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Energy Systems

Microturbine Developments At Ingersoll-Rand Energy Systems

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ASME Turbo Expo GT2005-69158

Key MT70 Specifications

Electrical Performance*

Characteristics	Specification
Nominal Electrical Power (±5)	70 kW @ 59°F
Maximum Electrical Power (±5)	92 kW @ 0°F
Voltage	480 VAC
Frequency	60 Hz
Type of Service	3 phase, wye, 4-wire ungrounded
Electrical Efficiency LHV (±2)	28% LHV including fuel-gas booster 29% LHV without fuel-gas booster
Heat Rate HHV	13,550 BTU/kWh including fuel-gas booster 13,080 BTU/kWh without fuel-gas booster

* At ISO Conditions (15°C @ sea level, 60% RH) unless otherwise noted

- Grid-parallel operation
- One package integrated with internal fuel gas booster and CHP heat recovery unit
- Suitable for indoor or outdoor use
- Can use a wide range of gaseous fuel types
- Very low emissions, dry low-NOx combustion system

Key MT250 Specifications

Electrical Performance*

Characteristics	Specification
Electrical Efficiency (±2)	30% LHV without gas booster 29% LHV with gas booster
Nominal Heat Rate (HHV)	12,645 BTU/kWh without gas booster 13,080 BTU/kWh with gas booster
Nominal Heat Rate (LHV)	11,380 BTU/kWh without gas booster 11,770 BTU/kWh with gas booster
Electrical Power (kW) (±15)	250 nominal @ 59°F without gas booster 242 nominal @ 59°F with gas booster 300 @ 0°F
Voltage	480 VAC
Frequency	60 Hz
Type of Service	3 phase, wye, 4-wire ungrounded
Grid-isolated Regulation (steady state)	±0.50% nominal voltage ±0.50% nominal frequency
Transient Handling (linear loads) (Recovery within 5 seconds)	±10% nominal voltage max ±5Hz frequency max

* at ISO Conditions (59°F @ sea level, 60% RH) unless otherwise noted

- Offers same benefits as 70kW model
- Also grid-parallel, dual-mode, or grid-isolated operation

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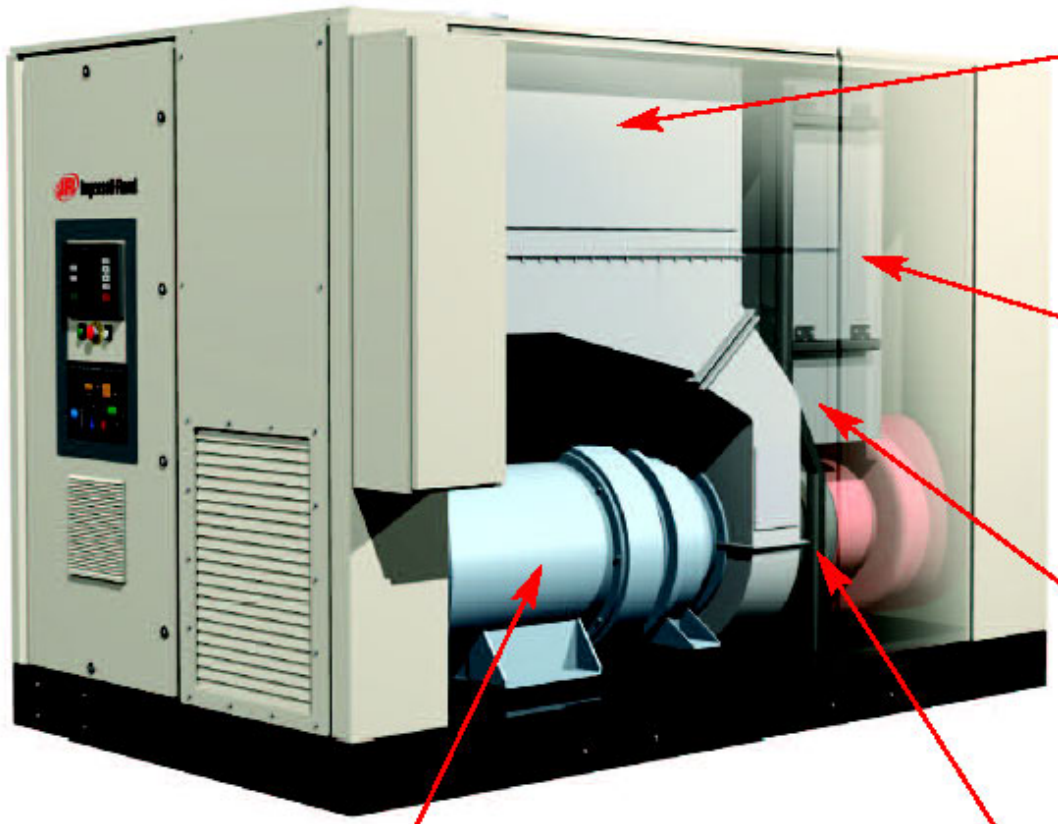
MT250 Features



Integrated Heat Recovery

- Controllable output level
- Reduces overall footprint
- No ducting

Patented Recuperator

- Critical to high efficiency
- Design life for 80,000 hour life

Patented Combustor

- Dry low NOx
- Easily meets stringent environmental regulations

Synchronous Generator

- Same technology used by utilities to power the grid
- Provides running backup capability

Rugged Turbine Engine

- Based on KG2 engine design
- Back-to-back rotating components
- All bearings at cold end

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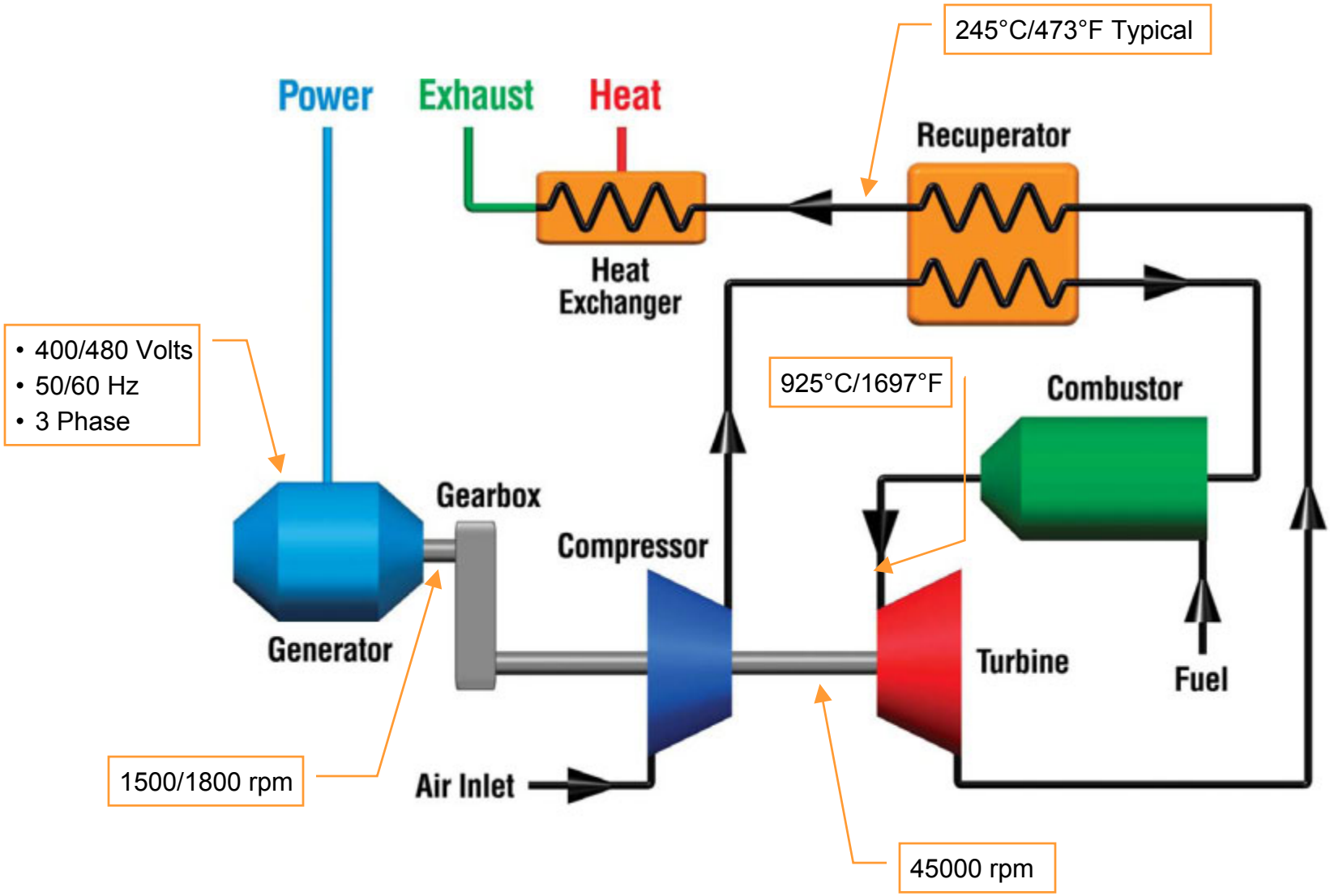
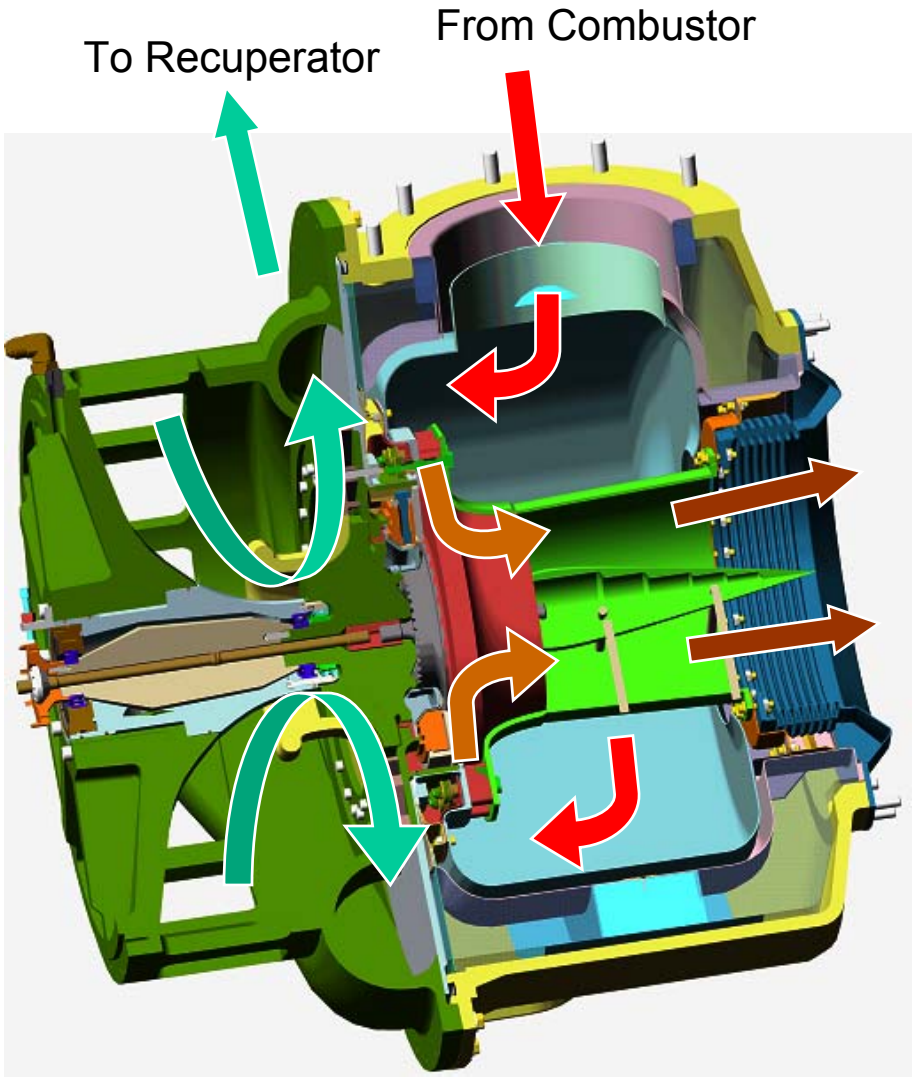
250kW System Cycle Diagram



250kW Engine Core Configuration

- Draws From Rugged KG2 Design
  - Overhung, back to back rotating components
  - All bearings in cold end
- 45,000 rpm
- Radial compressor and turbine
  - Vaned compressor diffuser
  - Turbine nozzle guide vanes
- 80,000 component life
- Up to 3,500 cold cycles
- Up to 20,000 hot cycles



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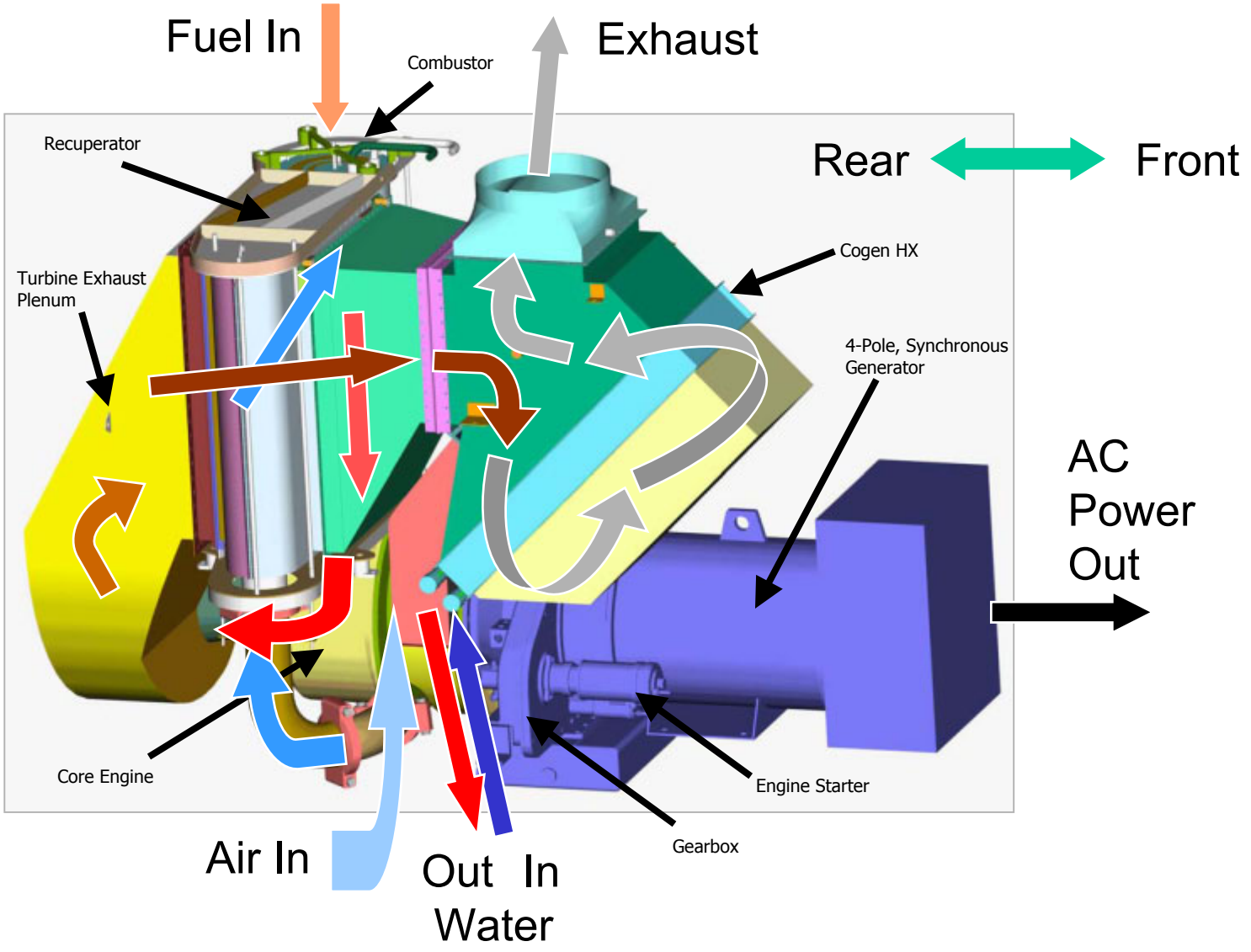
250kW Prime Mover Configuration



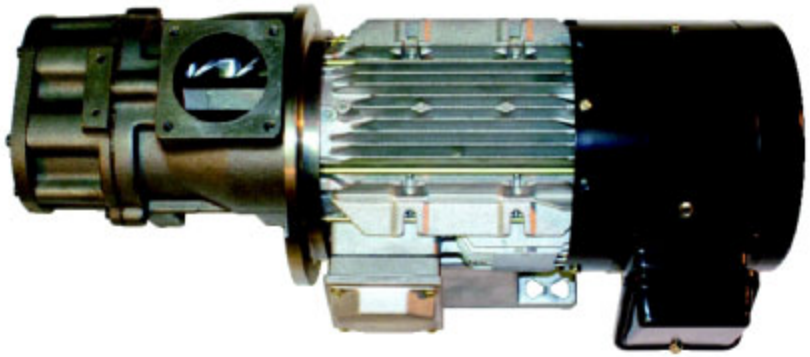
Input Fuel Types

- Wide variety of supported gaseous fuels
- Energy content range from 13,000 to 93,100 kJ/m^3 (350 to 2500 Btu/ft^3)

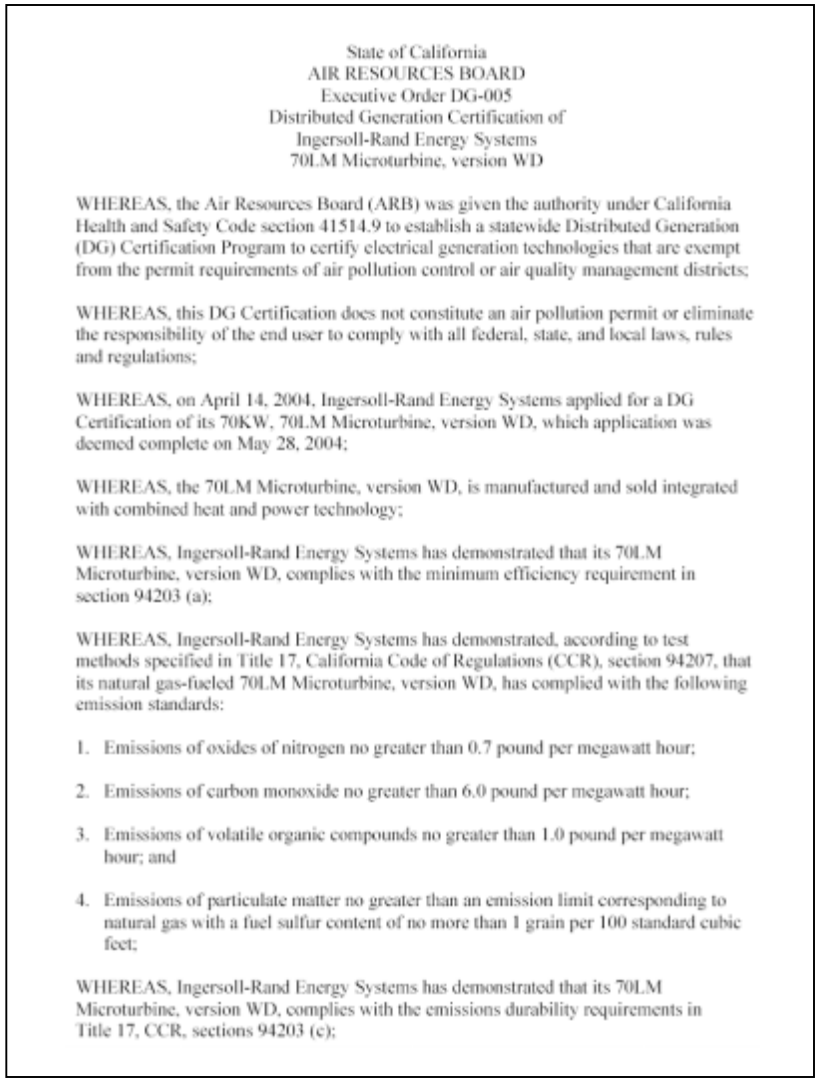
Model	Gaseous Fuel Type	LHV Energy Content kJ/m^3 (BTU/ft^3)
MT250W	Land Fill – Low BTU	13000 – 21400 (350 – 575)
MT250T	Waste Water – Low BTU	18600 – 29800 (500 – 800)
MT250M	Medium BTU Level 1 (includes Commercial Natural Gas)	26100 – 37300 (700 – 1000)
MT250R	Medium BTU Level 2 (includes Commercial Natural Gas)	37300 – 48400 (1000 – 1300)
MT250H	High BTU	44700 – 93100 (1200 – 2500)

Natural Gas Fuel Input

- Sealed fuel handling system
- Designed to safely vent outside of building
- Built-in fuel gas booster, no high pressure gas lines in building
- Minimum inlet pipe pressure = 0.02 kg/cm^2 (8” WC, 4” as an option)



Microturbine Emissions



State of California
AIR RESOURCES BOARD
Executive Order DG-005
Distributed Generation Certification of
Ingersoll-Rand Energy Systems
70LM Microturbine, version WD

WHEREAS, the Air Resources Board (ARB) was given the authority under California Health and Safety Code section 41514.9 to establish a statewide Distributed Generation (DG) Certification Program to certify electrical generation technologies that are exempt from the permit requirements of air pollution control or air quality management districts;

WHEREAS, this DG Certification does not constitute an air pollution permit or eliminate the responsibility of the end user to comply with all federal, state, and local laws, rules and regulations;

WHEREAS, on April 14, 2004, Ingersoll-Rand Energy Systems applied for a DG Certification of its 70KW, 70LM Microturbine, version WD, which application was deemed complete on May 28, 2004;

WHEREAS, the 70LM Microturbine, version WD, is manufactured and sold integrated with combined heat and power technology;

WHEREAS, Ingersoll-Rand Energy Systems has demonstrated that its 70LM Microturbine, version WD, complies with the minimum efficiency requirement in section 94203 (a);

WHEREAS, Ingersoll-Rand Energy Systems has demonstrated, according to test methods specified in Title 17, California Code of Regulations (CCR), section 94207, that its natural gas-fueled 70LM Microturbine, version WD, has complied with the following emission standards:

1. Emissions of oxides of nitrogen no greater than 0.7 pound per megawatt hour;
2. Emissions of carbon monoxide no greater than 6.0 pound per megawatt hour;
3. Emissions of volatile organic compounds no greater than 1.0 pound per megawatt hour; and
4. Emissions of particulate matter no greater than an emission limit corresponding to natural gas with a fuel sulfur content of no more than 1 grain per 100 standard cubic feet;

WHEREAS, Ingersoll-Rand Energy Systems has demonstrated that its 70LM Microturbine, version WD, complies with the emissions durability requirements in Title 17, CCR, sections 94203 (c);

- 70LM (natural gas) model certified to CARB 2003 Limits
  - Non-CHP model with blowout limit of 80% load
  - CHP model with full load range
- Emissions @100% load
  - NOx <0.13 lb/MWh
  - CO <0.25 lb/MWh
  - VOC <0.06 lb/MWh
- 250SM model CARB certification currently in process

Microturbine Emissions Using LFG

- Microturbines represent a clean method of eliminating “waste gases” such as LFG or digester gas that generally meets today’s non-attainment area permitting limits for such fuels
- Typical district NOx and CO permitting limits around 9 to 15 ppm @15% O_2
- California ARB-released LFG source testing results:

	LHV Btu/ft3	Location	Test Method	NOx ppm @15% (lb/MWh)	CO ppm @15% (lb/MWh)	VOC ppm @15% (lb/MWh)
I-R 70LM	534	Toland Road Landfill	EPA 7E, 10, 25c	1 (0.07)	2 (0.07)	5* (0.16)
Capstone 330	417	Calabasa Landfill	SCAQMD 25.1, 100.1	3	12	2.4*

California ARB, DG Technical Review, 2005-01-03

Why Condition the Fuel?

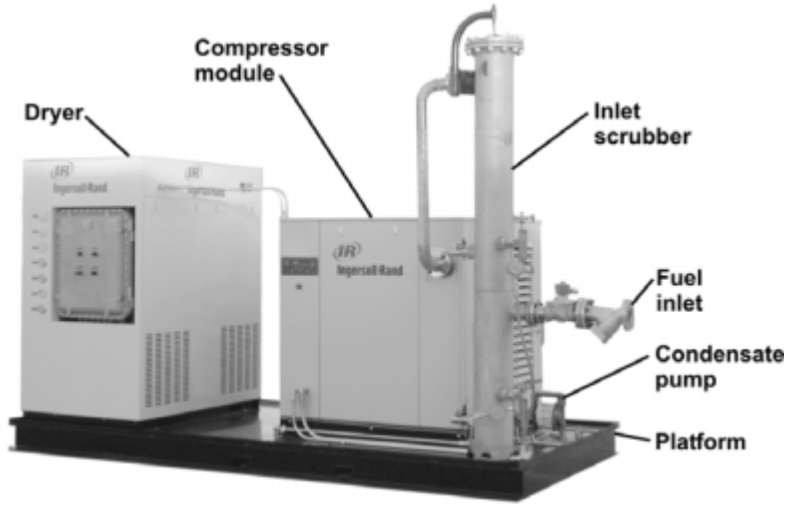
Typical biogas constituents

CH4	35-60% by volume
CO2	20-35% by volume
N2, O2	indicates air incursion into gas collection

Contaminants

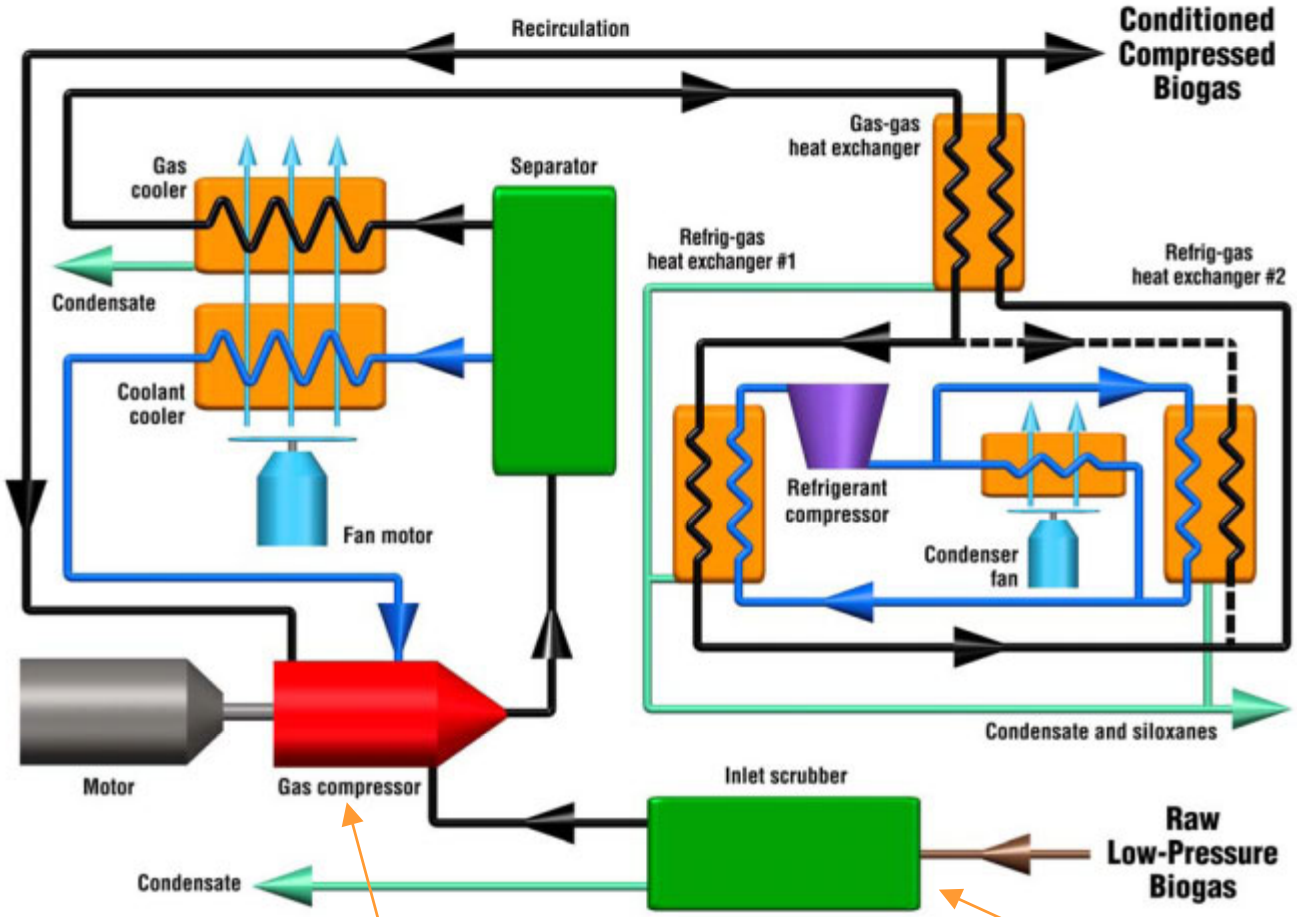
Water – H2O
Hydrogen Sulfide
Halides – Cl, F
Silicon containing compounds – SiO_2

Fuel Conditioning System



- Complete package supplied by IR
- Compressor, dryer, gas purification
- Factory assembled for reliability and low cost
- Removes water, siloxanes, other impurities
- Simple installation, just piping and wiring
- Full IR warranty and service

Fuel Conditioning Cycle



- Deep chilling technology
- Dedicated siloxane scrubbing
- No hazardous material disposal

- Established technology IR airend
- VFD controlled to save energy
- Low vibration levels

- High efficiency filtration
- Isolates system

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Thank You