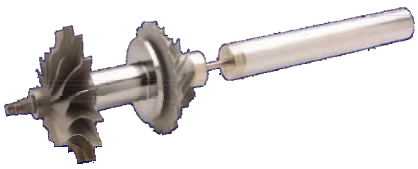
MicroTurbine Applications for the Offshore Oil and Gas Industry

May 2008

What is a MicroTurbine?

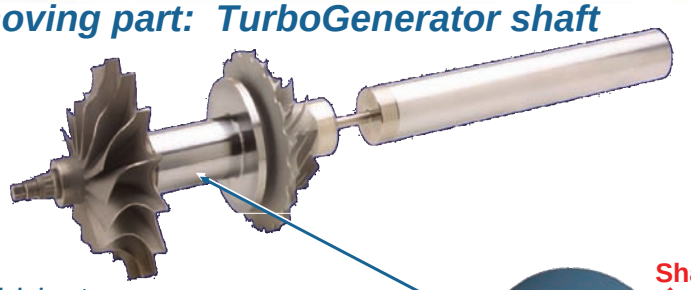
Power generator driven by a small scale gas turbine

- Efficiency of 26-33%
- Combined with CHP can achieve efficiency of 80%+
- Wide range of fuels – 350 btu to 2500 btu
  - Up to 7% H_2S
- Extremely Low Emissions - <9 ppm
- Low Maintenance Cost
- High Availability Rate

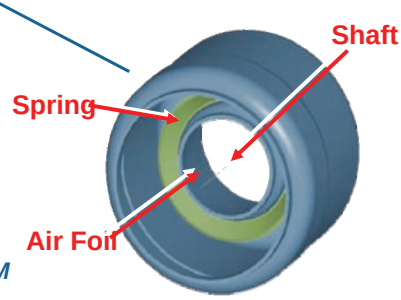


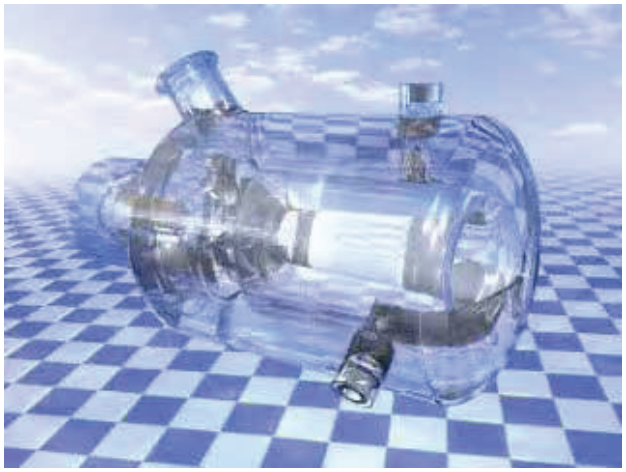
Simple: One Moving Part

One moving part: TurboGenerator shaft



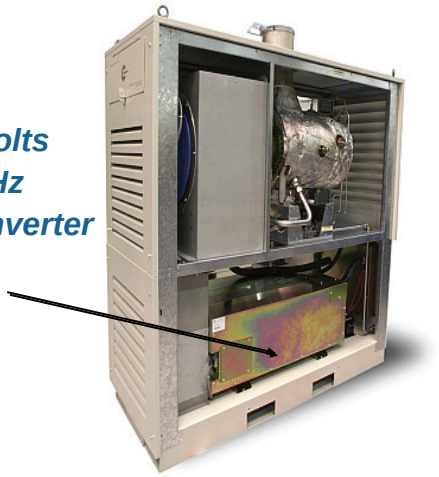
- *Air bearings*
  - *No oil or lubricants*
- *Air cooled*
  - *No anti-freeze or coolants*
- *Proven reliability*
  - *>18 million hours of operation*
- *Variable speed from 45,000 to 96,000 RPM*



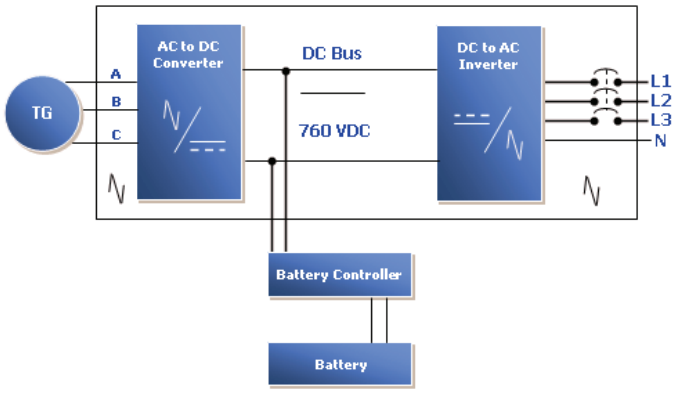


Power Electronics

- *"Electronic" Gearbox*
- *No moving parts*
- *Variable Voltage 400-480 volts*
- *Variable Frequency 10-60 Hz*
- *Voltage & Current source Inverter*
- *Built in Fault protection*



Inverter Based Electronics



4th-Generation Power Electronics

Regulated DC Bus

Engine Control Module
- All digital DSP control
- Controls turbine operation
- Wide speed control range
- Sensorless generator control
- Small and lightweight
- Built in dynamic brake
- Built in system power supply
- Air cooled

Battery Control Module
- All digital DSP control
- Transient power control
- Bi-directional power control
- Manages battery charge/health
- Air cooled

Load Control Module
- All digital DSP control
- Built in neutral
- Built in protective relays
- Built in synchronization
- Built in paralleling capability
- Grid Connect or Stand Alone
- No transformer required
- 100 kVA rating
- Air cooled
- IEEE 519 compliant
- UL 1741 certified
- NY & CA state certified for direct-to-grid interconnection

Preventative Maintenance

8,000 Hours	*Air Filters*	*Clean/Replace*
	Fuel Filter	*Replace*
	Igniter	*Replace*
20,000 Hours	*Injectors*	*Replace*
	Battery Pack	*Replace*
	Thermocouple	*Replace*
40,000 Hours	*Engine & Generator*	*Exchange*

- *Typical Maintenance cost of $0.016 kWh*
- *Average of 6 Hours of Planned Maintenance per year*
- *Capstone will guarantee cost of planned and unplanned maintenance through Factory Protection Plan*

Servicing injectors at 20,000 hrs on a BP platform Capstone MicroTurbine

Capstone Products

C30 & C65

C65 CHP

C200 & C200 CHP

Class I Div 2 & ATEX Zone 2
Available Jan 2009

Available with gas & liquid fuels

Capstone Products

C30 & C65
Class I Div 2
ATEX Zone 2

C30 & C65 SS

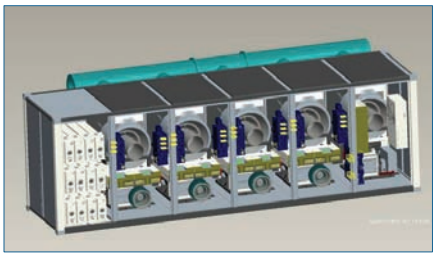
Performance

	C30	C65	C200
Rated Power	30 kw	65 kw	200 kw
Full Load Efficiency	26%	28%	33%
Heat Rate	12,200 Btu/kWh (12,800 kJ)	11,000 Btu/kWh (11,600 kJ)	10,300 Btu/kWh (10,900 kJ)
Liquid Fuel	D2, 1-K, Jet A, JP-8, JP-5	D2	In Development
Gas Fuel (HHV)	325-2131 Btu/scf	325-2550 Btu/scf	375-2550 Btu/scf
Output Current	46 Amps RMS	100 Amps RMS	310 Amps RMS
Nominal Voltage	400 to 480 VAC	400 to 480 VAC	400 to 480 VAC
Exhaust Gas Temp	530 F (275 C)	588 F (309 C)	535 F (280 C)
NOx Emissions	Gas : <9 ppm Liquid : <35 ppm	Gas: <9 ppm <5 ppm CARB	Gas: <9 ppm <5 ppm CARB
Acoustics	65 dBA	65 dBA	65 dBA

Packaged Solution

	C600	C800	C1000
Rated Power	600 kw	800 kw	1000 kw
Full Load Efficiency	33%	33%	33%
Heat Rate	10,300 Btu/kWh (10,900 kJ)	10,300 Btu/kWh (10,900 kJ)	10,300 Btu/kWh (10,900 kJ)
Output Current	930 Amps RMS	1240 Amps RMS	1550 Amps RMS
Nominal Voltage	400 to 480 VAC	400 to 480 VAC	400 to 480 VAC
Exhaust Gas Temp	535 F (280 C)	535 F (280 C)	535 F (280 C)
Exhaust Energy	4,050,000 BTU/hr	5,400,000 BTU/hr	6,750,000 BTU/hr

- 3, 4, or 5 C200 Units
- Stackable Footprint
- 28' ISO Container Footprint
- Load control from 100% to idle
- Flexible Maintenance
- Parts redundancy with C200



Installation

	Height (ft)	Width (ft)	Depth (ft)	Weight (lbs)
C30 Industrial	6.4	2.5	5.0	1271
C30 C1D2	7.7	3.1	7.0	2475
C65 Industrial	6.9	3.1	7.0	2471
C65 C1D2	8.2	3.1	7.0	3600
C200	8.2	5.5	12	7000
C1000	9.6	8.0	28	28,500

Oil & Gas Experience

- Pemex
  - 36 Units in Offshore Oil Production
    - Flare Gas Fuel
- Dominion Gas Transmission
  - 31 Units in Gas Transmission
    - CHP Applications
- Gazprom Russia
  - 50 Units in Remote Gas Transmission
- Petrobras
  - 65 Units in Gas Transmission
- More than 60 O&G customers worldwide
- More than 50 packages installed offshore

	Units Sold	O&G Installations
C30	3350	295
C60	1282	122
C65	360	125
C200	45	0
Total	>5037	>542

80% of all Microturbines Sold are Capstone

Offshore Experience

- **Gulf of Mexico**
  - Pemex (36)
  - Chevron (3)
  - BP (1) – Now Apache
  - Williams (1)
- **Alaska**
  - ConocoPhillips (1)
  - Marathon (2)
  - Unocal/Chevron (1)
- **South America**
  - Petrobras (5)
- **SE Asia**
  - Petronas (4)
- **Mediterranean**
  - ENI (4)
- **North Sea**
  - Wintershall (5)
- **Middle East**
  - BP Egypt (1)

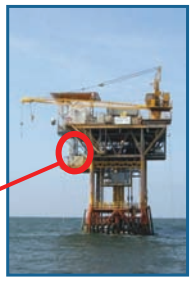
Resource Recovery Case Study:
BP Offshore Platform

The Issues:

- Provide a reliable power source in a hazardous oil and gas application on an offshore platform in the Gulf of Mexico
- Recover value from onsite flare gas which is normally lost to the environment

The Solution:

- A Capstone microturbine, UL certified for hazardous oil and gas applications
- The microturbine runs on onsite unprocessed wellhead gas which is normally flared, providing a power source to the platform
- The microturbine cut maintenance time by ~95% compared to reciprocating engine generators
- The microturbine ran almost non-stop for 25,000
- Capstone has microturbines running on other platforms in the Gulf of Mexico, Gulf of Alaska, Bay of Campeche, the North Sea, Mediterranean Sea, and South China Sea



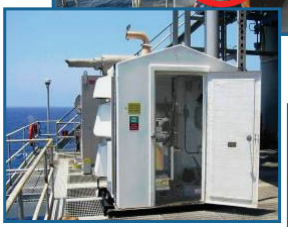
Offshore Platform Installations

Current installations:

- Gulf of Mexico
- Gulf of Alaska
- North Sea
- South China Sea
- Persian Gulf

BP platform in Gulf of Mexico

Units on Chevron platforms in the Gulf of Mexico



Conoco platform in North Sea

Unocal platform in Gulf of Alaska

Environmentally Sensitive

- Due to air bearings, there are no lubricants to store or maintain on site.
  - No Filters, Coolers, or Pumps to maintain.
- Due to the air cooling, there are no coolants to store or maintain on site.
  - No Coolers or Pumps to maintain.

No Leaks, Drips, Pigs, or Pads

1999: Platform in Gulf of Mexico to use untreated casing gas to fuel a Capstone MicroTurbine

Offshore Platform Installations

Deployed in the Gulf of Mexico

Offshore Enclosure

- *Fabricated from 316 SS*
- *Enclosure pressurized with (2) blowers (explosion proof motors)*
- *Gas Detection (1) with external calibration connection*
- *Space Heaters (3) for moisture protection*
- *Heat Detection*
- *CID2 MicroTurbine controller for safety functions*
- *UL Certified*

Uses for Methane Reduction

- Primary objective is to burn the fuel
  - Electric Power and Heat Energy are side benefits
- Fuel from flare gas
  - Associated gas from oil production
  - Boil off gas from condensate collection
  - Packing vents from recip compressors

Fuel Gas Requirements

- High Pressure Applications
  - C30
    - 50 psi Supply Pressure
    - 325-2100 BTU
    - 7% H2S
  - C65, C200, C1000
    - 75 psi Supply Pressure
    - 375-2500 BTU
    - 0.5% H2S
- Low Pressure Applications
    - 0 PSI Supply Pressure
    - No H2S
    - 600-1800 BTU

Exhaust Heat Utilization

Heat from two C30s running on untreated wellhead gas goes to "heater/treater" separator

Microturbines also generate voluminous exhaust heat

- ***C65 Generates 561,000 BTU/hr (591,000 kJ/hr) at 588F (309C)***

Exhaust Heat Utilization

Auxiliary Compression Station Power

- ***Dominion Transmission, VA***
- ***Three C30s provide prime power***
- ***Exhaust heat for fuel gas pre-heat, building heat, amine, and hot water***
- ***Six other Dominion Transmission compressor stations currently run C60s***

Benefits of MicroTurbines in O&G

- *Wide Range of Fuels*
  - *350-2700 BTU (Flare Gas)*
  - *As low as 32% Methane*
  - *Sour gas with H_2S – up to 7%*
- *Higher Availability*
  - *99% Reliability*
    - *15,000 Hours MTBF*
  - *99% Availability*
    - *6 Hours/Yr Planned Maintenance*
- *Lower Maintenance Cost*
  - *$0.016 per kw/hr Parts & Labor*

3-pack on oil flare gas in New Mexico

Benefits of MicroTurbines in O&G

Test prior to platform deployment, Netherlands

- *Low Installed Cost*
- *Short Commissioning Period*
  - *< 8 Hours for commissioning*
- *Ease of Operations*
  - *"Big turbine" style controls*
- *No Lubricants or Coolants*
  - *Nothing to drip*
- *Small Footprint, Light Weight*
  - *30% less than recips*
- *< 65dBA Acoustic Emissions*
- *Ultra-low NOx emissions with no post-combustion devices or chemicals*

Conclusions

- *Ideal power generation for oil & gas installations, onshore and offshore*
  - *More than 5,000 Capstone MicroTurbines sold and 18 million operating hours*
  - *Gas from 350 BTU – 2500 BTU with up to 7% H2S*
  - *Small footprint & light weight*
  - *Lowest maintenance cost of 0.016 $/kWh with 6 hours/year of planned maintenance*
  - *No lubricants or coolants*