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A Study on the Effectiveness of Flammable Gas Monitoring System in the Cargo Pump Room of Tanker

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Abstract : The flammable gas monitoring system is to be provided in cargo pump rooms of tankers in accordance with the requirements of SOLAS regulations, and flammable gas detectors are to be arranged in a proper position. In this paper, simulation tests and CFD analysis are carried out under the actual ventilation conditions of pump rooms in the ship in service. Based on the results, a new guidelines for an arrangement of flammable gas detectors are suggested.

Key words : Cargo pump room, Upper flammable limit (UFL), Lower flammable limit (LFL), Flammable gas monitoring system

1. Introduction

The vessels carrying liquid cargo are called tankers and these tankers are fitted with cargo tanks. The fire protection requirements as described in SOLAS Chapter II-2 are applied to tankers carrying crude oil or petroleum products having a flashpoint not exceeding 60℃ (closed cup test) and a Reid vapour pressure below the atmospheric pressure or other liquid products having a similar hazards.

The tankers have spaces which are considered hazardous such as cargo tank, tank deck area, double hull spaces and cargo pump room. In laden voyage, cargo tanks are filled up to 98% of their capacity and ullage spaces are filled with the high density cargo vapour above UFL(Upper Flammable Limit) or inert gas. In ballast voyage, cargo tanks are just filled with the cargo vapours and air mixture, except for vessels provided with the inert gas system. However, since there are no ignition sources in the cargo tanks, explosions do not occur normally. The explosions that occur in the cargo tank are usually caused during the cargo tank cleaning process.

A cargo pump room is regarded as one of the most hazardous spaces in the cargo area because of frequent personnel traffic during the cargo operations and the

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presence of flammable gases arising from possible cargo leakage due to many detachable joints and points. The room needs to be mechanically ventilated and the discharges from the exhaust fan need to be led to the open deck safely. Also, a high temperature alarm system for cargo handling pumps-bearings and a continuous gas monitoring system for detecting the concentration of hydrocarbon gases are required.

SOLAS[1] regulation II-2/4.5.10.1.3 prescribes that a system for continuous monitoring of the concentration of hydrocarbon gases shall be fitted in tankers and that sampling points or detector heads shall be located at suitable positions in order that the potentially dangerous leakage is readily detected. The regulation also requires that audible and visual alarm signal shall be automatically affected when the hydrocarbon gas concentration reaches a pre-set level which shall not be higher than 10% of the LFL (lower flammable limit).

According to the interpretation for suitable positions, a detector should be positioned where air circulation is reduced such as recessed corners, as contained in the Unified Interpretations of SOLAS chapter II-2, the FSS Code, the FTP Code, and related fire test procedures (MSC/Circ.1120). However, the positions prone to dangerous leakage and the pre-set level of flammable gas mixtures are not defined.

In most oil tankers, one detector is provided within the exhaust duct and one to two detector(s) are provided at 30 cm above the bottom floor in the pump room. The position of these detectors and the pre-set level of monitoring system varies according to the type and size of the ships.

In this paper, the results of an experiment carried out to examine the effectiveness of the detection and installation positions are introduced to provide a clear guidance.

2. Result of hydrocarbon measurement in cargo pump rooms of ships in service

In order to check the risk and the amount of hydrocarbon gas produced during the unloading work on board ships in service, measurements were done at the following positions in the cargo pump rooms of 8 sample ships:

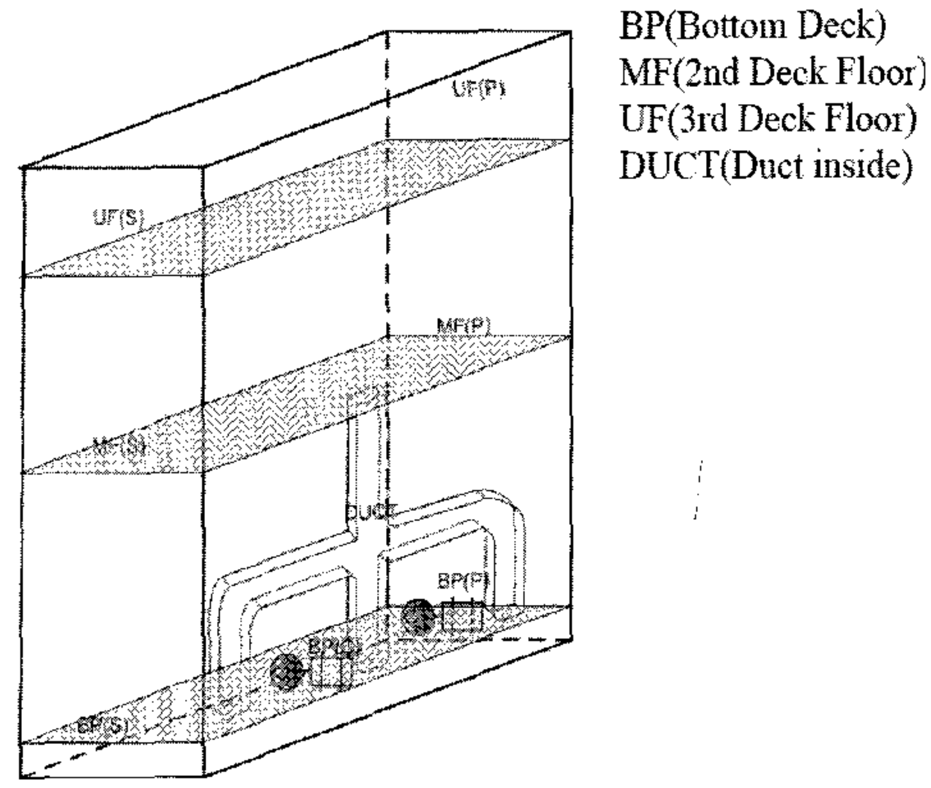

Fig. 2 Measuring points

(1) left side of 2nd deck floor;
(2) right side of 2nd deck floor;
(3) left side of bottom deck floor; and
(4) right side of bottom deck floor.

The Table 1 shows that if a ship is managed well, the cumulative amount of

Table 1 Measurement of the concentration of hydrocarbon in cargo pump room

No.	Ship's Type	Atm. Temp.	Room Temp.	Measurement(Vol %)			
				1	2	3	4
1	Oil/Chemical Tanker	14	24	0	0	0.3	2.0
2	Oil/Chemical Tanker	14	25	0	0	0	0
3	Oil/Chemical Tanker	9	40	0	0	0	0
4	Oil/Chemical Tanker	13	24	0	0	0.1	0.3
5	Oil/Chemical Tanker	11	24	0	0	0	0
6	VLCC	20	34	0	0	0	0
7	VLCC	17	38	0	0	0	0
8	VLCC	19	35	0	0	0	0

Measurement point

1: left side of 2nd deck floor 2: right side of 2nd deck floor;

3: left side of bottom deck floor 4: right side of bottom deck floor.

Table 2 Result of flammable gas concentrate(%, Vol.)

POINTS	BP(S)	BP(C)	BP(P)	MF(S)	MF(P)	UF(S)	UF(P)	DUCT
Flammable gas	0.8	1.2	0.8	0.0	0.0	0.0	0.0	0.5

flammable gas arising from the presence of minute amount of flammable liquid leaking from the pump gland, etc. does not necessarily produce a fire-prone atmosphere.

It is a general practice for tankers to load several different cargoes simultaneously. In these cases, the pre-set level is sometimes not corrected according to the kinds of cargoes or sometimes set at a level corresponding to the cargo with the lowest LFL level.

3. Result of simulation test

To measure the risk in case of flammable gas exposure, a tray (0.8mW x 0.8mB x 0.1mH) filled with gasoline, which easily produces flammable gas, was placed on the floor of cargo pump room in the sampled ship. The tested ship had in the cargo pump room two main cargo pumps and three branches of duct (size 200mm x 200mm) leading to 30cm above the bottom floor as shown in the Fig. 1.

The concentration of flammable gas was measured at points shown in the Fig. 1. The measured value of hydrocarbon gas was 13.2 Vol % at the point of 30cm above the tray. Virtually no gas was detected at points beyond 30cm zone. The Table 2 shows the result of gas measurements at various points.

According to the obtained results, in the decks higher than the 2nd deck level, virtually no flammable gas was detected. Even if the gas was produced, its detection would be difficult to be found unless a detector is placed very close to the leakage point.

Table 3 Specification of ventilator

Volume of Cargo Pump Room	Abt. 4,700 m^3
Fan Type	Exhaust, Axial, Explosion proof type
Capacity of Fan	50,000 m^3/hour x 2 sets
Ventilator size	1,600mm (radius)

4. Result of Flow Characteristic Analysis

In order to reconfirm the above results, a computational fluid dynamics analysis was conducted for a VLCC fitted with the ventilation system as described in the Table 3.

The dimension of cargo pump room of the tested ship was modelled as shown in the Fig. 2 and Fig. 3, to examine how flammable gas is distributed when the flammable liquid leaks onto the floor of cargo pump room and the air circulation is reduced.

According to the results as shown in the Fig. 4, Fig. 5, Fig. 6 and Fig. 7, the air current stays in the lower part of the recessed corner in the pump room, but the concentration of flammable gas is not high enough to be detected except at the leakage points.

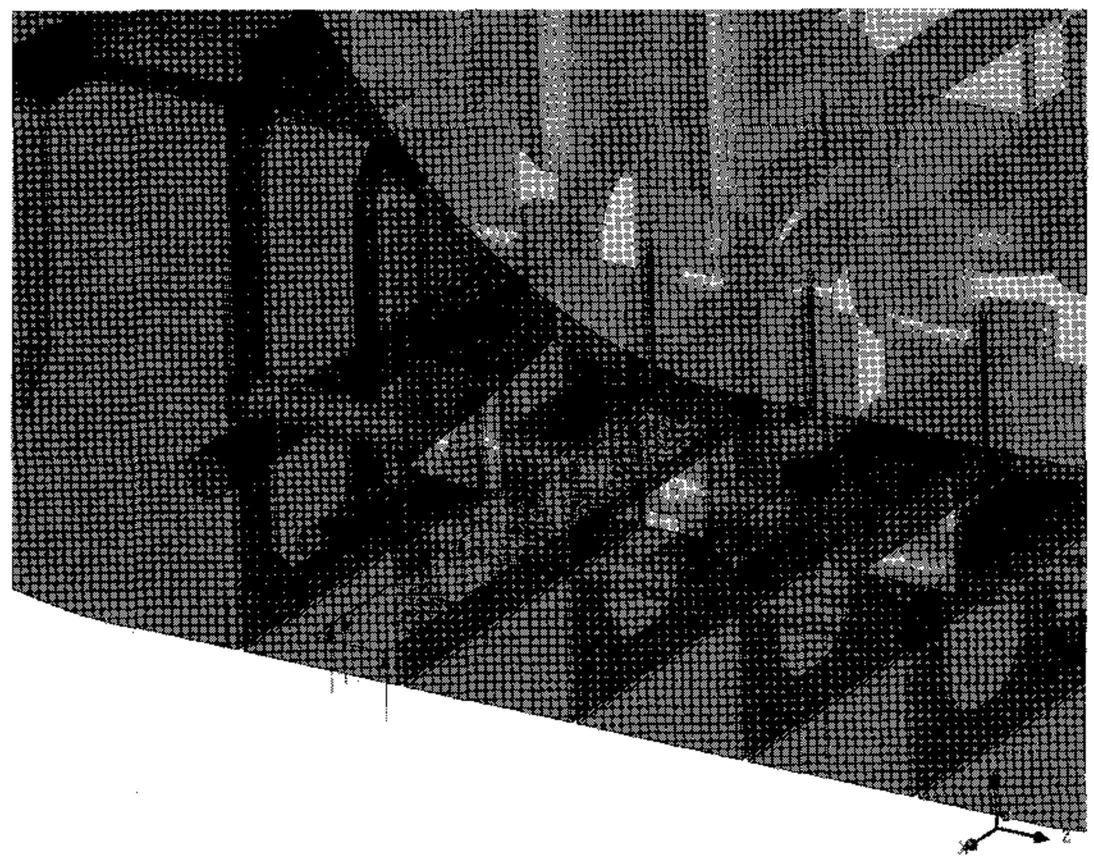

Fig. 3 Leaked flammable liquid

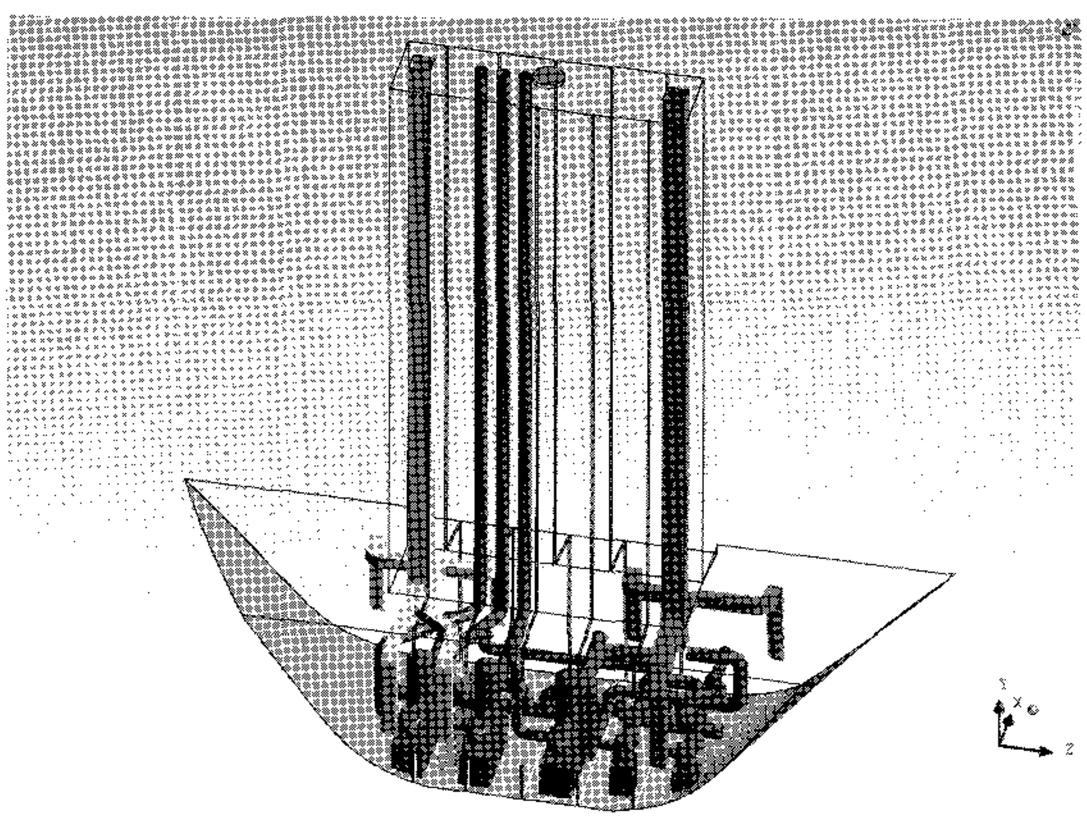

Fig. 2 Modeling of cargo pump room

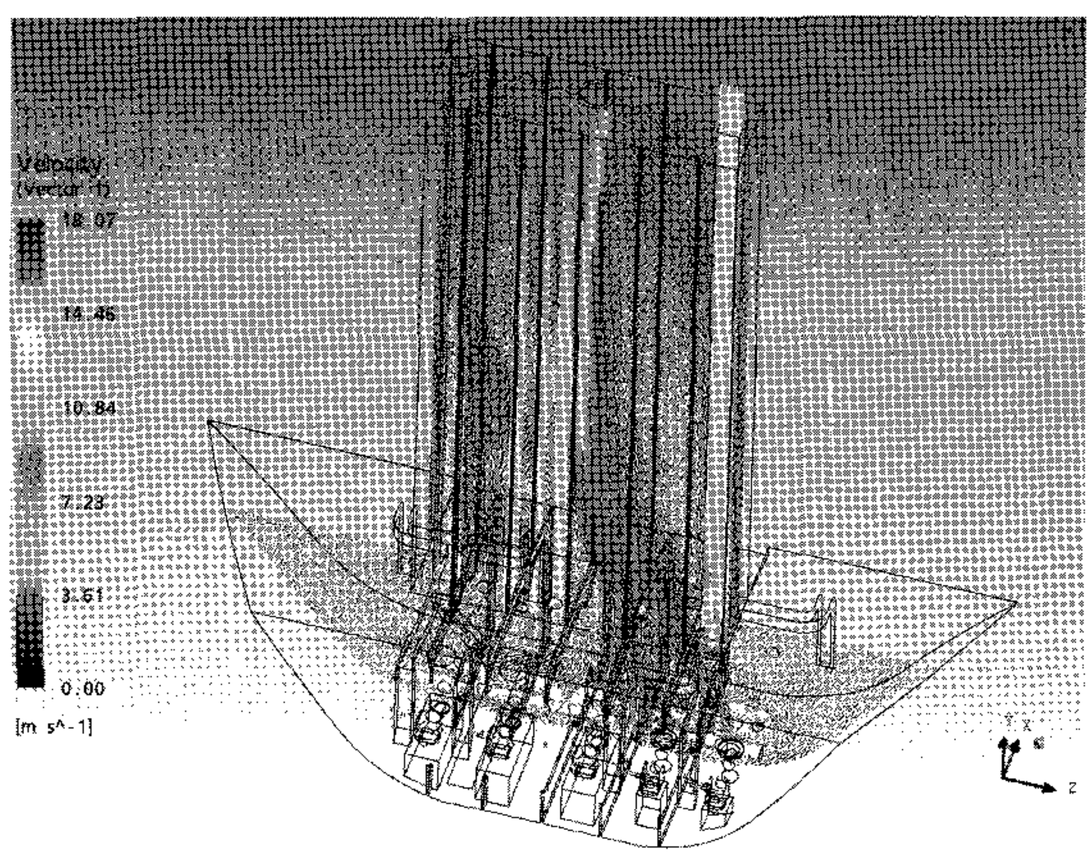

Fig. 4 Results of computational analysis - velocity

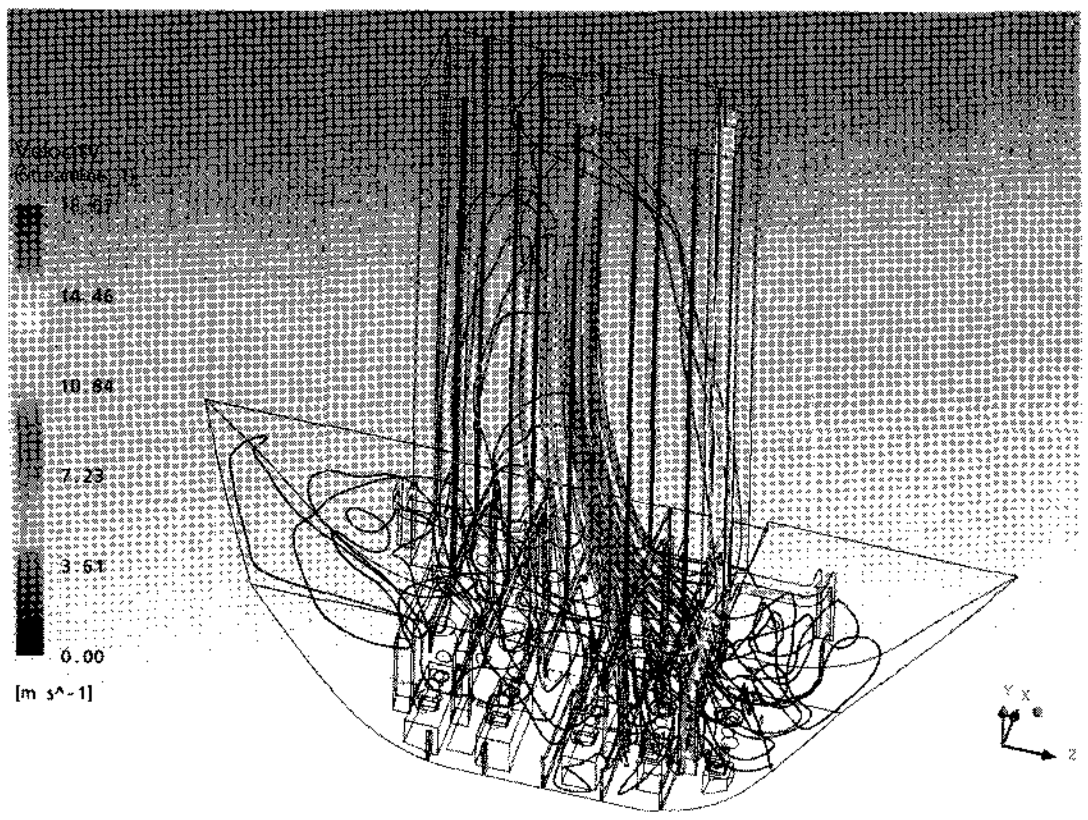

Fig. 5 Results of computational analysis - streamline

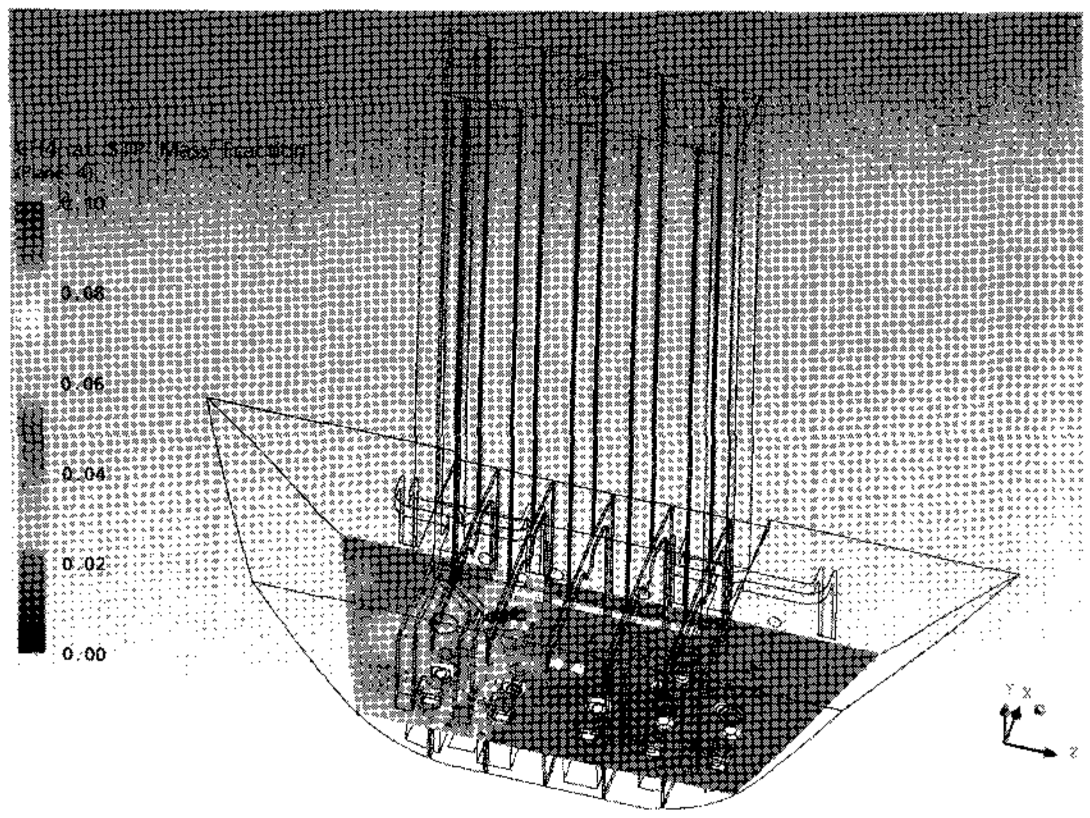

Fig. 6 Results of computational analysis - flammable gas concentration(elevation 2m)

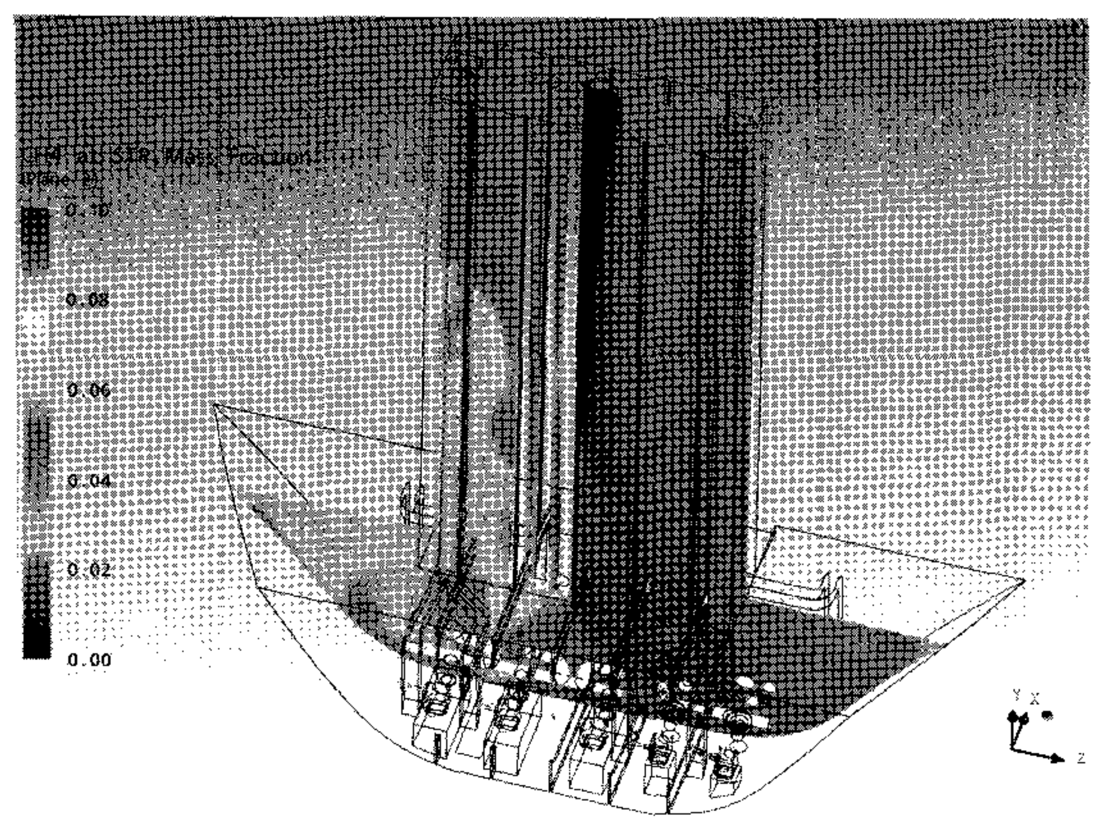

Fig. 7 Results of computational analysis - flammable gas concentration(section)

5. Guidelines for flammable gas monitoring system

Based on the results obtained, the following should be considered in selecting the flammable gas detector and the detection positions in the cargo pump-room:

(1) the shape of cargo pump room; and
(2) the placement of exhaust duct considering the flow characteristics.

If necessary, an actual demonstration test or a computerized simulation analysis should be carried out.

A flammable gas detector is recommended to be installed at the following places:

(1) the (perpendicular) upper part of main cargo pump or between two cargo pumps;
(2) one detector within 30 cm above the lowest part of the cargo pump room bottom floor; and
(3) one (1) detector every 10 meters length or width of the cargo pump room.

In case of a ship carrying two or more cargoes, a set values of alarm point should be corrected based on the mean LFL(LFL_m) calculated by the following formula or should be set to the minimum LFL value of the cargoes carried:

$$LFL_m = \frac{100}{\sum_{i=1}^{n}(C_{fi}/LFL_i)}$$

C_{fi} : the volume percent of cargo gas i in the gas mixture

LFL_i : the lower flammable limit of cargo gas i in the gas mixture

6. Conclusion

The flammable gas monitoring system is to be provided to cargo pump rooms because the pump room is exposed to explosive condition at all time. Therefore, the flammable gas detector is to be arranged in a proper position considering with the ventilation condition of pump room. The guidelines suggested in this paper would support to improve the detecting performance of the gas monitoring system.

7. References

[1] "International Convention for the Safety of Life at Sea", IMO, 2006 Consolidated Edition, IMO, 2006

Author Profile

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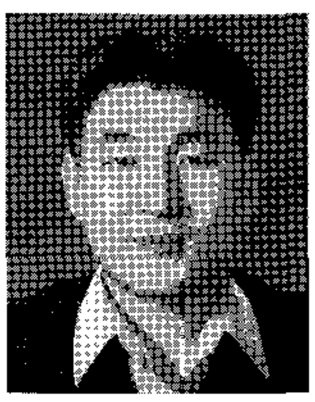

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