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Contributions to the study of functional parameters in exploitation of the heat, ventilation and air conditioning system for special ships

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Abstract. Under normal operating conditions, as a result of heat gains onboard ships from engine rooms and crew, the increase in humidity as well as due to the various releases of gases from onboard systems, room air deteriorates, requiring replacement and its processing through the HVAC (heat, ventilation and air conditioning) system. Another feature of the HVAC system for special ships is operating under heavy conditions such as CBRN tightness where operating parameters record extreme values in cooling engine rooms. In the paper, I will present contributions to the study of functional parameters in exploitation of the HVAC system on board special ships under different load operating conditions.

Keywords: HVAC, special ships, engine room, ventilation, heat, air conditioning

1. Introduction
For special ships, the heating, ventilation and air conditioning system is complex, vital and of large size, impacting each compartment of the ship. The HVAC system is divided into zones and is integrated with the chilled water system of the ship. In the figure below is represented the HVAC system schematic for a military ship.

At the same time, the heating, ventilation and air conditioning system can also be used to cool the engine rooms by opening intermediate flaps when the ship is in a tight condition.

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{Figure1.png}
\caption{HVAC system divided into zones [2]}
\end{figure}
2. Auxiliary engine room for special ships
Each of the engine rooms (Forward Auxiliary Machinery Room, Aft Auxiliary Machinery Room, Forward Engine Room, Aft Engine Room) are ventilated with 2 supply fans and 2 exhaust fans. When the special ship is weathertight against the contaminated atmosphere, the air in the engine rooms is recirculated through chilled water coolers by supply fans. At the same time, cold air can be introduced directly from the inside of the ship via flaps. The extraction capacity is greater than the air intake capacity in the machine rooms in order to ensure smoke and gas extraction and to cool the exhaust gas gallery (for F.A.M.R. compartment: intake capacity with 2 supply fan of $28746 \frac{m^3}{h}$, extraction capacity with two exhaust fan of $32716 \frac{m^3}{h}$).

The Forward Auxiliary Machinery Room (F.A.M.R.) comprises the following aggregates:

- 2 Paxman Ventura diesel generators;
- 2 air conditioning plants;
- 2 fin stabilizers.

![Figure 2. Special ship engine rooms](image)

2.1. Paxman Ventura 16YJ diesel generator
Design of the first Paxman Ventura engine started in 1958, leading on to the engine's launch in 1960. Type 22 frigates had onboard four 16 cylinder Paxman Venturas for electrical power. Paxman Ventura engines were used for fast patrol boats of the Royal Australian Navy. Also, the engines were used for rail traction.

![Figure 3. Paxman Ventura diesel generator](image)
Table 1. Diesel engine characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cylinder number</td>
<td>16 V</td>
</tr>
<tr>
<td>Diesel engine max power</td>
<td>1000 [kW]</td>
</tr>
<tr>
<td>Nominal speed</td>
<td>1200 [rpm]</td>
</tr>
<tr>
<td>Weight</td>
<td>8910 [kg]</td>
</tr>
<tr>
<td>Length with generator</td>
<td>5000 [mm]</td>
</tr>
<tr>
<td>Width</td>
<td>1800 [mm]</td>
</tr>
<tr>
<td>Height</td>
<td>2500 [mm]</td>
</tr>
</tbody>
</table>

2.2. Energy balance for Paxman Ventura diesel generator
For one Paxman Ventura diesel generator we have formulas for heat flux:

\[ Q_{\text{rad}} = (0.02 \ldots 0.04) \cdot \dot{Q}_d [kW] \]  \hspace{1cm} (1)

\[ \dot{Q}_d = \frac{1}{\eta_e} \cdot P_e = \frac{1000}{0.45} = 2222 [kW] \]  \hspace{1cm} (2)

\[ Q_{\text{rad}} = 0.03 \cdot 2222 = 66.66 [kW] \]  \hspace{1cm} (3)

- \( Q_{\text{rad}} \) - radiant heat flux;
- \( \dot{Q}_d \) - dissipated heat flux;
- \( P_e \) - engine effective power;
- \( \eta_e \) - effective efficiency.

2.3. Air flow calculation for Forward Auxiliary Machinery Room
Mass air flow calculation for engine room:

\[ Q_{\text{rad}} = \dot{m}_{\text{air}} \cdot c_{\text{air}} \cdot \Delta t [kW] \]  \hspace{1cm} (4)

\[ \dot{m}_{\text{air}} = \frac{Q_{\text{rad}}}{c_{\text{air}} \cdot \Delta t} \left[ \frac{Kg_{\text{air}}}{s} \right] \]  \hspace{1cm} (5)

- \( \dot{m}_{\text{air}} \left[ \frac{Kg_{\text{air}}}{s} \right] \) - air masis flow;
- \( c_{\text{air}} = 1 \left[ \frac{Kf}{Kg_{\text{air}}} \right] \) - specific air heat;
- \( \Delta t = [5 \ldots 10] [K] \) - temperature difference.

\[ m_{\text{air}} = \frac{66.66}{17} \left[ \frac{Kg_{\text{air}}}{s} \right] \]  \hspace{1cm} (6)

\[ m_{\text{air}} = 9.52 \left[ \frac{Kg_{\text{air}}}{s} \right] \]  \hspace{1cm} (7)
Volumic air flow calculation for engine room

\[ \rho = \frac{P}{RT} \]  

(8)

\[ \rho = \frac{100}{0.286 \cdot 300} \]  

(9)

\[ \rho = 1.16 \frac{[Kg_{air}]}{m^3} \]  

(10)

- \( P \left[ \frac{KN}{m^2} \right] \) - air pressure;
- \( R = 0.286 \left[ \frac{KJ}{KgK} \right] \) - gas constant;
- \( T = 300 \left[ K \right] \) - air temperature;
- \( \rho = 1.16 \left[ \frac{Kg_{air}}{m^3} \right] \) - air density.

\[ \dot{V} = \frac{m_{air}}{\rho} \]  

(11)

\[ \dot{V} = \frac{9.52}{1.16} \]  

(12)

\[ \dot{V} \] = 8.20 \left[ \frac{m^3}{s} \right]  

(13)

Volumic air flow calculation for engine room fan:

\[ P_{fan} = \frac{\dot{V} \cdot \Delta P}{\eta_{fan}} \left[ kW \right] \]  

(14)

\[ \Delta P = \frac{80 \cdot 100}{10200} = 0.78 \left[ \frac{KN}{m^2} \right] \]  

(15)

\[ \dot{V} = \frac{0.75 \cdot 9}{0.78} = 8.65 \left[ \frac{m^3}{s} \right] \]  

(16)

- \( P_{fan} \) = 9 \left[ kW \right] - fan effective power;
- \( \dot{V} \) - volumic air flow;
- \( \eta_{fan} = [0.65...0.75] \) - fan efficiency;
- \( \Delta P \) - pressure difference.

Figure 4. Paxman Ventura diesel generator ventilation diagram
3. **Ventilation cooling simulation in machinery space**

Ansys offers a complete range of simulation solutions, engineering kits offer almost any field of simulation engineering, and a pre-rendering machine is required. For simulate ventilation system working for engine room was used a machinery space geometry of $L \times l \times h = 9 \times 15 \times 6 \ [m]$.

![Paxman Ventura heat diagram](image)

**Figure 5.** Paxman Ventura diesel generator heat diagram

![Forward Auxiliary Machinery Room – Ansys geometry](image)

**Figure 6.** Forward Auxiliary Machinery Room – Ansys geometry

![Air velocity in the machinery room](image)

**Figure 7.** Air velocity in the machinery room

![Temperature contour for diesel generators](image)

**Figure 8.** Temperature contour for diesel generators
Ansys simulation gave the following values:

- air velocity in machinery room: from 0 to 0.774 m/s;
- temperature contour for diesel generators: from 289.98 to 346.48 [K];
- temperature contour for machinery room: from 290 to 328.48 [K].

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

- calculation of the airflow introduced into engine compartments;
- calculation of the airflow extracted from engine compartments;
- the calculation of the airflow required to evacuate the heat flow from the engine rooms.

To improve the energy usage required for air supply fans must consider the heaviness of warm drive machine works, to be specific the number of engines to run at the same time and the amount of steam boilers burners running at the same time.

The Ansys software displayed all information results from physical data to related calculations identified with geometry, mesh and mesh quality in order to give a large vision for HVAC simulation for ship machinery rooms. Ambient conditions require adjusting the airflow which ventilates the engine room and supplies the necessary air for engines, and engine room air temperature control.

References
[4] Lloyd’s Register – Military Design and Special Features, January 2015;