CONSTRUCTION OF AN EXCLUSIVE SHIP FOR TRANSPORT OF SPENT NUCLEAR FUELS - TECHNICAL FEATURES

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SUMMARY

A new ship was ordered from Mitsui Engineering & Shipbuilding Co.,Ltd by Nuclear Fuel Shipping Co.,Ltd, and was completed and delivered in September 1996. The ship is the first large-sized exclusive ship for the transport of spent nuclear fuels built in Japan, and is the first ship complying with the Japanese special regulations (KAISA520, classB) based on the INF code in the world. The special features of hull construction and equipment of the ship as a realization of Owner's concept presented in the report of PATRAM'98,and the requirements of KAISA520 and the "Regulations for the Carriage and Storage of Dangerous Goods in Ships", are reported in this paper.

MAIN FEATURES

The main features of the ship are shown in below :

Length over all	: approx.100.0 m	Length between perpendiculars	: 94.4 m
Breadth moulded	: 16.5 m	Depth moulded	: 9.4 m
Designed draft moulded	: 5.4 m		
Dead weight	: approx. 3000 m.ton	Hold capacity	: max. 20 sets of casks
Gross tonnage	: approx. 5000 ton		
Class	: NIPPON KAIJI KYOUKAI (NK)		
Main engine	: MITSUI-MAN B&W low speed marine diesel engine		

GENERAL ARRANGEMENT

Forward machinery room, holds, main engine room, aft machinery room, accommodation and etc. are arranged as shown in Fig.1. The propulsion system consists of one(1) set of main engine in main engine room, one(1) set of fixed pitch propeller, one(1) set of bow thruster and one(1) set of Vectwin rudder. Cargo holds located in the middle part, are double skin, and are divided into upper and lower part by movable mid deck. Each hold can stow four(4) sets of casks; two sets of casks in each upper and lower part of cargo hold. Movable hatch cover handling crane which can be remotely operated from the wheel house and crane itself, is provided on the upper deck. In addition to the main electric source of three(3) sets of main generators and one(1) set of port use generator in the aft machinery room, the alternative electric source which is the same capacity as one main generator, is provided in the forward machinery room.

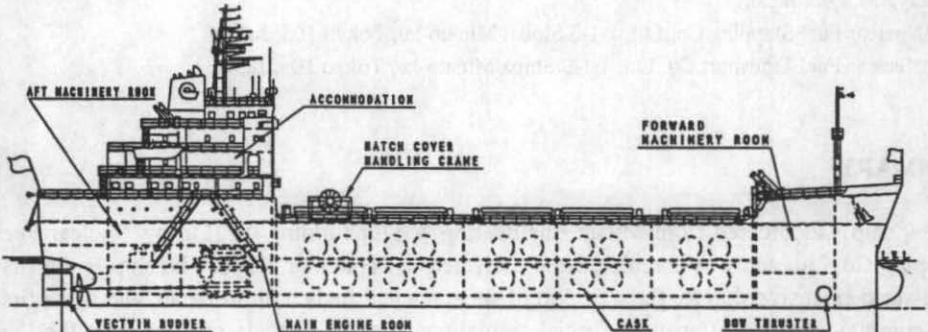

Fig.1 General Arrangement

PROPULSIVE PERFORMANCE AND MANEUVERABILITY

The vessel has the very large magnitude of the fullness up to the designed waterline on account of an increase in the light weight which is for the following items.

- the restrictions of the principal dimension and the draft for port types.
- shelter constructions and collision constructions for KAISA520.

Generally, a relation between speed performance and fullness has a suitable range. But the fullness of the vessel is beyond the above range. So the vessel's form was developed on the data of similar vessels to be built, the research of ultra full vessels, latest propulsive theory and the model test results carried out at MITUIZOUSEN AKISIMA LABORATORY. And the form of Vectwin rudders was designed for good maneuverability.

Consequently, the vessel obtained the excellent results of speed performance and maneuverability through the sea trials. The performance and the maneuverability using Vectwin rudders was excellent as well. For example, the crash stopping ability using Vectwin rudders approximately showed 50 percent decrease of the traveling distance and 15 percent decrease of the traveling time against the stopping ability using reversed propeller.

As mentioned above, it is expected that good performance and characteristics as planed will be proven after starting of service.

DAMAGE STABILITY

The requirements of damage stability in KAISA520 is very severe and requires that ships should meet the survival standard after assumed damage, which includes side damage to longitudinal watertight bulkheads that located at the required distances inboard.
The basic requirements of KAISA520 is that ships should be capable of surviving the assumed flooding involving one(1) transverse watertight bulkhead, so the survival requirements are the following criteria.

- the righting lever curve at final equilibrium after flooding
  the range beyond the position of equilibrium : 20 degrees or over
  the maximum residual righting lever : 0.1 meters or over
- the angle of heel due to unsymmetrical flooding : not more than 25 degrees

In addition, the vessel has undesirable factors of damage stability due to the heavy shelter constructions, which are located at the forward end wall of deck houses, the upper deck, the hatch covers, the aft end wall of the forecastle etc., are at the high position above the base line.
Therefore, at the planing stage, the study relating to the various subdivisions of the vessel was performed on the estimated light weight, dead weight and the center of gravity. So it was adopted that the vessel is divided into two(2) machinery compartments and five(5) cargo holds with watertight bulkheads. The subdivision of the cargo holds is defined by not only fitting the survival requirements but also having difficulty of foundering.
Additionally, from the designing stage to the building stage, the checking of the lightweight and the center of gravity has been carried out continuously with discretion.
As a result, the measured lightweight and center of gravity, through the inclining test, is approximately the planed ones. Therefore the damage stability of the vessel is verified as well as planed one.

HULL CONSTRUCTION

DOUBLE HULL CONSTRUCTION

The hold structure is designed according to the requirements of KAISA520 to be double hull to prevent from the damage of casks in holds at stranding and collision. The design condition required by KAISA520 is as shown below.

- Height of double bottom : not less than 1/8 of the breadth of hold
- Breadth of side shell : not less than 1/5 of the breadth of ship

The double hull hold structure of the ship which satisfy the above requirements, is shown in Fig.2.The side structure in hold is also used as the anti collision structure as described in the next item.

ANTI COLLISION STRUCTURE

The anti collision structure is required by KAISA520 to be provided on the both sides of cargo hold to protect the casks in hold from the damage at collision with other ship. The design condition required by KAISA520 is as shown the below.

· Striking ship to be considered : T-2 tanker(displacement : Δ23,400 ton, speed 15knots)

· Absorbable energy : The anti collision structure is to be able to absorb the collision energy of the above striking estimated by Minorsky's method without damaging of the casks in hold.

The anti collision structure of the ship which is designed to satisfy the above requirement, is consist of the upper deck, the inner bottom, bottom shell and four(4) stringers, and is arranged between the outer shell and the longitudinal bulkhead. The high tensile steel is used for the anti collision structure to lighten ship's weight.

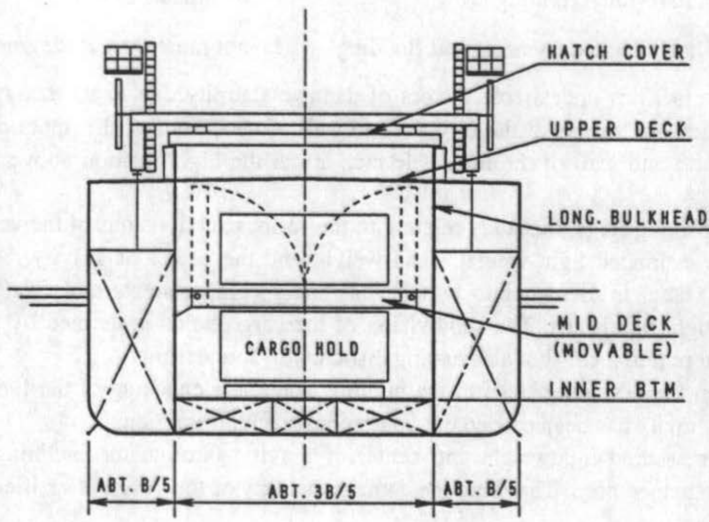

Fig. 2 Double Hull Construction

CASK COOLING SYSTEM

The cask cooling system is provided to remove the heat radiation from the spent fuel casks, and its capacity of about 97,000 kcal/h is decided according to the following requirements by KAISA520.

· Temperature around casks : less than 38℃
· Design temperature of atmosphere : 38℃
· Design temperature of sea water : 32℃

Main components of cask cooling system such as the chiller units, cooling pumps, and etc. are required by KAISA520 to be installed in duplicate for redundancy. Therefore, the chiller units and cooling pumps of the ship are provided in both aft machinery room and forward machinery room, and the piping connected the components is installed in duplicate.

CASK SECURING SYSTEM

The cask securing system is provided to prevent cask turning-over and shifting during navigation, was designed to have enough strength against estimated external force stipulated in KAISA520. The designated external force are based on following values.

Longitudinal direction	1.5 G	(G:gravity acceleration)
Transversal direction	1.5 G	
Upward direction	1.0 G	
Downward direction	2.0 G	

The following consideration was paid to reduce radiation exposure of crew and stevedore as shown in Fig.3.

Remote control securing system which is operated from the wheel house and in the hold was adopted.

Fixed entry guide was adopted to reduce the working time for cask positioning in the cargo hold.

In addition to the above securing system, the conventional securing system(bolt tie down securing) is provided for redundancy.

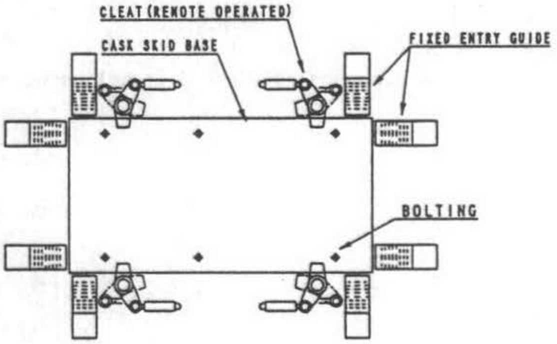

Fig.3 Cask Securing System

EMERGENCY WATER FLOODING SYSTEM

According to the requirement by KAISA520, the emergency water flooding system of flooding capacity 100 m3/h, is provided to cool down the casks in emergency case of fire and etc.

The following consideration is paid for high reliability.

Flooding pumps are provided in both aft and forward machinery room.

Flooding pumps and valves can be operated from wheel house(safety area).

Piping is installed in both port and starbord side for redundancy.

ALTERNATIVE ELECTORIC SOURCE

In addition to the main electric source, the alternative electric source is required by KAISA520 to be provided so that electric power can be supplied in case of engine room fire and damage. Design criteria for the alternative electric source by KAISA520 is as follows;

Location : outside of engine room where damage is not occured at the same time
Capacity : to be supplied electric power to the cask cooling system and emergency water flooding system
Driver : to be drived by the prime mover with lubricating oil supply unit indepent from main electric source
Supply time : not less than 36 hours
Starting : to be automatically started and supplied the electric power in case of main electric source failure

The alternative electric source which satisfy the above criteria is provided in the forward machinery room.

RADIATION MEASURING AND MONITORING SYSTEMS

The radiation measuring systems of the ship are mainly consisted of the following measurement instruments, monitors, survey meters and recording systems with an alarm.

Personal dosimeters for crews and workers.
- Radiation area monitors for each area of the ship.
- A hand-foot-cloth monitor for radiation control area.
- Measuring apparatus of the radio activity concentration in the hold air or the bilge water.
- Radiation protection apparatus.
- Decontamination apparatus.

The systematic diagram of the radiation monitoring system in the radiation control room of the ship is shown in Fig.4

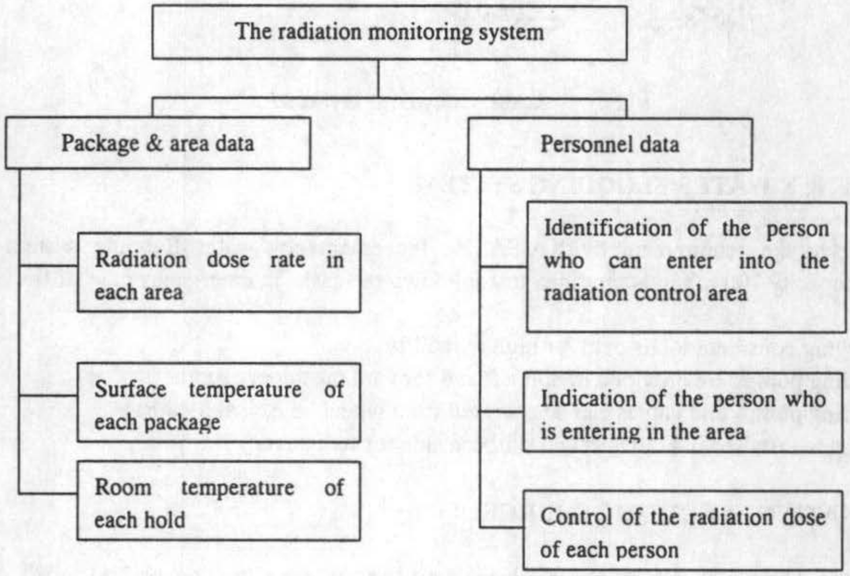

Fig.4 Systematic Block Diagram of the Radiation Monitoring System

RADIATION SHIELDING STRUCTURE

The radiation shielding of the ship was designed and approved in accordance with "Regulations for the carriage and storage of dangerous goods in ships", and the specification of the owner.

The shielding materials of the ship are serpentine concrete and polyethylene blocks, and also carbon steel plates for the hull structures of the ship.

These shielding structures are mainly installed at the wall between the cargo space and accommodation or normally occupied space, as well as on the deck and hatch covers as shown in Fig.5

Shielding performance tests for the shielding structures of the ship were successfully performed using the gamma-ray source at the completion of the construction.

The results of the tests are reported in the paper presented at PATRAM'98.

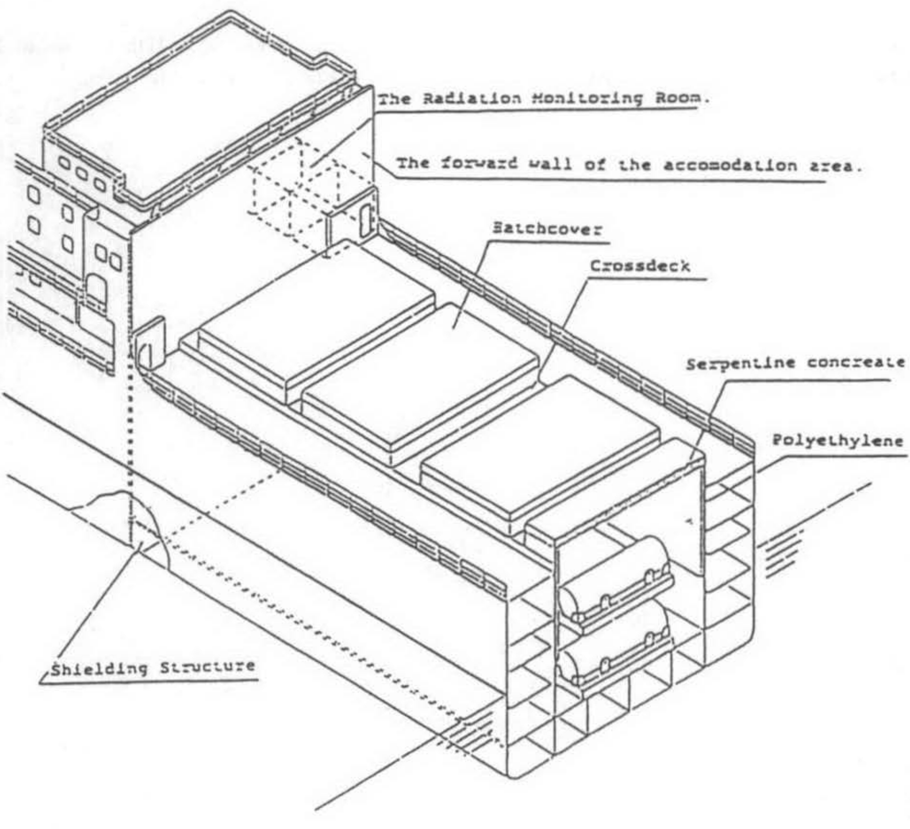

Fig.5 Shielding Structures of the Ship

CONCLUSION

The ship has been smoothly and successfully constructed and completed with good cooperation of the supervisors of ship owner, and the inspectors of Mot, NK. All performance such as propulsive performance was confirmed in good order at the on board tests and the official sea trials, and obtained the estimated results at the planning stage. The ship is the first ship applied the requirements of KAISA520 class B in Japan as well as the first ship complied with the equivalent international INF code.
The ship will be in service and expected to contribute to the safety and efficient transportation of spent nuclear fuels.

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