Piston or Reciprocating Engines

Sapugaskanda BOO Power Station,

Sri Lanka

4-Stroke medium speed diesel engines are mainly used for power generation on small islands, in remote areas and for industrial purposes. Medium speed technology is competitive for intermediate and base load power plants up to 200 MW: high levels of reliability and availability, rapid construction and installation, competitive capital cost and delivery times, and total efficiency approaching 90% for CHP plants.

Topics – Piston Engine

- Piston Engine, Its Uses, Fuels
- Types of Diesel Engines and Applications
- Compression Ratio and Efficiency of Engines
- Turbo-Charging of Engines
- Engine Heat Balance
- Basic Engine Construction & Support Systems
- Cost of Diesel Power
- Environmental Impact & Risks

Piston Engine Power Plants

- *Features:* reciprocating engines are either spark ignition (SI) or compression ignition (CI) engines; used mainly for peaking load but sometimes base-load operation for small island grids; highest compression ratio (SI – 14:1, CI – 21:1)
- *Fuels:* SI engines may burn gasoline, methanol, ethanol, natural gas, propane, LPG, landfill gas methane [CH_4], gasified biomass; CI engines run on heavier diesel, fuel oil, vegetable oils, CME, DME.
- *Facilities:* jetty and heated storage tanks to receive diesel and heavy fuel oil.
- *Emissions:* emits SO_2, NO_X and CO_2 just like an oil thermal plant, aside from excessive noise.

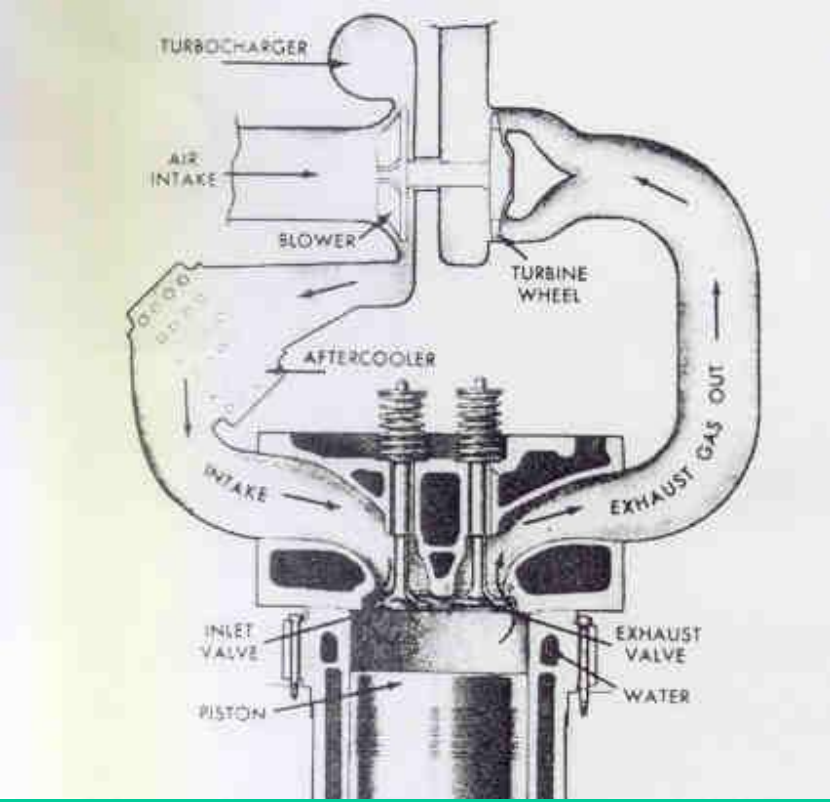
Piston Engine Power Plants (2)

- *Thermal Efficiency:* four-stroke diesel cycle with turbo-charging and air/fuel pre-heating may attain efficiencies of 36.5% or higher, and with CHP up to 50-90%.
- *Pollution Abatement:* low sulfur fuel is needed to meet Clean Air Act; noise mufflers are also needed to reduce noise levels.
- *Risks:* being oil based and subject to OPEC control, it is subject to risks in supply availability and high price volatility in the future; piston engines are also vulnerable to high maintenance costs.
- *Re-powering:* Coconut oil and methyl ester are also used in diesel engines. SI engines may replace CI engines and use renewable fuels like methanol, ethanol and methane from biogas and landfill gas.

Types of Diesel Engines

- **Small or high-speed –** units < 188 kW capacity
- **Medium speed –** units between 188 kW and 750 kW
- **Large or slow speed –** units over 750 kW, and up to 50 MW
- **Small** and **medium-sized diesel units -** used to generate power for remote communities; although expensive, it may prove more cost-effective than linking the community to the grid when transmission/distribution costs are considered
- **Large diesel units -** used primarily for marine propulsion and when used for power generation, are usually grid connected; operate at a low 100 rpm, extremely reliable and have long lifetimes.

Turbo-Charging of Engines



Turbo-charging System

- Turbo-charging provides increased air density to the working cylinder
- Two basic systems: pulse and constant-pressure
- Consists of blower or compressor section and exhaust or gas turbine section mounted on a common shaft.
- Cooled in large engines.

Engine Heat Balance

Engine System	Btu per bhp-h	W per kW	% of Total
Power output	2,545	1,000	36.5
Exhaust	2,420	951	34.7
Jacket water	800	314	11.5
Radiation	521	205	7.5
After-cooling	278	109	4.0
Lubricating oil	264	104	3.8
Turbo-charger	139	55	2.0
T O T A L	6,967	2,738	100.0

An engine with a 1,000 W power output has thermal efficiency of 36.5%; largest source of wasted heat is exhaust gas and cooling looses

Total Energy Cooling

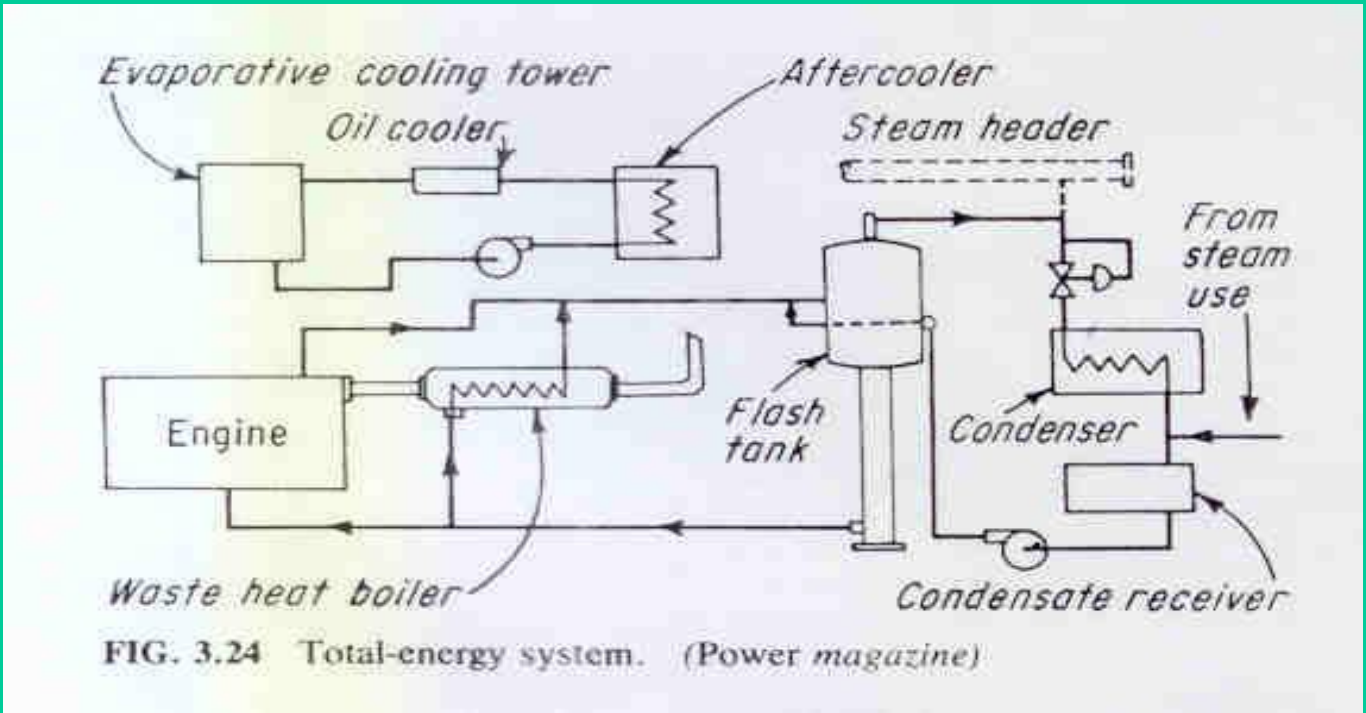


FIG. 3.24 Total-energy system. (Power *magazine*)

Total energy system reclaims almost all the heat from the engine jackets and exhaust thru a waste heat boiler.

Cost of Diesel Power Plants

- Between 1995-1998, a number of diesel power stations were built at a remarkably narrow range of $1,100-1,300/kW under build-own-operate-transfer (BOOT) arrangements:

Project	Country	Capacity MW	Cost $ million	Unit Cost $ / kW	Start Date
Kohinoor	Pakistan	120	140	1,167	1,997
Gul Ahmed Energy Co.	Pakistan	125	138	1,104	1,997
Jamaica Energy Partners	Jamaica	76	96	1,263	n.a.
APPL	Sri Lanka	51	63	1,235	1,998
IP	Tanzania	100	114	1,140	1,998

Environmental Impact

- Piston engines burning fossil fuels emit the same SO_2, NO_X, CO_2, CO, UHC and particulates as before.
- Gas (SI) engines are cleanest to operate since the fuel used have minimal sulfur, so only NO_X and CO_2 are cause of concern. Modern gas-fired piston engines have electronic control to keep NO_X emissions within limits.
- CO_2 is unavoidable and cannot be controlled, it is only lowered by raising thermal efficiency.
- NO_X emissions can be removed using a catalytic system fitted in the exhaust of small piston engines so long as sulfur is minimal (no poisoning)
- Small and medium-sized diesels burn lighter diesel oils with little sulfur while large/slow diesels burn cheap but heavy residual oils with 2-5% sulfur. If fuel is not treated, it has to be removed in the exhaust.
- Complete combustion will eliminate CO, UHC and particulate emissions but temperature has to be controlled to lower NO_X emission.

Risks

- **Technology –** used in the construction of piston engines is mature and the processes are well understood; improvements are continually made but these are minor in nature; overall performance and reliability of piston engine should fall within well established boundaries; *low risk*
- **Performance** – overall efficiency, reliability and lifetime should be guaranteed by the manufacturer; continuous operation of engine is desirable and performance would be predictable; however, continual startup and shutdown puts greater strain on the machine; *medium risk*
- **Fuel supply –** is probably the greatest risk as petroleum-based fuels prices change quickly, which has to be taken into account in both the fuel supply and power purchase agreements; if the security of supply cannot be guaranteed, the project cannot be considered viable; *medium to high risk*