# M3-9: Diesel / Natural Gas Power Generating System

**Dr. Md. Zahurul Haq**, *Ph.D., CEA, FBSME, FIEB*

Professor
Department of Mechanical Engineering
Bangladesh University of Engineering & Technology (BUET)
Dhaka-1000, Bangladesh

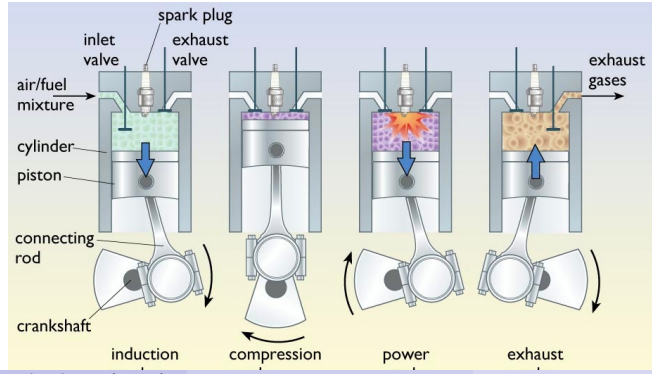
http://zahurul.buet.ac.bd/

Capacity Development Training Program on
**Energy Auditing and Energy Management**



## Reciprocating Combustion Engines

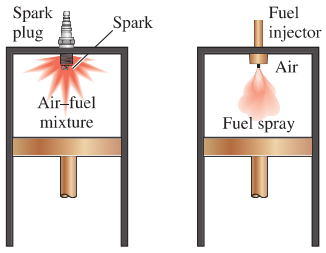
1. Intake stroke: Inlet valve (IV) open & Exhaust valve (EV) closed
2. Compression stroke: IV & EV are closed,
3. Power stroke: IV & EV are closed,
4. Exhaust stroke: IV closed & EV open,




T1272



## Spark or Compression Ignition Engines (SIE vs CIE)

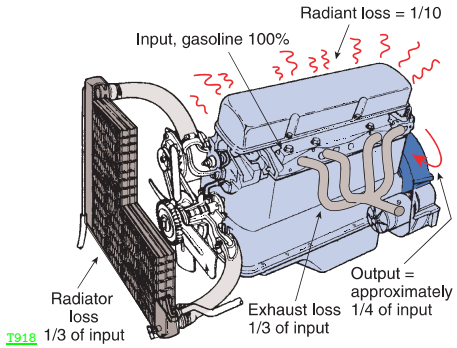



T503

- Spark initiates the flame in SIE; high compression in CIE generates high temperature for ignition in CIE.
- Part-load efficiency of CIE is better as load is regulated by fuel injection adjustment; in SIE throttling is used to reduce load which increases pumping work.
- SIEs are high speed engines with higher temperature exhaust.

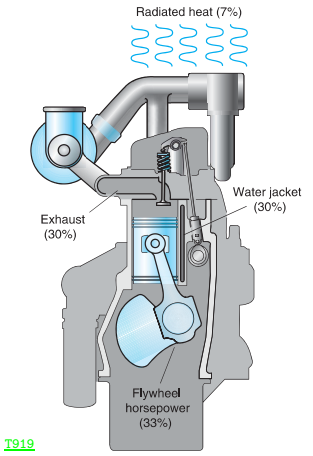


## Engine Energy Balance




T918

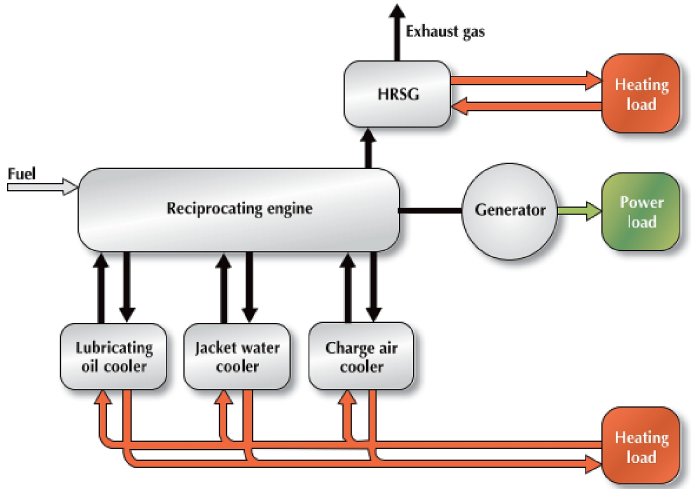
*SI Engine*




T919

*CI Engine*

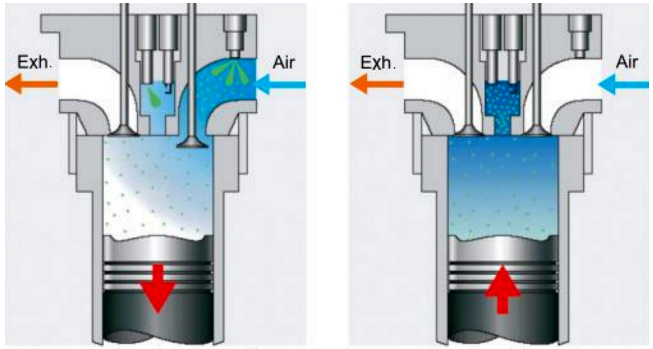
## Reciprocating Engine Cogeneration




T1755



## Natural Gas Engine

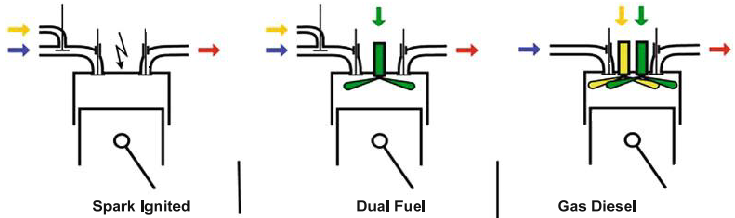



Air intake and gas injection in the prechamber and intake manifold

Compression of gas/air mixture

T1756






External mixture formation
Homogeneous mixture
Quantity control
Spark ignition

Electric
-
$p_{Gas} > p_1$ or $p_3$
$P \approx 0.8\ P_{Diesel}$

Pilot fuel
$x_{eB} = 0.5\% \ldots 100\%$
$p_{Gas} > p_1$ or $p_3$
$P \approx 0.9\ P_{Diesel}$

Internal mixture formation
Heterogeneous mixture
Quality control
Autoignition
Pilot fuel/gas

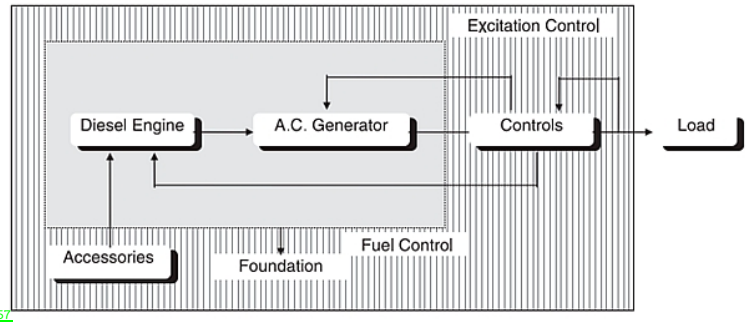
$x_{eB} = 5\% \ldots 100\%$
$p_{Gas} > p_x$
$P = P_{Diesel}$

T441

*Definition of the combustion process in gas engines.*



## Diesel Generating Set




T1757

## Energy Balance of Reciprocating Engine

| | Conventional cooling system | | Cooling system with engine jacket and exhaust heat recovery | |
|---|---|---|---|---|
| **500-kW natural gas engine generator*** | | | | |
| Electric power | 30% | | 30% | |
| Jacket-water heat | 38% | | 38% | 54% recoverable |
| Exhaust heat | 24% | 70% wasted | Exh recoverable 16% | |
| | | | Exh lost 8% | 16% wasted |
| Radiated heat lost to atmosphere | 8% | | 8% | |
| | 100% | | 100% | |
| **500-kW diesel engine generator*** | | | | |
| Electric power | 35% | | 35% | |
| Jacket water | 32% | | 32% | 48% recoverable |
| Exhaust heat | 24% | 65% wasted | Exh recoverable 16% | |
| | | | Exh lost 8% | 17% wasted |
| Radiated heat lost to atmosphere | 9% | | 9% | |
| | 100% | | 100% | |

T1758



- $\dot{m}_f$ : fuel consumption rate [kg/hr]
- $\dot{W}_b$ : brake power [kW]
- $bsfc$ : brake sp. fuel consumption [kg/kW-hr]
- $N$ : engine crankshaft rotation speed [rpm, rev/min]
- $\eta_{th}$ : thermal efficiency [%]

$$bsfc = \frac{\dot{m}_f\,[kg/hr]}{\dot{W}_b\,[kW]}$$

$$\eta_{th} = 100\frac{3600 W_b\,[kW]}{\dot{m}_f\,[kg/hr]\cdot LHV\,[kJ/kg]}\,\%$$

*If a gasoline based 1 kW generator consumes 1 litre/hr gasoline:*

- $\dot{m}_f = 0.8$ kg/hr
- $bsfc = \frac{0.8}{1} = 0.8$ kg/kW-hr
- $\eta_{th} = 100\frac{3600\times 1}{0.8\times 44.5\times 1000} = 10.1\%$