Diesel Engine continued

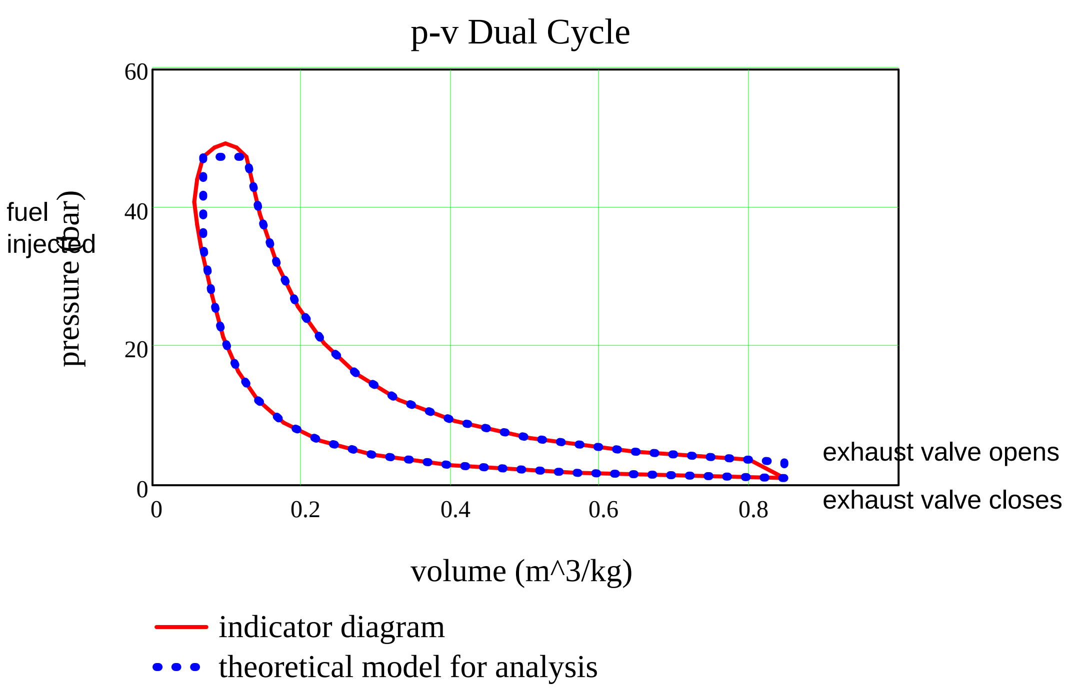
units definition $kJ := 1000J$

Limitations of air standard cycle
Features of real engine:

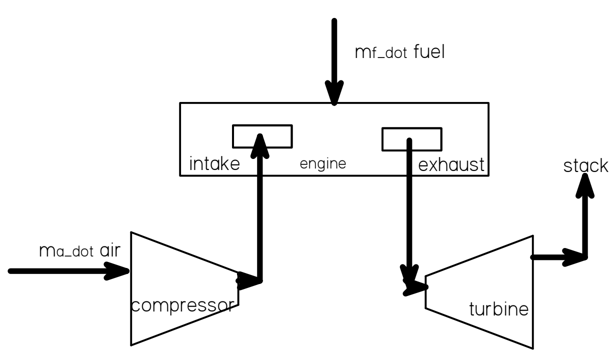
- real gas properties
- combustion parameters modify rate of pressure change
- heat transfer occurs during process & cylinder cooling
- intake and exhaust processes modify parts of the p-v diagram
- valve losses
- friction between piston rings and cylinder walls => reduced power output
- turbocharging modifies some of process

data for plot

$ftr := 1$ ftr = 1 for model



supercharging or turbocharging



inlet pressure increased + increased mass of air;
need more fuel; power ~ mass
but .. pressure + => increased loads
mass further increased by cooler
normally driven by exhaust turbine

see Woud 7.6

Designation of diesels (somewhat arbitrary)

	slow speed	medium speed	high speed
RPM	70 -250 rpm	350-1200 rpm	>1200 rpm A.D.C.
	76-250 rpm (2 stroke)	400-1000 rpm	750-1000 rpm Manbw.com marine engine programmes
piston ft/min	1200-1600	1200-1800	1600-2000
speed m/sec	6.1 - 8.1	6.1-9.1	8.1-10.2
BMEP psi	190-300	190-350	100-300
bar	13-21	13-24	7 - 21

2 stroke; 4 stroke

turbocharged vs. normal aspiration

fuel grade

1.3.1 Slow-, Medium-, High-Speed Diesel Engines

Slow-Speed Engines means diesel engines having a rated speed of less than 400 rpm.

Medium Speed Engines diesel engines having a rated speed of 400 rpm or more; but, approximately less than 1200 rpm.

High-Speed Engines means diesel engines having a rated speed of approximately 1200 rpm or more.

Operating Characteristics

$\text{MCR} = \text{maximum\_continuous\_rating}$ $\quad$ $\text{continuous\_service\_rating} = \text{MCR}\cdot(1 - \text{engine\_margin\%})$

$\text{mean\_indicated\_pressure}\cdot\eta_{\text{mechanical}} = \text{mean\_effective\_pressure}$ $\quad$ $\text{MIP}\cdot\eta_{\text{mech}} = \text{MEP}$

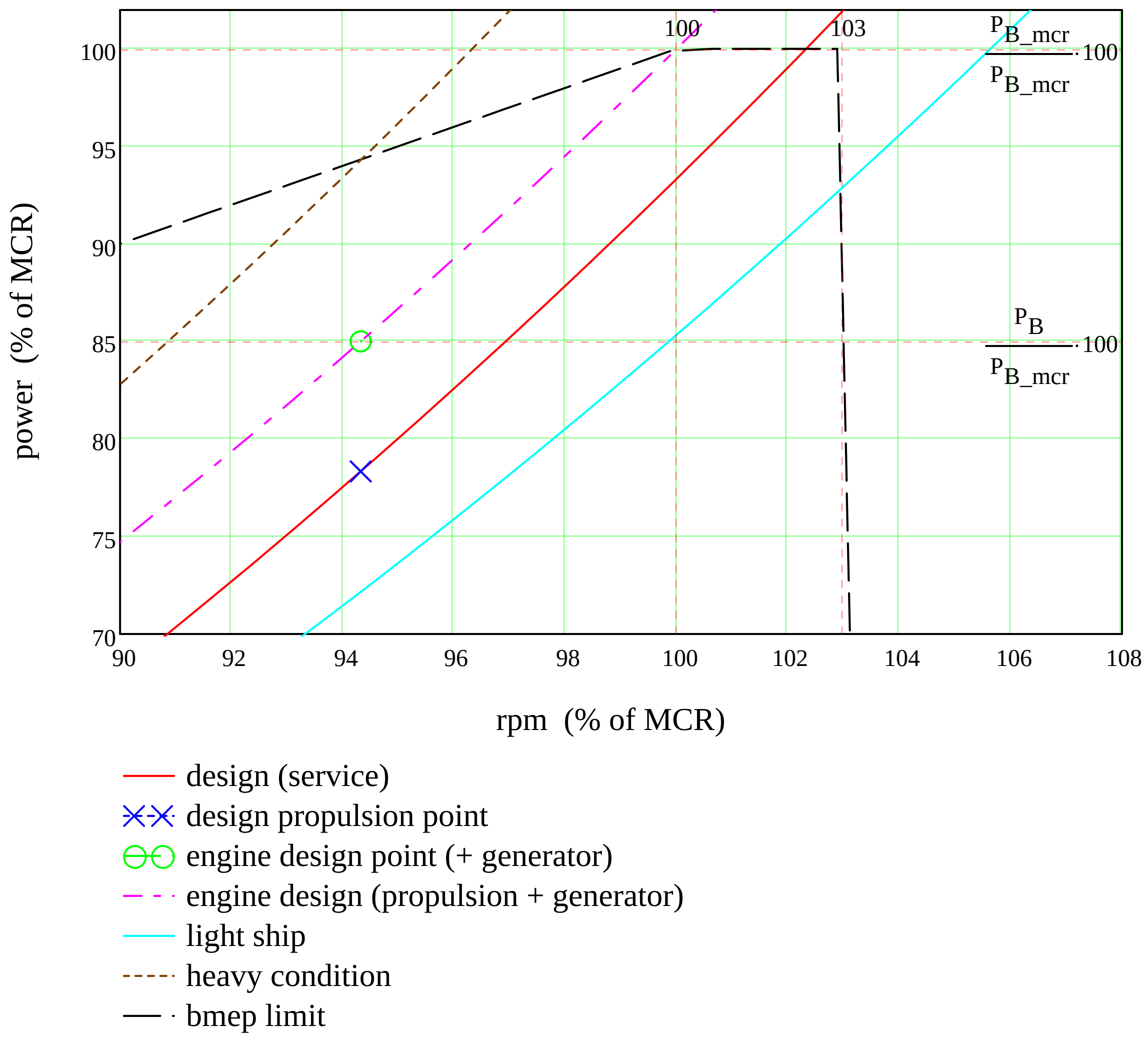
$\text{MEP}\cdot\text{rpm} = \text{brake\_power\_output}$ $\quad$ $\text{rated\_MEP}\cdot\text{rated\_rpm} = \text{MCR}$ $\quad$ MEP limits engine power example 11.7 calculations

Engine Layout (ship power with engine design limits, MCR minimum determined
data sourced from text example 11.7 page 462. Ship has attached generator. Design condition (propulsion specified (and power) - plotted, plus generator - plotted) shown with two additional off design plots:

light load (lower resistance with half load on generator)

heavy - weather, heavily fouled etc

Engine margin (EM) = 0.85, engine is limited to 103% rpm at MCR and constant Bmep below MCR.



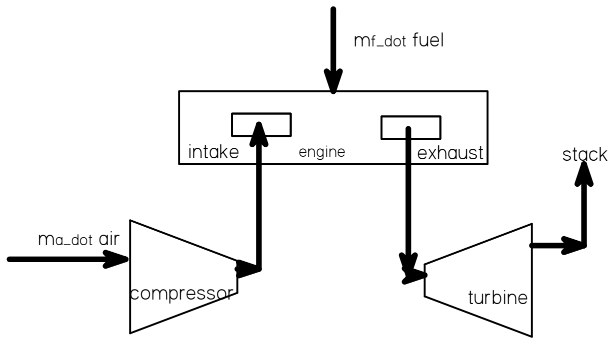
This is a busy curve and will be explained in lecture.

fuel consumption see handout and **PA6B chart** also typical operating zone

Improvements to Diesels

- fuel efficiency increased 15-25% over two decades
- use of lower quality fuel

waste heat recovery



energy balance typical large 2 stroke diesel

Input:	100 %	$m_{f\_dot} \cdot LHV$
Outputs:		
W_x	45 %	$0.45 \cdot m_{f\_dot} \cdot LHV$
exhaust @ 560 K cooled to 25 C	29 %	$m_{prod\_dot} \cdot c_{p\_prod} \cdot (560 - 298.15)$
charge air cooler cooled to 450 -> 30 C	14 %	$m_{a\_dot} \cdot c_{p\_air} \cdot (450 - 303.15)$
cooling 360 K -> 340 K	11 %	$m_{water\_dot} \cdot c_{water} \cdot (360 - 340)$
oil cooler	~ 1 %	

Diesel Engine Pollution Control

Ref: **Low Emission Medium-Speed Diesel Engines**,
Horst W. Koehler and Claus Windlev, Marine Technology,
Vol. 38, No. 4, October 2001, pp. 261-267

Typical engine:
volume

air (7.5 kg/kW*hr) 71 % N
19 % O2

fuel (180 gm/kW*hr) 97 % H
3 %

lube oil (0.8 gm/kW*hr 97.5 %
Ca=calcium 1.5 %
1 % S

18 cyl 4 stroke 26,000 hp @ 500 rp

=> 82 tonnes (1000 kg) fuel per da
3400 tonnes induced air
1/2 tonne lube oil

=> ~ 3500 tonnes combustion prod

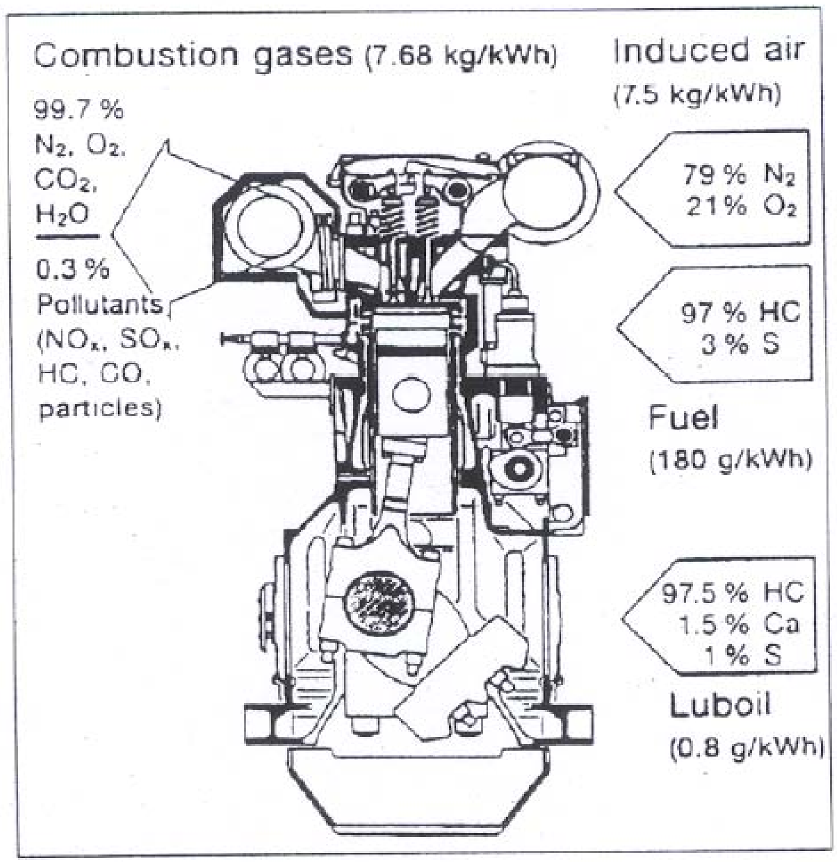


Fig. 3 Specific mass flow rates of a large medium-speed diesel engine

combustion products

99.7 % N_2, O_2, CO_2, H_20 typical:

N_2, 74.3 %
O_2, 11.3 %
CO_2, 6 %
H_20 8.1 %

0.3 % pollutants: NO_x, SO_x,
HC, CO, particles

gm/KW-hr
NO_x, 17
SO_x, 10
HC, 1
CO, 0.8
particles 0.25

CO_2 => greenhouse effect, coastal areas may require low sulpher fuel
most serious NO_x

NO_x Control

see NVR emissions

- strongly dependent on peak temperature during burning

Control

1) reduce amounts formed
    - a. reduce maximum pressure by delaying injection
    - b. recirculating part of exhaust
    - c. reduce amount of scavenging air
    - d. spray water during combustion
    - e. use emulsion of oil and water - reduces NO_x by ~ 25 %
2) remove from exhaust
    - catalytic converters not practical - too much air
    - a. Selective Catalytic Reduction (SCTR)
      mix exhaust gases (300-400 C) with correct amount of amonia - pass through catalyst

$$4 \cdot NO + 4 \cdot NH_3 + O_2 = 4N_2 + 6H \cdot O_2$$

$$6 \cdot NO_2 + 8 \cdot NH_3 = 7N_2 + 12H \cdot O_2$$

urea - organic compoound of Carbon, N_2, O_2, & H_2 used more widely

90 % reduction can be achieved

In use today - typically during entry to port

see ASNE **presentation re: emissions**

and ... **New rules to reduce emissions from ships enter into force**
http://www.imo.org/Newsroom/mainframe.asp?topic_id=1018&doc_id=4884

The Annex VI regulations set limits on sulphur oxide (SO_x) and nitrogen oxide (NO_x) emissions from ship exhausts and prohibit deliberate emissions of ozone-depleting substances

and ... **Shipping Emissions Abatement and Training (SEAaT) paper**
http://www.seaat.org/media/EmissionControlv052.doc on emissions

This international legislation covering all shipping activity establishes Sulphur Emissions Control Areas (SECAs) which are geographically defined areas where ships must limit their SOx emissions

The first of these, the Baltic Sea, will come into effect on May 20, 2006, with the North Sea and English Channel becoming SECAs in 2007

Shipping Emissions Abatement and Training (SEAaT)

SEAaT is a cross-industry, unique, pro-active and self funding group, whose mission is to encourage and facilitate efficient reduction of harmful emissions to air from shipping

N.B. these links do not work in the pdf format. It is necessary that the linked files be located and connected - they can be made to work but it take some time. the ASNE presentation, PA6B chart and Marine Technology paper (documents) are on the web. The other links are on the web