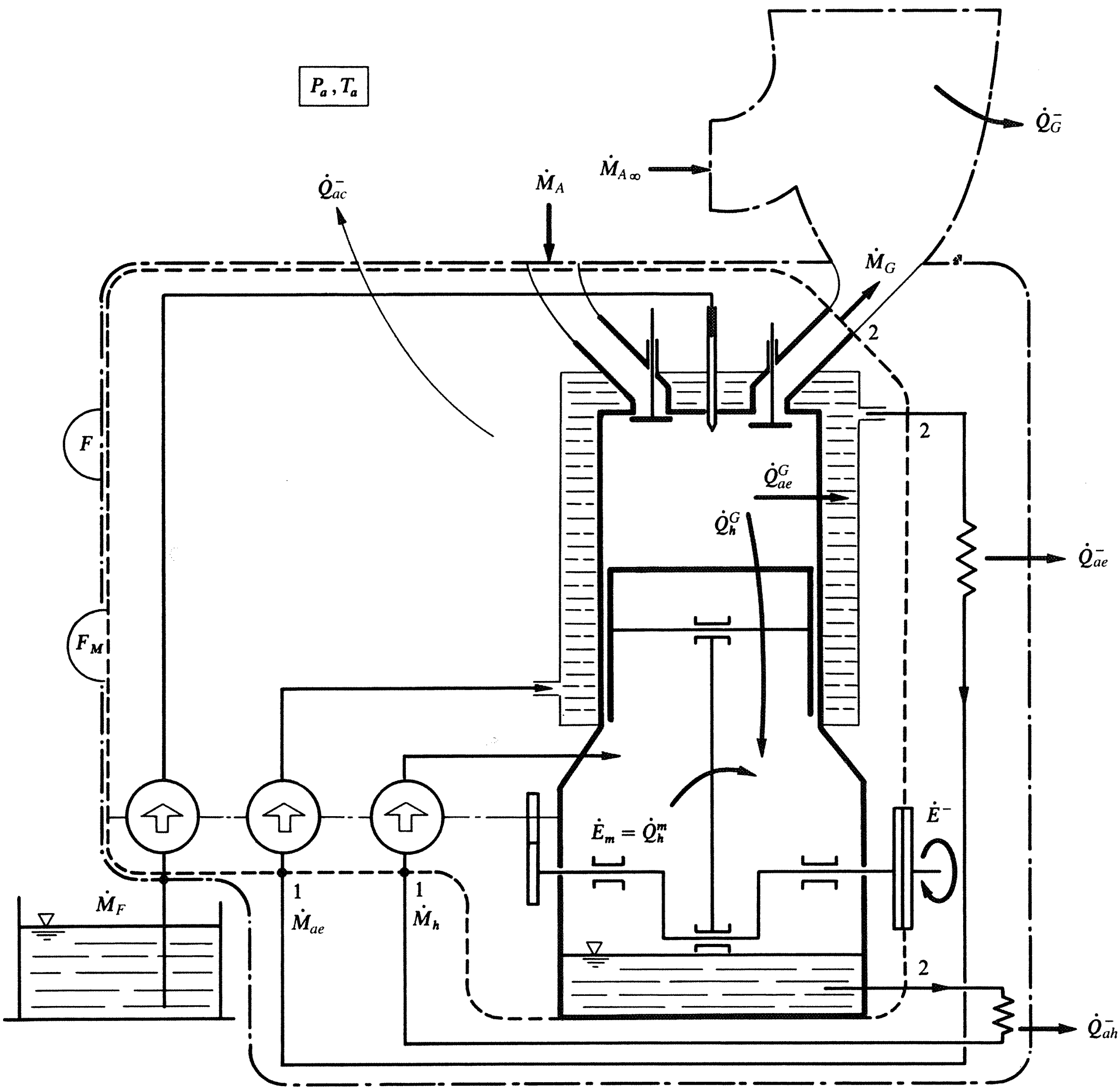
Engines

Exercise III: Energy and exergy balance of a Diesel engine

Data:

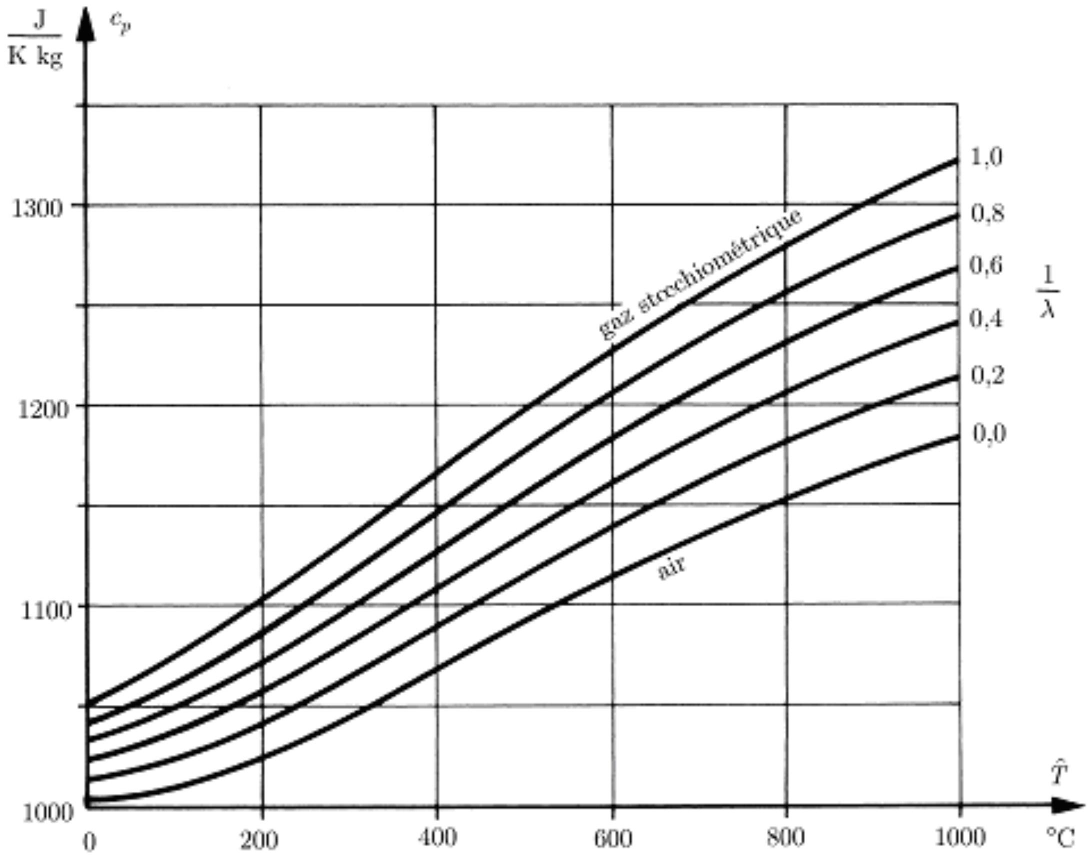
Let us consider the following Diesel engine:



Schematics of a naturally aspirated Diesel engine.

Atmospheric state:	P_a = 1 bar, T_a = 25 °C
Standard state:	P^0 = 1 bar, $\hat{T}^0$ = 25 °C
Fuel elementary analysis:	c_C^F=0.856 kgC/kgF
	c_{H2}^F=0.134 kgH2/kgF
	c_S^F=0.006 kgS/kgF
	c_{O2}^F=0.001 kgO2/kgF
Fuel state at the engine inlet:	P_F = 1 bar, $\hat{T}_F$ = 25 °C
Fuel lower heating value:	Δh_i^0 = 42600 kJ/kg
Fuel exergy value:	Δk^0 = 45000 kJ/kg
Fuel mass-flow:	$\dot{M}_F$ = 21.13 kg/h
Mechanical power at crankshaft:	$\dot{E}_E^-$ = 100 kW
Air state at the engine inlet:	P_A = 1 bar, $\hat{T}_A$ = 25 °C
Air / Fuel factor for the combustion:	λ = 1.2
State of the combustion gases at the engine outlet:	P_{G2} = 1 bar, $\hat{T}_{G2}$ = 550 °C

Isobaric specific heat of the air and of the combustion gases c_{pG} (for a complete combustion)



Heating value of carbon monoxide: Δh^0_{CO} = 10100 kJ/kg

Exergy value of carbon monoxide: Δk^0_{CO} = 9830 kJ/kg

Mass-flow of carbon monoxide at engine outlet: $\dot{M}_{CO}$ = 0.93 kg/h

Temperatures of the engine cooling water: $\hat{T}_{e1}$ = 85 °C , $\hat{T}_{e2}$ = 90 °C

Isobaric specific heat of the cooling water: c_{pe} = 4.2 kJ/(K kg)

Mass-flow of the cooling water: $\dot{M}_e$ = 145 kg/min

Temperatures of the engine oil: $\hat{T}_{h1}$ = 90 °C, $\hat{T}_{h2}$ = 100 °C

Isobaric specific heat of lubricating oil: c_{ph} = 1.8 kJ/(K kg)

Lubricating oil mass-flow: $\dot{M}_h$ = 23 kg/min

The system boundary F of Figure 1 defines the entire system including all auxiliaries systems (pumps and heat exchangers of the cooling water and lubricating oil networks, fuel network and others mechanical energy transfer systems).

The subsystem boundary F_M, only defines the engine alone.

Hypothesis:

Consider that the condensation water flow rate is equal to 0. $\dot{M}_{cond} = 0$ kg/h

Questions:

1. Formulate and calculate the different terms included in the energy balance of the system (boundary F).

2. Calculate the effectiveness ε of the system (boundary F)

   Optional:
   Calculate the exergy efficiency η of the system (boundary F)

3. Calculate the effectiveness ε_M of the engine subsystem (boundary F_M)

   Optional:
   Calculate the exergy efficiency η_M of the engine subsystem (boundary F_M)

4. Calculate the effectiveness ε'_M of the engine if the unburned hydrocarbons are considered as part of energy losses (boundary F_M)

   Optional:
   Calculate and the exergy efficiency η'_M of the engine if the unburned hydrocarbons are considered as part of exergy losses (boundary F_M)