BorgWarner Turbo Systems

Regulated 2-Stage (R2S) Charging Systems for Future Diesel Applications

Patrick Sweetland

Dr. Frank Schmitt

Outline

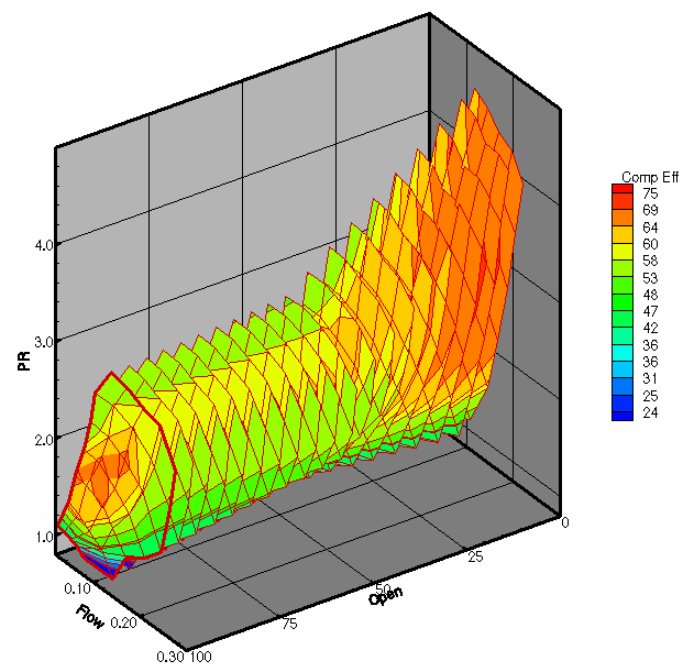
- Future Turbocharging Needs
- Challenges and Tradeoffs
- R2S Concept & Application
  - Heavy Duty
  - Light Duty Vehicle
  - Passenger Car
- Application Options and Examples
- Summary

Air System Requirements

- Several drivers for air system performance
- Emission Regulations
  - Boost increase to enable increased EGR
  - Improved low speed lug/transient A/F ratio
  - Altitude capability
- Performance Needs
  - Low speed torque
  - Transient capability
  - Increased ratings

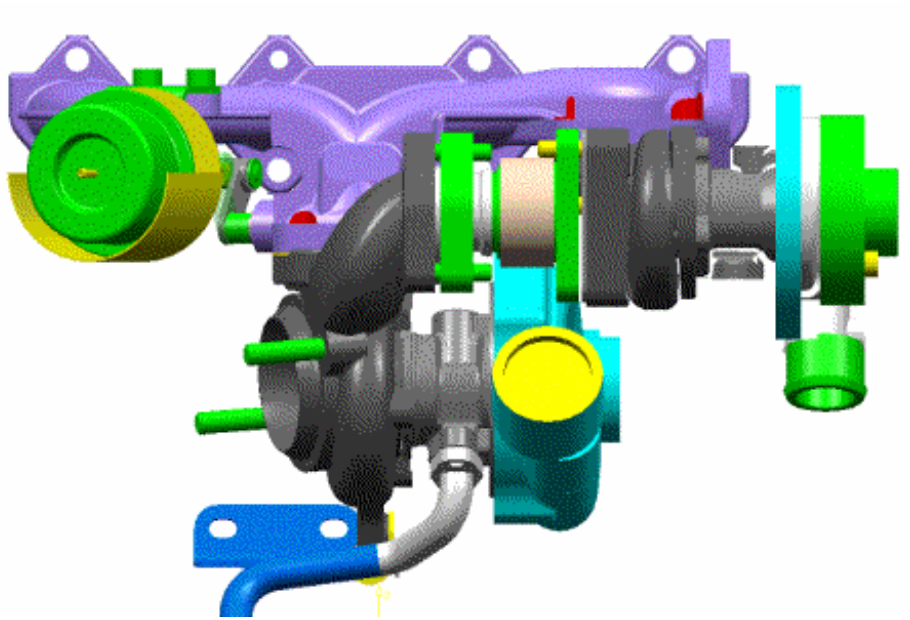
Challenges and Trade-offs

- Single stage VTG turbocharging – current state of the art
  - Broadened turbine characteristic increases compressor flow width requirements
  - New compressor map developments have increased width
  - Additional width required
- Variable compressor geometry provides limited width improvements



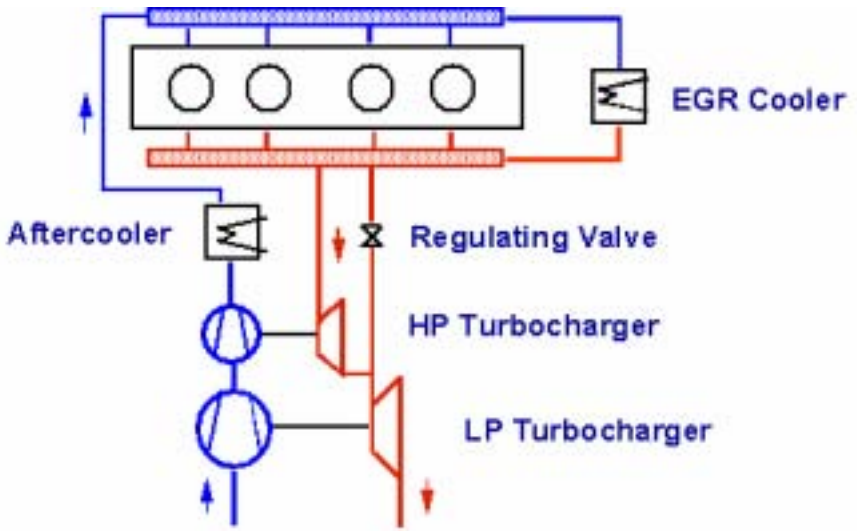
R2S Concept

- Two-stage boosting has existed for many years
- Primarily used to provide very high boost levels
- Regulation increases R2S capabilities
  - Increased flow range
  - Reduced inertia
  - More altitude capability
- High Pressure (HP) and Low Pressure (LP) stages can be arranged in several ways



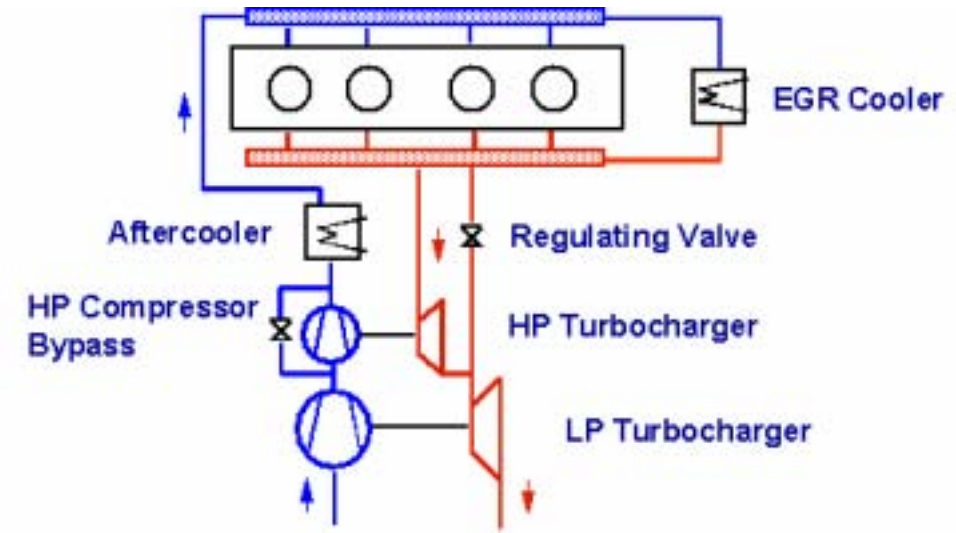
R2S with HP Turbine Bypass

- HP – Low engine speed contribution – sized for LP overlap and flow
- LP – High engine speed contribution – sized for rated
- 2-stage compression at all operating points
- High PRs achievable
- Excellent flow range
- Limited by LP stage matching and HP stage swallowing capacity
- Well suited to heavy duty applications



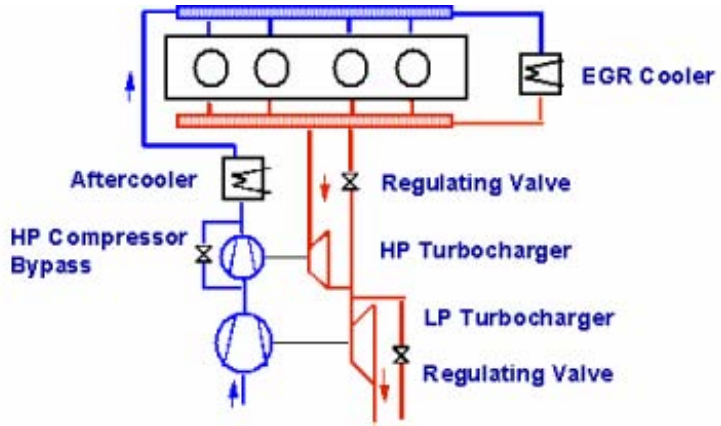
R2S with HP Stage Bypass

- HP stage compressor bypass added
- Swallowing capacity of HP stage removed as a limit
- 2-stage compression at low speeds, only LP compression at high speeds
- Good single stage PR achievable by high speed dedicated LP stage
- Excellent flow range
- HP stage reduced in size – better transient and low speed performance
- Well suited to light duty vehicle and mid-rated heavy duty applications



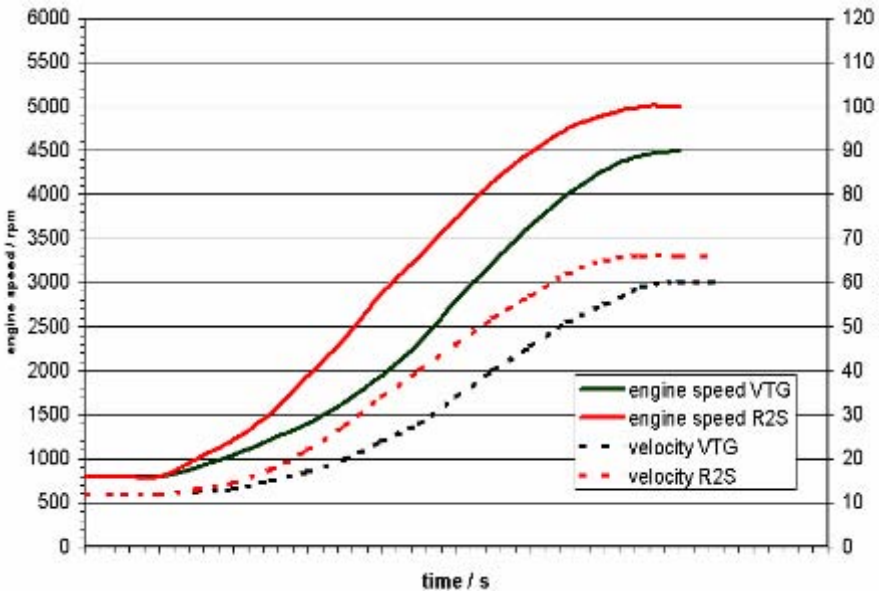
R2S with HP Stage and LP Turbine Bypass

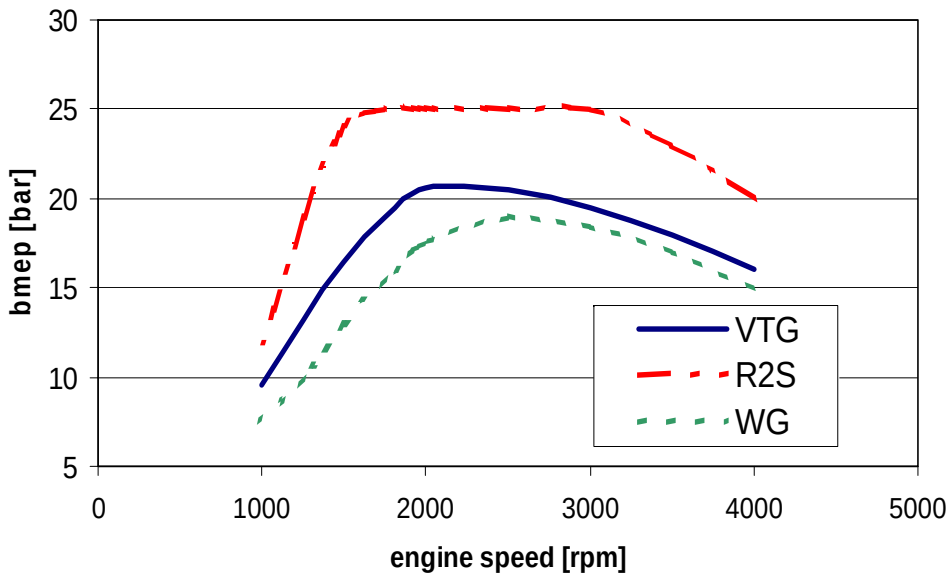
- LP turbine stage bypass added
- LP size reduced for rated match – HP size reduced simultaneously
- HP – Low engine speed contribution only
- LP – High engine speed contribution
- 2-stage compression at low speeds, only LP compression at high speeds
- Good single stage PR achievable by high speed dedicated LP stage
- Excellent flow range – some rated BSFC penalty
- HP stage further reduced in size – better transient and low speed performance
- Well suited to passenger car and chassis certified light duty diesel applications



R2S Performance

- Relative to current state of the art VTG applications;
  - Significantly lower HP rotor group inertia
  - No VTG turbine efficiency penalties
  - Increased flow range





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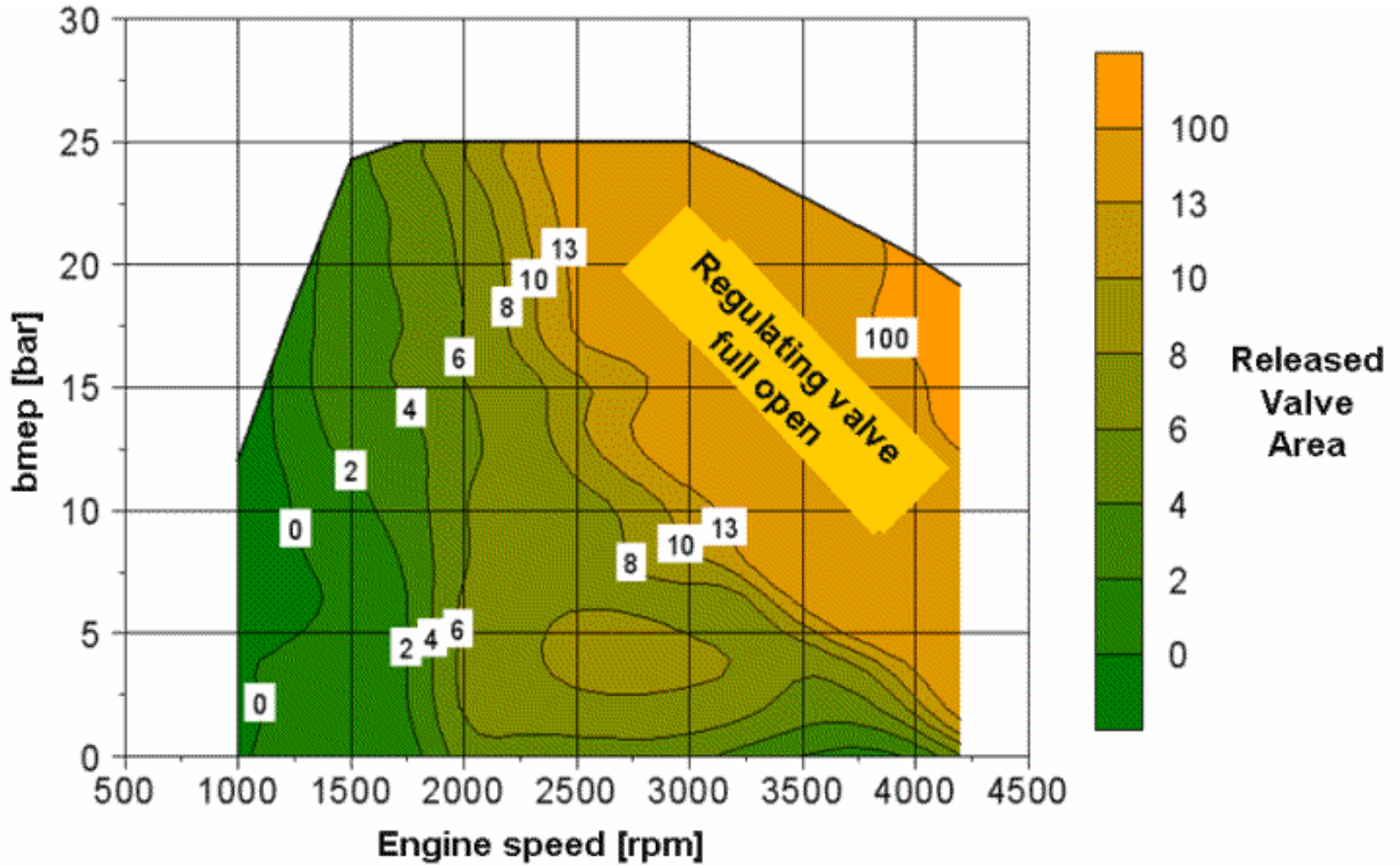
R2S™ engine maps: HP regulating valve



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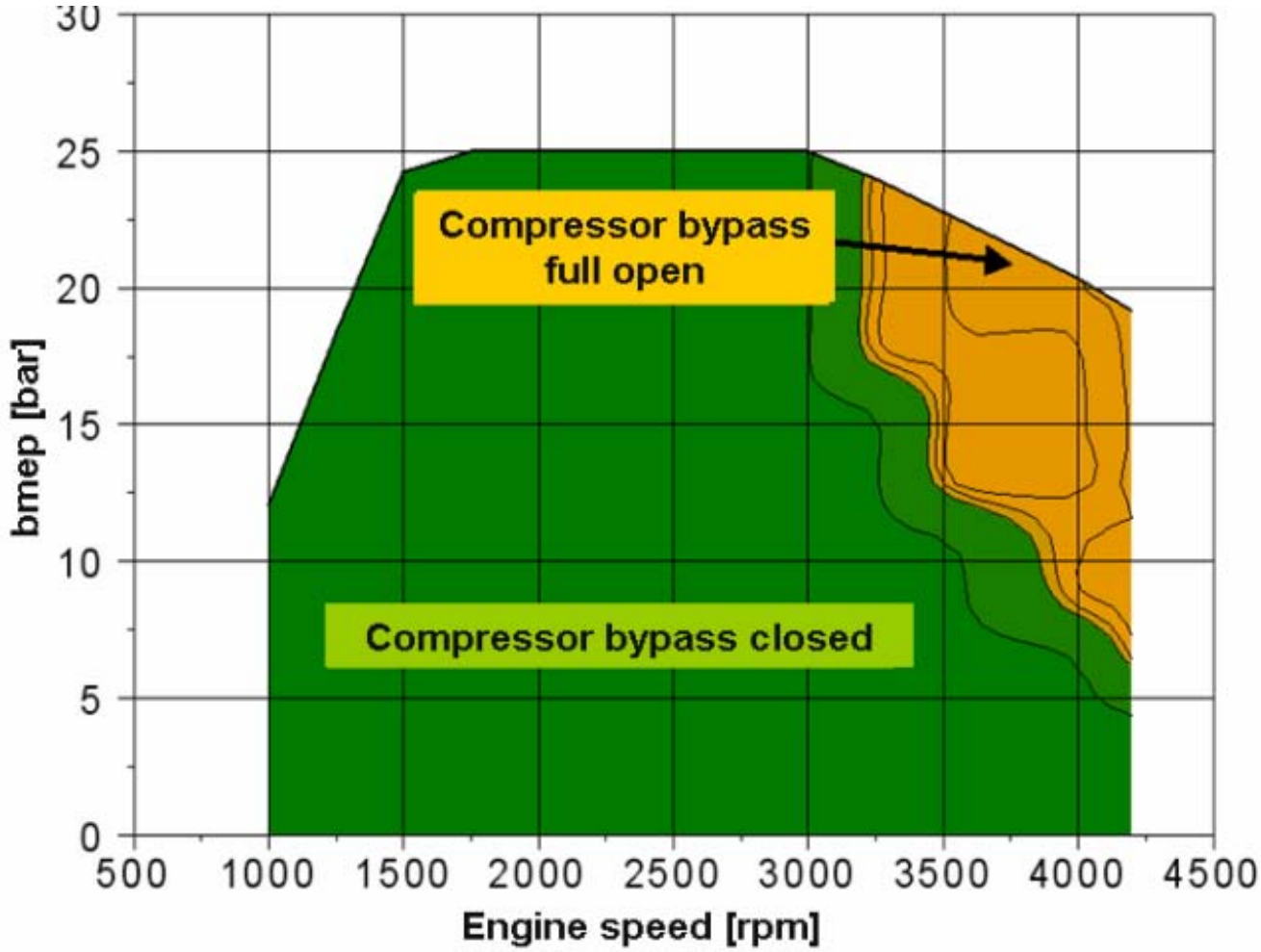
R2S™ engine maps: HP compressor bypass



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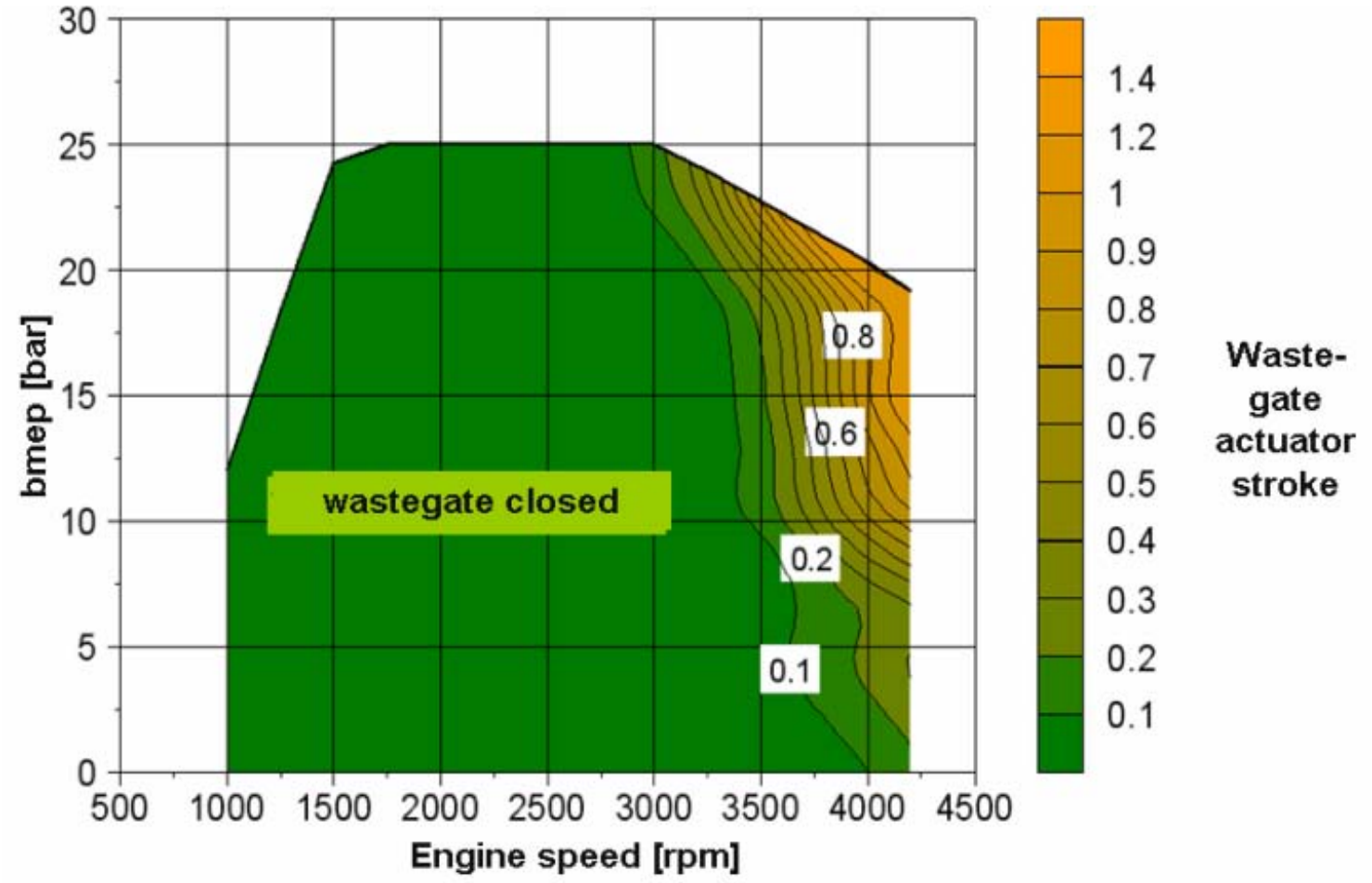
R2S™ engine maps: LP turbine waste-gate



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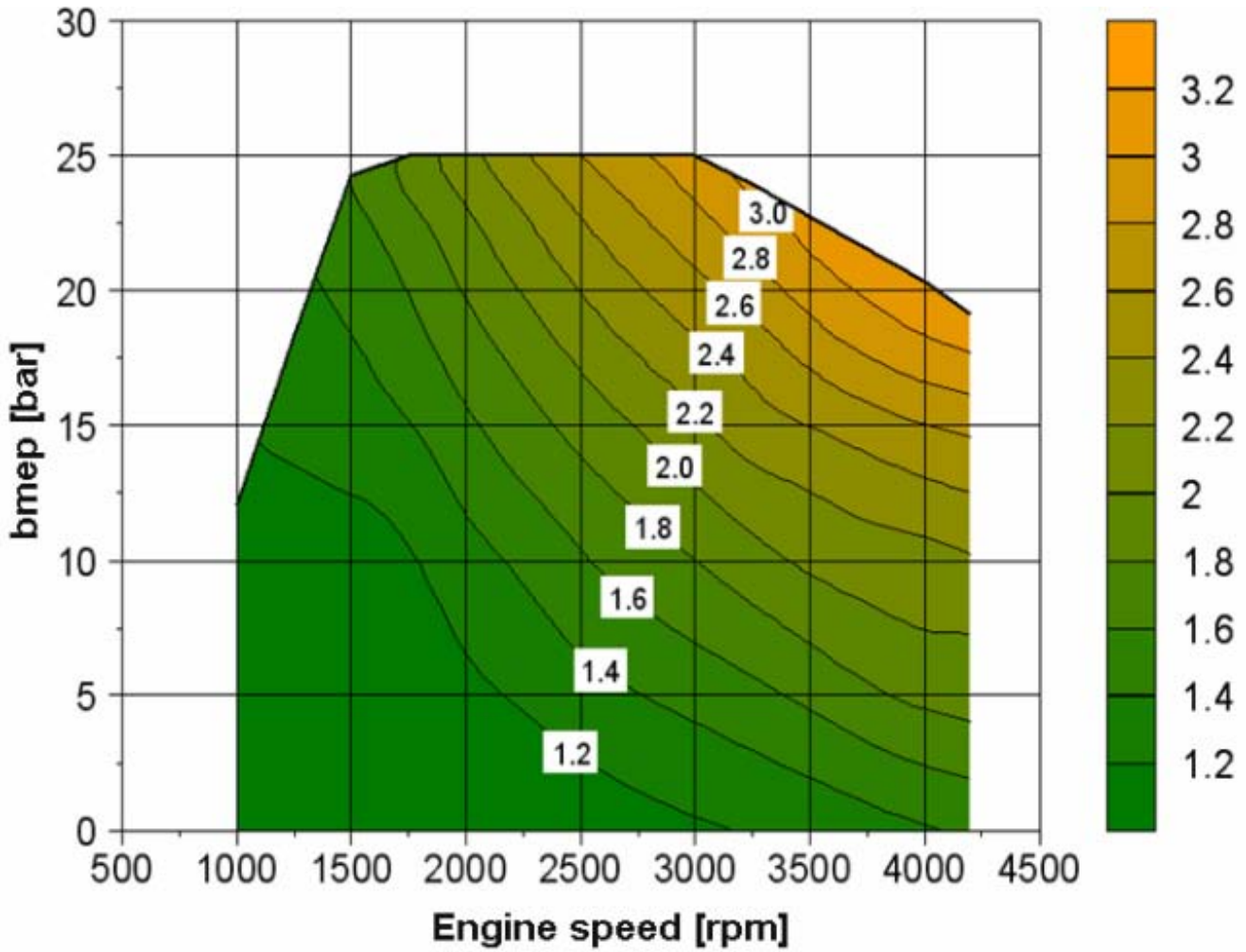
R2S™ engine maps: LP compressor pressure ratio



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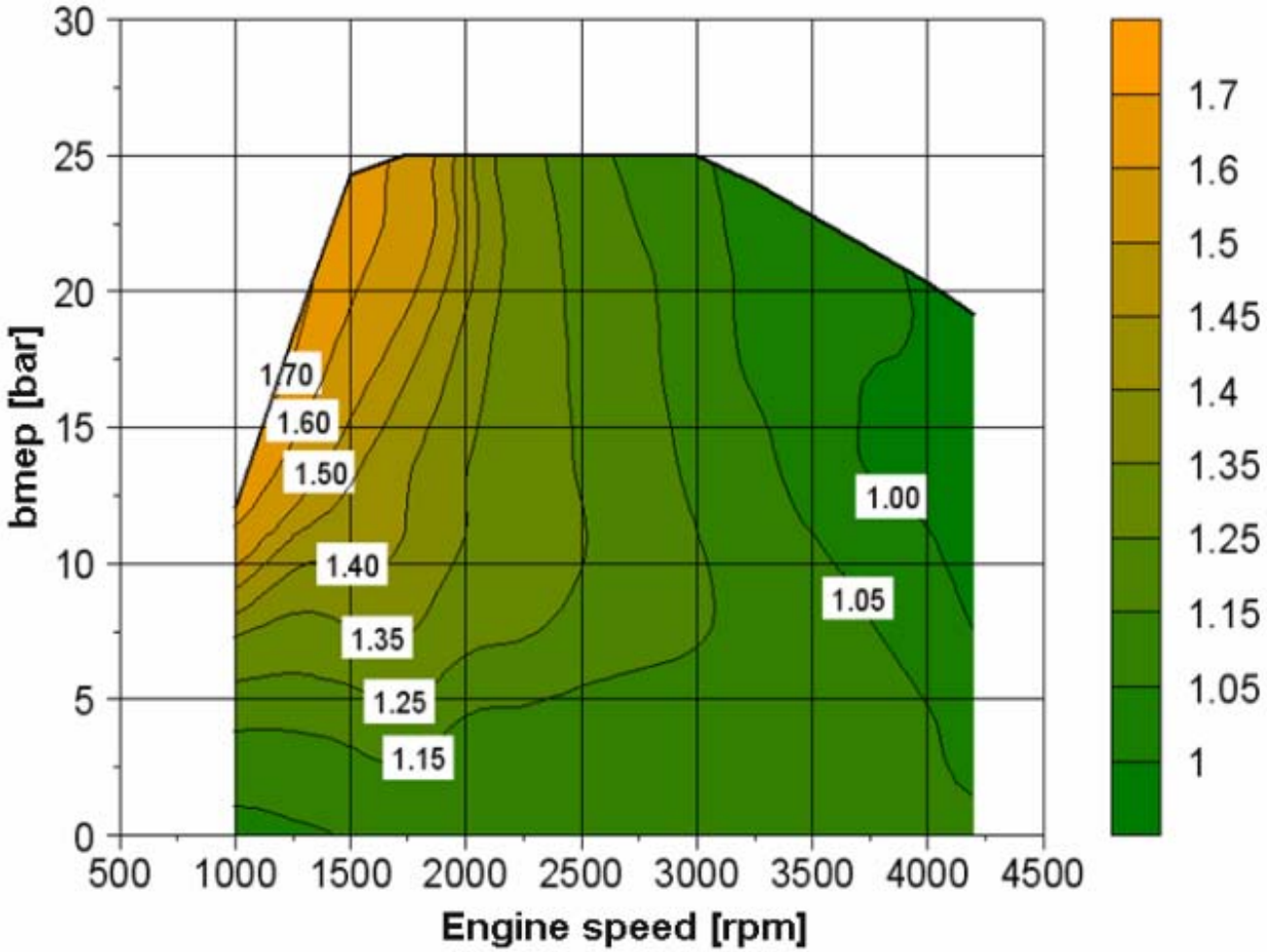
R2S™ engine maps: HP compressor pressure ratio



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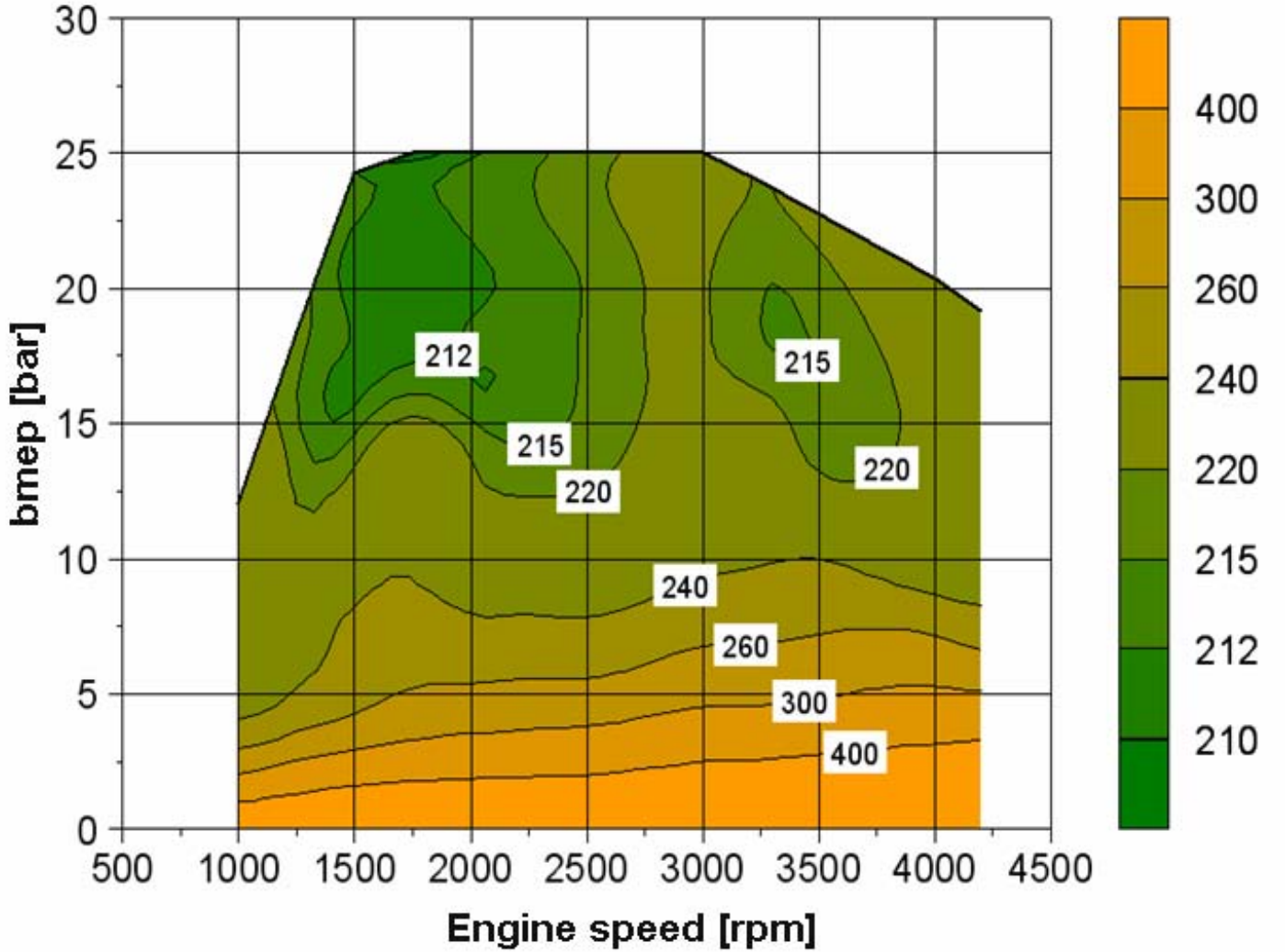
R2S™ engine maps: fuel consumption



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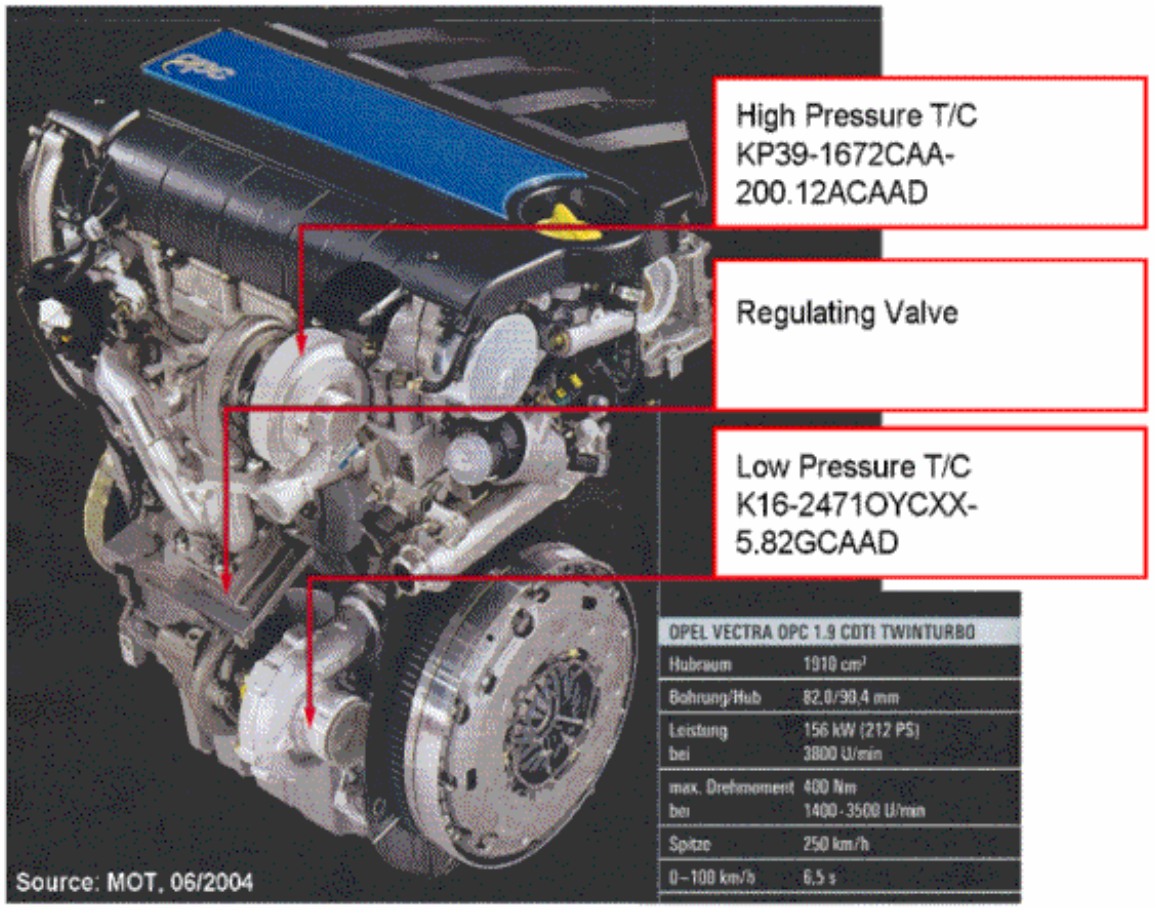
Passenger car applications: Opel

OPEL OPC 1,9 ltr.

Power = 156 kW
(82kW/ltr.)

Torque = 400 Nm
@1400-3500 rpm

Passenger car applications: Opel

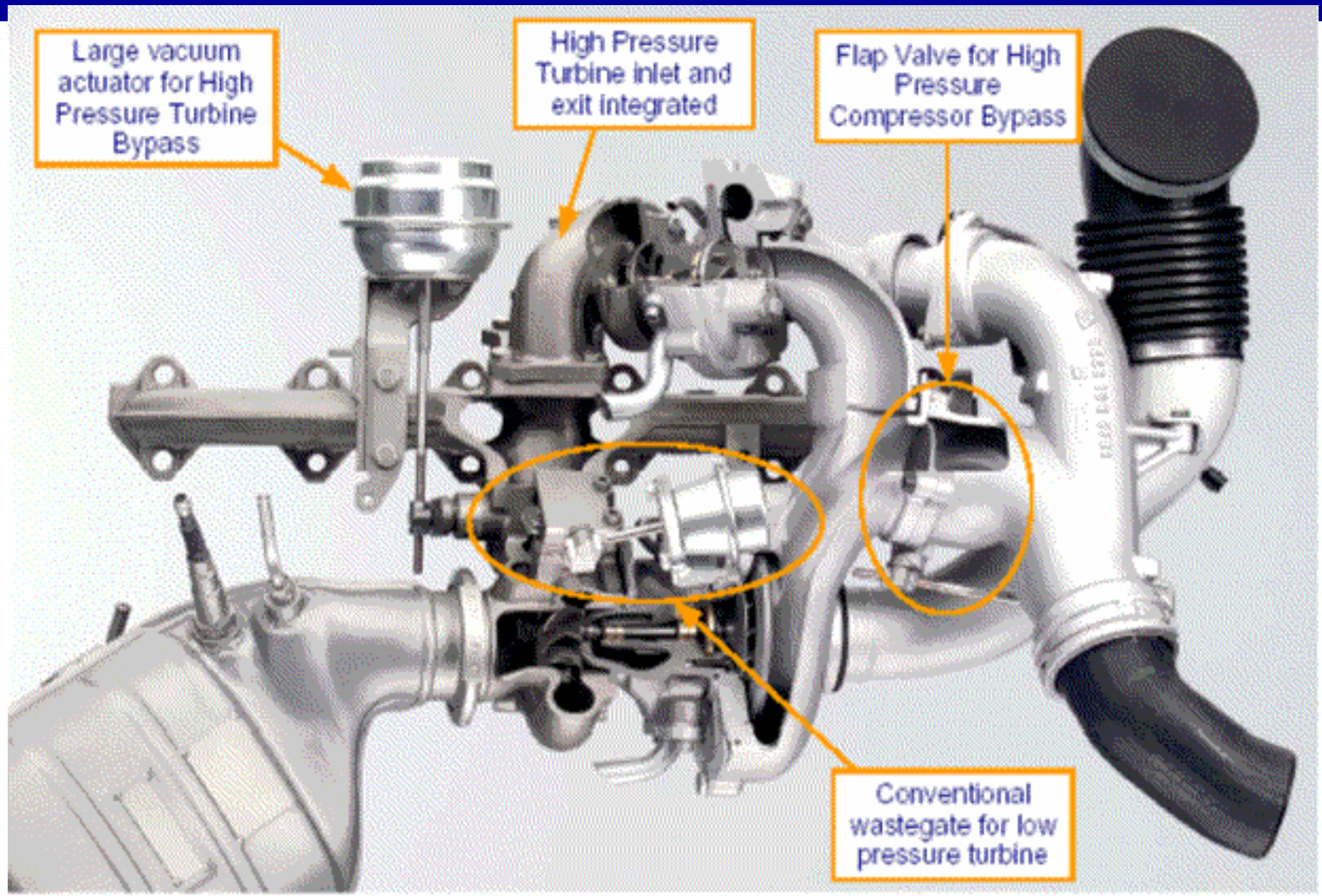


Passenger car applications: BMW

BMW 535 3,0 ltr.
Power = 200 kW Torque = 560 Nm@2000 rpm
R2S charging system: K26 & KP39

Passenger car applications: BMW

Passenger car applications: BMW



Picture Source: BMW Geneva Motor Show Press Pack, March 2004, 43pp

Commercial Diesel Applications

22.8L V12
Marine
Application

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Summary and R2S Conclusions

- Relative to current state of the art VTG applications, R2S systems exhibit;
  - Significantly lower HP rotor group inertia
  - Increased flow range
  - Simple technology
- Which results in;
  - Improved low speed torque
  - Improved transient response
  - Better BSFC over a wider operating range
  - Robust technology