Development of the Ceramic Adiabatic Engine Having 68% Thermal Efficiency

Hideo Kawamura

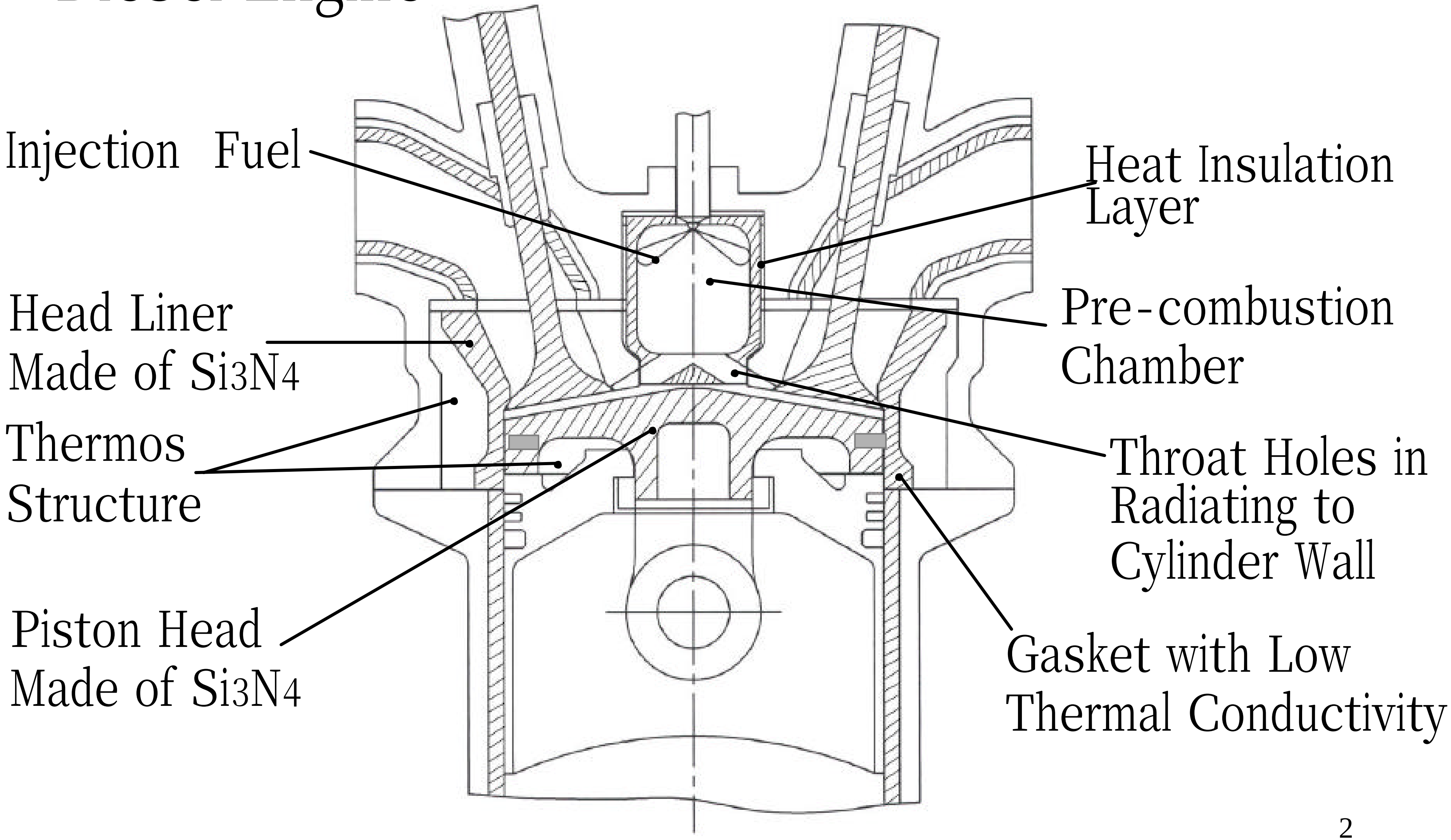
(Technical Advisor, Ship and Ocean Foundation)

Fostered by a Nippon Foundation grant from the proceeds of motorboat racing, The Ship and Ocean Foundation, in a joint project with Isuzu Ceramics Research Institute, is sponsoring research into the Ceramic Adiabatic Engine.

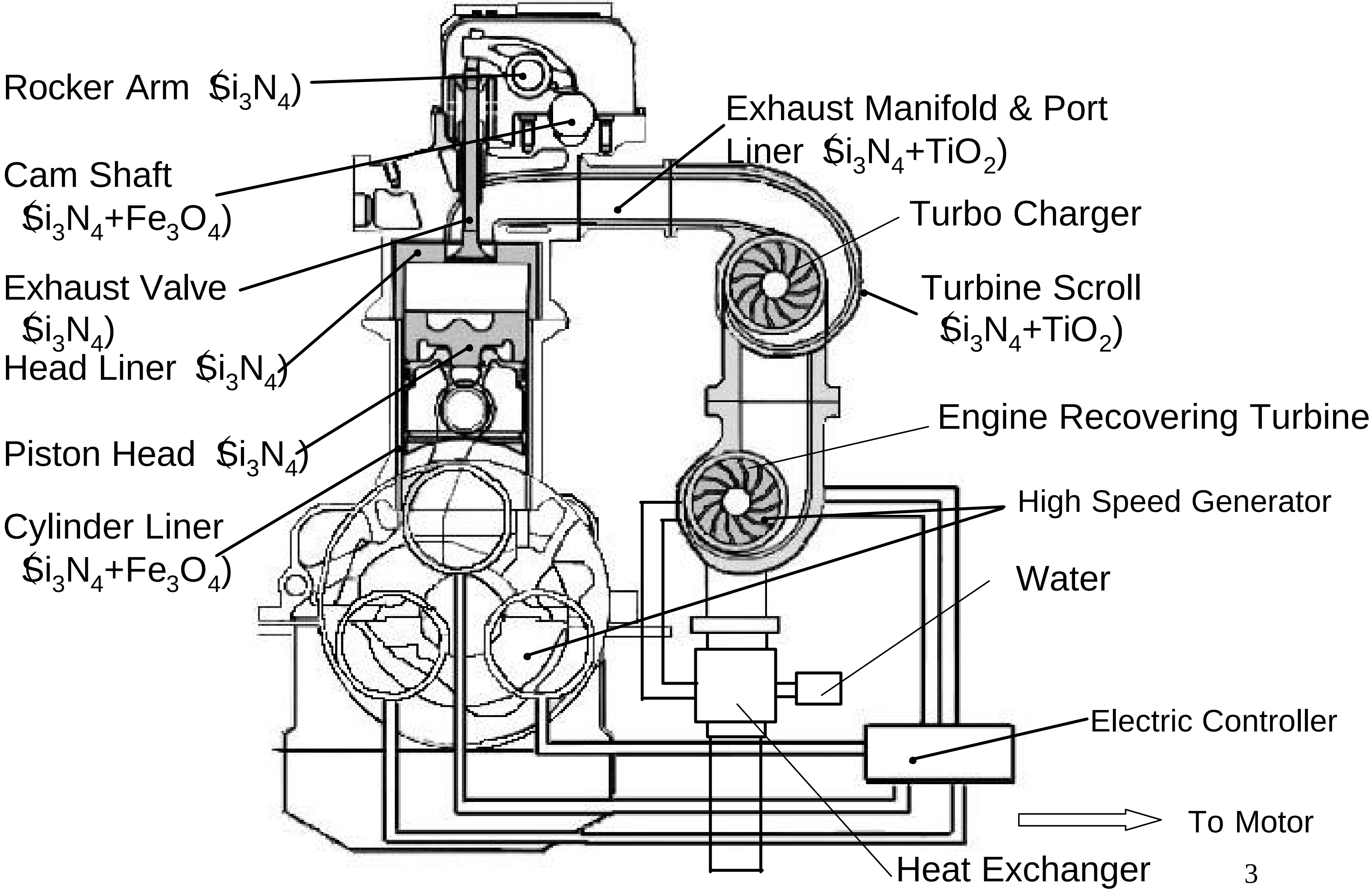
The following presentation on the engine was made at the ASME 2000 FALL TECHNICAL CONFERENCE, held in Peoria, United States in September 2000.

(ASME：the American Society of Mechanical Engineers)

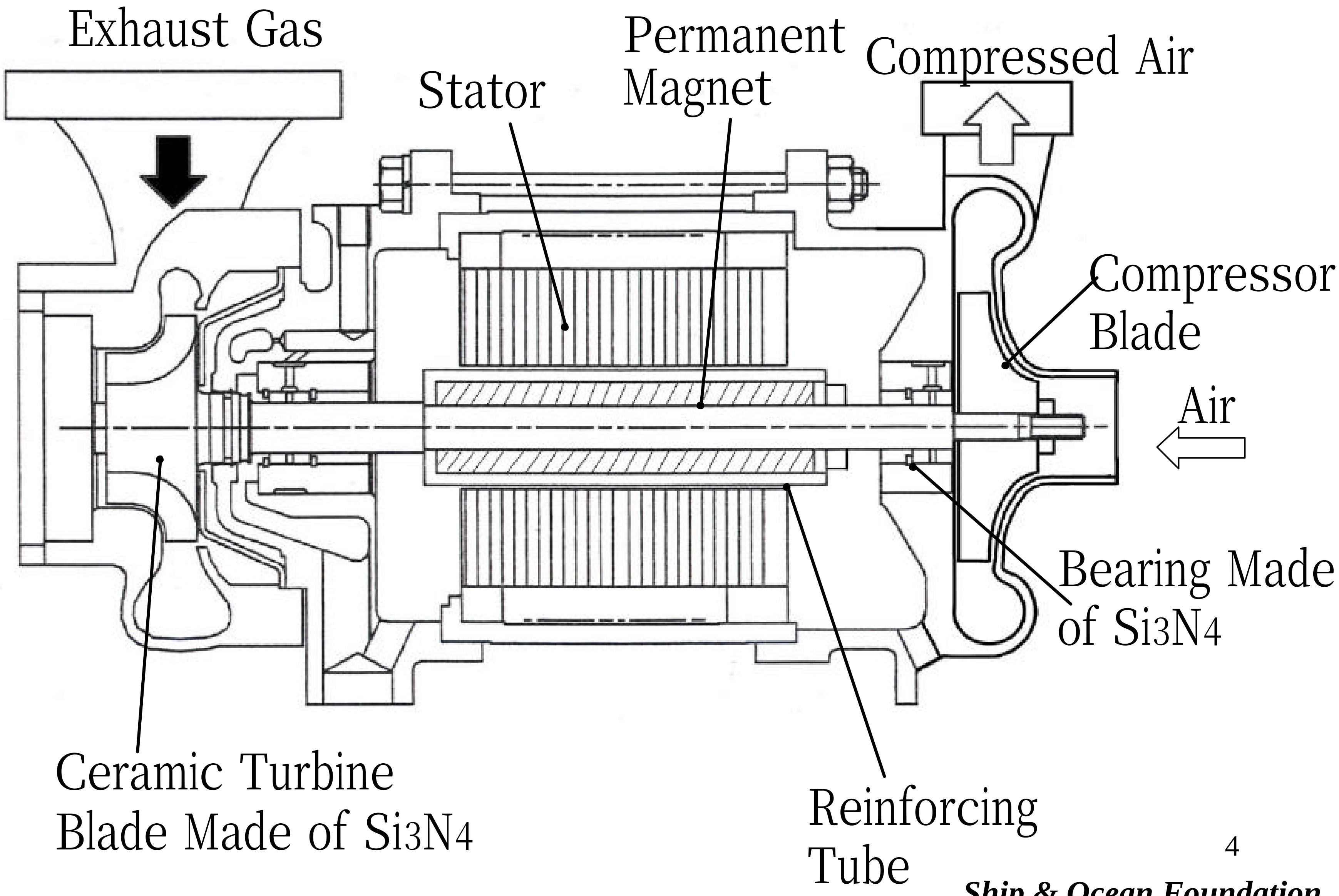
Structure of Combustion Chamber for L.H.R Diesel Engine



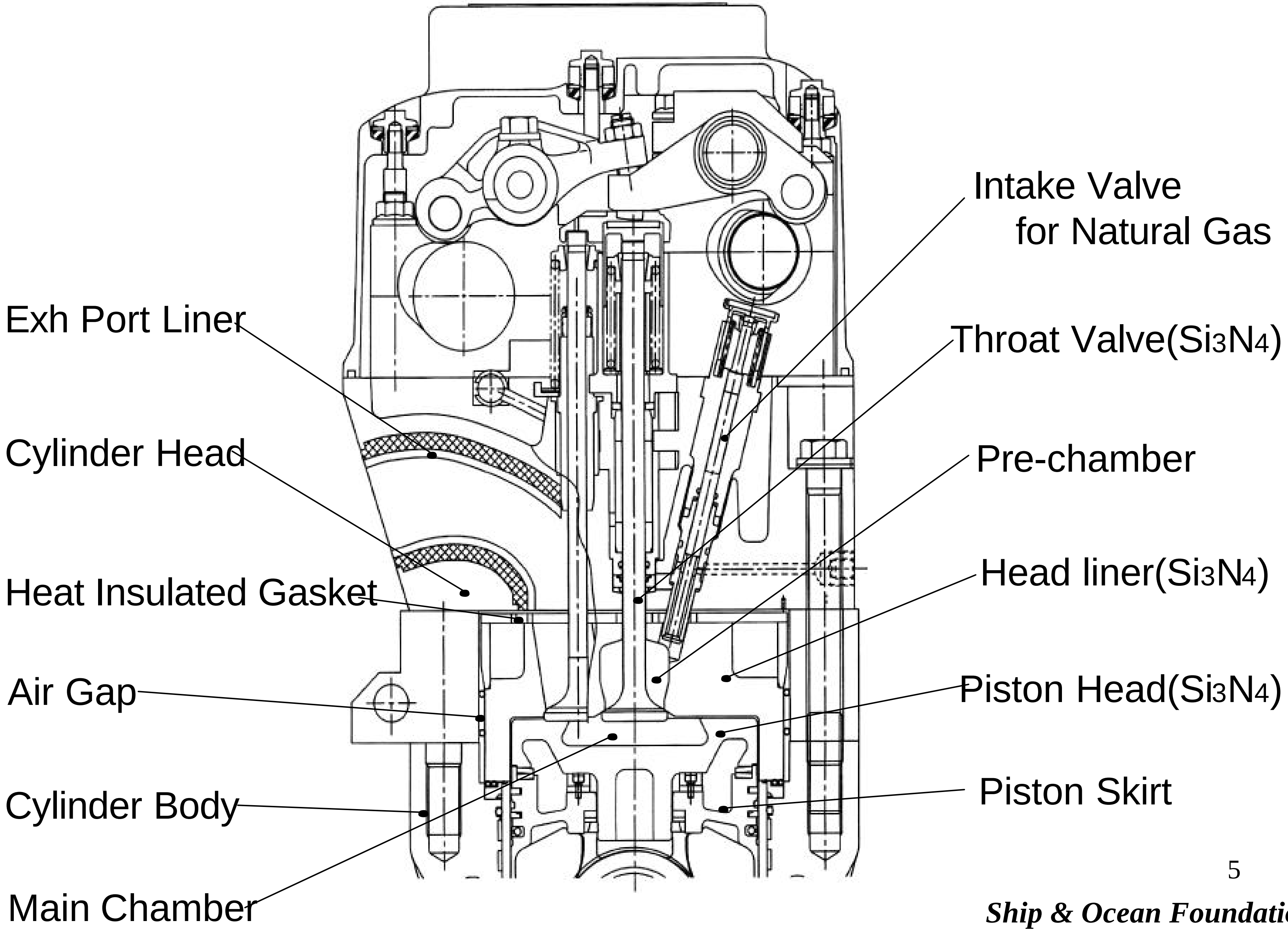
Schematic of a Turbo Compound System



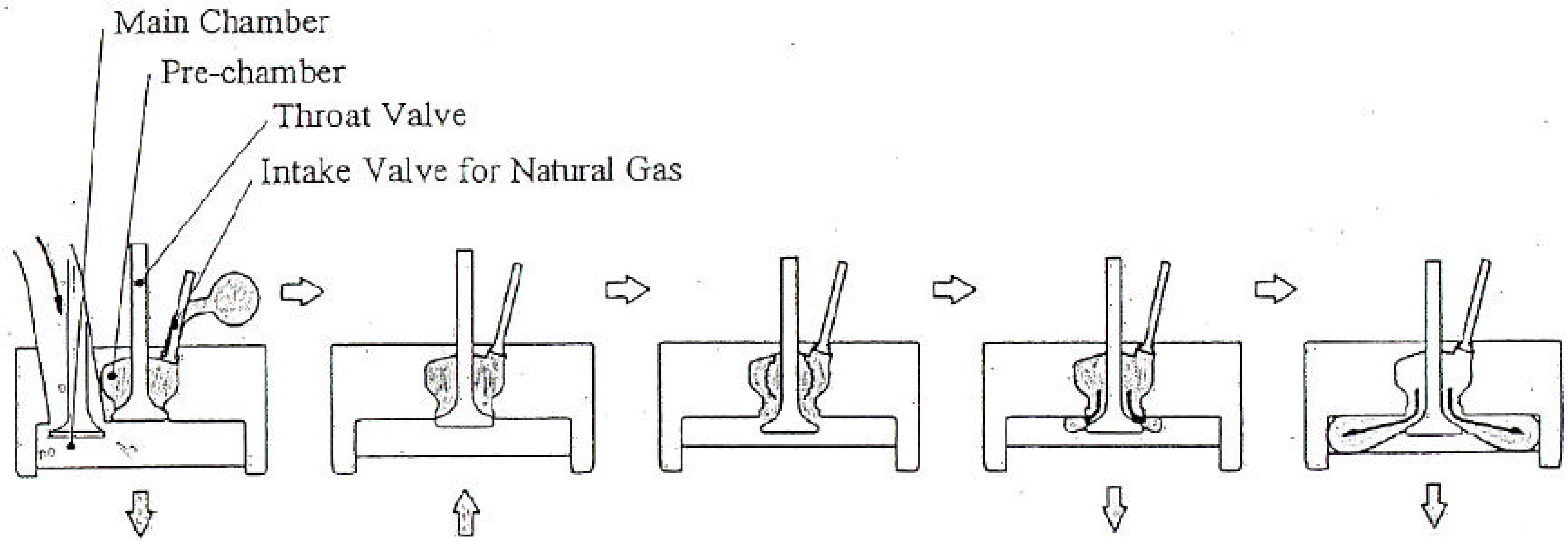
Structure of The Energy Recovering Turbo Charger



Structure of Heat Insulated Engine



Outline of New Combustion System

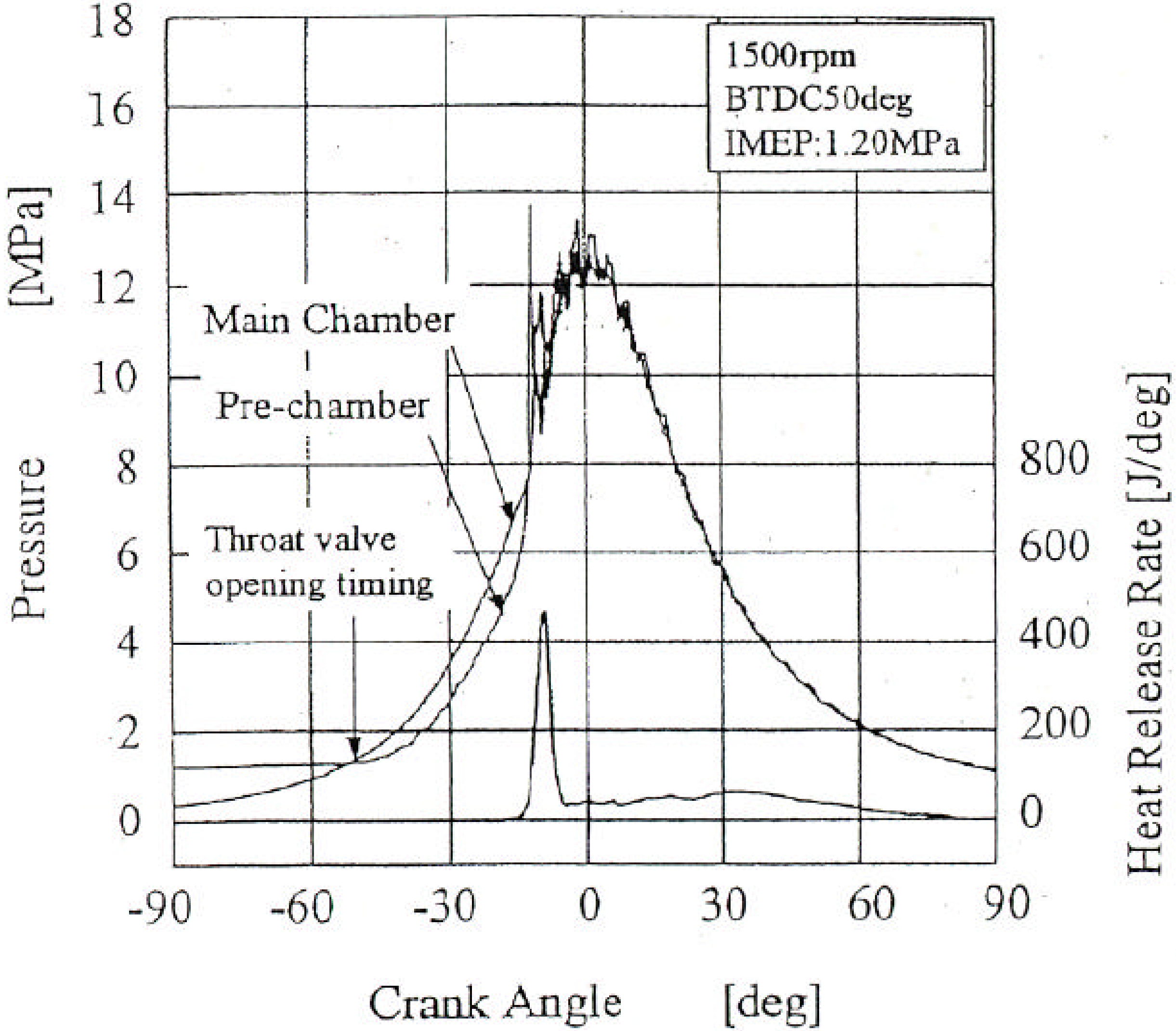


[Intake Stroke]	[Compression Stroke]	[Throat Valve Opening]	[Beginning of Expansion]	[Expansion Stroke]
• Throat Valve Close • Charge Natural Gas to Pre-chamber • Air Intake to Main Chamber	•Throat Valve Open •Mixture Formation	• Auto Ignition in Pre-chamber	• Combustion in Pre-chamber • Mixture Flow out to Main Chamber	• Combustion in Main Chamber

Specifications and Test Condition

Engine Type	Single Cylinder
Bore × Stroke	Φ132.9×145mm
Displacement	2011cm^3
Compression Ratio	16
Pre-Chamber Volume Ratio	20%
Engine Speed	1500rpm
Boost Pressure	187kPa
Exhaust Pressure	187kPa
Fuel Supply	All Fuel into the Pre-chamber
Total Air Excess Ratio	λ=2.3
Throat Valve Opening Timing	bTDC50deg
Cam Profile for Throat Valve	Lower accsleration

Indicator Diagram on EGR ratio: 50%, Fr: 0%

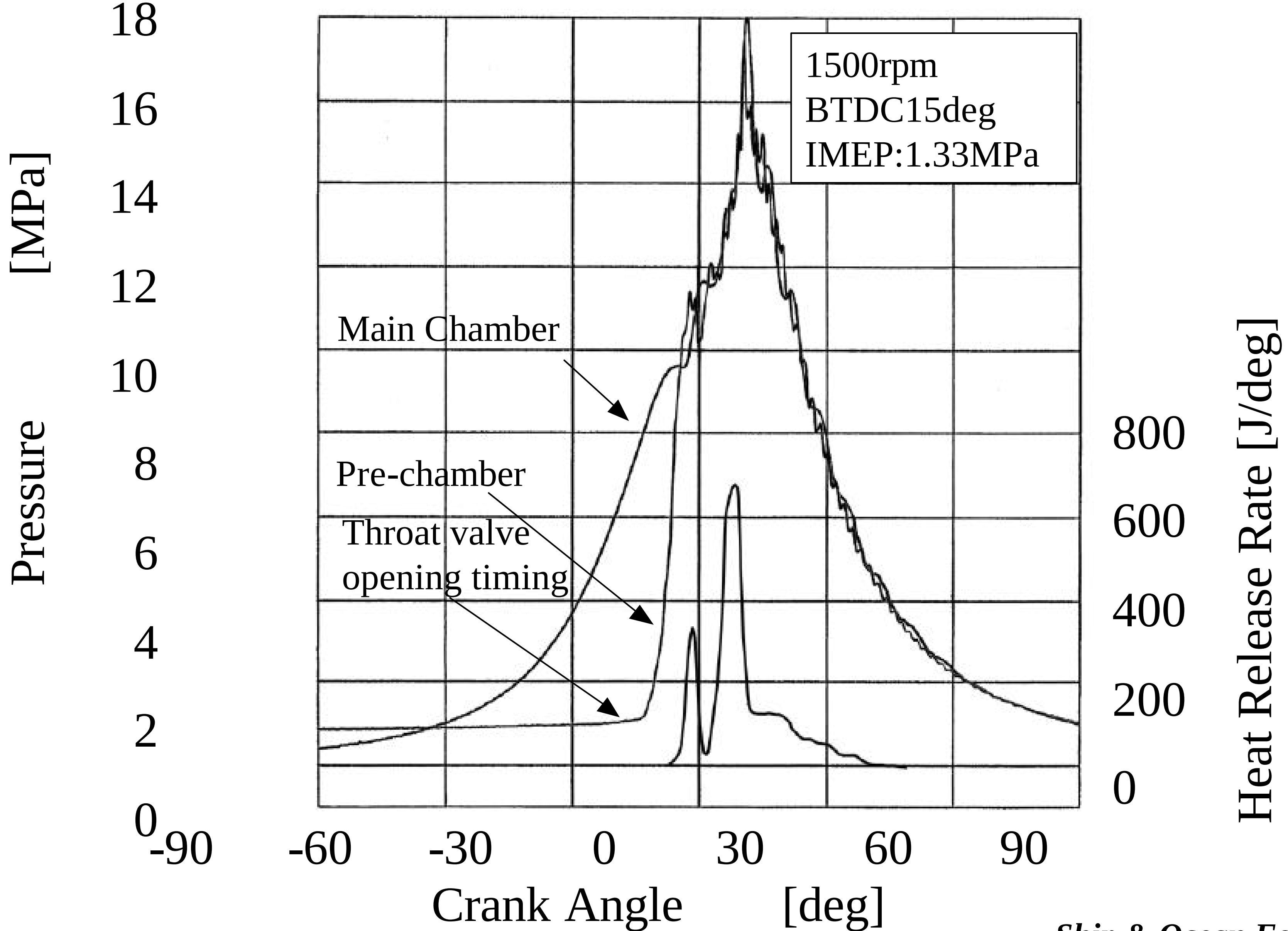


Ship & Ocean Foundation

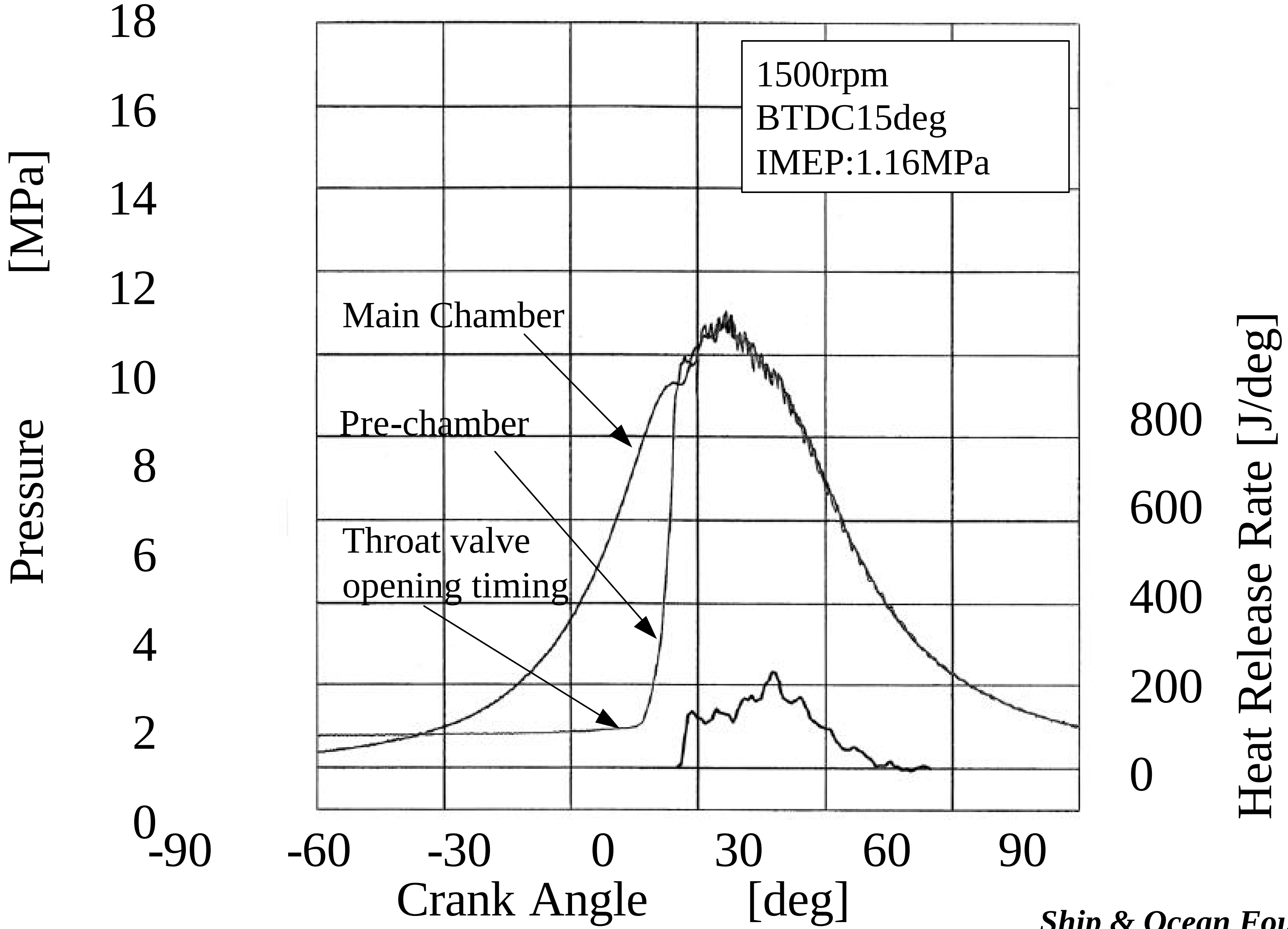
Specifications and Test Condition

Engine Type	Single Cylinder
Bore × Stroke	Φ132.9×145mm
Displacement	$2011cm^3$
Compression Ratio	15
Pre-Chamber Volume Ratio	9%
Engine Speed	1500rpm
Boost Pressure	187kPa
Exhaust Pressure	190kPa
EGR Ratio	Variable
Fuel Supply[Fr]	85%
Fuel Flow Ratio	105Nl/min(const.)
Total Air Excess Ratio	1.07-1.45
Throat Valve Opening Timing	bTDC15-35 deg
Cam Profile for Throat Valve	Higher Acceleration Type

Indicator Diagram of L.H.R.E with O_2 : 21% and HMR 85% of CNG

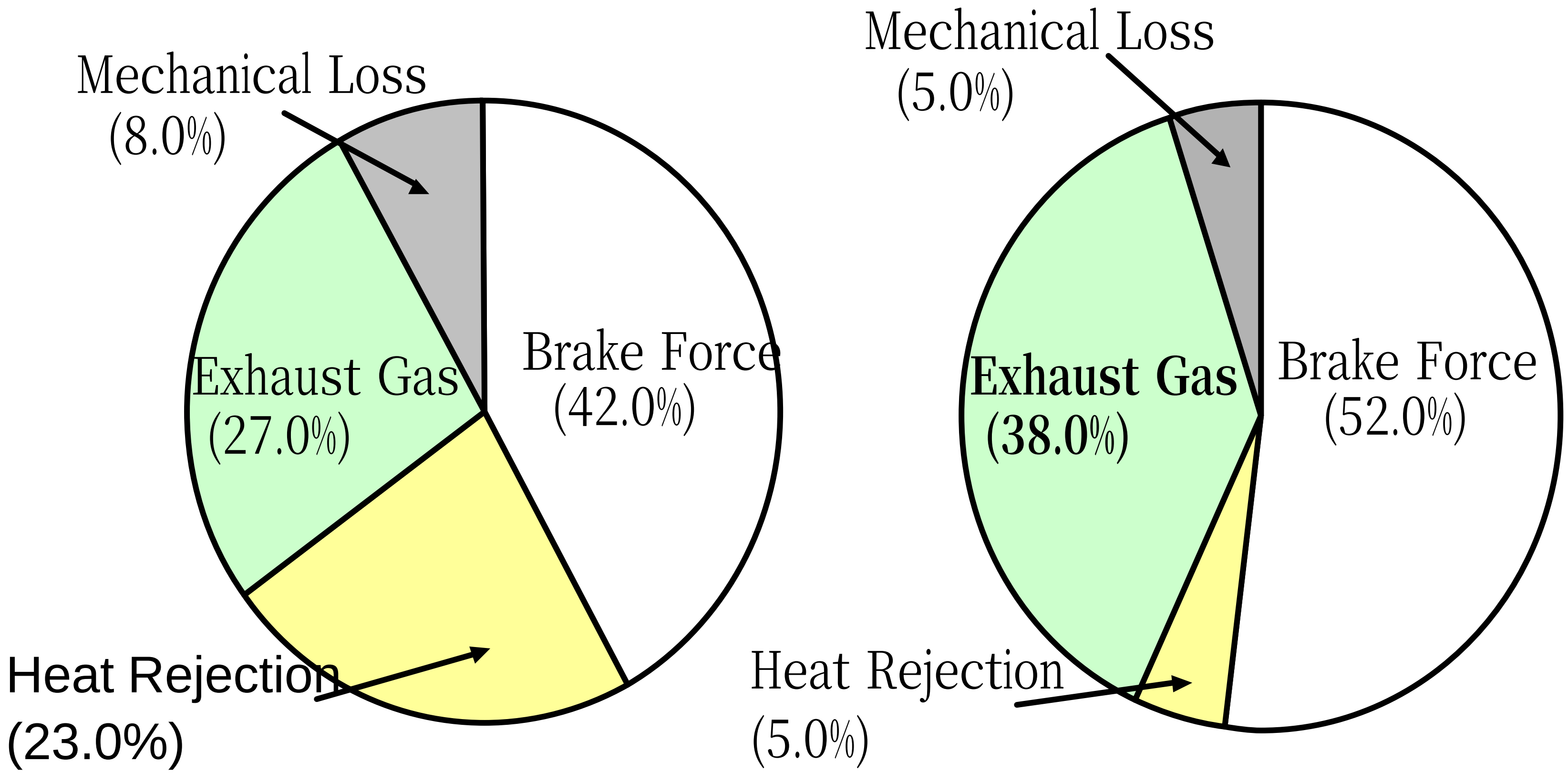


Indicator Diagram of L.H.R.E with O_2 : 17% and HMR 85% of CNG



Ship & Ocean Foundation

Comparison of Heat Balance between Conventional Cooled Engine and L.H.R.E



Conventional Cooling Diesel Engine

Ceramics L.H.R.E

$$CO_2+CH_4+59{,}190\text{kcal/kmol} \longrightarrow 2CO+2H_2 \quad \cdots\cdots\cdots\cdots (1)$$

(In Catalytic Converter)

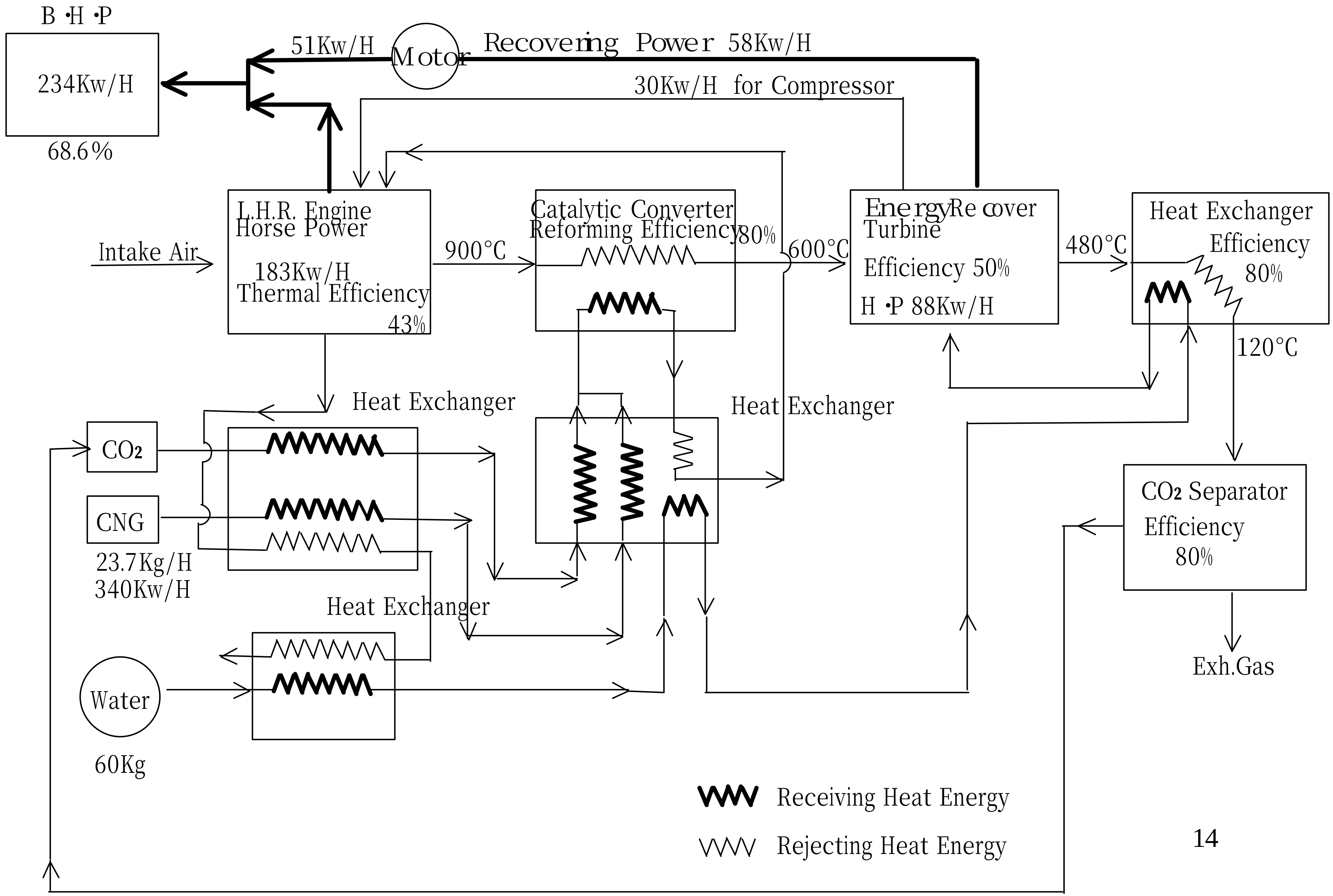
$$2CO+2H_2+2O_2 \longrightarrow 2CO_2+2H_2O+250{,}580\text{kcal/2kmol} \quad \cdots (2)$$

(Combustion)

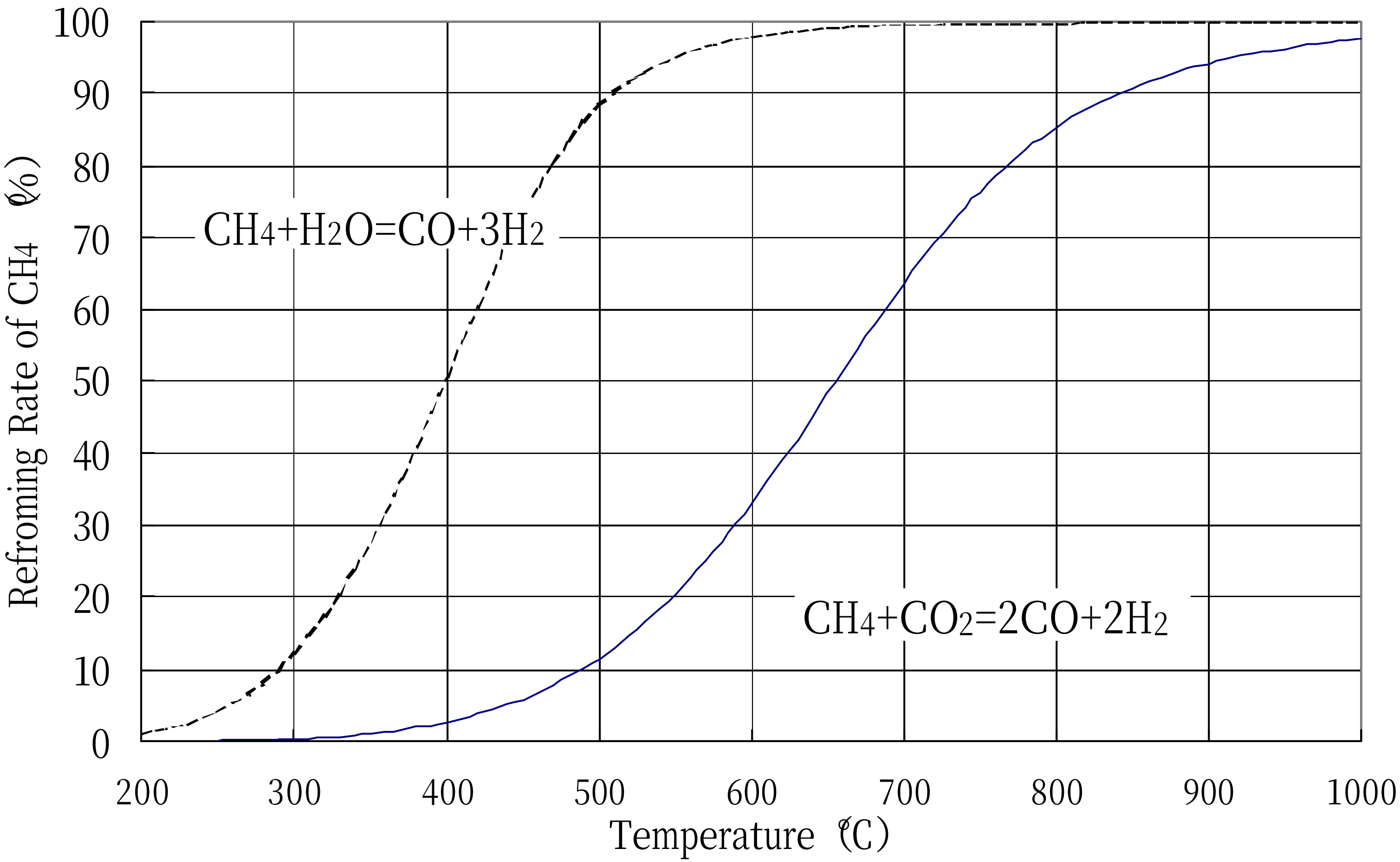
$$CH_4+2O_2 \longrightarrow CO_2+2H_2O+191{,}290\text{kcal/kmol} \quad \cdots (3)$$

(CH_4 Combustion)

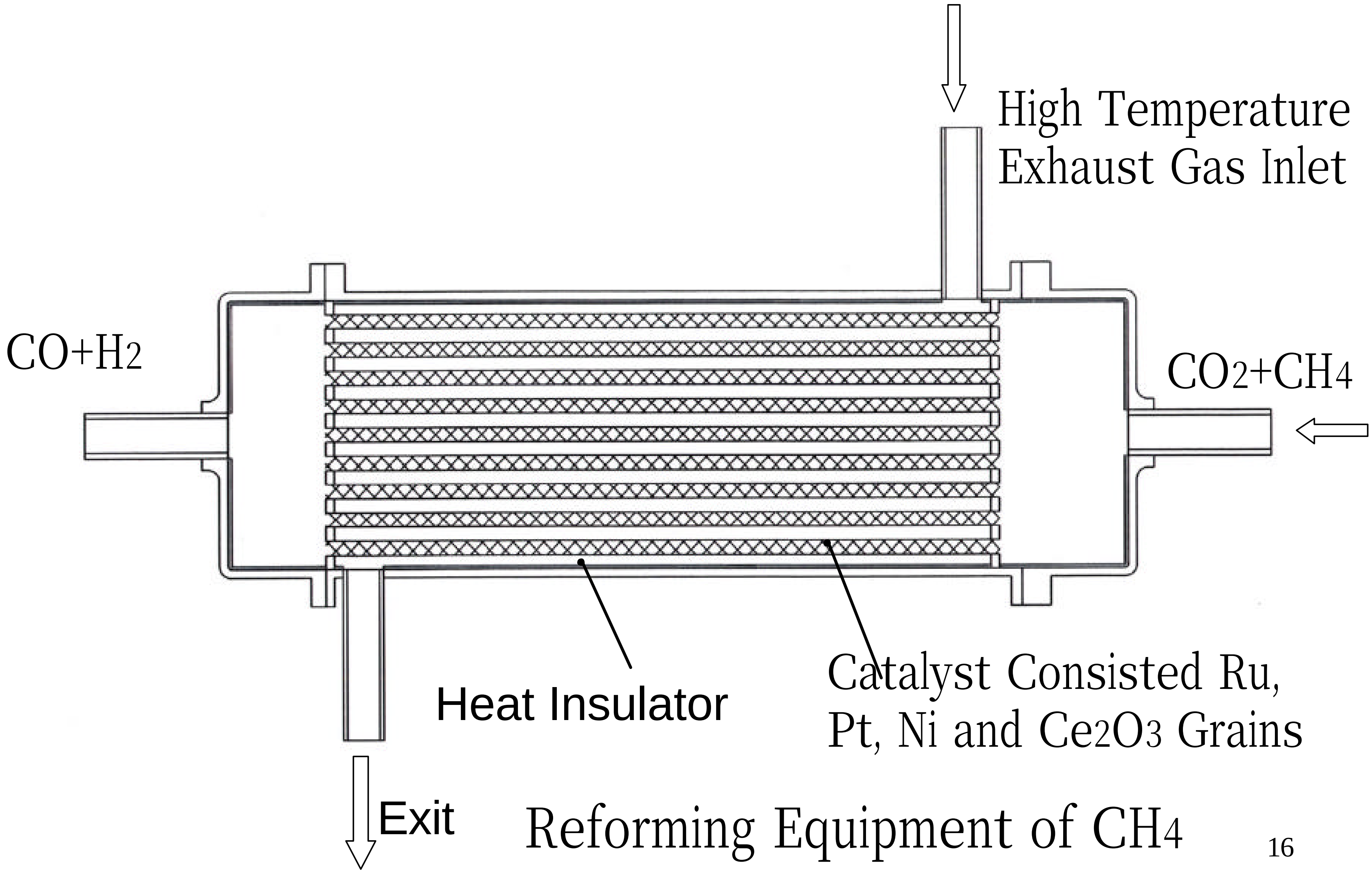
Energy Flow of Reforming CH_4 Engine with L.H.R Structure



Reforming Rate of CH_4 when CH_4 React to CO_2 or H_2O or in Catalytic Converter

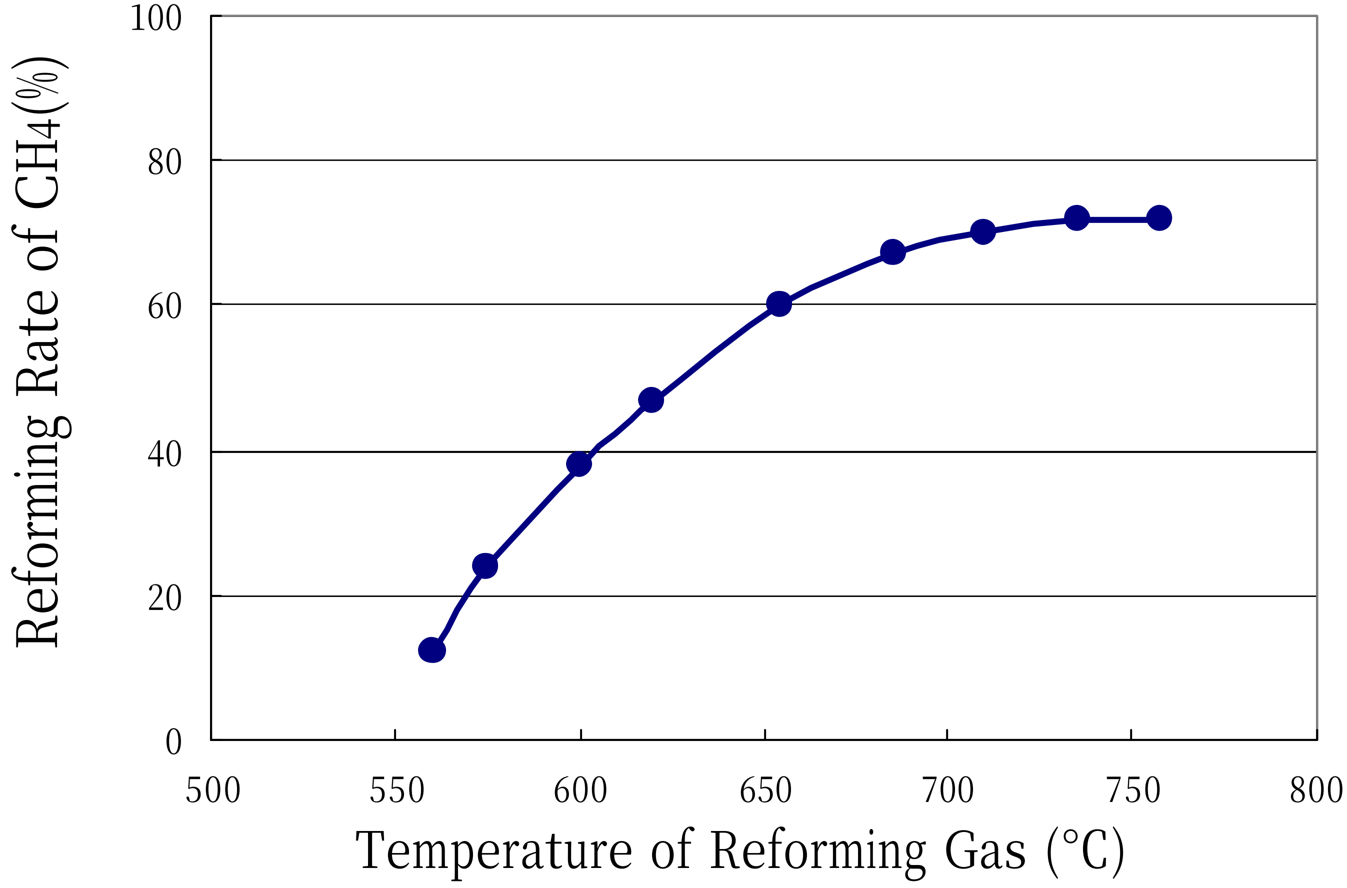


The Structure of Vessel for Reforming CH_4

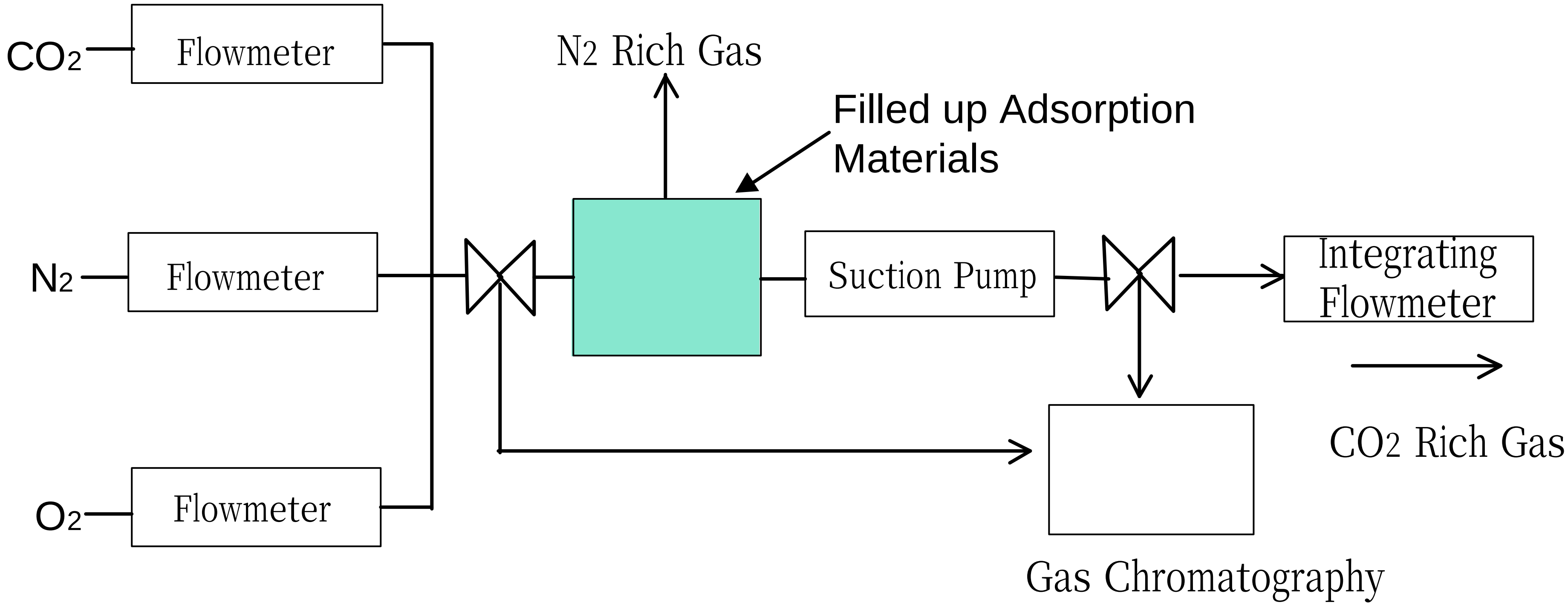


Reforming Equipment of CH_4

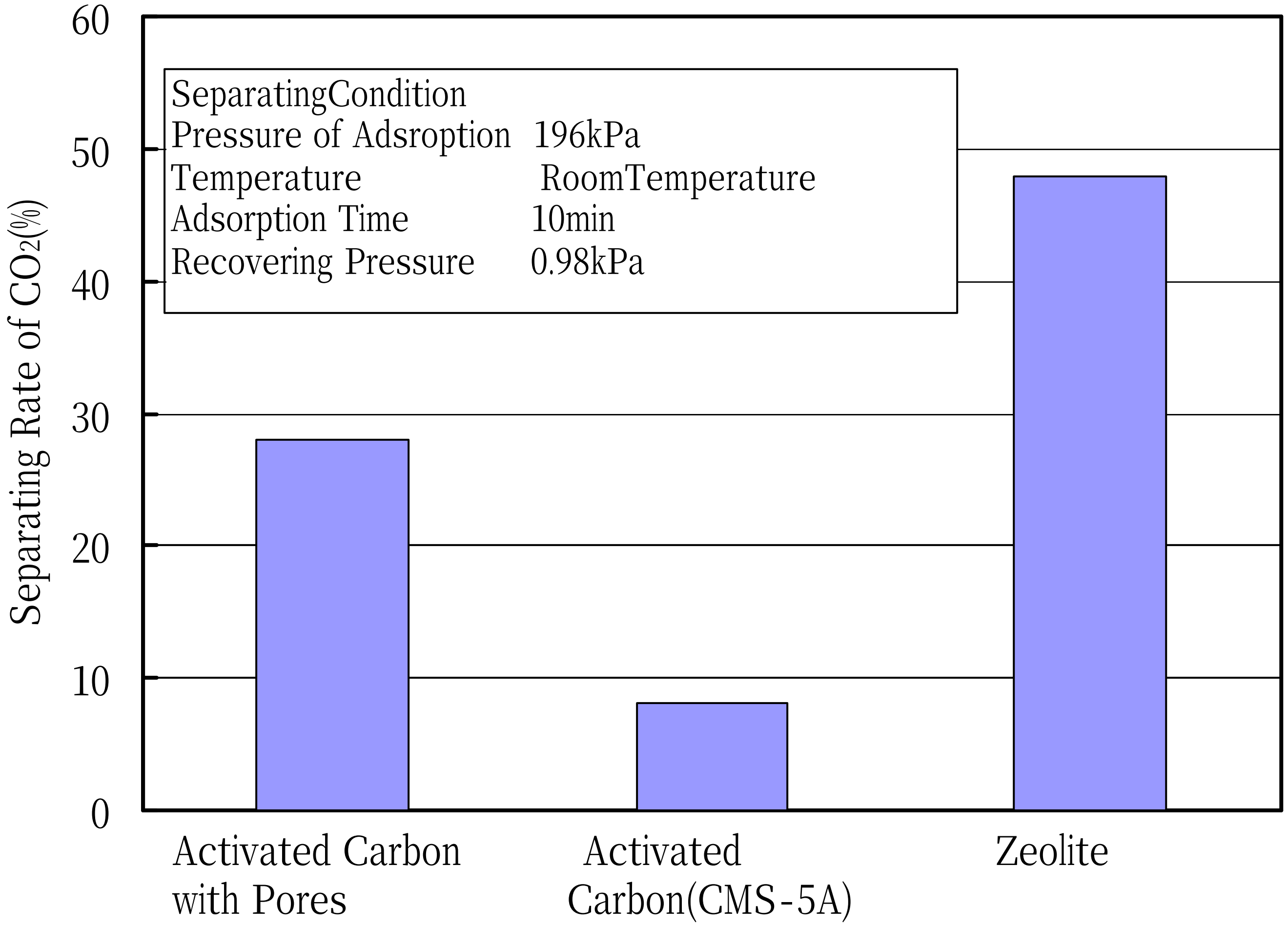
Reforming Rate of CH_4 when Temperature or Reforming Gas is Changed(Experimental Data)



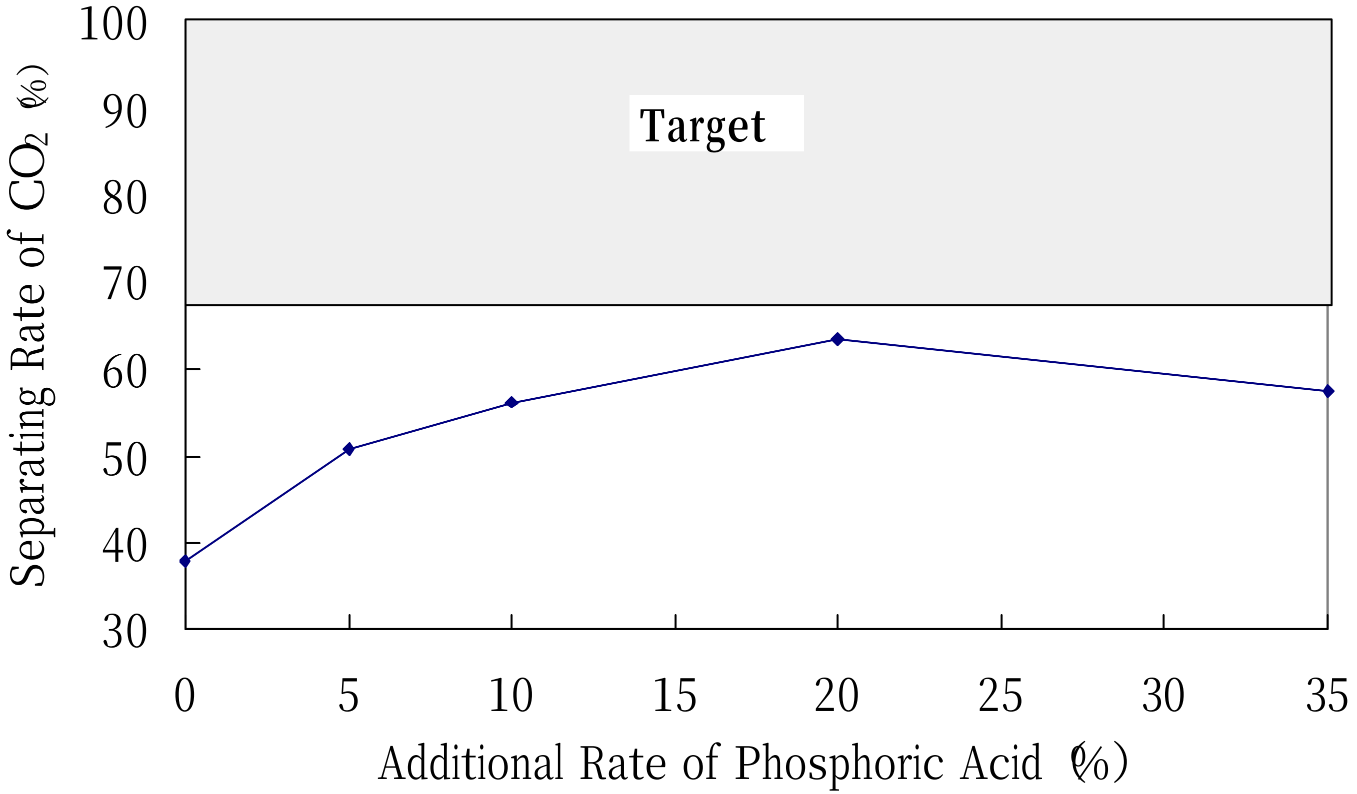
Scheme of Investigating System for Separating CO_2



Separating Performance of CO_2 in case of using Conventional Materials



Separating Rate of CO_2 when Carbon Graphite Deposited Phosphoric Acid is Used for Separating Materials



CONCLUSION

1. By creating air gaps and a combustion chamber using ceramic components, we developed an “Adiabatic Engine” that substantially reduces heat rejection from the combustion chamber.

2. Due to a reduction in the heat loss ratio of the calorific value of the fuel to 5%, the exhaust gas energy increases to 48%. Placing the exhaust gas energy through the “Energy Recovery Turbine” and thereby converting it to engine energy, we were able to achieve 48% thermal efficiency.

3. The exhaust gas that leaves the "Energy Recovery Turbine" is vaporized to drive the steam turbine, which enables the thermal efficiency in the ceramic turbo compound engine to increase to 52%.

4. In order to efficiently use up the energy that remains in the exhaust gas after the heat exchanger of the steam supply system, we investigated reforming the natural gas fuel and CO_2, and converting them into carbon monoxide and hydrogen, therefore absorbing the remaining thermal energy. This increases the calorific value by about 30% and enables the thermal efficiency of the engine to increase to 68%.

5. Aiming at 68% thermal efficiency, the catalytic converter and CO_2 separator were developed and the performance target of the system was achieved.