

SECA Core Technology Program

*Cummins Power Generation
10kWe SOFC Power System
Commercialization Program
Team Program Overview
November 16, 2001
Pittsburgh, PA*

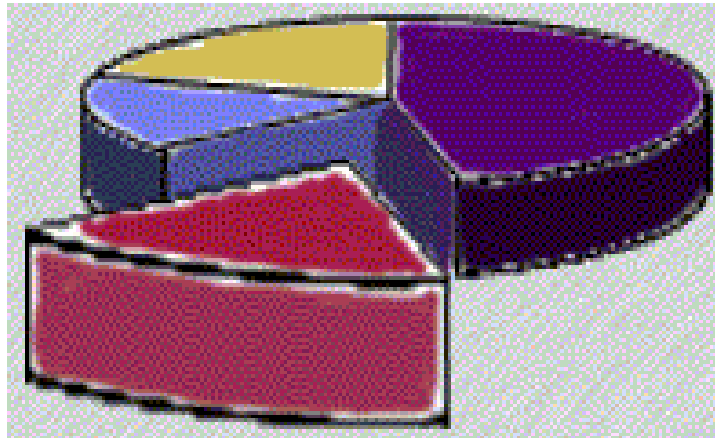


- In 1992, Cummins acquired Onan Corporation
- Commercial Gensets are branded Cummins Power Generation
- Consumer Gensets (RV, Marine) are branded Onan
- Cummins Engine Company renamed Cummins Corporation to reflect diversification and Power Generation focus

Cummins revenues - \$6.6 billion in 2000

Filtration \$1.1 billion

Industrial
\$1.0 billion



Automotive
\$3.2 billion

Power Generation \$1.3 billion

Market Leadership

Cummins Power Generation is the largest volume manufacturer and distributor of premium Gensets in the 3kWe to 12 kWe size range for

- Commercial
 - Standby
 - Peaking
 - Distributed Generation
- Consumer
 - Recreational Vehicle (RV)
 - Marine
 - Portable
- Department of Defense

Sales and Markets

- CPG Sales \$1.3 billion in 3kWe to 2 MWe range
- \$200 million in 3kWe to 12 kWe range
- System meeting SECA program cost and performance targets will displace current reciprocating engine technology in 3-12 kWe range
- Driving factors are low noise, low vibration, high reliability, and low emissions

***Cummins Power
Generation Products
Represent Innovation***





- 170 distribution centers worldwide
- Manufacturing sites in U.S., U.K., Singapore, China

Cummins Power Generation leads the industry in generator manufacturing



Cummins Power Generation Americas
Minneapolis Headquarters and Manufacturing

Existing Markets Identified in SECA Program

- Recreational Vehicle (RV)
- Commercial Mobile
- Telecommunications Standby

CPG Fuel Cell Product Vision

Rating

- Base rating 10kWe
- Supplemented by battery boost system
- Control provides load sharing between battery and SOFC

Fuel

- LP (Propane)
- Simple and cost effective
- Already in use on RV's for cooking, heating, water heating, refrigeration, Gensets
- Market research indicates customers will accept LP on vehicles to gain benefits
- LP may gain market share as propulsion fuel over Fuel Cell development period

Operating Mode

- Start-up sequence initiated from cold when power need is anticipated
- Development program will minimize start-up time
- Battery boost inverter can power loads during warm-up
- Idle mode during low electrical demand
- Shut down when no power need is anticipated for extended time

Installation

- Same size envelope -- 0.4 m³ (15 ft³) as Diesel Genset

Recreational Vehicle Market

RV Power

Why do RV's need Power Generation?

To run:

- Air conditioners
- Microwave ovens
- TV's
- VCR's
- Blenders
- Hair Dryers
- Lighting
- Water pumps
- Battery chargers



Fuel Cells for RV's



Why Fuel Cells for RV's?

- Noise
- Vibration
- Reliability
- Environmentally responsible

Noise dBA

Gasoline RV GenSet Noise Levels

4kw - 3 Meters - Uninstalled

5.0/ 6.5 Emerald



5.5/ 7 Marquis



4.0 Microlite



Marquis Platinum



1980

2000

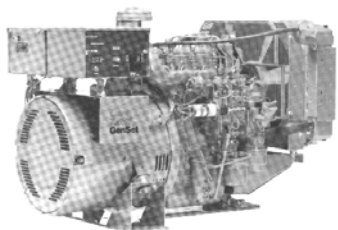
79
78
77
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68
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65
64

Noise dBA

Diesel RV GenSet Noise Levels

7.5 kWe

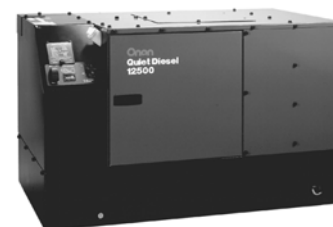
4kw- 3 Meters - Uninstalled



80
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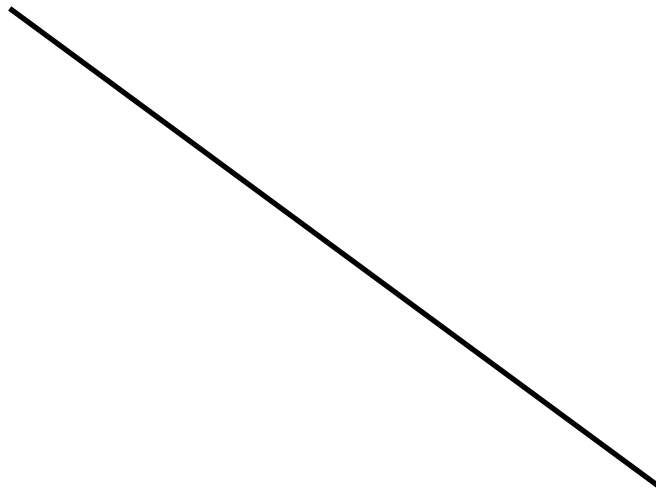
12.5 Quiet Diesel

7.5 Quiet Diesel



1980

2000



Commercial Mobile Markets

Commercial Mobile



- Utility boom and lift trucks,
- Telephone repair trucks,
- Emergency and rescue vehicles
- Vendor vans
- Mobile health care
- Product requirements similar to RV

Commercial Mobile Market Drivers

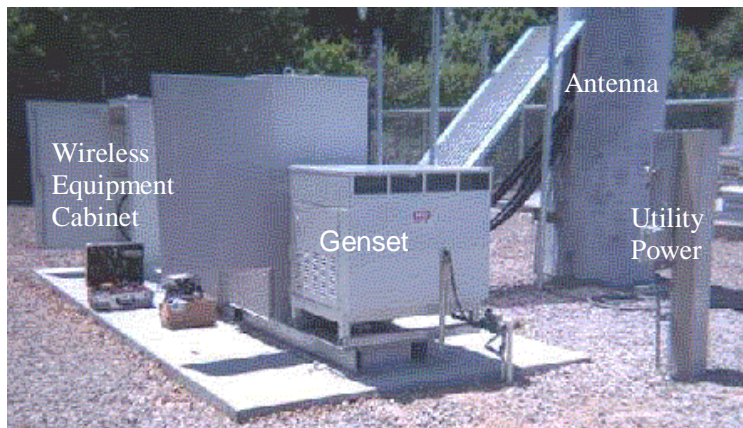
- High reliability
- Low maintenance
- Low noise
- Increasing awareness of emissions

Telecommunications Markets

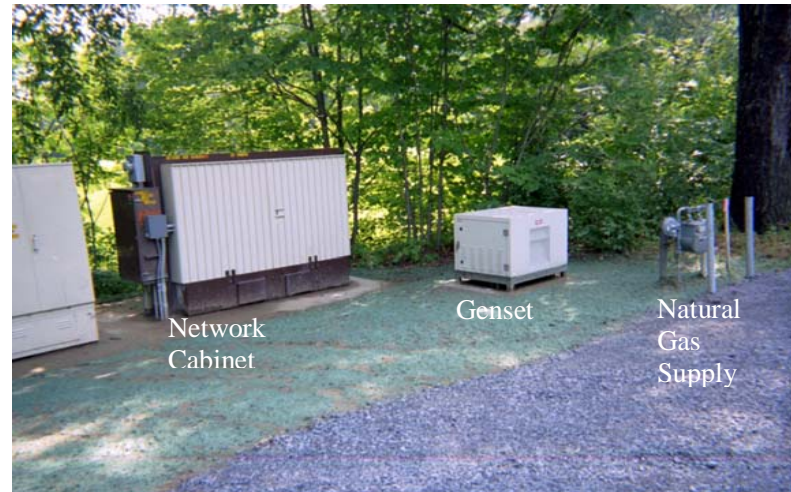
Telecommunication Emergency Power

- Wireless cell site cabinets
- Remote fiber optic network terminal cabinets
- Coax broadband cable cabinets

Telecommunications Applications



Wireless cell site with Cummins Genset.



Fiber optic network site with Cummins Genset.

Telecommunications Market Drivers

- High reliability
- Suitable for long term storage without degradation
- Lower scheduled maintenance
- Low noise for use in residential areas

Cummins Power Generation SOFCo

***10kWe Commercialization
Team***

CPG - SOFCo Team



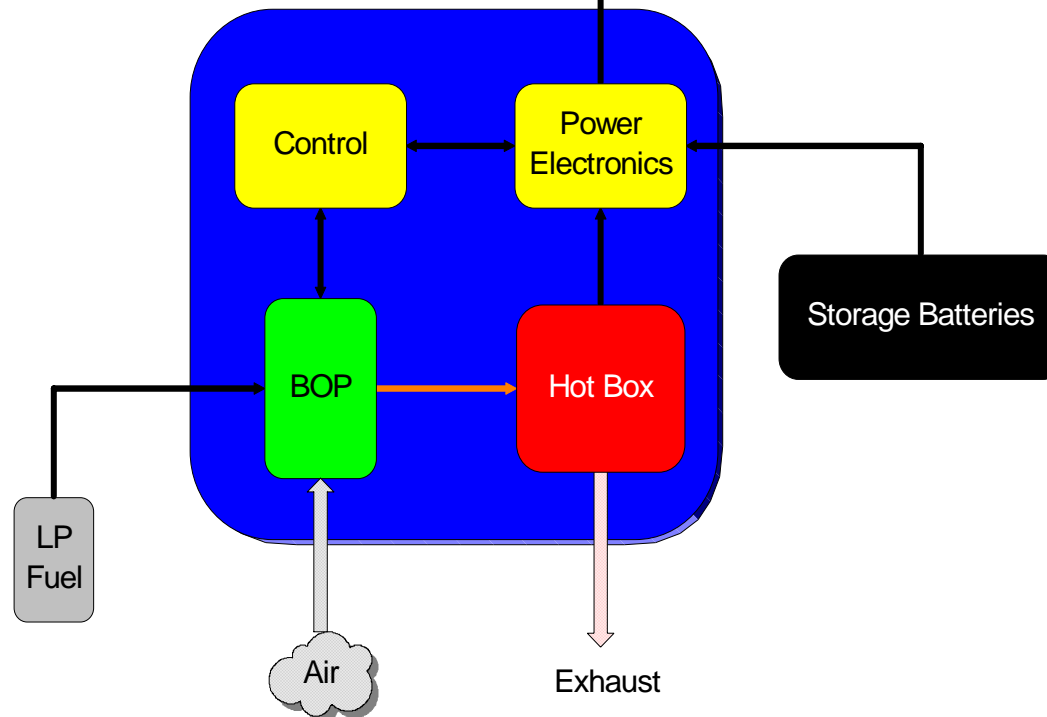
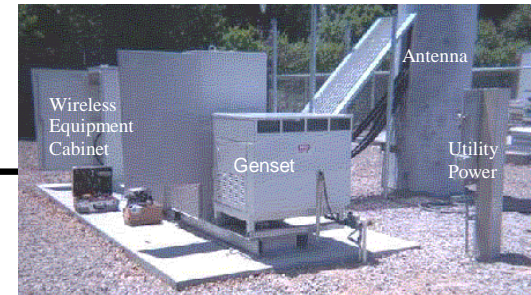
Clean Energy for the World



- Electronic Controls
- Power electronics
- Fuel systems
- Air handling systems
- Noise and vibration
- System integration
- Manufacturing
- Marketing, Sales, Distribution

Planar SOFC technology
Reformer technology
Material Science
Heat Transfer
Computational Fluid Dynamics
Numerical modeling
Multi-Layer Ceramic (MLC)
manufacturing

CPG SOFC System Architecture



SOFC System Architecture

Team responsibilities

	Responsibility	Description
System Integration	Cummins Power Generation	Control system logic and algorithms, BOP interface
SOFC Fuel Cell / Hot Box	SOFCo	SOFC stack, manifolding, heat exchange, high temp insulation
Balance of Plant (BOP)	Cummins Power Generation	Fuel system, air system, insulation, shock and vibration isolation, packaging
Control	Cummins Power Generation	System level control for all sub-systems including SOFC-Battery Load Sharing
Power Electronics	Cummins Power Generation	DC Boost and Inverter, Power Conditioning
LP Fuel Storage	Vehicle Manufacturer	Conventional Pressure Tank
Storage Batteries	Vehicle Manufacturer	Conventional Wet Lead-Acid

Commercialization of 10 kWe SOFC Power System

Objective: develop a SOFC system including

- SOFC stack
 - Balance of plant
 - Factory cost of \$400/ kWe net by end of Phase III
 - Commercialized at earliest possible date
- Phase I -- 4 years
 - Phase II -- 3 years
 - Phase III -- 3 years

Commercialization of 10 kWe SOFC Power System

- Phase I -- 4 years
- Objectives: develop a fuel cell system capable of:
 - 1) demonstrating the SECA Phase I requirements at \$800 / kW
 - 2) removing base technology barriers to commercialization in the target markets

Commercialization of 10 kWe SOFC Power System

- Phase II -- 3 years
- Objectives: continued development and improvement to:
 - 1) demonstrate the SECA Phase II requirements at \$600 / kW
 - 2) releasing the Phase II design to limited production

Commercialization of 10 kWe SOFC Power System

- Phase III -- 3 years
- Objectives: further enhance the fuel cell system to:
 - 1) demonstrate the SECA Phase III requirements at \$400 / kW
 - 2) release the Phase III design to full production

Program Summary

Program **Benefits** for identified Markets...

- Low noise
- Low vibration
- High reliability
- Clean power

Program Summary

Project challenges...

- Start up time
- Idle fuel consumption
- Power density
- Cost, cost, cost...

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Commercialization Program

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