Construction and Classification of Chemical Tankers †

Typical procedures for the design, construction and survey including a field aspect in accordance with the IMO BCH Code and IBC Code

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The design and construction techniques involved in building chemical tankers are characterized to combine already established and conventional methods of an extremely wide range in a complexed but efficient way. Further, some kinds of international conventions and codes, which have been established and improved after the beginning of the 1970's and incorporated into the national regulations, have been applied to the chemical tankers. In this paper, special features and complexity of the chemical tankers are summarized as for the basic design of the cargo containment/handling system, construction, field survey, maintenance and periodical inspection after the delivery.

1. Introduction

Since the coming into force of **IMO** Resolution A. 212 (VII) "Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk" (hereinafter referred to as the "BCH Code") on April 12, 1972, with all amendments thereto up to the 10th, these requirements have been incorporated into the national regulations of a number of administrations as a single and sole set of the international regulations governing the construction and equipment of chemical tankers, and are being widely used by those shipping and shipbuilding concerns. It is now anticipated that the provisions of the BCH Code have already been introduced to Regulation 13 (3) of MARPOL 73/78 Annex II "Regulation for the Control of Pollution by Noxious Liquid Substances in Bulk" and will exert mandatory power as a part of the said Convention in the near future.

In the 2nd revision of the SOLAS 1974, which came into force on May 25, 1980, a decision was taken in the manner with which the provisions of the BCH Code will be introduced to the Convention so that they serve as the mandatory requirements under the SOLAS Convention as distinct from the previous mode of implementation, where they were referred to by respective administrations merely on a recommendation basis. In this work of revision, the BCH Code was converted into the "International Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk" (hereinafter referred to as the "IBC Code") and coordination of the requirements of these two Codes is now being worked out.

Chemical tankers built during the 1970's and since were designed and constructed, in most case, in accordance with the requirements of the BCH Code. However, we must pay due attention to the new set of requirements of the IBC Code whenever we are involved in decisions on future shipbuilding plans.[1]

A number of chemical tankers have so far been built to the requirements of the BCH Code in Japan. The total number of NK-classed chemical tankers at the end of September, 1984, including those under construction, is 166. Given in Table 1 are 144 of these chemical tankers classified according to ship size, ship type and cargo tank arrangement.

Chemical tankers built in Japan are predominantly in a deadweight range from 3,000 to 15,000 tons, of which Type II and Type III ships assume the majority. The Japanese-built chemical tankers are generally of the medium and small sized for medium range trade service, in preference to large, exclusive parcel chemical tankers employed in world-wide service.

As distinct from the case of design and construction of liquefied gas carriers, where the application of highly sophisticated shipbuilding techniques is indispensable, those required for chemical tankers feature the optimum and complex combination of more conventional shipbuilding techniques, enabling the shipowner to have a ship capable of loading and carrying diverse cargoes. In other words, the structural elements of the hull (cargo tanks) of ordinary multi-purpose chemical tankers, except for special carriers of specified chemicals, basically differ little from the case of general oil tankers, only the cargo tank arrangment and tank capacity distribution constituting the differences between them. Also, the components involved in the cargo piping arrangement for

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chemical tankers are basically similar to those for ordinary oil tankers. The distinguishing features lie in the greater number of piping systems, diversified piping connections, the complexity in system segregation and the special materials.

The purpose of this paper is to establish the mutual relationship between those design elements for chemical tankers, and at the same time, to indicate special aspects in the construction and equipment of chemical tankers by summarizing the design, construction and classification survey differences from general oil tankers.

2. Basic Design

2.1 Selection of tank type and tank arrangement

In ordinary cases of basic shipbuilding design, the type of cargo constitutes one of the given principal design conditions, together with the principal dimensions and cargo deadweight of a ship. This also holds true in the case of chemical tankers. Particularly, in chemical tankers, both the BCH Code and IBC Code prescribe the requirements for the construction and equipment according to the properties of cargo chemicals, and no assessment of damage stability affecting the determination of the principal particulars of a ship can be made without establishing the loading plan of the cargo chemicals intended to be carried.

Determination (or assumption) of the kinds and quantities of cargo represents the most important point of consideration for both the designers of the chemical tanker and the shipowner, and it is necessary that a basic agreement is reached between these parties at the initial planning stage of shipbuilding. In chemical tankers, additions and modifications to the cargoes in the course of design may, in many cases, require a complete revision of the basic plans.

By determining the kinds and quantities of cargo, outlines of the basic conditions for the construction and equipment created under the requirements of the BCH/IBC Codes and those of owners can be grasped.

Fig. 1 is a flow chart showing the basic design procedure for a chemical tanker. The check points shown on the flow chart not only represent those for design but also those for approval of the design by an administration or a classification society.

At the first stage of the initial design, the basic properties of each cargo chemical extracted from the cargo list submitted by the owner should be classified, followed by correlating the general and special requirements under the BCH/IBC Codes according to the properties of each classified group. In this case, classification should at least be developed in such a way that the existence and degree of the following physical and chemical properties are categorized. Through this procedure, the cargo tank construction and arrangement, which are the basic need, can be determined.

Specific gravity and vapour density
Vapour pressure and boilling point
Melting point
Reactivity (self-reactivity and reactivity with other substances including air and water)
Toxicity
Flammability
Corrosivity

From the information of specific gravity, vapour pressure and melting point, selection of independent-gravity/or-pressure tank or integral-gravity tank becomes possible. From the reactivity and toxicity information, the necessity for segregating tanks and connected piping lines to handle a cargo with these properties can be verified.

At the second stage of the initial design, a preliminary cargo loading plan is drawn up. The physical and chemical properties of the cargo, its compatibility with the structural members, the maintenance of cargo purity, various piping layouts and many other design elements interweave in an extremely complex manner, and hence, in-depth assessments are necessary.

The capacity of each cargo tank and the tank arrangement are determined by the service route of the ship and by the kinds and quantities of cargo to be carried simultaneously in a voyage. In the case where the integral-gravity type has been selected as the cargo tank construction, several alternative combinations of tank arrangment can be considered as given in Note 4) of Table 1. To determine the tank arrangement, proper balance between structural hull strength and adequate distribution of cargo tank capacity compatible with the intended cargo quantities to be carried must be established in conjunction with the shipowner.

At the same time, considering the cargo weight distribution and tank arrangement so far developed, computing the damage stability of the ship must be attempted according to the preliminary cargo loading plan under several worst-case conditions so that the critical value can be ascertained.

The points of consideration at the second stage of initial design are also as shown in Fig. 1. The following items should also be assessed in the mean time, giving due consideration to the references[2][3] made public so far and past experience.

(i) **Cargo loading taking into account the chemical properties of the cargo**:
   (a) Dangerous reaction with other cargo
   (b) Dangerous reaction with air and water
   (c) Separation of toxic products (separation from other cargo or from fuel oil)

(ii) **Cargo loading taking into account the cargo tank strength, tank type and structural materials**:

(a) Specific gravity of the cargo and tank structural strength
(b) Tank structural strength when half-full (consideration against sloshing)
(c) Compatibility between the cargo and tank structural materials/tank lining materials/or coating materials
(d) Necessity for controlling the temperature and/or pressure of the cargo
(e) Necessity for environmental control of the cargo containment system (inerting, drying, ventilation or padding)
(f) Physical properties of the cargo chemicals related to tank cleaning

(iii) **Separation of the cargo from sea water and outer shell plates** (Regulatory requirements by ship type and those against inorganic acids)

(iv) **Filling limits for cargo tanks and the maximum estimated cargo volume to be carried**

(v) **Damage stability considerations**

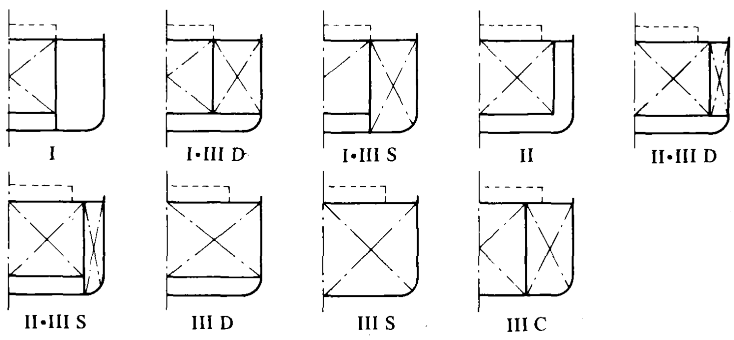
In making assessments on"(ii) Cargo loading taking into account the cargo tank strength, tank type and structural materials", it is suggested that such loading conditions should preferably be used for considering the initial cargo loading plan when the number and capacity of cargo tanks with special construction (e.g., cargo tanks with an increased structural strength, cargo tanks with thermal insulation, cargo tanks using special materials) are needed to be determined most economically.

In cases where the cargo loading plan is to be determined for a chemical tanker, items of general consideranton for ordinary merchant ships such as the

Table 1 Statistics of chemical tankers classed with NIPPON KAIJI KYOKAI (NK) and applied with the BCH Code (at the end of September, 1984, including those under construction)

Size of chemical tanker (Deadweight tons)		Total number	Ship type1)		Number of cargo products			Type of tank construction4)				
			II & III	III	Max.	Mean3)	Min.	I·III D-E	I-III D	III D-E	IIID	Others
Parcel chemical tanker	DWT<3,000	5	2	3	91	40 (11.8)	1	2	1	0	1	1
	3,000≦DWT<7,000	63	26	37	144	61 (15.9)	3	6	24	13	13	7
	7,000≦DWT<10,000	28	17	11	118	53.3 (18.5)	4	11	10	5	0	2
	10,000≦DWT<15,000	19	11	8	201	52.3 (16.1)	17	3	11	4	0	1
	15,000≦DWT<20,000	15	14	1	118	66.9 (17.6)	2	0	12	0	1	2
	20,000≦DWT<30,000	9	5	4	118	42.1 (15)	2	0	6	0	0	3
	30,000≦DWT	2	0	2	7	4.5 (1.5)	2	0	0	0	0	2
Exclusive purpose chemical tanker2)		4	0	4	–	–	–	1	1	0	0	2
Total		145	75	70	–	–	–	23	65	22	15	20

Notes:
1) Ship's type according to the BCH Code
2) Three liquid sulphur carriers, one aqueous ammonia carrier
3) ( ) shows number of dangerous chemicals designated by Chapter VI of the BCH Code.
4) Types of cargo tank construction (integral–gravity) are as follows:



"E" denotes a type of the ship with an expansion trunk, e.g. I-E, I·III D-E etc.
– – – represents the cargo tank.

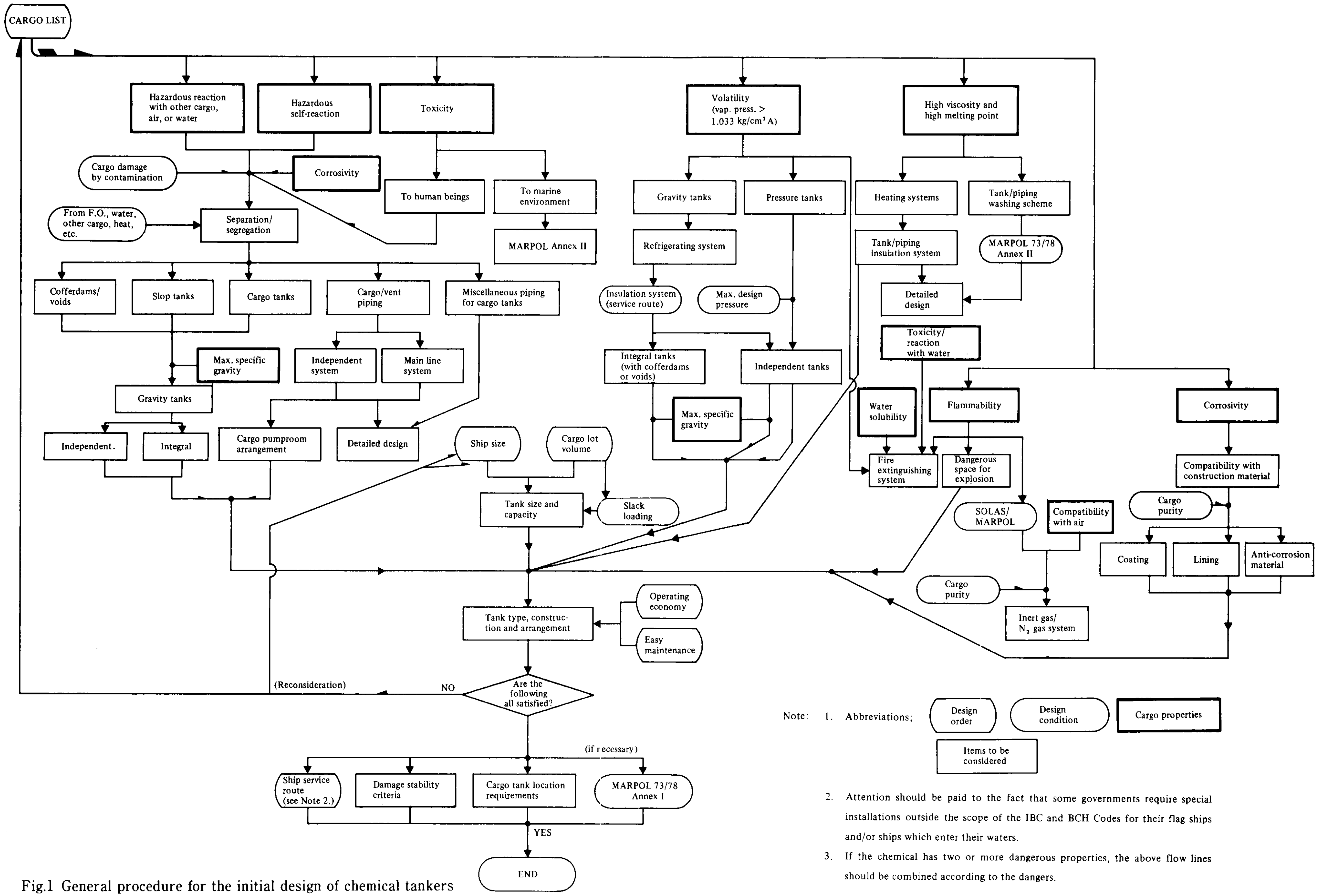


Fig.1 General procedure for the initial design of chemical tankers

Note: 1. Abbreviations; Design order / Design condition / Cargo properties / Items to be considered

2. Attention should be paid to the fact that some governments require special installations outside the scope of the IBC and BCH Codes for their flag ships and/or ships which enter their waters.

3. If the chemical has two or more dangerous properties, the above flow lines should be combined according to the dangers.

intact stability, trim and longitudinal bending moment should, of course, also be assessed.

When the number of cargo chemicals is large, it is convenient if they are categorized into appropriate groups and a loading plan is assessed for each classified group of cargo chemicals. If the classification of cargo chemicals is developed in such a manner that they are grouped into those with similar specific gravity, reactivity and degree of danger, the requirements of the BCH/IBC Codes may be better served with ease of investigation and evaluation. However, any attempt at making a too meticulous classification can result in the loss of significance of grouping effect, and hence, classification into the following cargo groups is recommended:

[I] Group by specific gravity:
Classification of cargo chemicals into groups in specific gravity increments of 0.10 to 0.20

[II] Group by reactivity:
Classification of cargo chemicals into groups of those with similar reactivity against cargo chemicals of other groups or air/water

[III] Group by toxicity:
Classification of cargo chemicals in accordance with the toxicity rating according to the provisions of the BCH/IBC Codes

[IV] Group of special chemicals:
Cargo chemicals in this group represent those requiring special conditions which are different from chemicals of other groups and which should be loaded only into specified tanks. These should be dealt with independently without being grouped (e.g., propylene oxide, carbon disulphide, liquid sulphur and phosphorus)

This grouping can readily be made if the list of cargo chemicals is referred to, which tabulates the basic properties of each cargo chemical as dictated by the applicable provisions of the BCH/IBC Codes at the first stage of the initial planning.

One of the distinct features of chemical tankers is that the cargo chemicals planned originally are often changed or newly added after putting the ship into commercial trade. In cases when the need for such later changes arises, it is necessary to evaluate in a short period of time if the proposed additinal loading of cargo chemicals complies with the requirements of the BCH/IBC Codes, including the special consideration of damage stability. Accordingly, a workable evaluation method for each ship must be settled and provided to the shipowner before delivery so that any future changes in cargo loading plan can be flexibly accommodated. This evaluation work may, depending on circumstances, require same procedures as highly complicated in those at the construction stage, and it is proposed that a handy computer programme readily used on board the ship will be employed.[4]

2.2 Design of cargo tanks

In developing the design of cargo tanks (including the supporting structures in the case of independent-type tanks) that was determined at the initial planning stage, quantitative evaluation of some or all of the loads listed below must be made as necessary:

(i) Static loads

- (a) Tank net weight including insulation
- (b) Tank internal pressure (design vapour pressure+liquid head)
- (c) Hull deflection in still water (longitudinal strength and transverse strength of the hull structure) and static external pressure
- (d) Tank internal pressure during the hydrostatic pressure test
- (e) Negative pressure (difference between external and internal pressures of the tank) for independent tank with the surrounding hold spaces inerted and/or pressurized and other case where lining tanks have spaces between the lining and tank walls.
- (f) Effect of the most unfavorable static heel angle within the range 0° to 30°
- (g) Buoyancy and water pressure when the hold spaces are flooded (for independent tanks only)
- (h) Reaction force in way of independent tank supports

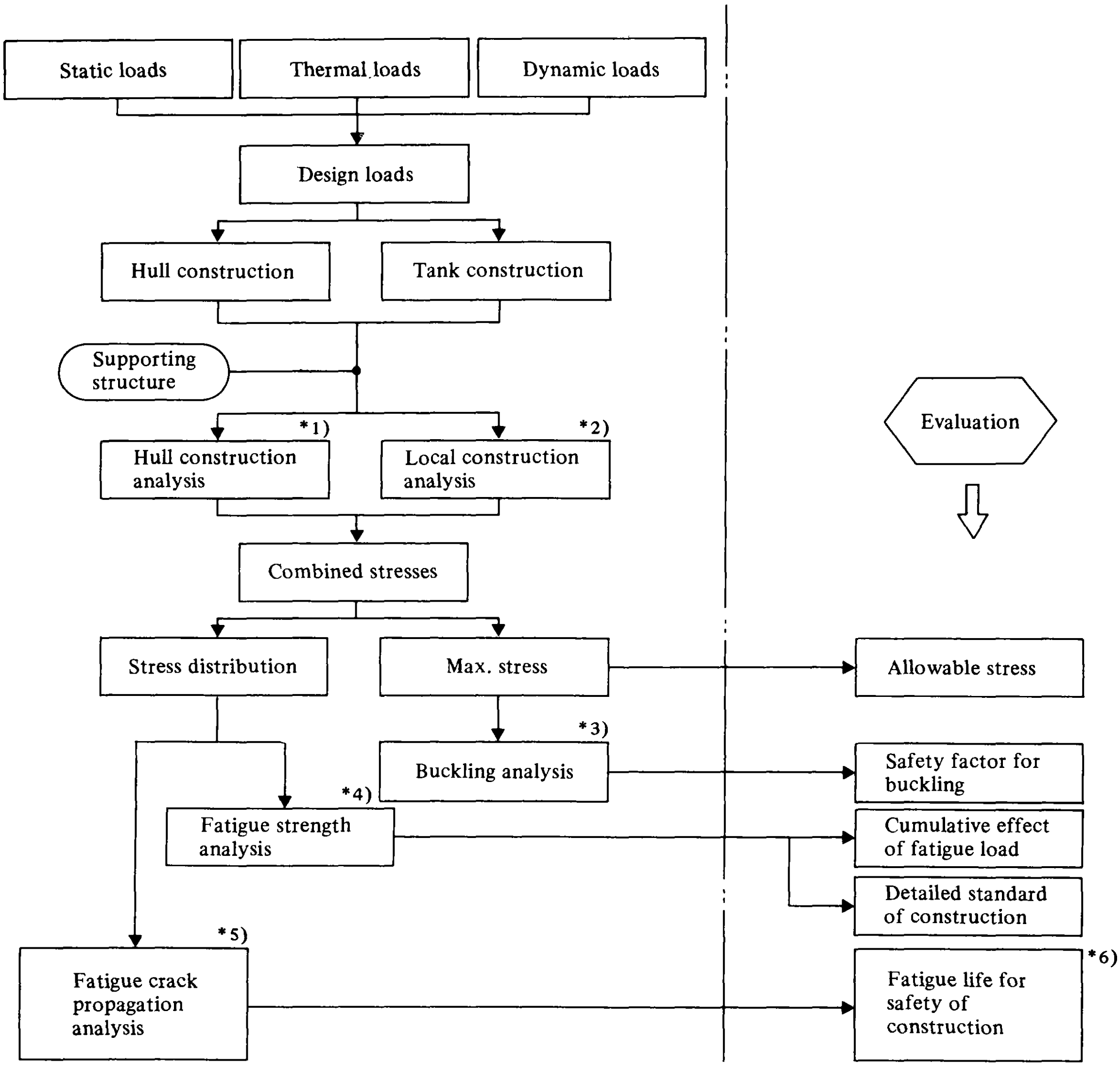
(ii) Thermal loads

- (a) Stationary thermal loads (full loaded voyage or ballasted voyage), when cargo temperature controls are adopted and the difference between cargo temperature and the surrounding temperature is 70℃ or more
- (b) Transient thermal loads (any rapid increase/decrease of the temperature should be avoided)

(iii) Dynamic loads

- (a) Acceleration due to ship motion
- (b) Hull deflection in sea-going conditions (longitudinal bending, horizontal bending and torsion)
- (c) Varying external pressure acting on the hull
- (d) Sloshing loads
- (e) Hull vibration
- (f) Longitudinal acceleration at the moment of collision (for independent tanks only)

When an attempt is made to design a cargo tank of a completely new construction (including tank materials) by taking into account the loads given in (i)(a) to (iii)(f) above, the design procedure called “Design by Analysis” must be employed. Shown in Fig. 2 is the design concept of “Design by Analysis”. This kind of design procedure



Notes: *1) Stress should be measured on the ship in order to confirm the accuracy of stress analysis.

*2) Model test may be required in order to confirm the stress concentration factors.

*3) Fabrication accuracy should be taken into consideration. Buckling analysis for the whole and local areas should be carried out.

*4) Fatigue test should be carried out considering the expected service conditions to obtain S-N diagrams of the basic construction elements. Fatigue test of a large structural model may be required.

*5) Fatigue test should becarried out considering the expected service conditions for which the construction material is exposed in order to obtain the fatigue crack propagation characteristics. Model test may be required in order to confirm the analysis accuracy.

*6) If necessary, no probability of unstable crack propagation under the expected service conditions should be confirmed by toughness test, etc.

Fig.2 Flow chart of strength analysis for new cargo tank design concept
(except evaluation for vibration and sloshing)

has been originally developed and applied as the design procedure using the latest analysis techniques to the design of liquefied natural and petroleum gas carriers and off-shore rigs[5][6][7] and now is also utilized for the evaluation of new cargo tank design concept of chemical tankers. The design procedure based on analysis is to be used for assessing a new construction system with few proven records. The structural element of the hull and cargo tank of chemical tankers basically differ little from the case of general oil tankers as already stated. It has been the recognized practice in chemical tankers that the construction details and scantlings of a ship (cargo tanks) are determined by considering the aforementioned loads where the caluculation formulae specified in the rules for hull and tank construction laid down by each classification society (e.g., regulations for the construction of oil tankers, regulations for the construction of deep tanks, etc.) and recognized national standards or classification society rules for pressure vessels are applied mutatis mutandis. Such a design procedure is called "Design by Rules." It must be noted that even when the "Design by Rules" procedure is carried out, it is not necessarily warranted that all details of the tank construction are covered by such rule requirements (e.g., support construction for independent-type tank, special lining construction, etc.). In such a case, a procedure partially relying on "Design by Analysis" should be employed.

Essential precautions to be observed when the procedure known as the "Design by Rules" is employed, are summarized below:

(1) Specific gravity

Specific gravity is the most important item for the structural strength of gravity-type tanks. In cases where the specific gravitites of all the cargo chemicals planned to be loaded fall within a range from 1.05 downwards, a cargo tank conforming to the construction requirements applicable to ordinary oil tankers may be acceptable. However, in a design specific gravity range greater than the above, corrections to the term for cargo liquid head of the relevant calculation formula should be made according to the specific gravity. In this connection, specific gravity values for 173 out of the 177 items of those dangerous chemicals prescribed in Chapter Ⅵ of the BCH Code, and 145 out of the 153 items prescribed in Chapter Ⅶ of the same Code are given in Table 2. Given in Table 3 is the range of design specific gravity for tanks employed in 33 NK-classed ship. From these two tables, it can be seen that in multipurpose chemical tankers, the basic cargo tank structural strength requirements for almost all chemicals can be substantially met with greatly improved adaptability to a vast diversity of cargo chemicals if some cargo tanks with a maximum design specific gravity in a range from 1.5 to 1.8 are provided for the ship.

(2) Vapour pressure, boiling point, viscosity and melting point

These physical properties are relevant to cargo temperature and pressure controls, and are further related to the cargo tank type.

For chemicals with a vapour pressure greater than 1.033 kg/cm^{2}A at 37.8°C, i.e., higher than the atmospheric pressure, either the design vapour pressure of the tank should be made sufficiently high (higher than the cargo vapour pressure at a temperature of 45°C) or an appropriate cargo temperature control system (cooling or thermal insulation) should be provided, thus constituting as an important condition in selecting the tank type.

In integral-gravity or independent-gravity tanks, the construction requirements for ordinary oil tankers and deep tanks can be applied when the allowable vapour pressure acting on the tank ullage space is 0.25 kg/cm^{2}G. In cases where tank pressure relief valves or breather valves are set at a pressure higher than 0.25 kg/cm^{2}G by taking account those cargo chemicals with slightly higher vapour pressure, the design vapour pressure (P_0) should be equal to or higher than the preset value of these valves: In the application of the classification society's regulations, corrections to the term of the load due to the tank internal pressure in the calculation formula should be made. (An example is shown in Fig. 3) Although the design vapour pressure of these gravity type tanks can be accepted up to 0.7 kg/cm^{2}G under the provisions of the BCH/IBC Codes, when this limit is exceeded, the independent-pressure type tank should be employed.

The melting point and viscosity requirements are relevant to setting the cargo heating temperature necessary for maintaining the cargo chemicals at a pumpable fluidity, and these are particularly important for such cargoes as sulphur, naphthalene and phosphorus, which are in a solid state at room temperature. When the melting point is high (80°C or more), an assessment of thermal stress is also necessary, and the thermal isolation of cargo tanks from the hull structure must also be assessed.

Heating is necessary for substances with high viscosity in order that cargo handling and tank cleaning can be facilitated. Further, additional structural considerations such as smoothing the internal tank surfaces and provisions to prevent the heated cargo tank wall from coming into contact with other non-heated cargo or sea water may be necessary in regard to precluding heat dissipation or ensuring thermal insulation effect. In cargo tanks adjacent to those carrying cargoes requring heating, prohibition to load cargo chemicals of low boiling point or those whose self-reaction is accelerated by heating should also be considered. Generally, when the boiling point of the cargo loaded into a tank adjacent to a heated cargo is 10°C higer than the maximum heating

Table2 Specific gravities of cargo chemicals in the BCH Code

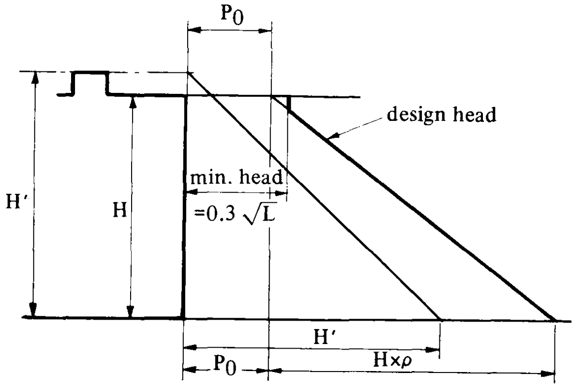
Specific gravity	~ 1.00	1.00 ~ 1.10	1.10 ~ 1.25	1.25 ~ 1.50	1.50 ~ 1.75	1.75 ~ 2.00	2.00 ~
Dangerous chemicals listed in Chapter VI of the BCH Code	90	19	25	21	12	5	1
Chemicals listed in Chapter VII of the BCH Code	117	12	9	6	1	–	–

Note: Figures signify the number of chemicals.

Table3 Designed value of the specific gravity for cargo tanks[3]

Designed specific gravity for cargo tank	1.0	1.25 ~ 1.30	1.40 ~ 1.53	1.60 ~ 1.70	1.85 ~ 1.90
Centre tank	3	4	17	4	9
Wing tank	3	4	24	2	0

Note: Figures signify the number of chemical tankers. Four ships have been designed for dual specific gravity and the total number is different from 33 ships.



P_0 : design vapour pressure
ρ : design specific gravity

Fig.3 Example of correction to the design load(for the bulkhead plate when the design vapour pressure(P_0)is over 0.25kg/cm² G)

temperature, no separation by means of cofferdams or the like need be considered.

(3) Structural materials

In cases where integral-type cargo tanks are employed in chemical tankers, solid or clad stainless steel materials are sometimes used for the centre tanks and wing tanks with a double side shell. Since the classification society rules for the construction of ordinary oil tankers specify, in general, strength calculation formulae on the basis of ordinary hull structural material (mild steel and high tensile steel), corrections for allowable stress related to yield point, tensile strength and fatigue strength may be required depending on the situation whenever special materials like stainless steels are used.

(4) Access openings

Openings used for the access to/from each space within the cargo tank areas of a chemical tanker should, under the provisions of the BCH/IBC Codes, be larger (i.e., 600mm×600mm for horizontal openings; 600 mm× 800 mm for vertical openings) than the access openings of ordinary ships. At the same time, arrangements should be such that a person wearing protective and safety equipment can pass through without difficulty.

This signifies that structural problems may arise if the structural dimensions of double bottoms, double side shells, cofferdams and access trunks of small and medium size chemical tankers are not made sufficiently larger than those of ordinary cargo ships. This suggests that determination of the structural dimensions of access openings is so important that it is closely linked to the determination of ship's principal dimensions.[(3)]

When the rules for general hull construction apply to the structural members where these access openings are provided, it is necessary to ensure a well balanced design, for exmple, by providing locally increased plate thickness or reinforcements by applying doublers/stiffening rings. Futhermore, the assumptions and conditions conceived at the time when the relevant rules were established should be reassessed in a logical manner.

2.3 Design of piping systems for cargo handling

Cargo piping for chemical tankers is either of the following two systems:

(i) **group-main main line system**

(ii) **independent system**

(a) one pump installed within each tank (a submerged or deep-well pump) (one tank/one pump system)

(b) installation of a pump outside the tank (in cargo pumprooms or within another cargo tank)

(c) combined/changing system

The group-main system quoted in (i) above is a piping system generally used in oil tankers, but this is not suitable for cases where many kinds of cargo are loaded simultaneously as in chemical tankers. The combined/changing system quoted in (ii) (c) above is basically the same as the group main system. When cargoes of compatible properties are loaded under this system, the piping system is used as a group-main, whereas when incompatible cargoes (in number corresponding to the number of group-mains) are loaded simultaneously, the main lines are used separately in accordance with the predetermined procedure. These two systems were once used in conventional chemical tankers, but they have generally been replaced by the independent system even in chemical tankers of small and medium sizes. This is in recognition of such shortcomings as the limited number of kinds of cargo which can be loaded simultaneously, restrictions on separating procedures imposed under the provisions of the BCH/IBC Codes, and further operational failures and timewise losses likely to be involved in the line separating work.

Cargo vent lines are either of the following two systems:

(i) **common line main-line system**

(ii) **independent system one tankone line system**

Just as in the case of cargo piping systems, it has become general practice to employ a completely independent system in chemical tankers where a variety of diversified cargo chemicals are carried.

Shown in Fig. 4 is a flow chart of the design procedure for cargo and vent lines.

In planning cargo and vent lines, selection of the most appropriate piping system should be made first. Special attention should be paid to the toxicity and danger of reactivity of a given cargo chemical, which determine the needs for separation of the specific piping system under consideration. Even when the system is free from these hazards, sufficient care must be tanken to prevent cargo damage due to mutual contamination and to the level of product purity maintenance whenever a piping system other than the independent type is employed.

The piping system for cargo with a vapour pressure greater than 1.033 kg/cm^2A at a temperature of 37.8°C should be made independent from other ordinary liquid chemicals, and at the same time, assessments should be made for thermal insulation requirements and the design pressure value necessary according to the type of each cargo tank.

In selecting the cargo pump type and capacity, consideration should be given to the piping system, specific gravity of cargo chemicals and their viscosity as earlier mentioned.

The pipe diamater and design pressure of cargo lines bear a close relationship with the cargo pump capacity, cargo flow rate and the length of cargo lines. When assumptions are made on the flow resistance in a line pipe, additional consideration should be given to the cargo viscosity, pipe bends connections and various arrangements of valves and expansion joints.

In determining the diameter of vent line pipes for cargo tanks, careful checks should be made on the relationship between the cargo line pipe diameter and the vent line pipe diameter so as not to cause an excessive rise of internal pressure in the cargo tanks at time of cargo operation. At this stage of assessment, it should be verified that there is a sufficient allowance for the tank strength by calculating the vapour flow resistance within the vent line according to the vent line system, cargo loading/discharging rates, and whether or not the cargo vent lines commonly serve also as the inert gas lines. Incidentally, toxic cargo chemicals and those with a vapour pressure greater than 1.033 kg/cm^2A at 37.8°C are subjected to a closed cycle cargo operation, and therefore piping connections to the shore lines for returning the cargo vapour ashore are necessary. For this installation, precautions comparable to those for vent line systems should be taken, and at the same time, all conditions involved in the shore facilities must also be investigated.

After determining the pipe diameters and basic layout of cargo and vent lines through the aforementioned procedures, detailed layouts of various valves, expansion joints, overflow protections, etc. are determined in consideration the properties of the cargo and improvement in the efficiency of cargo handling. Proper selection

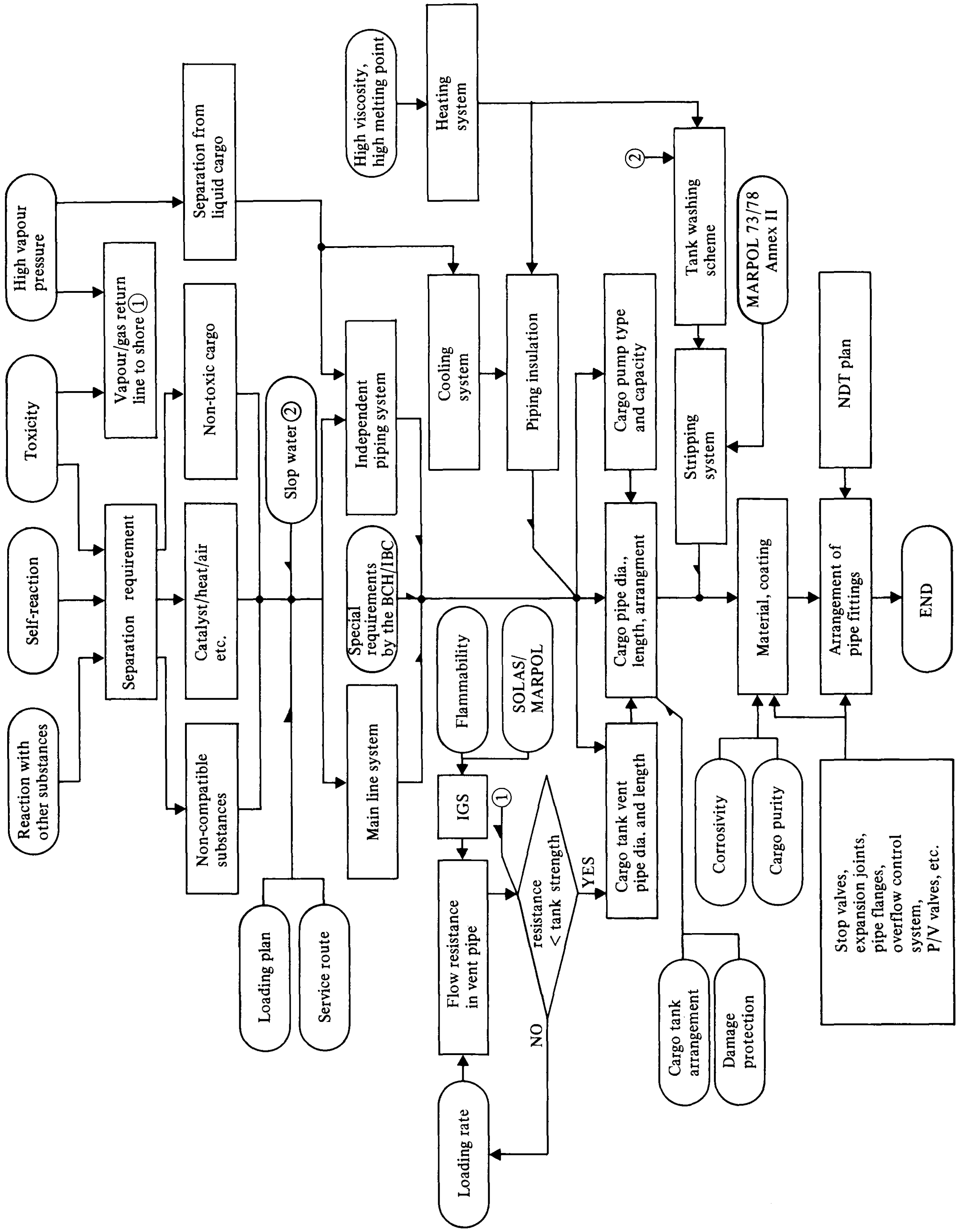


Fig.4 General procedure for the inital design of cargo piping and vent piping

of the piping and/or pipe inside coating materials should be made by taking into account the corrosivity of cargo and the product purity maintenance requirements.

Since it is required under the provisions of the BCH/IBC Codes that the cargo piping should, in principle, be joined by welding except for approved connections to stop valves and expansion joints, sufficient consideration should be given to the ease of on-board welding, non-destructive testing, and effective arrangements for stop valves when cargo line arrangement is being determined.

Almost all arrangements and strength calculations necessary for the other pipe lines (bilge, ballast, F. O., air and sounding lines) in chemical tankers can be managed by applying the conventional techniques available for ordinary oil tankers. However, care must be taken on the following points by giving reference to the requirements of the BCH/IBC Codes when planning is made on the above mentioned arrangements:

(a) Damage stability (An extended flooding in area other than the assumed flooded space can be caused by water through the pipe lines installed in the assumed flooded space)
(b) Separation from the cargo lines (particularly when toxic or highly reactive cargo chemicals are involved)
(c) The possibility of coming into contact with the liquid or vapour of cargo chemicals (correct selection of materials and protective coatings should be made for pipe lines and ventilation ducts running through the cargo pumproom)
(d) Access in spaces where pipe lines penetrate, particularly the double bottom spaces or other narrow spaces (maintaining ample space in the vicinity of access openings and difficulties in access imposed by pipe line, especially in the aft double bottom space and other aft compartments in cargo tank area where pipe lines are heavily concentrated, should be considered)
(e) Pipe lines penetrating cargo tanks
(f) Measures against the possible event of fracture or pitting of the cargo heating/cooling pipes or plates within the cargo tank or heat exchangers, and the detection of such defects

3. Construction and Survey

The points of difference between the construction of chemical tankers and ordinary oil tankers are the greater number of cargo tanks, the application of special materials such as stainless steel in many cases, and the greater diversity and complexity of line pipes. Further, many items of protective and safety equipment which are less familiar in ordinary ships are often used in chemical tankers.

On the left-hand side of Fig. 5, the general flow chart for construction and survey of ordinary oil tankers is shown, and on the right-hand side of the figure, those characteristic check points applicable to chemical tankers corresponding to the oil tanker flow process are given.

As can be seen from Fig. 5, the shipbuilding process for a chemical tanker involves special features that become evident in the fittingout work after launching. Careful assessment at this stage of the shipbuilding process should therefore be made, and an effective work schedule must be drawn up. Particularly when the independent system is employed for cargo and vent lines, pipe lines compatible in number with the number of cargo tanks must be installed. As a result, the piping including other miscellaneous piping become highly complicated on deck. This is also true in the work of surveys, and in this connection, it is indispensable to draw up an overall survey plan closely matched to the work progress in the latter half of the construction phase where various jobs are to be simultaneously handled. This plan will eliminate work losses and erroneous surveys, also prevent delay of the work schedule arising from any reconditioning work required as a consequence of the survey. In recognition of the prevailing practice in shipbuilding that relies on the block building system where part or all of various piping outfits and painting work is assembled in blocks, the surveyor responsible is required to make himself well-conversant with the total concept of the ship before he attends on board. This will involve scrutinizing all the design and fabrication drawings approved either by the government or by the classification society even at the block assembly stage.

In chemical tankers of recent design, the use of stainless steel (solid or clad) for the centre tank structure and wing tank structure with double side shell is increasing. When such a special material is used, sufficient investigation into the various fabrication methods, welding procedures and material storage, including their surveys, is necessary. In cases where stainless steel is used, the survey to be carried out before launching a ship should include, in addition to routine survey items, the selection of appropriate welding rods (especially for welded joints between disimilar materials, e. g., mild steel + stainless steel), pre-welding treatments, prevention of the generation of excessive distortion and cracks should be supervised with a complete grasp of all the problems inherent in the use of stainless steel.

In coating tanks, care must be taken for the surface condition of steel plate including the welding beads. It is the recent major trend that painting work on the structual hull assemblies including water ballast tanks is increasingly carried out in the process of block building on the ground in an attempt to improve the painting quality and work efficiency. In some cases, the coating work on the inside of the cargo tanks is also carried out

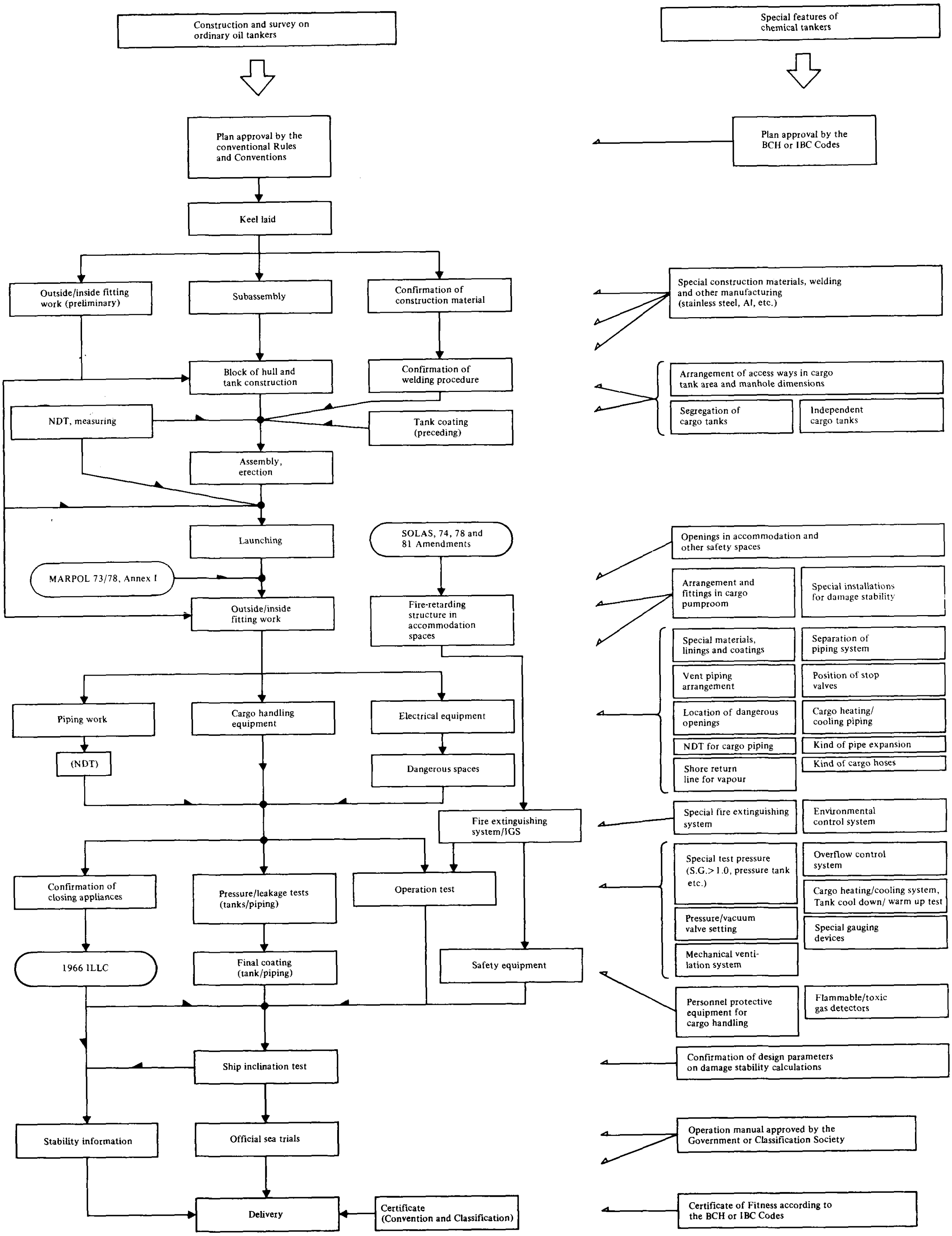


Fig.5 General procedure for construction and struction and survey (except machinery aspects)

at the block assembly stage on the ground for the same reasons. In such an event, care must be also taken with the proper protection of the preceding coating (especially at final coating work on board) and with the suitable procedure for fitting work of pipe and equipments.

Those special precautions required in the workmanship, installation and survey of various piping work and equipments are shown in Fig. 5 which can be summarized as follows:

(a) In view of a number of pipe lines involved, particular care must be taken to prevent possible mistakes in line pipe connections and erroneous connection between pipe lines and equipment.
(b) In cases where the main line system and combined/-changing system are employed, the position of separation and the ease of separating work should be verified.
(c) All cargo line flanges should be welded joints except those approved ones. Buttwelded joints should be subjected to non-destructive testing as necessary.
(d) Distances between the tank vent outlets/cargo pumproom ventilation duct outlets and the openings in the safety area such as the accomodation space should be verified.
(e) The arrangement of piping fittings and equipment in the cargo pump room should be checked.
(f) In cases where stainless steel or other special materials are used, the fabrication procedure, welding method and materials should be verified.
(g) The cargo vapour return lines to shore, overflow control system and crossover lines for improving damage stability and other special arrangements should be checked for their condition.
(h) Emergency procedures in cases of accidental failure of cargo heating/cooling lines should be established.
(i) The relationship between the installed position of the cargo lines and the assumed maximum extent of damage should be ascertained.
(j) Special fire extinguishing systems (alcohol foam, water spray, dry chemicals, etc.)
(k) Various gauging and measuring devices including gas detectors.
(l) Cargo hoses should conform to the prototype test requirements of the BCH/IBC Codes.
(m) An environmental control system (inerting, padding, drying or ventilation).
(n) Other special equipment should be provided according to the properties of the cargo.

4. Maintenance and Periodical Inspection after Delivery

As has already been stated, the cargo containment and handling system s for chemical tankers are highly complex and diversified according to the number of cargo chemicals intended to be carried. Those elements constituting the essential check points of the construction and equipment of chemical tankers and their damage as viewed from the standpoint of maintenance, inspection and survey after the delivery of the ship are summarized in Table 4. These Check points are also useful and applicable for the survey and supervision during construction.

Needless to say, chemical tankers are to be operated by skilled and experienced seafarers in accordance with the authorized Operation Manual, and such importance is recognized internationally. With respect to the problems of education and training of seafarers to serve on board chemical tankers, the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978[8] and Resolution 11 adopted in the conference for the Convention[9], have laid down detailed requirements.

In the operation of chemical tankers, strict observance of all the safety requirements is necessary not only when at sea but also while in port, where shipboard cargo handling and ship/shore cargo operation are carried out.

In this connection, the international conventions, rules and guidance apart from the BCH Code and IBC Code, which are listed below, and are internationally recognized and widely used may be found useful by both operators of chemical tankers and also by those engaged in building ships of this type. It is suggested that the shipping and shipbuilding concerns in this special category should make themselves familiar with the wealth of data and information as well as the spirit and philosophy incoporated therein.

a) International Maritime Dangerous Goods Code (IMDG Code)
b) IMO/WHO/ILO Medical First Aid Guide for Use in Accidents Involving Dangerous Goods
c) IMO/ILO Guidelines for Training in the Packing of Cargo in Freight Containers
d) International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)
e) IMO Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (including 1 st to 4th amendments)
f) IMO Code for Existing Ships Carrying Liquefied Gases in Bulk (including 1 st to 4th amendments)
g) IMO Code of Safe Practice for Solid Bulk Cargoes
h) ICS Tankers Safety Guide (Liquefied Gases & Chemicals)
i) ICS/OCIMF International Safety Guide for Oil Tankers and Terminals (ISGOTT)
j) ILO Code of Practice, Safety and Health in Dock Work
k) Recommendation on Principles and Operational Guidance for Deck Officers in Charge of a Watch in Port, adopted by the International Conference on

Table4−1 Check points for the survey and maintenance of cargo tank construction

Construction aspect		Check point to survey and maintenance	Kind of defects
Integral cargo tanks (hull construction)	Highly stressed areas	Strut ends, each corner, bulkhead boundaries, ship corners, and poor continuity of construction	Crack Deformation Corrosion Others
	Stress concentration areas	Openings (manholes, hatches), stiffener slots, drainage courses and pipe connections	
	Excessive deformation areas	Swash, corrugated and other bulkheads	
	Vibrating areas	Structural unbalance	
	Poor condition of tank coating	Production of rust, detachment of coating	
	Stainless steel	Welded part and tank bottoms	
Spaces adjacent to cargo tanks (hull construction)	Cofferdams/voids	Similar to integral tanks (Especial attention should be paid to the bottom condition of cargo pump room and to the welded joints between dissimilar materials e.g. mild steel x stainless clad steel.)	Ditto
	F.O.T./W.B.T.		
	Double bottoms		
	Cargo pumprooms		
Independent cargo tanks (gravity type)	Tanks	Similar to integral tanks	Ditto
	Tank supports and keys	Connections to cargo tanks/hull construction	
	Hold spaces	Similar to hull construction	
Independent cargo tanks (pressure type)	Shell and end plates	Welded areas	Ditto
	Highly stressed areas	Stiffening rings, Y-connections, domes, sumps, equipment foundations and bulkheads	
	Tank supports	Connection to cargo tanks/hull	
	Hold spaces	Similar to hull construction	
Insulation	Insulation and covering	Surface (remove covering and/or insulation if necessary)	Crack Ageing Tearing/detachment Water permeation
	Insulation supports	Ditto	
Tank fittings and equipment	Ladders, piping and supports	Connections to cargo tanks (Special attention should be paid to welded joints between dissimilar materials e.g. stainless steel x mild steel.)	Corrosion Crack
	Pipe connections to cargo tanks		
	Hatch covers and coaming	Packing, Tightening equipment, coating	

Table4–2 Check points for the inspection and maintenance of piping and equipment

(a) Piping

Piping
Cargo/slop lines
Cargo tank vent lines
Cargo heating lines
Cargo cooling lines
Ballast lines
Tank cleaning water lines
Inert gas lines
Control (air/oil) lines
Hydraulic/pneumatic power lines
Gauging/measuring lines

Check points	Kind of defect
Pipe work	The following aspects should be checked carefully: i) corrosion (especially on stainless steel and inside of coated pipes) ii) operating condition iii) blockade iv) leakage
Pressure/vacuum valves	
Stop valves/cocks/plugs	
Expansion joints	
Connection fittings	
Hoses	
Filters	
Flame arresters	
Pipe flanges	
Welded connections	

(b) Cargo handling equipment(except driving system)

Cargo pumps	centrifugal
	screw
	gear
	reciprocating
Fans/blowers	axial
	radial
	gear/screw
Tank cleaning machines	
Refrigerating units	
Heat exchangers (cargo heating)	
Eductors	
Diffusers	
Inert gas/N_2 gas systems	

Check points	Kind of defect
Shafts/bearings/couplings	Corrosion, cracks, wear, loosening of bolt and cavitation
Shaft sealing devices	Wear and leakage
Casings/cylinder covers	Corrosion, cavitation and cracks
Impellers/blades/gears/screws	Corrosion, cavitation, cracks and deformation
Cylinders/liners	Erosion, corrosion, cracks and scratches
Pistons/rods/rings	Ditto
Suction/exhaust valves	Ditto
Beds/supports	Corrosion, cracks, deformation and loosening of bolts
Nozzles	Corrosion and cavitation
Heating tubes/elements/plates	Ditto
Scrubbers, deck water seals, etc.	Corrosion, cracks and leakage

Check point

(c) Cauging and measuring devices

			Check point
Cargo liquid level	Float/purge/ultrasonic/tape/vibration/radder types	⇨	Control circuit (electric/air/hydraulic)
Cargo liquid/vapour flow	Orifice/turbine/nozzle/electro-magnetic/gear/float types		Driving mechanism
Cargo liquid/vapour pressure	Diaphragm/bellows/bourdon tube types		Sealing device
Cargo liquid temperature	Electric resistance/bi-metallic/thermo-couple/bourdon tube/bar types		Sampling line
Cargo vapour/O_2 concentration	Combustion/infra-red ray/tape/semi-conductor/detecting tube/galvanic cell/magnetic/zirconia/polarographic cell types		Operating condition of sensor and monitor
			Corrosion

(d) Miscellaneous safety equipment

			Check point
Personal protection equipment	Coverall/foot wear/aprons/gloves/boots/goggles/face shields/breathing apparatus/safety lamps/helmets/rescue lines/stretchers/O_2 rescuscitators/antidotes/showers/eye washers/compressors	⇨	Confirmation of number and arrangement required by the BCH/IBC Codes and SOLAS
Fire extinguishing system	Alcohol resistant foam/regular foam/water spray/dry chemical/CO_2/water jet types		Operating condition
			Periodical checks and maintenance
			Ageing of fire-extinguishing media and antidotes

Training and Certification of Seafarers, 1978

l) International Convention for the Safety of Life at Sea, 1974, 1981 and 1983 amendments

m) Protocol of 1978 relating to the International Convention for the Safety of Life at Sea, 1974

n) International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto

o) International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978

p) United Nations: Transport of Dangerous Goods

q) IMO, Safe Transport, Handling and Storage of Dangerous Substances in Port Areas

5. Concluding Remarks

The basic precautions to be observed in the design, construction and survey of chemical tankers to which the provisions of the BCH Code or the IBC Code apply have been explained in line with the requirements laid down in these Codes. It goes without saying that chemical tankers are not constructed under the single and sole influence of the philosophy of these Codes but are built and operated with all the knowledge, experience and expertise possessed by shipowners, charterers, shippers, shipbuilders and all others concerned which are equally authentic and valuable.

As stated in the Introduction, the design and construction techniques involved in building chemical tankers are characterized to combine already established and conventional methods of an extremely wide range in a complex but efficient way. It may be stressed that to master shipbuilding techniques in this field, sustained effort to solve the extreme complexity in most persevering manner is required.

References

(1) IMO, BCH 11/15, Annex Ⅳ

(2) S. Kakubari et al., Nippon Kaiji Kyokai "Chemical Tanker, Vol. Ⅰ & Vol. Ⅱ", Senpaku Gijitsu Kyokai Co., Ltd.

(3) H. Emi, Nippon Kaiji Kyokai, "Consideration for Designing Chemical Tankers Complying with the IMO Bulk Chemical Code", The 6th International Symposium on the Transport of Dangerous Goods by Sea and Inland Waterways, Oct. 1980, Tokyo

(4) H. Jin, Nippon Kaiji Kyokai, "Approach for an on-board computer aided total system for the maximum possible loading variations under the IMO IBC Code", The 8th International Symposium on the Transport and Handling of Dangerous Goods by Sea and Associated Modes, Havana, Cuba, 1984
(5) IMO Resolution A 328 (IX), "Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk"
(6) IMO, "International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk"
(7) NK, "Rules for the Survey and Construction of Steel Ships, Part P Mobile Offshore Units"
(8) International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978
(9) STCW, Resolution 11, Training and Certification of Officers and Ratings of Chemical Tankers