

***1998 GT-SUITE User Conference (US)***



***An Analytical Study On Turbocharging A  
V6 SUV High Speed Direct Injection (HSDI)  
Diesel Engine***

***FEV***

# ***An Analytical Study on Turbocharging A V6 SUV HSDI Diesel Engine***



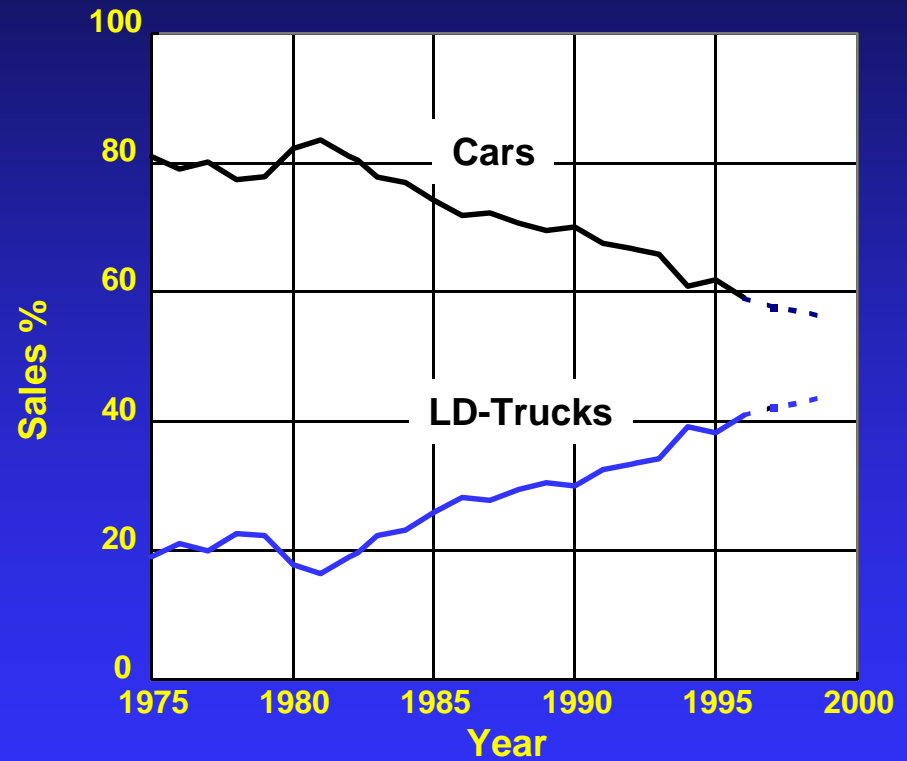
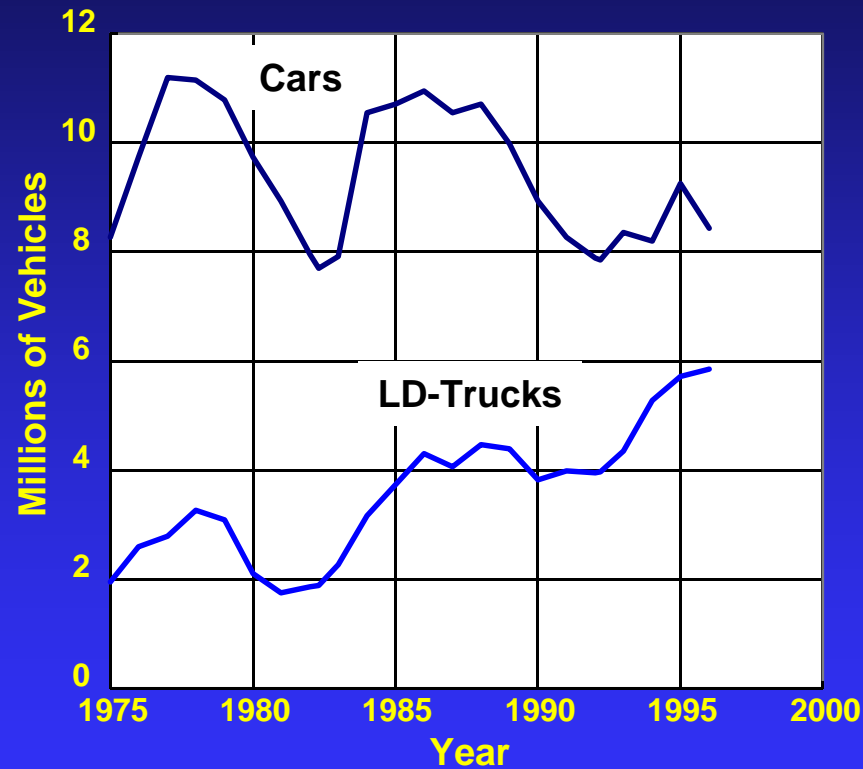
- **Introduction**
- **Simulation Boundary Conditions**
- **Simulation Results**
- **Summary**

## *Sport Utility Vehicles (SUV)*



*FEV*

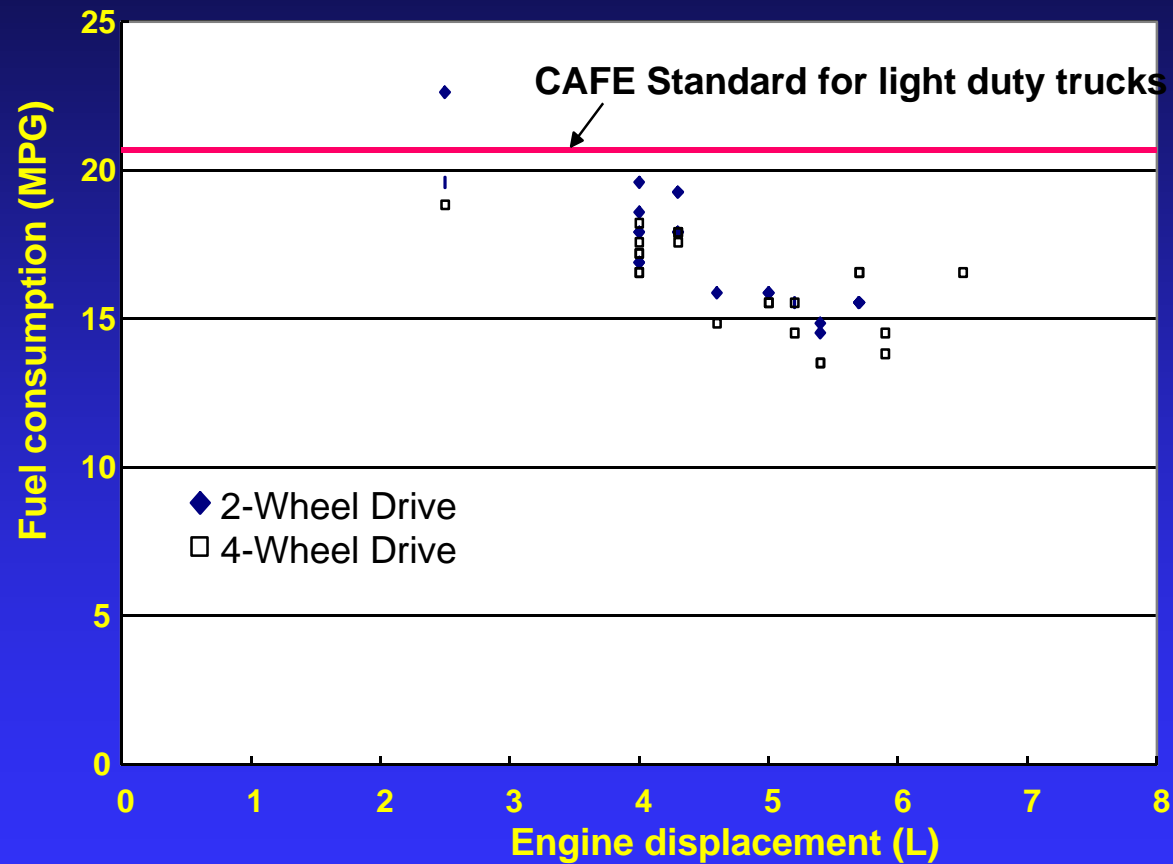
# Passenger Car and Light Duty Truck Sales in the US



Source: EPA

**FEV**

# Combined Fuel Economy (City+Highway) for SUV



Source: EPA

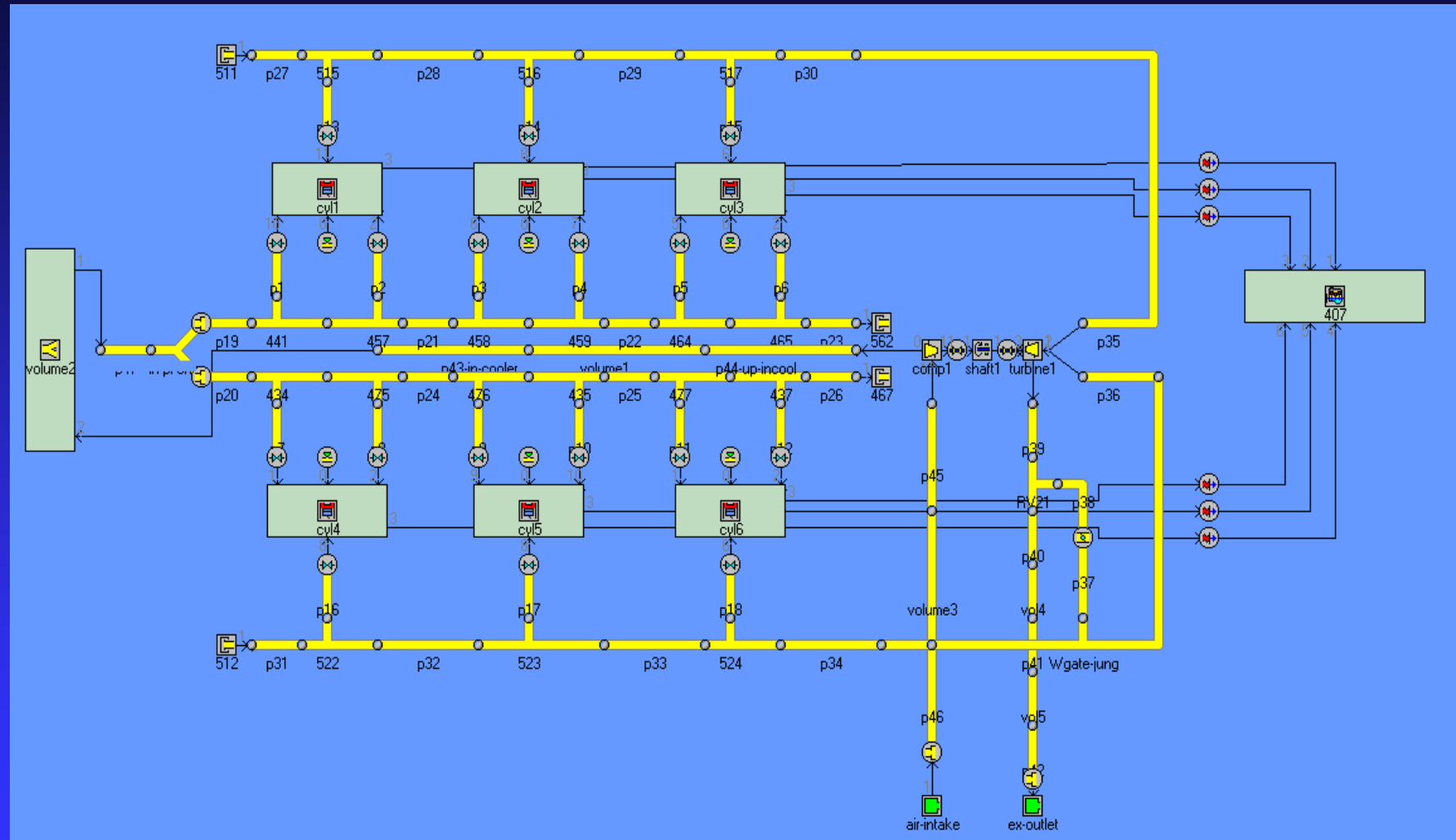
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## Boundary Conditions

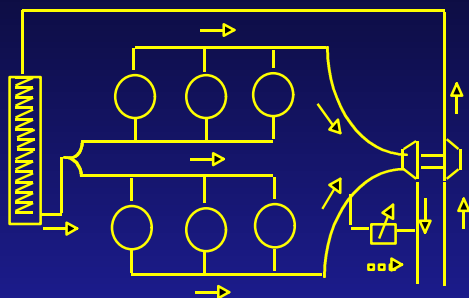


Engine configuration	90°-V6, turbocharged and intercooled
Rated power @ rated speed	186 kW (250 hp) @ 4,000 rpm
Rated torque	583 Nm (430 ft-pds) @ 2,000 rpm
Low end torque	257 Nm (190 ftpds) @ 1,000 rpm or: $\lambda \geq 1.3$ (A/F $\approx$ 18.8)
Displacement	4.0 L
Bore	92 mm (3.62")
Stroke	101 mm (3.98")
Firing order	even: 1-6-3-5-2-4-1 (split-pin crankshaft)
Compression ratio	17.5
Maximum peak pressure	155 bar
Intake valves Exhaust valves	2 x Ø34 mm 2 x Ø28 mm
Turbocharger	Derived from existing hardware
Computer code	GT-Power

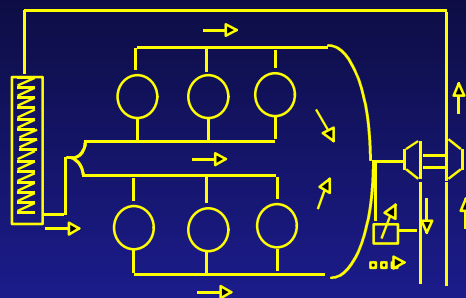
# GT Power Model - Baseline, One Turbocharger with Waste Gated Twin Flow Turbine



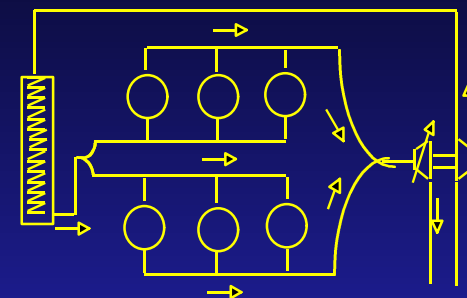
# Turbocharger Arrangements



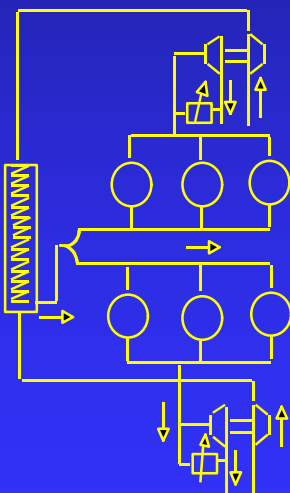
a. One turbocharger with twin flow turbine, waste gated



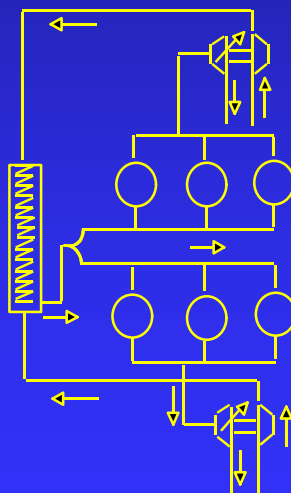
b. One turbocharger with single turbine entry, waste gated



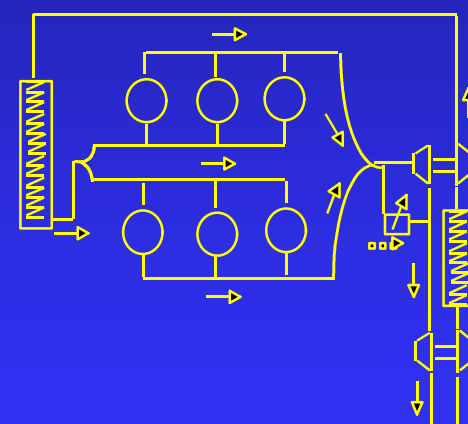
c. One turbocharger with single flow variable turbine geometry (VGT)



d. Bi-Turbocharger system with single flow turbine, waste gated



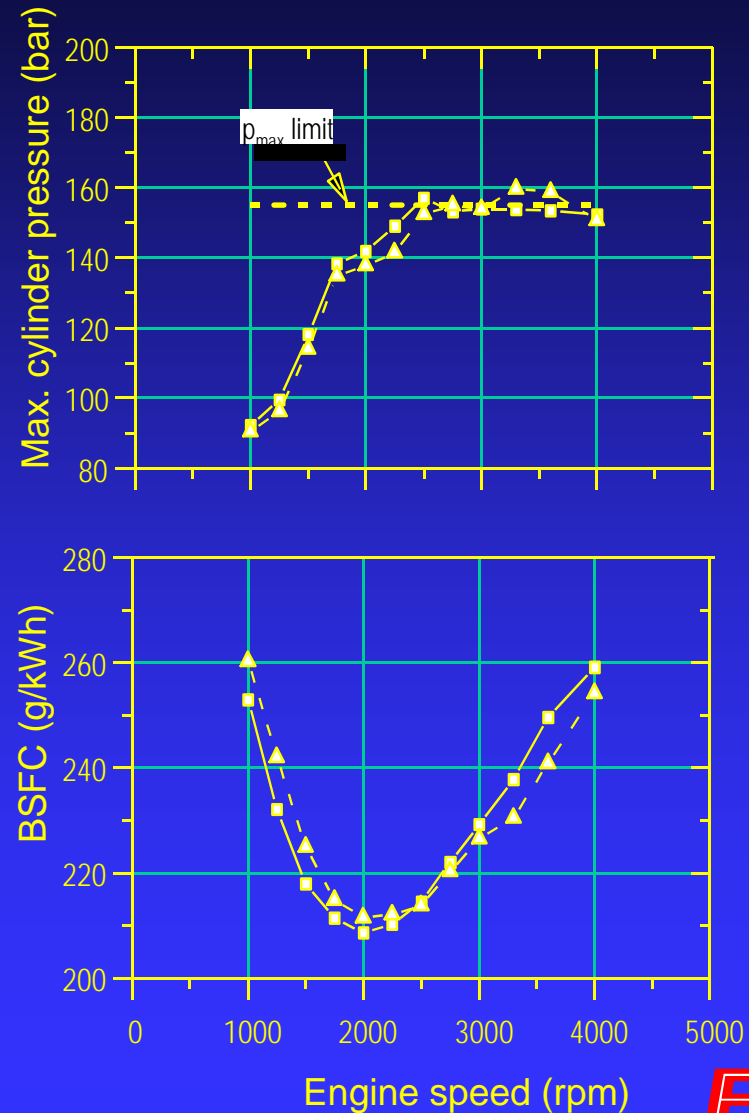
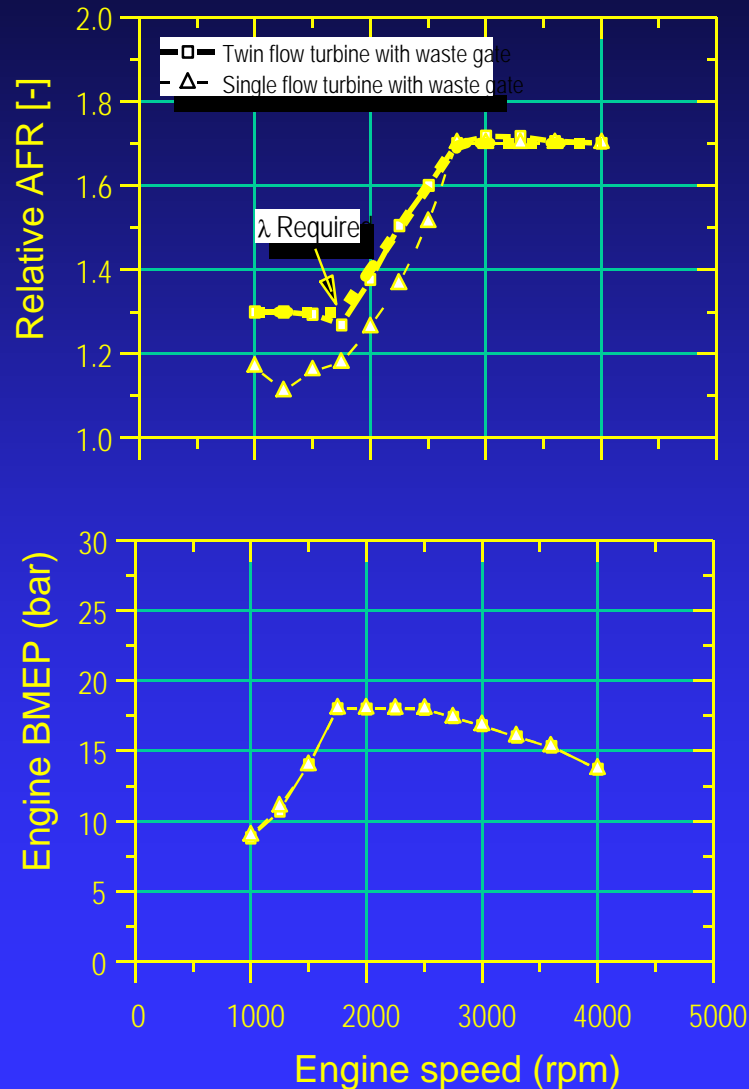
e. Bi-VGT turbocharger system with single flow turbines



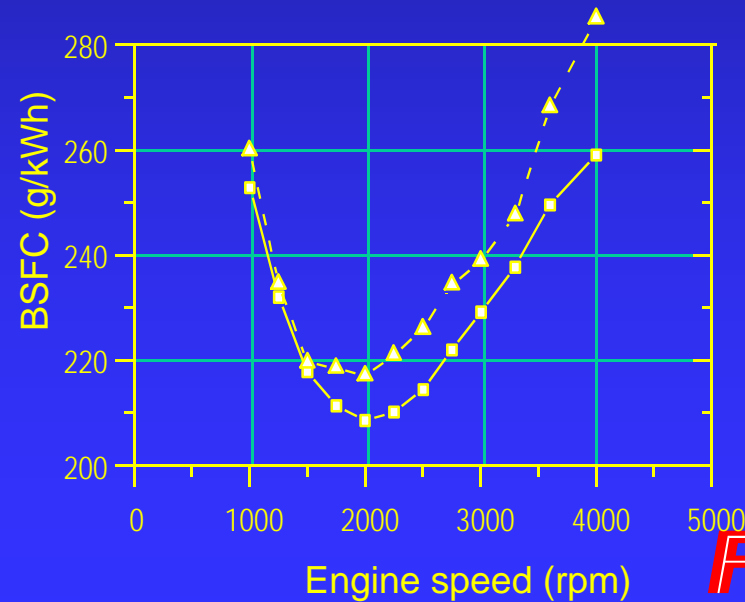
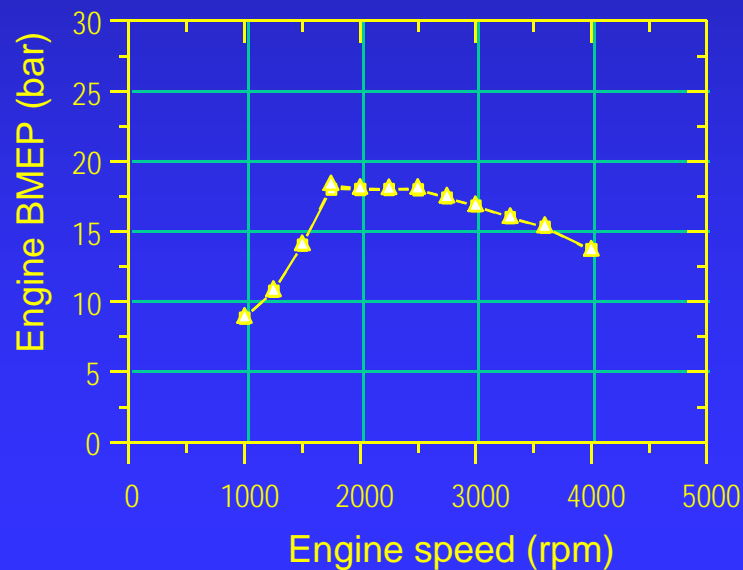
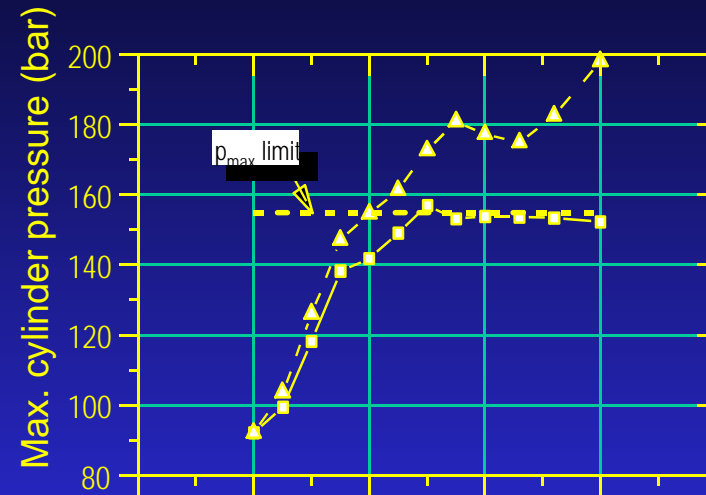
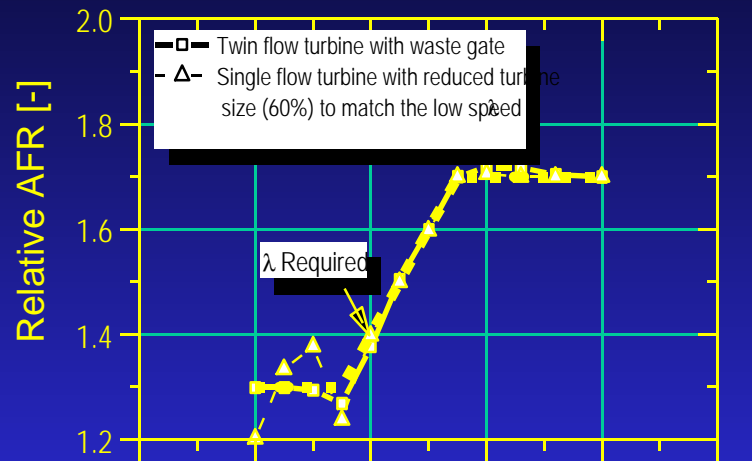
f. Two stage turbocharging system with single entry turbines



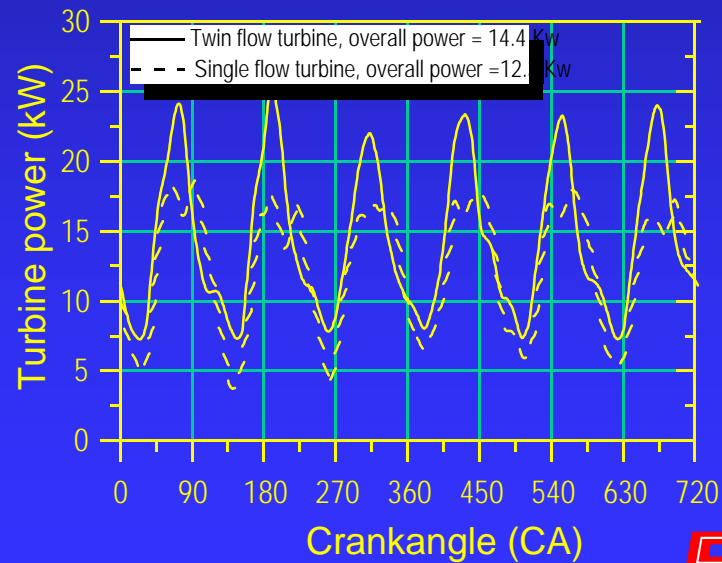
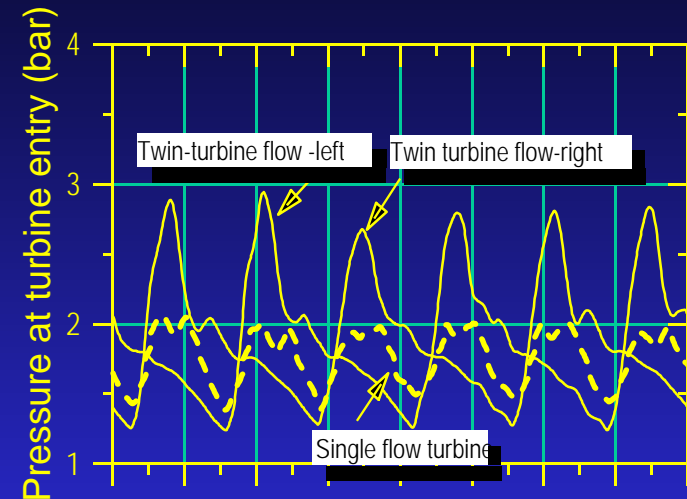
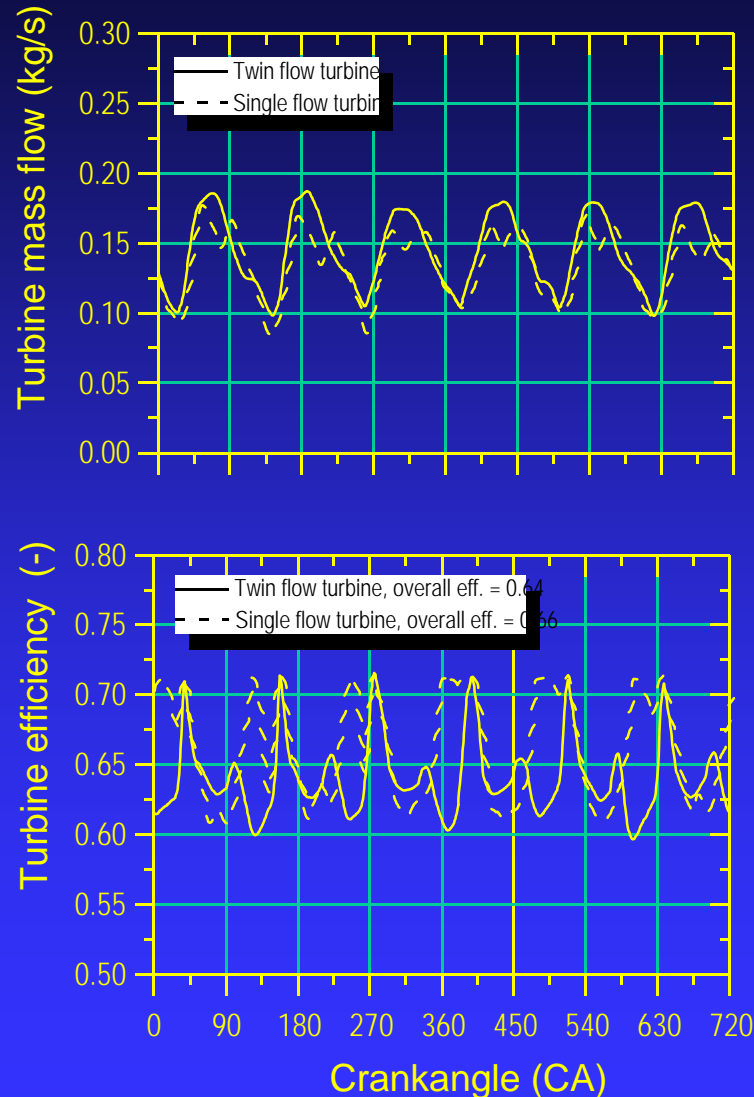
# Comparison of Waste Gated Twin Flow and Single Flow Turbine with Same Compressor, and Same Turbine Size



# Comparison of Waste Gated Twin Flow and Single Flow Turbine - Same AFR @ 2000 rpm

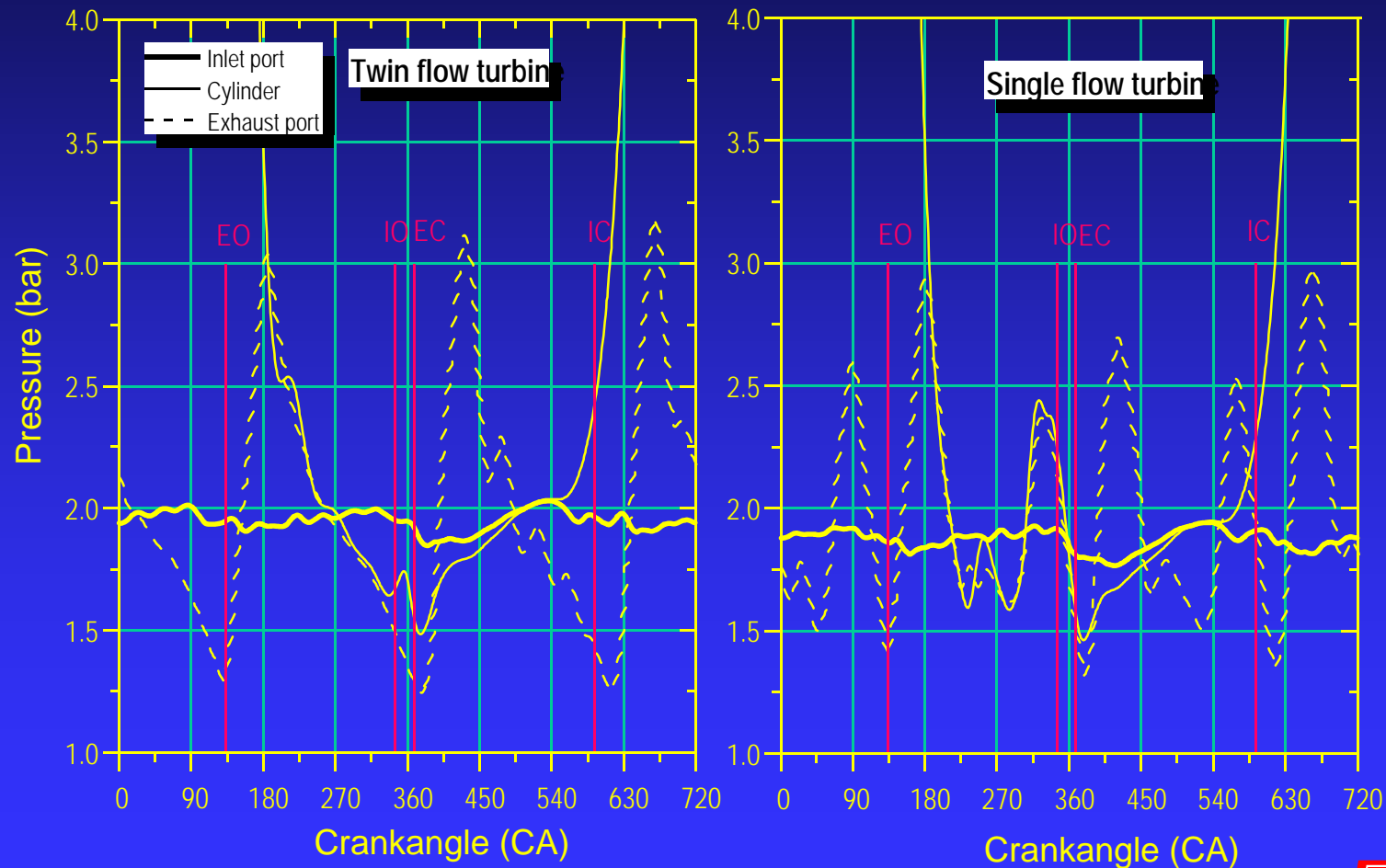


# Comparison of Engine Performance @ 2,000 rpm, Twin Flow vs. Single Flow Turbine, Waste Gate Closed

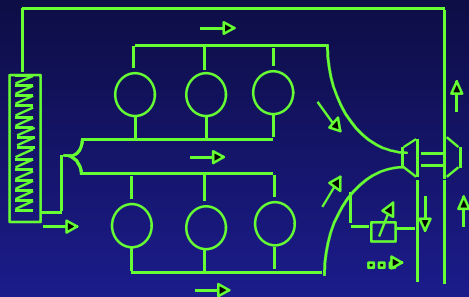


# Comparison of Gas Pressure Across Engine Cylinder No. 1 - Twin flow and Single Flow Turbine @ 2000 rpm

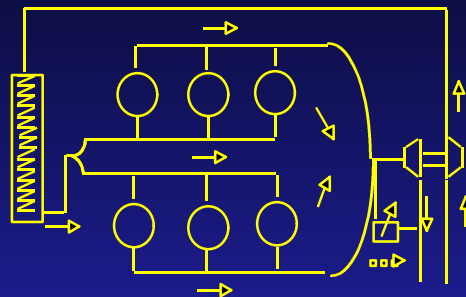
Waste gate closed



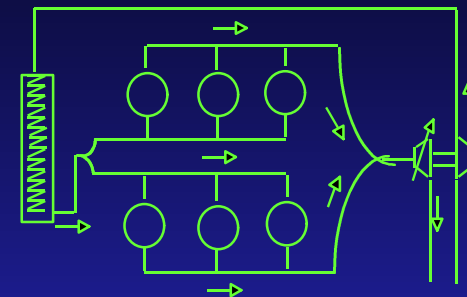
# Turbocharger Arrangements



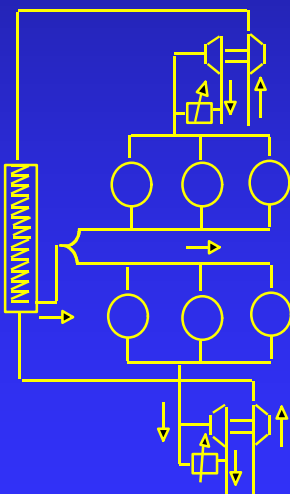
a. One turbocharger with twin flow turbine, waste gated



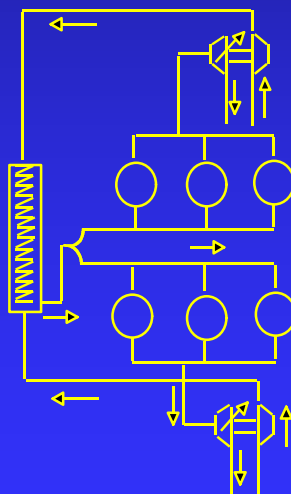
b. One turbocharger with single turbine entry, waste gated



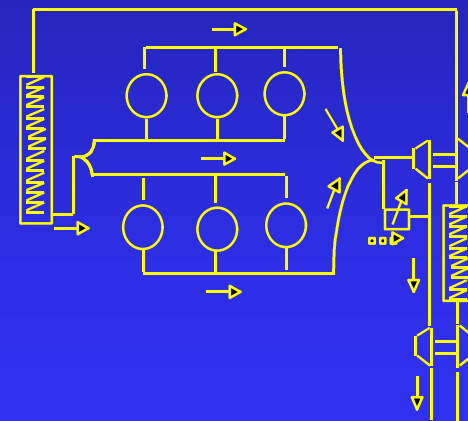
c. One turbocharger with single flow variable turbine geometry (VGT)



d. Bi-Turbocharger system with single flow turbine, waste gated

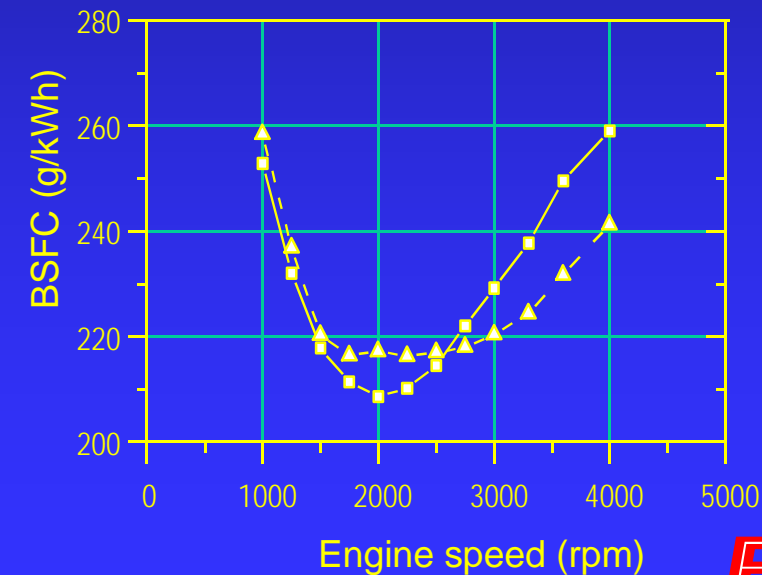
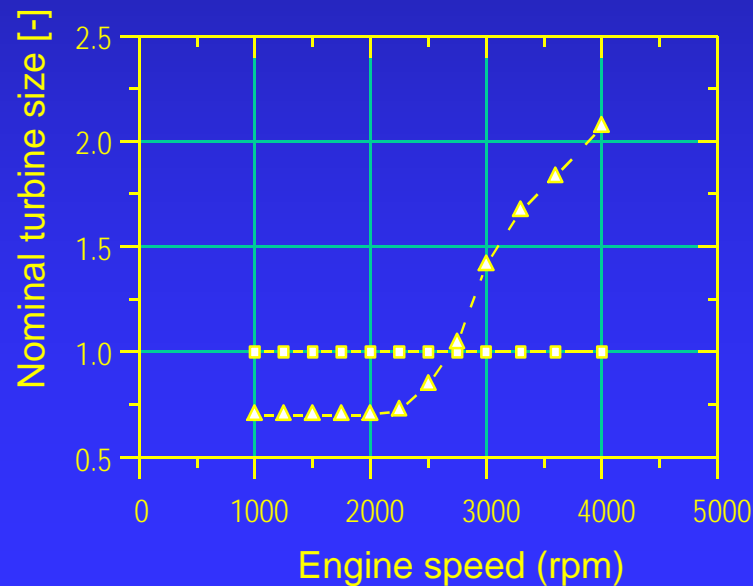
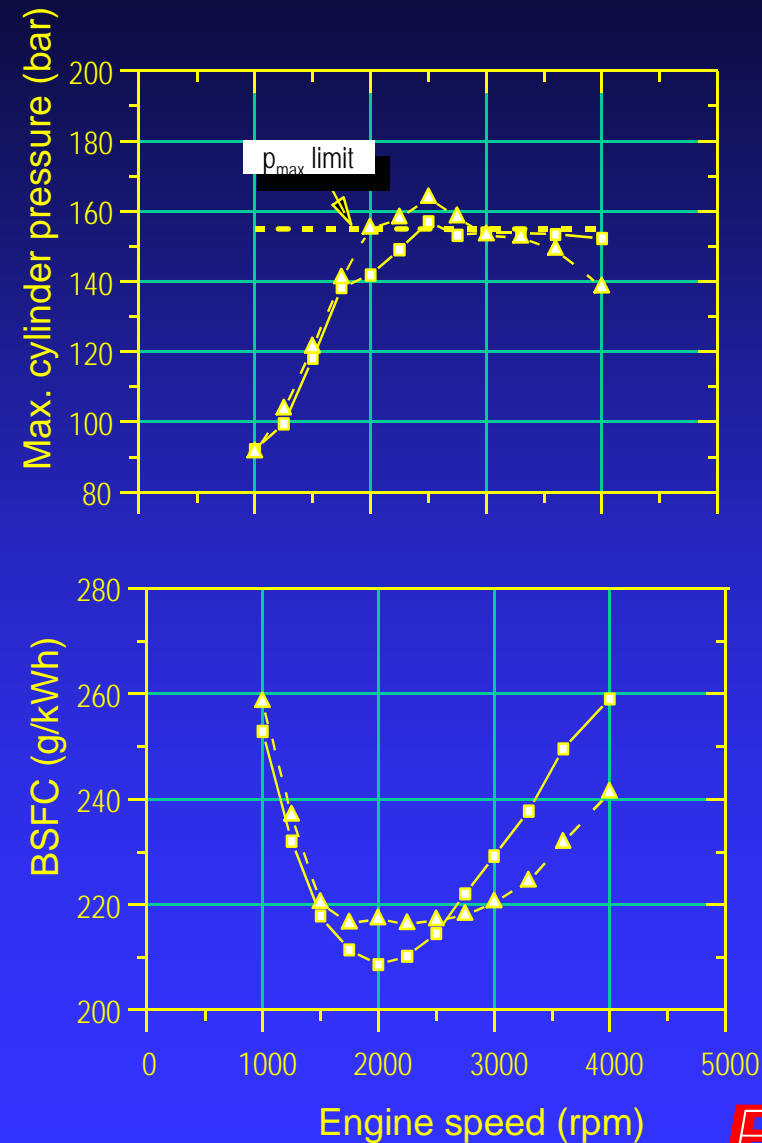
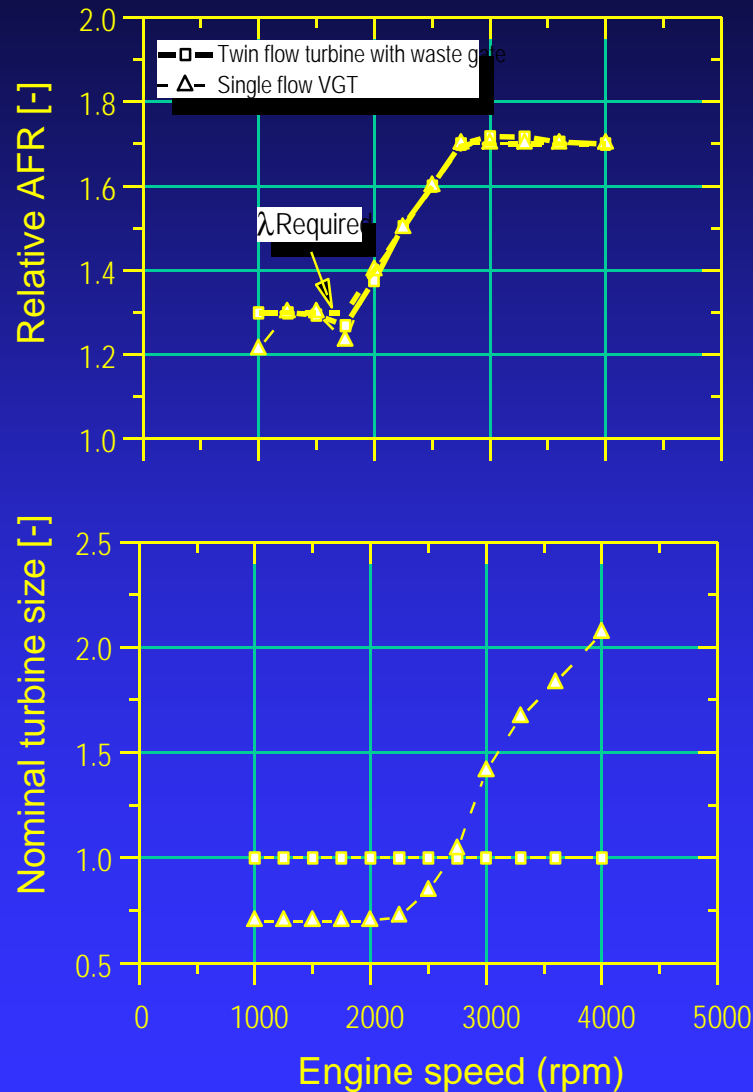


e. Bi-VGT turbocharger system with single flow turbines

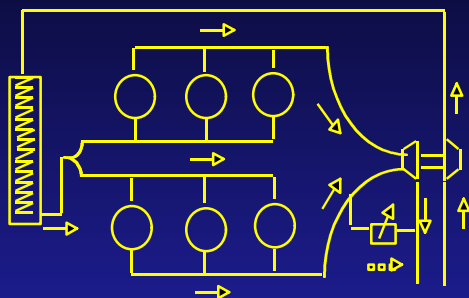


f. Two stage turbocharging system with single entry turbines

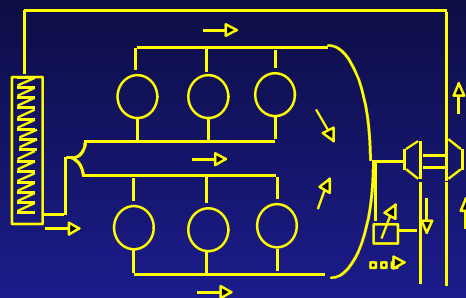
# Comparison of Waste Gated Twin Flow Turbine Turbocharger with Single Flow VGT Turbocharger



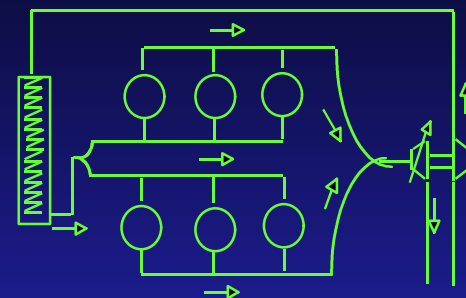
# Turbocharger Arrangements



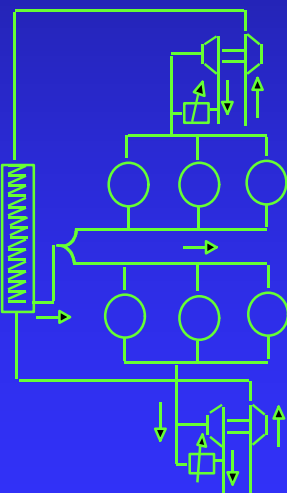
a. One turbocharger with twin flow turbine, waste gated



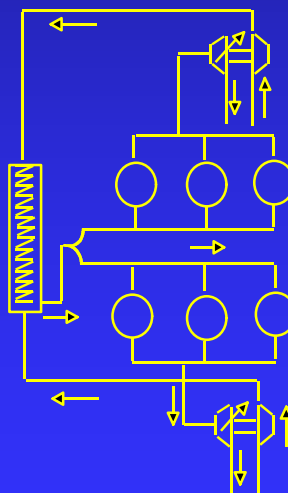
b. One turbocharger with single turbine entry, waste gated



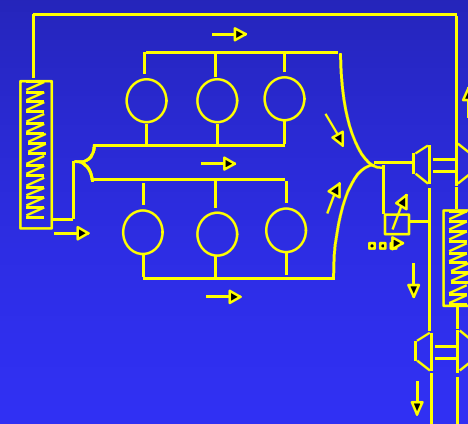
c. One turbocharger with single flow variable turbine geometry (VGT)



d. Bi-Turbocharger system with single flow turbine, waste gated

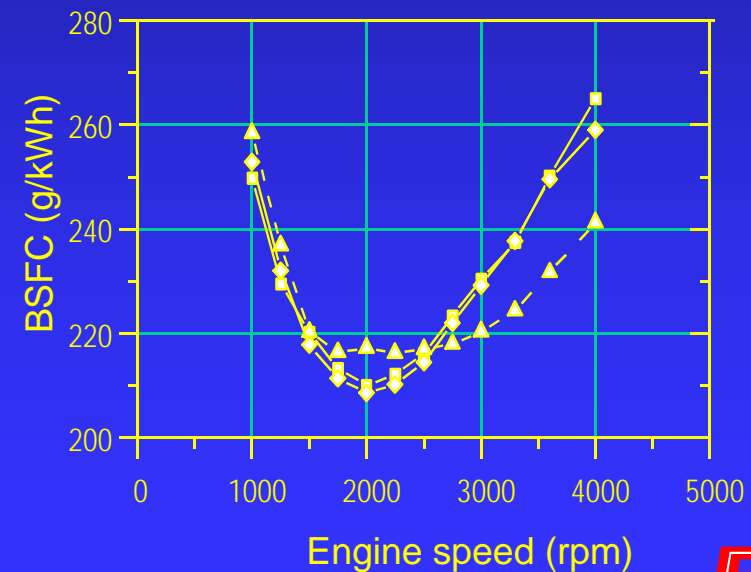
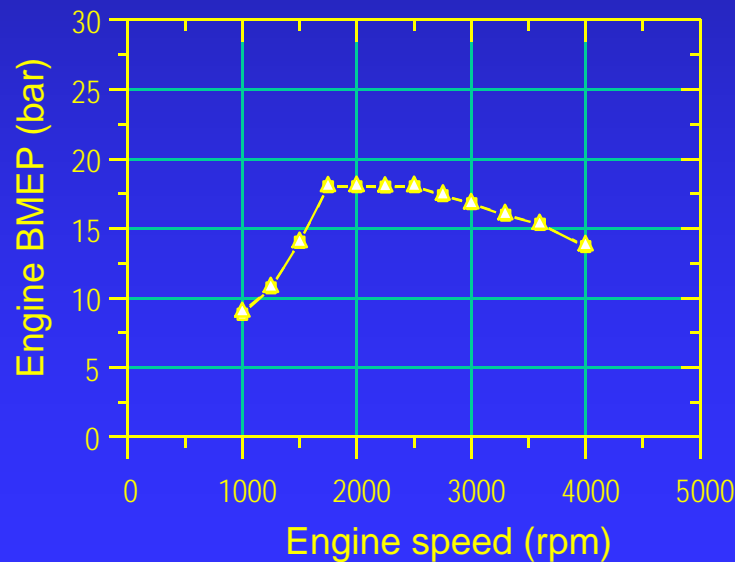
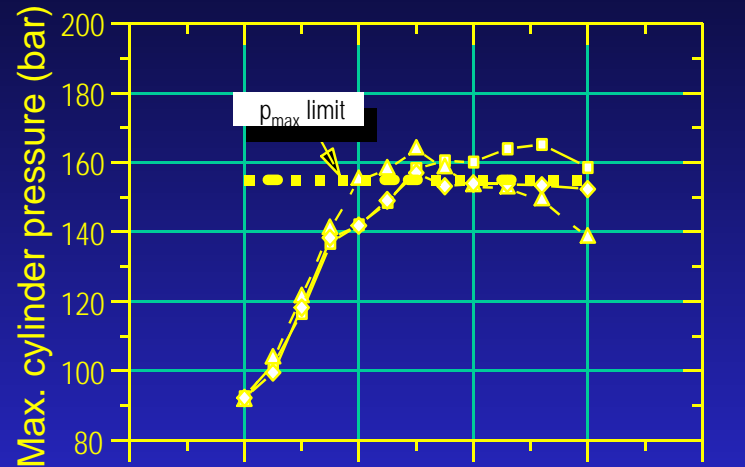
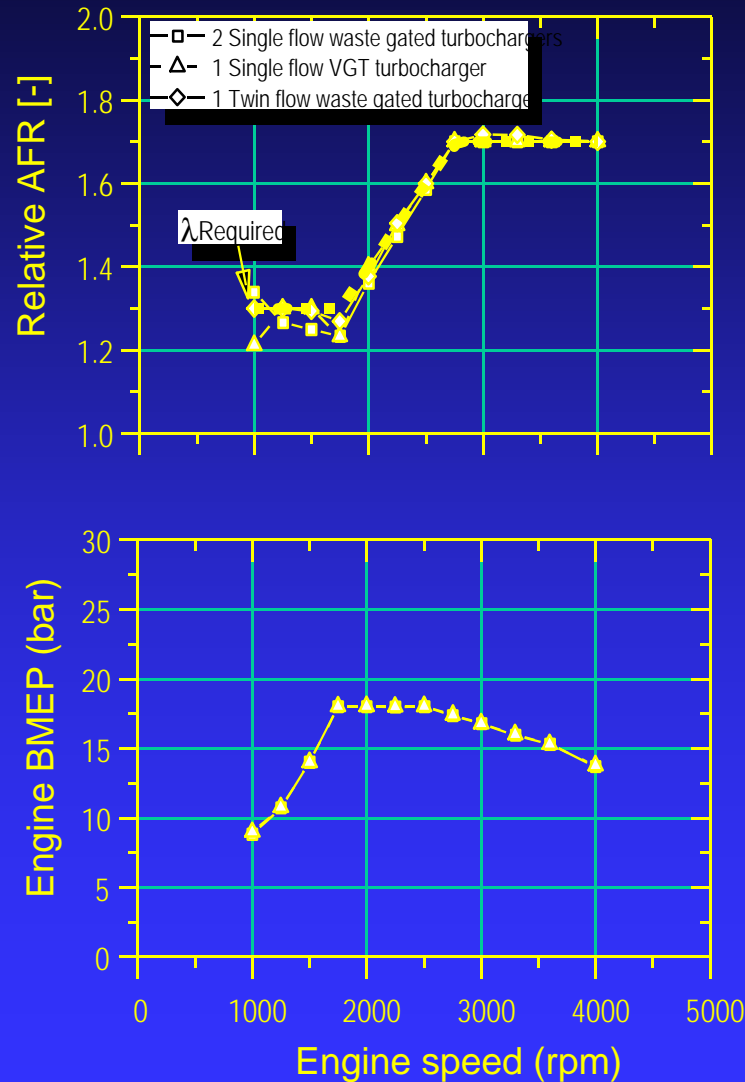


e. Bi-VGT turbocharger system with single flow turbines



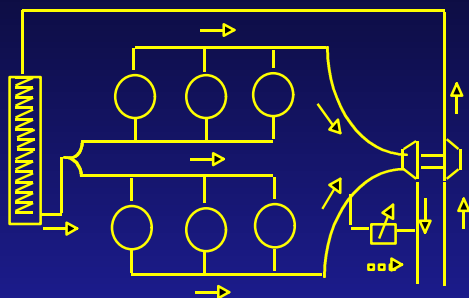
f. Two stage turbocharging system with single entry turbines

# Comparison of Biturbo Waste Gated Single Flow with One Single Flow VGT Turbocharger

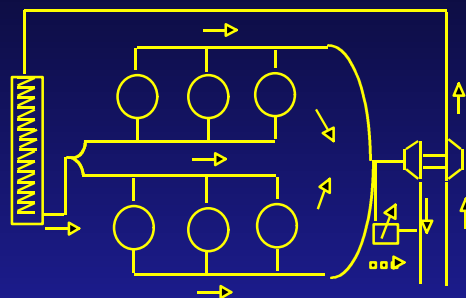




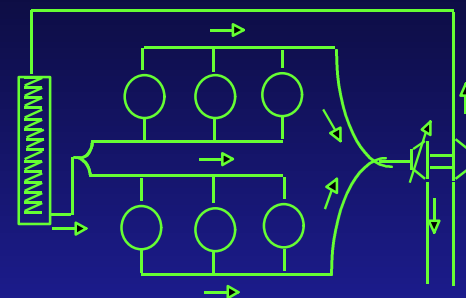
# Turbocharger Arrangements



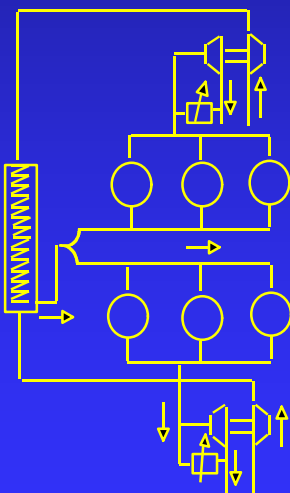
a. One turbocharger with twin flow turbine, waste gated



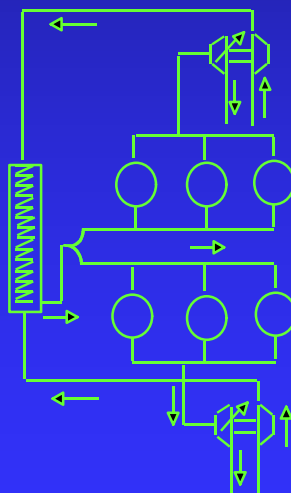
b. One turbocharger with single turbine entry, waste gated



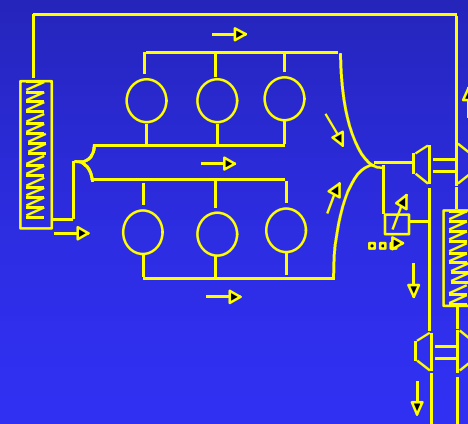
c. One turbocharger with single flow variable turbine geometry (VGT)



d. Bi-Turbocharger system with single flow turbine, waste gated

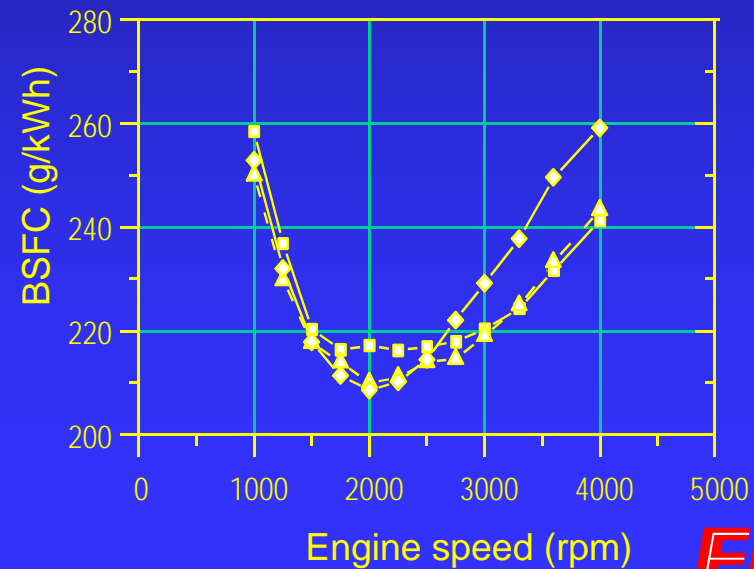
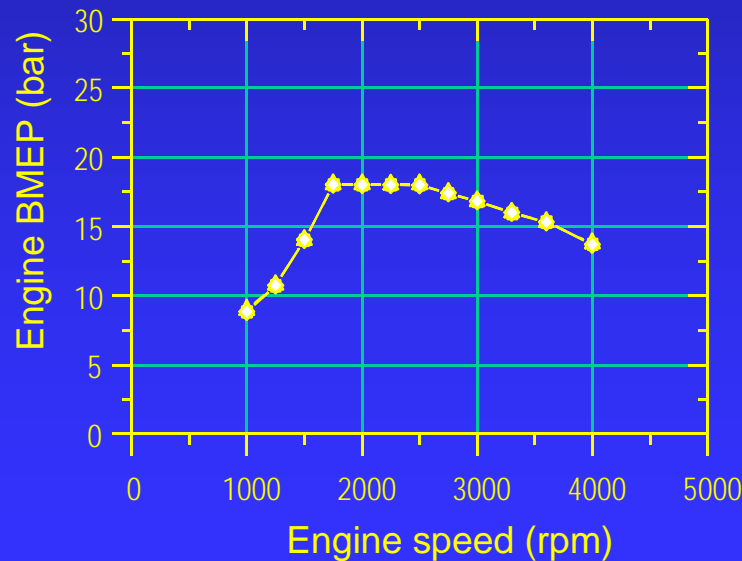
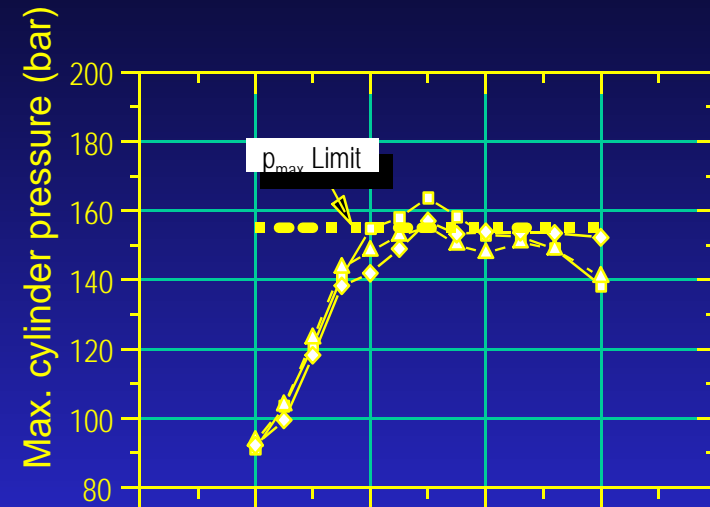
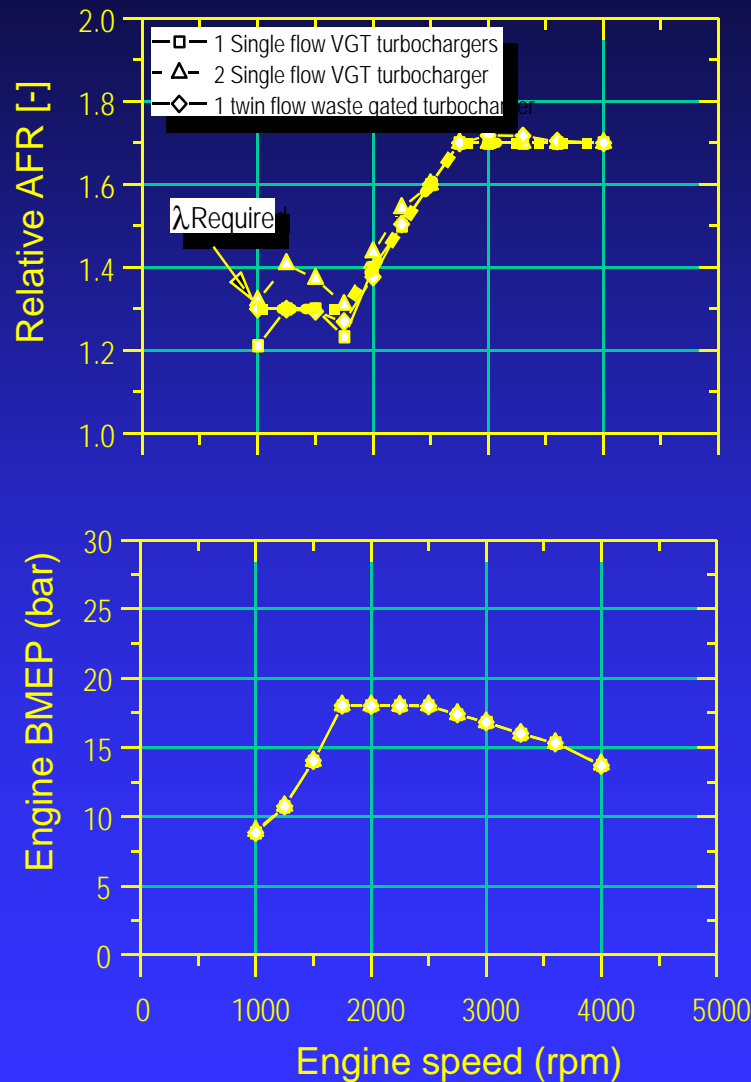


e. Bi-VGT turbocharger system with single flow turbines

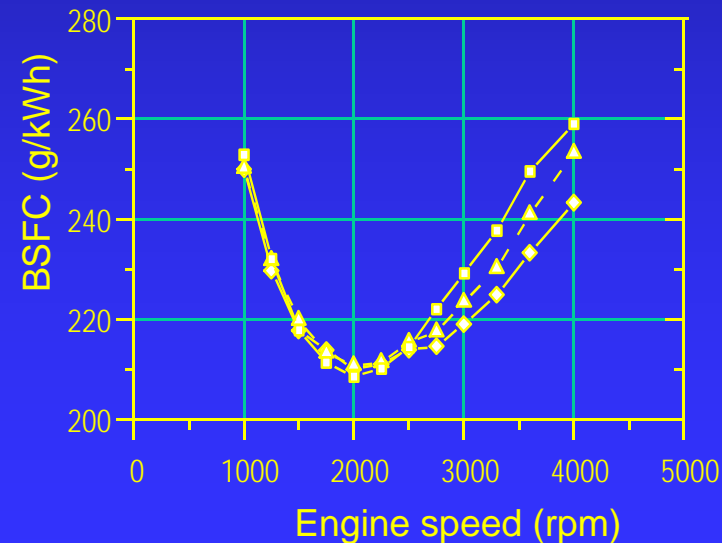
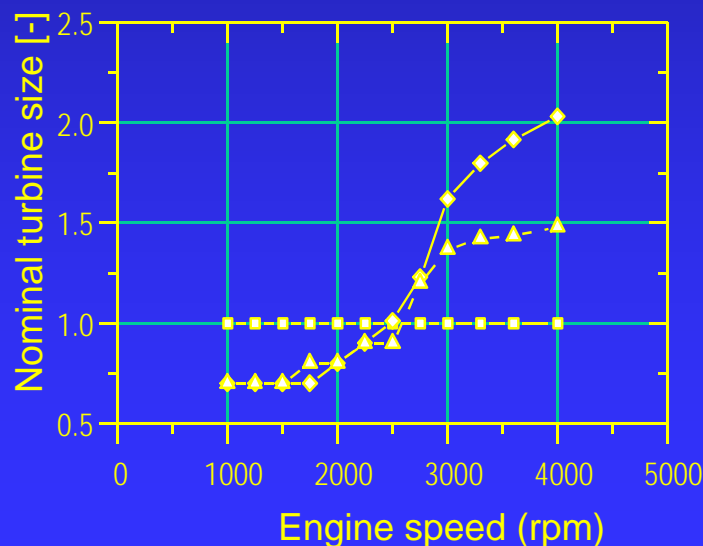
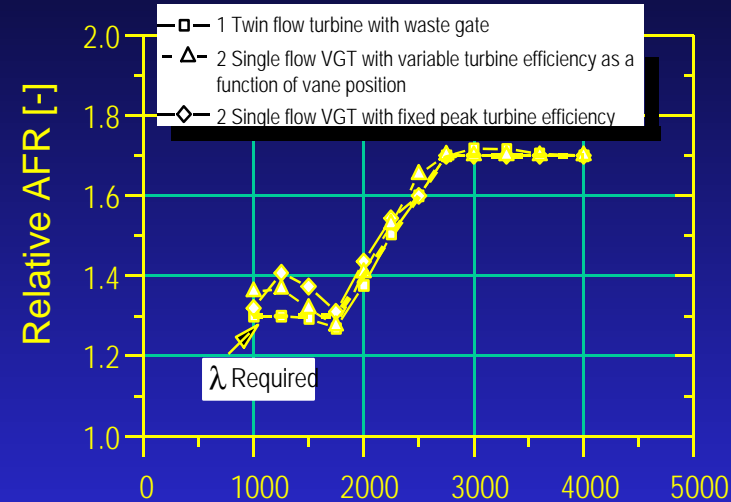
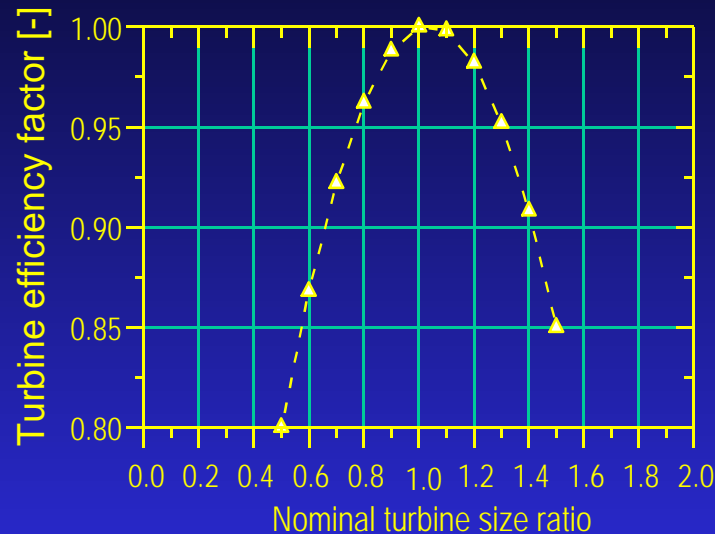


f. Two stage turbocharging system with single entry turbines

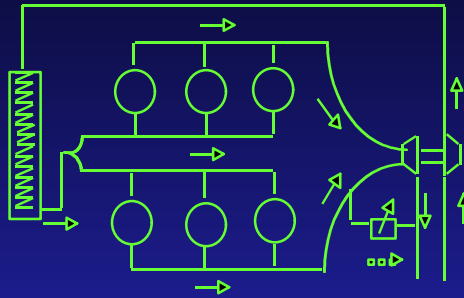
# Comparison of One Single Flow VGT Turbocharger With Bi-Turbo Single Flow VGT Turbochargers



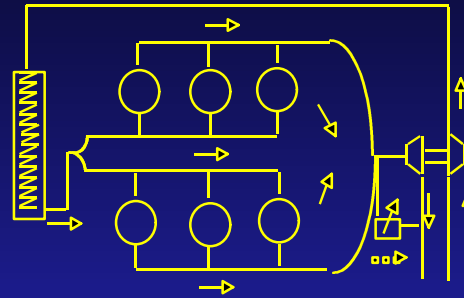
# Comparison of Two Single Flow VGT With One Waste-Gated Twin Flow Turbine Turbocharger - Influence of VGT Vane Position Dependent Turbine Efficiency



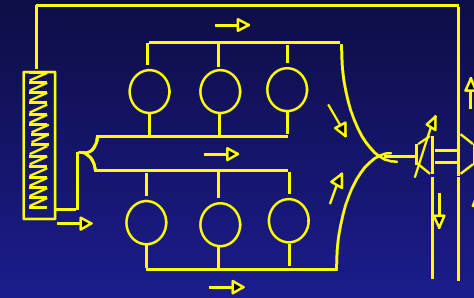
# Turbocharger Arrangements



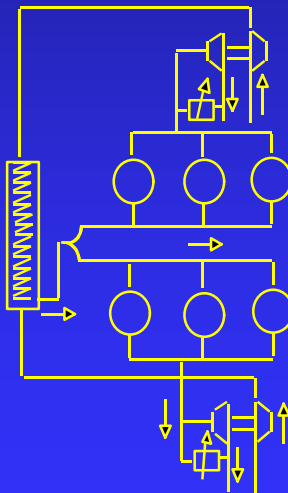
a. One turbocharger with twin flow turbine, waste gated



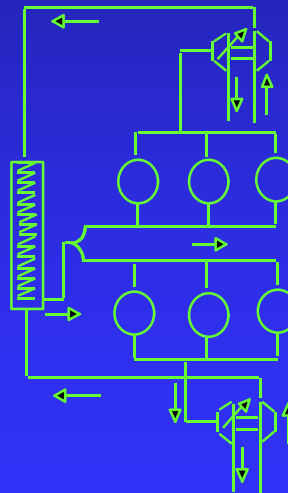
b. One turbocharger with single turbine entry, waste gated



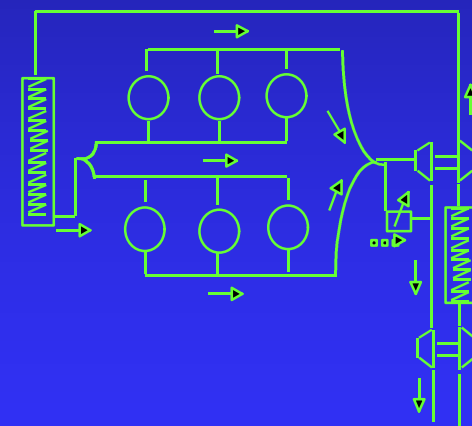
c. One turbocharger with single flow variable turbine geometry (VGT)



d. Bi-Turbocharger system with single flow turbine, waste gated



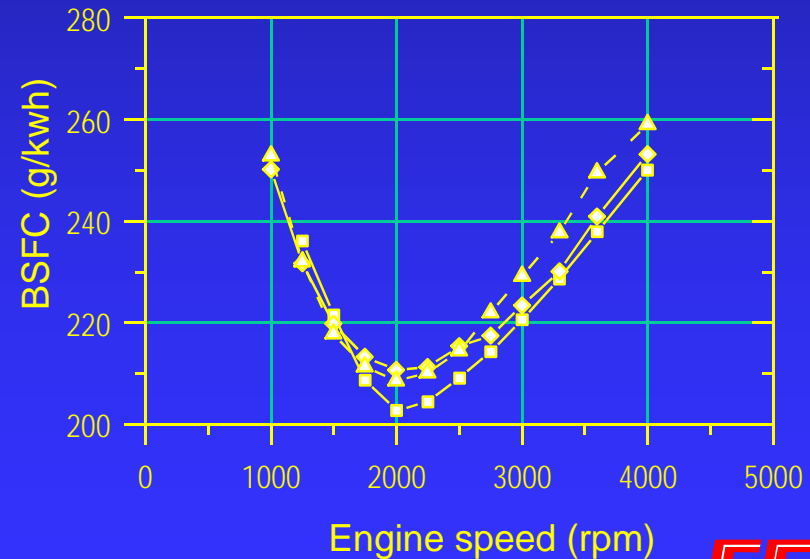
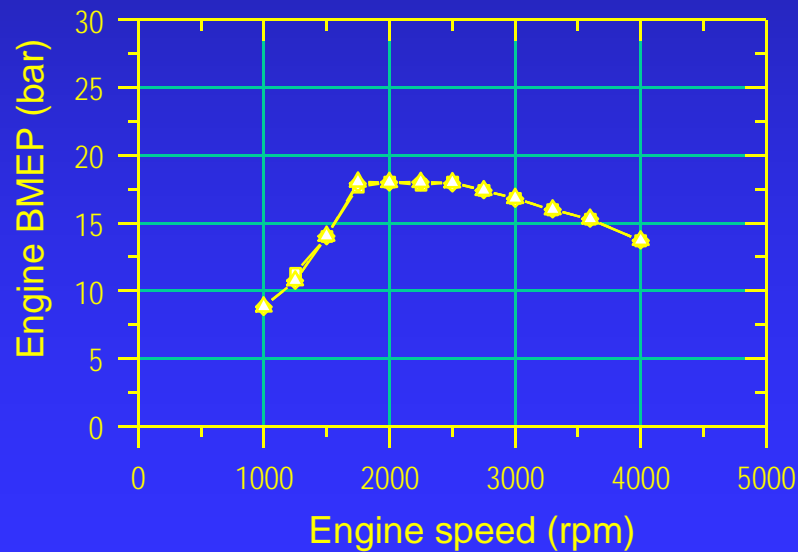
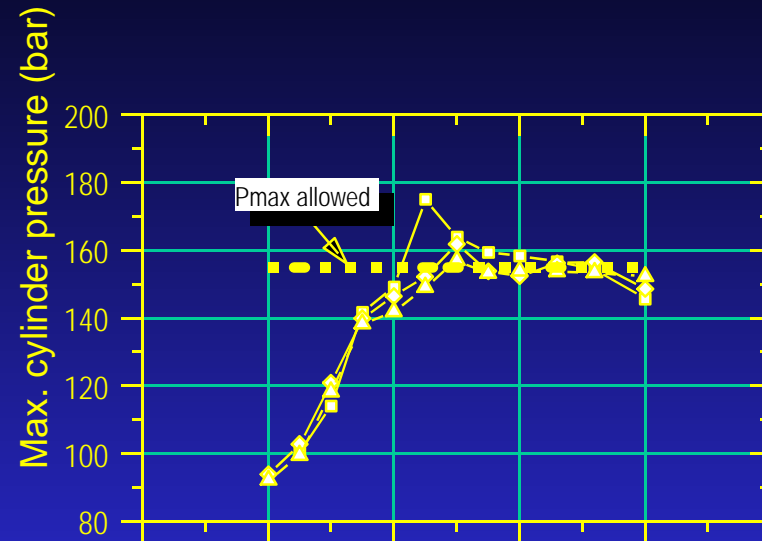
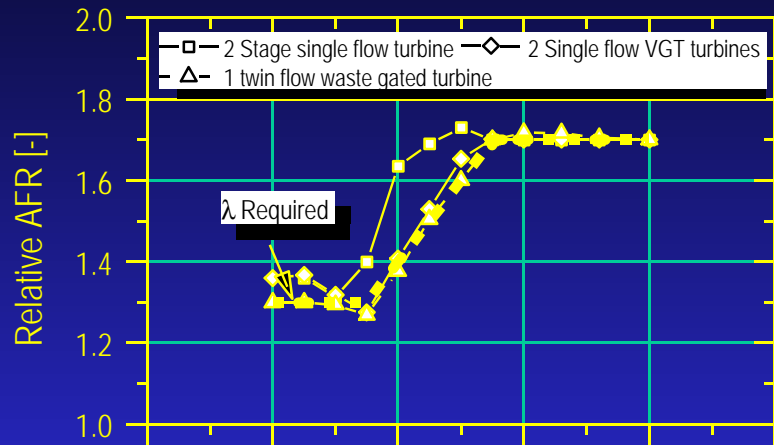
e. Bi-VGT turbocharger system with single flow turbines



f. Two stage turbocharging system with single entry turbines

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# Comparison of Two-Stage Turbocharging System vs. Other Arrangements



## Summary



- The V6 engine with even firing order is beneficially turbocharged using a system with two separated exhaust volutes.
- The engine equipped with one twin-flow waste-gated turbocharger offers high low end torque at low cost compared to other turbocharging systems.
- The engine equipped with one VGT turbocharger improves high speed fuel economy compared to the waste-gate turbocharger, and will become the standard turbocharger system.
- The engine equipped with a bi-turbo VGT turbocharger system shows the best low end torque capability and high speed fuel economy but it adds cost and complexity.
- The two-stage turbocharging system offers the highest potential for low end torque and best-in-class fuel economy but adds complexity. It is superior for extended downsizing with dramatic improvement in transient response.