DRIVING AUTOMOTIVE INNOVATION

Honeywell

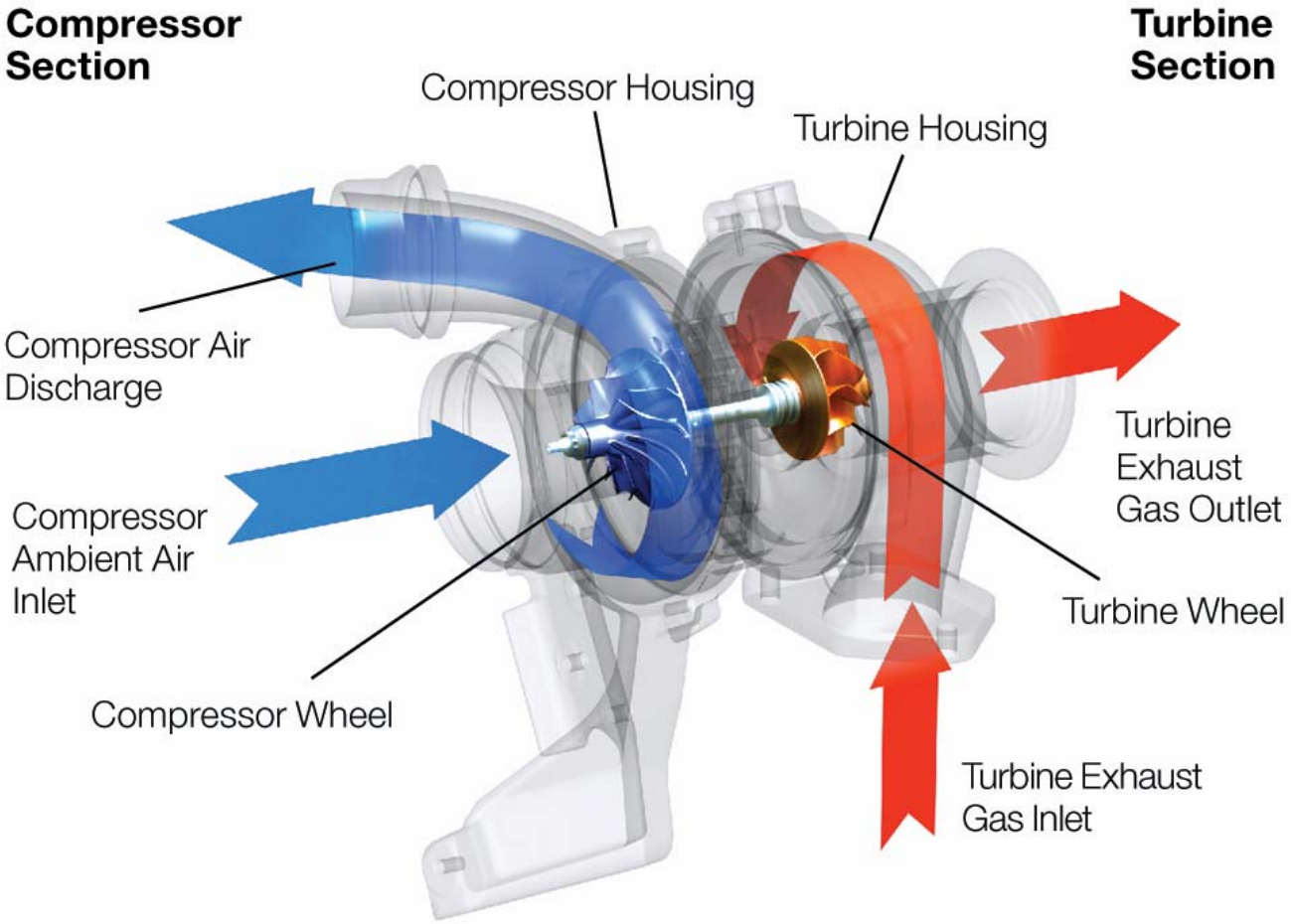
Turbocharging & Miller Cycle

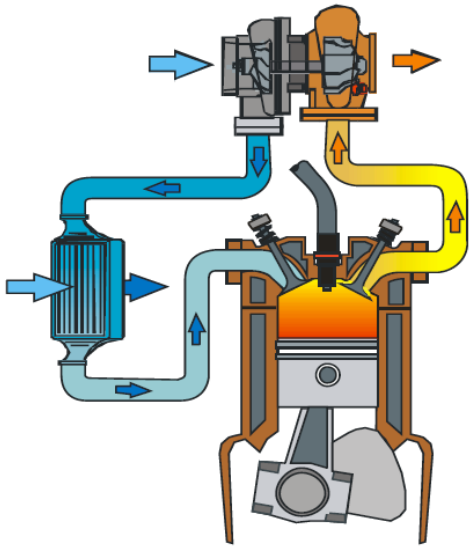
- Turbocharging enables engine downsizing for significant fuel economy benefits without performance compromise.
- More stringent regulation is demanding more efficiency from internal combustion engines.
- One solution to increasing engine efficiency is by adopting a Miller Cycle strategy.
- Technologies available today including, VNT (variable nozzle turbines) Turbochargers, Variable Valve Timing & Valve Lift, and Direct Injection, allow engines to use higher levels of Miller to meet future regulation.

© 2015 by Honeywell International Inc. All rights reserved.

Honeywell

How a Turbocharger Works





© 2015 by Honeywell International Inc. All rights reserved.

Modern Turbo Gasoline Engines

No-Compromise Solution

3L 6 Cylinders
Naturally Aspirated

2L 4 Cylinders
Turbocharged

240
Horsepower

=

240
Horsepower

+30%
Torque

+25%
Fuel Efficiency

20%
CO_2

More Stringent Regulations

Enacted Targets*

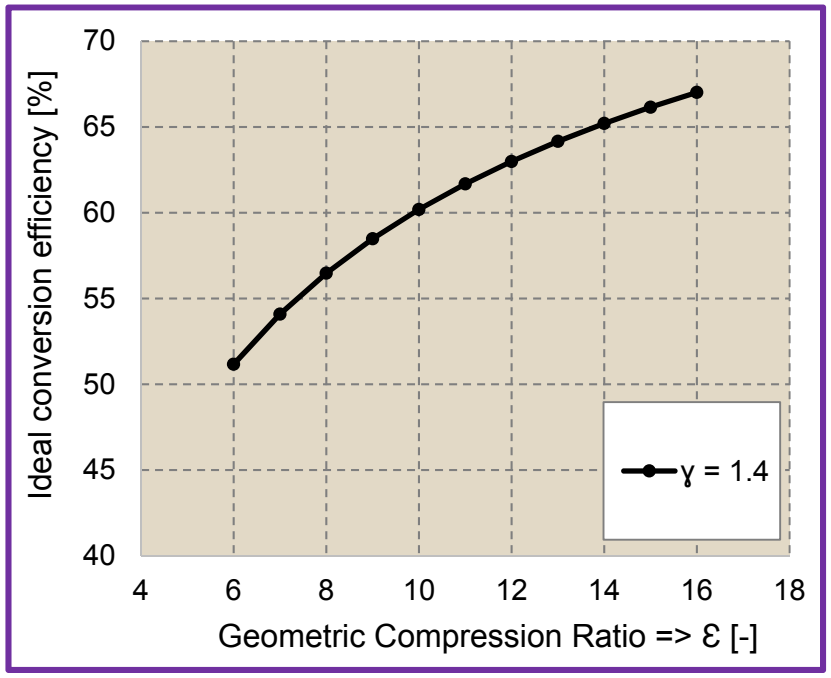
54 MPG	~24% Improvement By 2021
48 MPG	~39% Improvement By 2020
56 MPG	~54% Improvement By 2025
49 MPG	~17% Improvement By 2022
41 MPG	~11% Improvement By 2017

** Source ICCT Fuel Economy Standards – August 2015 Light Vehicles Only. MPG Improvement vs 2014 Levels.*
† Equivalent Standards to Euro 5 (5mg/km PM, 60-180mg/km NOx) and Euro 6 (5mg/km PM, 60-80mg/km NOx)

© 2015 by Honeywell International Inc. All rights reserved.

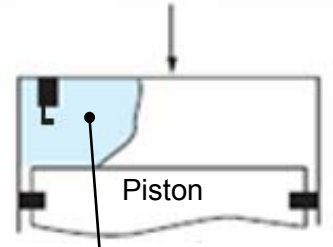
Turbochargers are a Key Enabler to Current & Future Regulation

Increasing Gasoline Engine Efficiency



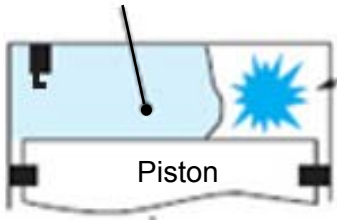
Increasing Compression Ratio

Normal Combustion



Flame Propagation

Knock



© 2015 by Honeywell International Inc. All rights reserved.

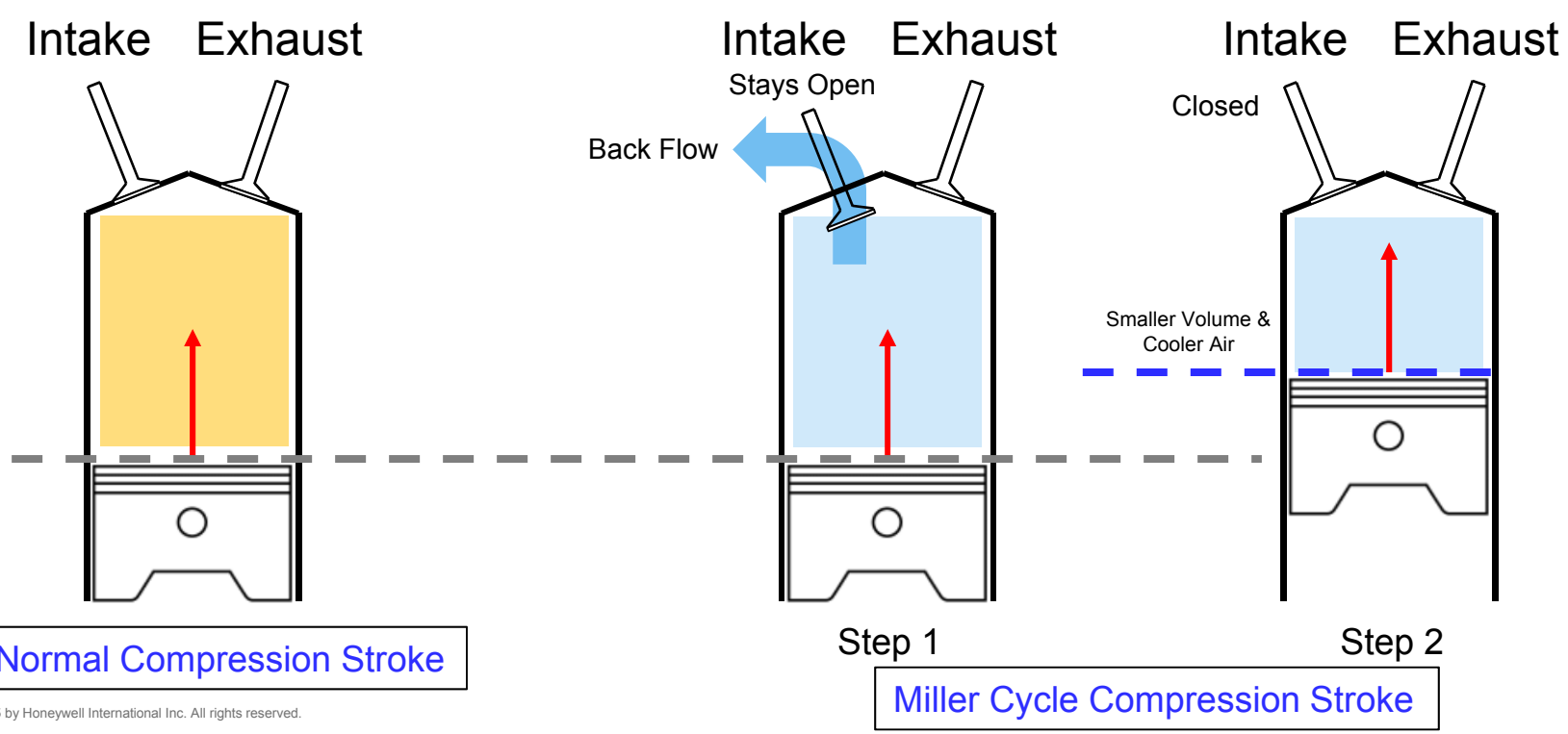
Ɛ Increase Is Key, But Knock Is A Challenge

Miller Cycle

What is Miller? - Delayed closing of the intake valve during the compression stroke.

Why do it? – Reduces work by the engine to compress air resulting in fuel economy improvement and enables higher efficiency/compression ratios without Knock

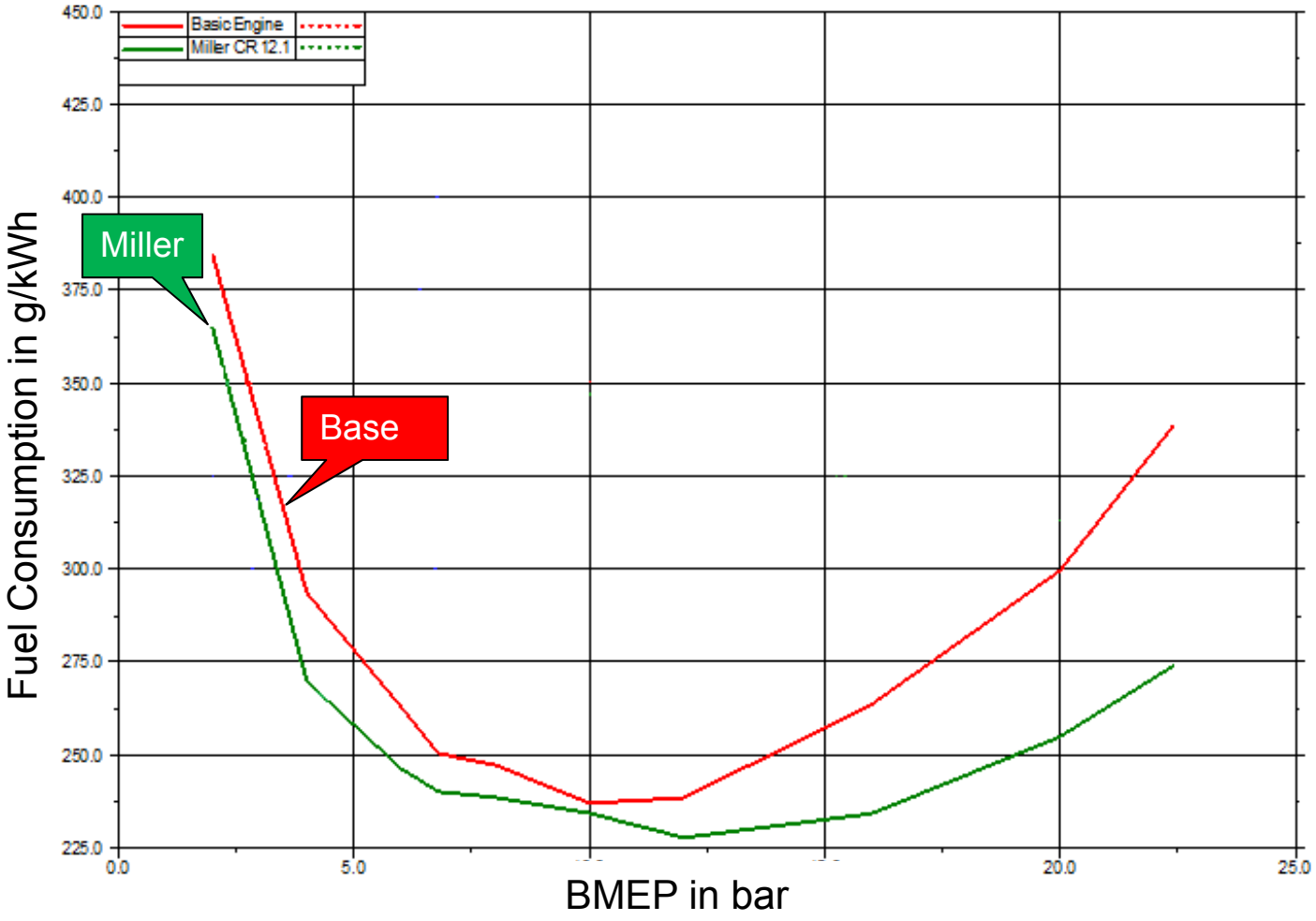
How is this done? – Turbocharging, variable valve timing/valve lift, & direct Injection



© 2015 by Honeywell International Inc. All rights reserved.

Old Concept Made Possible with Modern Engine Technology

Miller Cycle Benefits



automotive engineering iav

© 2015 by Honeywell International Inc. All rights reserved.

Increased CR + Miller = Fuel Efficiency At All Load

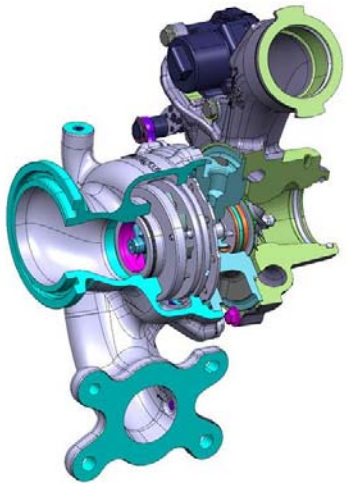
Conclusion

- Miller Cycle can improve gasoline engine efficiency and fuel economy and is currently being used on many engines today.

- New technologies allow higher amounts of Miller pushing the benefits further without sacrificing engine performance.

- VNT Turbos, a key enabler for higher levels of Miller, have been available on main stream diesel engines for over 25years and have been adapted to Gasoline applications.

Gasoline VNT



Honeywell

© 2015 by Honeywell International Inc. All rights reserved.