

A Seasonal Indoor Thermal Conditions of a Newly-launched Training Ship

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Abstract : *The living performances of crews and passengers in cabins have been less received attention, while Korea is a top leading country in ship building industry. To develop a high value added ships like 5-star cruisers, researches on the comfort and productivity in cabins should be carried out with urgent. The purpose of this study is to measure and analyze of the ship's indoor thermal conditions in spring, summer and winter, and also to compare the seasonal differences, of which conditions are supplied from and controlled by marine HVAC. The temperature, humidity and air supply volume of 5 different needs of cabins on a training ship were measured through a year, which was launched at Dec. 2005 and totally 246 crews can go on board for education. The following results were obtained : (1) In the spring, the temperature in cabins was measured as 20~25°C and humidity was below 30%. (2) In the summer, the temperatures were controlled at 21~27°C in almost cabins and humidity was between 40~60% which is known as comfort conditions. (3) In the winter, temperature and humidity was maintained between 19~26°C, and humidity was between 10~50%. (4) It is clear that the humidity conditions in cabins are not properly controlled at all through a year to satisfy the Comfort Standards provided by ASHRAE and/or ISO. In conclusion, humidification and dehumidification of cabins must be treated with importance for more comfort living and working environments for crews and passengers.*

Key words : *Marine HVAC, Indoor Thermal Conditions, Comfort Standard, Crew, Passenger*

1. Introduction

With the national economic growth, the ship cruising on board has gradually been of interest. In 2005, about 14.4 million people were experienced ship cruising all over the world. In 2020, 27 million passengers and 112 new cruise ships are expected, which has a capability of 2,500 passengers on board per ship (Ocean Shipping Consultants, 2005). Naturally, passengers will request more comfort and convenience on cruiser than they pay for boarding. And also as the result of the FTA (Free Trade Agreement) between countries, the freights by shipping are rapidly being increased. These social changes result in the extension of boarding hours of crews, therefore crews begin to have interest in a comfortable cabin environment for productivity.

Although Korea has been a top leading country in the ship building industry from 2000, because of the insufficient interest from ship owners and immature ship cruising market, the reports on the subject of the marine HVAC (Heating, Ventilating and Air-conditioning) and comfort

index of the cabins have been printed only a few. Hwang (2007) reported the thermal conditions are different according to the cabins' location and the interiors, and the temperature differences between the floor and the ceiling point in a cabin were measured as 4~6°C. Doe (2003) proposed to supply more air supply volume to cabins because of the high air-tight structure of ships. Because the relative humidity was varied between 10% and 45% depending on the opening ratio of diffusers of each cabin in a 590P Ro-Pax ship, it is ensured that the comfort environments can be served to cabins if a user-friendly instruction manual is provided to crews and passengers.

The purpose of this study is to investigate the seasonal characteristics of the cabins' indoor thermal conditions on a ship, and to support the development of a high value added passenger ship. As a case study, the temperature, humidity, and air supply volume of 5 different types of cabins on a training ship, has been measured and evaluated in spring, summer and winter, because the indoor thermal conditions are generally known to be affected and varied simultaneously with weather, inside load factors, wall structures and others.

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And the seasonal comforts are also evaluated and compared with the comfort standards presented from American Society of Heating Refrigeration and Air Conditioning Engineers (abbreviated as ASHRAE) and International Organization for Standardization (abbreviated. as ISO) 15138:2007(E).

2. Measurement overview

2.1 Outlines of the measured ship and cabins

On this study, a training ship is measured, which was built in December 2005 to educate the students for navigation officers and marine engineers. Fig. 1 shows the external appearance and the specifications of the ship are summarized in Table 1. As shown in Fig. 1, this ship consists of 6 decks ; Navigation and bridge deck (hereafter abbr. as Navi. Bri. deck), Boat deck, Shelter deck, Upper deck, Main deck, and 2nd deck from top to bottom.

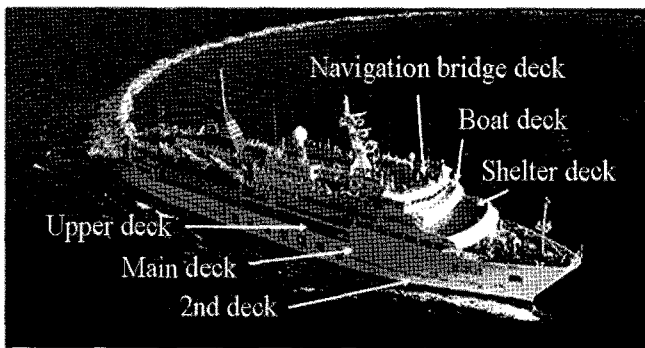


Fig. 1 The external appearance of the training ship

Table 1 The specifications of the training ship

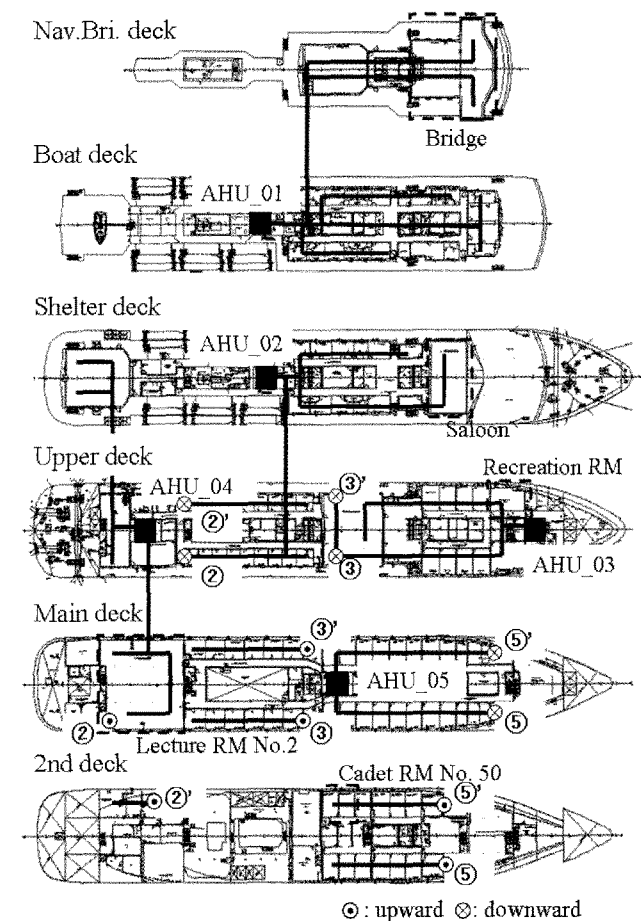
Length	117.20 m	Width	17.80 m
Gross Ton	6,686GT	DLWL	5.9 m
People	Total 246 (Crew 42, Trainee 204)		
Speed	Max. 19, Av. 17.5 kts		

This ship has 5 Air Handling Units(hereafter abbr. as AHUs) which serve heating, air-conditions and ventilation to all cabins such as bridge, saloon, recreation room, lecture room, cadet and etc. And 2 package air-conditioners are additionally installed on the bridge room to maintain the space with stable thermal conditions, where can be disturbed by the heat from the many types of electric navigation equipments. The heating and cooling capacity, air supply design volume of each AHU is listed on Table 2. And fig. 2

shows the schematic diagram of AHUs and the supply duct lines to every cabins.

Table 2 Specifications of each AHUs

AHU No.	Heating Capacity[kcal/h]	Cooling Capacity[kcal/h]	Air supply volume[CMH]
1	120,400	190,920	15,255
2	89,440	141,040	11,290
3	108,380	170,280	12,160
4	113,520	177,160	13,365
5	135,000	188,820	14,965


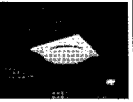



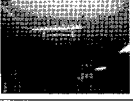

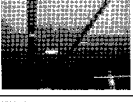

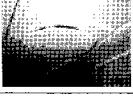


⊙ : upward ⊗ : downward

Fig. 2 AHU schematic diagram of the ship and the locations of the measured cabins

To find out the differences of the indoor thermal conditions, 5 types of cabins are chosen from the each decks and different needs : bridge in Navi. Bri. deck, saloon in Shelter deck, recreation room in Upper deck, lecture No.2 in Main deck, and cadet No.50 in 2nd deck, as listed in Table 3.

Table 3 Outlines of the measured cabins

Measured cabins			Volume[m ³]	AHU No.
Name	Indoor	Diffuser		
Bridge			-189m ³ ×2m -24 diffusers	1
Saloon			-94.5m ³ ×2m -Plenum diffusers	2
Recreation Room			-27.7m ³ ×2m -4 diffusers	3
Lecture No.2			-200.9m ³ ×2m -Plenum diffusers	4
Cadet No.50			-15.2m ³ ×2m -1 diffusers	5

2.2 Measuring methods

Temperature and humidity of indoor and outdoor, air supply volume to each cabin are measured with equipments listed on Table 4 and following processes. TR-72s are positioned at the center of the each cabin and obtained temperature and humidity for every 5 minutes automatically. And to check the thermal conditions from the air supply diffuser, HT-3006 is manually used for every 2 hours. Balometer and hot wire anemometer measures the air supply volume to each cabin for 3 times, because this ship supplies air to cabins by Constant-Air-Volume(CAV) system.

Table 4 Specifications of the measuring instruments

Instruments	Model	Specifications
Balometer	EBT-721	Air Volume : 42~4250m ³ /h Air Speed : 0.125~40m/s Humidity : 0~95% Temp. : -40℃~250℃
Thermo-hygrometer	HT-3006	Humidity : 10%~95% Temp. : -50℃~1230℃
	C.A 846	Humidity : 0%~100% Temp. : -20℃~60℃
Infrared thermometer	Testo 860	Temp. : -30℃~900℃
DAQ	MX-100	
Thermo couple	Type T	Temp. : -200℃~350℃

2.3 Measurement periods and weather conditions

This study had performed through 3 seasons, in spring (from 2nd ~ 5th April 2007), in the summer (from 25th ~

27th July 2007), and in winter (from 26th ~29th November 2007). And cruising lines of the ship are between Busan and Jeju island in the spring, Busan and Ullung island in the summer, Busan and Yeosu in the winter.

Outdoor conditions are observed by TR-72 as mentioned previously, which is set at the middle of the ceremony area of Upper deck. The temperature was varied between 5℃ and 15℃, and average relative humidity was 45% in the spring. In the summer, the weather was very wet because of the high relative humidity(average 95%) and the temperature fluctuation. In the winter, temperature is similar to spring, but relative humidity is a little higher, between 50% and 90%RH.

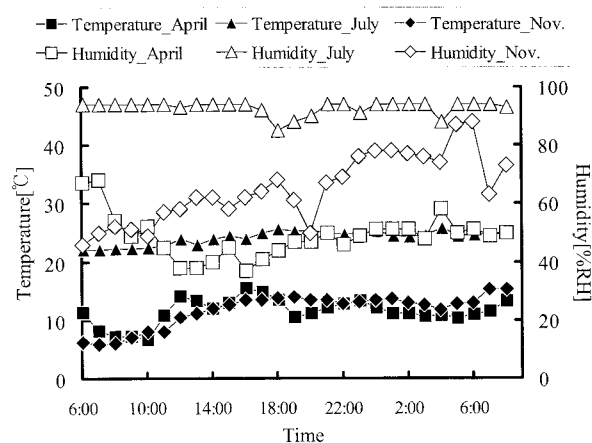


Fig. 3 Temperature and Humidity variations of outdoor on each season

3. Result and Analysis

3.1 Bridge

The results of temperature, humidity and air supply volume of each season on bridge are shown in Fig. 4(a). The air supply volumes were 1,117 CMH (17% against to air supply capacity) on April, 962 CMH (15%) on July and 1,136 CMH (17%) on November. It is found out that only 15~17% of the designed air supply volume had been served through a year.

The temperature of each season are widely varied in bridge shown as Fig. 4(b)~(d). In the spring, temperature is measured as between 20.8 and 24.9℃(ΔT= 4.1℃), in the summer between 23.1 and 27.7℃(ΔT= 4.6℃), and in the winter between 13.4 and 23.4℃(ΔT= 10℃). One of the major reason of the temperature differences between seasons is that many crews come in and out at any time in bridge. And the

second is that bridge is placed on top and exposed directly to outdoors. The low performance of mechanical air supply mentioned previous sentences is caused from the same reasons.

Relative humidity in the spring is recorded as between 13 and 29 %, of which value is normally classified as very dry condition. But the relative humidity is between 38 and 53% in the summer and between 30 and 52% in the winter, which values are satisfied with comfort standards presented by ASHREA and ISO 15138:2007(E), which recommend that the relative humidity be kept between 30 and 70%.

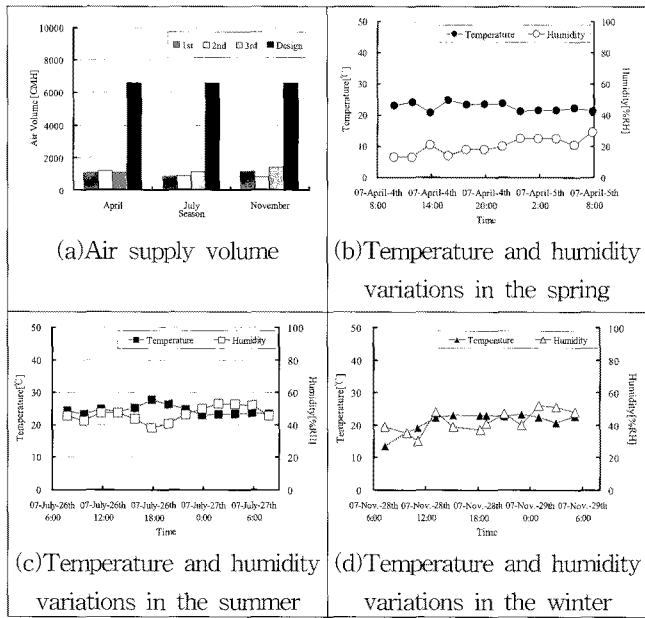


Fig. 4 Measured thermal conditions of bridge

3.2 Saloon

As shown in Fig. 5(a), the air supply volumes in saloon are measured as 751 CMH (41%) in April and 820 CMH (45%) in July and 784 CMH (43%) in November. And it is near the half of the design capacity.

From the Fig. 5(b)~(d), it is clear that the temperature in saloon is comparatively stable through a year. In the spring, the temperature is maintained at average 22.3°C, and between 18.2 and 20.9°C in the summer, and in the winter it was varied between 21.8 and 26.4°C. And almost of the measured temperatures are satisfied with ISO 15138:2007(E) which recommends that the cabin be kept between 19 and 24°C.

The relative humidity in the spring is measured between 18 and 23% and never reached to the 30% which is recommended from ISO as minimum condition. But, relative

humidity in the summer is average 74%, which is the value that exceeds the maximum ISO recommendation. And in the winter, the relative humidity is maintained between 24 and 44%.

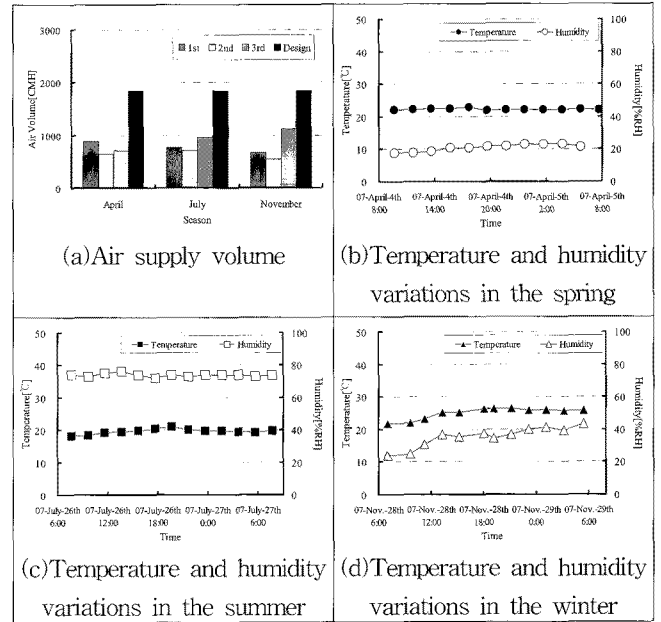


Fig. 5 Measured thermal conditions of saloon

3.3 Recreation room

In recreation room, the air supply volumes are measured as 168 CMH(14%) in April, and 177 CMH(15%) in July, and 173 CMH(15%) in November as shown in Fig. 6. This is the lowest performance against the design capacity comparing to other 4 types of cabins.

In the spring, the temperature is varied between 21.6 and 26.8°C, and between 24.1 and 25.7°C in the summer, and between 17.4 and 25.1°C in the winter.

The relative humidity is observed as between 18 and 29% in the spring, and between 55 and 60% in the summer, and between 24 and 47% in the winter. The variation patterns of the relative conditions are very similar to saloon.

3.4 Lecture No.2

The highest performance of air supply is obtained in lecture No.2 among cabins. The air supply volumes in lecture No.2 is shown in Fig. 7(a). The air supply volumes are measured as average 6,324 CMH(70%) on April, 5,104 CMH(56%) on July and 4,629 CMH(51%) on November.

Fig. 7(b)~(d) show that the temperature is varied between 19.3 and 24.2°C in the spring, and between 21.6 and 27.8°C in the summer, and between 20.6 and 24.1°C in the

winter. The relative humidity is measured between 14 and 31% in the spring, and between 50 and 70% in the summer, and between 15 and 44% in the winter. Because this space is next door to galley and used as students' restaurant for every meal time, the control of relative humidity is not easy.

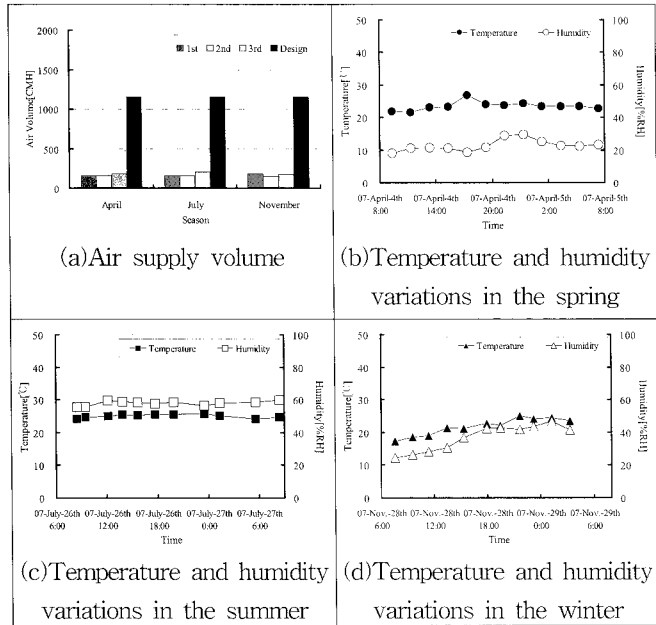


Fig. 6 Measured thermal conditions of recreation room

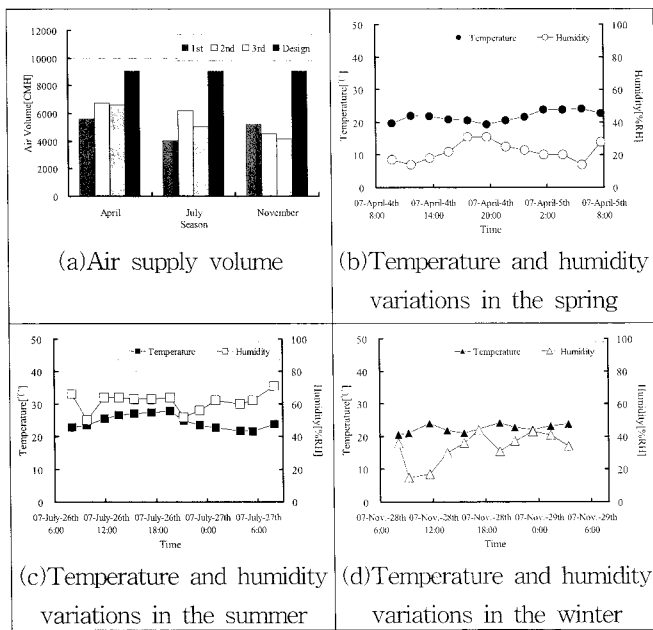


Fig. 7 Measured thermal conditions of lecture No.2

3.5 Cadet No.50

The air supply volume in cadet No.50 are measured as 185 CMH (60%) in April, 190 CMH (61%) in July, and 138 CMH (44%) in November shown as Fig. 8(a).

The average temperature is 23.8°C in the spring and the temperature is measured between 24.5 and 26.8°C in the summer. Because the cadet No.50 is located at the lowest deck and is not exposed directly to the outdoor, thus the cadet No. 50 is less influenced from outdoors, and it maintains stable conditions under the mechanical control. But the relative humidity is measured between 19 and 24% in the spring, between 57 and 63% in the summer, and between 16 and 34% in the winter.

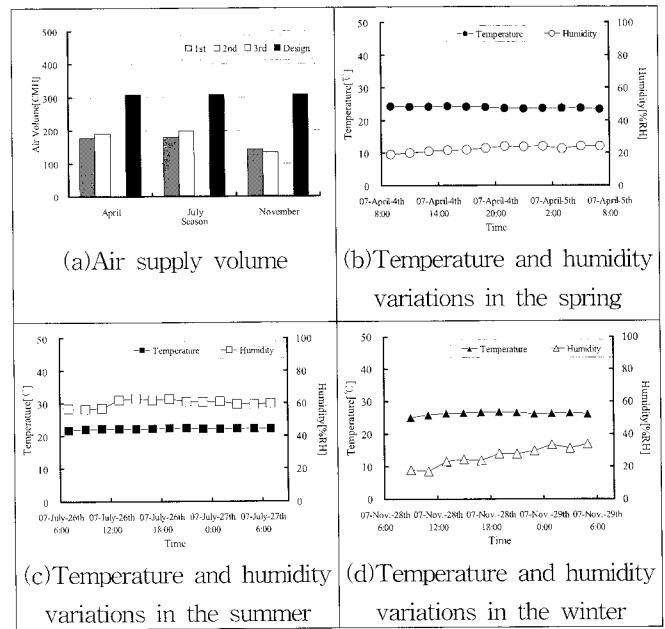


Fig. 8 Measured thermal conditions of cadet No.50

3.6 Evaluation of thermal comforts

By ISO 15138:2007(E) regulation and ASHREA comfort standards, the seasonal indoor thermal comforts of each cabin are evaluated, respectively. As shown in Fig. 9, in the spring, only 16% among measured data are satisfied with ASHREA comfort standard and even not a datum is included in ISO 15138:2007(E) comfort standards. It is clear that the excessively low relative humidity in all cabins makes these results. Fig. 10 shows that 26% among measured data are satisfied with ASHREA comfort standard and 48% with ISO 15138:2007(E). In the winter, as shown in Fig. 11, 51% and 48% among measured data are satisfied with ASHREA comfort standard and ISO 15138:2007(E), respectively.

To sum up the above evaluation, the temperature has been generally maintained between 20~25°C that is classified as good, but the relative humidity through a year has been widely varied from below 10% over 95%, which is a main reason of low level of satisfaction estimation.

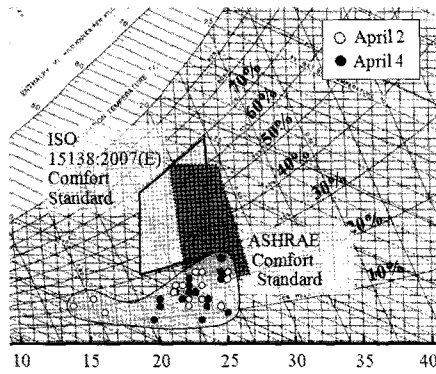


Fig. 9 Satisfaction evaluation on April 2nd~5th

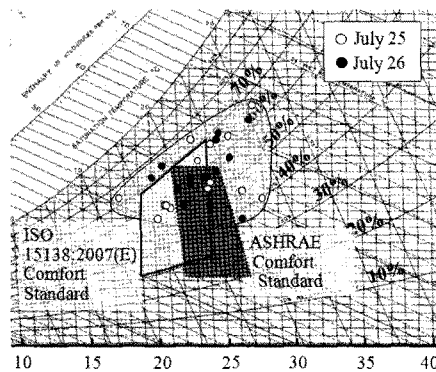


Fig. 10 Satisfaction evaluation on July 25th~27th

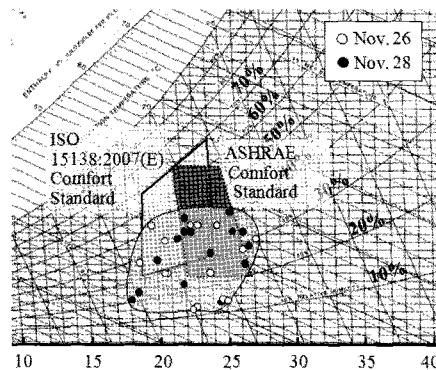


Fig. 11 Satisfaction evaluation on Nov. 26th~28th

4. Conclusion

A training ship that was launched at Dec. 2005 and totally 246 crews can go on for education was observed through a year, to find out the seasonal differences of the indoor thermal conditions. As key variants, the temperature, humidity and air supply volumes are measured and evaluated in spring, summer, and winter.

In the spring, the temperature in cabins was measured as 20~25°C and humidity was below 30%. In the summer, the temperatures was controlled at 21~27°C in almost cabins and humidity was between 40~60% which is known as comfort

conditions. And in the winter, temperature and humidity was maintained between 19~26°C, and humidity was between 10~50%. To summary the results, the temperature has been generally maintained between 20~25°C that is classified as good, but the relative humidity through a year has been widely varied from below 10% over 95%. It is clear that the humidity conditions in cabins are not properly controlled at all and it leads the indoor condition worse. Consequently, only 16%(none) among obtained data in the spring, 26%(48%) in the summer, and 51%(48%) in the winter are satisfied with ASHRAE (ISO15138:2007(E)) comfort standard, respectively.

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