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# Naval vessels microclimate investigation. Microclimate parameters measurement on the river minesweeper - RML336

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**An important objective for the vessel owners is to minimize operating costs by decreasing energy consumption for the interior space heating, ventilation and air-conditioning. The rationalization of energy consumption for these purposes and energy efficiency improvement has high priority in many countries. Some results of the experimental investigation and microclimate parameters measured on the river minesweeper - RML336 have been presented and analyzed. An original experimental approach for determining the microclimate parameters and complex heat consumption in the naval vessels presented here contributes to better understanding and estimating the prospects for energy saving.**

*Key words*: **ship,battle ship, air-conditioning, microclimate, heating, ventilation, energy efficiency.**

## Introduction

IN the field of investigation of microclimate on naval vessels [1-3], experimental measurements of the microclimate parameters were executed on the vessel RML336, over a period of time, i.e. November 09-30, 2004 on Ušće in Belgrade.

The experiment was executed in real conditions and heating regime in the period planned for vessel and objects use on Ušće in Belgrade.

The main objectives of the executed measurement were:

- evaluation of the thermal comfort [5-10] and indoor microclimate parameter changes in the winter conditions,
- evaluation of the heating and ventilation installations state
- energy efficiency improvement
- rational use of the energy resources
- acquiring and improvement of the scientific knowledge [11-14], etc.

Moreover, one of the investigation objectives is to use the acquired knowledge in the future to minimize experimental efforts, accompanied by insufficient amount of measurement results which will be compensated with adequate mathematical tools to avoid mistakes due to the lack of appropriate experiences.

## Vessel description

River minesweeper - RML336 (vessel), Fig.1, is designed for detection and destroying of mines in the rivers, lakes and channels. Furthermore, the vessel is capable of barricading navigable ways with mines. It is composed entirely of welded aluminum.

Main dimensions of the vessel, length/width/height are 27/6,50/2,70m. Draught of the vessel is 1,10/1,20m and power of the marine engines are 2x195kW.

Thermo insulation structure of the vessel consists of: **upper walls structure** - aluminum plate (4mm), air layer (60mm), polyurethane (25mm) and interior plate (3mm); **deck -** aluminum plate (4mm), air layer (60mm), polyurethane (25mm) and interior plate (3mm); **flange** - aluminum plate (4mm), air layer (150mm), polyurethane (25mm) and interior plate (3mm); **curtain walls in the upper structures -** aluminum plate (4mm), polyurethane (25mm) and aluminum plate (4mm); **curtain wall to the machine room** - aluminum plate (4mm), mineral wool (60mm) and aluminum plate (4mm).


**Figure 1.** River minesweeper - RML336

In order to ensure good thermo-enviromental conditions for humans occupying it, the vessel has incorporated:

- System for interior space heating using equipment for heating by hot air
- Mechanical ventilation system of the interior space
- Ventilation system of the marine engines room.

**System for interior space heating using equipment for heating by hot air,** illustrated in Fig.2, consists of two

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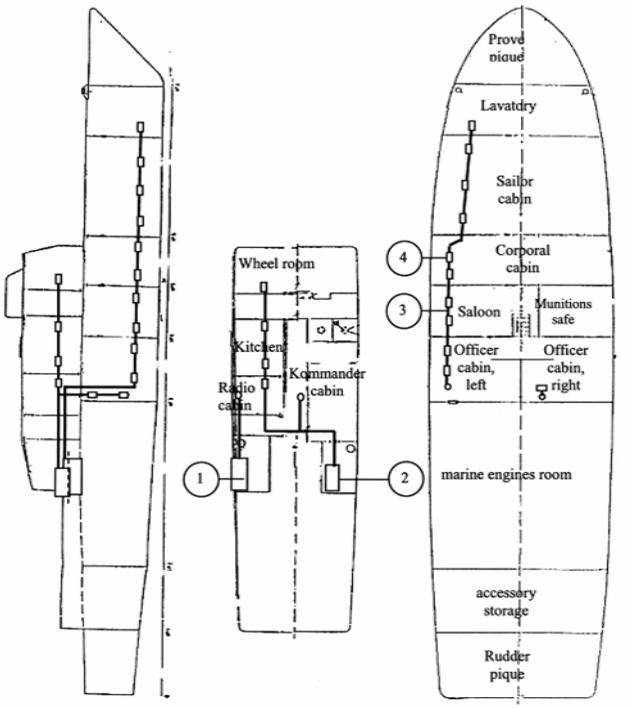
JUGO-WEBASTO units [4] incorporated in the marine engines room and connected by two separated ducts. The ducts have outlet openings, situated in the cabins - rooms.




*JUGO-WEBASTO - type 125GH, JUGO-WEBASTO - type 95 GV, Duct, Outlet openings*

**Figure 2**. System for interior space heating by equipment for heating by hot air

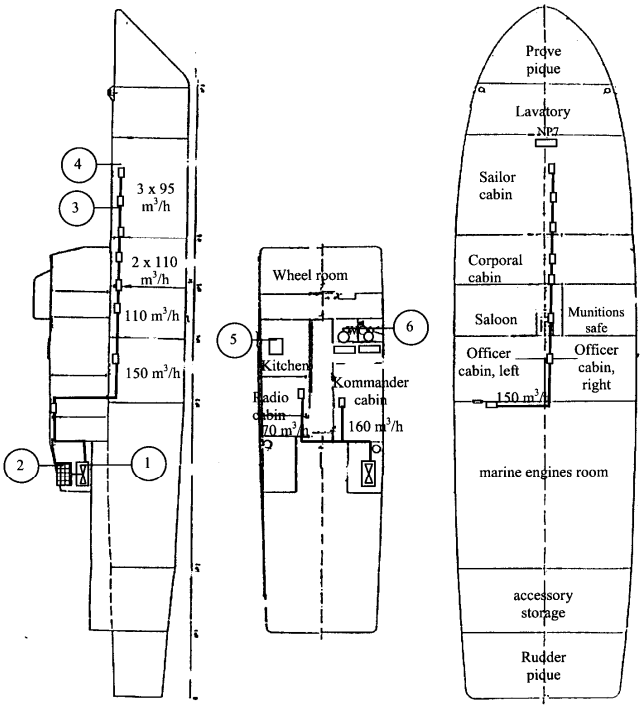
The equipment for heating by hot air, JUGO-WEBASTO - type 125GH (heat power of 14,5/10,5kW; hot air flow of 500m$^3$/h) [4], Fig.2, is connected by ducts for heating by hot air with these rooms - cabins in the hull: officer cabin – left, saloon, corporal cabin, sailor cabin and lavatory.

The equipment for heating by hot air, JUGO-WEBASTO - type 95GV (heat power of 11/8,5kW; hot air flow of 500m$^3$/h) [4], Fig.2, is connected by ducts for heating by hot air with these rooms - cabins in the upper part of the craft: commander cabin, radio cabin, kitchen, officer cabin in the hull – right and wheel room.

This equipment works only with constant hot air flow (only exterior air) and two constant heating sources (full/partial), i.e, not without adequate regulation.

**Figure 3.** Part of the room heating system - Duct with outlet opening in the sailor cabin

**Figure 5.** Ventilation opening with air flow regulation in the corporal cabin




1. Fan
   - Manufacture: Ventilator Zagreb
   - Type: Novent, 139-2780
   - Capacity: Q=1260 m$^3$/h
   - Static pressure: $p_{st}$=90 mmWC
   - Weight: 27 kg
2. Inlet opening
3. Ventilation duct
4. Ventilation opening with airflow regulation
5. Ventilation cover
6. Outlet air equipment

**Figure 4.** Mechanical ventilation system of the interior space

Mechanical ventilation system of the interior space is illustrated in Fig.4.

On the overpressure ducts of the mechanical ventilation system there are outlet openings with airflow regulation, Fig.5. The designed air velocity behind the opening is maximum 5m/s. Mechanical ventilation systems work without thermal treatment of the air.

All the sanitary rooms in the upper part of the vessel have natural ventilation through outlet air equipment.

The kitchen also has natural ventilation through the ventilation cover on the roof.

The designated air quantity of the vessel rooms according to the scheme given in Fig.4 is shown in Table 1.

**Table 1.** Designated air quantities of the vessel rooms

| Number of the room | Name | Air quantity (m3/h) Total in room |
|---|---|---|
| 1.1 | Radio cabin | 70 |
| 1.2 | Kitchen | Natural |
| 1.3 | Wheel room | Natural |
| 1.4 | Commander room | 160 |
| 0.1 | Officer cabin | 300 |
| 0.2 | Saloon | 110 |
| 0.3 | Corporal cabin | 220 |
| 0.4 | Sailor cabin | 285 |
| TOTAL (mechanical ventilation) | | 1145 |

For **marine engines room ventilation** the following systems are applied:

- during the sailing regime, special equipment for wind capture is used,
- during the non-sailing regime, two fans with nominal airflow of 1150m$^3$/h per fan are used.

Air quantity needed for the marine engines room passes through the openings (400x600mm) located on the outsides of the upper structure of the vessel. The openings have removeable covers on the outside.

On the inner parts of the openings metal plates are located to direct the air flow and prevent the light passing from marine engines room outwards.

The designed air velocity in the marine engines room is 2m/s max.

The vessel is not equipped for flirtation of the exterior air contamination, namely, it does not incorporate equipment for collective **Nuclear Biological Chemical (NBC) Protection**.

For crew protection, facilities of the personal NBC protection are planned.

There is no equipment for irrigation for the purpose of contamination reduction and primary decontamination of the outsides surfaces of the vessel. Equipment for irrigation is also partaking in the heat signature mutation in the IR (Infra Red) zone of the electromagnetic radiation.

## Description of the measurements and results analysis

A data acquisition system (Hewlett-Packard), Fig.6, was used to couple the sensors and a computer, where the signals were sampled, pre-calculated, and finally recorded.

**Figure 6.** Data acquisition system

Solar radiation was measured by Solarimeter, manufactured Adolph Thies, Germany, with spectral range 0,3$\mu$m – 2,5$\mu$m. The outside air velocity was measured by instrument for air velocity and temperature measuring - type 1650, produced by TSI, USA. For the air humidity and temperature measurement a hygro - thermometer manufactured by Adolph Thies, Germany was used. Other temperature measurements were performed using Pt100 thermometers, manufactured by Heraus, Germany and thermocouples manufactured by Philips, Holland.

**Figure 7.** Location of the solarimeter for the solar radiation measurement and hygro-thermometer for exterior air humidity and temperature measurement

Total measuring period was November 09-30, 2004. However, the period presented in the figures is November 26-30, 2004.

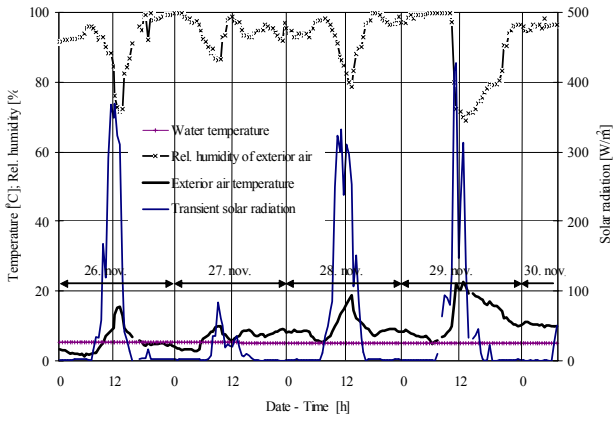



**Figure 8.** Changes of the solar radiation on the horizontal plane, temperature and relative humidity of the exterior air and water temperature

Fig.8 presents daily changes of the solar radiation on the horizontal plane, temperature and relative humidity of the exterior air and changes of the water temperature for the measured period. Water temperature changes of the Danube effluent (Ušće in Belgrade) was negligible on daily and weakly basis and water temperature decreased slightly from 5,2$^o$C to 5$^o$C, for the measured period.

Figures 9 - 12 depict changes of the relative humidity and temperature changes in the specified cabins - rooms.

Measurement was done for real conditions of the vessel usage over the planned period. The vessel was used daily within working hours, between nine and two o'clock. The

crew performed their normal duties according to plan.

When the heating was on, the relative humidity in the heated rooms was ranging from 40% to 60%. When heating was not operating, relative humidity in the rooms was above 60%.

Microclimate in all the rooms - cabins is characterized by a significant temperature and relative humidity differences between rooms. Also, within the rooms significant fluctuations of temperature occur, differing per different beds and also in vertical direction. The absence of the adequate thermoregulation in rooms and consequently in the vessel, causes overheating (above the designated temperature of 21°C, [8]) of the interior space and significant energy dissipation. In some rooms the temperature was approximated to 30°C and more.

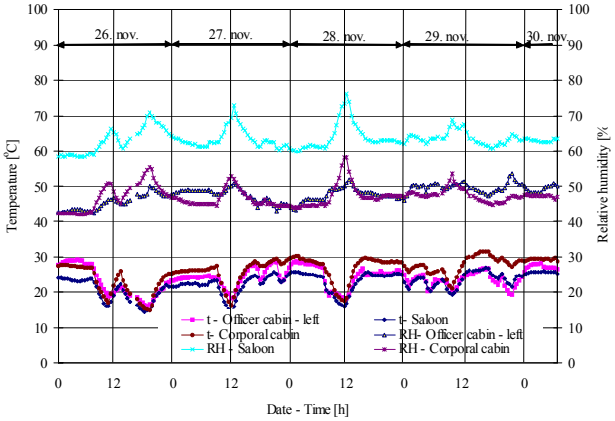



**Figure 9.** Changes of the relative humidity and interior air temperature in the specified rooms - cabins in the hull of the vessel.

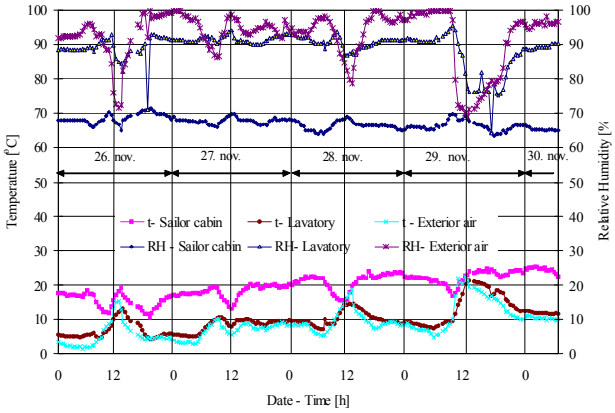



**Figure 10.** Changes of the exterior air relative humidity and temperature and changes of the interior air relative humidity and temperature in the specified rooms - cabins in the hull of the vessel.

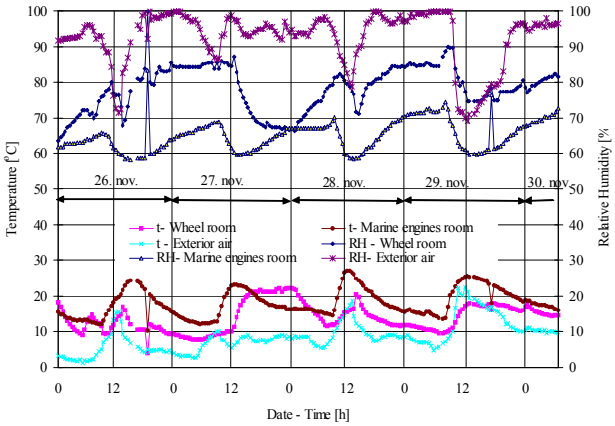



**Figure 11.** Changes of the exterior air relative humidity and temperature and changes of the interior air relative humidity and temperature in the wheel room and marine engines room

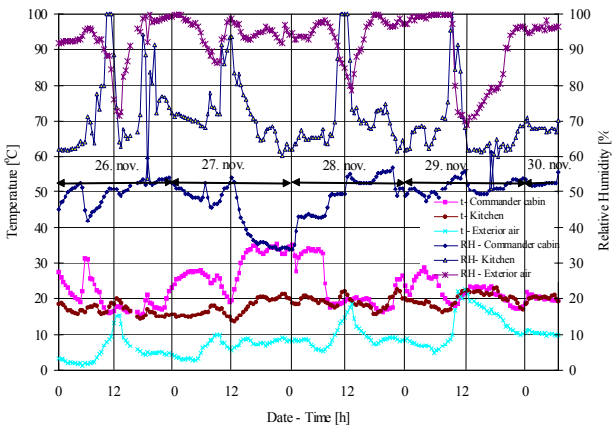



**Figure 12.** Changes of the exterior air relative humidity and temperature and changes of the interior air relative humidities and temperatures in the commander cabine and kitchen

## Conclusion

An important objective for the vessel owners is to minimize operating costs by decreasing energy consumption for the interior spaces heating, ventilation and air-conditioning. The rationalization of energy consumption for these purposes and improving energy efficiency has high priority in many countries. It is crucial to understand that improving energy efficiency is a continuous process that requests organized, systemized and systematic approach from all the participants. Being more energy efficient means to live, work and operate in the same or improved conditions but with lower energy consumption.

The presented experimental approach in determining micro-clime parameters and complex heat consumption in the naval vessels contributes to better understanding and estimating the possibility of energy saving. A more sophisticated control strategy design can be based on either simple, instantaneously measured data or on complex, predictive algorithms that estimate the energy consumption.

The vessel structure, incorporated equipment for heating, ventilation and air-conditioning and the modality of the equipment and vessel usage, play an important role in energy consumption.

By modifying the heating and ventilation systems and microclimate parameters regulation it is possible to achieve significant energy saving, i.e. to improve the living and working conditions for crew but with lower energy consumption. Modification should be performed after experimental measurements with the microclimate parameter changes for the vessel use in the summer period and eventually incorporate the air-conditioning system.

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# Istraživanje mikroklime na plovnim objektima. Merenje parametara mikroklime na objektu - RML 336

**Važan cilj vlasnika plovnih objekata je da smanje troškove upotrebe broda smanjenjem potrošnje energije za grejanje, ventilaciju i klimatizaciju. Racionalizacija potrošnje energije u te svrhe i povećanje energetske efikasnosti ima visok prioritet u mnogim zemljama. U radu je prikazan deo rezultata eksperimentalnih istraživanja i merenja parametara mikroklime na rečnom minolovcu - RML336. Prikazani originalni eksperimentalni pristup određivanju parametara mikroklime i kompleksnoj potrošnji energije u vojnim brodovima doprinosi boljem razumevanju i određivanju moguće uštede energije.**

*Ključne reči:* **brod, vojni brod, klimatizacija, mikroklima, grejanje, ventilacija, energetska efikasnost.**

# Исследование микроклимата на судоходных объектах. Измерение параметров микроклимата на речном судне - РМЛ 336

**Очень важной целью собственников судоходных объектов является уменьшение расходов при пользовании судна уменьшением потребления энергии для обогрева, вентиляции и кондицировании воздуха. Рационализация потребления энергии с такой целью и увеличение энергетической производительности отличаются высоким приоритетом во многих странах мира. В настоящей работе приведена часть результатов экспериментальных исследований и измерений параметров микроклимата на речном судне - РМЛ 336. Приведённый оригинальный экспериментальный подход к определиванию параметров микроклимата и ко комплексным расходам энергии во военных суднах приводит к лучшему пониманию и определению возможного сбережения энергии.**

*Ключевые слова*: **судно, военное судно, кондицирование воздуха, микроклимат, обогрев, вентиляция, энергетическая производительность.**

# Investigation du microclimat sur les vaisseaux navaux. Mesurement des paramètres sur le dragueur de mines fluvial RML 336

**L'objectif important des propriétaires des vaisseaux est de réduire les frais de leur utilisation en diminuant la consommation de l'énergie pour le chauffage, la ventilation et la climatisation. La rationalisation de la consommation énergétique ŕ ces effets et l'augmentation de l'efficacité énergétique sont prioritaires dans de nombreux pays.Dans ce travail on a présenté une partie de résultats des essais expérimentaux ainsi que les mesurements des paramčtres du microclimat sur le dragueur de mines fluvial – RML 336. L'originalité de l'approche expérimentale démontré dans la détermination des paramčtres du microclimat et la consommation complexe de l'énergie chez les vaisseaux contribue ŕ une meilleure compréhension et l'estimation des possibilités ŕ l'égard de l'épargne d'énergie.**

***Mots clés*: vaisseau, navire de guerre, climatisation, microclimat, chauffage, ventilation, efficacité énergétique.**