Microturbines
US DoE DER Roadshows
April, 2003

# What Is A Microturbine?

- Microturbines: a new way to locally supply continuous energy to facility
- Installed inside or near a building to provide electricity and optionally, heat
- Similar to a placing a furnace, boiler, backup genset, or chiller in a facility

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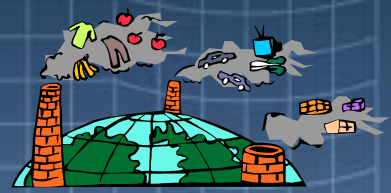
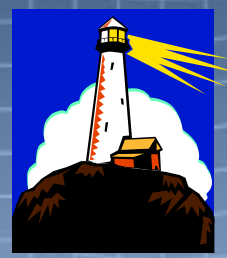
# How Does It Help The Customer?

An opportunity to:

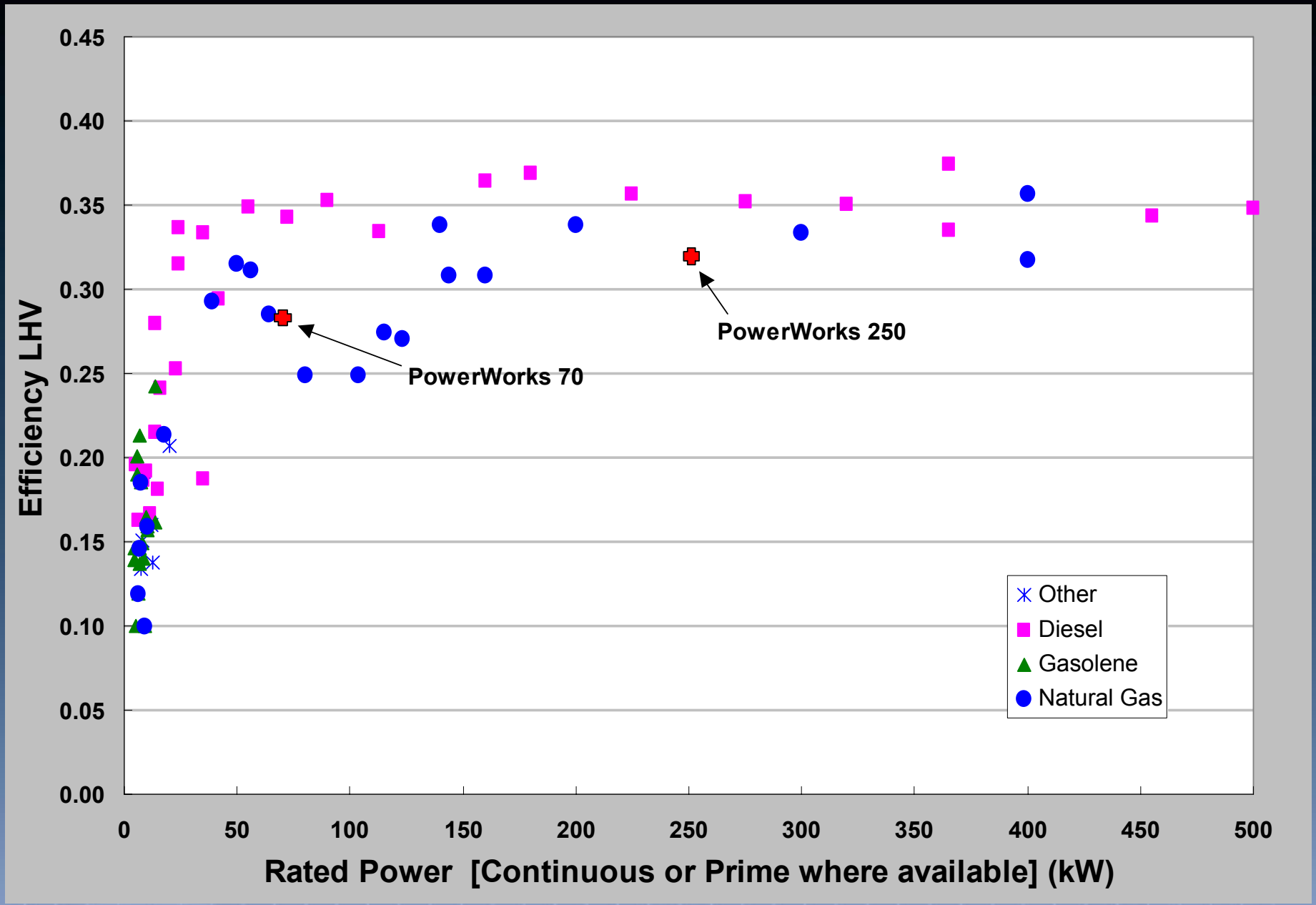
- Save money buying energy
  - Avoid penalty tariffs
  - Isolate loads to minimize demand charges
- Support energy conservation efforts
- Reduce environmental impact
  - Stop flare emissions
  - Safely destroy VOCs
- Avoid power outages
  - Eliminate production losses
  - Provide power during emergencies
  - Isolate priority loads in problem power areas
- Potentially helps solve facility power problems
  - Produce power where needed
  - Help correct power factor problems
  - Provide power to remote sites





# Microturbine Advantages

- Clean electricity
- Very low emissions
- Quiet operation
- Low maintenance
- Long engine life
- High system efficiency
- Multi-fuel operation
- Cogeneration heat


0.45
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Efficiency LHV
0
50
100
150
200
250
300
350
400
450
500
Rated Power [Continuous or Prime where available] (kW)
PowerWorks 70
PowerWorks 250
Other
Diesel
Gasolene
Natural Gas

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# Applications

| | | | | | |
|---|---|---|---|---|---|
| *Customer Motivations* | Cost Savings | Power Availability | Power Generation | Power Quality | Environ. Compliance |
| *Typical Application Segments* | Agriculture, Hotel, Chemical | Health Care, Universities, Food Distrib. | Landfill, Mining, Wastewater | Communication, IT, Hi-Value Mfg | Petroleum, Process, Materials |

*Type of Service*

| | | | | | |
|---|---|---|---|---|---|
| Cogeneration | ✓ | ✓ | ✓ | | ✓ |
| Peak Shaving | ✓ | ✓ | ✓ | | ✓ |
| Prime Power | | | ✓ | ✓ | ✓ |
| Running Backup | ✓ | ✓ | | ✓ | |
| Remote Power | | | ✓ | ✓ | |

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# PowerWorks® 70kW Key Features

**Patented Combustor**

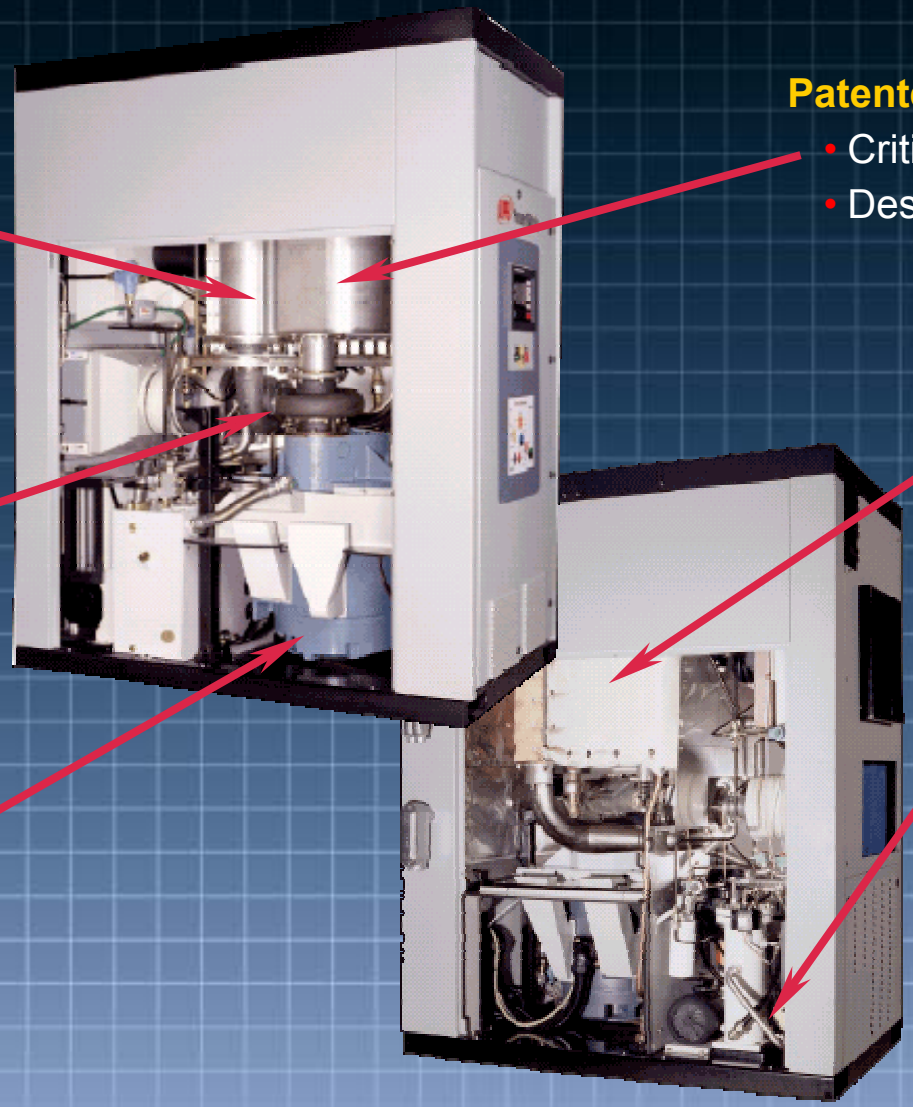
- Dry low NOx
- Easily meets stringent environmental regulations

**Two-Shaft Engine**

- Reduces stress for longer life

**Proven Generator Technology**

- Well understood by utilities
- Same technology used by utilities to power the grid



**Patented Recuperator**

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

**Integrated Heat Recovery**

- Smaller footprint
- Controllable output level

**Fuel Gas Booster**

- Long-life design
- Fully integrated
- IR technology already used in thousands of critical industrial applications

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# PowerWorks 70kW Specifications

- 70kWe model
- Has 130% peaking power capacity on cold days (92 kWe)
- Efficiency
  - Induction system: 29% LHV electric (28% w/booster)
  - Synchronous system: 28% LHV electric (27% w/booster)
  - Up to 70% total with cogeneration
- Low emissions with natural gas
- 8,000 hour maintenance interval
- 80,000 hour engine life
- Grid-parallel or grid-isolated electrical generation
- Closed transitions to grid-isolated mode during grid outages
- Automatic block load handling up to 70kW

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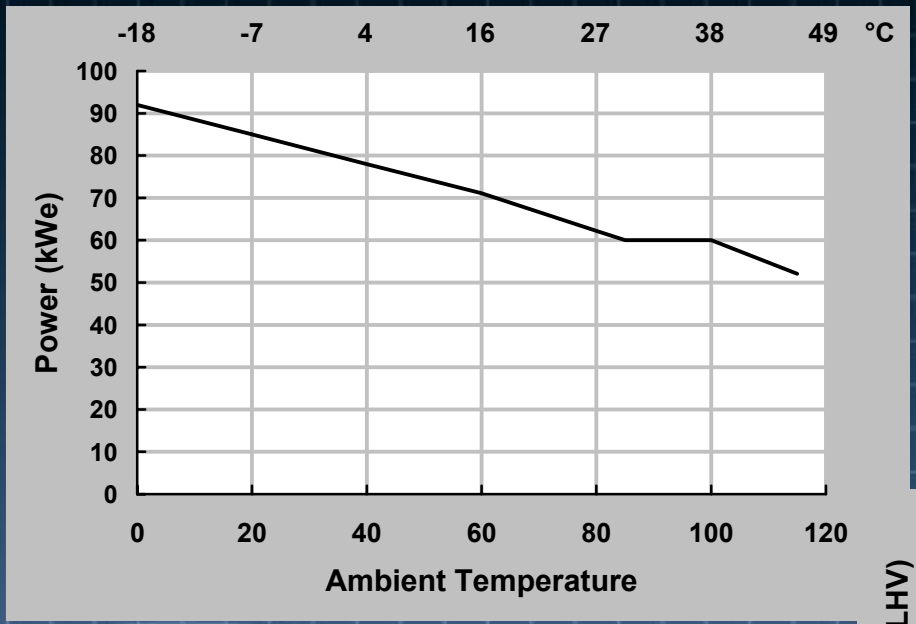
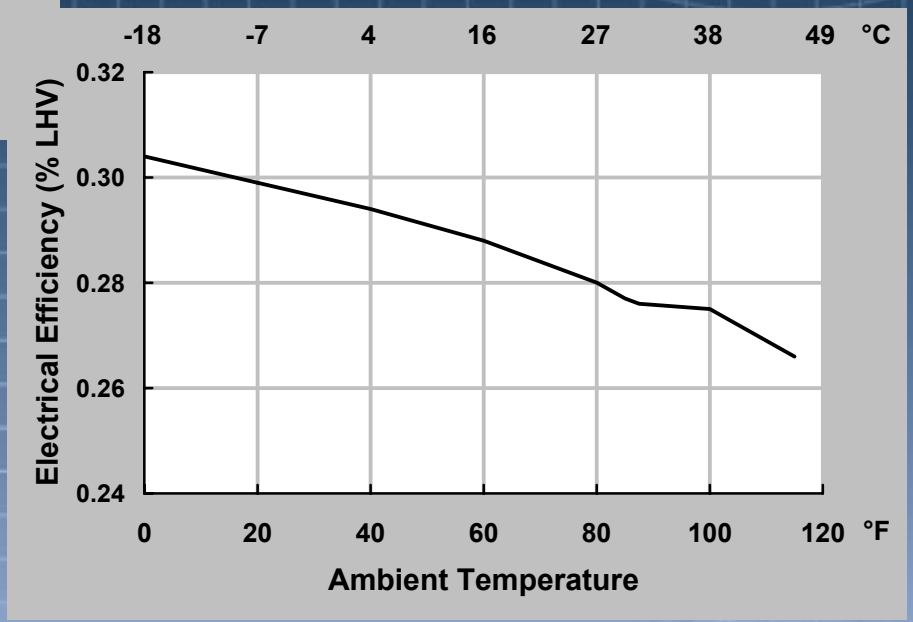
# 70kW PowerWorks Performance (Induction)




Note: KWe is electrical output at terminals corrected for parasitics, but not including gas booster power.

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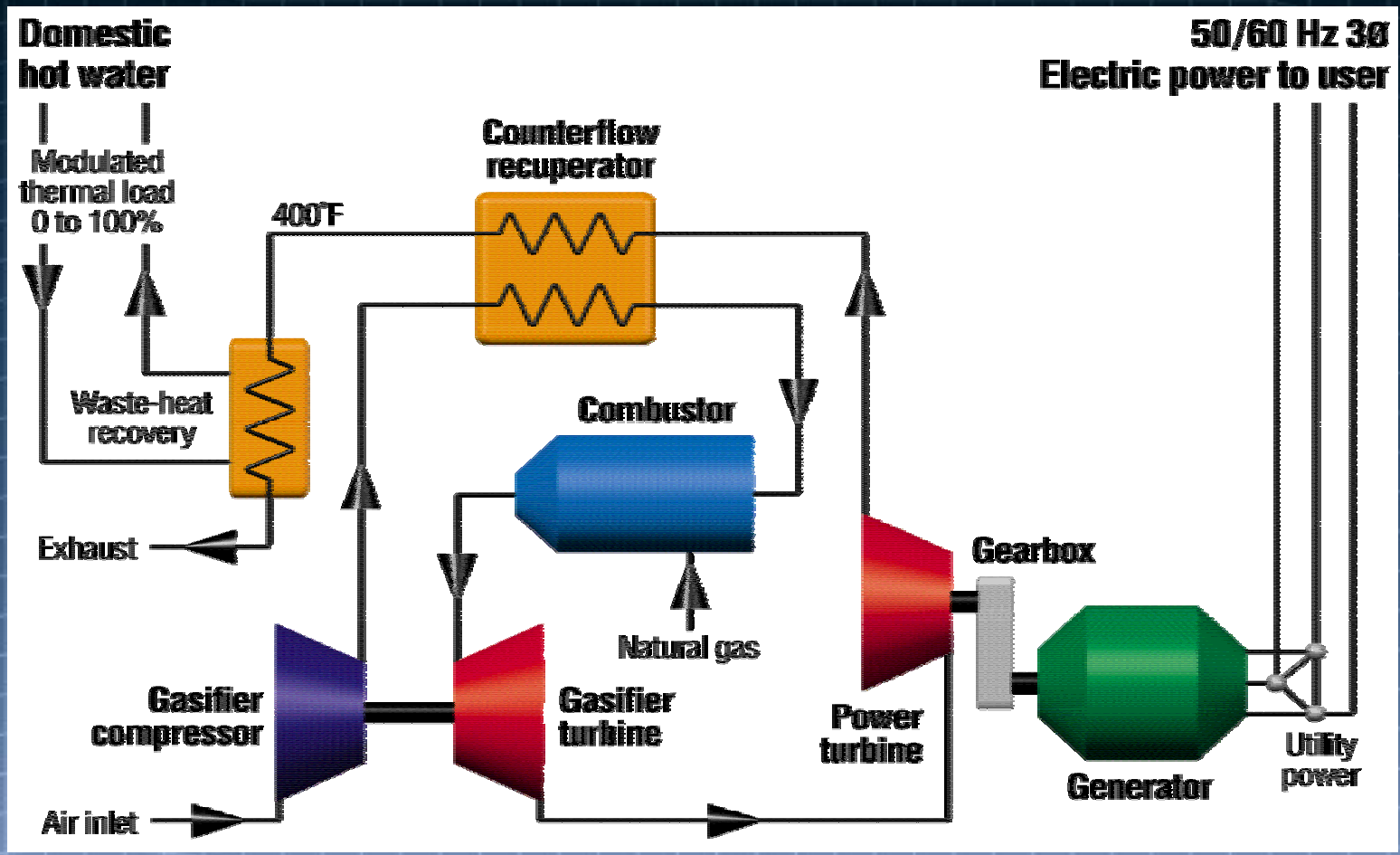
# System Cycle Diagram

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# 250kW PowerWorks Specifications

- 250kWe model at ISO conditions
- Has 120% peaking power capacity on cold days (300 kWe specified)?
- Efficiency
  - 32% LHV electric w/booster
  - Up to 70% total with cogeneration
- Low emissions with natural gas
  - <9 ppmv NOx @ 15% excess $O_2$
- 8,000 hour maintenance interval
- 80,000 hour engine life
- 3x footprint of 70kW
- Grid-parallel or grid-isolated electrical generation (synchronous gen.)
- Closed transitions to grid-isolated mode during grid outages
- Engine principally handles block load changes alone

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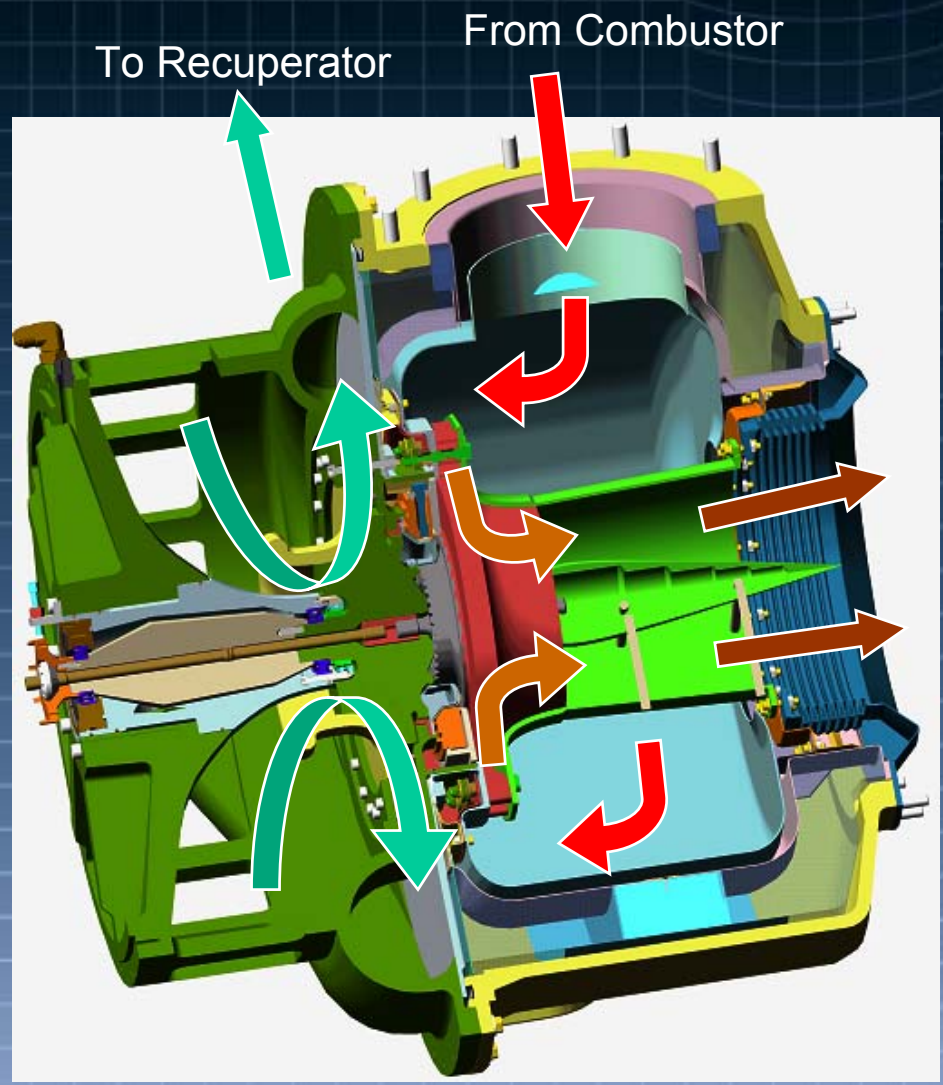
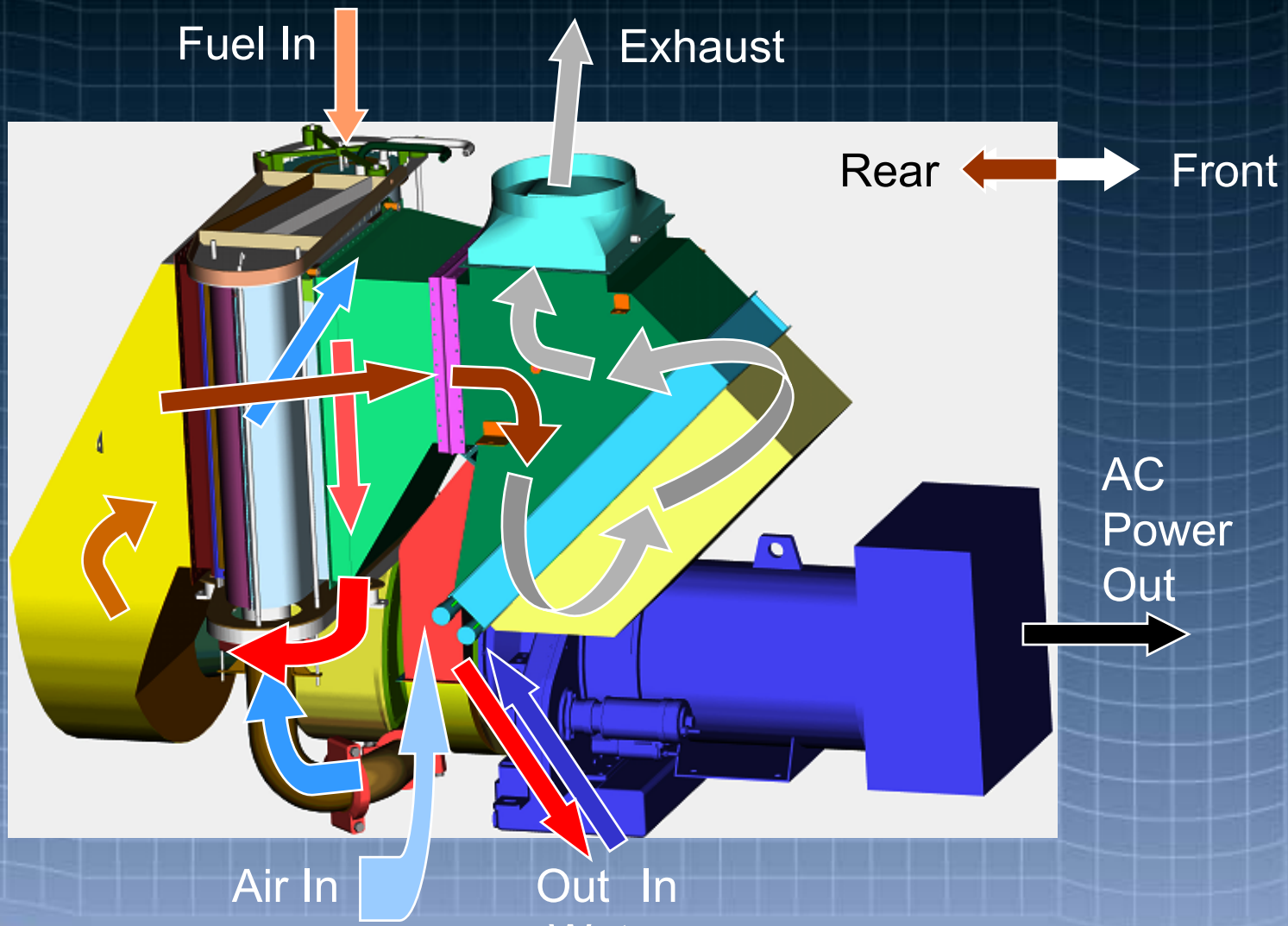
# Engine Core Configuration

- 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



# Prime Mover Configuration

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# Davidson, NC Final Assembly

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# IR's US Service Coverage

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# Codes Used in Development

- UL 2200 — Stationary Engine Generator Assemblies
- NFPA 37 — Stationary Combustion Engines
- NFPA 54 — National Fuel Gas Code
- NFPA 70 — National Electric Code
- EGSA — Safety Codes Required by States & Major Cities
- ANSI / NSF 51 — Standard for Food Equipment
- ANSI C84.1 (60Hz) — Electric Power Systems & Equipment Voltage Ratings
- ANSI 133.8 — Gas Turbine Installation Sound Emissions
- ANSI 133.9 — Measurement of Exhaust Emissions From Stationary Gas Turbine Engines
- ANSI B133.10 — Gas Turbine Information to be Supplied by User and Manufacturer
- EPA Section 1417 — Safe Drinking and Water Act
- CSA C22.2 #100 — Motors and Generators, Industrial Products
- OSHA 1910.95 — Occupational Noise Exposure
  - .101 — Compressed Gases
  - .144 — Safety Color Codes for Physical Hazards
  - .145 — Signs and Tags
  - .146 — Permit Required Confined Spaces
  - .147 — Control of Hazardous Energy

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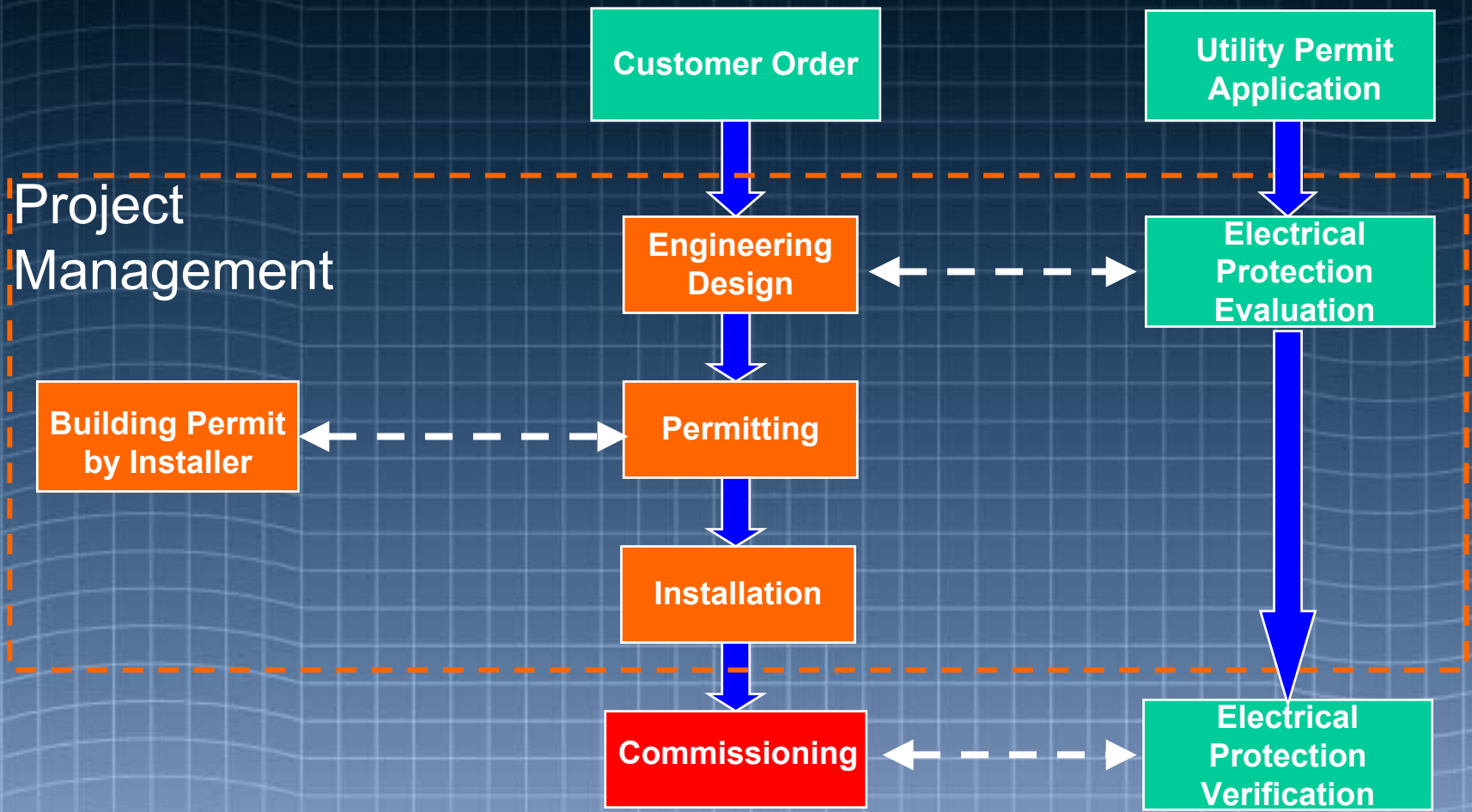
# Other Codes That Can Apply

- UL1741 - Converters / Inverters / Charge Controllers For Independent Power Systems
- Existing Electrical Interconnect Standards
  - NY: PSC Standardized Interconnect Requirements …
  - CA: Rule 21
- Future:
  - IEEE SCC21 P1547 National Interconnect
  - FERC Small Generator Interconnect
  - MA: Collaborative Interconnection Standard
- Major building codes :
  - National Building Code
  - Uniform Building Code
  - Standard Building Code
- Geographic-specific codes:
  - New York State Uniform Fire Prevention and Building Code Title 9B NYCRR
- US EPA, State, and Local Emissions Requirements

# The Installation Process

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# Compact Footprint Enclosure

- Qualified for indoor use
- Low noise level: 78Dba @ 1 meter
- Built-in industrial controls
- Special foundation not required
- Independent inlet air ducting
  - 1100 to 1500 scfm typical
  - Cool, filtered air preferred
  - Consider using building exhaust

**69L x 42W x 87H in (175L x 107W x 221H cm)**
**4100 or 4850 pounds (1860 or 2200 kg)**

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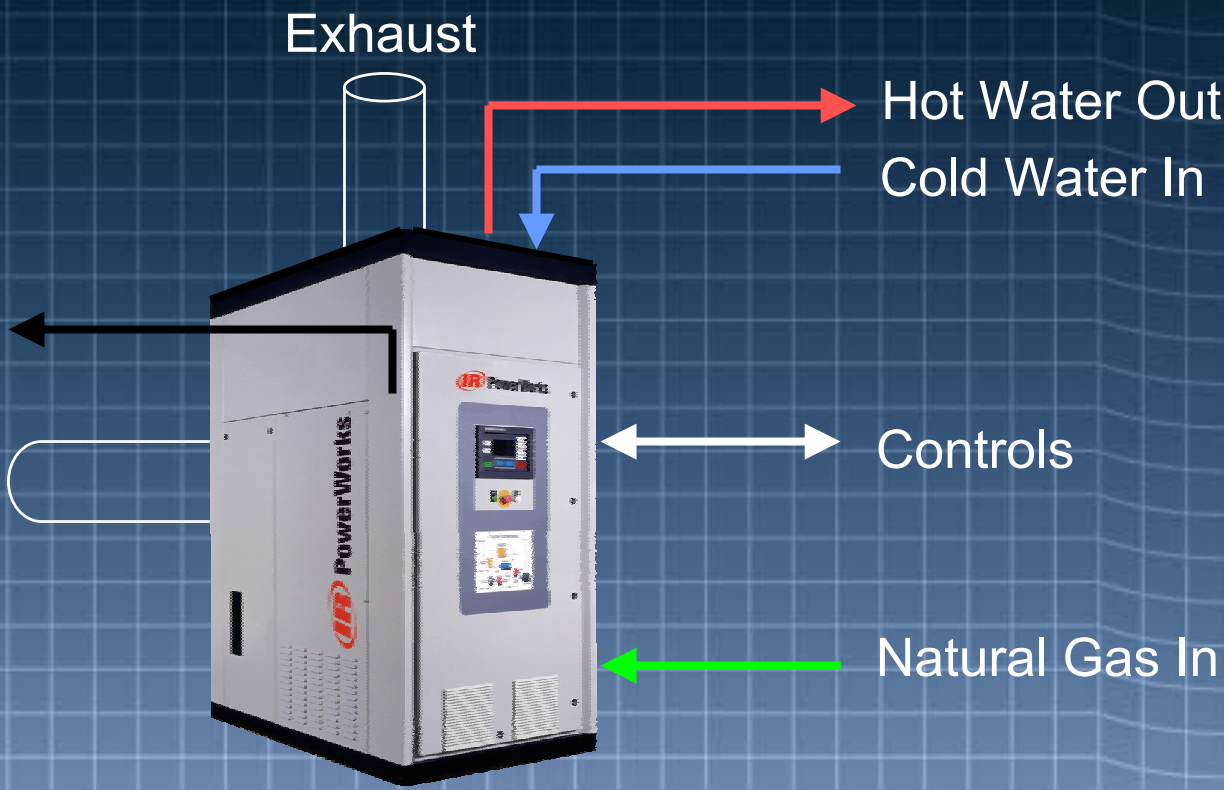
# Facility-Microturbine Integration

Physical Layout

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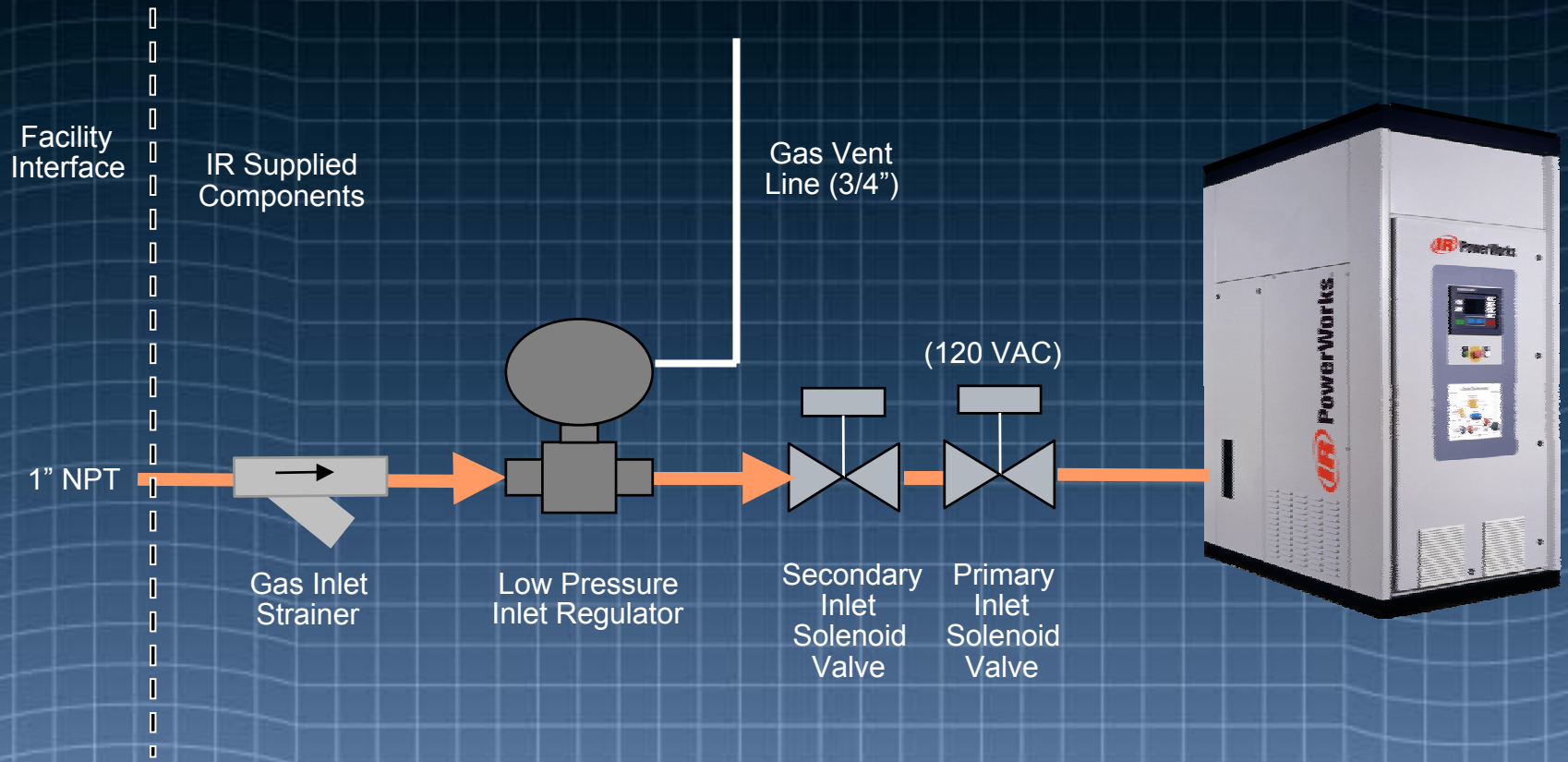
# Typical Indoor Installation

# Natural Gas Input




- **Sealed fuel handling system**
- **Minimum inlet pipe pressure = 0.29 PSIG**
- **Minimum flow = 52.9 lbm/hr**

# Prime Mover Fuel Specifications

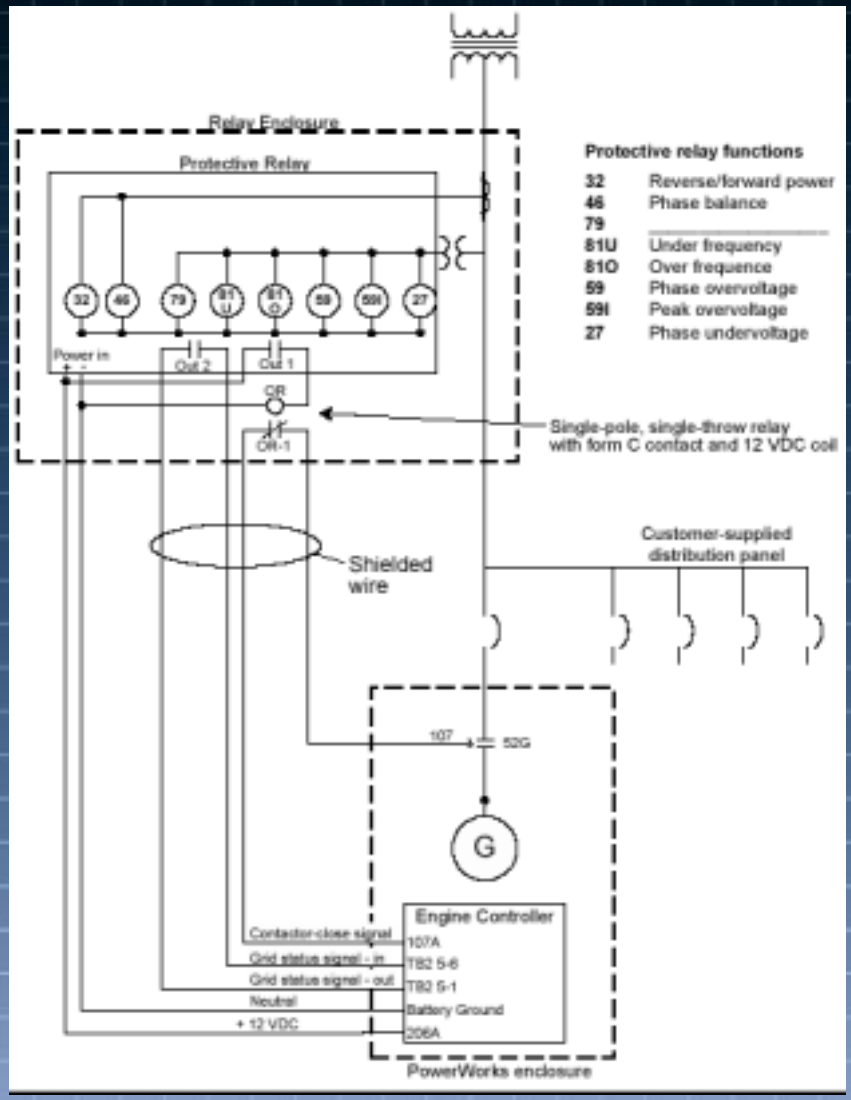
**Table 4: Composition of the Gaseous Fuel**

| Composition | Limit | Comment |
|---|---|---|
| Oxygen | 3% max | Do not exceed the flammability limits. |
| Hydrogen | 5% max | Concern is that this increases flame speed which could lead to durability reduction of the fuel injection apparatus of the combustor |
| Fuel Bound Nitrogen | 2 ppmv | Forms fuel bound NOx |
| Carbon Dioxide | 45% max | Limit corrosive potential of gas in presence of moisture |
| Methane | 38% min | Equals minimum required fuel energy content |
| Ethane | 8% max | |
| Propane + Butane | 2% max | |
| Moisture | 150 ppmv max | Corrosion concerns |

**Table 5: Contaminate Limits of Gaseous Fuels**

| Contaminate | Limit | Comment |
|---|---|---|
| Hydrogen Sulfide (H2S) | 25 ppmv max | Brief periods to 200 ppmv allowed |
| Siloxanes | 5 ppm max | Concern of corrosion and fouling |
| Particulate | 3 microns avg. size | Prevent rapid plugging of fuel filter |
| Halogenated Organic Compounds | 200 ppmv max | |
| Non-methyl Organic Compounds | 1500 ppmv max | |
| Alkali metal sulfates (Na, K, Li) | 0.6 ppm mass max | Hot section corrosion |

# Simple Intertie Electrical Interconnect

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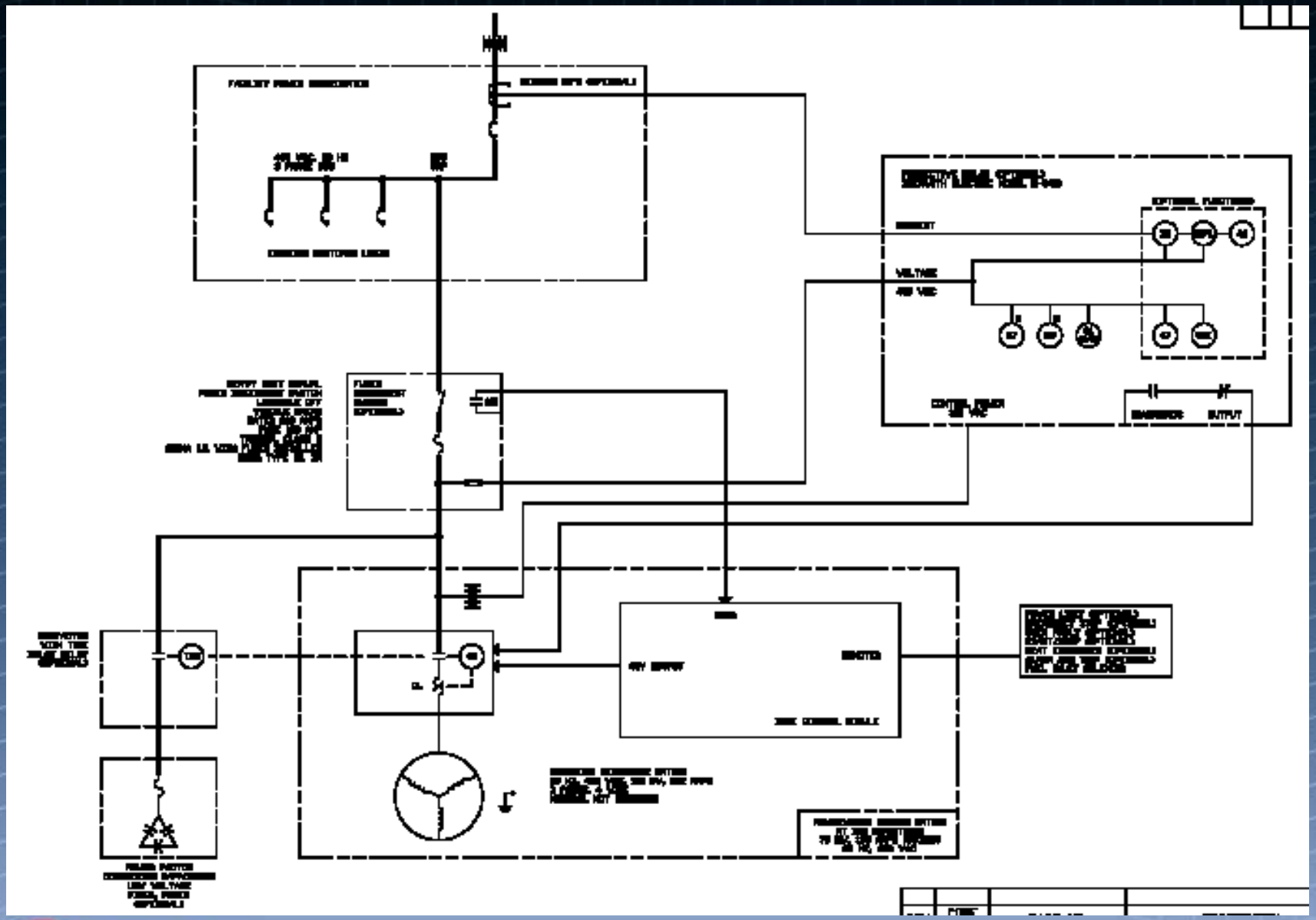
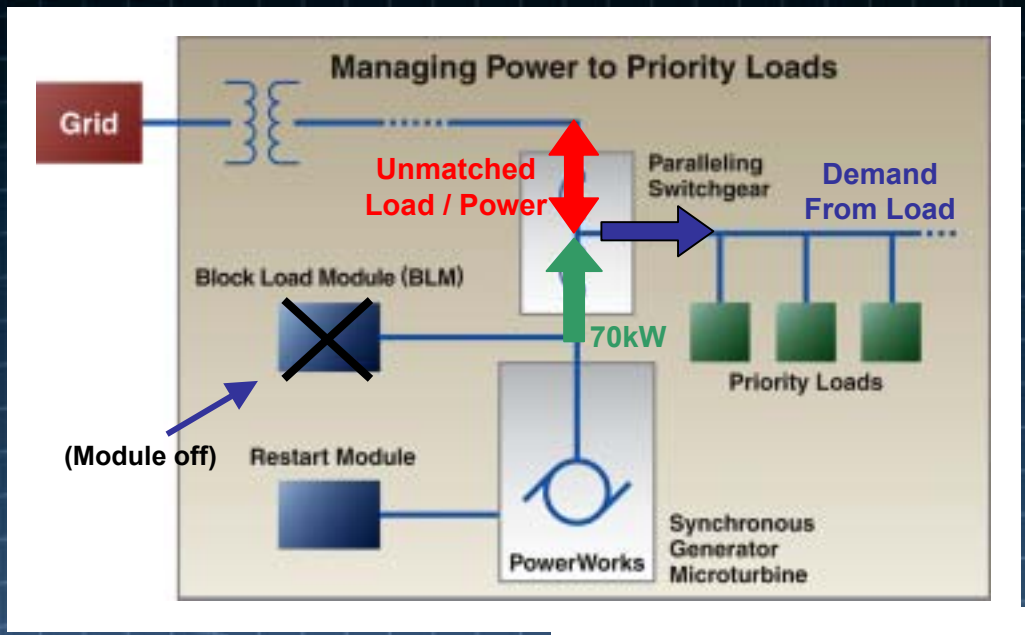
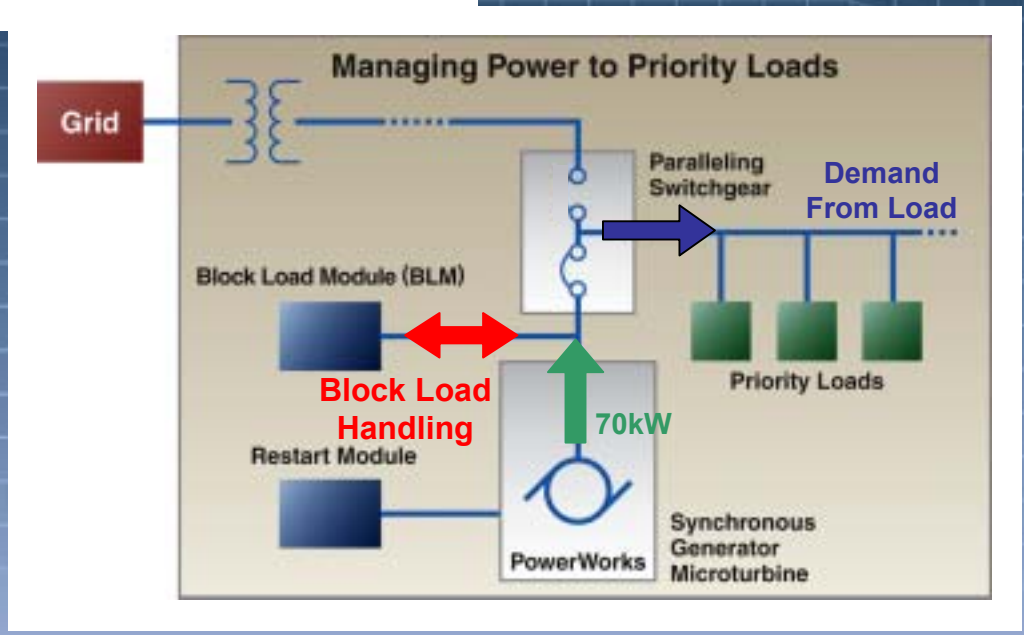
# Typical Induction System One-Line



# Synchronous System Capability

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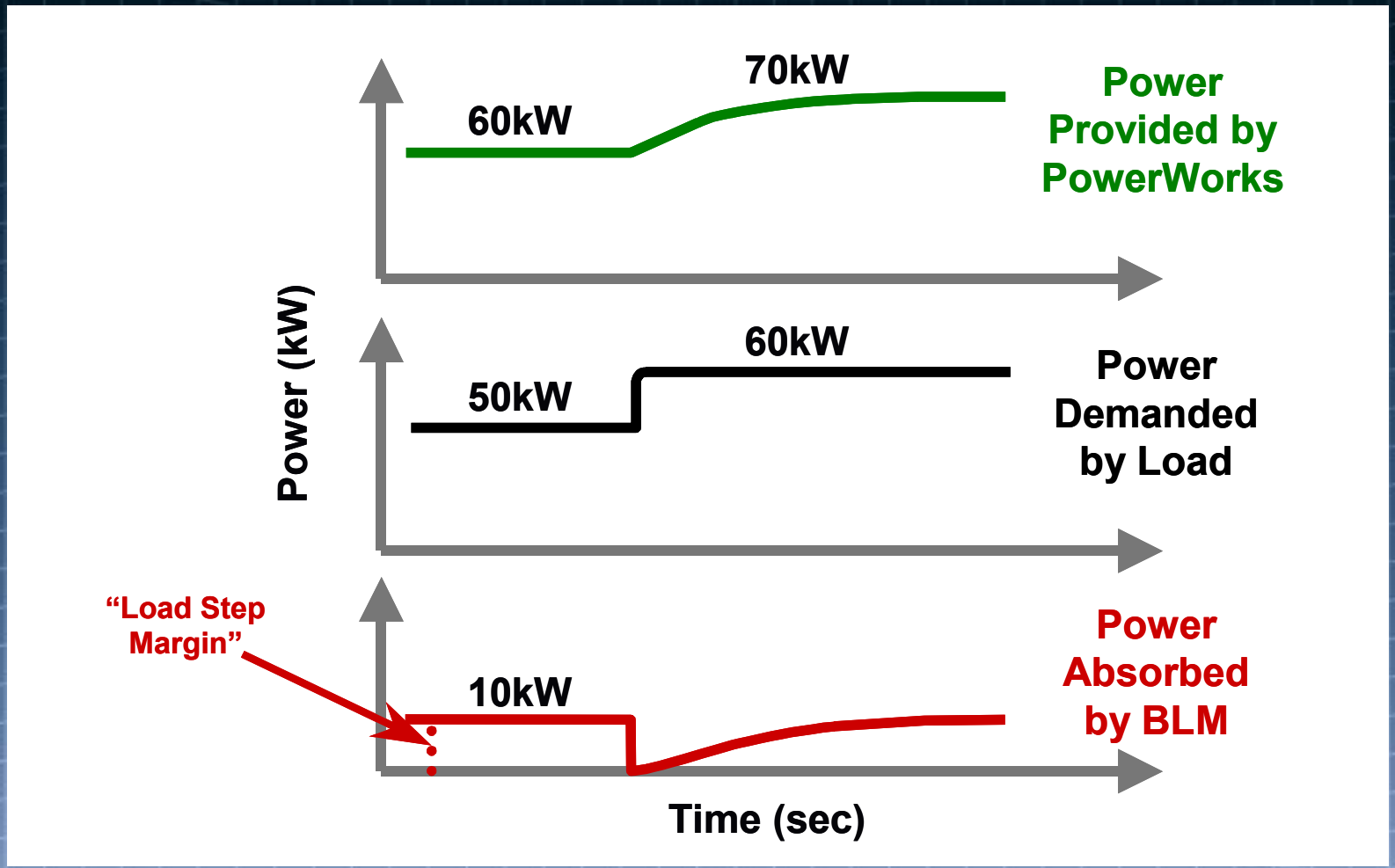
# Block Load Margin Control

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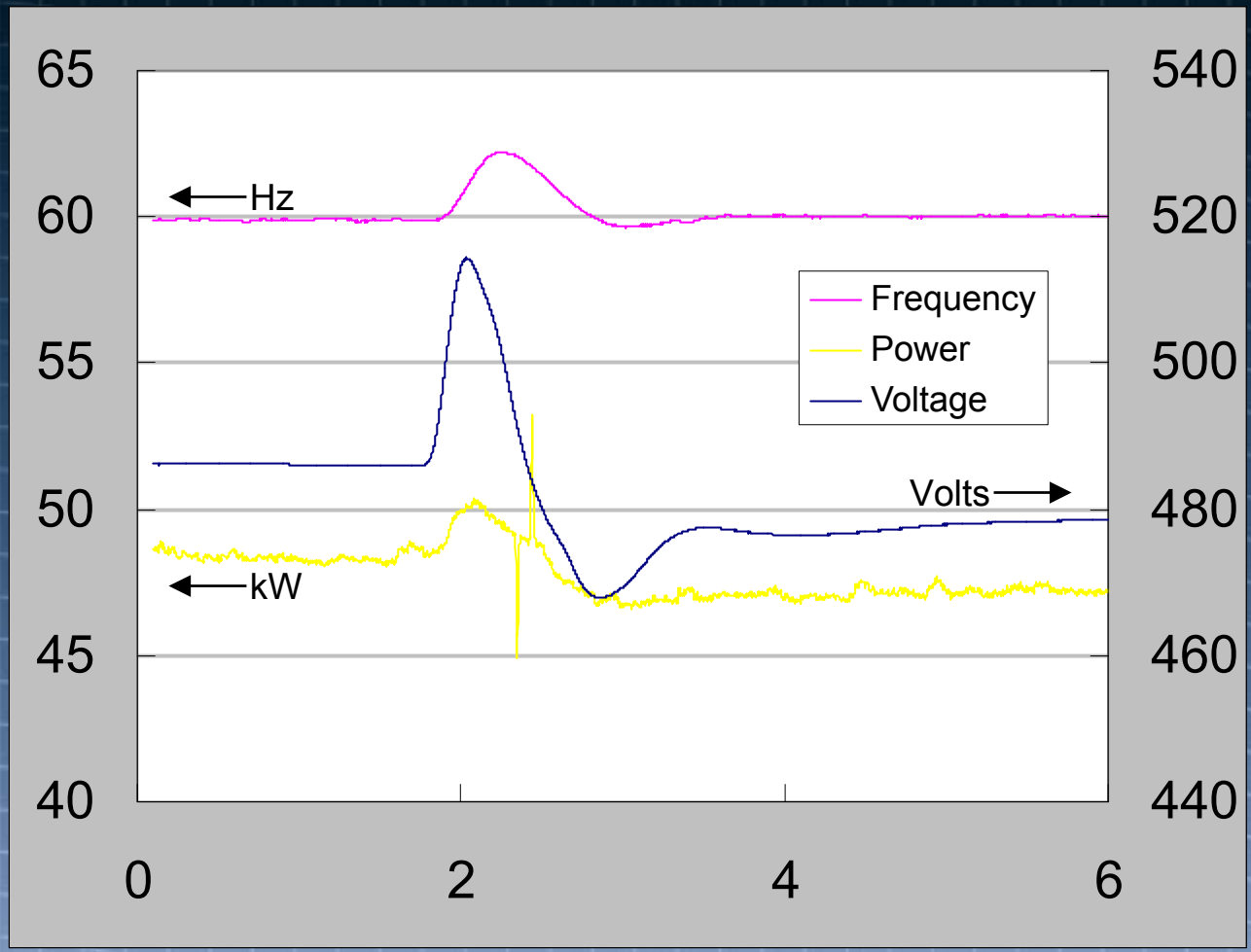
# Grid-Parallel To Grid-Isolated Detail

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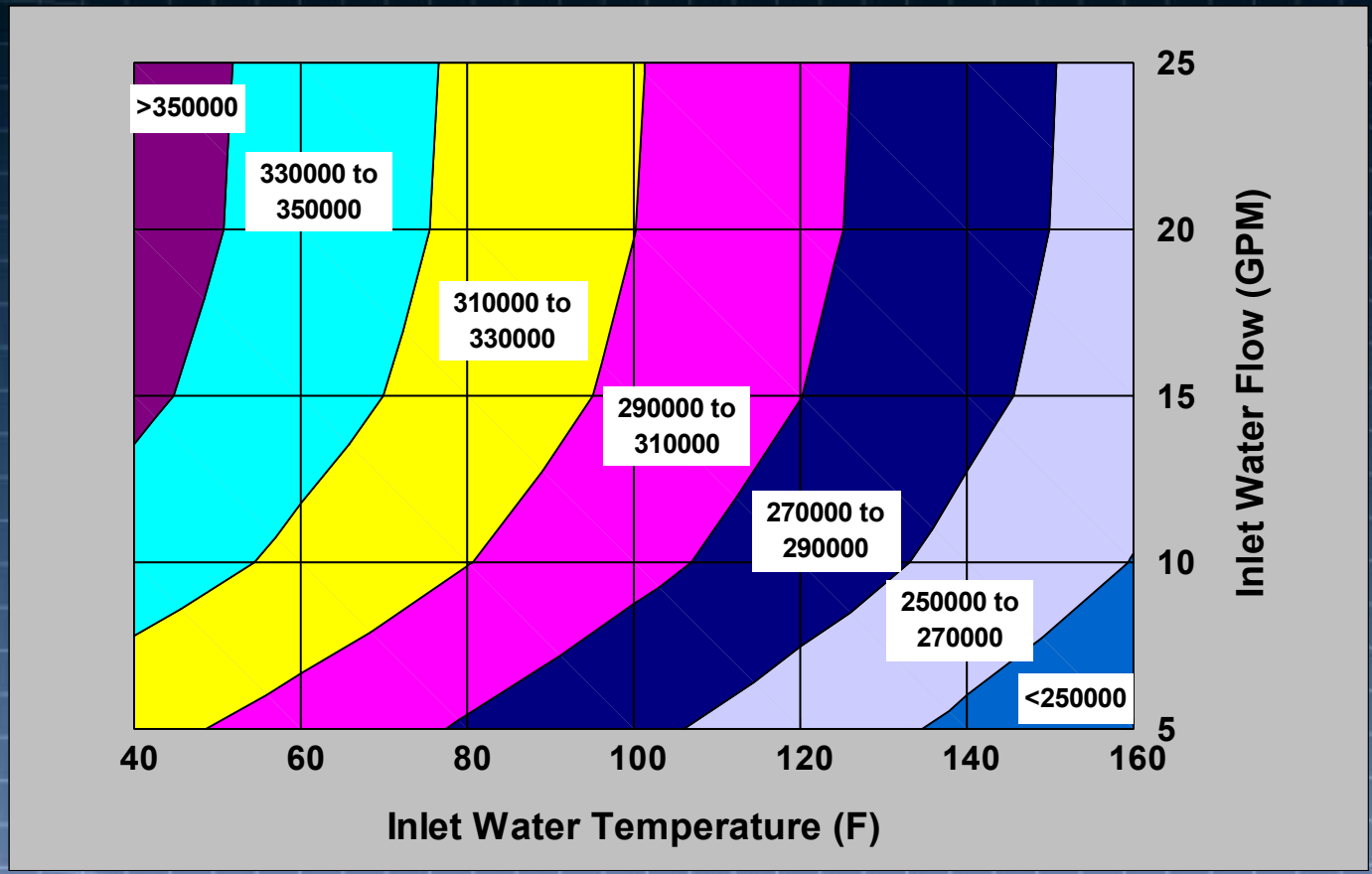
# Fully Integrated Heat Recovery System

- Built into exhaust plenum immediately after recuperator
- Designed for heating water
  - 6 to 26 gpm
  - Up to 200°F water output
  - Suitable for potable water up to 125 psig
  - Example: 278,000 BTU/hr @ 20GPM with inlet water temperature of 140ºF
- Heat can also be recovered directly from exhaust
  - About 421°F after recuperator
  - Very clean, perhaps cleaner than input air!

# Heat Recovery Output BTU/hr




- Recovered BTU/hr depends on inlet temperature and flow rate

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# 70kW Air / Exhaust Handling

- Independent inlet air ducting
  - 1100 scfm typical
  - Cool, filtered air preferred
  - Max duct pressure loss = 0.25” H2O
- Exhaust
  - Dry, low-NOx technology
  - NOx: <9 ppmv @15% O2
    <0.045 lbm/hr (<20 gm/hr)
  - CO: <9 ppmv @15% O2
    <0.045 lbm/hr (<20 gm/hr)
  - Max duct pressure loss = 0.75” H2O

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# Low Emissions Combustion

- 70kW Specification at ISO Conditions:
  - NOx <0.41 lb/MWh (<9 ppmv @ 15% excess O2)
  - CO <0.25 lb/MWh (<9 ppmv @ 15% excess O2)
- 2003 California Air Resource Board Limits:
  - NOx <0.5 lb/MWh
  - CO <6.0 lb/MWh
  - VOC <1.0 lb/MWh
- Preliminary certification testing of 70LM:
  - NOx <0.15 lb/MWh
  - CO <0.25 lb/MWh
  - VOC <0.05 lb/MWh
- Testing by outside agencies confirms low levels

# Hard-Wired Control Inputs and Outputs

- Remote Emergency Stop
- Remote Stop/Start
- Facility Fault Input
- Heat recovery On/Off
- Upstream Breaker Contact Position
- PowerWorks Alarm Indicator
- Fuel Inlet Solenoid Valve
- Protective Relay Contact

# Remote Serial Monitoring / Control

**Analog Values**

- Remote kW Setpoint
- Electric power
- Fuel orifice differential pressure
- Fuel orifice temperature
- Fuel inlet temperature
- Water inlet temperature
- Water inlet temperature setpoint
- Water outlet temperature
- Gas generator compressor inlet temperature
- Turbine outlet temperature
- Compressor inlet temperature
- Intake air filter differential pressure
- Gas generator spindle rpm
- Electric generator rpm
- Running hours
- Number of starts
- Power-on hours

**Digital Values**

- Engine state flags
- Generator state flags
- Generating electricity
- First out alarm
- First out trip

**Digital Commands**

- Remote start
- Remote stop

# Typical Power Needs For Facilities

| | |
|---|---|
| • Convenience Stores | 40 to 50 kW |
| • Fast Food | 40 to 50 kW |
| • Restaurant Chain | 50 to 70 kW |
| • Filling Stations | 50 to 70 kW |
| • Box Stores | 200 to 400 kW |
| • Older Supermarkets | 150 to 300 kW |
| • Landfills | 500kW (gas equiv) |
| • New Supermarkets | 300 to 2,000 kW |
| • Hospitals | 100 to 6,000 kW |
| • Hotels | 200 to 2,500 kW |
| • Large Office Buildings | 400 to 3,000 kW |
| • Universities | 1,000 to 4,000 kW |
| • Factories | 500 kW and up |
| • Waste Treatment | 1.5 to 10MW |

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# Applications - Community Center

- Skilled nursing facility located in NY
- 60,000 sqft facility
- PowerWorks generates hot water that provides most of the facility's Domestic Hot Water (DHW) needs
- Installed in new outside building
- Natural gas fuel
- 24/7 electricity (base load)

# Applications - Landfill

- Replaces Honeywell microturbines
- Installed in newly roofed area
- Low BTU fuel from degradation of biological waste (350 BTU / ft3 minimum?)
- 24/7 electricity (base load) exported to grid
- No heat recovery components (cogeneration)

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# Applications - Greenhouse

- Claims highest yield of roses per sq-m in the world
- Winter: electricity defers sun lamps load
- Summer: electricity defers heat pumps load
- Recovered heat used to warm plant beds

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# Applications - Industrial

- LCN - Division of IR Security & Safety in Illinois
- Offers heavy-duty fire/life/safety door closers
- Reservoir pumps city water to the microturbines which heat the water for use in a five-stage parts washing process
- Natural gas fuel input

# Applications - Landfill

- OII (Operating Industries), Monterey Park, CA
- Inactive super-fund toxic waste landfill site
- Constant flaring at ~24% methane content
- Six PowerWorks units operating at 38-40%
- Exhaust gases are flared to ensure complete burning of gas
- Perimeter wells prevents landfill gases from affecting surrounding family dwellings

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