ABOUT RELATING TO THE RECOVERY OF ENERGY FLOWS FROM THE EXHAUST GASES FROM MARINE ENGINES

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Abstract: *In this paper are presented the main IMO regulations requiring energy management, the main possibilities for recovery of energy flows from the exhaust gases from marine engines and reducing CO2 production, based on the study of bibliography and teaching experience on board ships*
Keywords: *Energy efficiency, energy flow.*

INTRODUCTION.

For commercial ships over 400 GRT tonnage since 1 January 2013 shall be compulsory in international energy efficiency certificate (IEEC). The condition imposed is a result of the Kyoto Protocol on the reduction of CO2 in the production of energy in installations that consume liquid and gaseous fuels, renewable by 2020 States of the United Nations Convention on climate change, in Doha. International Association of Classification Societies (IACS) must approve the design and supervise the construction of ships in accordance with the taxation of the IEEC, and for ships in service, redesign and alterations in energy facilities to implement the IEEC. By international law is an indicator of the output of CO2 design Index called energy efficiency (EEDI) is recommended for and limited to the type of ship, tonnage and types of cargo carried. In this paper are presented some highlights of the legislation on the international shipping and an application for a plant to recover energy flows created by the combustion gases from a propulsion engine. The form and content of the study can be used for designing and carrying out energy balance on the ship where the transducers are installed the main parameters of thermodynamics. According to the scheme in principle of the plant, it follows that the only CO2 production is given to fuel consumption of engine propulsion based on operational load required by the conditions of navigation.

Functional parameters

Table 1

Nr. crt	Parameter	Nominal operating conditions	Operating conditions of exploitation
1	Specific fuel consumption $\left[\frac{kg_{cb}}{kWh}\right]$	$c_{e\ n}$	$c_{e\ exp}$
2	Theoretical required air mass of 1 kg fuel combustion $\left[\frac{kg_{cb}}{kg_{cb}}\right]$	$m_{aer\ min}$	$m_{aer\ min}$
3	The coefficient of excess air for gas exchange $[-]$	$\alpha_{sg\ n}$	$\alpha_{sg\ exp}$
4	Specific air flow for gas exchange $\left[\frac{kg_{aer}}{kWh}\right]$	$d_{a\ n}$	$d_{a\ exp}$
5	Specific gas flow $\left[\frac{kg_{gaze}}{kWh}\right]$	$d_{g\ n}$	$d_{g\ exp}$
6	Effective power of engine $[kW]$	$P_{e\ n}$	$P_{e\ exp}$
7	Flow massic of air for gas exchange $\left[\frac{kg_{aer}}{s}\right]$	$\dot{m}_{a\ n}$	$\dot{m}_{a\ exp}$
8	Gas flow massic $\left[\frac{kg_{g}}{s}\right]$	$\dot{m}_{g\ n}$	$\dot{m}_{g\ exp}$

Calculation parameters:
Poz 4 by table 1

$$d_a = c_e \cdot d_{s\,g} \cdot m_{aer\ min} \left[\frac{kg_{aer}}{kWh}\right] \quad (1)$$

Poz5 by table1 $d_g = c_e + d_a = c_e(1 + d_{s\,g} \cdot m_{aer\ min}) \left[\frac{kg_{gaze}}{kWh}\right]$ (2)

Poz 7 by table 1 $\dot{m}_a = \frac{d_a \cdot P_e}{3600}\left[\frac{kg_{aer}}{s}\right]$ (3)

Poz 8 by table 1 $\dot{m}_g = \frac{d_g \cdot P_e}{3600}\left[\frac{kg_{gaze}}{s}\right]$ (4)

Functional parameters

Table 1

Nr. crt	Parameter	Nominal operating conditions	Operating conditions of exploitation
9	Gas temperature at the entrance of the supercharging turbine $[°C]$	$t_{A\ n}$	$t_{A\ exp}$
10	The gas temperature entering the gas turbine electric generator $[°C]$	$t_{A\ n}$	$t_{A\ exp}$
11	The temperature of the exhaust gases from the gas turbines of turbocharger aggregates $[°C]$	$t_{B\ n}$	$t_{B\ exp}$
12	The temperature of the exhaust gases from the gas turbines electrical generator $[°C]$	$t_{C\ n}$	$t_{C\ exp}$
13	The temperature of the exhaust gases from the gas turbines and the entrance of the boiler recovery $[°C]$	$t_{D\ n}$	$t_{D\ exp}$
14	Exhaust gas temperature after HP steam superheated	$t_{E\ n}$	$t_{E\ exp}$
15	Energy flow in gas turbines aggregates turbocharger [kW]	$\dot{Q}_{gnTGSA}$	$\dot{Q}_{gexpTGSA}$
16	Energy flow in gas turbine to electric generator [kW]	$\dot{Q}_{gnTGGE}$	$\dot{Q}_{gexpTGGE}$
17	Energy flow in gas superheated steam HP [kW]	$\dot{Q}_{gnSIHP}$	$\dot{Q}_{gexpSIHP}$
18	Exhaust gas temperature after the evaporator HP $[°C]$	$t_{F\ n}$	$t_{F\ exp}$
19	Energy flow in gas evaporator HP [kW]	$\dot{Q}_{gnVHP}$	$\dot{Q}_{gexpVHP}$
20	Exhaust gas temperature after the superheat steam LP $[°C]$	$t_{G\ n}$	$t_{G\ exp}$
21	Energy flow in gas superheated steam LP [kW]	$\dot{Q}_{gnSILP}$	$\dot{Q}_{gexpSILP}$
22	Exhaust gas temperature after the evaporator LP $[°C]$	$t_{H\ n}$	$t_{H\ exp}$
23	Energy flow in gas evaporator LP [kW]	$\dot{Q}_{gnVLP}$	$\dot{Q}_{gexpVLP}$
24	The maximum energy transferred to the gas recovery boiler [kW]	$\dot{Q}_{gn\ maxCR}$	$\dot{Q}_{gexpmaxCR}$

Poz 15 by table 1

$$\dot{Q}_{gTGSA} = \dot{m}_g \cdot c_g \cdot (t_A - t_B)[kW] \quad (5)$$

Where$c_g\left[\frac{kJ}{kg\cdot grd}\right]$ - specific heat of gases

In the turbocharger $Q_{TGSA}\cdot\eta_{TG}=\frac{\dot{Q}_{aerSA}}{\eta_K}$ (6)

Where- $\dot{Q}_{aerSA}\,[kW]$ – the flow of energy taken up by the air supercharger- η_{TG} – gas turbine efficiency;

- η_K – turbocharger compressor efficiency.

Results:

$$\dot{m}_g\cdot c_g\cdot(t_A-t_B)=\frac{1}{\eta_{TG}\cdot\eta_K}\cdot\dot{m}_a\cdot c_a\cdot(t_S-t_0) \qquad (7)$$

where

- $c_a\left[\frac{kJ}{kg\cdot grd}\right]$ - specific heat of air
- t_s [℃]- temperature of the exhaust air from the turbocharger unit;

$T_s=273{,}15+\ t_s\,[K]$; $T_0=273{,}15+\ t_0\,[K]$

$$T_S=T_0\cdot\left(\frac{p_s}{p_0}\right)^{\frac{n_S-1}{n_S}}\ [K] \qquad (8)$$

where

- $p_s\,[bar]$– absolute supercharger air pressure;
- $p_0\,[bar]$– ambient pressure
- n_S– politropic compression exponent in supercharger compressor

Observation: The compressor is load for gas turbine, so equation (7) determines the temperature t_B;

Poz 16 by table 1

$$\dot{Q}_{gTGGE}=\dot{m}_{gTGGE}\cdot c_g\cdot(t_A-t_C)[kW] \qquad (9)$$

This energy flow is dictated by the power consumers of electricity through TPD (main switchboard), so the temperature is required for turbine efficiency, efficiency of electric generator and power required by the electricity consumers.

Poz 13 by table 1

Entry test "D" using the energy balance relationship:

$$\dot{m}_{gTGSA}\cdot c_g\cdot\left(t_B-t_{ref}\right)+\dot{m}_{gTGGE}\cdot c_g\cdot\left(t_C-t_{ref}\right)=\left(\dot{m}_{gTGSA}+\dot{m}_{gTGGE}\right)\cdot c_g\cdot\left(t_D-t_{ref}\right)[kW] \qquad (10)$$

wheret_{ref} – the reference temperature is calculated from the difference in temperature and energy flow;

Observation: Specific heat of gases depends on temperature $c_g=a+bt+ct^2+dt^3+\cdots$. (11)

To show specific heat application may be considered constant.

Poz 22 by tablel 1 - t_H [℃] - the reference to the quantity of sulphur from fuel and temperature of the condensation of water vapour from the gas. $t_H=t_{pra}+20$ [℃] (12)

where - t_{pra} [℃] - the acid dew point temperature.;

Poz 24 bytablel 1 $\dot{Q}_{gma\,xCR}=\dot{m}_g\cdot c_g\cdot(t_D-t_H)[kW]$(13)

This energy flow is required by consumers of electricity produced by the electric generator entrained steam turbine and steam users for heating various fluids from the ship.

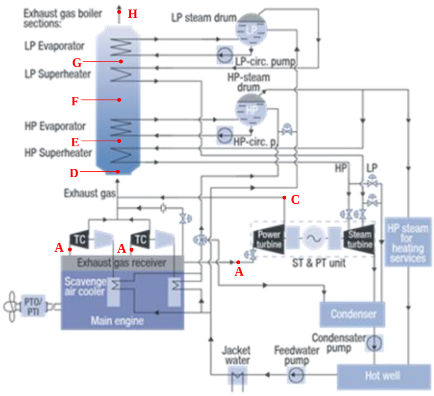

Figure 1. The principle of energetic installation. [3]

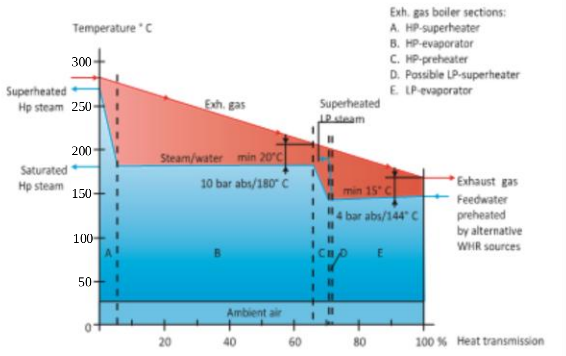

Figure 2. TemperatureVenergy flow diagram for steam pressure stages. [3]

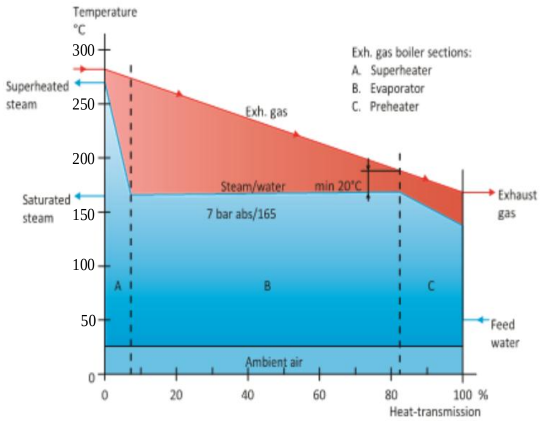

Figure 3. TemperatureVenergy flow diagram for steam system.[3]

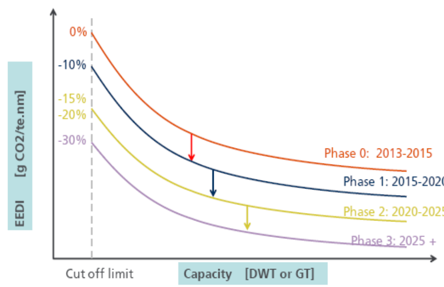

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Figure 4. Concept EEDI. [6]

Determination of CO2 production.

Fuel combustion.

$C_h\left[\frac{kg_{cb}}{h}\right]$ - Fuel consumption per hour;

$C_{Mn}\left[\frac{kg_{cb}}{Mn}\right]$ - Fuel consumption per Mn(Marine miles);

$C_{Mn}=\frac{C_h}{V_n}\left[\frac{kg_{cb}}{Mn}\right]$ where $V_n\left[\frac{Mn}{h}\right]$ - ship speed.

$C_{t\,Mn}\left[\frac{kg_{cb}}{t\cdot Mn}\right]$ – Fuel consumption per (tdw) şiMn

$$C_{t\,Mn}=\frac{C_{Mn}}{\Delta_S}\left[\frac{kg_{cb}}{t\cdot Mn}\right] \qquad (14)$$

Elementary analysis of the fuel, carbon constitutes 0,75 - 0,87 kg carbon/kg fuel.

- $M_{CO_2}=44$ - molecular weight of CO2
- $M_C=12$ - molecular weight of carbon.

Production of CO_2 : $m_{CO_2}=\frac{C_{Mn}}{\Delta_S}\cdot(0{,}75\div 0{,}87)\cdot\frac{44}{12}\left[\frac{kg\ CO_2}{t\cdot Mn}\right]$

The calculation for the oil tank of a ship 150000 tdw:

$$m_{CO_2}=\frac{C_{Mn}}{\Delta_S}\cdot(0{,}75\div 0{,}87)\cdot\frac{44}{12}=\frac{3600}{16}\cdot\frac{1}{150000}\cdot(0{,}75\div 0{,}87)\cdot\frac{44}{12}\left[\frac{kg\ CO_2}{t\cdot Mn}\right]$$

or

$$m_{CO_2}=\frac{C_{Mn}}{\Delta_S}\cdot(0{,}75\div 0{,}87)\cdot\frac{44}{12}\cdot 10^3=\frac{3600}{16}\cdot\frac{1}{150}\cdot(0{,}75\div 0{,}87)\cdot\frac{44}{12}\left[\frac{g\ CO_2}{t\cdot Mn}\right]$$

Fuels	Mass of carbon by fuels kgC/kg cb	The production of CO2 in the air with\/without recovery of energy flows	
		$\left[\frac{kg\ CO_2}{t\cdot Mn}\right]$	$\left[\frac{g\ CO_2}{t\cdot Mn}\right]$
LNG	0,75	0,004125	4,125 4,331-4,537
LPG	0,825	0,004538	4,538 4,765-4,992
HFO	0,85	0,004675	4,675 4,91-5,14
DFO	0,87	0,004785	4,785 5,02-5,26

CONCLUSIONS

The work developed by the authors identify energy flows that can be recovered from the power plants. Energy flows that can be retrieved are based on installations where they are transferred, and that these operations at various powers modifies energy flows that can be recovered. \u000d\u000aThe team of authors believes that other theorists and engineers operating in the field, that the variations

The technically and economically are those that involve recovery installations and technical variations of energy.

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