SIEMENS

With
Rolls-Royce
Aero Engine
Technology

The Industrial Avon 200 Engine

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The Industrial Avon 200

Technology heritage

Advanced technology used in civil and military engines is incorporated into the new, higher power Industrial Avon 200 to upgrade the proven performance of the Industrial Avon gas generator.

The result is an industrial engine with:

- Higher power capability
- Improved thermal efficiency
- Extended component life
- Reduced maintenance costs
- Improved environmental impact

Siemens acquired the Rolls-Royce aero-derivative gas turbine and compressor business effective December 1, 2014. References to Siemens and products are intended to refer to such business as acquired and incorporated into Siemens as from such effective date.

"With over 60 million operating hours in industrial applications, the Industrial Avon gas generator has proven time and again that it is the class leader for reliability."

Improving performance

Most operators know the Industrial Avon gas generator. They know its performance specification and its reputation for unsurpassed reliability. With over 60 million operating hours in industrial applications, the Industrial Avon gas generator has proven time and again that it is the class leader for reliability. Operators continue to plan their projects based on the Industrial Avon's reliability.

Today, Siemens is offering Industrial Avon operators more value than ever with the Industrial Avon conversion. This engine sets new standards of power, efficiency, life cycle costs and environmental impact.

Applicability

The Industrial Avon 200 comes with Rolls-Royce Aero Engine Technology and has unrivalled experience to meet these values.

Industrial Avon 200 conversion by Mod 5020 is available for retrofit to all in–service versions of the engine and can be installed at overhaul when many other complementary upgrades can also be incorporated.

Performance improvement

Power increase of 7.5–9.0 per cent at base load

Improved thermal efficiency up to 4.4 per cent at base load

Improved emissions*

Significant reductions in CO and CO_2 emissions can be expected when operating at the enhanced or current base rating

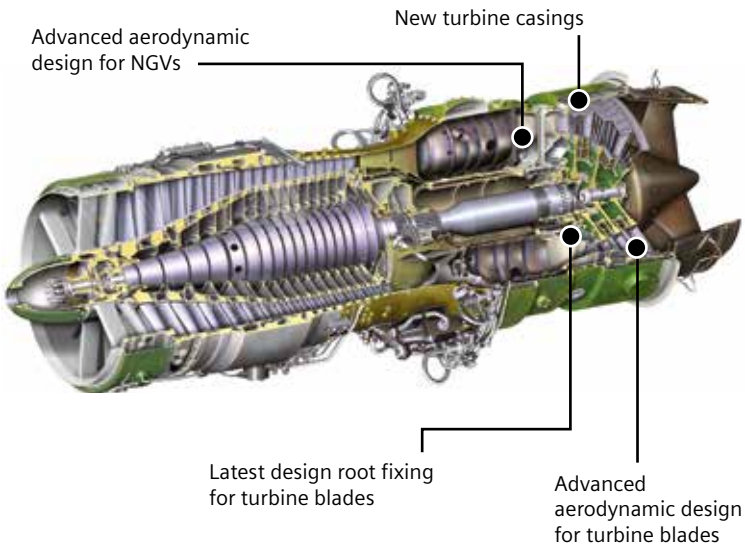
Increased mean time between overhauls*

An expected 20 per cent increase in current mean time between overhauls (MTBO) when operated at the pre–upgrade base load rating

Reduced overhaul work scope

Design changes have been made that either extend component life or reduce the replacement effort during overhaul (details provided within)

**Note: Site specific performance can vary. Please see your local Siemens representative for a site specific rating.*




HP turbine assembly

Design benefits

Turbine blades

The Industrial Avon 200 applies cutting edge technology proven in other Siemens engine models to the turbine section of the Industrial Avon gas generator.

This provides increased power, efficiency, component life and reliability without increasing the exhaust gas temperature. These improvements are achieved by making material, sealing, geometry and cooling changes to the HP, IP and LP turbine sections.

Key benefits

- Parasitic loss through air leakage is reduced by improved root and tip shroud sealing of the turbine blades improving overall unit power and heat rate performance.
- Material for all three rows of turbine blades is upgraded and coated for corrosion resistance. Together with new aerofoil designs this results in reduced overhaul costs.
- The HP blade material is changed to a single crystal material, eliminating the need for aerofoil cooling and contributing to the overall improvement in power and heat rate performance.
- The skewed cutting fir tree blade roots are replaced with an axial cut, two–lobe design to reduce peak stress concentrations. This improves resistance to high–cycle fatigue damage, resulting in reduced overhaul costs.
- The HP blade features an under–platform damper to reduce blade vibration stresses and fatigue damage.

Industrial Avon 160 root

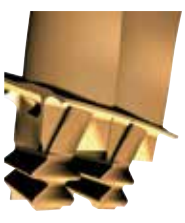
Old fir tree blade root

Industrial Avon 200 HP root

Two lobe root reduces stresses, improves stress distribution and fatigue resistance

Old root with weld–on seal plate and 25 degree skew

Revised root blade with integral seal plate – Zero degree skew provides better resistance to high cycle fatigue



Two lobe axial cut serrations provide improved fatigue resistance

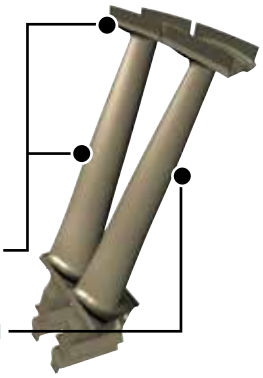
HP turbine blade under–platform damper to reduce aerofoil vibratory stresses and fatigue damage

"The Industrial Avon 200 applies cutting edge technology proven in other Siemens engine models to the turbine section of the Industrial Avon gas generator."

Turbine blades *(continued)*

Key benefits

Profiled end walls and 3D aerodynamic design techniques improve stage efficiency, overall unit power and heat rate performance.



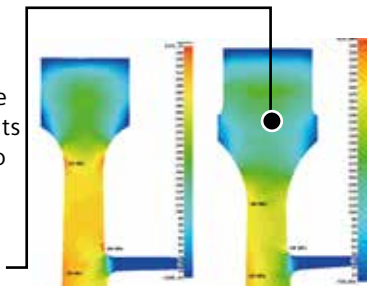
3D aerofoil design and profiled end wall improve turbine efficiency and overall power and heat rate performance

Single crystal material removes the need for cooling, improving efficiency

Disc

Key benefits

Disc head geometry has been modified to provide lower stresses. This results in improved resistance to fatigue damage and reduced overhaul cost.



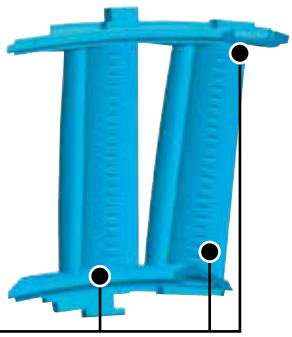
New disc geometry reduces stress, improves stress distribution and fatigue resistance

Old disc geometry **New disc geometry**

Nozzle Guide Vanes (NGV)

Key benefits

IP and LP NGVs are changed from hollow to solid aerofoils for a more robust design.



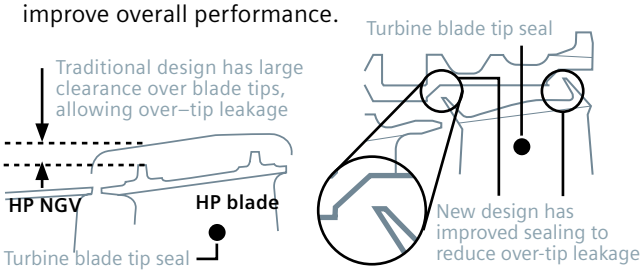
Profiled NGV end walls improve efficiency

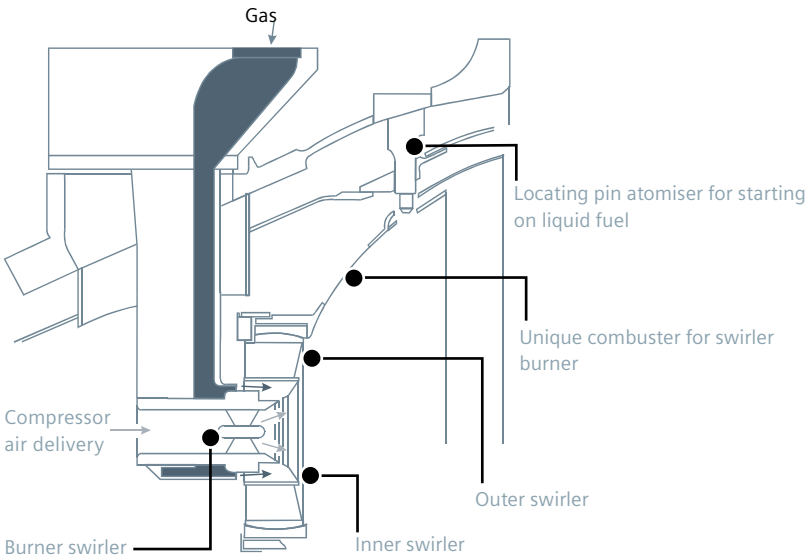
Profiled HP NGV end walls and 3D aerodynamic design techniques improve stage efficiency and overall unit power and heat rate performance

Turbine casings

Key benefits

- Steel material is retained with forgings replacing the original centri–spun castings. Thicker casing walls reduce operating stresses, creep damage and overhaul costs.
- All three stages of rotor blade tip seal liners now use segmented rings with stepped radial seals. This improves tip clearance control and reduces over–tip leakage to improve overall performance.





Avon Swirler burner improvement

Design benefits

Combustion system

Key benefits

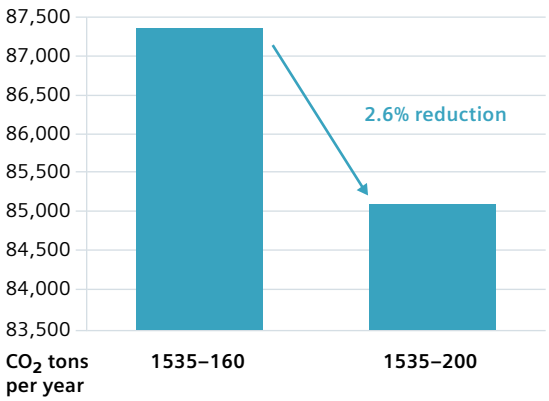
- The Swirler burner configuration is the standard and mandatory combustion system used with the Industrial Avon 200, which has demonstrated extensive service experience.
- Swirler burner technology helps reduce combustion instability associated with liquid hydrocarbon carryover from the gas fuel. This gives smoother combustion, extended discharge nozzle life and reduces burner fouling, giving improved availability.
- Increased reliability and reduced overhaul costs can also be expected by minimising the effect of high cycle fatigue (HCF) on turbine blades and discs.
- In addition, significant reductions in CO and CO_2 emissions can be expected when operating at the enhanced or current base rating (as seen in the chart below). No change in NOx emissions is anticipated.

Industrial Avon 200 nominal emissions vs Industrial Avon 1535–160

		Industrial Avon 1535–160 Std Triple Dish Combustor (natural gas)		Industrial Avon 200 with Swirler Burner (natural gas)	
Exhaust Gas Power EGHP		19,578	26,000	19,578	26,000
NO_X 15% O_2	vppm	69	84	69	85
	lb/hr	66	87	67	89
CO	vppm	146	106	28	25
	lb/hr	86	67	17	16

Industrial Avon 200 reduced carbon footprint

1535 CO_2 reduction with Industrial Avon 200 conversion



2.6% reduction in CO_2 at 1535 base load power

"The Swirler burner configuration is the standard combustion system used with the Industrial Avon 200, which has demonstrated extensive service experience."

Scope of work

Requirements

- Engine conversion
- Minor control system changes
- Review balance of package and drive train

Undertaken

- Ideally at time of overhaul

A measurable difference

- The benefits of increased power and efficiency are quantified in the charts opposite

Complementary Upgrades

- RT48S power turbine conversion (ES4001)
- New exhaust transition duct (ES6011)
- Controls upgrade (ES6006)
- Lube oil console (ES2007) – Phase 1 and 1.5 engine conversion to Phase 2
- Rotary Variable Differential Transducers (RVDT) (ES2008)
- Closed loop VIGV control (ES2009)
- New discharge nozzles with thermal barrier coating (Mod 4604)
- New compressor coatings (Mod 5010)
- New combustors (Mod 5026)

Notes: Values are based on comparisons to Industrial Avon 1535, ISO conditions. Fuel is cost of fuel gas. Production is value of process or electricity production. Standard equipment, specifications and data are subject to change without notice.

Fuel savings

Fuel $/mm BTU	Fuel savings between overhauls
1.0	$142,000
2.0	$284,000
2.5	$355,000
5.0	$710,000
7.5	$1,065,000
10.0	$1,420,000
12.5	$1,755,000

Production value

Process $/mm BTU	Electricity $/kWe–hr	Incremental production between overhauls
0.06	0.03	$1,272,000
0.10	0.05	$2,121,000
0.14	0.075	$3,182,000
0.29	0.15	$6,363,000
0.42	0.22	$9,332,000
0.57	0.3	$12,726,000
0.72	0.38	$16,120,000
1.0	0.55	$23,331,000
2.0	1.1	$46,662,000
2.5	1.34	$56,843,000
5.0	2.68	$113,686,000
7.5	4.0	$169,680,000
10.0	5.35	$226,947,000
12.5	6.69	$283,790,000

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