

Lightweight 2-kW Generator with Integrated Starter Alternator (ISA)

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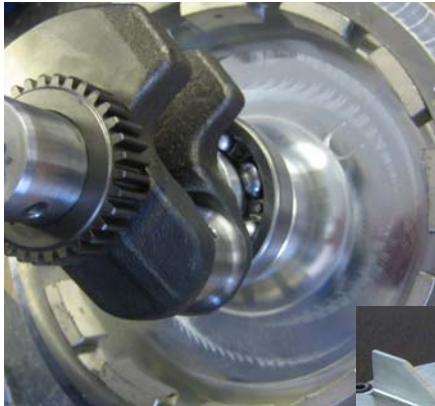
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Origin of Mainstream's 2-kW Generator

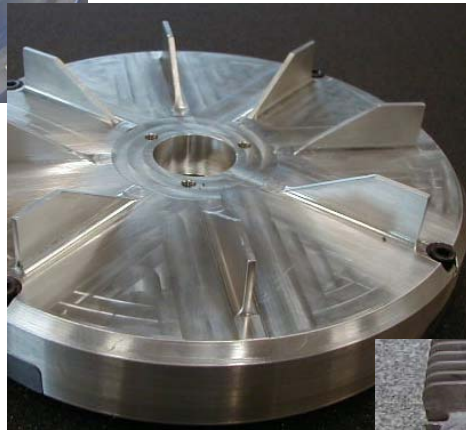
- Engine Development (1991-)
 - Customer: U.S. Army RD&E Center (Natick)
 - Application: Small, diesel-powered, personal cooling system
- Alternator Development (1994 -)
 - Customer: U.S. Army Aberdeen / OST
 - Application: Miniature, multi-fueled generator
- Results
 - Diesel-cycle is better than Rankine, Stirling, Brayton, and converted spark ignition (gasoline)
 - Mainstream designs and produces integrated, custom machines

Advantages of Mainstream's 2-kW Generators



Alternator integrated into engine flywheel

- smaller and lighter
- more reliable



Fan integrated into flywheel

- cools power electronics, engine head, oil sump
- runs cooler - increases life and reliability



Custom engine and generator designs

- sized specifically for application
- not just packaging of commercial components

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Evolution of Mainstream's 2-kW Generator



48 lbs unmounted

80 lbs fully instrumented and framed



2000-05: SBIR Program to develop generator for Marine Corps' Team Portable Collection System (TPCS)

- Marines wanted 1-kW (min.) 28-VDC generator weighing less than 50 lbs
- Manual recoil starter was desired because external starting power not available for electronic start
- Voltage regulation was not required because external power conditioning system in use
- Result: 2-kW 28-VDC generator

Future of Mainstream's 2-kW Generator



- 2006-07: IR&D
 - Developed patent-pending ISA
 - Developing integral AC inverter with soft-start motor technology
- 2006-2007: Hybrid-Electric Refrigerated Container
 - Mainstream's generator powers a 24-VDC bus and recharges batteries
 - Demo at JOCOTAS next week
- 2007: Cooperative Research and Development Agreement (CRADA) with Army RDECOM
 - Army RDECOM to perform lab tests this summer at Ft. Belvoir

Integrated Starter/Alternator

- Electric start
- Voltage regulation
- Auto-start/stop
- Battery charging circuit
- Allows integration into 24-VDC hybrid electric systems

Army RDECOM Laboratory Tests (per MIL-STD-705C)

- Physical Characterization
- 503.1c Start and Stop Test
- 601.4b Voltage Waveform Test (Harmonic Analysis)
- 601.5 Voltage Waveform Test (Deviation Factor)
- 602.1b Voltage Modulation Test
- 608.1b Frequency and Voltage Regulation, Stability, and Transient Response Test (Short Term)
- 610.1b Voltage and Frequency Droop Test
- 619.2c Voltage Dip and Rise for Rated Load Test
- 640.1d Maximum Power Test (at 125°F)
- 650.1b Ripple Voltage Test
- 660.1d Inclined Operation test
- 661.2c Sound Level Test
- 670.1b Fuel Consumption Test
- 690.1d Endurance Test
- 701.1d Starting and Operating Test (Extreme Cold Battery Start)
- 710.1d High Temperature Test

Physical Characterization

28-VDC Generator Comparison		
Model	MEP-501A	Mainstream MFEG-020028
Dry Weight	124 lbs ¹	93 lbs
Wet Weight	138 lbs ²	102 lbs
Size	30'' (L) ¹ 16'' (W) ¹ 22'' (H) ¹	18'' (L) 18'' (W) 20'' (H)

120-VAC Generator Comparison		
Model	MEP-531A	Mainstream MFEG-020120
Dry Weight	143 lbs ¹	118 lbs ³
Wet Weight	158 lbs ²	127 lbs ³
Size	30'' (L) ¹ 16'' (W) ¹ 22'' (H) ¹	18'' (L) 18'' (W) 20'' (H)

¹ Army TM 9-6115-673-13&P

² <http://www.pm-mep.army.mil/technicaldata/2kw.htm>

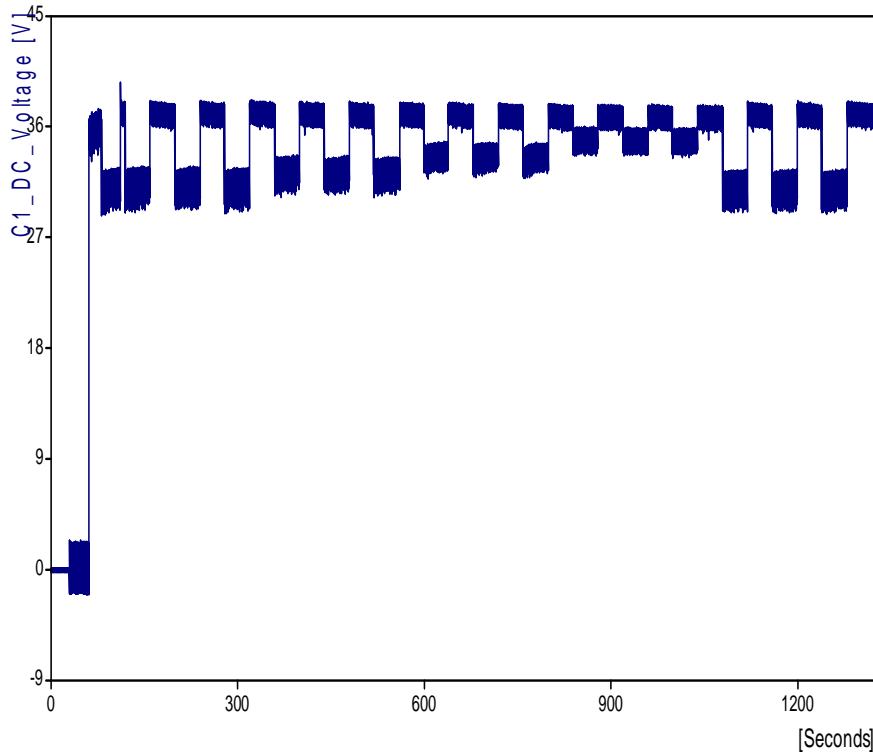
³ Projected based on design

503.1c Start and Stop Test

28-VDC Generator		
	Performance Specification For Military Mobile Power Sources (0.5kW TO 15kW)	Mainstream MFEG-020028
Start Time	Threshold – 5 min Objective – 3 min	3.3 sec
Stop Time	2 min	3.8 sec

608.1b Frequency and Voltage Regulation, Stability, and Transient Response Test

Prior test results from Army RDECOM with Mainstream's unregulated generator



28-VDC Generator

	MIL-STD-1332B	Mainstream Unregulated Generator
Voltage - Regulation	4%	20.9%
Voltage - Steady-State Stability	2%	6.6%

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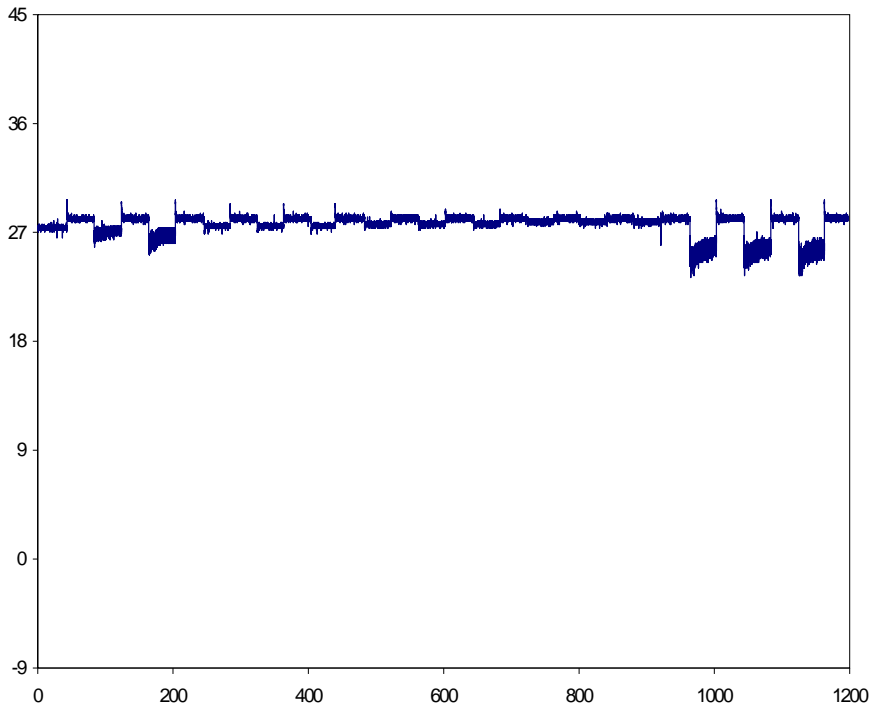
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608.1b Frequency and Voltage Regulation, Stability, and Transient Response Test

Current test results with Mainstream's regulated generator with ISA



28-VDC Generator

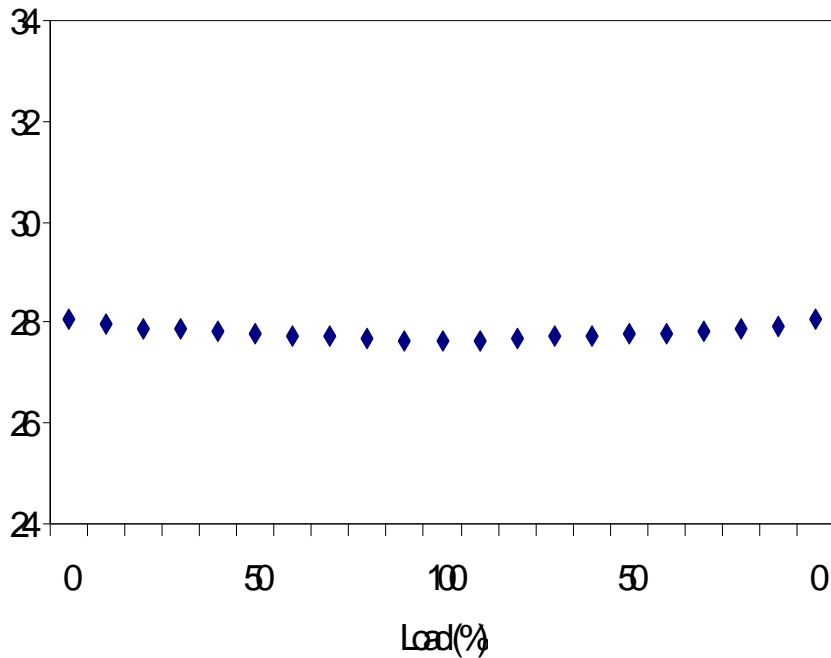
	MIL-STD-1332B	Mainstream MFEG-020028
Voltage - Regulation	4%	3.9% @ 100% load* 3.9% @ 75% load 3.4% @ 50% load 2.8% @ 25% load
Voltage - Steady-State Stability	2%	1.1 @ 100% load 1.1 @ 75% load 1.1 @ 50% load 1.1 @ 25% load 1.0 @ 0% load

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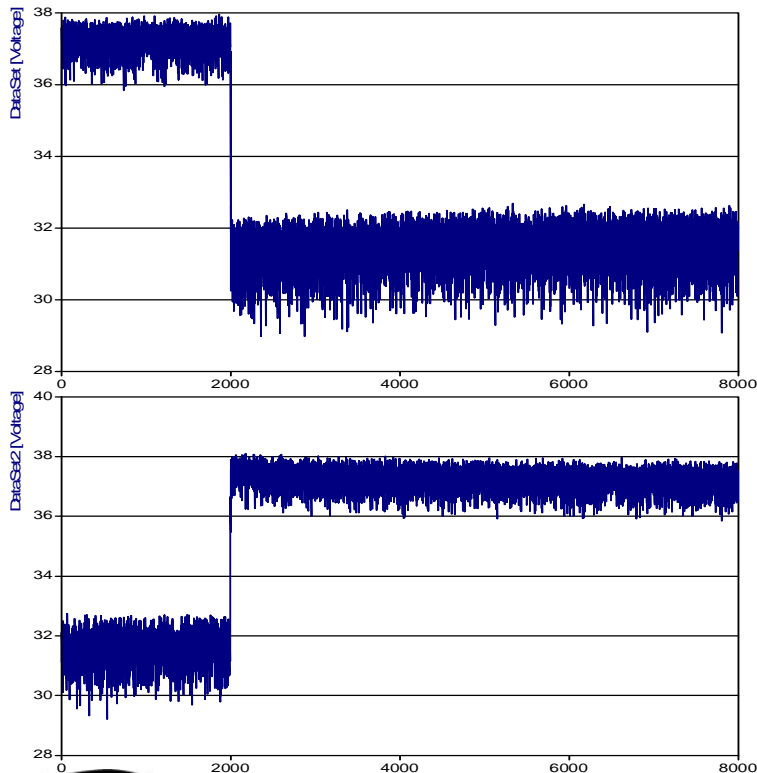
610.1b Voltage and Frequency Droop Test



28-VDC Generator		
	MIL-STD-1332B	Mainstream MFEG-020028
Voltage - Droop	not specified	1.4%

619.2c Voltage Dip and Rise for Rated Load Test

Prior test results from Army RDECOM
with Mainstream's unregulated generator



28-VDC Generator

	MIL-STD-1332B	Mainstream Unregulated Generator
Voltage – Dip	30%	24.8%
Recovery Time	2 sec	0 sec
Voltage - Rise	40%	22%
Recovery Time	2 sec	0 sec

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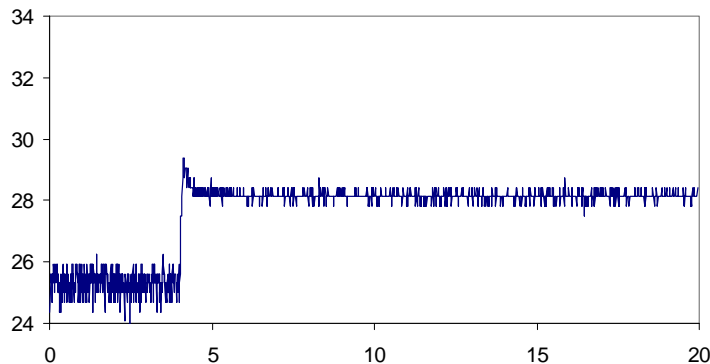
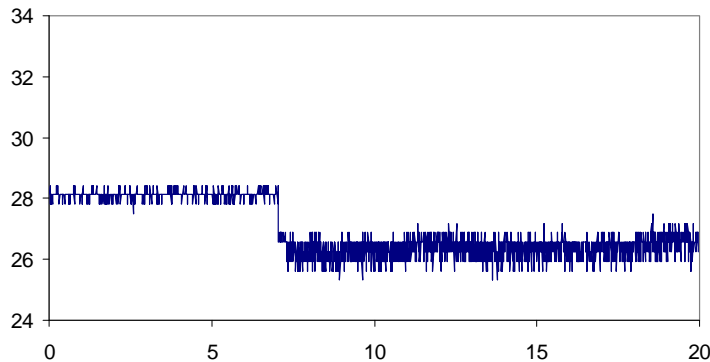
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619.2c Voltage Dip and Rise for Rated Load Test

Current test results with Mainstream's regulated generator with ISA



28-VDC Generator

	MIL-STD-1332B	Mainstream MFEG-020028
Voltage – Dip	30%	6.2%
Recovery Time	2 sec	0.1 sec
Voltage – Rise	40%	5.5%
Recovery Time	2 sec	0.6 sec

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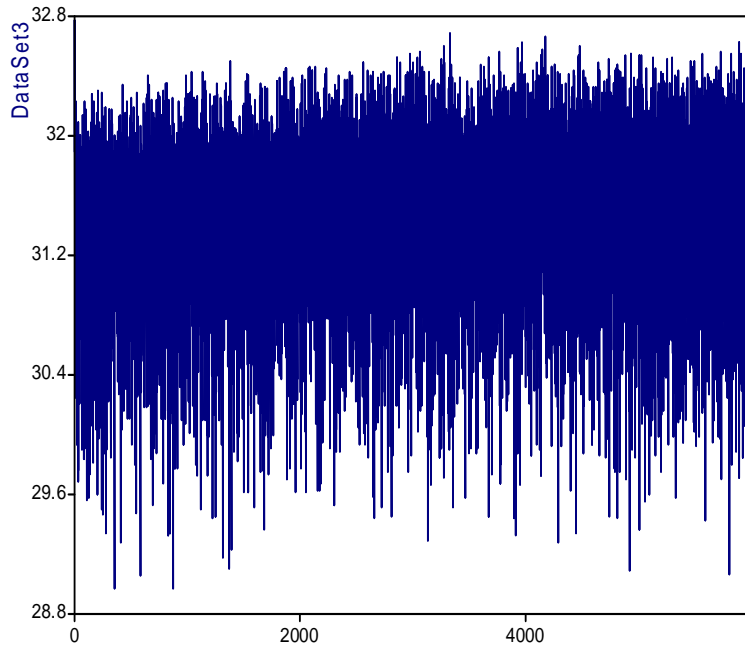
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650.1a Ripple Voltage Test

Prior test results from Army RDECOM
with Mainstream's unregulated generator



28-VDC Generator

	MIL-STD-1332B	Mainstream Unregulated Generator
Voltage - Ripple	5.5%	9.4%*

* Reduced to 2.9% with 0.16 lb capacitor

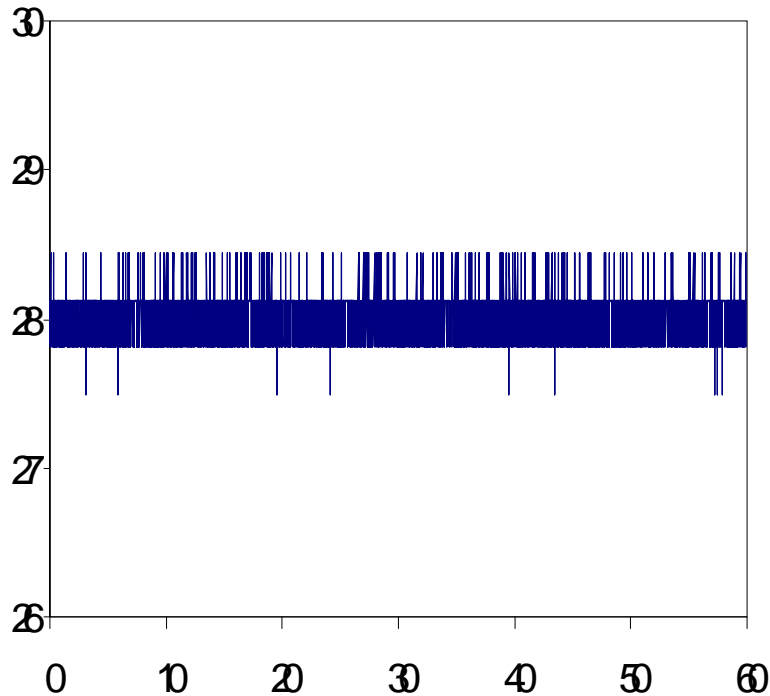
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650.1a Ripple Voltage Test

Current test results with Mainstream's regulated generator with ISA



28-VDC Generator		
	MIL-STD-1332B	Mainstream MFEG-020028
Ripple 0% Load	5.5%	0.55%
Ripple 25% Load	5.5%	0.55%
Ripple 50% Load	5.5%	0.60%
Ripple 75% Load	5.5%	0.59%
Ripple 100% Load	5.5%	0.63%

670.1b Fuel Consumption Test

Prior test results from Army RDECOM with Mainstream's unregulated generator

28-VDC Generator			
Load (W)	Load (%)	Fuel Consumption (lbs/hr)	Fuel Consumption (gal/hr)
0	0%	0.80	0.120
425	21%	1.04	0.156
975	49%	1.07	0.160
1460	73%	1.23	0.185
1990	100%	1.49	0.223

For Comparison: “The Power Generation Branch has numbers showing some MTGs to use only 0.26 gal/hr of JP-8 at full load. The 0.33 is a fleet maximum.” – Army CECOM

No Change Expected for the Following Tests

- 660.1d Inclined Operation Test
 - 20°
- 661.2c Sound Level Test
 - 79 dBA at 7 m
- 690.1d Endurance Test
 - RDECOM testing for 150 hrs
- 710.1d High Temperature Test
 - RDECOM will test to 135°F (previously 125°F)

Changes Expected for the Following Tests

- 640.1d Maximum Power Test
 - More efficient power converter will increase max power
- 701.1d Starting and Operating Test (Extreme Cold Battery Start)
 - ISA with electric start will allow for extreme cold weather starting

Summary



- Mainstream's 2-kW Generators
 - 28 VDC
 - 120 VAC, 60 Hz
- 39% smaller than MTG
- 17-25% lighter than MTG
- 33% more efficient than MTG
- 3-6x more reliable than MTG
- New Features:
 - ISA
 - Battery charging circuit
 - Auto-start/stop
 - Hybrid-electric ready
 - AC inverter with soft-start

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