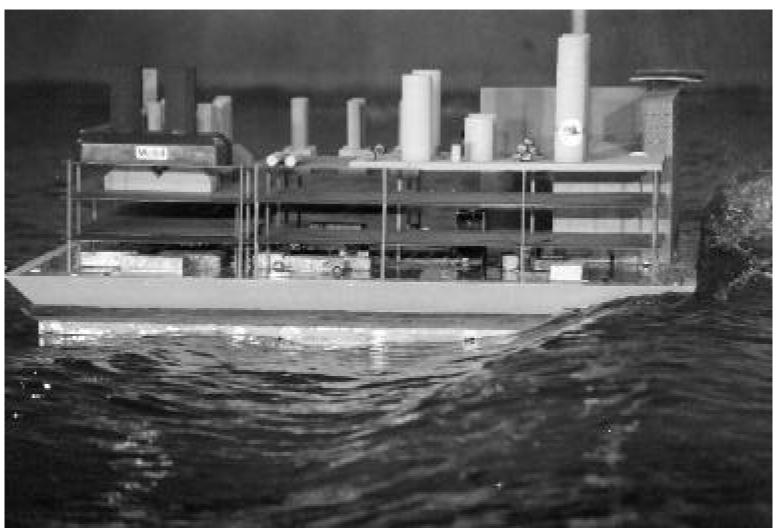

Figure 3 Model Test Photograph

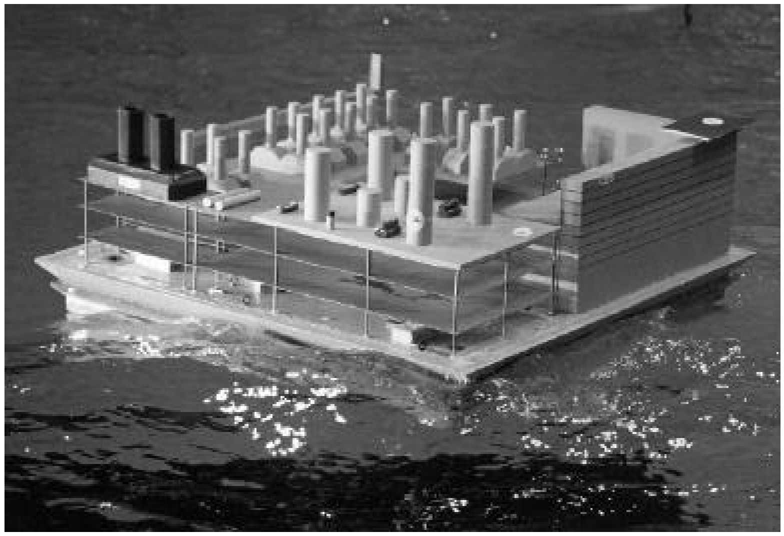

Figure 4 Model Test Photograph

The hydrodynamic stability of the hull was examined for a number of scenarios. For example, collision cases were analyzed for flooding of one entire side of the barge (three ballast tanks plus two corner compartments). It was found that the barge was stable, and only a 5^{o} tilt resulted without any counter ballasting.

The superior motion performance of the hull makes offloading availability virtually 100%, reduces wear and tear on the risers, and results in very stable process operations.

In order to ensure smooth process operations in rough weather, even during a typhoon, all treating towers and fractionators were designed with packing rather than trays. And to compensate for the potential effect of motion, 10-20% additional packing height was included.

The liquid distributors were specifically designed to offset any impact from motions. And the ballast system was designed to prevent any permanent tilt, even during offloading.

Concrete was chosen for the hull material primarily for the superior low-temperature behavior of concrete, low maintenance requirements, excellent fatigue life, and improved motion characteristics due to the heavy hull weight, high mass moment of inertia, and low center of gravity.

The barge will be constructed in a graving dock or dry dock, then towed to a protected harbor for outfitting. Prefabricated LNG tanks will be brought to a dry dock and lowered into the hull prior to fabrication of the barge main deck (Figure 5).

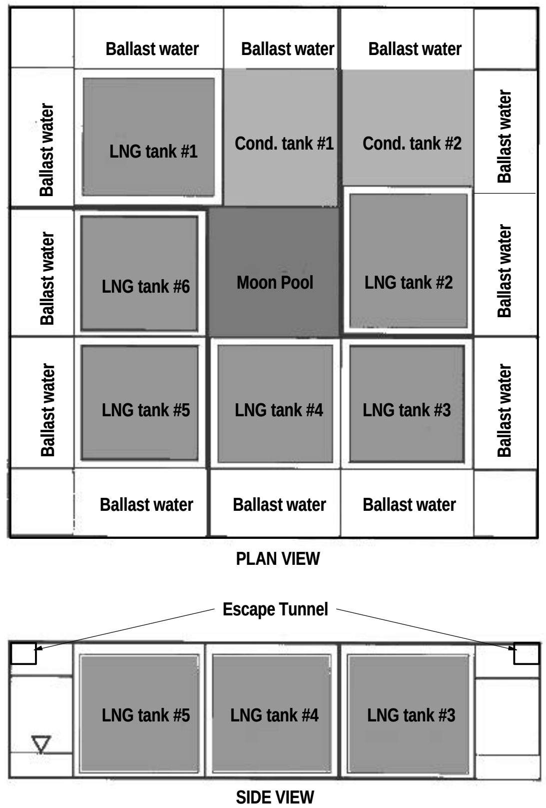

Figure 5 Hull Layout Arrangement

The topsides will be constructed in modules and skidded onto the barge. The plant is then towed to the field where it will be spread-moored with six anchor chains at each corner.

Topsides Design

Mobil conducted initial scoping studies to establish the best design criteria for determining the floating LNG plant throughput. It was concluded that full utilization of gas turbines would provide the most efficient and cost-effective design.

The conclusion was driven by the fact that the turbines constitute a major share of the topsides costs and are the primary contributors to plant operating costs. The turbine selected was the General Electric LM6000, the largest two-shaft machine in the industry and the most efficient. A total of 14 of these are used for the refrigerant compression, power generation, and booster compression in the 6 MMTA case.

Booster compression is provided should the field pressure decline below plant inlet pressure. Field processing will be handled on the barge, and the wells will be managed from the barge. Drilling and workovers must be handled by separate rigs.

In the design, the topsides are located on four decks on the hull. The main deck is the top of the hull and is exposed to heavy seas. Therefore, no equipment is located on the main deck, except for the condensate rundown tanks which have no connections exposed to the main deck.

The spar deck is located above the main deck. The motors for all the submerged pumps in the tanks in the hull are located on the spar deck, as well as the primary topsides. The mid deck is located above the spar deck, and the top deck is located above the mid deck. The top deck is only required for a few unit operations.

Living quarters for 250 will be on the barge and, unlike most offshore developments, maintenance shops and warehouses will also be on the barge to support the operation totally. With no shops and warehouse onshore, duplication of infrastructure will be eliminated.

Mobil evaluated various liquefaction processes. For floating LNG, a single mixed-refrigerant process was selected. The process uses plate-fin heat exchangers, resulting in a process less vulnerable to motion. Because the entire refrigerant loop is designed for the settle-out pressure, no refrigerant is lost when the process trips or is shut down for extended periods. This allows a faster restart, resulting in increased stream time. In addition, the single refrigerant loop has a smaller layout and is less complex.

The associated fractionation train is much smaller because it is only required for refrigerant makeup. And with the elimination of the propane-precooling loop, the quantity and risks associated with LPG storage are significantly reduced.

Reliability

The LNG industry demands high reliability from its plants. A floating LNG plant should be no different. The Mobil floating plant was designed with features that will make it more reliable than any existing grassroots LNG plant in operation today. The LM6000 aeroderivative turbine, the driver for both the refrigerant compressors and power generation, requires much less downtime for maintenance compared to the industrial frames traditionally used for onshore plants. The liquefaction process chosen uses plate-fin heat exchangers, enabling the entire refrigerant loop to be designed for the settle-out pressure. No refrigerant is lost when the process trips or is down for extended periods, resulting in a faster restart and increased stream time. A full 100% redundancy is provided in power generation, including a 100% spare bus. Spare capacity was built into all the utilities, meeting or exceeding the sparing philosophy of an onshore plant.

A key feature is the location of the warehouse and maintenance shops on the barge, so that the plant is fully contained. Equipment has been standardized to minimize warehouse and maintenance requirements. Parts and personnel are immediately available to facilitate repairs, and there are no delays waiting on a helicopter to show up with the right part. Only a small onshore base will be needed for helicopters and supply staging.

Offloading the LNG from the FPSO to the LNG tanker is one of the challenges of floating LNG. Offloading offshore must be at least as reliable as from an onshore plant. (Note that neither will offload during a typhoon.) Mobil met the offloading challenge with the barge shape. The transfer must take place between two moving bodies. Because of the unique shape, with the barge having practically no pitch or roll most of the time, offloading is possible with mechanical loading systems. The Mobil barge will be equipped with loading systems located at opposite corners of the barge (Figure 6) which will allow offloading, regardless of wind direction. The designated LNG tankers will have both tandem manifolding for loading from the FPSO and side-by-side manifolding for offloading in port.

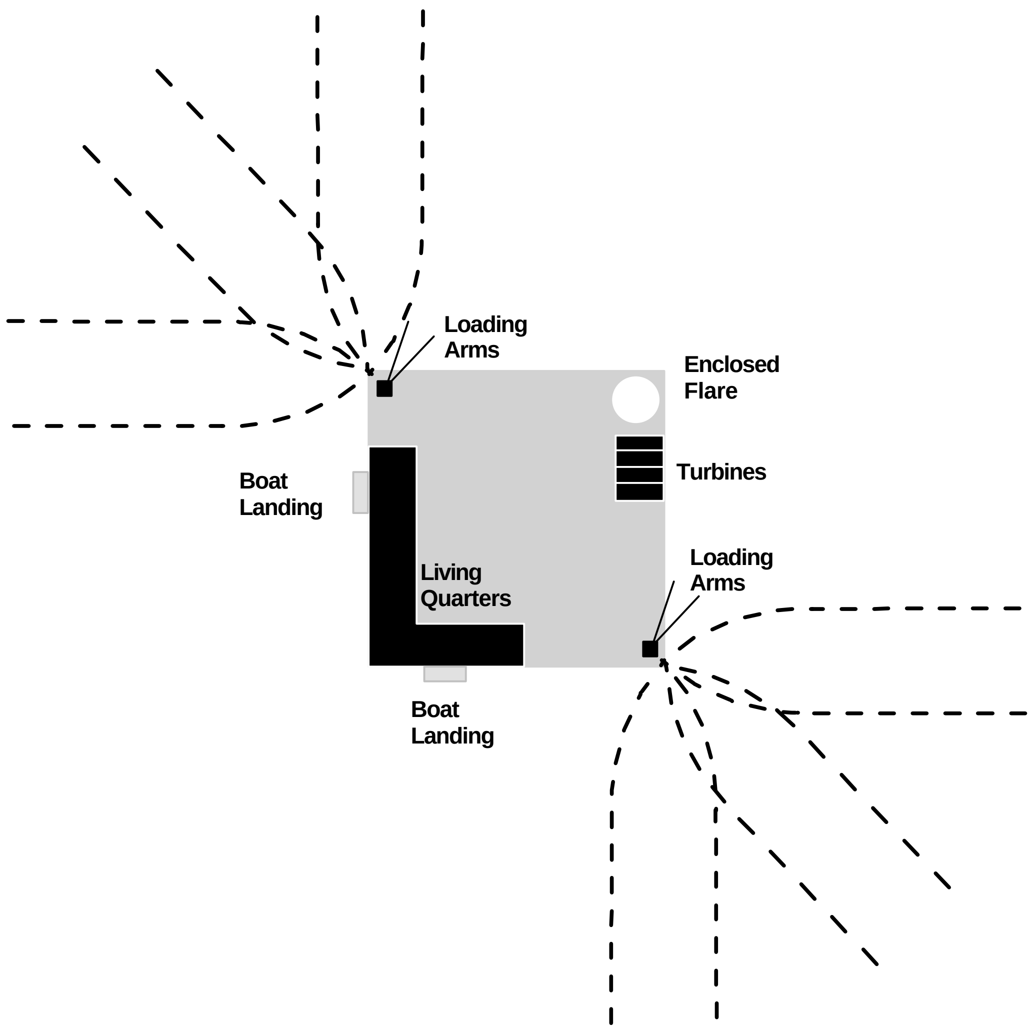

Figure 6 Offloading Layout Arrangement

Safety

Safety was a major consideration throughout the design. With all the heat requirements in the process being supplied by waste heat from the turbines and generators, no direct-fired equipment is required. This not only increases the safety of the process, it makes the plant extremely fuel-efficient.

The liquefaction process was selected with safety as a primary criterion. The equipment is arranged on the barge so that if one were to draw a diagonal line across it, the higher risk areas are on the opposite side, away from the hotel, and the lower risk facilities are near the hotel and maintenance shops (Figure 7).

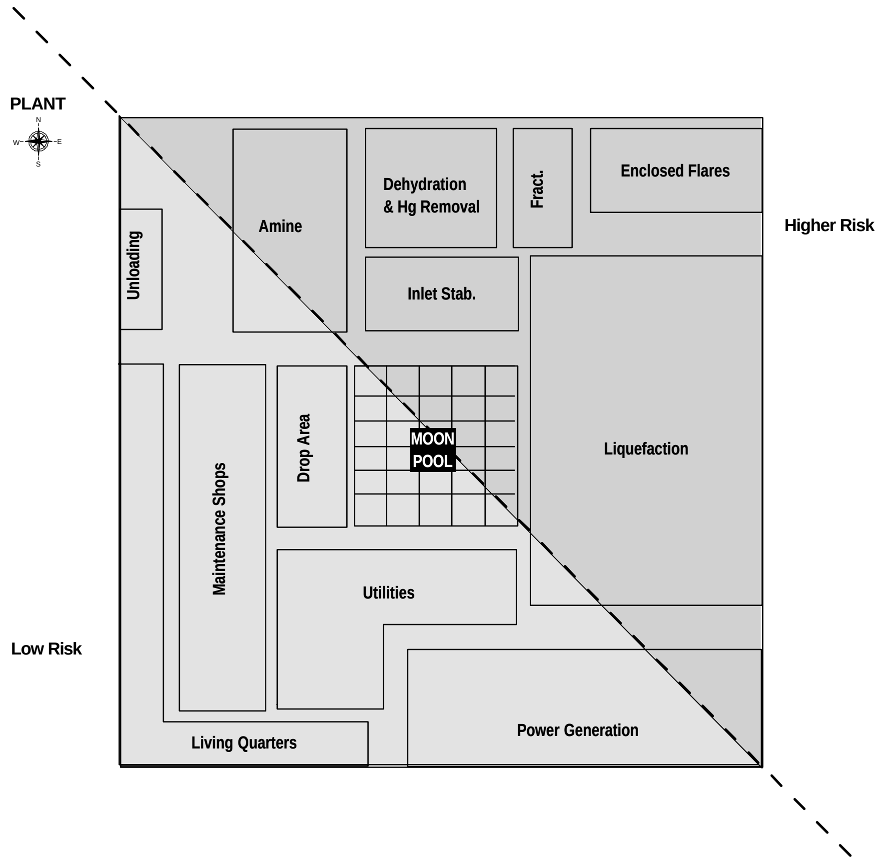

Figure 7 Equipment Layout Showing Risk

There is a double wall around the exterior of the hull, in which ballast water, cooling water, and potable water are stored in separate compartments. This wall acts as a barrier in the unlikely event of collision. A large personnel escape tunnel runs around the perimeter of the hull.

In addition, the facility has full-containment LNG storage (Figure 8). The LNG prismatic storage tanks are located in the hull, surrounded by bulkheads. Each tank is totally surrounded by concrete coated with PU Foam. The bulkheads and hull bottom will have double walls, resulting in triple containment redundancy. There is no penetration through the LNG tank with the exception of the pump shaft at the top.

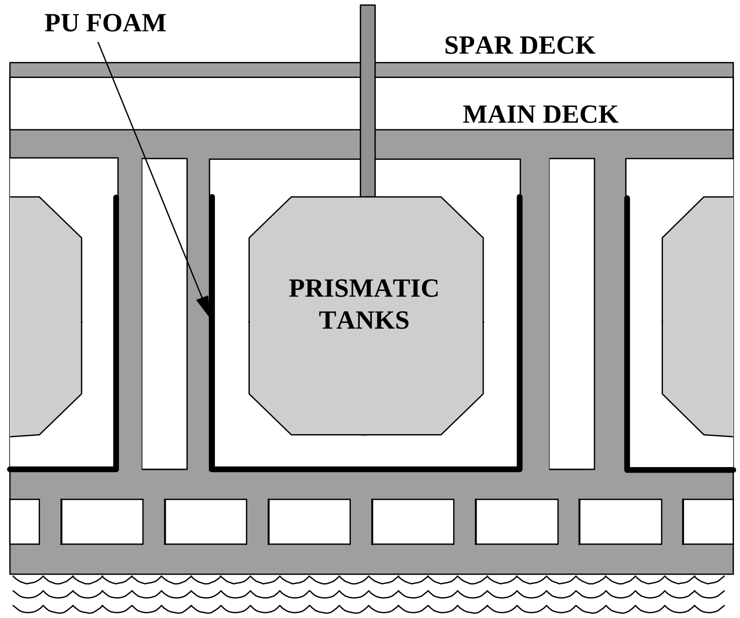

Figure 8 Full Containment of LNG

The flare system is unique in several ways. First, there is a floating flare located 1 mile from the barge. The floating flare also acts as a vent for the CO_2 that is removed from the treating process. As an alternative a CO_2-injection facility can be added if needed. On the barge's top deck are two enclosed flares to handle low pressure and cryogenic blowdown streams. These enclosed flares block noise and radiation to the rest of the plant.

Because the design was developed by a highly qualified, multidiscipline, integrated team, the result is quite different from what is generally proposed by the industry. However, this type of analysis is required to provide the industry with a competent design, which will serve the industry over time. A safe, reliable, efficient design could make floating LNG the preferred way to produce LNG.

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