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

Dave Andrews
Senior Application Engineer
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OUR BELIEFS
Respect
Collaboration
Excellence
Integrity
Community
What exactly do we sell?

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

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 its 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.
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**

HP Comp Map: 060T76

**LP Compressor**

LP Comp Map: 080S72AA

**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?

<table>
<thead>
<tr>
<th>Series Sequential</th>
<th>R2S</th>
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<tbody>
<tr>
<td>(Variable) Regulated 2 Stage w/ Bypasses &amp; Wastegates</td>
<td>Regulated 2 Stage – Non Bypassing</td>
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<tr>
<th>Medium VTG</th>
<th>Small VTG</th>
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<tr>
<td>Single Stage, Such as BV63</td>
<td>(BV50 shown)</td>
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VTG Technology
(Variable Turbine Geometry)
Assembly Diagram of Heavy-Duty VTG Turbine Stage

- Turbine Housing
- Lower Vane Ring
- Vane Spacer
- Vane Lever
- Upper Vane Ring Assm
- Precision Stud
- Adj Ring Assm
- Small Pin
- Large Block
- Small Block
- Large Pin
- Actuation Pivot Shaft
- Bearing Housing
- Stand-off Pin
- Vane

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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

- Leading Edge
- Trailing Edge

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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 °C (1832 °F) Exhaust Gas Temps
- Electronic Actuation (Dual)
Passenger Car VTG

• Lower Cost, Light-Duty Mechanism

• Single-Axle Vane Pivoting
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?

Low-Torque Electronic Actuator for Small VTG Turbos

Medium-Torque Electronic Actuator for Intermediate Sized VTG Turbos

Pneumatic (Vacuum or Boost)

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!