Guidelines for Ventilation During the Repairing Process of Ship-Hull in an VLCC

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ABSTRACT

During the repairing process of the ship hull of a very large crude carrier (VLCC), large amount of smoke, heat and harmful gases are generated. In order to improve the productivity of the workers, their health condition and safety, ventilation is needed to have better indoor air quality. A new ventilation system is proposed which basically transfers fresh air from the deck (top) to the bottom of the ship-hull via an air duct and then spread to the entire ship hull by an air-distributor before being sucked out at the deck. A set of design and usage guidelines for this ventilation system was prepared for the convenience of engineers' use. It caters for ship hulls of different dimensions and the number of air-distributors, supply and suction fans to be used. It is important that in order to achieve maximum ventilation efficiency, due to different physical characteristic for different ship hull, correct configuration must be selected from the guidelines.

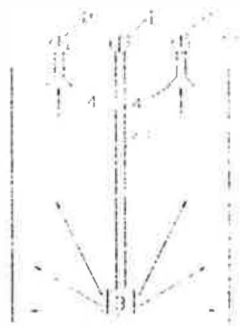
1. INTRODUCTION

1.1 During the repairing process of the ship hull of a very large crude carrier (VLCC), large amount of smoke, heat and harmful gases are generated. From experimental analysis, smoke and dust are the main harmful substances produced. In order to improve the productivity of the workers and their safety, the ship hull needs to be ventilated. The main purpose of this ventilation is therefore to reduce the level of smoke and dust concentration to an acceptable and safe level. At present, there is no any international standards for ship-repairing ventilation. With reference to the present ship-building ventilation (Japan) standards, the acceptable smoke and dust concentration level is 3 mg/m^3.

1.2 The ship hull repairing has the following characteristics:

a. The ship hull is very large;
b. a number of harmful substances are generated;
c. the repairing locations are not fixed;
d. the amount of repair required at each location is not fixed;
e. the internal construction of the ship-hull is complex;
f. the number of openings on the deck are limited;
g. the repair duration is short (from one week to one month);
h. the ventilation system needs to be dismantled after the repairing works.

1.3 With the above characteristics, the following ventilation system has been designed (see Fig. (1)).



1. air supply pump
2. air suction pump
3. air-distributor
4. suction hoods
5. air duct

Figure 1: Air flow pattern of the ventilation system

Fresh air is supplied from the deck by air supply pump 1, via air duct 5 to the air-distributor 3 at the bottom of the ship-hull. The air is then spread through the entire ship-hull by the air distributor before being sucked out via suction hood 4 by air suction pump 2 to the atmosphere. The above proposal can be referred to as "all-directional, global ventilation using the push-pull and upward moving displacement method".

This configuration has several advantages:

a. The displacement type of ventilation not only conforms to the construction characteristics of the ship hull, it also follows an upward-flowing flow pattern. This aids the process of removing the harmful substances in the hull while reducing the risk of explosions.

b. The different elevated-angled supply of air reduces the amount of circulation while raising ventilation efficiency and saving energy.

c. The ventilation system is simple (Fig. (1)) making the task of assembling / dismantling easy. Thus it is suitable for short duration works such as ship repair.

d. The jet of air from the air distributor is able to supply air to the working zones improving the working conditions.

2. DESIGN PROCEDURES OF THE VENTILATION SYSTEM

2.1 Determination of the Air-Flow Rate

2.1.1 According to the dimensions of the ship-hull, the layout and number of the air-distributors are chosen. From there, the air flow rate L_1 is determined. For example, dimension of ship hull already known $l \times w \times h = 40m \times 20m \times 20m$. From Table 7, two air-distributors are required with air flow rate $L_1 = 2 \times 13000 = 26000 m^3/h$.

2.1.2 According to the allowable smoke and dust concentration level, the air flow rate L_2 is calculated.

$$L_2 = \frac{M}{C_2} \bullet K$$

where: K is the safety factor, taking $K = 4$.

C_2 is the allowable smoke and dust concentration level, taking $C_2 = 3\ mg/m^3$.

M is the rate of generation of smoke and dust i.e. $M = n_c m_c + n_w m_w$

n_c, n_w are the number of workers doing cutting and welding respectively.

m_c, m_w are rates of generation of smoke and dust due to cutting and welding respectively. (see Table (1), ref.(1)).

Table 1: Rates of generation of smoke and dust due to cutting and welding

Experiment No.		1	2	3	4	Average
m_c (mg/s/torch)	heavy rusting	0.16	0.20	0.26	0.17	0.20
m_w (mg/s/torch)	no rust	0.13	0.12	0.07	-	0.11

2.1.3 Lastly, by comparing L_1 and L_2, the larger air flow rate is chosen.

2.2 *Precautions and Treatments to be Taken when Setting up the System*

2.2.1 Flexible plastic tubings are used as the ducts. Due to its flexibility, special precautions and treatments are needed when the duct passes through the deck opening, when bending is required and when the duct needs to be joined either to one another or to the air-distributor.

a. For the portion from the fan exhaust to the deck opening of the ship hull (Fig. (2)), the duct should be made of rigid material to reduce the pressure loss due to any acute bending.

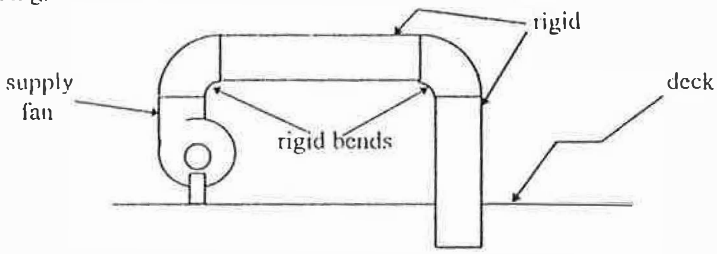


Figure 2: Portion from the fan exhaust to the deck opening of the ship hull.

b. At the joint of the duct and entrance of the air distributor, the vertical angle, α, between the duct and the air distributor must be less than 15° (i.e. $\alpha < 15°$). This is to prevent a lobe-sided distribution of air to the air-distributor.

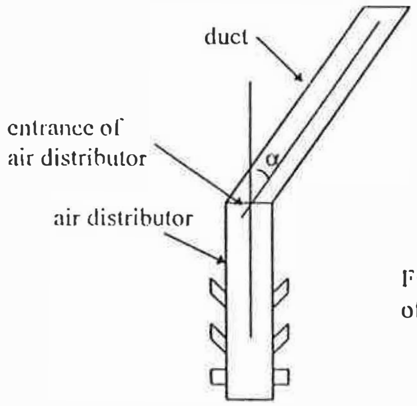


Figure 3: Joint of the duct and entrance of the air distributor.

2.2.2 The duct diameter should not be less than ϕ400mm. This is because smaller diameter would result in higher resistance and cause a pressure rise.

2.2.3 At the exhaust, there should not be any gap between the suction pump and the deck opening. This is to prevent any short circuit of the air flow which would affect the effectiveness and efficiency of the suction pump. If any gap does exist, it should be properly sealed.

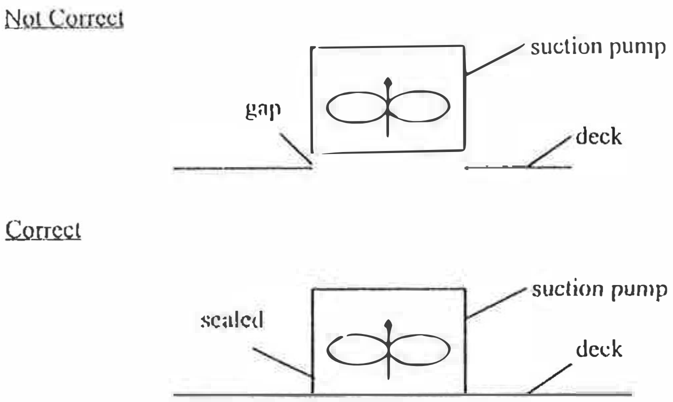


Figure 4: No gap should be between the suction pump and the deck opening.

2.3 Determination of the resistance of the duct and air distributor

2.3.1 Some of the resistances for different flow rates are listed in Table (2) whereby the total resistance of the system can be calculated as follows:

Total resistance = Frictional loss + Local loss + Air distributor resistance.

Table 2: AD400 ventilation system internal resistance for different air flow rate.

Air flow rate (m^3/h)	Frictional loss per unit length (Pa/m)	Frictional loss* (Pa)	Local loss@ (Pa)	ξ_{AD}+ (total pr./ dyn. pr.)	Resistance of air distributor (Pa)	System total resistance (Pa)
6000	4.0	120	60	5	530	710
7000	5.0	1500	75	5	720	945
8000	6.0	180	90	5	940	1210
9000	8.0	240	120	5	1190	1550
10000	10.0	300	150	5	1470	1920
11000	11.5	345	173	5	1770	2288
12000	13.0	390	195	5	2110	2695
13000	15.0	450	225	5	2480	3155

* duct diameter = 0.4m + obtained experimentally
# duct length = 30m @ local loss is taken as 0.5 times of frictional loss

2.4 Selection of fan

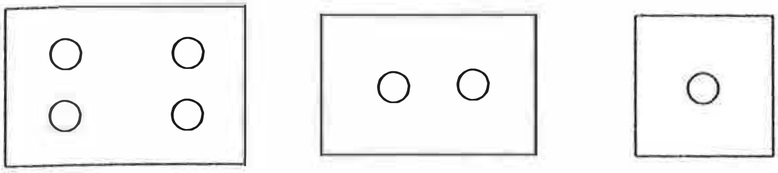
From Table (2), with reference to the air flow rate and total resistance, the fan is selected.

2.5 Determination of layout and number of air distributor in the ship hull

2.5.1 Fig. (5) shows the different layouts and arrangements of the air distributor(s) for different ship hull sizes. This is for selection and reference during the designing process.

2.5.2 The largest length that will be discussed here is 40m. The ratio for the ship hull dimension is $l : w : h = 1 : (0.5\text{-}1.0) : 0.5$.

2.5.3 In the Fig. (5), "O" represents the air distributor. The recommended air distributor is Model AD400 (i.e. the entrance pipe diameter of ϕ400mm). The air flow rate has a range of 6,000-14,000 m^3/h.



(a) Four AD required (b) Two AD required (c) One AD required

Figure 5: Plan view of position of the air distributors (AD) in the ship hull when different number of AD are required.

2.5.4 The relationship between the air flow rate and the distance reach by the jet of the air distributor is governed by the equation (ref.(2))

$$\frac{v_x}{v_o} = \frac{0.48}{\frac{as}{d_o} + 0.147}$$

Table 3: Relationship between the air flow rate and distance reach by the jet of air distributor

Air flow rate (m^3/h)	9000	10000	11000	12000	13000
Velocity at the nozzle v_o (m/s)	21.7	24.1	26.5	28.9	31.3
Distance, s, reach by the jet (m)	6.8	7.6	8.3	9.1	9.9
Remarks	Taking: Final axial velocity v_x = 1.5 m/s Turbulence coefficient a = 0.09 Number of nozzles = 18 (of 0.08 x 0.08 m) Equivalent diameter, d_o, of nozzle = 0.09m				

2.5.5 The suction rate at the exhaust is determined by the number of openings available on the deck and the exhaust rate **must be equal** to the supply rate.

2.5.6 Some of the recommended supply flow rates and the number of air distributors to be used are shown in Tables (4) to (7).

Table 4: $\frac{l}{w} = 1.0$

Ship hull's l (m) x w (m)		30 x 30	25 x 25	20 x 20	15 x 15
No. of air distributor AD (unit)	13,000 $m^3/h/AD$			1	
	12,000 $m^3/h/AD$				
	11,000 $m^3/h/AD$				
	10,000 $m^3/h/AD$	4			1
	9,000 $m^3/h/AD$		4		

Table 5: $\frac{l}{w} = 1.2$

Ship hull's l (m) x w (m)		40 x 33	35 x 29	30 x 25	25 x 21
No. of air distributor AD (unit)	13,000 m³/h/AD	4			
	12,000 m³/h/AD		4		
	11,000 m³/h/AD				
	10,000 m³/h/AD			4	
	9,000 m³/h/AD				4

Table 6: $\frac{l}{w} = 1.6$

Ship hull's l (m) x w (m)		40 x 25	35 x 22	30 x 18	25 x 16
No. of air distributor AD (unit)	13,000 m³/h/AD	4			
	12,000 m³/h/AD		4	2	
	11,000 m³/h/AD				2
	10,000 m³/h/AD				
	9,000 m³/h/AD				

Table 7: $\frac{l}{w} = 2.0$

Ship hull's l (m) x w (m)		40 x 20	35 x 18	30 x 15	25 x 13
No. of air distributor AD (unit)	13,000 m³/h/AD	2			
	12,000 m³/h/AD		2		
	11,000 m³/h/AD				
	10,000 m³/h/AD			2	
	9,000 m³/h/AD				2

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4. REFERENCES

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