- Turbo Architecture Types
- Two-Stage Turbocharging
- VTG Technology

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March 29, 2008

OUR BELIEFS

Respect

Collaboration

Excellence

Integrity

Community

BorgWarner

What exactly do we sell?

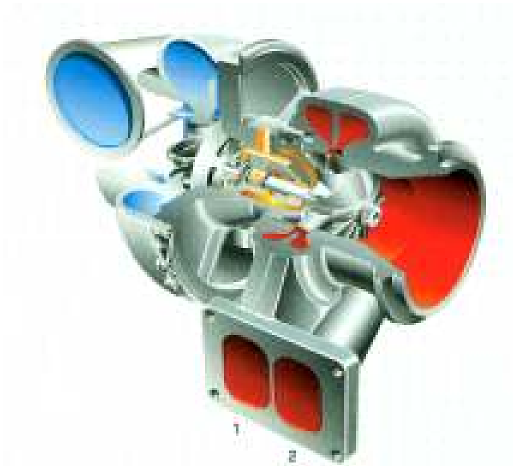
BorgWarner
Turbo & Emissions Systems

We sell performance. In other words, the ability to efficiently and reliably turn exhaust energy into boost pressure.

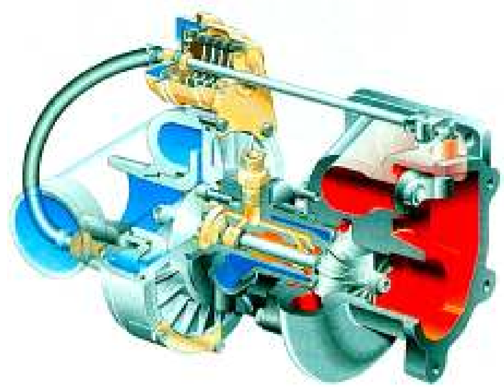
How Did We Get To Where We Are Today?

- **Swiss (Alfred Buchi) patent in 1905, applied to engine in 20's**
- **Turbos commercialized in 40's and 50's (e.g.- 3K and Schwitzer)**
- **On-road usage becomes more popular in 60's and 70's, advent of the wastegate**
- **Schwitzer facility in Asheville built in early 80's**
- **VTG and Two-Stage turbocharging developed in 80's and 90's**
- **Borg Warner purchases 3K and Schwitzer (competitors) in 1999 and 2000**
- **VTG, Electronic Actuator, and Two-Stage technologies commercialized in the last 5 years**
- **Today's Borg Warner Turbo Systems is the result!**

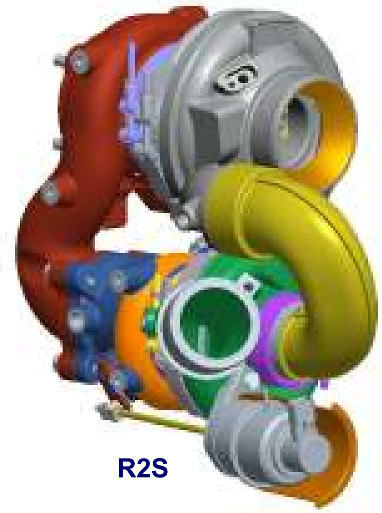
What Does “Turbo Architecture” Mean?



Fixed Geometry

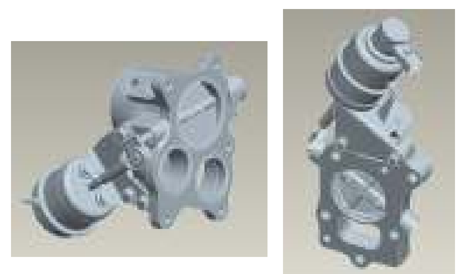


Wastegated



R2S

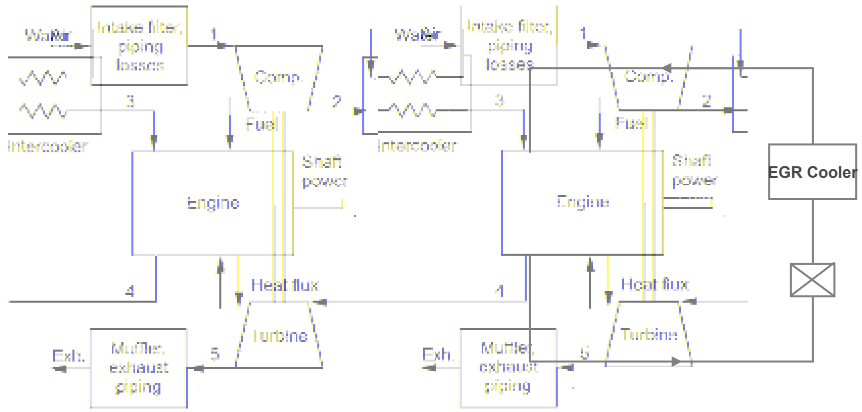
VTG



Bypass Valves (Throttles)

We use the word “architecture” to define the turbo system’s layout or arrangement.

Where does all the fuel go?



Fuel (100%)

- **28-33% to Crankshaft**
- **25-28% to Heat**
- **30-35% to Exhaust**

Turbo Overall Efficiency is 45-55%

Approximately 13-17% of the fuel energy makes it's way back into the boost air

(Percentage values are approximate, and representative of full-load CI operation)

What is the primary source of Asheville engineering's workload?

Diesel Emission Regulations

In the past 5-7 years, two major events occurred that created the need for advanced turbo architecture for medium and heavy duty diesel engines.

1. *Use of EGR as a combustion diluent which lowers peak cylinder temperatures and hence NOx formation, coupled with exhaust aftertreatment to reduce PM emissions.*

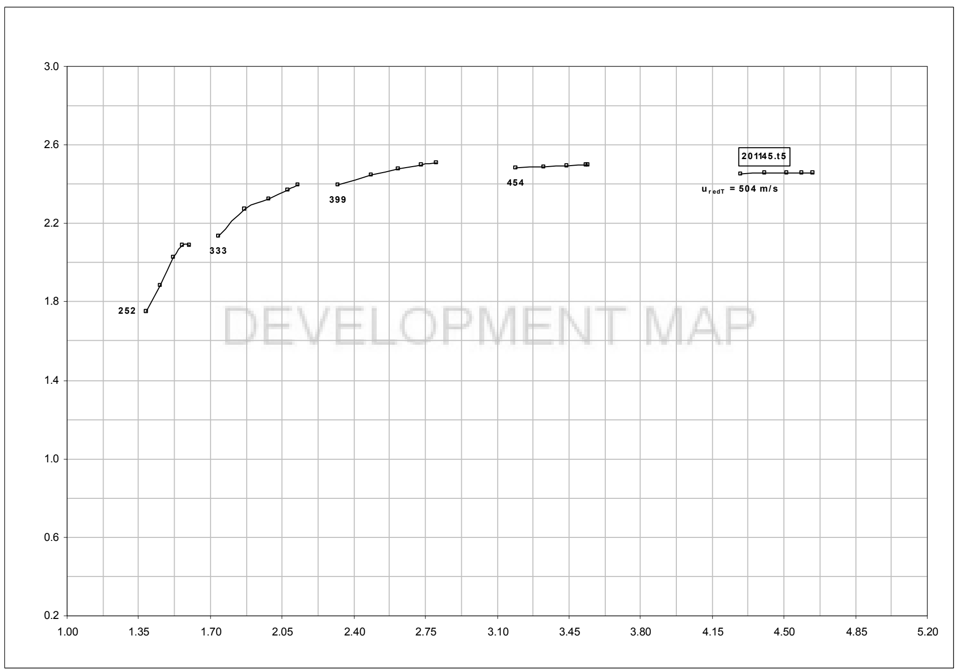
\+

2. *Emergence of "chassis certification" drive cycle testing as a viable alternative for diesel engines in relatively light trucks, comparable to the way that passenger cars are regulated.*

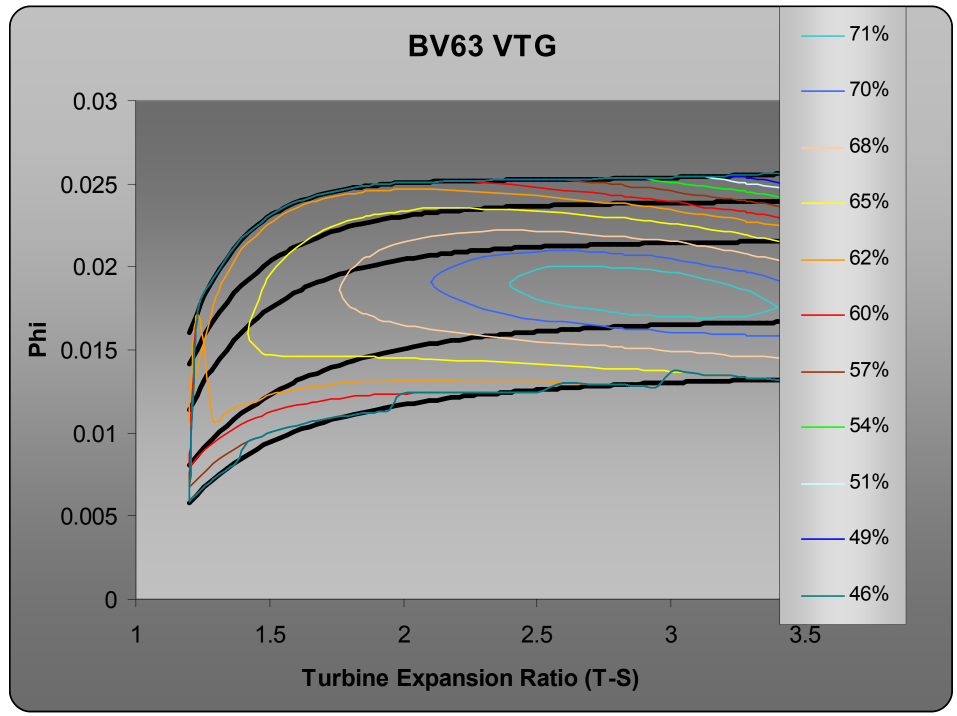
Why choose a VTG?

When you are still within the capabilities of a single compressor, a VTG allows tremendous flexibility.

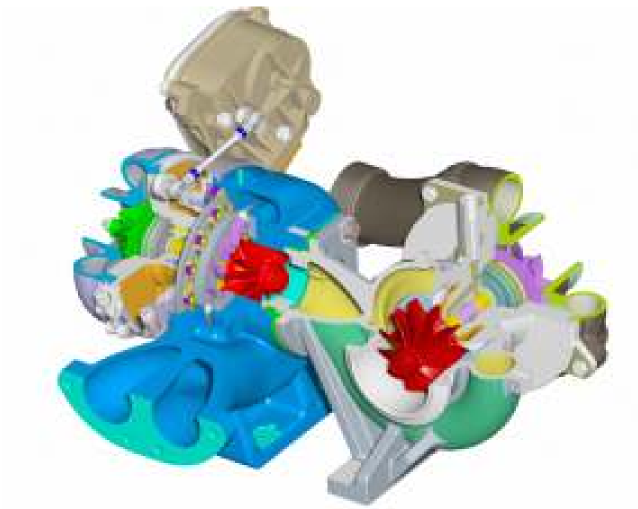
Fixed geometry turbine

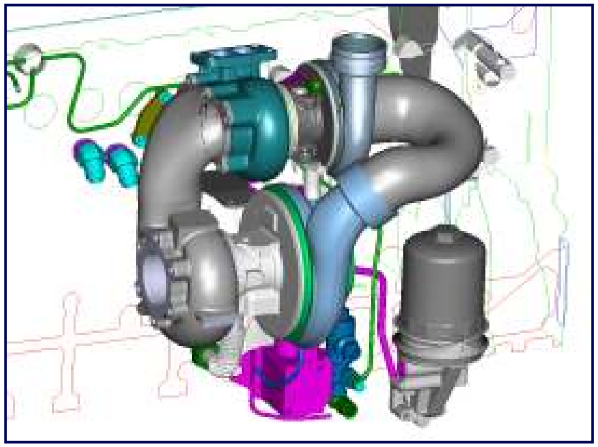


BV63 Variable Turbine Geometry Map



Why use two-stage?

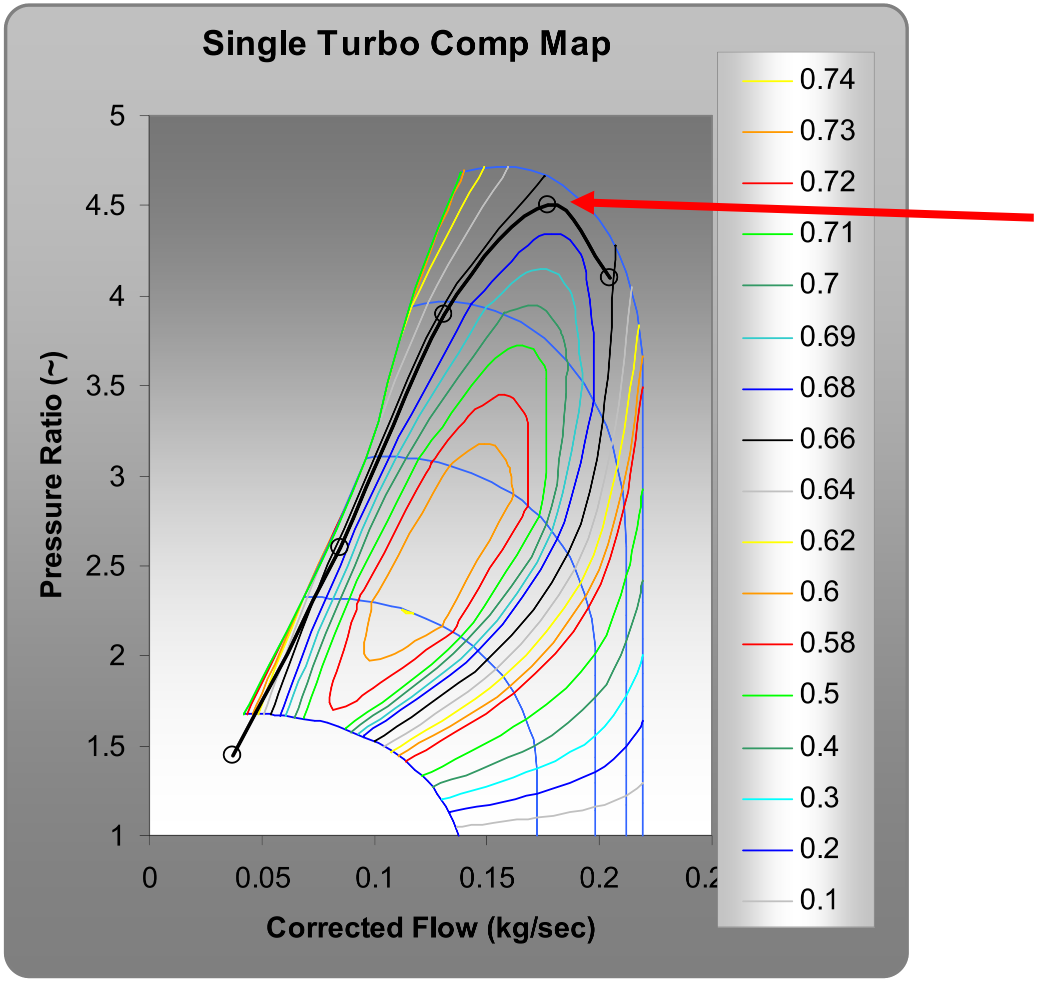




The prevailing reason is that many of today's applications overwhelm the capability of a single compressor stage.

- *Two Stage systems allow significantly higher boost pressures and higher EGR%'s than a single turbo*
- *A two stage system can also offer higher stage efficiency*

Why use two-stage?

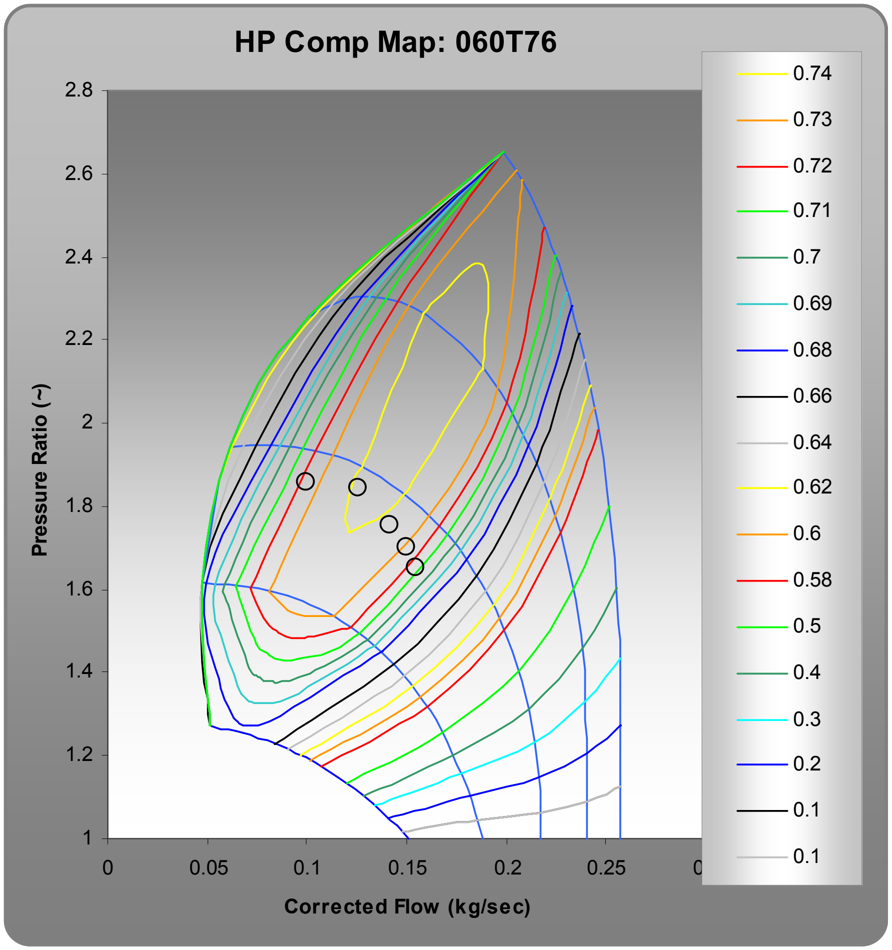


Operation along lugline gives poor results:

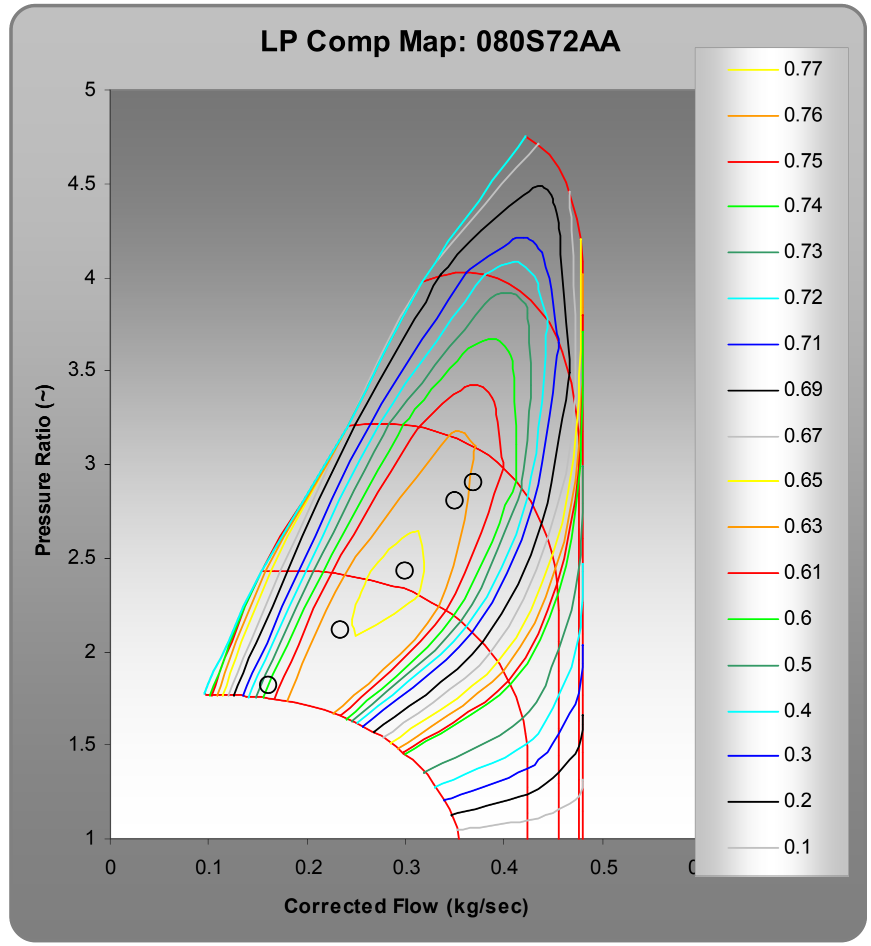
- Overly high tip speeds (>560 m/s)
- Very high compressor outlet temperatures (>500 deg F)
- Poor compressor efficiency
- No surge margin or altitude capability
- Requires titanium compressor wheel for durability

What happens when you divide the task?

HP Compressor

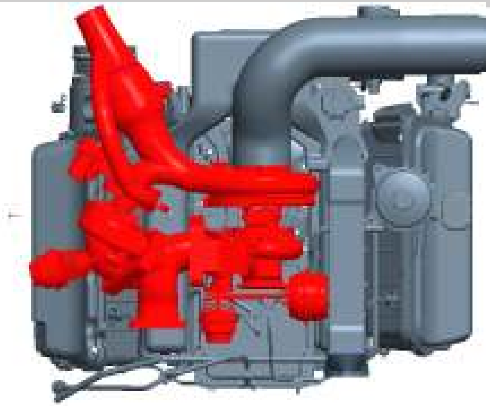


LP Compressor



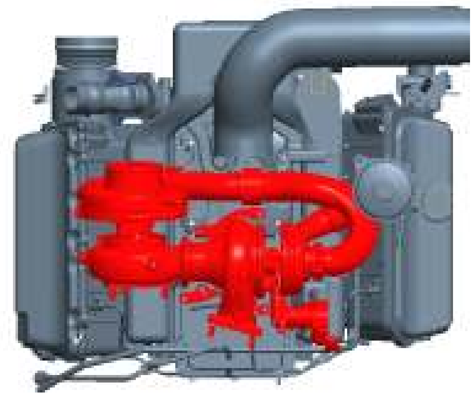
Everything gets better: speeds come down, efficiency goes up, lots of surge margin and altitude capability, etc.

We've now made the right choice for performance. Will it fit?



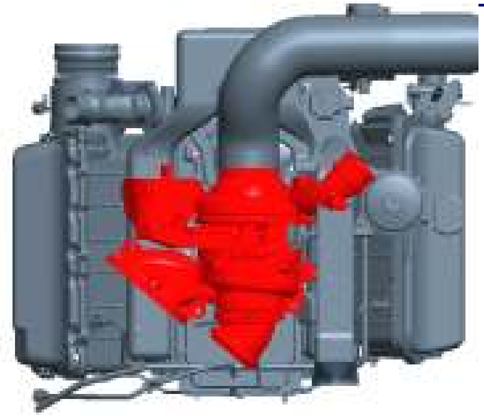
Series Sequential

(Variable) Regulated 2 Stage w/ Bypasses & Wastegates



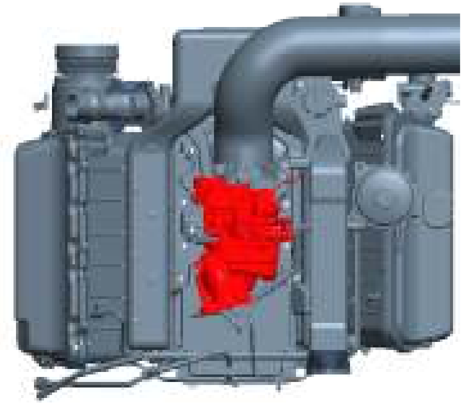
R2S

Regulated 2 Stage – Non Bypassing



Medium VTG

Single Stage, Such as BV63

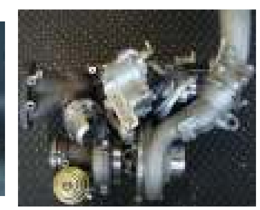


Small VTG

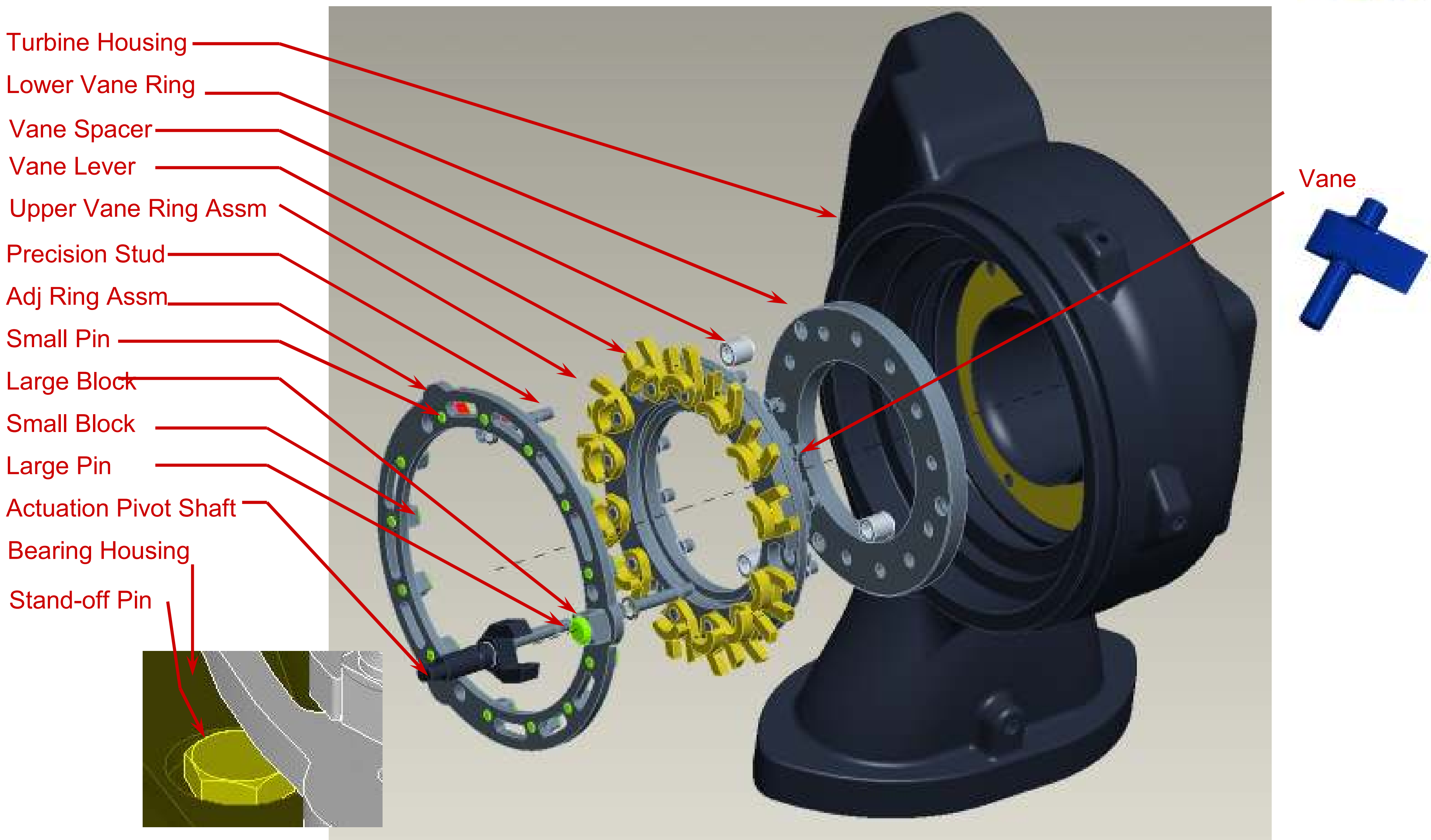
(BV50 shown)

VTG Technology
(Variable Turbine Geometry)

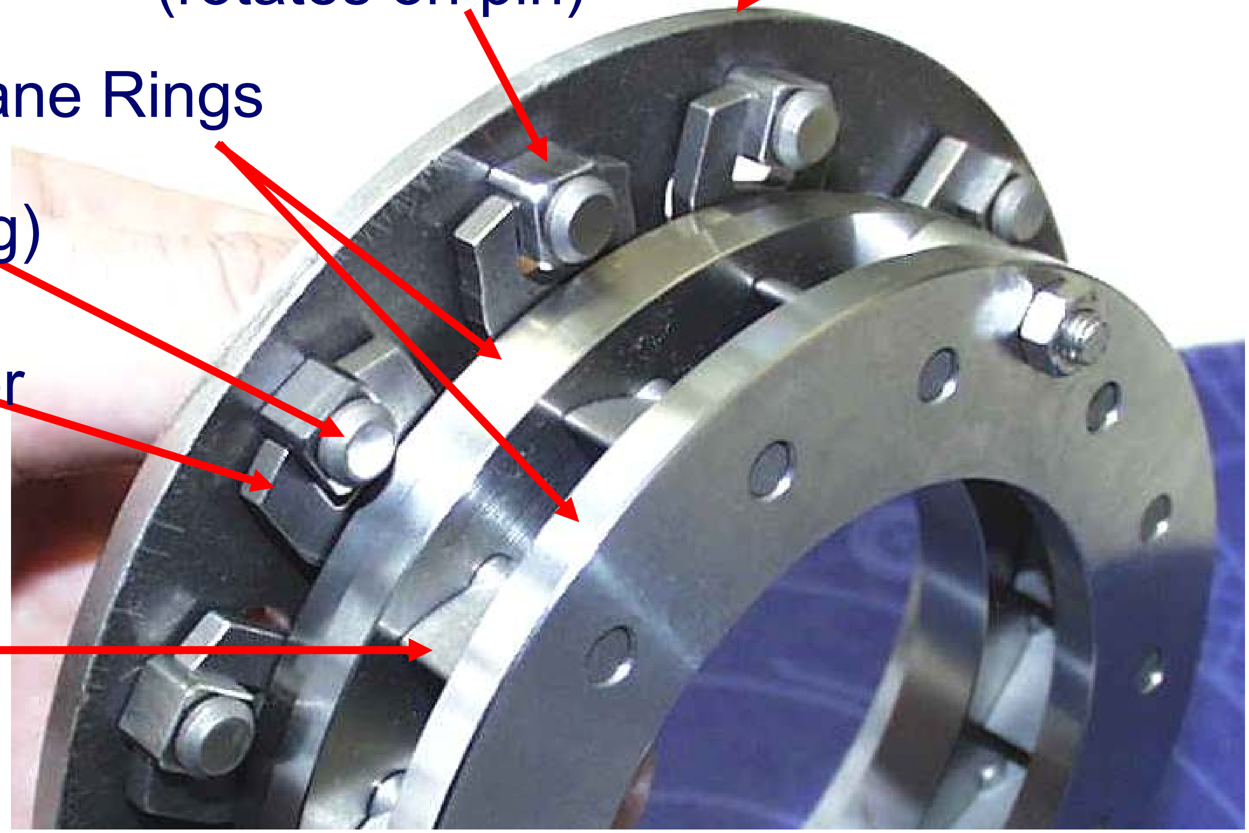
VTG Usage



Assembly Diagram of Heavy-Duty VTG Turbine Stage



VTG Adjustment Mechanism (Heavy Duty)

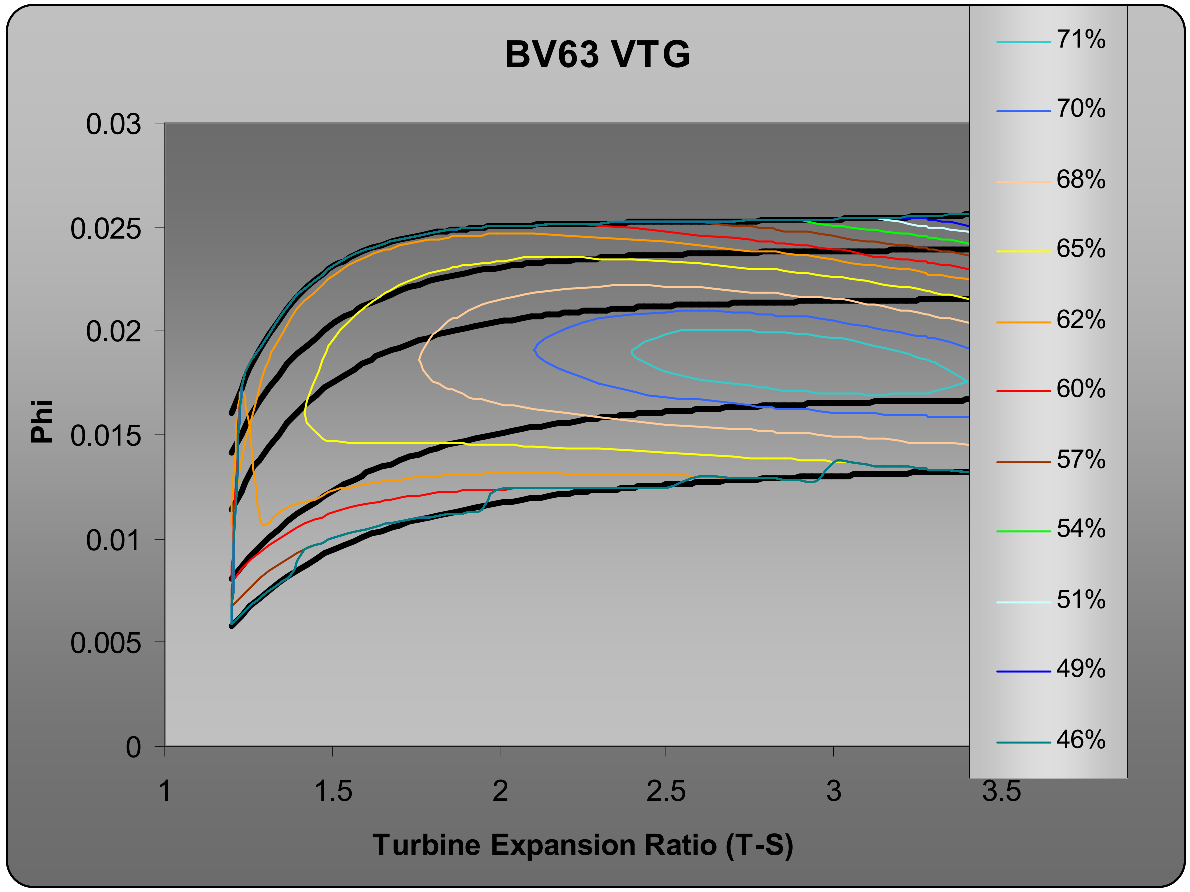


Aerodynamic Inlet From Volute into VTG

(Vanes Open)

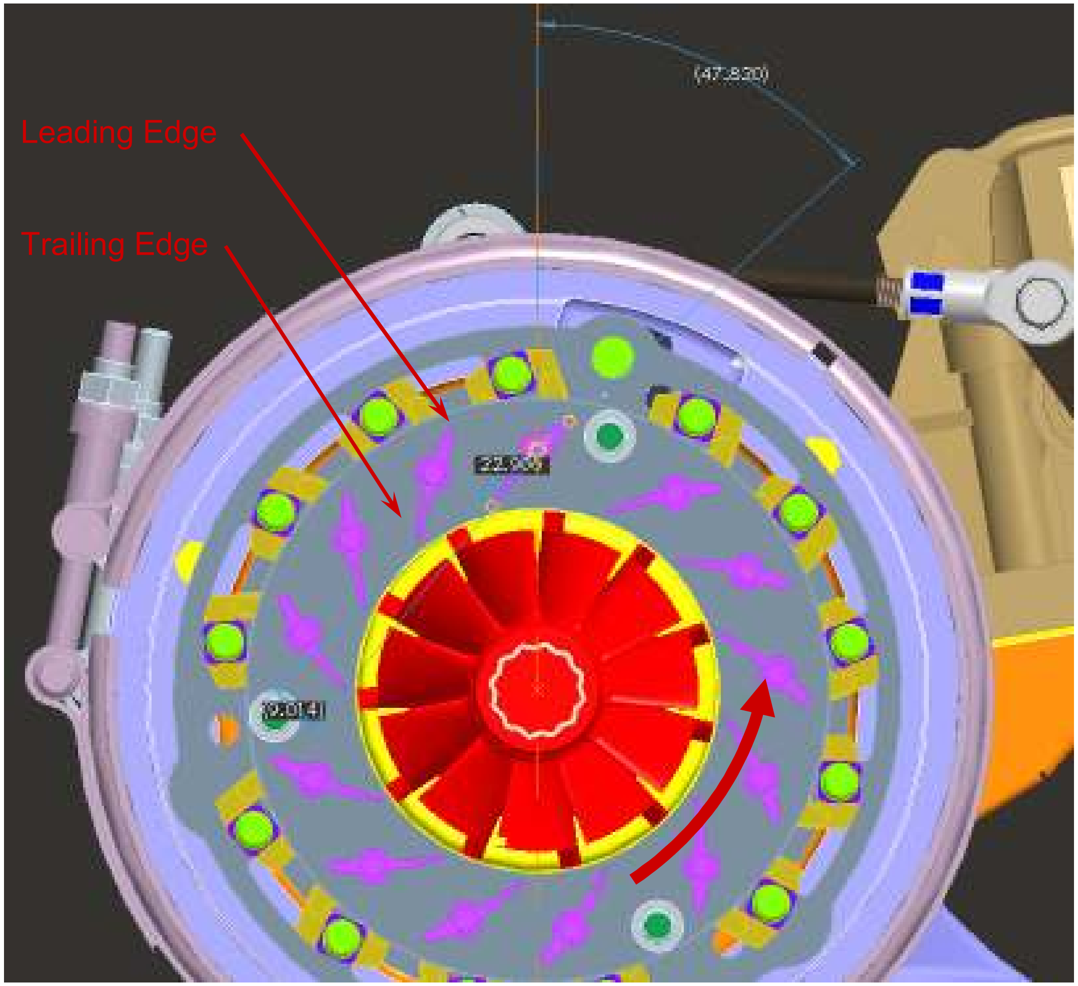
(Vanes Closed)

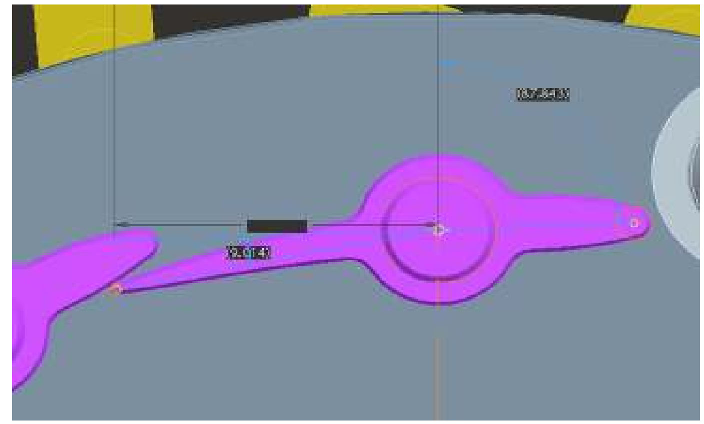
Vane Position, and How It Modulates Turbine Power

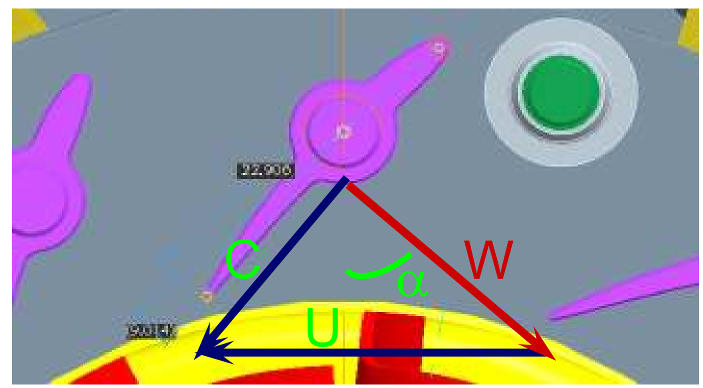


VTG can act like a small turbine when the vanes are closed, and a large turbine when the vanes are fully open

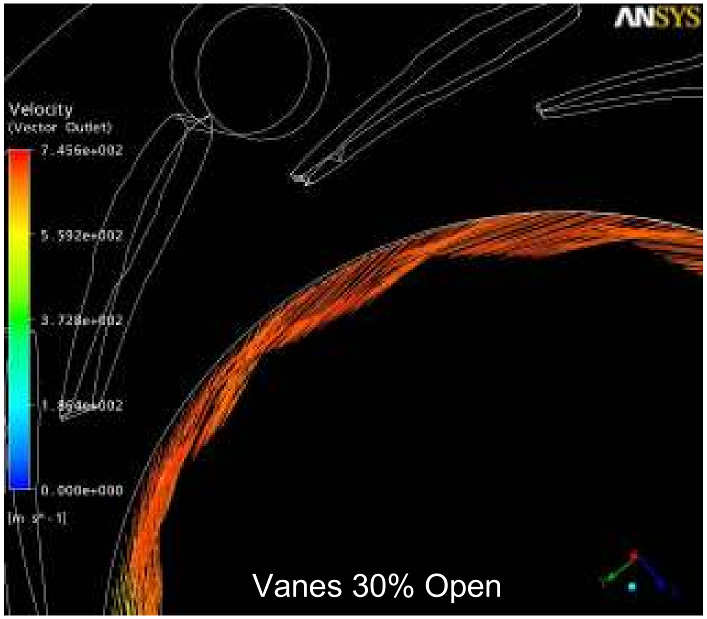
Turbine Wheel Incidence Angle



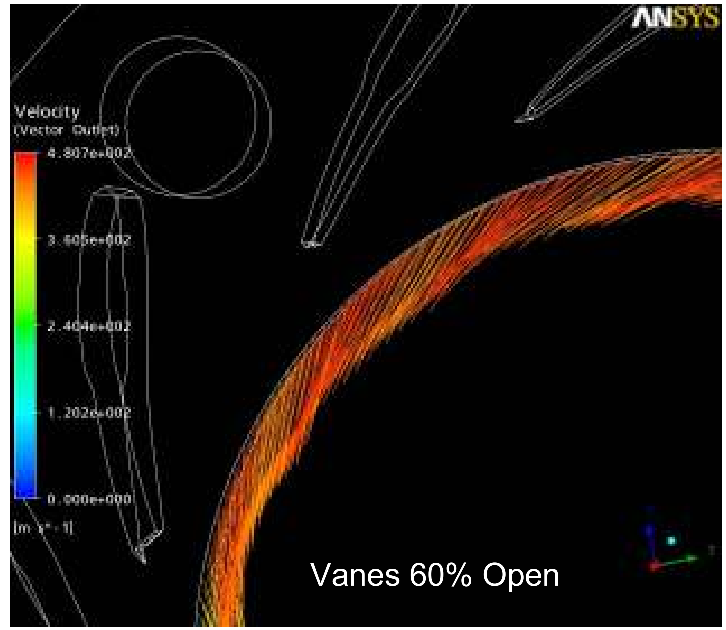




VTG – Gas Flow Modeling (CFD)

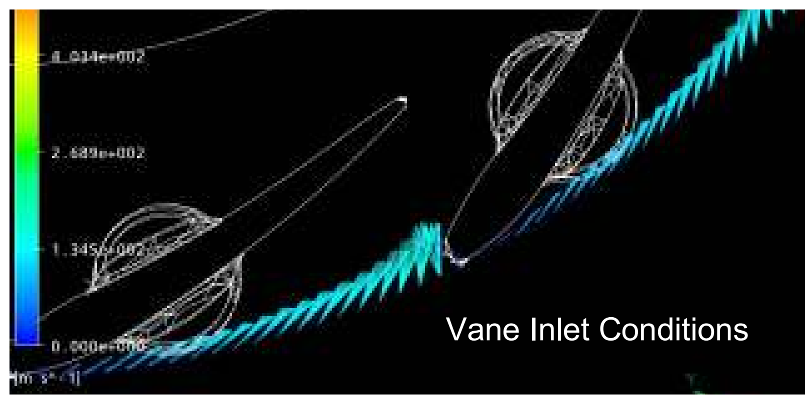


Vanes 30% Open



Vanes 60% Open

Pressure Loss Through Vane Pack

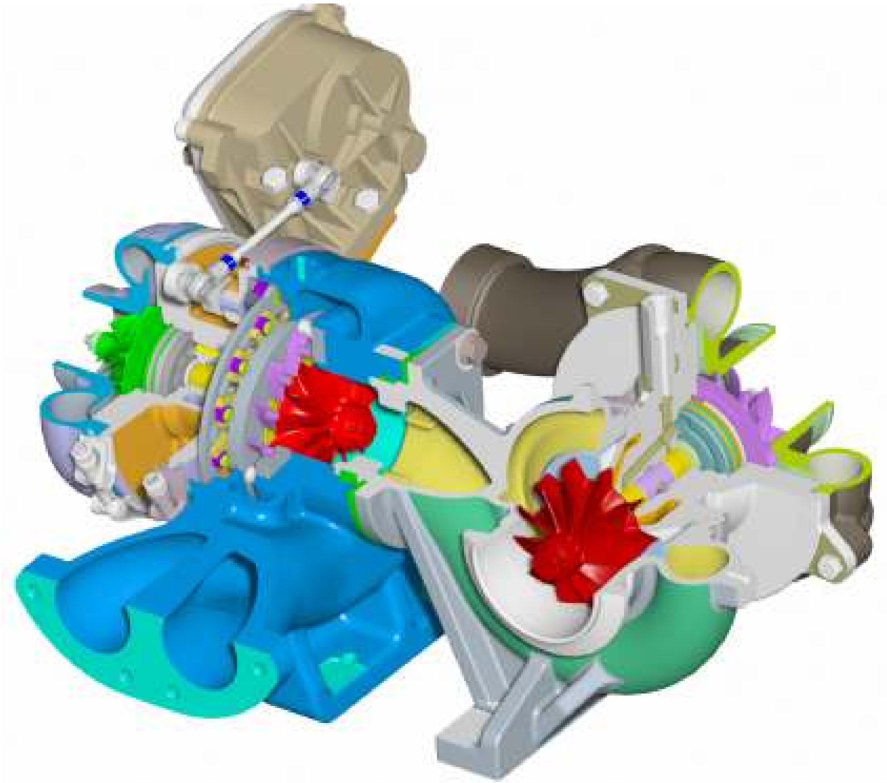


Vane Inlet Conditions

Recent Technology (Market Releases)

2007 (2008MY) Ford Diesel Super-duty Truck

- Heavy Duty VTG incl. corrosion resistance
- Two-stage Compounded Turbocharging
- Electronic Actuation



2007 Porsche 911 (Gasoline) Twin VTG

- 1000 º C (1832 º F) Exhaust Gas Temps
- Electronic Actuation (Dual)

Passenger Car VTG

- **Lower Cost, Light-Duty Mechanism**
- **Single-Axle Vane Pivoting**

VTG – Durability Challenges

- Moving parts, subjected to:
  - Extremely High temperature (Softening, Warpage, etc..)
  - Vibration
  - No lubrication
  - Corrosion risk
  - Very large number of accumulated movements
    - (Often more than 50 million movements during vehicle life!)

→ Robust design and rigorous testing required

VTG Durability Testing

- High Temperature On-Engine Testing
- Thermal Shock Testing
    - 5 min. cold, 5 min. hot (alternating)
- Turbine Wheel Fatigue Testing
- Thermal Mapping
- Actuator / Linkage Endurance Testing
- Corrosion Chamber Testing
- Customer Engine/Field Testing

How Is the VTG Movement Controlled?

Pneumatic (Vacuum or Boost)

Low-Torque Electronic Actuator for Small VTG Turbos

Medium-Torque Electronic Actuator for Intermediate Sized VTG Turbos

Pneumatic with Position Sensor

High-Torque Electronic Actuator for Heavy Duty VTG Turbos

ANY QUESTIONS?

Thanks, and we hope you enjoy your stay in Asheville!