Instituto Panamericano de Ingeniería Naval
Instituto Pan-americano de Engenharía Naval
Pan-american Institute of Naval Engineering

XI CONGRESO PANAMERICANO DE INGENIERIA NAVAL,
TRANSPORTE MARITIMO E INGENIERIA PORTUARIA.

SPECIALIZED SHIPS:
THE TECHNICAL ANSWER TO CHALLENGES IMPOSED BY THE OPENING OF NEW FREIGHT MARKET

CONFERENCIA N° 1

HUGHES LAURIN
CHAIRMAN & PRESIDENT OF BUREAU VERITAS

FOREWORD

The last century saw the emergence of specially designed and constructed vessels to meet the requirements of a new freight market : the oil market. The SS "GLUCKAUF" was the first sophisticated vessel, as she was designed and built for solely carrying crude oil in bulk. Compared to previous vessels, all built as general cargoships carrying more or less passengers, and not significantly different one from the others as regards their cargo possibilities, she appeared to be the most suitable vessel for the carriage of oil, and became the precursor of a new generation of ships.

The development of other new freight markets, such as gas and chemicals, the concept of standard containers to carry dry cargoes, led to a mutation of the world fleet pattern into great families of specialized ships. Nowadays, the evolution is much finer and the tendency comes to an actual sophistication in terms of suitability to the freight markets. The goal now is to find or design best adapted ships, while being more flexible and remaining in compliance with increasingly stringent international regulations.

In this situation, we have selected the following types of vessels :

- liquefied gas carriers,
- chemical tankers,
- combined liquefied gases and chemical tankers,
- oil and product tankers,
- container liners,
- cruise vessels,

which are at the moment more subject to this process of increased adequacy to a precise freight market.

We will try to develop how they follow closely the trends of these markets, the technological problems inherent to them and the solutions which have been adopted.

1. LIQUEFIED GAS TANKERS

1.1. Foreword

Carriage at sea of liquefied gases in bulk dates from 1940 and was developed mainly in America and Europe in the early fifties.

This type of carriage developed for power gases as natural gas (methane) or propane and butane (liquefied petroleum gases) as well as petrochemical gases used as raw material by chemical industry such as ethylene, ammonia, ...

The early development was carried out for transportation of methane on US rivers and LPG in pressure vessels on board coastal units. The development in technological side grows with the shipment of large quantities of LNG and LPG in seaborne trade.

The first ships both for LNG and LPG were converted tankers or cargo ships such as the "METHANE PIONEER", 5000 cbm LNG carrier, converted from a tanker by Alabama drydock. Real development of specially designed and built vessel came later on, after this low investment experimental craft. In the LNG field, the first vessels directly built as methane tankers were the "METHANE PRINCESS" and her sistership "METHANE PROGRESS" built in UK ; at the same time the "JULES VERNE" was built in France. The first LNG links from Algeria to Northern Europe were starting at this date.

1.2. Main products and trade patterns

The first step is to recall briefly what is a liquefied gas on a shipping point of view. The physical definition of a gas is a substance which is present in vapour phase at 15°C and 1.0 atmosphere. For the ruling maritime authorities a liquefied gas is a substance for which the Reid vapour pressure is more than 2.8 kg/cm^2 or a product presenting such a significant hazard that it is to be carried with the same precautions as a liquefied gas.

On a practical point of view, the only consideration is that products which are allowed to be carried in bulk and for which gas tankers are required are those exhaustively listed by IMO.

For trading consideration, the liquefied gases are considered in two main families :

- energy (LNG, LPG)
- petrochemical (ethylene, propylene, ammonia ...),

the trading of which is quite different commercially speaking.

In fact, for trading consideration, it exists three families :

- *LNG (Liquefied Natural Gas)*, which is a 90 % content methane. This product is mainly used for energy making and the sea transportation is part of an LNG link which comprises :

  - liquefaction plant,
  - export storage and terminal,
  - ship,
  - import storage and terminal,
  - gazeification plant.

The vessel being only one part of this LNG chain, there is a strictly determined correlation between an LNG project and a ship. The ship being chartered on the basis of the duration of the gas supply contract.

The trade is established between the producting countries :

	MM Tons/Year	%
ALGERIA	18.58	36.03
LYBIA	0.76	1.47
USA	2.08	4.03
BRUNEI	5.14	9.97
ABU DHABI	1.97	3.82
MALAYSIA	6.00	11.64
INDONESIA	17.04	33.04

and the consuming countries :

	MM Tons/Year	%
FRANCE	7.1	13.77
BELGIUM	3.8	7.37
SPAIN	3.16	6.13
UK	0.14	0.27
TOTAL EEC :	14.20	27.54
USA	4.86	9.42
JAPAN	30.51	59.16
KOREA	2.00	3.88

According to the following main patterns :

ALGERIA	to	EUROPE
LYBIA	to	SPAIN
ALGERIA	to	USA
ALGERIA	to	JAPAN
BRUNEI	to	JAPAN
ABU DHABI	to	JAPAN
MALAYSIA	to	JAPAN
INDONESIA	to	JAPAN
USA	to	JAPAN
INDONESIA	to	KOREA

- LPG (Liquefied Petroleum Gases) : Propane and Butane

Two types of traffic exist for these products on a simplified way. We may consider the large imports from Arabic Gulf to Europe, Japan and USA, and the feeding between USA and American countries, coaster operation for Europe and Japan.

These two types of traffic are obviously leading to very different types of chartering ; the large imports are carried out with line chartered vessels (normally 3 years contract time), on the opposite, feeders are operated mainly on a tramp basis.

- PETROCHEMICAL (Ethylene, Propylene, Ammonia ..)

The basic petrochemicals are Ethylene, Propylene and Butadiene. They are obtained by the cracking of natural gas, or naphtha and gas oil both of which are produced from crude oil.

Ethylene is the simplest member of the olefine family. It is the largest volume organic chemical, being used in 30 % of all petrochemical products. Because of insaturated nature, ethylene is very reactive and has become one of the main building blocks of the petrochemical industry.

The main source of ethylene in Europe is the steam cracking of naphtha while the USA traditionally produces most of its ethylene from natural gas.

Propylene is a coproduct of the ethylene production in the steam cracking of naphtha. Propylene is the second member of the olefine family and is currently a high growth chemical because of the high demand for polypropylene, a principal derivative. Crude propylene is also obtained from oil refinery gases in a state which needs purifying for chemical production.

Butadiene is the most widely used of all the synthetic rubber raw materials and is one of the by-products of the steam cracking process. A number of rubbers are derived from butadiene, the commonest of which is styrene butadiene rubber, which has three widest ranges of use, including shoe soles, waterproof boots, sponges, carpet underlays, garden hoses, tyre treads and rubber dinghies. With acrylonitrile, butadiene forms nitrile rubber used in products which must combine elasticity with resistance to oil and grease, e.g. oil hose linings. Polybutadiene is also used extensively in car and truck tyres. A further use of butadiene is with acrylonitrile and styrene in the production of ABS plastics, terpolymer or plastics "alloy". ABS is used for engineering components, casings, car body panels, in aircraft, and for the heads of golf clubs.

The traffic for these products is very much in line with the development of the chemical industry and could also be affected by cost of production, or, as it appears a few years ago, by repetitive problems on European steam crackers.

Basically, the size of batches is quite different from less than 5000 m^3 for butadiene up to about 12 000 m^3 for ethylene.

Most of the ships are working upon a tramping basis or a mass contract which is then allowing the ships to get other cargoes on a voyage basis.

1.3. Rules and regulations

The liquefied gas tankers have to comply in their design, construction and operation with various rules. The rules to be fulfilled are :

- International Gas Carriers Code, which is part of the SOLAS Convention as amended in 1986.

- Some national requirements, principally USCG requirements for foreign flag vessels carrying liquefied gases in the US waters.

- Rules of the Classification Societies, for instance Chapter 22 of the BV rules.

It is to be noted that ships built before July 1986 are not to comply with the above I.G.C. Code, as no IMO mandatory requirement was existing and rules for gas carriers were considered as optionallly applicable by the flag administrations.

The basic concepts of the regulations governing the gas tankers are the following :

a) the ship is to be conceived as to survive certains types of damage and cargo tanks are to be arranged to minimize their failure in case of collision or stranding ;

b) the low temperatures of carried products may remarkably reduce the ductility of materials employed for the tanks and for the hull ;

c) many of these products are flammable and may produce explosive mixture with air ;

d) the product is to be kept at the carrying temperature or be maintained in the containment under pressure because of the external ambient temperature ;

e) the product is to be loaded and discharged with a whole safety and with a suitable redundancy in the means of unloading in order to allow the ship to be emptied of its cargo in case of a possible failure of the containment.

According to the above, the following points are considered :

- ship requirements,
- cargo containment system,
- static and dynamic loads and allowable stresses as well as fatigue behaviour ;
- loading, discharging and refrigeration systems,
- safety systems, instrumentation, inerting plants and cargo controls.

1.4. Conditions of carriage

For carrying a liquefied gas in a tank, the following possibilities of storage exist to keep it inside of the cargo tank :

- isotherm,
- fully refrigerated,
- semi-refrigerated,
- pressurized.

The liquefied gas is most of the time in a colder condition than the ambient, it will receive from the outside some calorific energy. This energy flow may be reduced by fitting an insulation decreasing the heat ingress.

In the case of an isotherm carriage, the cargo will remain to the same temperature and pressure and the cargo boil-off vapour created by the heat ingress is sent out of the tank to be vented on the atmosphere or used as fuel in the boilers. This is the normal carriage condition used on board LNG tankers.

Fully-refrigerated means that the heat ingress inside of the tank will be balanced by a refrigeration system which will maintain the temperature of the cargo to its boiling point and therefore to keep the pressure in the tank close to the atmospheric pressure.

Semi-refrigerated is a condition similar to the fully-refrigerated except that by using a pressure vessel the temperature to which the cargo is maintained can be chosen up to a value for which the vapour pressure becomes equal to the maximum allowable pressure of the tank.

Pressurized means that cargo is carried inside a pressure vessel which allows the temperature of cargo and its pressure to increase.

Depending on the type of cargo, the size of the vessel and possible operational problems like the condition of storage of the feeding or supplied storage, the condition of carriage will be determined.

For construction reason, the size of pressure vessels will be limited to 20 000 m^3 ships (except for one existing 30 000 m^3), ships of higher capacity will be built for isotherm or fully refrigerated conditions. On the other hand, the physical characteristics of the product will define the condition of carriage. The important parameter being the value of the critical temperature, if this temperature is lower than 45°C (the defined maximum temperature that could reach a cargo not reliquefied), the product cannot be carried on pressurized condition.

These basic physical data are :

	Boiling Point	Critical temperature
	°C	°C
Butane	- 6.25	143
Vinyl chloride	- 13.70	156
Methyl chloride	- 23.80	143
Ammonia	- 33.40	132
Propane	- 42.05	96.8
Propylene	- 47.70	92
Ethylene	- 103.70	- 9
Methane	- 161.52	- 80

1.5. LNG Tankers

As we mentioned it earlier, an LNG tanker is a part of an LNG chain ; it implies that the degree of choice let in the design is restricted, and in particular the size is 130 000 m^3. This capacity of ship is first in line with the present size of the land storages and also permitting a free access in terms of dimensions to the terminals. It is nowadays the best suited size for scale of economy as it can be considered.

Up to now, all the LNG tankers are carrying their cargo under isotherm condition. It means that produced boil-off vapour is led from the cargo tanks to the machinery space, after heating and pressure building, in order to be used as fuel.

Presently, all LNG tankers are propulsed by a steam turbine, which is the simpliest way to use gas as fuel.

Existing LNG carriers, from the point of view of their cargo containment systems, can be classed as follows :

Membrane type tank

There are two existing membrane systems : TECHNIGAZ MARK I and GAZ TRANSPORT Standard.

Both systems are based on the same criteria : the cargo containment system consists of two containers, the first, in continuous service, is a thin metallic membrane (GT : flat INVAR membrane thickness : O.7 mm - TGZ : corrugated stainless steel membrane, thickness : 1.2 mm).

This membrane is supported by the adjacent hull structure through the load bearing insulation. The thermal stresses are either very low (GT : INVAR is a material having a very low thermal contraction coefficient) or released by the corrugations (TGZ).

The secondary container is designed to contain the full quantity of cargo with the assumption of a catastrophic failure of the primary barrier. This is a very conservative assumption since the two systems have been extensively studied in fatigue, and the Miner sum is very low (noticeably lower than required by the Rules for a system, for which a partial secondary barrier only is required).

On GT, the secondary barrier is made as the primary barrier (INVAR sheets) ; on TGZ, the secondary barrier is the combination of a plywood sheet with the associated secondary insulation (Balsa blocks).

On GT, the insulation is perlite (powder) contained in plywood boxes ; on TGZ, the insulation is Balsa.

Independent type tank

a) The major competitor of the membrane system is the spherical system classified as "Independent type B" by the Regulations (Moss Rosenberg in particular).

The concept is totally different to the membrane one : it is assumed that no catastrophic failure of the primary container can arise (the concept is "leak before failure", the leak being detected before the crack can reach its critical length).

So, only a receptacle is provided at the bottom to collect possible leakages since they are assumed to be always controlled.

In addition, however, International Regulations require a thermal protection of the bottom of the hold space which contains the independent tank.

The spherical tanks are made either of Aluminium alloy or of 9 % Ni Steel.

b) For historical purposes, it may be recalled that other types of independent tanks have been used in the past, some with, some without success. These tanks were of various shapes, and the majority of them were classified as type A tanks. We can in particular mention the JULES VERNE built in 1965 and still in successful operation, fitted with vertical cylindrical tanks with torispherical top end and conical bottom end, built in 9 % Ni Steel.

Evolution of the main existing systems

The three main systems briefly described hereabove could be up-graded, either to take into account the experience gained in service, or for economical reasons.

The main reason for such evolution is related to the tendency to try to reduce the boil-off rate.

Presently, the average boil-off rate is of about 0.25 % per day, this figure could be lowered down to 0.10 % or even less, depending on the equipment of the ship, the cargo containment system and her intended traffic.

For this reason, foam could be used as the insulation material of the membrane system.

The idea is to use a material having better thermal properties than those previously used, (Balsa for instance) and to reduce the price or to permit the deletion of the secondary metallic barrier; Here are some examples :

- *TGZ Mark III*

Technigaz proposes to replace the insulation and the secondary barrier of Mark I by panels of polyurethane foams and by a thin composite liner (sandwich of fiber-glass and aluminium alloy) acting as the secondary barrier).

This system would allow to easily obtain a low or even very low boil-off rate.

Similar systems have been used satisfactorily on land LNG storage tanks (in France and in Japan).

The experience of the existing systems is, of course, to be taken into account for upgrading the systems when necessary. This is the case of Gas Transport Standard membrane system from the view-point of resistance to sloshing and the reliability of the chair tube connections with the secondary barrier.

Other systems

The prismatic independent type B tanks

IHI shipyard, in Japan proposes prismatic tanks for which a full secondary barrier would not be required by the Regulations (same philosophy as for the spherical tanks).

This system has reached the level of conceptual approval by the regulatory agencies.

The last evolution concerning the LNG ships was very limited, and it seems worth thinking that it will be the same for a further period of time.

The improvement specially comes in way of the boil-off production and the speed of the vessel. Both are correlated as directly linked as soon as boil-off gas is used as propulsion fuel.

The speed of the new ships was decreased from 20'5 to 19' with an accordingly reduction of the boil-off rate.

This reduction was achieved by changing ship containment system from 5 to 4 tanks and by increasing the thickness of the insulation.

1.6. LPG tankers

The fleet of LPG tankers may be roughly considered in two sizes :

- the large ships for import from the producing main sources to heavy consumer areas,

- the distribution ships, most of the time engaged also in petrochemical gases.

The large size LPG tankers are commonly the ships from 40 to 85 000 m^3, these ships are fully refrigerated type an using prismatic independent tanks built of cargo manganese steel as their minimum service temperature is - 48°C for propylene.

Two different arrangements have been used for these ships. First concept is double hull with perlite pulverulent insulation filling the space between double hull, double bottom and cargo tank. The second arrangement is based on a structural arrangement of ships with single hull, double bottom and tank insulated with polyurethane panels.

A consequence of the shipping crisis on this type of vessels was the look for flexibility in terms of possible cargoes. When the trade of LPG comes to reduce, these high cost vessels could not remain idle and were employed for carriage of liquid cargoes. The range of cargoes for which they may be used was the light density and relatively high vapour pressure : light naphthas and light petroleum cuts.

This is still influencing the new projects, as charterers are still fearing a possible recession in LPG trading and wish to have flexible ships able to handle replacement cargoes. Unfortunately, this now involves two problems :

- first the real design of the ship upon a higher specific gravity (0.72 instead of 0.63) which increases the price of the ship,

- second a difficulty to meet the requirements of the new IMO rules concerning pollution.

The contemplated cargoes being ruled either by MARPOL Annex I regulations applicable to oil products or by MARPOL Annex II requirements as considered as chemicals.

These last considerations having obviously also an influence upon the price of the ship. As a result, building of a new large LPG tanker comes to be difficult as either the ship is built without flexibility and cannot find a long term time charter or is designed and constructed with a full flexibility and comes to a too high price compared to the chartering rate.

The medium and small size gas carriers are arranged with pressure vessels which allow these ships to carry products under fully refrigerated or semi-refrigerated conditions as needed according to the type of shore storage they are trading for.

The type of trade being based upon tramping with a large volume of transportation of petrochemical they are arranged for these carriages. Two types may be distinguished : those equipped for ethylene, leading to built ships with a minimum service temperature of - 104°C, and others limited to propylene only needing a temperature of - 48°C. The costs of the two types of ships are significally different because of the materials and increased insulation, on the other hand the ethylene chartering rates are much more attractive, whichever is the market position, than other rates. For this reason, it seems that presently for ships less than 12 000 m^3 the share of ethylene tankers significally increase in the fleet.

2. CHEMICAL TANKERS

2.1. Historical background

After World War II, a field of chemical industries developed along the US Gulf Coast. These industries were supplied with raw chemical feedstocks by the Texas Oil fields and the sulphur mines of Louisiana. At the beginning, the low production authorized transportation by drums, portable tanks and railroad tanks. During the 1950's, the production increased significantly and induced a development of larger means of transportation. At first, the deep tanks of dry cargo ships were used for this purpose but a further increase of the size of batches to be shipped led to the necessity of using specially dedicated vessels.

The first chemical carriers to exist were converted T2 tankers. The conversion consisted in the following :

- realize actual segregation for incompatible products ;

- segregate the products from possible external damage by using only centre tanks for the most hazardous cargoes.

The first really extensively converted vessel as a chemical tanker was the "R.E. WILSON", which was fitted with double bottom and deepwell pumps enabling carriage of nine different products in the centre tanks. She entered into service in 1949 and be operated up to 1971 when she was scrapped.

Further development of the technology took place with using of special materials for protecting the ship structure from the aggressive cargo as well as to guarantee the quality of the product during the seaborne shipment. Special coatings or linings were used or corrosion resistant materials as stainless steel, first in independent cargo tanks located inside the ships and further on with tanks integrated to the ship's structure.

2.2. Main products and track patterns

On the contrary of the liquefied gases, the chemical products are a large number and specially the limit between a product, in the sense of carriage onboard product tanker, and a real chemical exists only in the rules.

The IMO Regulations give an exhaustive list of the products considered as "chemicals" in the consideration of its seaborne carriage. If we consider, the origin and the use of the chemicals, we may list :

a) the petrochemical products. Principally the derivates from ethylene and propylene :

- *ethylene derivates :*

. ethylene dibromide : additives
. ethanol : paints, solvants, pharmaceutics
. styrene : plastics, polystyrene
. polyethylene : plastics, fibers, films

- *propylene derivates :*

. propylene oxide : paints, resins
. isopropanol : paints, fuel
. acrilonitril : rubber
. polypropylene : plastics

- intermediate products :

. methanol
. isobutylene
. aromatics (benzene, toluene, xylene)

b) products derivated from coal, principally aromatics :

. naphthas
. naphthalen
. tar acides (phenolics and crecsotis compounds)

c) products derivated from carbohydrates :

. molasses
. fermentation alcohols

d) animal and vegetal oils or fats :

. soja beam
. nut oil
. palm oil
. tallow

e) "large quantities chemicals"

- mineral acids (sulfuric, nitric, phosphoric)
- caustic soda
- caustic potash.

The quality of these above very different products being to be steady, the design of chemical tankers must take into account the basic points :

- segregation of cargoes,
- easiness in stripping and washing,
- coating of tanks or use of stainless steel,
- reduce number of stiffeners inside the tanker,
- avoid any liquid trap in the hull structure, piping, valves or instrumentation.

According to a careful design upon the above basis, the ship is open to a large range of cargoes and even may be used for carriage of edible products.

The chartering of these ships, except those dealing with mineral acids like phosphoric, is most of the time done on a tramping basis. Another type of operation is that of the large parcel tankers which are operated in a sense similar to container ships as they are offering some places onboard the ship for a reduced batch of cargo.

2.3. Rules governing the construction and operation of chemical tankers

International Regulations for the transportation of dangerous liquids in bulk have developed in the seventies. In 1971, the Resolution A.212 adopts the Code for the construction and equipment of ships carrying dangerous chemicals in bulk (code BCH). These Rules are not considered mandatory at the international level.

In 1974, the SOLAS Convention devoted a part of Chapter II.2 to tankers in order to regulate the precautions necessary for the carriage of flammable liquids : cargo segregation, fire bulkheading of accommodation spaces, specific firefighting equipment, and inert gas systems.

In 1978, the Rules of part D of Chapter II.2 of SOLAS 74 were improved through a protocol (mainly, reduction to 20 000 TDW for the IG system, and retroactivity of this regulation).

Since, the 1974 SOLAS Convention was amended twice, in 1981 and 1983. For tankers, the results concern mostly cargo tank venting and gas freeing.

Since its origin, the BCH Code has been regularly amended. Its specifications were harmonized to give birth to the international Code for the construction and equipment of ships carrying dangerous chemicals in bulk (IBC). Besides, these Rules became mandatory for these types of ships, through the 1983 amendments in Chapter VII of the 1974 SOLAS Convention.

Concurrently, the MARPOL Convention which was issued in 1973 includes in its two mandatory appendices, Rules to avert polluting the marine environment by oils (Annex I) and by noxious liquid substances carried in bulk (Annex II). Annex I of the Convention put into force in 1983, was amended in 1978, which Annex II enforcement was postponed to the year 1986. However, in 1985, and before it came into force, Annex II was amended, and its enforcement deferred to April 7, 1987, that is 14 years after its original adoption.

Time span and postponing were mainly due to the difficulties arising in the practical implementation of the provisions of this Annex : the lack of shore reception facilities, criteria for possible discharge, as a function of parameters not directly available, although simple in theory : in particular, total amount of residue per tank and concentration of effluent in the wake astern of the ship.

Annex II distinguishes 4 categories of noxious chemicals (A, B, C and D) according to the hazards for marine resources or for human health, and to their harmful effects on the amenities of sights or on other legitimate uses of the seas.

Category A : substances with a major hazard or serious harm
Category B : substances with a hazard or harm
Category C : substances with minor hazard or minor harm
Category D : substances with recognizable hazard or minimum harm.

A fifth category of chemicals has been determined by the exclusion of those chemicals in Appendix III which are not covered by the Rules of the present Annex.

Annex II provides a series of Regulations for the management of operational discharge of residue or mixed noxious substances carried in bulk by ships, coming from the washing up of tanks and pipes, the deballasting of cargo tanks that were not previously washed, or else from bilges of the cargo pump-rooms.

Annex II prescribes the measures to be taken to minimize the accidental discharge of such substances, following the collision or the stranding of a Chemical carrier.

2.4. <u>Different types of chemical tankers</u>

The fleet of chemical tankers, which consists of about 900 ships for 7 million ton.deadweight is composed of several types of vessels.

a) the easy chemical tankers

These ships are generally simple hull arranged (similar to the oil tankers). Their cargo tanks are most often coated with a protective paint. According to the MARPOL Convention beyond 30 000 tdw, the ship is arranged with segregated ballast tankers as most of the time these ships are also oil tankers.

b) the parcel tankers or pure chemical carriers

These ships are designed for eventual carriage of a large number of chemicals (normally 200 to 300) ; they are designed for a simultaneous carriage of several products, some of them incompatible each to the others. The cargo arrangement is based upon a large number of tanks, the volume of which depends upon the size of parcels of cargo (often about 500 tons). The enlarging of size of the vessel is directly increasing the number of tanks, as individual tank volume remains almost unchanged.

The central tanks are more often built of stainless steel (either solid or cladded), side tanks being coated. Side tanks are also used as ballast tanks except in the case of ships more than 30 000 tdw carrying also oil products.

Ships are fitted with double bottom either partial (under central tanks) or integral.

Each tank is fitted with its own cargo piping and pumping systems.

Central tanks scantlings are based upon heavy products (specific gravity 1.8 to 2.2), in wing tanks lower specific gravity about 1.1 is considered.

c) Specialized chemical carriers

These ships are designed and built for carriage of one or a few number of products, such as :

- Phosphoric acid carrier. A ship dedicated to carry only phosphoric acid is built with tanks rubber lined ; it must be considered that this design is no more in favour and that modern phosphoric carriers are built with stainless steel tanks. This design, though the raise of price, increases significantly the flexibility of the vessel.

- Liquid sulfur carrier. This type of ships is fitted with independent self supporting tankers insulated on the outer face.

- Wine or alcohol carrier. This type of ship is similar in her design to the b) above ships, fitted with stainless steel tanks, except that cargo tanks scantlings are based upon a lower specific gravity close to 1.

3. PURPOSE OF COMBINED LPG/CHEMICAL TANKERS

3.1. Background

The LPG market is continually evolving with typical charters not exceeding one or two years. On the other hand, the costs of building and maintaining gas tankers are quite high ; the unemployment of such a vessel can therefore be a major problem.

Accordingly, gas tankers should be as flexible as possible to ensure the maximum possibilities for chartering.

Depending on their size, this flexibility will be different : for sizes under 30 000 m^3 capacity the first option will be to use pressure vessels with full reliquefaction facilities in order to suit the requirements of land storage working either at atmospheric pressure or ambient temperature. For reasons of size and cost, this cannot be done for large tankers (30 000 to 70 000 m^3), and would not in fact add flexibility to the vessels, as due to their dimensions, they cannot enter most of the ports for liquefied gas storage.

For these large tankers, flexibility is achieved by adapting the vessels for the carriage of clean products or light cuts. Most of them are being presently chartered for trading naphtha.

Large scale flexibility may be therefore contemplated for smaller size vessels, the smallest size being dictated by the need to achieve a balance between the length the loaded voyage and the time spent for changing from one type of cargo to another. This latter time is of course more or less fixed and the smaller the ship the more important this time becomes in comparaison to the maximum length of loaded voyage.

The full effectiveness of a flexible ship may be in fact limited presently to a range of vessels of a cargo capacity from 6 000 m^3 to 30 000 m^3.

3.2. Types of product

The liquid cargoes commonly transported in bulk onboard these ships may be classified as follows :

1. Liquefied gases

These products are those included in Chapter 19 of the INTERNATIONAL CODE FOR THE CONSTRUCTION AND EQUIPMENT OF SHIPS CARRYING LIQUEFIED GASES IN BULK (I.M.O. IGC Code) and they can be as a first approach classified in three categories depending on the minimum design temperature needed :

Methane (LNG)	- 163°C
Ethylene	- 104°C
Propylene, propane, butane, ammonia, butylene, butadiene, VCM	Above - 50°C

The minimum design temperature and additionally the specific gravity will define the design and more especially the material for the construction of the cargo tanks.

2. Oil products

These cargoes are the refined or clean products produced by the processing of crude oil. Basically, they consist of :

- Naphthas
- Light refined products
- Gasolines
- Lube-oil
- Kerosene
- Diesel-oil
- Gas-oil
- Turbo-fuels

No special problems are expected either from transport temperature or specific gravity, but the ship is to be considered as an oil tanker for purpose of safety (i.e : application of SOLAS Convention Chapter II.2 E) and MARPOL 73/78 Annex I is to be complied with except for some exceptions normally agreed by the flag administration.

The equipment of the ship is to include means of cleaning and stripping of the tanks. These products, not being corrosive, do not require coating of the cargo tanks.

3. Easy chemicals

These products are the chemicals which have been judged by IMO as low hazard chemicals. The criteria used for this judgement are :

- flammability
- toxicity
- corrosive effect
- hazardous reaction possibilities with water
- pollution hazards.

They are listed in either IMO Resolution A.212 (CODE FOR THE CONSTRUCTION AND EQUIPMENT OF SHIPS CARRYING DANGEROUS CHEMICALS IN BULK) Chapter 7, or in the IBC Code (INTERNATIONAL CODE FOR THE CONSTRUCTION AND EQUIPMENT OF SHIPS CARRYING DANGEROUS CHEMICALS IN BULK) Chapter 18.

These products are normally non corrosive and no coating or special tankage material is required for the protection of the ship. Nevertheless, some of them, if used for special applications, may require a coating or a material for avoiding any pollution or deterioration of the product (e.g : methanol when not used for bulk industrial purposes).

Apart from this, for the carriage of such cargoes attention is to be paid to specific gravity, heating capability and cleaning effectiveness. Special fire fighting equipment using foam efficient for polar products is to be provided. (A polar product is a product which, due to its molecular arrangement destroies the foams of regular type).

4. Edible liquids

Such cargoes as wine or edible alcohols or vegetable oils are required to be carried in tanks specially approved for the transportation of products for human consumption. Therefore, special coating or material of tanks is required. Heating of the cargo may be necessary and special attention to the temperature control is to be paid as some cargoes such as vegetable oil could be damaged by slight overheating. In addition, some of the alcohols depending on the flash point (i.e : pure alcohol content) are to be treated as cargoes having a flash point less than 60°C, in such a case a foam fire fighting system suitable for polar products is to be provided.

5. Chemicals

These are the products listed in Resolution A.212 Chapter 6 or IBC Code Chapter 17. These are hazardous chemicals as stated by IMO.

Attention is to be paid for their transportation to the following points :

- compliance with either A.212 or the IBC Code,
- specific gravity,
- heating capability,
- cleaning efficiency, with compliance of the system with MARPOL 73/78 - Annex II,
- corrosiveness : in that respect, special products like acids do require a containment system fully suitable for such cargoes and only a thick lining or stainless steel may be used. For the flexibility of the vessel and in order to be suitable for a significant number of chemicals or liquefied gases only stainless steel may be used.

3.3. Conceptual design

As stated in the background presentation, the option to build a combined LPG/Chemical tanker is linked to the flexibility of the vessel. This flexibility is based upon the ability of the ship to carry various types of cargo and to be chartered as easily as possible. Taking into account the present chartering rates, where LPG rates and the market are rather unstable and weak, quite a lot of other liquid cargoes may be transported at a competitive rate of chartering and this is obviously preferable to the unemployment of the ship.

Another aspect to be considered is the ability of the ship to be positioned in the world for a charter whilst carrying another cargo on her way to the new loading port. This will allow the ship to sail to a new loading port with a charter in place of sea water ballast.

Considering the turn around duration and the time spent for adapting the ship to a different cargo, full flexibility for ships designed, for other reasons, with a cargo capacity less than 6 000 m^3 is perhaps not the best compromise.

On the other hand, such a tanker cannot be reasonably built, for technological and practical reasons, fully optimised for several cargoes. Thus a leader product is to be considered.

At the present time, the most profitable liquefied gas cargo is ethylene. Bearing in mind the fact that the ship could during her life be used only on a restricted range of products and not use the flexibility granted to her, the leader product to be chosen should be the maximum profitable one.

A ship design for transportation of ethylene is basically to be built for a minimum service temperature of - 104°C. Such a temperature leads to a high alloy steel, minimum material being a 5 % nickel steel. The use of such material, which is corrosion resistant, assists the flexibility of the design.

The difference in price of the tanks in a material suitable for chemicals (316 grade stainless steel) is therefore reduced and such a stainless steel will provide a suitability for the corrosive chemicals such as acids.

The evolution in price of the ship vessels, depending on the flexibility required, can roughly be summarized as follows :

Cargo	Tank material	Price
Propylene, LPG, Isoprene	CMn	N
Propylene to Isoprene and clean product	CMn	1.05 x N
Propylene and ethylene	5 % Ni	1.17 x N
Propylene and ethylene and chemicals	316 LN	1.25 x N

Additionally, consideration should be given to the maximum size of the vessel. Ethylene being the leader product, the maximum capacity is to suit the maximum profitable size for this product ; following the increase in the last ten years of capacity of the ethylene land storage, the maximum size of ethylene carriers grew from 6000 m^3 to 12 000 m^3.

The maximum size to be expected presently for such a ship is therefore 12 000 m^3, this also meets most of the size limitations in possible ports.

Lastly, the design is to suit the various specific gravities of the cargoes to be handled (from 0.58 up to 2.2 tons/m^3). This question is basically a problem of adjusting the maximum deadweight to a chosen specific gravity. The option of the maximum specific gravity for a 100 % loading will in fact influence the volume of the hull and therefore the gross tonnage of the vessel as the parameter involved will be the depth of the vessel, if the breadth and length are designed for a compromise between cost effective building and energy economy for propulsion of the vessel.

The present practice is to design the ship for a maximum deadweight with a relative density of 1.4 which seems to be the most efficient compromise.

3.4. Special arrangements and technological aspects of combined gas and chemical tankers

In order to suit either the rule requirements or the technical and operating necessities linked with the handling of different cargoes, certain arrangements, more or less specific to this type of vessel, are necessary.

3.5. General arrangement of the ship

The type of vessel described in this paper, as far as the arrangement of the vessel is concerned, is defined for the cargo part as follows :

- tanks for the carriage of ethylene and heavy chemicals ;

- slop tanks for handling cargo tank washing water before release at sea according to the requirements of MARPOL 73/78. These slop tanks may be also used as cargo tanks and their arrangement is to fulfill the requirements of the largest range of chemicals ;

- the design is to be suitable for the handling of cargoes having a density of from 0.58 to 2.2 t/m^3.

Regarding the cargo tanks, designed as stated previously as pressure vessels for the purposes of vessel flexibility and as no secondary barrier is required, several arrangements are possible :

- longitudinal cylindrical tanks,
- transverse cylindrical tanks,
- bilobe longitudinal tanks,
- spherical tanks.

All these designs present some advantages and disadvantages :

- longitudinal cylindrical tanks : ease of construction and cleaning but no optimisation of fitting in the ship's hull and possible sloshing problems ;

- transverse cylindrical tanks : good fitting in the ship's hull with the possibility of a higher number of tanks and therefore of different grades but stability problems and reduced rate of loading for this reason ;

- bilobe longitudinal tanks : good fitting in the ship's hull but reduced efficiency of the cleaning of the stiffened longitudinal bulkhead ;

- spherical tanks : excellent cleaning efficiency, no sloshing problems but poor fitting in the ship's hull and more difficult to build, and eventually stability problems.

As the cost effectiveness of the overall ship design becomes a more and more important factor of the design, the bilobe tank arrangement, which permits a decrease of the length to breadth ratio seems to be the preferred one.

The slop tanks may be either :

- independent deck tanks,
- integral forward tanks.

The advantage of deck tanks is that there will be no difficulty with the shape and arrangement of the forward part of the vessel. On other hand, the deck of these ships does not leave a lot of space for fitting deck tanks, especially if good access to all parts of the cargo piping is required. In addition, stability problems may be encountered.

An integrated gravity tank has the advantage of not requiring any space on the deck except for the piping and equipment associated with it, but the design of the forward part of the vessel may be affected.

Cofferdams are to be provided between this tank (or tanks) and ballast or fuel oil tanks if there is to be no restriction on the products to be carried in it. A cofferdam will always be required at the forward end of the tank.

Such slop tanks, depending on the cargoes intended to be loaded in them, while considered as cargo tanks, may be either built of normal steel with a suitable coating or lining, or built of stainless steel, especially if acids are contemplated. A solution especially for integrated tanks may be the use of austeno-ferritic steel (ASTM A 240 UNS 31 803) like URANUS 45 N of CREUSOT LOIRE, which associates very good corrosion resistance (especially for crevice or stress corrosion and where cleaning are contemplated) with mechanical characteristics similar to structural steels.

Another major concern for the design is the large range of densities from 0.58 to 2.2 t/m^3. The problem is to define which density to take into consideration for the maximum deadweight of the vessel associated with a complete filling of the tanks.

This density is normally taken as 1.4 t/m^3 to 1.6 t/m^3, which permits an efficient use of the vessel in low densities without much reduction of the filling ratio for the high densities.

This leads to the following additional needs :

- large ballast capacity,

- possiblity to adjust the trim of the vessel for propulsion effectiveness with the range of cargoes,

- ability of the vessel to sail with cost effectively with significantly different draughts.

The first requires that sufficient space is to be left in the hull for ballasting purposes with good arrangements for controlling the trim.

The last will lead to the choice of a controllable pitch propeller and a low profile bulbous bow with large vertical part of the stem.

The hull structure will not need to be specially modified, except some increases of scantlings will be needed for the bending moments induced by alternate loading and for heavier loads in way of tank supports.

No major problem is likely with stability or stability after damage, except in the case of transverse tanks or open longitudinal bulkheads in bilobe tanks.

The stability after damage, although involving the criteria of the bulk chemical code does not present difficulties for the gas loaded cases as the freeboard is significantly greater in this condition that for the heavy chemical loading cases.

As a last remark, foam may be more efficient than powder or water spray on these "Gas Code" cargoes which are liquids, including Acetaldehyde, although this one, being one of the most polar liquid, requires a very efficient foam.

3.5. Operation

The combined tankers in addition to the operational requirements of either liquefied gas transportation or chemical transportation are also to be designed for changing cargoes between liquefied gases and chemicals.

The transportation of chemicals emphasizes the problems of stripping and draining of the cargo piping and cargo tanks, and which has already been commented upon previously.

In addition, means of cleaning the tanks are to be provided for cargo changes. In addition to the cargo changing procedure used on chemical tankers, there is also the problem of drying cargo tanks.

The operations of cargo changing for a multipurpose tanker are summarized in the following diagram :

DISCHARGING CARGO 1
STRIPPING AND/OR PUDDLE HEATING
(HEATING)
INERTING
PURGING CARGO VAPOUR 2
(COOLING)
EQUALISING PRESSURE
LOADING CARGO 2

GAS

DISCHARGING CARGO 1
STRIPPING
(VENTING WITH AIR)
(INERTING)
(PRE WASHING)
(EQUALISING TEMPERATURE)
DRYING
COOLING
(VENTING WITH AIR)
(INERTING)
PURGING CARGO VAPOUR 2
EQUALISING PRESSURE
LOADING CARGO 2

DISCHARGING CARGO 1
STRIPPING/PUDDLE HEATING
HEATING
INERTING
(VENTING WITH AIR)
WASHING
LOADING CARGO 2

CHEMICAL

DISCHARGING CARGO 1
STRIPPING
(VENTING WITH AIR)
(INERTING)
(PRE WASHING)
WASHING
(VENTING WITH AIR)
(DRYING)
(INERTING)
(EQUALISING TEMPERATURE)
LOADING CARGO 2

The ship is to be fitted with a cleaning system. This system is to be operated with either sea water, fresh water or chemicals. The operation with sea-water reduces the required capacity of industrial fresh water tanks but can never be used alone and will always be followed by fresh water cleaning. Moreover, sea water is not recommended for warm or hot washing as the stainless steel could be affected by it.

Washing water is normally classified according to the following temperature range :

ambient	up to	20°C
warm	up to	60°C
hot	above	60°C

The steaming in the cargo tanks is not suitable for cleaning of insulated tanks as no condensation will appear on the tank wall.

The washing system normally consists of an arrangement of distribution piping in order to deliver the cleaning medium through pumps, heaters and valves to tank cleaning machines located inside the tank.

The washing machines of a chemical tanker are normally of the removable type. However, for the combined tankers fitted with pressure tanks, this is not convenient. Such machines would need to fit several washing openings distributed along the tank and such an arrangement on a pressure tank would create as many tank domes as washing positions, which would neither be structurally desirable or economically practical.

Moreover, the arrangement on deck of openings to the tanks is not easy, specially in way of the cargo compressor room or electric motor room.

Thus, fixed machines are provided inside the tank. These are of stainless steel construction without any use of brass or other unsuitable material and lubricated by the washing fluid.

The arrangement of washing machines in the tank is detrimental to the capacity of the heating system of the washing plant as all the machines of a tank are supplied by the same line in order to limit the tank penetrations.

The machines are normally fitted near the bottom of the tank for easy maintenance. Some special arrangements for washing may also be necessary according to the design of the tanks such as a spray ring in the gas dome for convenient cleaning or water injection pipes for washing the U tube in the case of bilobe tanks.

The major problem for changing cargo from chemical to liquefied gas is the drying of the tank. Proper stripping of water is to be performed and this will require for completion a crew entry into the tank ; in fact completion of washing is often done by hand hoses inside of the tank. This need not be detrimental to the duration of cargo changing as normally the carterer will carry out an internal cargo tank survey on such an occasion.

After proper drying of the tanks, the normal sequence is for venting with air, then with inert gas and finally new cargo vapour is introduced into the tank. For cryogenic cargo, any moisture left in the tank at this stage will immediately create problems for the equipment associated with cargo handling located in the tank.

4. CRUDE AND PRODUCT TANKERS

4.1. Historical background

The first known large consignment of hydro-carbon oils was carried from the oilfields of Pennsylvania to London in the brig "Elisabeth Watts" in the year 1861. The cargo was carried in wooden barrels and considerable difficulty was experienced both in actually loading the cargo and transporting it because of leakage from the barrels. After the safe arrival of the "Elizabeth Watts" in London, transatlantic trade in oil gradually increased. The oil was still being shipped in wooden barrels, however, with the consequent problems of broken stowage, caused by the shape of barrels, and considerable leakages, particularly when the ship suffered heavy weather. This was further on solved by using iron tanks which would not leak and by making them of rectangular section, they could more easily be fitted into a ship's cargo hold, thus allowing a greater tonnage of oil to be carried on each voyage.

The continuing demand for oil caused the shipbuilders to look for ways in which the various transporting problems could be overcome and the solution found was a ship with the hull built of iron with tanks forming an integral part of the hull. The first of these tankships was the "Gluckauf" laid down on the Tyne in 1884, 91 metres long, driven by a triple expansion steam engine and capable of carrying some 3500 tons of cargo. This ship has justly been acclaimed as the forerunner of the modern tanker and she continued in service for several years.

The size of the tankers grew steadily up to the last forty years when the increase of the tonnage of ships become very sharp :

- from 1946 to 1968 deadweight come from 20 000 tdw up to 120 000 tdw ;
- in 1968, the first VLCC ("Very Large Crude Carriers") 200 000 tdw appeared and in 1973 the first 550 000 tdw.

The evolution in size towards the giant ships was fully justified at this time for the economical savings which were provided both on building and operating costs.

This evolution, actually necessary because of the constant growth of the energy demand from industrial countries, probably took place even if the Suez crisis in 1967 had not existed.

4.2. Present situation

Further to the bonanza in crude transportation caused by Middle East political troubles, the energy crisis took place. The overcapacity in tankers appeared with the direct consequences of increasing the number of ships to be laid up and further on scrapped.

Since a few years, the overcapacity decreased quickly up to a situation of a lack of tonnage or more precisely of a lack of suitable tonnage for the present market.

The development of refining facilities in producers' countries, particularly in the Middle East, made appear a balance to certain level between carriage of crude oil and refined products. The product tankers which were before only used for coastal or reduced voyage came to be real part of the energy seaborne trade.

On the other hand, the reopening of the Suez Canal combined with the reduced demand for crude oil led European owners to turn back to Suez optimised tankers.

Nowadays, oil products patterns of trade is really based upon the two types of cargoes :

- crude oil

- refined products, i.e :

. gazoline
. jet fuels
. fuel oils
. gas oils

and to a certain limit

. nhaphtas
. condensates

Roughly speaking, the crude oil transportation used "VLCC's or Suezmax tankers".

The VLCC (250 to 280 000 tdw) i.e : 2 million barrels is presently, taking account of the economy of scale as well as the batches size, the most suitable vessel for carrying crude oil from Arabic Gulf to USA or Japan.

On the other hand, the Suezmax (120 to 130 000 tdw) i.e : 1 million barrels optimised for the largest size to cross Suez Isthmus in northbound ladden traffic is the most suitable vessel for European traffic.

The growing of the product transportation principally affected the European countries and conducted to build product tankers which are suitable for these cargoes in terms of size of batches as well as in terms of specific gravity. A crude oil tanker is based upon a mean specific gravity around 0.85, on the country, the product tankers are designed or we would say should be designed for much lower specific gravity, about 0.7, which is most of the time a subject of misunderstanding between shipyards, shipowners and charters, as the first one is taking about deadweight capability and the last one about cubic capability, which is in fact only a lack of consideration for the suitable design specific gravity.

The sizes of vessels used for product transportation, apart special trades which have led some companies to convert VLCC to products, may be roughly summerized, to the following :

- FEEDERS	29 900 tdw	42 000 cbm
- HANDY SIZE	40 000 tdw	50 000 cbm
- PANAMAX	60 000 tdw	85-90 000 cbm
- AFRAMAX	80 000 tdw	110 000 cbm

4.3. Influence of the rules on the design and arrangement

At the same time as the first generation of VLCC's where delivered, several casualties took place, among which the one affecting the "TORREY CANON" in March 1967, off the British Coast. These casualties had the consequences of a collective awake to pollution hazards presented by giant tankers. As a matter of fact, the quick growth of the tankers size increased these risks by :

- increasing the length and capacity of the tanks increasing the oil quantity released in case of collision ;

- increasing the draft and consequently the grounding risks ;

- aft position of the wheelhouse reducing visibility ;

- reduction of the scantlings thanks to a better knowledge of the phenomena ;

- increase of the energy consumed in case of a collision ;

- lower manoeuvring suitability.

In order to limit the pollution in case of casualty such as collision or grounding, the IMO proposed in 1973 and 1978 some rules which may be summed up as follows :

- limitation of the size of tanks in order to reduce the crude oil release to the sea in case of collision ;

- definition of a minimum draft and trim in ballast condition ;

- need to arrange segregated ballast tanks located for building up the best protection of the cargo in case of collision ;

- fitting of a crude oil washing system for dilution of the sludge in tanks.

This series of rules, which was implemented to cope with the two major aspects of the pollution collision and grounding, mainly affected the design and construction of the tankers.

The last pollutions which took place in USA some months ago are making most of the tanker shipping people, and particularly shipowners and charterers, to fear a reinforcement of these rules. In particular, the present product tankers are more or less ordered with both double hull and double bottom ; although this is not mandatory by the present regulations, it is thought that, whichever is the evolution, it could not come beyond a requirement for the above arrangement. As for a product tanker, the suitability in stripping as well as the efficient washing is needed, the ships are improving in terms of commercial efficiency with this design.

Concerning the crude oil tankers, though the owners and charterers are fearing some possible modifications of the rules, it is not presently considered for economic reason as sound to anticipate as a possible reinforcement of the requirements.

4.4. Technological aspects

The optimisation studies done at the time when the 550 000 tdw tankers were built, showed that the optimum in terms of size for economical reasons was about 750 000 tdw, which was significantly overestimated. The major factor influencing the value of the required freight rate was demonstrated to be the hull structure cost. Obviously further on the variation of the bulkers price as well as the implementation of the MARPOL Convention affected deeply these conclusions.

Nowadays, it is to be considered that the VLCC's are not to exceed 280 000 tdw because of the protective location of the segregated ballast tanks which cause over this size a drastic modification of the complete structure of the vessel leading to a real gap in the price of the building.

The decrease in price of the bulkers also caused the consequently reduction of the L/B factor for a reduction of structural weight. This factor is enhanced by the explosion in prices of shipbuilding.

The present technology of building the product tanks and crude oil tankers is largely using high tensile steel which allows a reduction of cost at the building and present the advantage of a slight increase of the deadweight of a given ship.

Concerning the product tankers the most significant parameters are :

- efficient stripping and washing by use of flat surfaces for tanks bulkheads ;

- suitable painting of the cargo tanks ;

- cargo handling system designed for carrying simultaneously four different grades of cargo.

5. CONTAINER LINERS

5.1. Historic

Nowadays, container ships are the result of a long evolution. First idea of containerisation was issued in 1911, in an American advertisement. The real interest for improving the cargoes handling appeared in fact at the end of World War II.

Containerisation really developped when it appeared that this concept was an ideal arrangement for both marine and land transportation.

The first experiments were limited, containers being only stowed on opendeck. In 1950, the first container terminal was opened in Newark and two tankers employed on an experimental basis for carrying containers between New-York and Houston.

The first real container ships were types C2 and C3, converted in 1957 and 1960.

In the course of the 60's, the integrated transportation, based upon the paletts concept as developed by Scandinavian owners, with the advantages of the vertical handling came to leading position.

5.2. Development of the container standard

There is no doubt nowadays about the importance of container transportation. The main concern is now for a shipping company to be fully in line with the intermodal transportation system, or even, as most of the majors, to organize his own system.

The first generation of containers appeared in the sixties, were dimensioned :

- 20' length
- 8' width
- 8' height

with a steady progression the boxes got longer for reaching 30' then 40' long. Briefly speaking, after the "high cubes", the "super high cubes" came and the "ultra high cubes" are beginning. If we come back to the beginning of the seventies, the US shipping company American President Line began with the use of "out of standards" containers, with 9'6" height, on their lines between US West Coast and Far East Asia. The fitting of the landbridges across the North American continent allows them to start or increase a railway continuation to their maritime trade without particular restrictions.

Still in USA, the implementation in 1983 of a new road regulation applicable to the interstates highways allows the traffic with containers with all or part of the following maximum dimensions :

- length 48'
- breadth 8'6"
- height not defined (only limited by the clearance given by the encountered structure).

For the US shippers, this new regulation was also the beginning of ladder step effect for marine side and a generalisation of the "super high cubes". 49' long or even 53' were reported to operate on US side.

Further on, the European Owner MAERSK LINE, operating mainly in the Northern Atlantic, came to use 9'6" high boxes with 45' long and built ships to meet this new standard. This was the beginning of a wave in Europe which will affect the "round the world" traffic.

As we saw, the containerisation concept has in the recent past, become more associated with the developments in the United States, where units tailor-made for the internal market are coming into service but were restricted in world basis development as not suiting the European market. But now, a similar process is taking place in Europe. A "EUROCONTAINER" system is shaping, prompted by the changing requirements of shippers who now want wider containers. Based to a large extent on the use of 40 ft long, 2.5 m wide units, of various heights, this system is rapidly becoming the standard for short sea operators and international rail carriers, superseding the ISO containers which have a standard width of 8 ft (2,435 m). The non-ISO containers have grown in popularity as shippers have switched to the Europallet with dimension of 1 m x 1.2 m. To be able to stow two of these pallets side by side in practice, the external width of 2.5 m is essential. Moreover, whereas the standard 40 ft ISO container can carry a maximum 21 Europallets, the 2.5 wide equivalent can handle up to 24 pallets, which is as many as non ISO Standard 45 ft container. This greater loading efficiency of around 14 % is an important consideration, expecially for short sea lines which are having to compete with operators of 12 m long trailers. Even the shippers which are not using Europallets in their distribution are tending to prefer the wider containers, because easier loading suitability that the 8 ft wide ISO units. Even this trend is, in addition to the dry freight containers, affecting the tank and bulk containers used in Europe as it allows extra cubic from the 8 ft units.

European owners involved in the short sea container services are therefore largely coming to the 2.5 m wide system. Some of them took also advantage of increasing the height of the boxes to 9'6" which is giving an extra volume of 11 % compared with the standard boxe. These boxes were in addition optimized in terms of structural construction which allowed to reduce the container's weight such as the operator may offer a 23 ton payload despite the greater cube. Other operators drastically increased the boxes dimensions, always to offer higher cubic to the basic customer and come to 40', 8'6" and 9'6" boxes representing the ultimate high cube standard on European basis for a 40 ft standard.

Given the intermodal boom and necessity for the competitors to suit the market request, it appears that most operators will seek to move towards the 48 ft length, although 53 ft and why not beyond. The uncertainty about what the eventual domestic container dimension will be is, perhaps, a major factor holding back even faster growth in the concept. No company wants to invest considerable amount of money on new containers whatever the model and to see these or their present fleet to become obsolete.

There is clearly a need for a new standard to be formulated for these new generation containers, but as yet this seems some way off. The technical committee of ISO that deals with container standards has set up a working group to specially look at this question but up to now no agreement was met on a definite specification. Various options have been considered. Until recently, it seemed that 49 ft length, 9 ft 6 in height and 8 ft 6 in width should be adopted as new series standard with half module length of 24 ft 5 in. Unfortunately, during the last ISO meetings, delegates were unable to come to an agreement and therefore the uncertainty remains.

The ships improvement

The large competition existing between the operators of container lines is leading to an optimisation of the full intermodal service.

It could be summarized as :

- propose to the final shipper the highest cubic at the earliest delivery for a reasonable price. This is first leading to be able to suit the vessel to the maximum of commercial standards of boxes :

  - length (20', 40', 43', 45', 48', 50', 53')

- width (8', 8'6")
- height (8', 8'6",9')

without any present standardization or even foreseen trend in this subject.

The second point is to have a ship with reasonable speed, and not to come to the failed econ-ship concept, as shippers seem to prefer higher price for slot than slower delivery.

The third point is to define an optimisation of the scale effect, by :

- optimizing boxes rotation,
- increase the size of the vessel and specially the number of boxes to be carried, presently large lines are 4000 to 4500 TEU capacity.

If the speed is now almost defined to 22 knots for the large liners, still two options are competing :

- the ultrapanamax vessel,
- the overpanamax vessel.

These two concepts are based upon a different approach on the intermodal field, which either operate round-the-world or ocean bound vessels.

The implications are very different, the ultrapanamax ships are leading to very tough structure problems as design is giving ships of 965' long over a 106' breadth. The ratio of length to breadth, and consequently to depth, makes the ship very flexible longitudinally with possible consequences upon hatchcovers tightness a fatigue life of the unit.

In addition, the stability needed as well as the increase of boxes content of the ship are leading to increase the number of rows fitted in the holds. Normal design is now based upon 11 rows in breadth on a panamax ship instead of previous 10 rows.

The width of the double hull is then reduced depending upon the interval between boxes accepted by the operator from 1.4 to 1.8 m.

In order to be able to rearrange the ship for different width of boxes, the longitudinal center girders are to be suppressed.

The deck extent on the side of the ship, which is to meet the requirements for longitudinal bending, is therefore leading to high thickness of high tensile steel going up to 40 mm which means in hatches corners to more than 50 mm.

The workmanship and the welding procedure needed to achieve a satisfactory construction as well as the quality of basis material are to reach a very high standard in quality.

Moreover, the possible flexibility in terms of length of containers, is leading to increase the length of the hold spaces and to design the vessel with reduced transverse strips of deck. The direct consequence is the difficulty to meet the torsional strength of the ship.

Besides, the overpanamax vessels present a less sophisticated design and construction as the breadth is not limited and extent of deck is not restricted. On the other hand, on the basis of the full intermodal system, it needs a sophisticated load or railways system through the US continent for not losing some market shares because of a larger voyage time for some containers.

Some owners have also thought about reducing the operation time during loading and unloading. A conventional container liner has a rupture in her container transfer onboard ship as for each hold : one over hatchcover, another under hatchcover.

From the existence of these two spaces, a complete operation of the slots as a vertical system is not possible and a reduction of the flexibility of operation of the vessel appears.

The possibility of handling boxes upon a pure vertical system has been investigated and led to the hatchcoverless concept. By using this concept, it is possible to achieve a continuous cell-guide system from the bottom of the hold up to the last row above deck, with the direct consequence of reducing the loading unloading time of the ship.

This concept creates some technical problems in the ship design :

- freeboard and survival capability of a fully opened ship ;

- need of specially reinforced containers for using stacks of more than 7 tiers or fitting of mechanical tackles in the cell-guides to support the tiers above the seventh bottom tiers.

- protection of the containers against water ingress.

6. CRUISE LINERS

6.1. Introduction

Up to the 30's, the only way to travel from a continent to another was marine transportation onboard the cargo passenger liners of this time.

As this was the only means of travelling, different social condition passengers took place onboard the vessels, whichever were the needs or wishes for intercontinental trips. It was therefore necessary that every passenger, of all classes, be in a suitable environment and that obviously the ones willing to perform a luxurious voyage had to pay for it. The speed factor was also a major point as business travelling people had also to use this means of transportation.

In ten years, the whole pattern was changed with the development of airtransportation, which, thanks to the speed, was interesting the businessmen in their travels. Shipowners have been urged to change their strategy, and consequently, to propose ships with improved luxury and in line with leisure which they still have on the other hand to propose cheaper prices for those who need to travel but could spend a larger time for it.

The direct consequence was a reduced demand for large passenger liners. And the concept of cruise liners began to appear, in conjunction with the increased confort and suitability for leisure activities while the speed was no more a major concern.

At the end of the 70's and during the 80's, the airtransportation development came to a unique level in the whole history of transportation. Speed is now proposed with confort and this means of transportation is no more limited to businessmen. The tariffs of airtransportation also decrease up to enable more and more people to travel quickly for more and more distant destinations. As a result, the intercontinental seaborne passengers transportation almost completely disappeared but in conjunction a leisure market considerably increased and the demand for luxurious cruise liners grew, most of the time including in the cruise fees the price for airtransportation to and from the departure and arrival of the cruise.

The growing demand for more confortable and more suitable accommodations also affects other fields of maritime industry, namely the one of "cruise ferries".

Together with providing installations fully suitable for cars or truckers transportation, the owners propose leisure and recreation areas in order to meet the wishes of their customers. The sea transportation is then understood as a pleasant experience and confort as well as services are important elements to offer to the passengers. Tourists are to be encouraged to use ferries for the vacation trips and the travel time is to be considered by them as fully part of their holidays and not as a loss of time. To meet this goal, cabins are becoming more and more confortable and public rooms or recreation areas increasing in number as well as in surface.

6.2. Influences upon ship arrangement

In the hotel industry, on shore, a huge change have been taking place for ten years. The client is offered more and more possibilities and leisures (swimming pool, tennis, sauna, bridge room ...).

In addition, an hotel may also host congresses with all the inherent annexed services.

The flexible answer is the leading principle in order to be always adapted to the needs of the clients.

Basically, the customer of a cruise liner needs to feel at sea when he wishes to be or to feel as he would be in a vacation hotel situation on shore.

The keypoint in the design of a cruise liner is then to satisfy the above but in way which is leading to an economically sound position in building and for easy maintenance.

The first factor to consider when a cruise liner is designed is the range of possible contemplated customers which will give the price at which the week will be offered for a person.

On the same consideration, the basic surface of the cabin will be chosen and the economical balance is to be checked with consideration of the number of passengers that may be expected which gives the size of the ship and the surface of the public spaces. Inside, decoration will obviously suit, as for hotel accommodation, the level of price to which the cruise is proposed.

According to the level of passenger's price and the size of the ship, the volume of public spaces will be increased.

6.3. Technical aspects

As stated above, the cruise liner is more or less an hotel accommodation fitted inside a ship. The major technical problem will come from a safety point of view in order to suit the requirements of the SOLAS Convention for passenger ships with a basic inside arrangement and decoration which is largely inspired by the shore buildings.

The main subjects to be considered being :

- fire protection,
- escape routes,

as the major risks in terms of safety for a passenger ship being fire and collision.

In order to meet the criteria of stability as defined per SOLAS both in intact or damage condition, the construction of the hull structure, principally in the high level decks, is to be realised as light as possible. Various solutions are used involving either aluminium upper parts or thin steel strakes. The first of the two solutions implies the use of transition prices made of dual steel plate and aluminium plate welded by explosion. The second one needs from the shipyard a skilled workmanship and procedures of assembly of the steel work in order to avoid deformations which are detrimental to the look of the ship or to cause possible troubles of maintenance associated with deck covering ageing. For both solutions, nowadays the whole superstructure contribution to the hull web modulus is taken into account. This needs a fine mesh finite element calculation to take care of the stress concentration caused by the repetitive openings or large bays wished by the decorators.

The second main concern in operating a cruise liner is to achieve a vibration and noise free ship.

For this purpose, deep analysis are to be carried out in order to prevent the ship hull to present resonance frequencies in phase with the excitators fitted on board :

- main engines
- rotating machines
- propeller.

Nevertheless, whichever is the care taken to avoid such resonances, it is difficult to meet low level standards if the above excitators are not discoupled from the hull in order to limit, for several modes, the energy transferred in vibration. For this reason, the major vibration sources which are diesel engines, use because of their lower consumption, are to be elastic mounted. This is now achieved by a special arrangement of the engines chocking using elastic pods.

Nowadays, actually low levels of vibration and noise may be achieved onboard these passenger ships.

New ideas for offering a more traditionally maritime leisure during the cruise raised. In particular, building and projects concerning sail cruise liners took place. Two categories of these vessels can be defined :

- wind propulsion with auxiliary engine, or,
- engine propulsion with auxiliary sails.

Onboard these ships, the sail manoeuvres have been fully automatised for achieving an optimisation of the assistance or use of the wind propulsion and an equivalent manning of the vessel.

CONCLUSION

As we saw, the technical answers for precise freight markets do exist. In addition, it is worth considering that according to the market trends, almost on a mean duration consideration, the economical balance is sound.

Another problem when starting with a project associated with such vessels, most of them like cruise liners or LNG carriers a very expensive investment, is to consider the life expectancy.

For different reasons, the ship's life is limited to a certain number of years, after which the vessel is coming to an obsolete status. Such a status for ship is based on several aspects that we may classify in the following ways :

- economical obsolescence,
- loss of reliability,
- increase of the level of occurrence of a major risk.

These three subjects of concern may be, on a general basis, defined as :

Economical obsolescence is one of several reasons which may be estimated in a planned manner and which are leading to consider that the operation of the ship will no more be profitable. It includes itself three main items :

Commercial obsolescence : the ship is no more suitable in terms of size, cubic, speed, list of cargoes, or loading/discharging time.

Technical obsolescence : the improvement of the technology changed some factors, like fuel consumption or mannning. As well as amendments to International rules, flag administration requirements or port authorities rules put her in a non compliance status.

Increase of the maintenance works : due to the running time of parts of the ship, the level of necessary works to perform a proper maintenance increases.

Loss of reliability is the fact that, due to ageing, the ship is subject to incidents causing delays and even leading to unscheduled stops which affect on an unplannified way her profitability.

Increase of the level of occurrence of major risk means that, in connection with factors affected by the running time and age of the vessel, the probability of major casualty is growing up.

This major risk may be one or a combination of the following :

- loss of crew members,
- loss of the ship,
- damage to the environment or to the surrounding places;

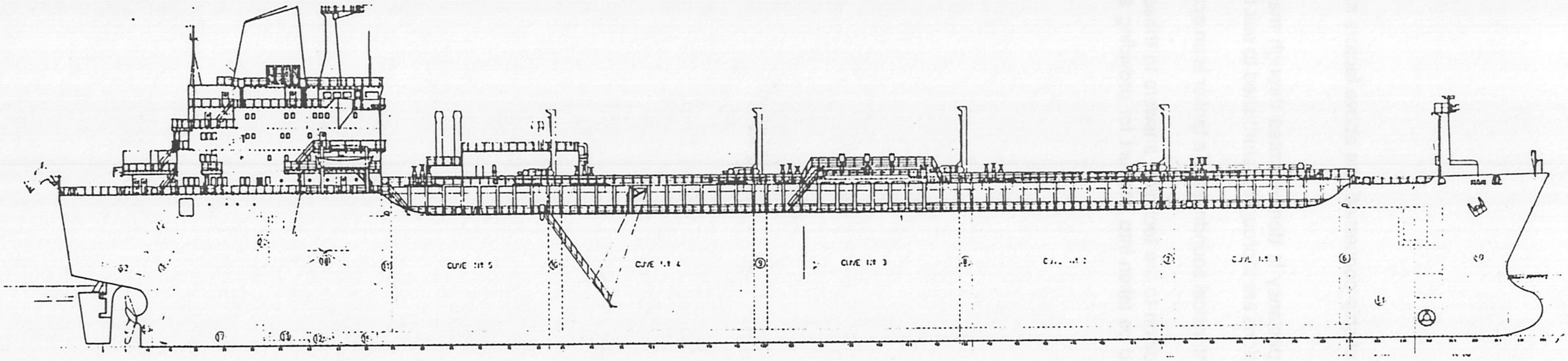
This last aspect of the three main families is sometimes the most difficult to combine with economical situation and an efficient control of it is necessary in order to avoid to go beyond the limits, as it is now happening in the air transportation.

Depending on the type of ship concerned, the above factors are significantly different and are leading to different positions.

The cruise liners life expectancy is demonstrated through many of these to reach 50 years, provided the ship's accommodations are thoroughly refurbished to suit the market.

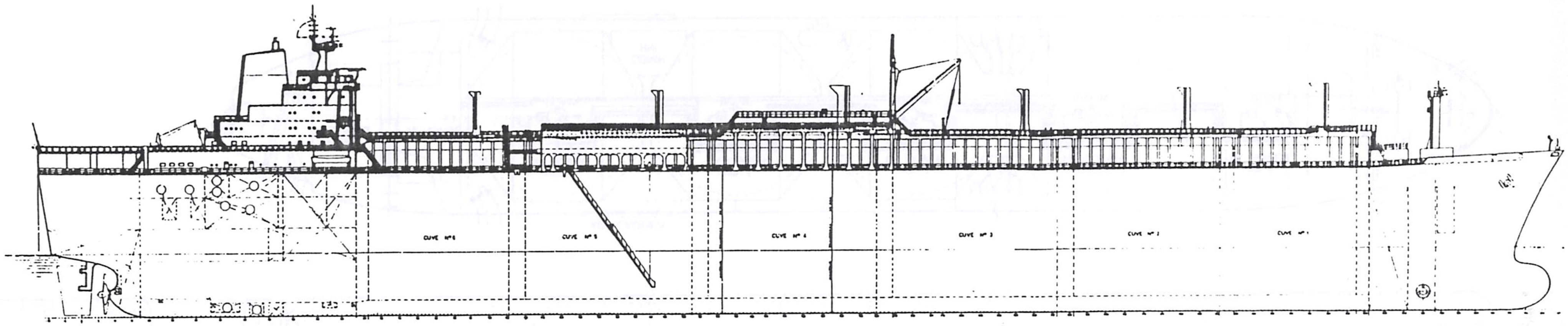
On the other hand, the intrinsical soundness of a tanker is an actual problem.

Then, we see that in addition to the technical answers to these freight markets at the building date, some considerations are to be taken into account for providing a suitable life expectancy to the vessel.



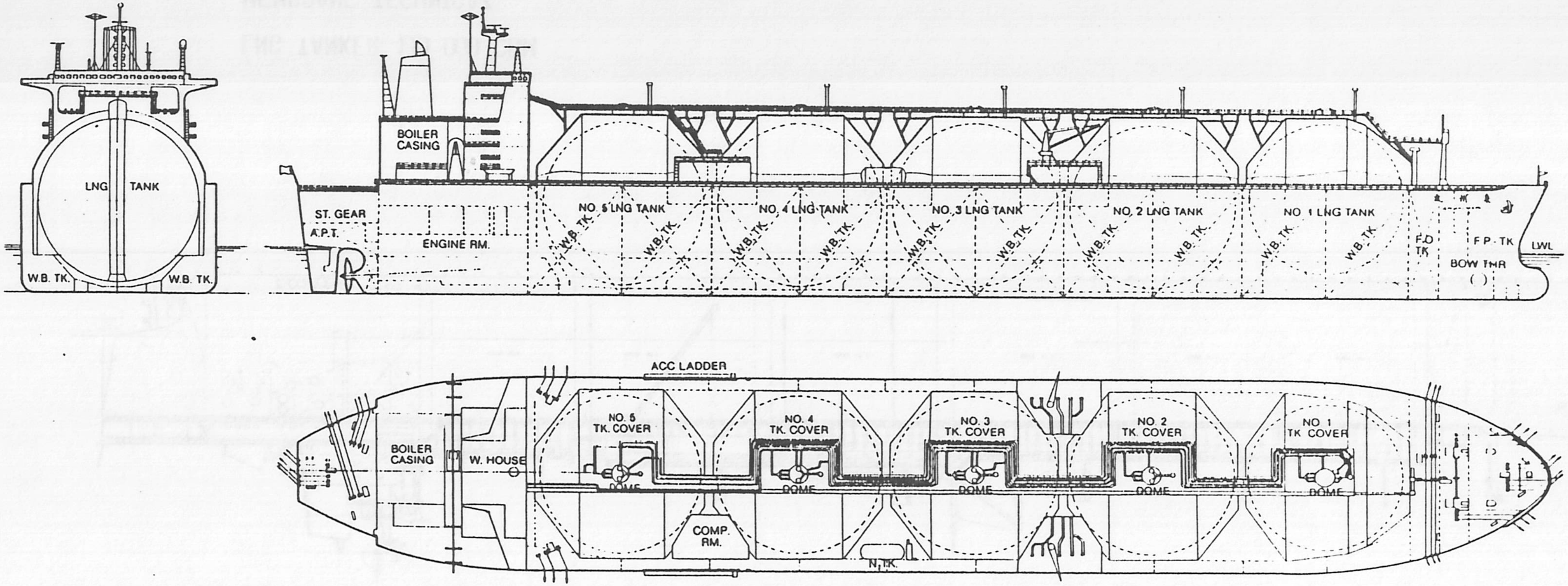
LNG TANKER 40 000 CBM

MEMBRANE GAZ TRANSPORT



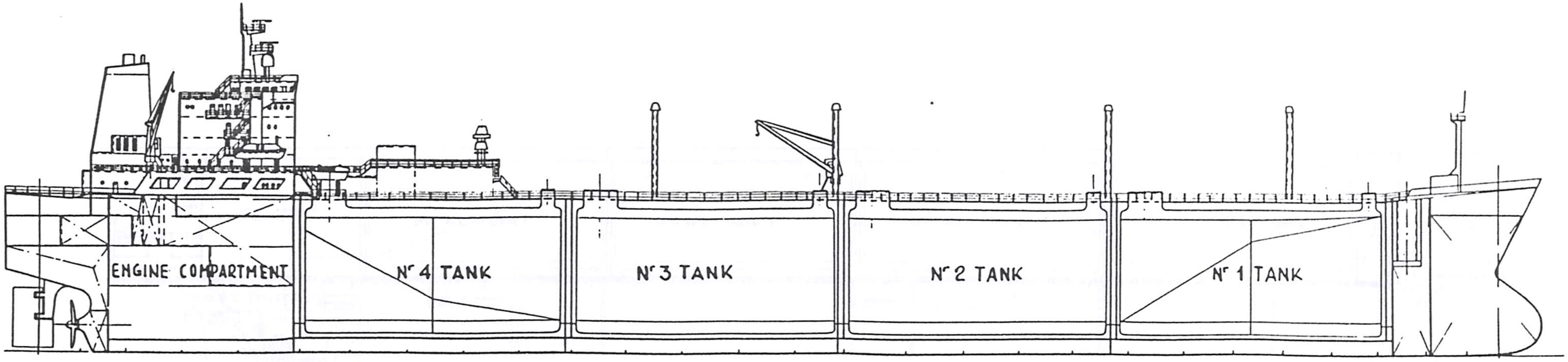
LNG TANKER 130 000 CBM

MEMBRANE TECHNIGAZ

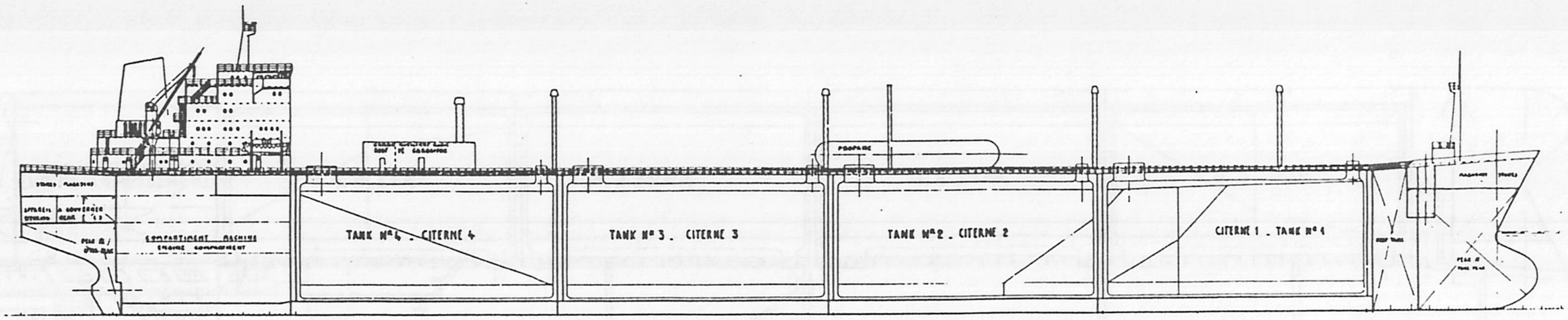


LNG TANKER 130 000 CBM

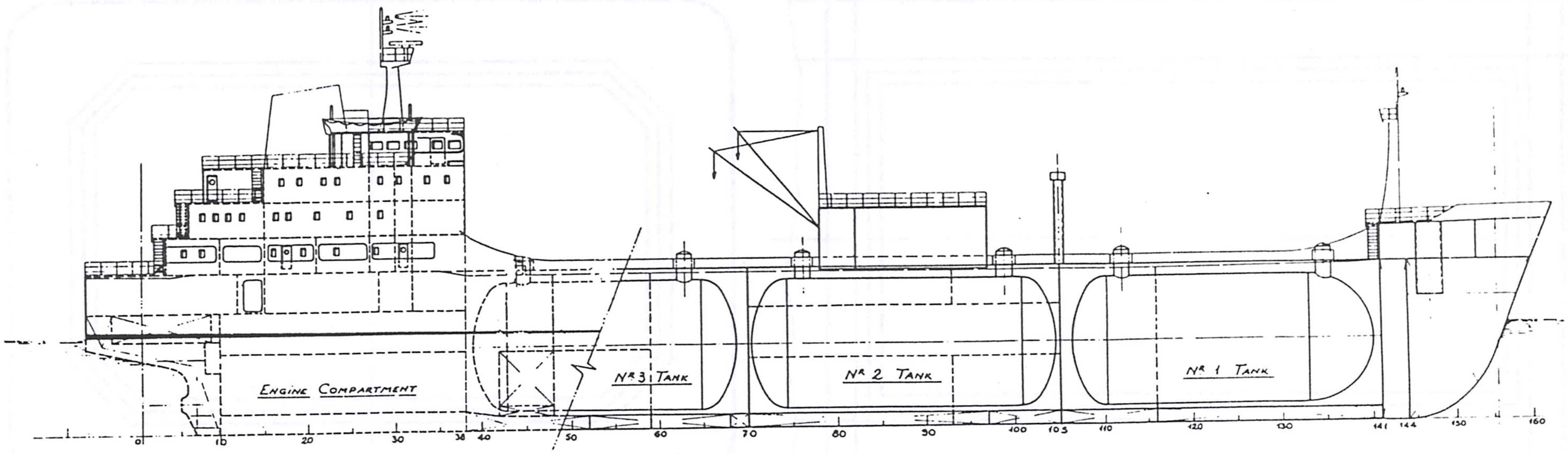
INDEPENDENT TYPE B KVAERNER MOSS



LPG TANKER 40 000 CBM

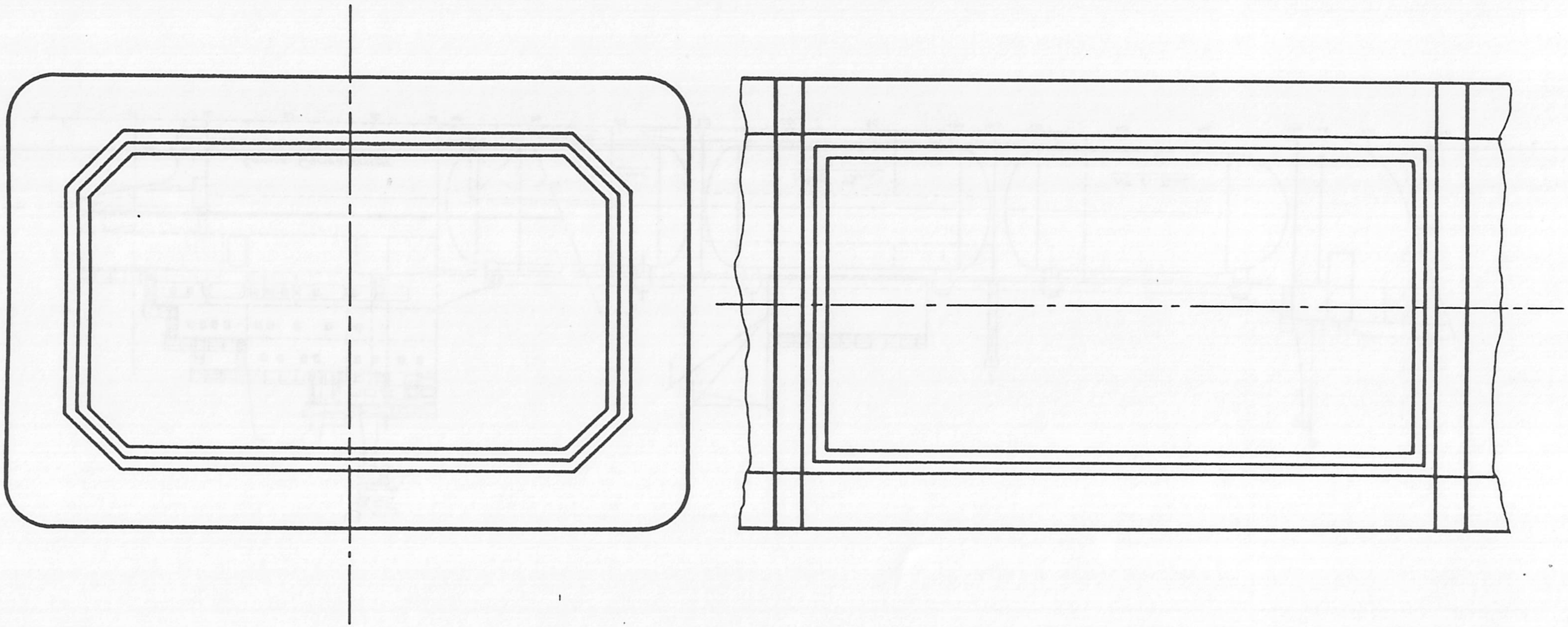


LPG TANKER 85 000 CBM

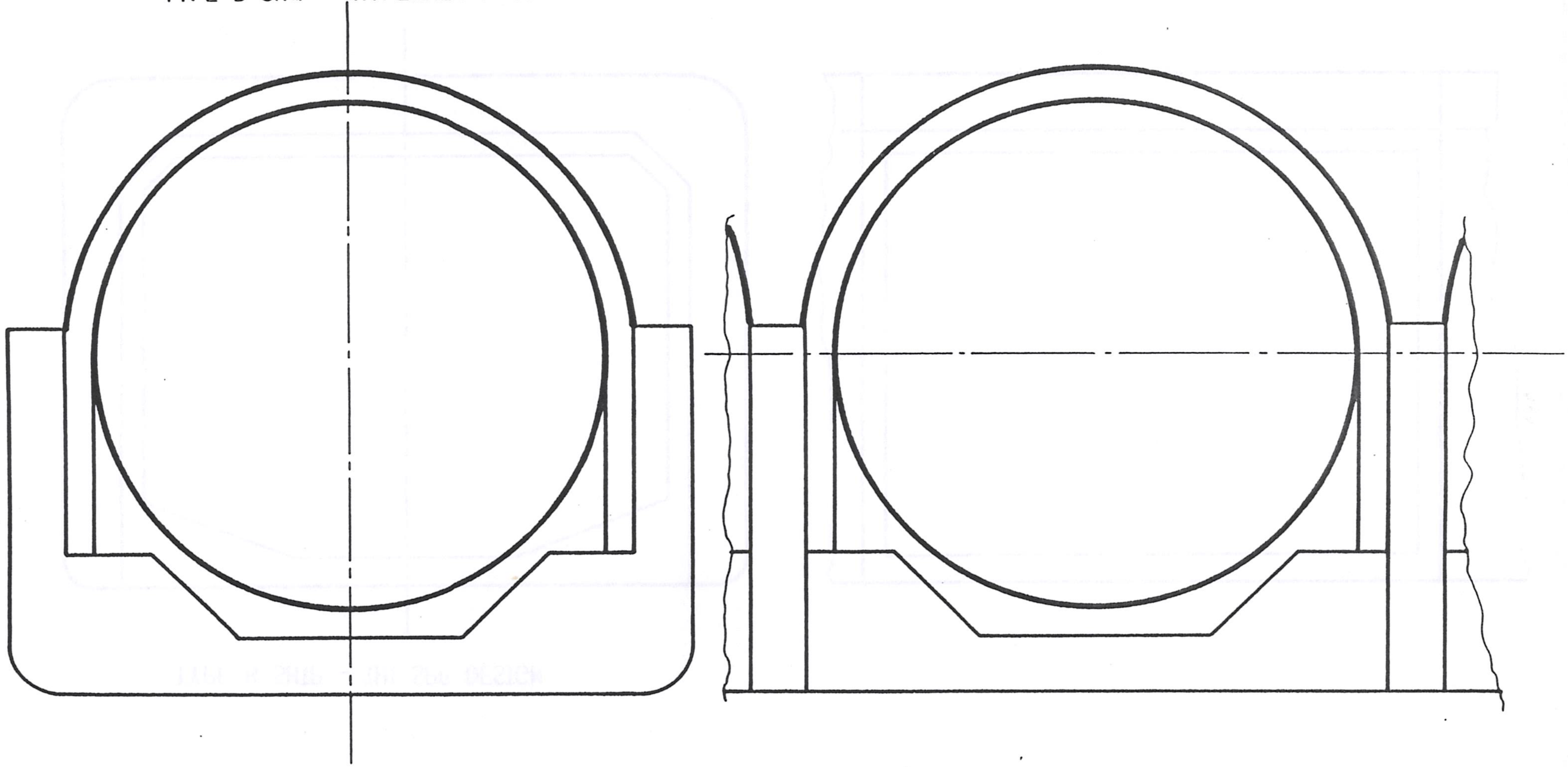


LPG TANKER 8000 CBM

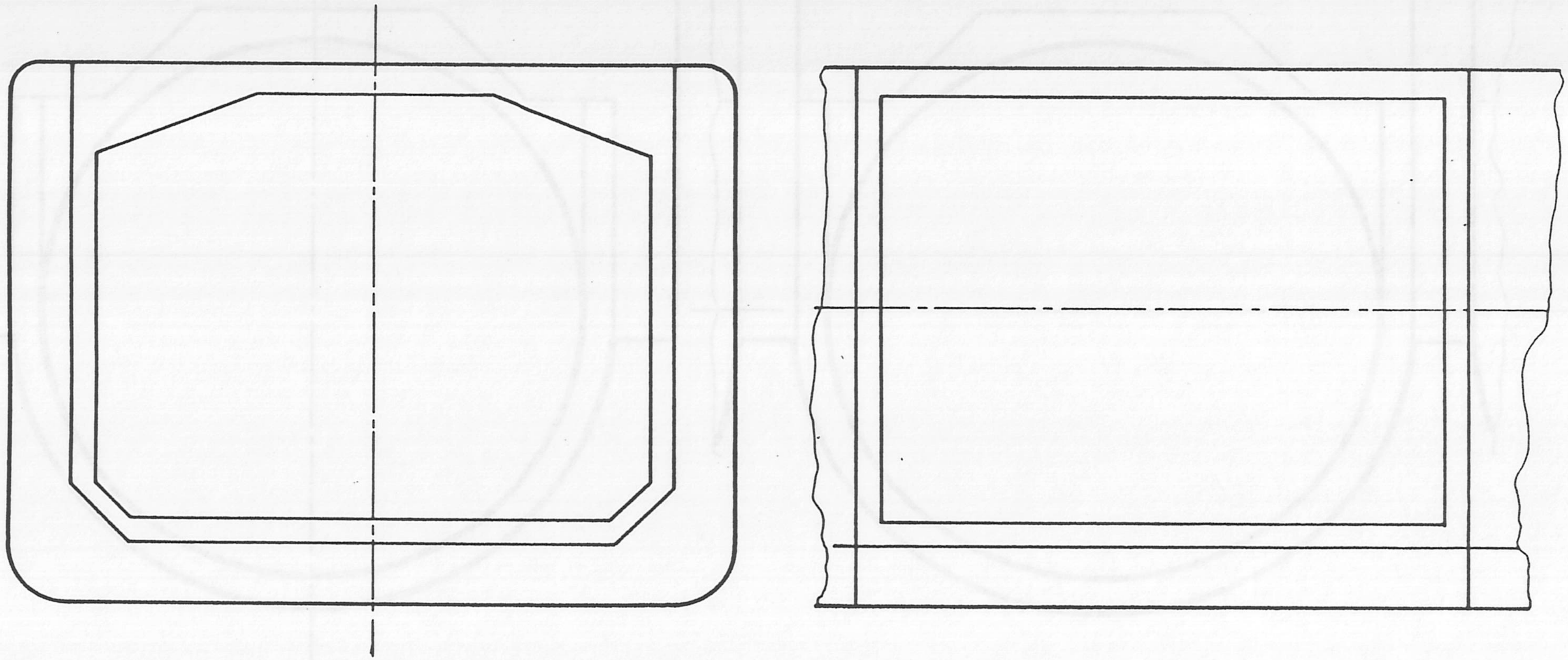
MEMBRANE SHIP



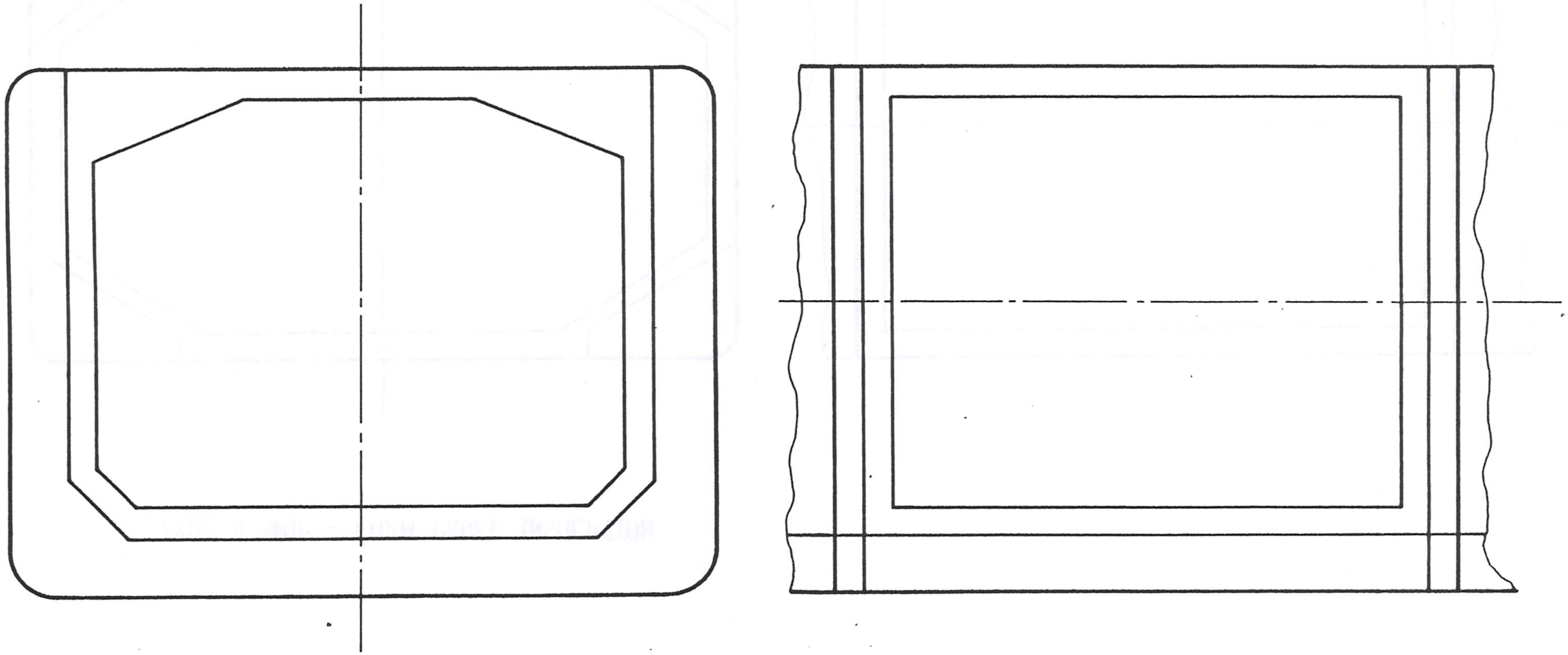
TYPE B SHIP – KVAERNER MOSS DESIGN



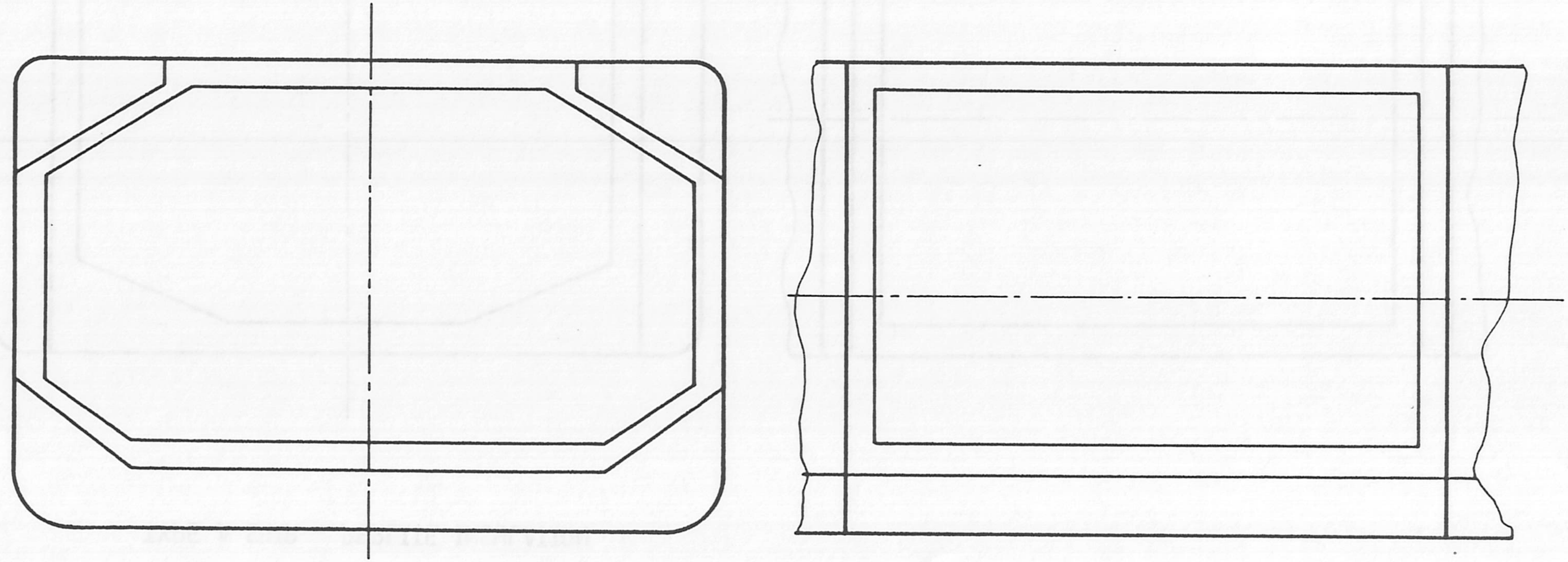
TYPE B SHIP – IHI SPB DESIGN



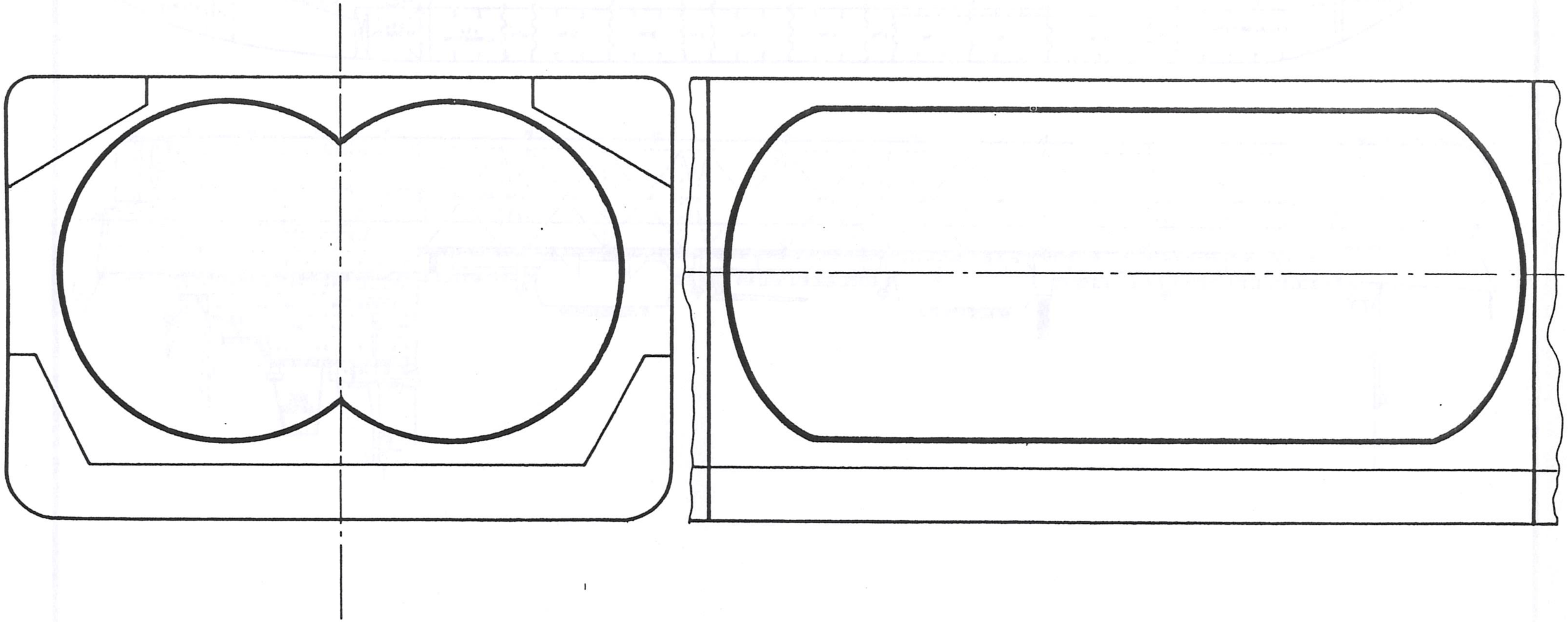
TYPE A SHIP - PERLITE INSULATION

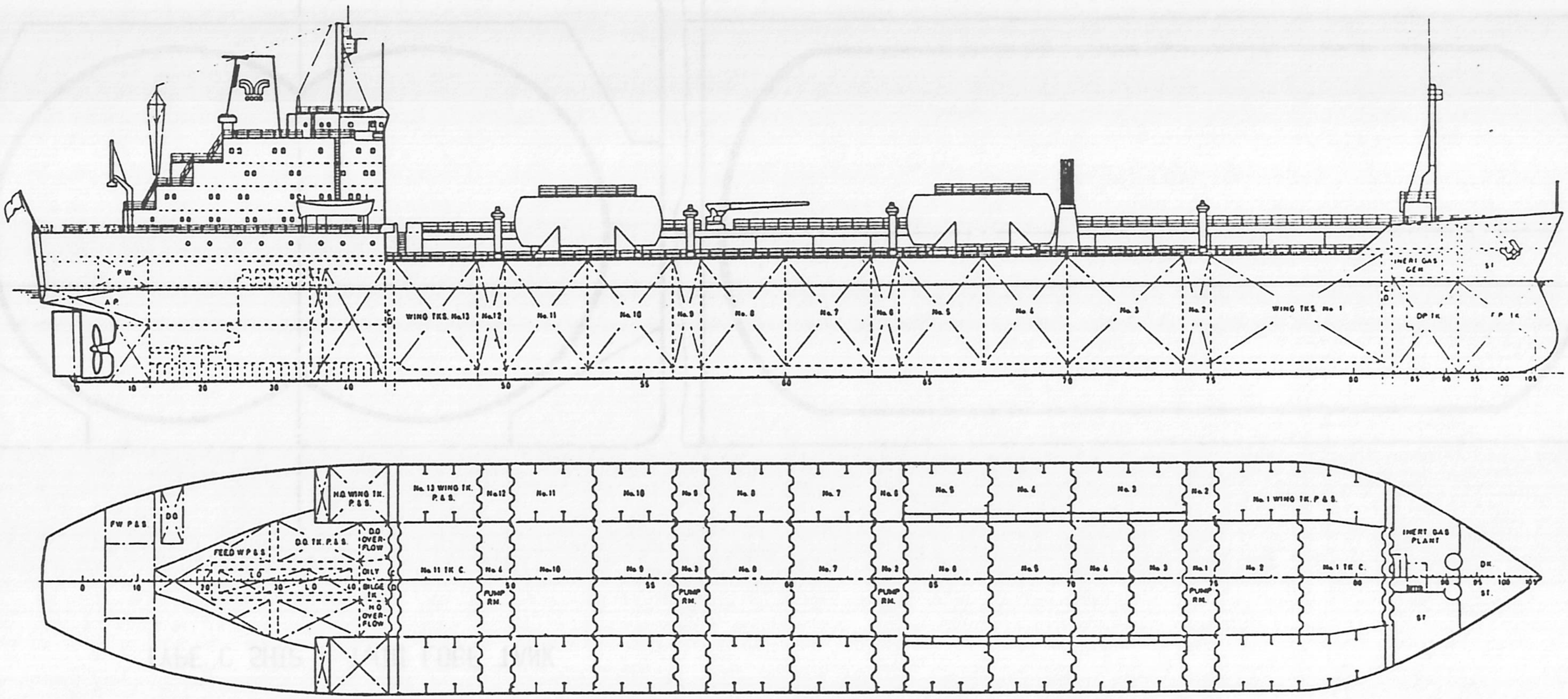


TYPE A SHIP - FOAM PANEL INSULATION

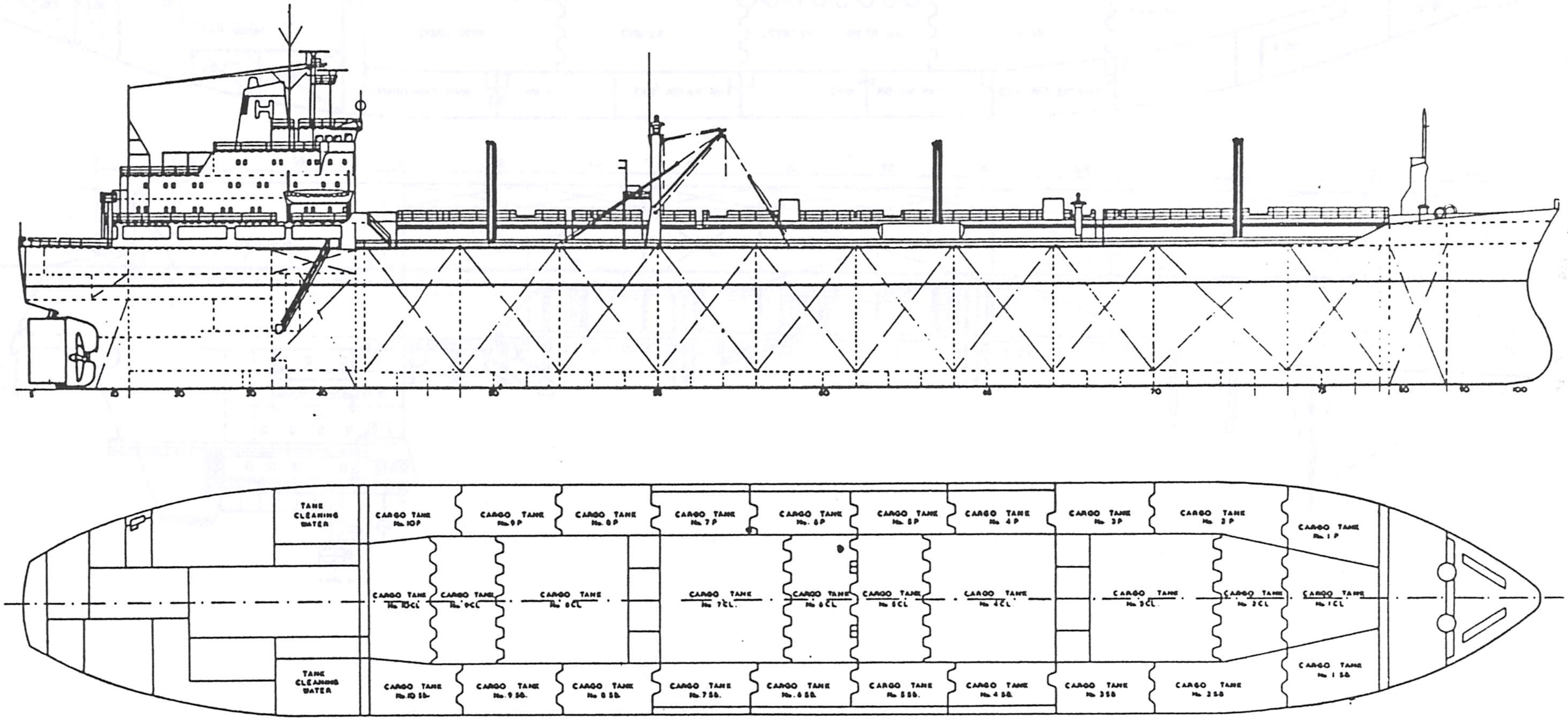


TYPE C SHIP - TWIN LOBE TANK

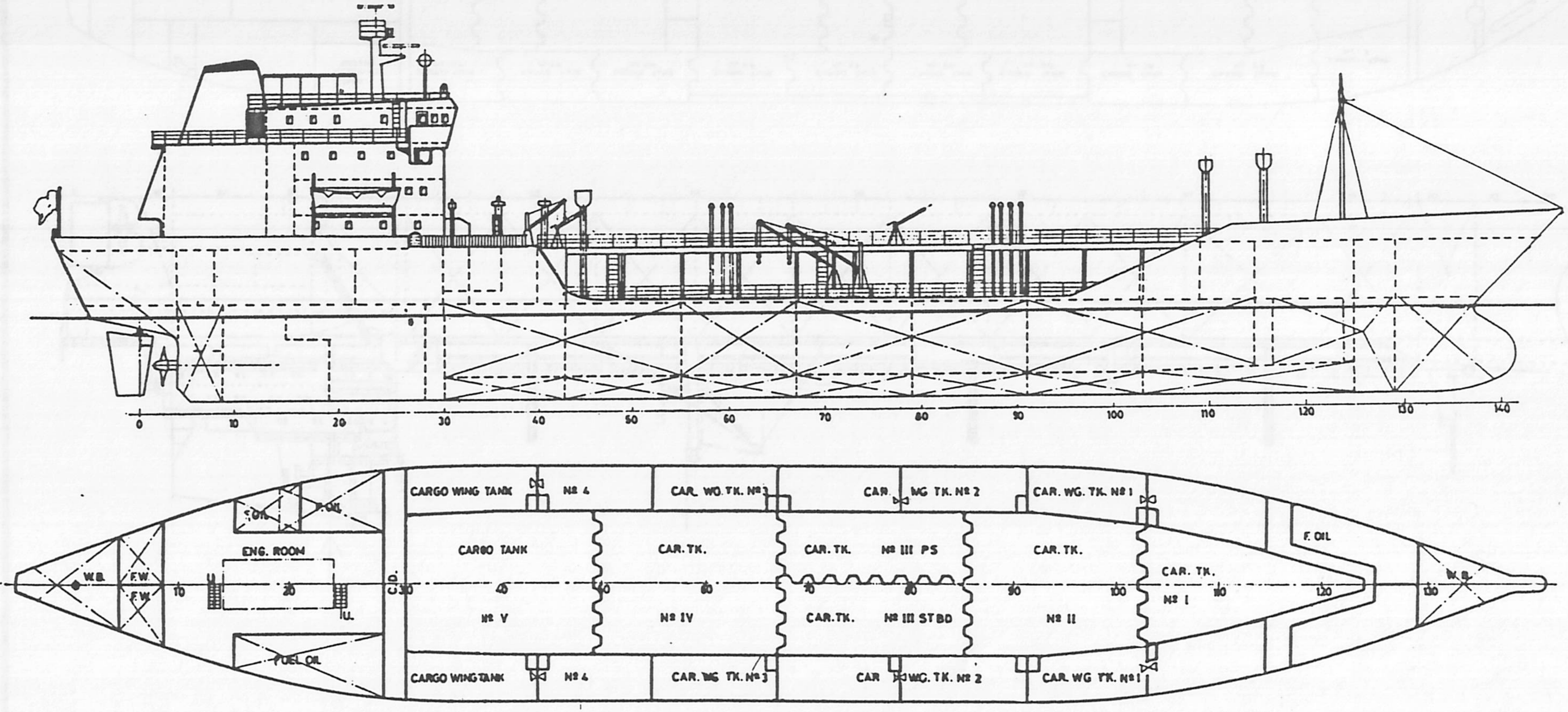




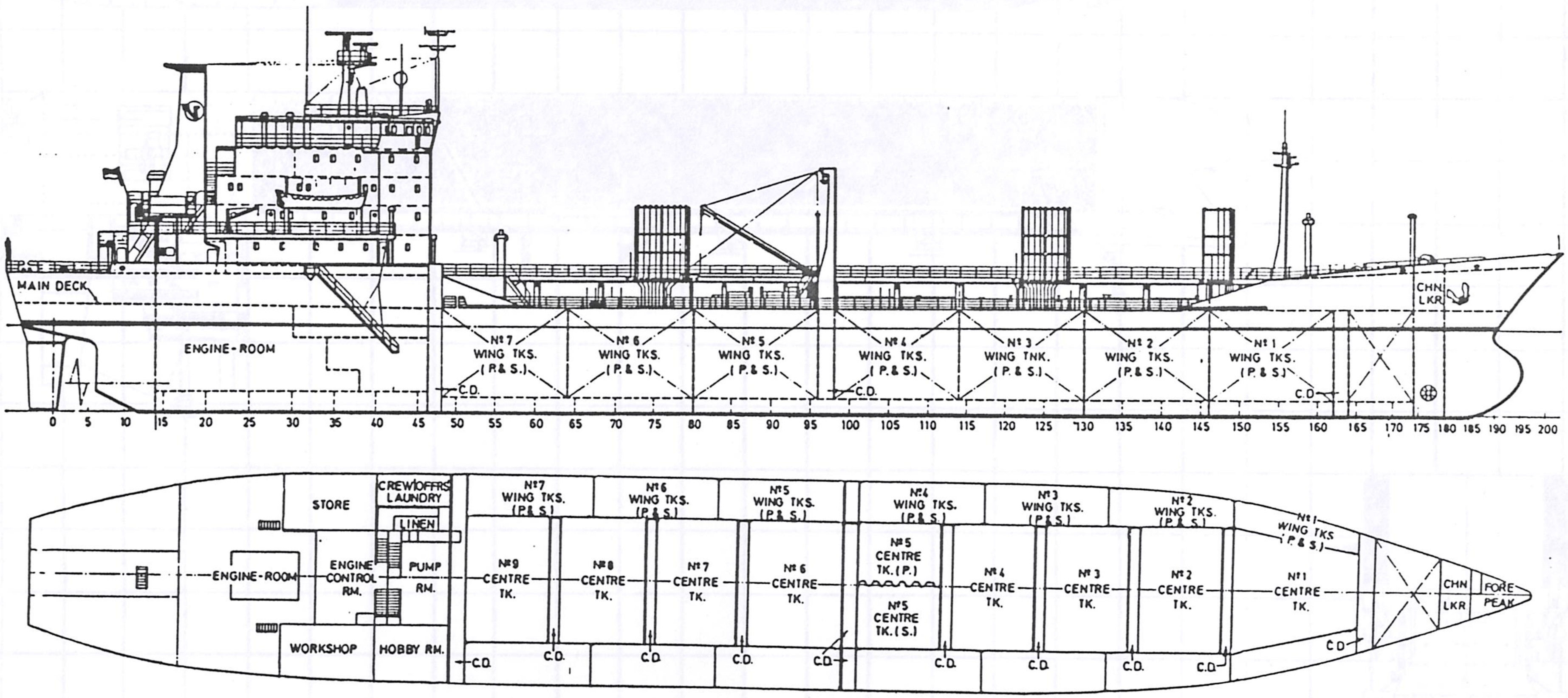
25,300 dwt Sophisticated Parcel Tanker



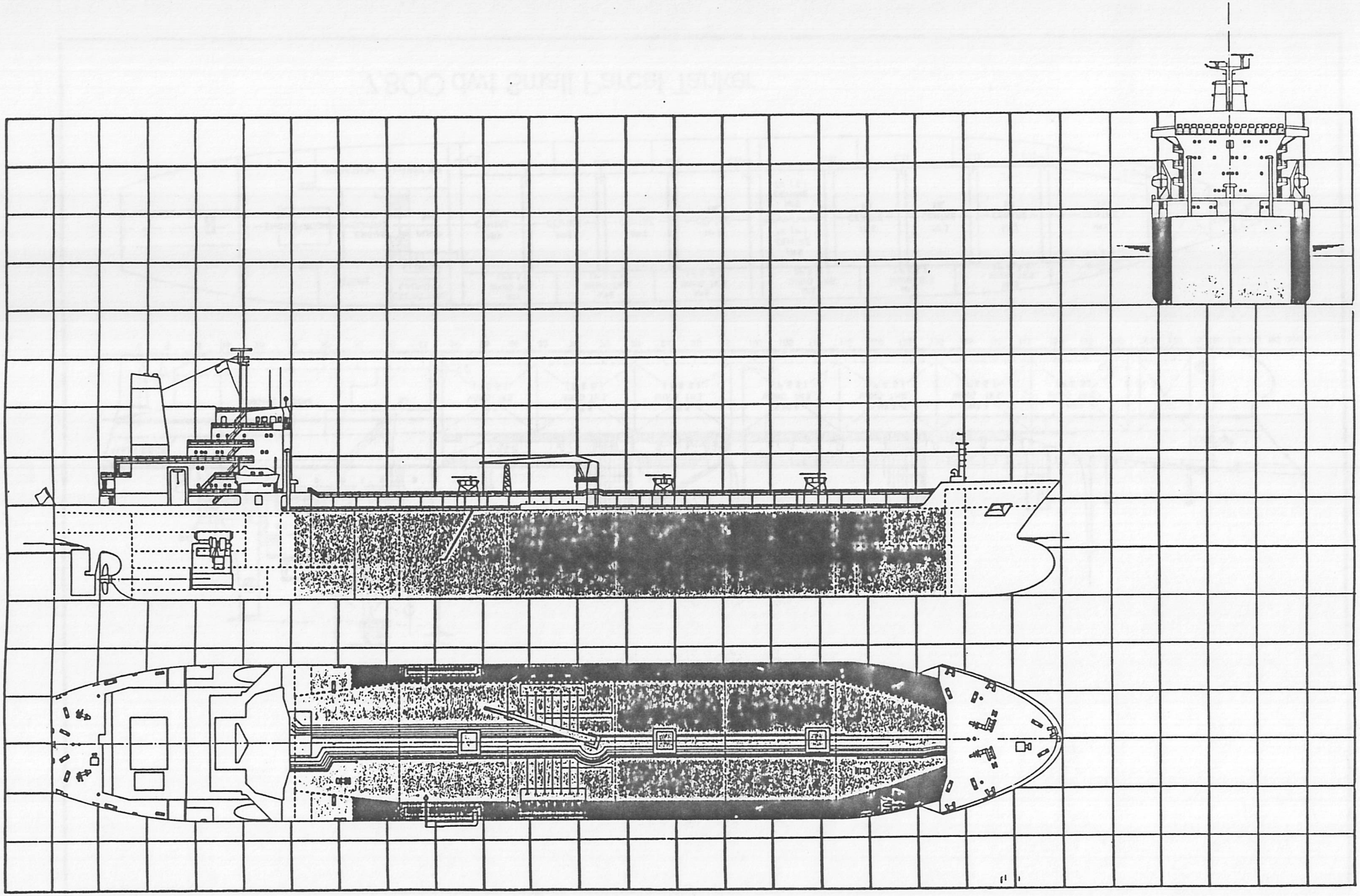
31,500 dwt Sophisticated Parcel Tanker



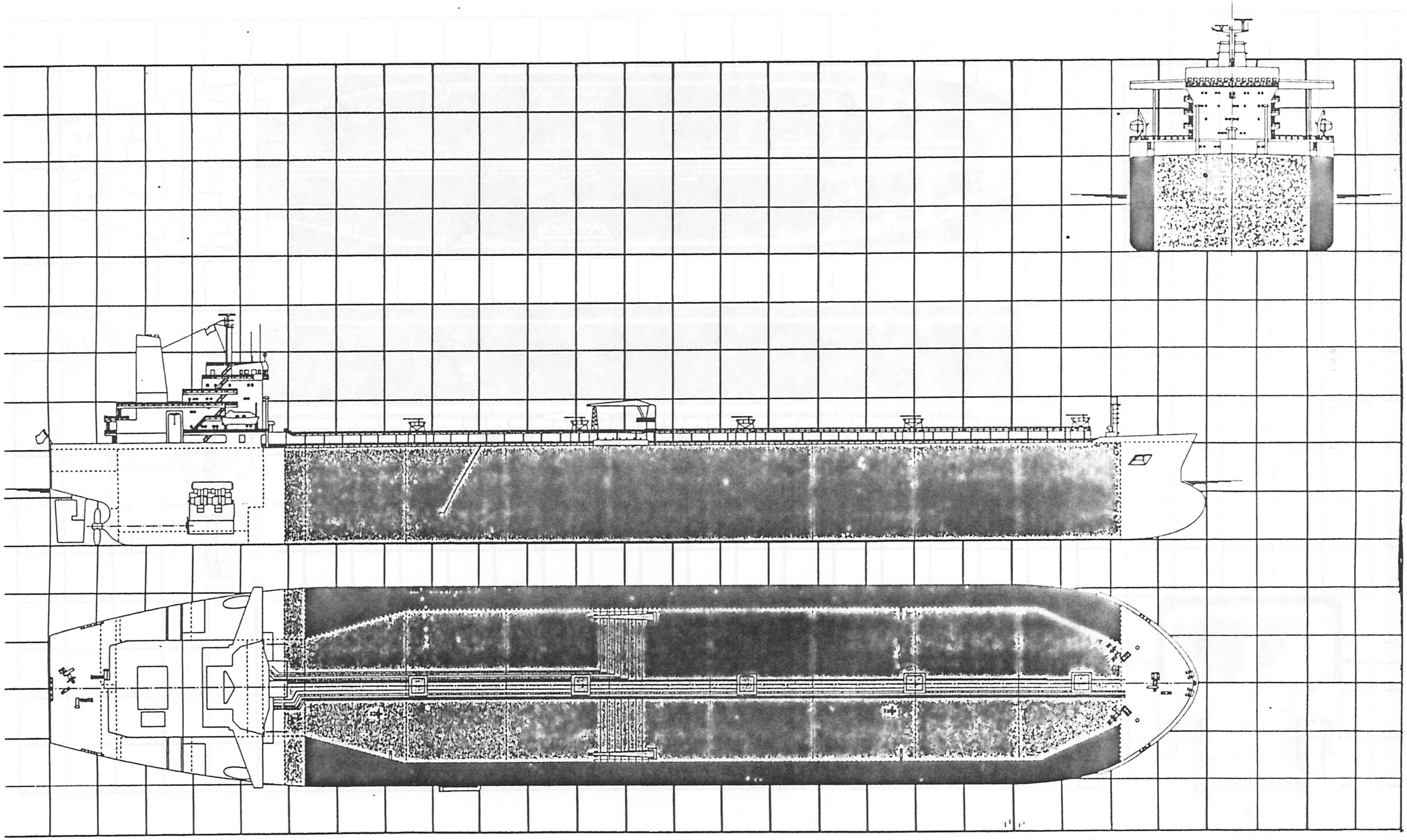
3,455 dwt Small Chemical Tanker



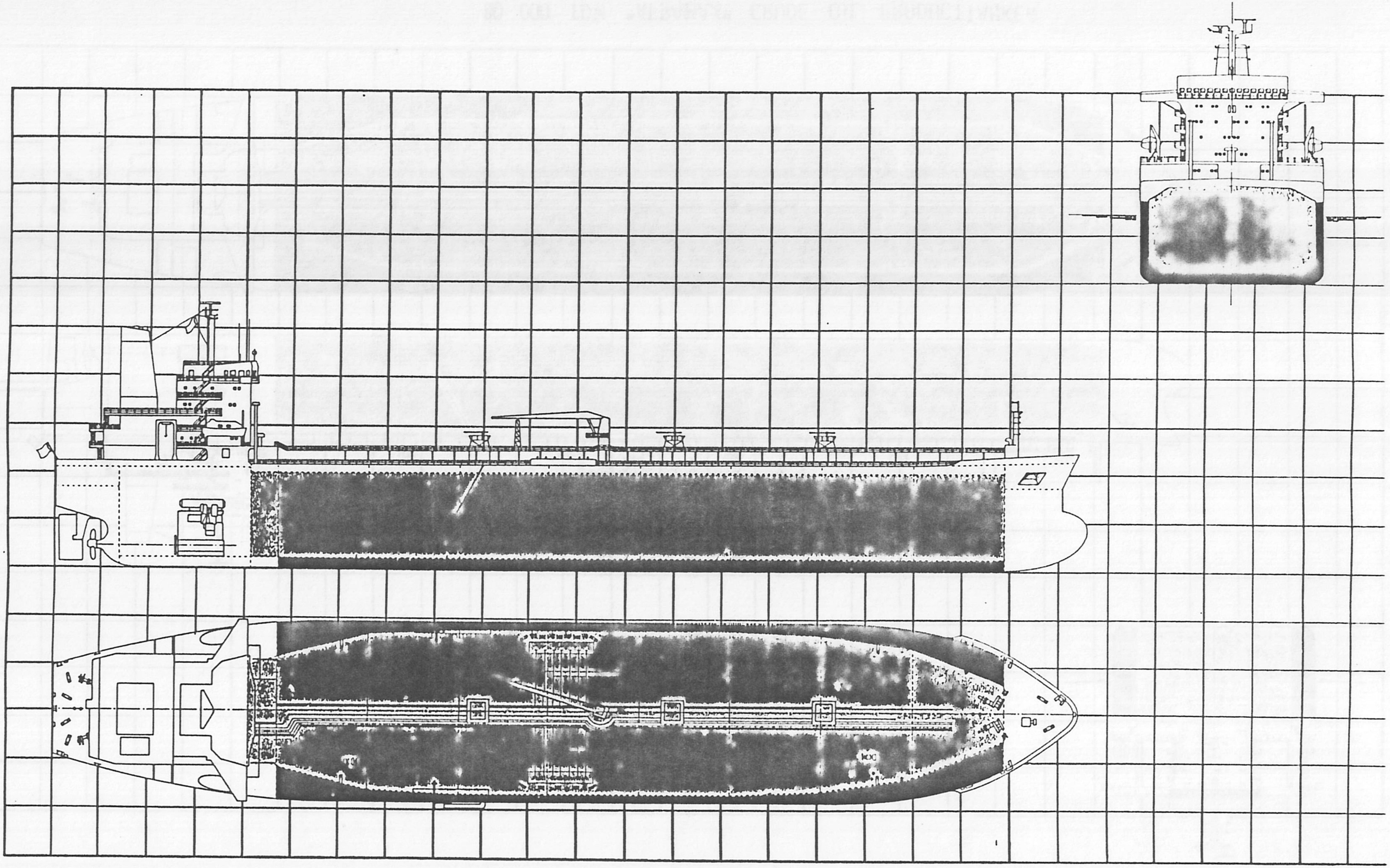
7,800 dwt Small Parcel Tanker



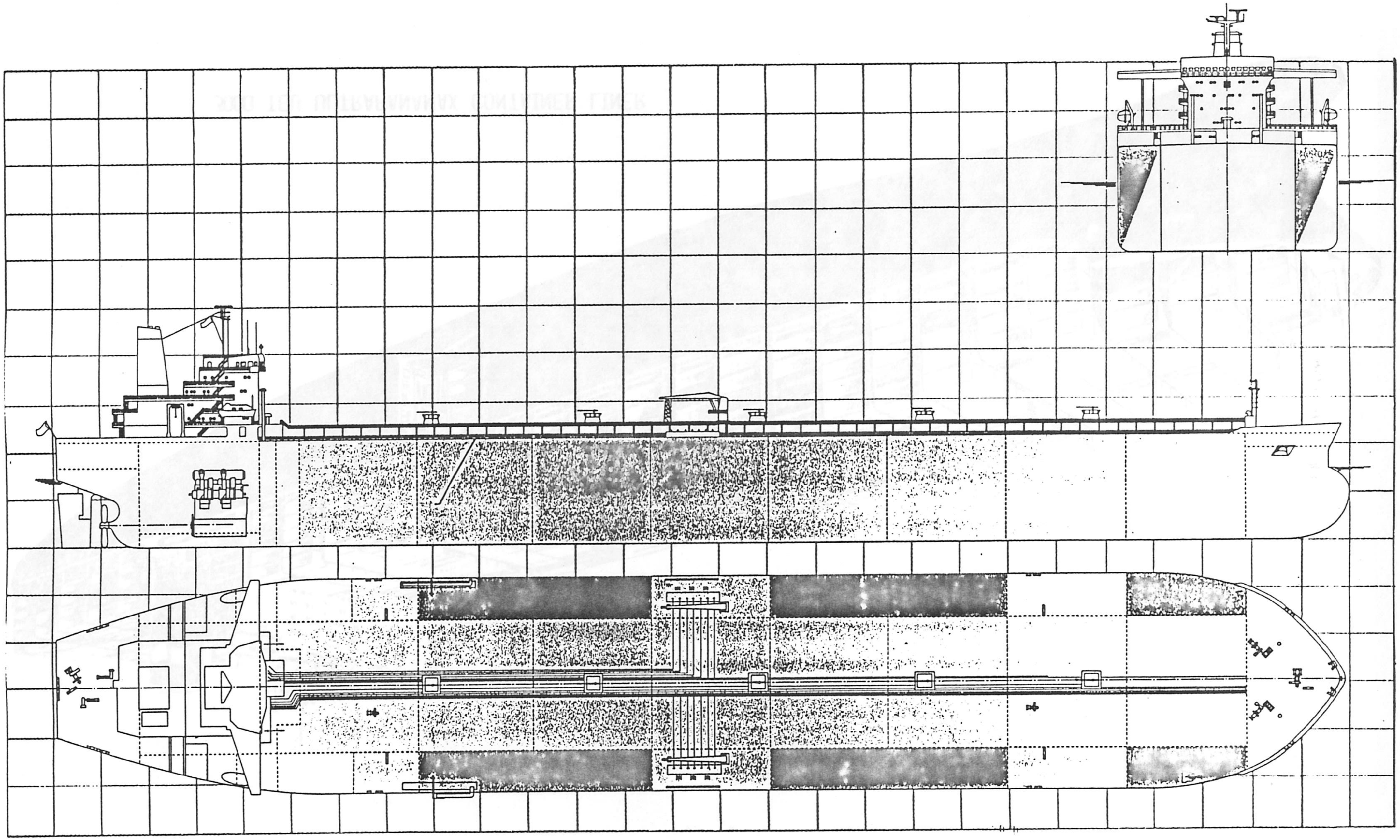
30 000 TDW PRODUCT TANKER



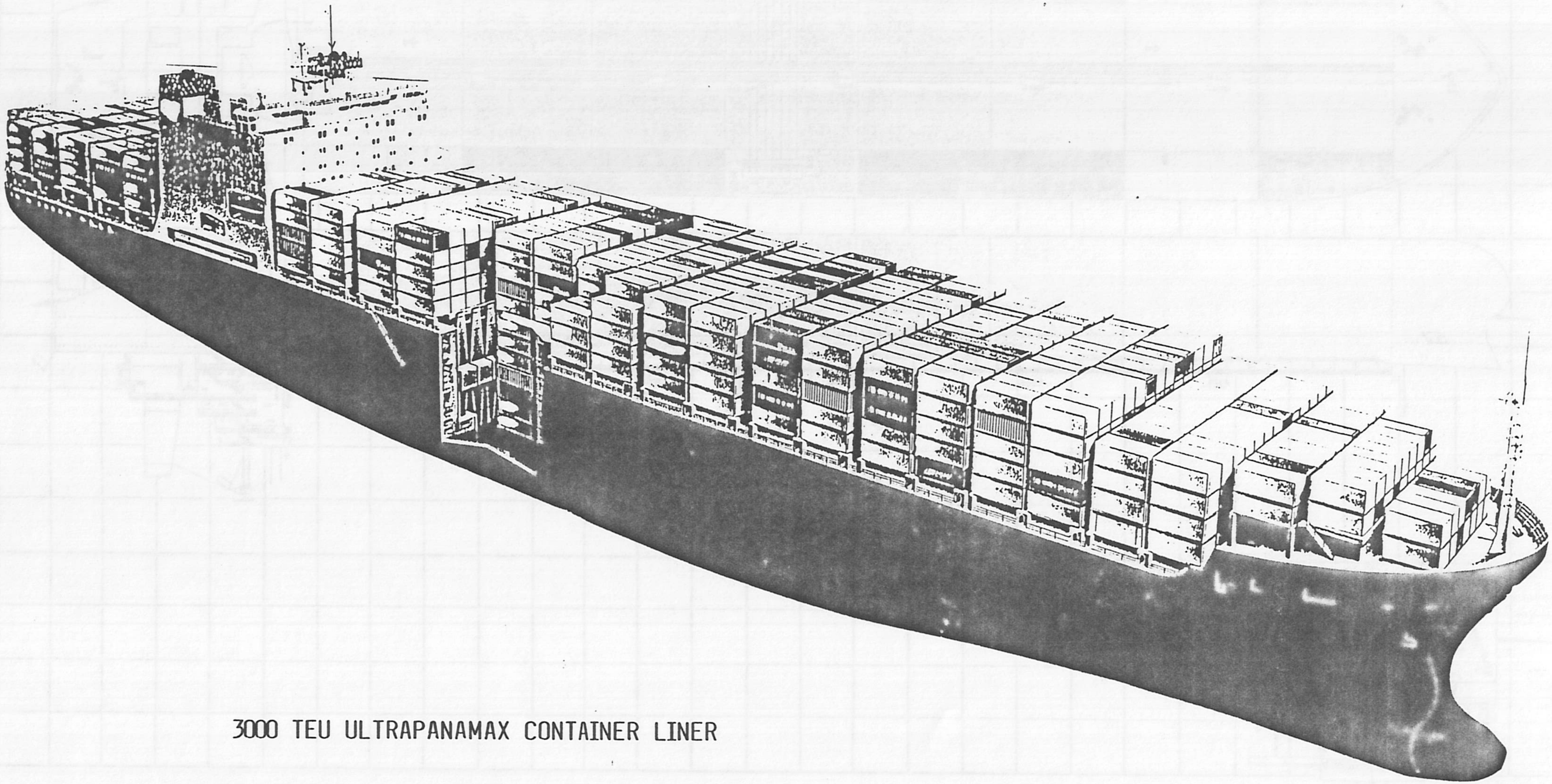
80 000 TDW "AFRAMAX" CRUDE OIL PRODUCTTANKER



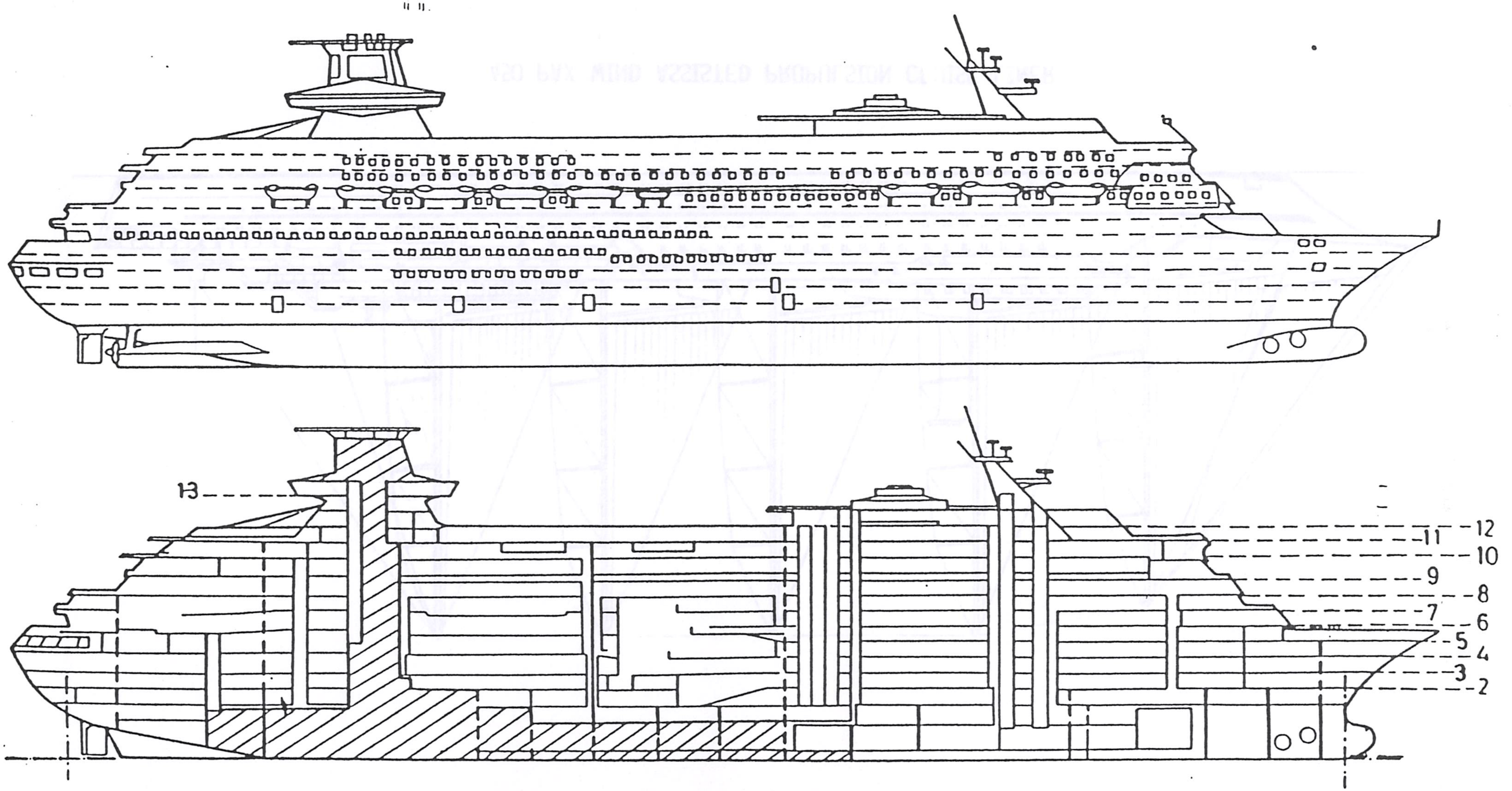
40 000 TDW PRODUCT TANKER



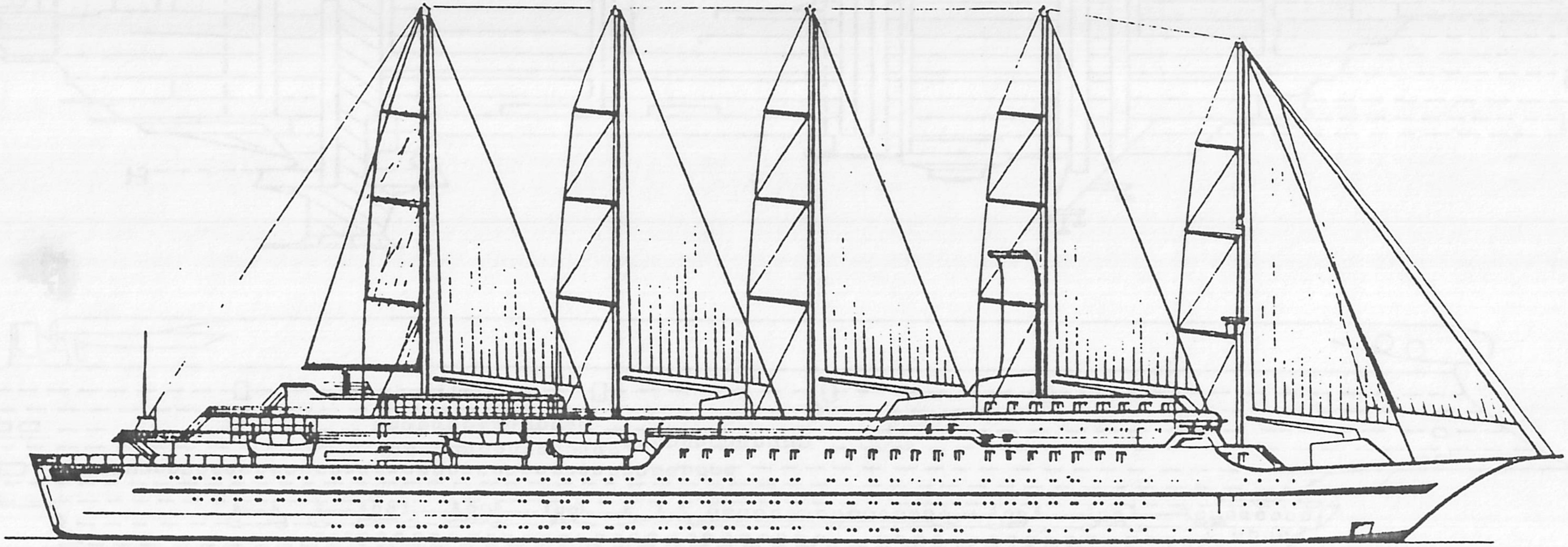
140 000 TDW "SUEZMAX" CRUDE OIL TANKER



3000 TEU ULTRAPANAMAX CONTAINER LINER



2300 PAX CRUISE LINER



450 PAX WIND ASSISTED PROPULSION CRUISE LINER