VENTILATION SYSTEMS FOR SPECIAL SHIPS

Ing. drd. **Octavian Narcis VOLINTIRU**[1], Prof. univ. dr. ing. **Anastase PRUIU** [2],
Ing. dr. **Ionuț Cristian SCURTU**[3],

[1] Fregata Regina Maria, Constanța, România,
[2,3] Academia Navală Mircea cel Bătrân, Constanța, România

REZUMAT. Eficiența sistemului de încălzire, ventilație și aer condiționat depinde de procesele care au loc în compartimentele navale deservite, precum și de condițiile meteorologice din mediul exterior. În acest sens, semnificația proceselor pe instalație este dictată de sezon, ținând seama de situațiile extreme care corespund sezoanelor de vară și de iarnă. Rentabilitatea alegerii unuia sau mai multor grupuri de instalații este determinată de condițiile de funcționare ale diferitelor încăperi, de încărcările din instalație, de amplasarea instalației, în strânsă corelare cu problemele legate de gabarit, greutate, zgomot, și asa mai departe.

Cuvinte cheie: sistem de ventilație, sistem de încălzire, sistem de aer condiționat, citadela, unitate tratare aer, unitate filtrare aer.

ABSTRACT. The efficiency of HVAC (heating, ventilation, air conditioning) system, depends on the processes taking place in the rooms served as well as the weather conditions of the outside environment. In this way, the meaning of processing on the plant is dictated by the season, taking into account the extreme situations corresponding to the summer and winter seasons. The profitability of the ship's choice of one or more groups of installations is determined by the operating conditions of the various rooms, the volume of workload embedded in the installation, the location of the installation, closely correlated with the gauge and weight problems, the noise, and so on.

Keywords: ventilation system, citadel, HVAC, air treatment unit, air filter unit.

1. INTRODUCTION

HVAC installations include: ventilation installations, heating installations, cooling systems, conditioning plants (complex processing).

Ventilation systems have the function of delivering air without wetting, eliminating heat, NO_x and humidity.

Also, the heating and cooling systems perform the thermal processing of the air in the living compartments.

Fig. 1.1. Special ship – military ship [9].

The normal comfort conditions of seafaring personnel on board ships, a good keeping of cargo and normal operation of the aggregates depend on temperature, humidity, speed and chemical composition of the air. Determination of air parameters in living rooms is based on physiological and hygienic-sanitary norms, taking into account the specific conditions of the navigation (low volume of rooms, different climate conditions, navigation area, etc.). In case of machinery and aggregate rooms, the determination of the air parameters is made on the one hand according to their functional parameters and on the other hand to ensure the working conditions for the crew.

2. MICROCLIMATE CONDITION FOR SPECIAL SHIPS COMPARTMENTS

2.1. Microclimate condition for crew rooms

Air conditions in the ship's compartments depend on temperature, humidity and movement. The effect of air on the crew in the compartments is dictated by their metabolism, health, acclimatization, effort and their clothing.

For example, The American Society for Heating and Air Conditioning Studies has developed a series of tests on a large number of people and has developed a template chart. The temperature graph is based on the results. For example at a temperature of 27 [°C], a value of humidity of 50 [%] and air speed of 1 $\left[\frac{m}{s}\right]$, the effective temperature should be 22.2 [°C].

2.2. Microclimate condition for ship compartments in NBC area

Ventilation of the special ship citadel is intended to operate in a contaminated atmosphere and the overpressure must not fall below 0.5 [mbar] than the outside atmosphere in any of the spaces.

The following concentrations of CO2 must not be exceeded for the air inside the citadel:

– service and recreation spaces: 0.15 [%];
– dining areas: 0.25 [%];
– mechanical, electrical and electronic workshop: 0.50 [%].

The following overpressure values must be followed in relation to the outside atmosphere as follows:

– living rooms, service and working spaces: 4 [mbar];
– machinery rooms: 3 [mbar];
– machinery modules: 2 [mbar];

$$\dot{V}_{aerfılt} = \dot{V}_{aerresp} \cdot n \cdot \frac{a}{b2-b1}\left[\frac{\mathrm{m}^3}{\mathrm{h}}\right] \qquad (2.1)$$

– $\dot{V}_{aerfılt}$ – filtered air quantity;
– $\dot{V}_{aerresp}$ – amount of breathing air has values:
– a person who is resting: 0.50 $\left[\frac{\mathrm{m}^3}{\mathrm{h}}\right]$;
– a person working light: 0.75 $\left[\frac{\mathrm{m}^3}{\mathrm{h}}\right]$;
– a person working hard: 1.25 $\left[\frac{\mathrm{m}^3}{\mathrm{h}}\right]$;
– n – number of the person onboard;
– a – CO_2 quantity from breathing air (4 % of volume);
– b_1 – CO_2 quantity from outside atmosphere (0.03 % of volume);
– b_2 – CO_2 quantity of onboard air volume:
– 0.15 % in service and resting spaces;
– 0.25 % in dining spaces;
– 0.50 % in workshops.

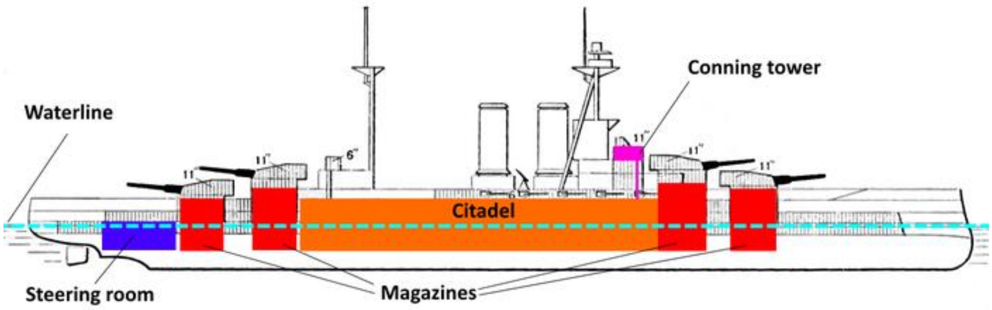

Fig. 2.1. Citadel system for a military ship [10].

3. NATO RULES FOR SPECIAL SHIPS

3.1. Special performance requirements

The ventilation system must have special performance requirements for:

– machinery spaces;
– compartments with technical equipment;
– living spaces;
– space of complementary crew on board;
– medical compartments and facilities;
– galleys;
– storage rooms for hazardous materials;
– hangars for aviation;
– warehouses including refrigeration areas.

3.2. Operational performance requirements

The operational requirements are as follows:

– normal operation;
– special operating conditions;
– operation in the chemical, biological, radiological and nuclear environment.

4. SPECIAL HVAC SYSTEMS

In both, normal and contaminated atmospheres, all air conditioners are designed to work with AFUs (air filtration units) all the time. From air filtration units, the air is introduced into the ship and then recirculated through the air treatment unit (ATU) throughout the ship.

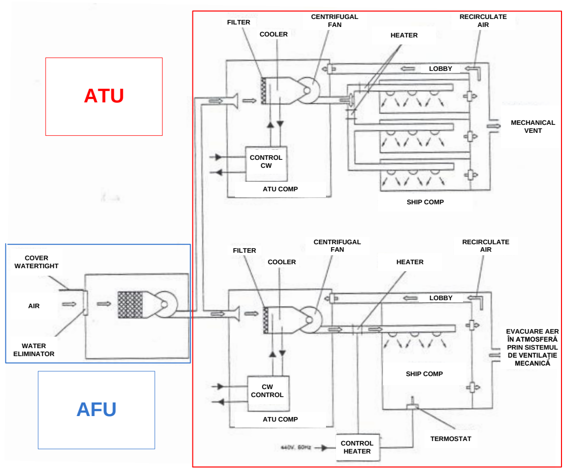

Fig. 4.1. System operation AFU-ATU.

For special ships, the artificial microclimate system is complex, vital and large size, impacting each compartment of the ship. The artificial microclimate system is divided into zones and is integrated with the chilled water system of the ship.

In simple terms, there are three types of subsystems of the artificial microclimate system onboard the ship (intake fans, exhaust fans and recirculation fans).

The compartments of the vessel are either ventilated or air - conditioned. In ventilated compartments, there is an air intake system for introducing air into the compartment, and an extraction system that returns air to the atmosphere. In air-conditioned compartments, the air is recirculated, a quantity of air in the compartment is evacuated into the atmosphere and a quantity is replaced by fresh air. Generally, air is introduced into the ship through ventilators installed in compartments fitted with heaters and coolers.

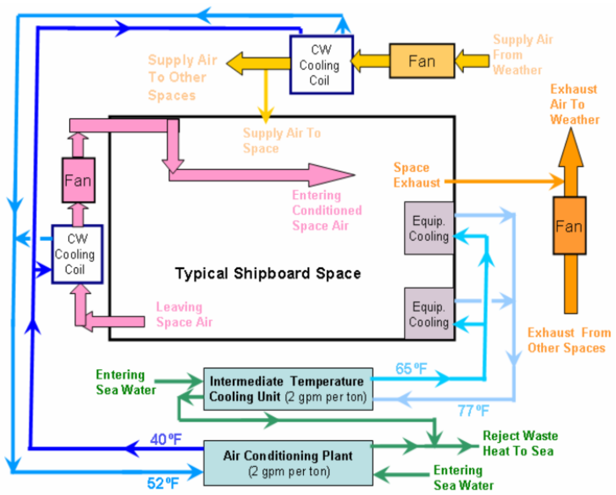

Fig. 4.2. HVAC operation [8].

5. MACHINERY SPACES VENTILATION

5.1. Machinery spaces configuration

Each of the engine compartments (Forward Diesel Generator Space, Aft Diesel Generator Space, Forward Gas Turbine Space, Aft Gas Turbine Space) are ventilated with two supply fans and two exhaust fans. When the special ship is weathertight against the contaminated atmosphere, the air in the engine compartments is recirculated by means of chilled water coolers for air-induction fans. The extraction capacity is greater than the air intake capacity in the machine compartments in order to ensure smoke and gas extraction in the compartments and to cool off the gas discharge routes (inlet capacity: 11530 $\left[\frac{m^3}{h}\right]$, exhaust capacity: 13250 $\left[\frac{m^3}{h}\right]$).

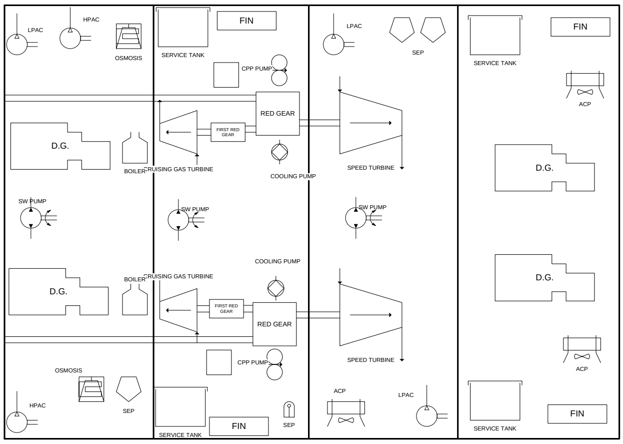

Fig. 5.1. Machinery spaces configuration for special ships.

Coolers of machinery spaces should be insulated and drained as needed. The system must be ventilated during coolers recharging.

The machinery spaces ventilation must be reduced sufficiently in order to maintain an ambient temperature above 2 [ºC].

In the NBC atmosphere, the machinery spaces will be contaminated with gas and the area will become a contaminated one. Before starting the intake fans, the intake galleries must be drained by the water that has accumulated during spraying of the ship with the sprinkler.

Machine room exhausts are also used to cool out gas routes for engines and turbines.

The turbine modules are ventilated by a separate natural ventilation system that uses the depression in the turbine suction galleries to maintain a cooling air flow for the mode when the turbines are in operation.

All fans mounted in machinery spaces are of the axial type with constant flow and vertical position. The upper end of the fan is provided with a screen to protect foreign objects that may enter.

The rainwater infiltration shutters are fitted to all the openings in the deck for ventilation. At the top of the vessel, the ventilation openings are provided with hinged caps, except for openings for ventilation of turbine modules.

In a contaminated atmosphere, the air of the machinery is evacuated by means of air valves that open when the internal pressure is more than half the atmospheric pressure.

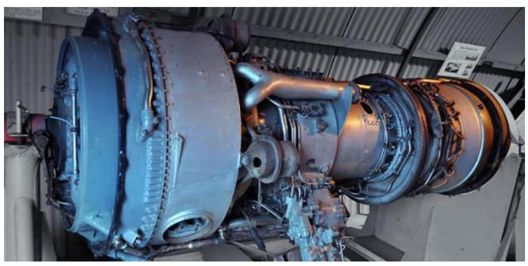

Fig. 5.2. Rolls Royce Tyne RM1C gas turbine [11]..

We will consider a machine compartment for a special ship equipped with two Rolls Royce Tyne RM1C turbines.

The characteristics of the reference engine are as follows:

– effective power: 2 x 4500 = 9000 [kW];

– specific fuel consumption: 0.260 $\left[\frac{\text{kg}}{\text{kWh}}\right]$;

5.2. Air flow calculation for cruising gas turbines compartment

Specific air flow for gas exchange:

$$d_{asg} = m_{tsg} \cdot \alpha_{sg} \cdot C_e \left[\frac{\text{kg air}}{\text{kWh}}\right] \quad (5.1)$$

where:

– m_{tsg} = 14.2 $\left[\frac{\text{kg air}}{\text{kgcomb}}\right]$ - theoretical air mass needed for burn of one fuel kilogram;

– α_{sg} = 1.8 - excess air coefficient for gas exchange;

– C_e = 0.260 $\left[\frac{\text{kg comb}}{\text{kWh}}\right]$ - specific fuel consumption;

$$d_{asg} = 14.2 \cdot 1.8 \cdot 0.260 = 6.64 \left[\frac{\text{kg air}}{\text{kWh}}\right] \quad (5.2)$$

Specific air flow needed for ventilation:

$$d_{av} = 2 \cdot d_{asg} = 13.29 \left[\frac{\text{kg air}}{\text{kWh}}\right] \quad (5.3)$$

Mass Air Flow for Ventilation:

$$\dot{D}_{av} = 2 \cdot d_{asg} \cdot P_e = 119620.8 \left[\frac{\text{kg air}}{\text{h}}\right] \quad (5.4)$$

Volumetric Air Flow for Ventilation:

$$\dot{V}_{av} = 2 \cdot \frac{d_{asg}}{\rho_a} \cdot P_e = 108845.1 \left[\frac{\text{m}^3_{\text{air}}}{\text{h}}\right] \quad (5.5)$$

6. VENTILATION FLOW SIMULATION IN MACHINERY SPACES

Ansys offers a complete range of simulation solutions, engineering kits offer almost any field of simulation engineering, and a pre-rendering machine is required.

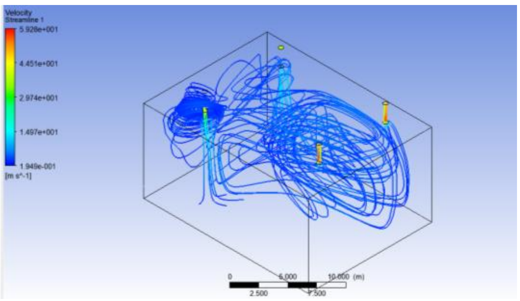

Fig. 6.1 Air velocity – Ansys CFX – 25 points [4].

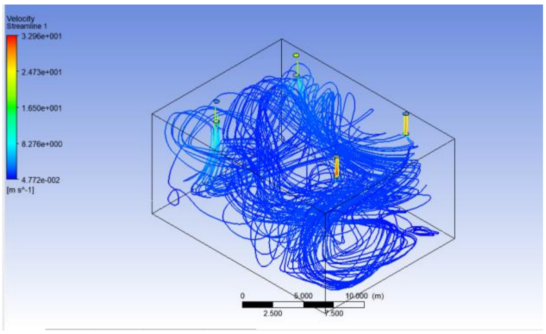

Fig. 6.2 Air velocity – Ansys CFX – 40 points [4]

7.CONCLUSIONS

The introduction of air into these rooms may be natural. In certain well-justified cases, with the permission of the register, ventilation may be allowed by artificially introducing air and natural extraction provided that all entries into the accommodation spaces, machinery and service spaces (including stairwells and lifts) to be equipped with facilities to prevent the penetration of dangerous vapors and gases.

Through studies and researches, psychrometric templates and graphs were established to establish optimal air parameters for the compartments of the ship. These graphs allow us to determine the optimum air quality in the compartments so that the maximum comfort index is reached.

In order to eliminate thermal flows in the compartments of the ship, it is necessary to calculate the following:

– calculation of the air flow introduced into air-conditioned compartments;

– calculation of the air flow extracted from the crew compartments;

– calculation of the airflow required to evacuate the heat flow from the engine compartments.

To optimize the energy utilization required for air entrainment fans must consider the warm drive machine works, number of motors running all the while, the quantity of steam boilers in operation at the same time.

Ambient conditions require adjusting the air flow which ventilates the engine room and supplies the necessary air for engines, and engine room air temperature control.

8. REFERENCES

[1] American Bureau of Shipping, *Crew habitability on ships*, February 2016;

[2] ANSI/ASHRAE Standing Standard Project Committee, *Ventilation for Acceptable Indoor Air Quality*, 2007;

[3] Serbanescu, I, *Consideration Regarding Maritime Ship Engine Room Ventilation System*, January 2016;

[4] ISO 7547, *Ships and marine technology — Air-conditioning and ventilation of accommodation spaces — Design conditions and basis of calculations*, 01.09.2002;
[5] ISO 8861, *Engine room ventilation in diesel-engined ships*, January 2001;
[6] Lloyd's Register, *Military Design and Special Features*, January 2015;
[7] NATO Standard, *Naval Ship code*, April 2017 – NATO Standardisation office;
[8] Naval Surface Warfare Center Carderock Division, *21 Century HVAC System for Future Naval Surface Combatants – Concept Development Report* , USA, September 2007;
[9] *https://forum.keypublishing.com;*
[10] *https://forum.worldofwarships.eu;*

Despre autori

Ing. drd. **Octavian Narcis VOLINTIRU**
Academia Navală Mircea cel Bătrân Constanța

Absolvent al Academiei Navale „Mircea cel Bătrân", promoția 2009, În prezent șef mecanic la fregata „Regina Maria" și cadru didactic asociat. Domenii de competență: Inginerie electromecanică, Analiza software Ansys.

Prof. univ. dr. ing. **Anastase PRUIU**
Academia Navală Mircea cel Bătrân Constanța

Absolvent al Universității „Politehnica" București/ Facultatea de mecanică/Secția mașini termice, promoția 1974, doctor inginer din anul 1993. În prezent, Profesor universitar: Academia Navală „Mircea cel Bătrân". Domenii de competență: Analiza proceselor termodinamice în mașini și instalații frigorifice; determinarea parametriilor funcționali nominali și de exploatare ai mașinilor și instalațiior frigorifice; determinarea fluxurilor energetice și a bilanțurilor energetice; dimensionarea mașinilor și instalațiilor frigorifice, Mecanică teoretică; rezistența materialelor; organe de mașini; termotehnică; motaoare cu ardere internă; cazane de abur; turbine cu abur; turbine cu gaze; transmisia căldurii; schimbatoare de căldură; mecanica fluidelor; instalații frigorifice.

Șef lucr. dr. ing. **Ionuț Cristian SCURTU**
Academia Navală Mircea cel Bătrân Constanța

Absolvent al Academiei Navale „Mircea cel Bătrân", promoția 2010, doctor inginer din anul 2015. În prezent, șeful Biroului Tehnico-administrativ cercetare științifica al: Academiei Navale „Mircea cel Bătrân" și cadru didactic asociat. Domenii de competență: Analiza CFD software Ansys, Analiză software structuri mecanice, dinamica structurilor plutitoare, construcția navelor.