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

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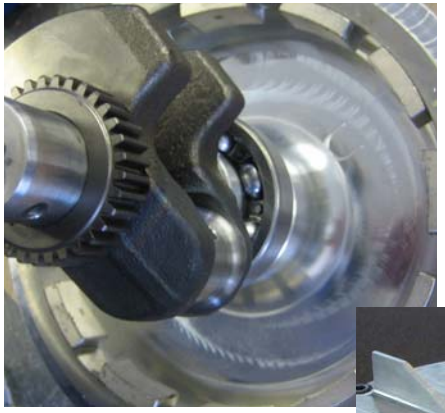
Origin of Mainstream's 2-kW Generator

- 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)

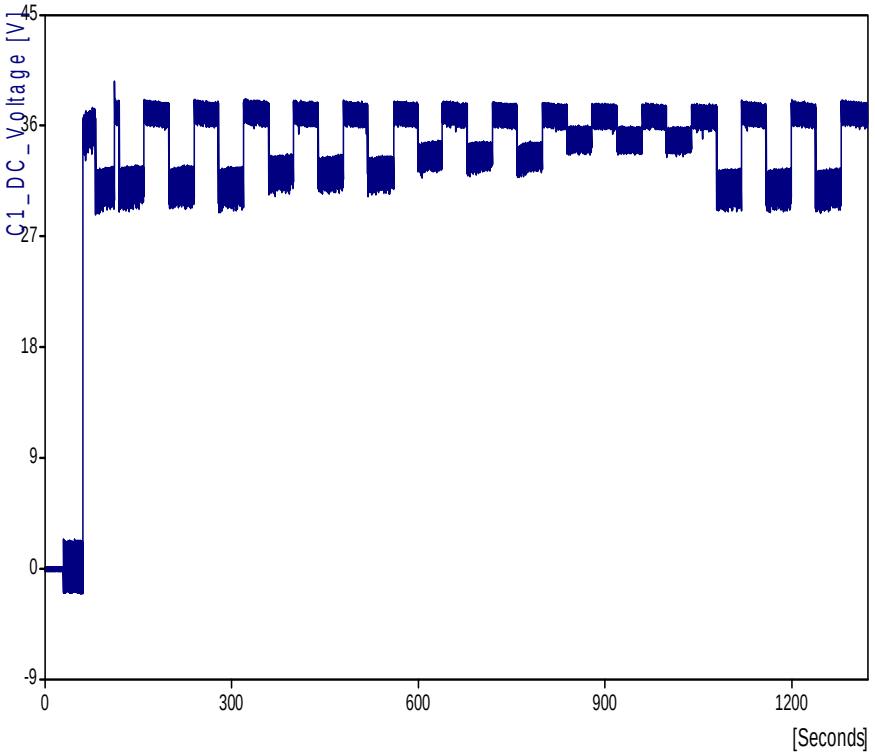
[1] Army TM 9-6115-673-13&P
[2] http://www.pm-mep.army.mil/technicaldata/2kw.htm
[3] Projected based on design

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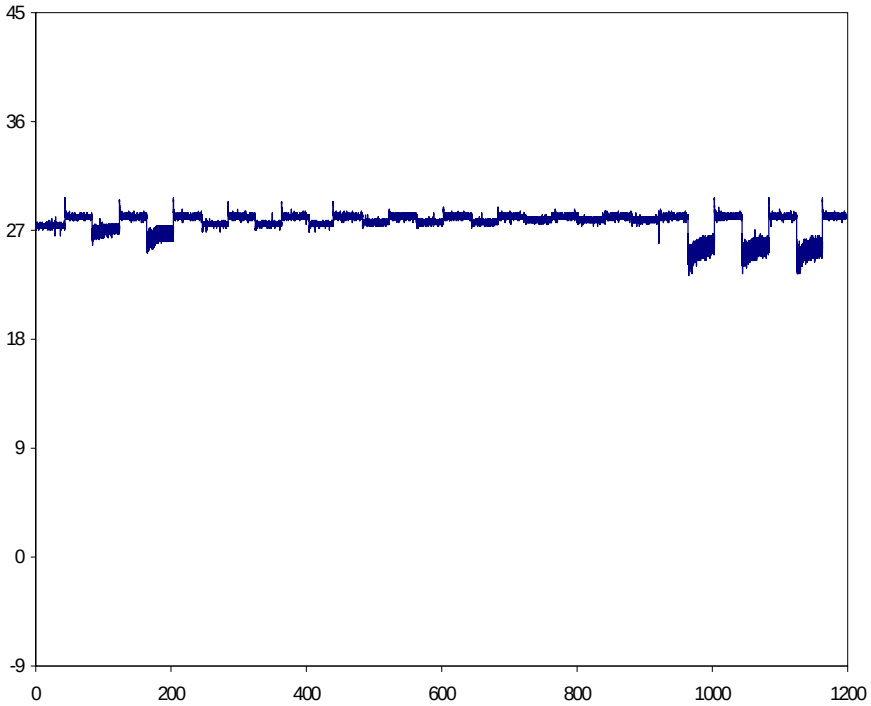
608.1b Frequency and Voltage Regulation, Stability, and Transient Response Test

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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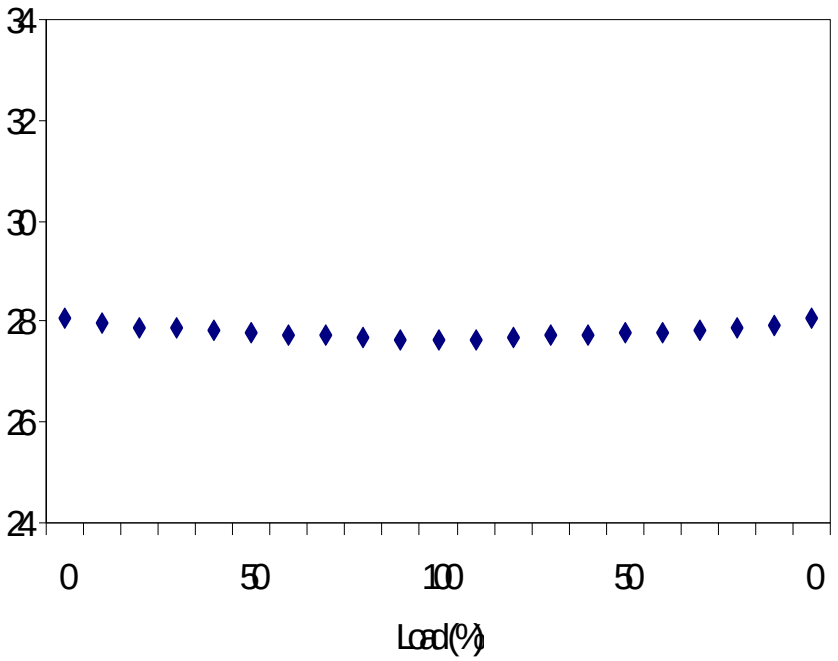
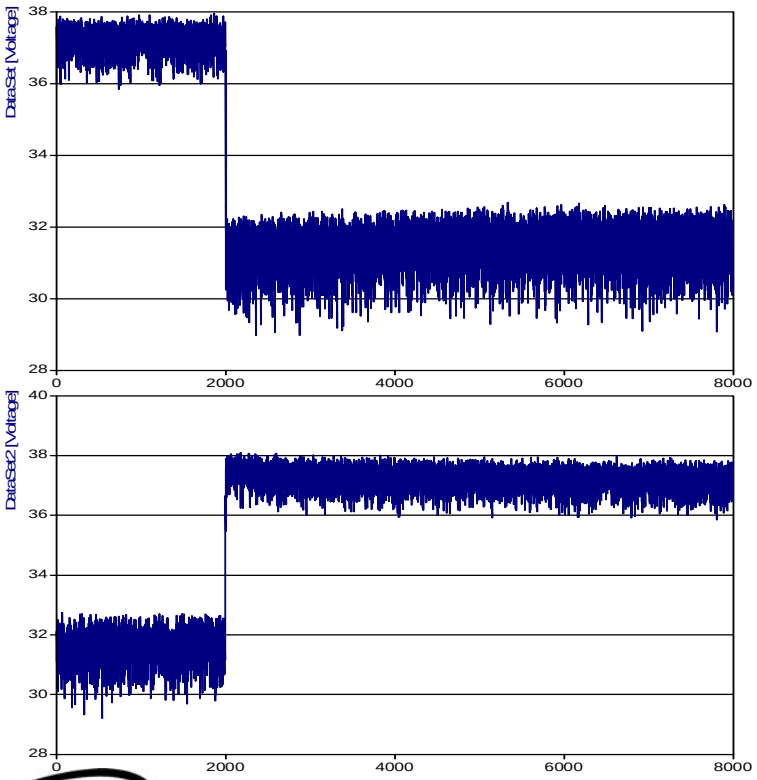
610.1b Voltage and Frequency Droop Test



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

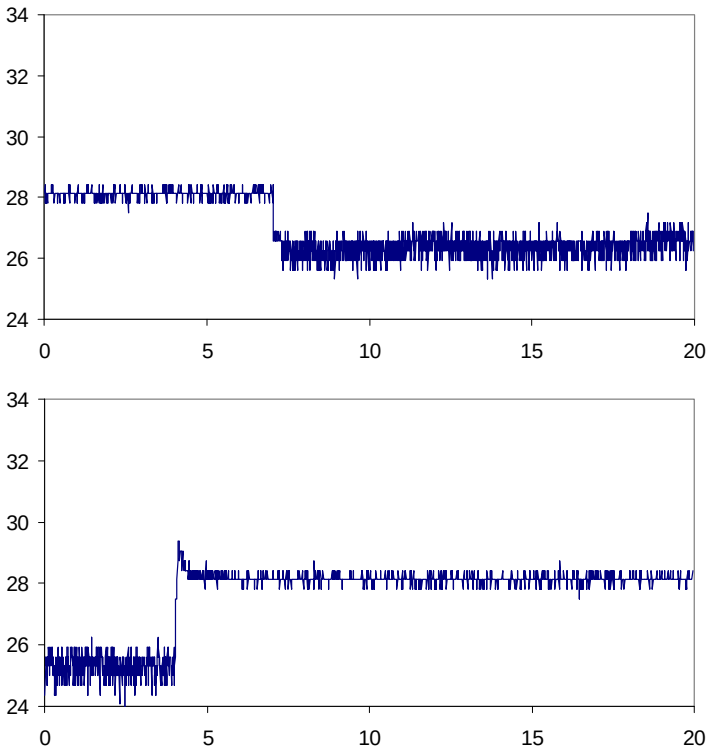
Prior test results from Army RDECOM with Mainstream's unregulated generator



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

619.2c Voltage Dip and Rise for Rated Load Test

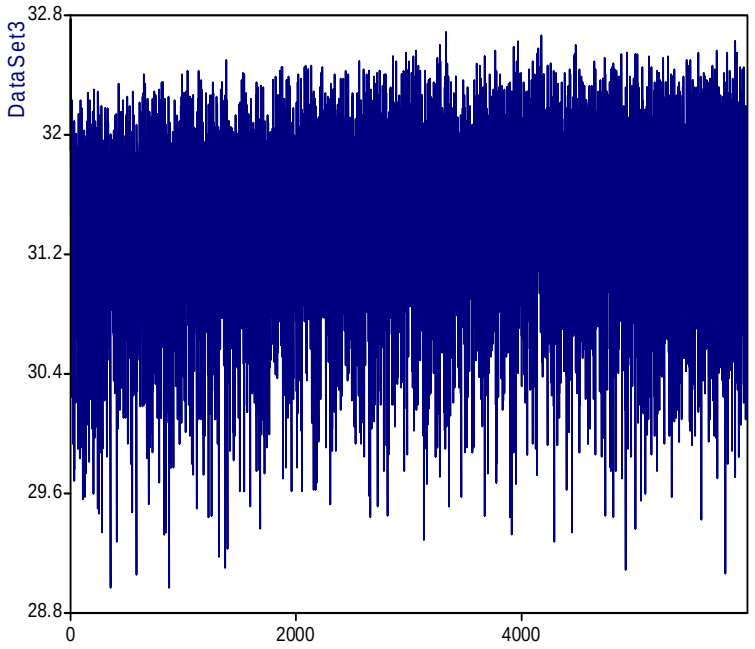
Current test results with Mainstream's regulated generator with ISA



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

650.1a Ripple Voltage Test

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

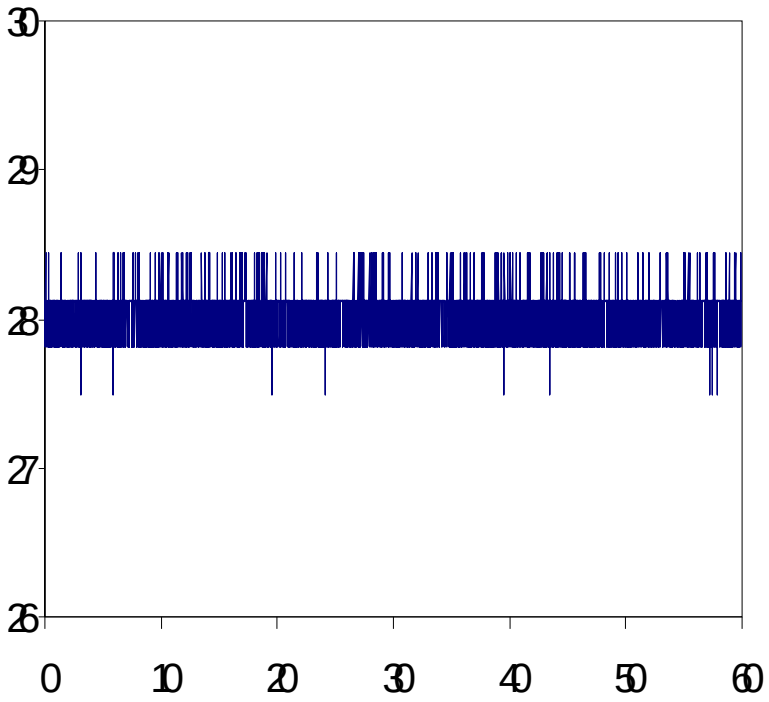


28-VDC Generator		
	MIL-STD-1332B	Mainstream Unregulated Generator
Voltage - Ripple	5.5%	9.4%*

* Reduced to 2.9% with 0.16 lb capacitor

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

Contact Information

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