Bipropellant Propulsion

AEROJET ROCKETDYNE

AR has delivered >2,500 bipropellant engines

HiPAT™ Dual Mode 100 lbf

HiPAT™ 100 lbf

R-4D 110 lbf

R-42 200 lbf

R-40B 900 lbf

R-6F 5 lbf

R-1E 25 lbf

R-1E 25 lbf Shuttle Vernier

AJ10-220 14 lbf

AJ10-190 6,000 lbf

Bipropellant rocket engines range from 5 lbf to 6000 lbf

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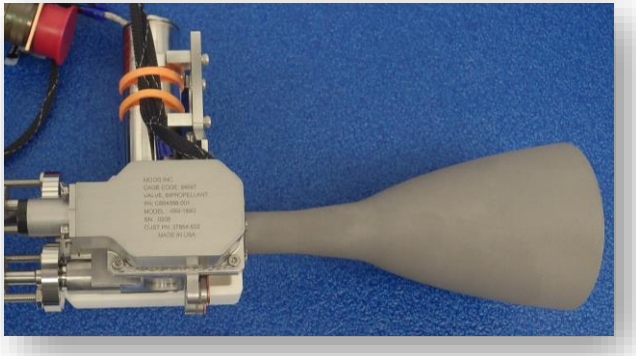
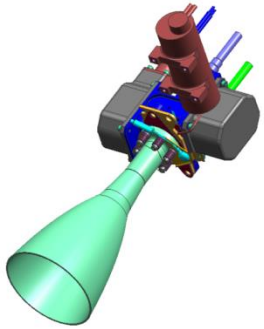
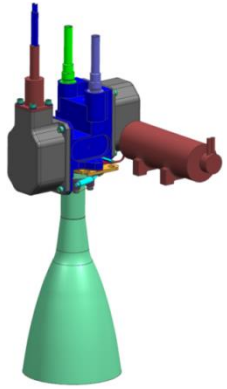
(425) 885-5000 FAX (425) 882-5747

AJ10-220 62.3 N (14.0 lbf) Reaction Control Thruster







Design Characteristics

- Propellant . . . . . .MMH/NTO (MON-3)
- Nominal Thrust (steady state) . . . . . .62.3 N (14.0 lbf)
- Thrust Range (steady state)* . . . . . .59.2–65.4 N (13.3-14.7 lbf)
- Chamber Pressure* . . . . . 6.89 bar (100 psia)
- Inlet Pressure* . . . . . 15.2 bar (220 psia)
- Inlet Pressure Range . . . . . .25.5 – 9.99 bar (370 – 145 psia)
- Valve, Power . . . . . .Moog, 38 W @ 28 VDC
- Expansion Ratio 75:1
- Nominal Flow Rate . . . . . .22.3 g/s (0.049 lbm/s)
- Nominal Mixture Ratio (O/F) 1.65
- Mixture Ratio Range (O/F) . . . . . .1.50 -1.80
- Mass . . . . . 1.95 kg (4.3 lbm)

Performance

- Specific Impulse @ 220 psia, 70°F and MR=1.65…… ……285 s (Steady firing) / 268 s (Pulse Mode)
- Total Impulse Qualified ……..…685,000 N-s (154,000 lbf-s)
- Minimum Impulse Bit . . . . 0.898 N-s (0.202 lbf-s)
- Demonstrated Steady State Firing Duration .. . . . . .300 s
- Total Number of Pulses Qualified . . . . .65,000+ starts

Status

- Flight Proven
- Currently in Production

Dimensional Envelope

- 19.0 cm (7.5 in) long, 7.30 cm (2.9 in) diameter

References

- 1993-AIAA-2218

** Standard Inlet Conditions*

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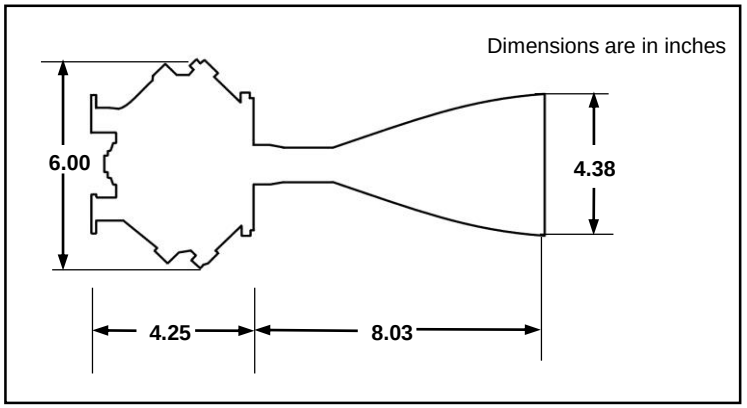
R-1E 110N (25 lbf) Bipropellant Rocket Engine



Design Characteristics

- Propellant….. . . . . MMH/NTO(MON-3)
- Thrust/Steady State . . .. 111 N (25 lbf)
- Inlet Pressure Range . . . . . 27.6-6.9 bar (400-100 psia)
- Chamber Pressure*. . . . . 7.3 bar (106 psia)
- Expansion Ratio…….. . . . . 100:1
- Flowrate* . . . . 40.4 g/sec (0.089 lbm/sec)
- Valve. . . . . Aerojet Solenoid, Single Coil, Single Seat
- Valve Power . . . . 36 Watts @ 28 Vdc
- Mass. . . . . 2 kg (4.4 lbm)

Performance

- Specific Impulse*. . . . . 280 sec (lbf-sec/lbm)
- Total Impulse. ….11,120,000 N-sec (2,500,000 lbf-sec)
- Total Pulses 330,000
- Minimum Impulse Bit . . . . . .0.89 N-sec (0.2 lbf-sec)
- Steady State Firing (sec). .. . . . . No Limitations

Status

- Flight Proven
- Currently in Production

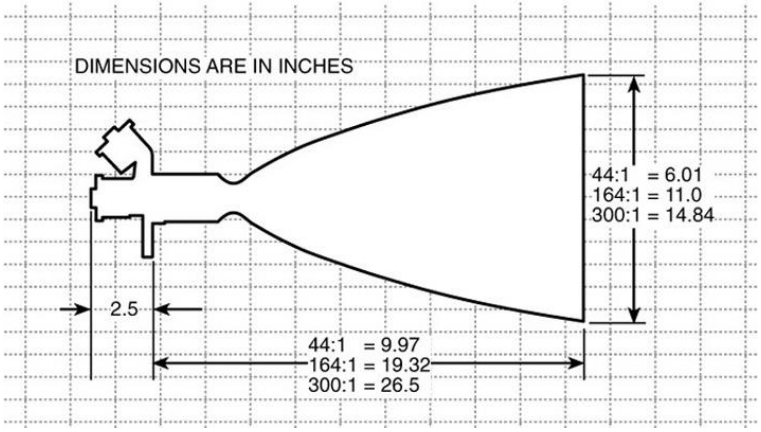
Reference

- AIAA - 1990 - 1837

** At rated thrust*

11411 139th Place NE • Redmond, WA 98052
(425) 885-5000 FAX (425) 882-5747

R-4D-11 490 N (110 lbf) Bipropellant Rocket Engine



Design Characteristics

- Propellant . . . . . MMH/NTO (MON-3)
- Nominal Thrust (steady state) . . . . . .490 N (110 lbf)
- Thrust Range (steady state) . . . . . .378 – 511 N (85-115 lbf)
- Chamber Pressure* . . . . .7.45 bar (108 psia)
- Inlet Pressure* . . . . . >14 bar (>205 psia)
- Inlet Pressure Range . . . . . .4.1 – 29.3 bar (60 – 425 psia)
- Valve . . . . Aerojet Rocketdyne, Single Coil, Single Seat
- Expansion Ratio 164:1, 300:1
- Nominal Mixture Ratio (O/F) 1.65
- Mixture Ratio Range (O/F) . . . . . .1.17 – 2.13
- Mass …..164:1 = 3.76 kg (8.3 lbm), 300:1 = 4.31 kg (9.5 lbm)

Performance

- Specific Impulse @ 70°F and MR = 1.65 . . . . . ……... . . . . .164:1 = 311 sec (lbf-sec/lbm) . . . . .300:1 = 315.5 sec (lbf-sec/lbm)
- Total Impulse Demonstrated……20,016,000 N-sec (4,500,000 lbf-sec)
- Minimum Impulse Bit . . . . .15.6 N-sec (3.5 lbf-sec)
- Demonstrated Steady State Firing Duration….. . . . . 12,000 s
- Total Number of Pulses Qualified . . . . .31,950 starts┼ ……..C-103/Ti 300:1 = 85 thermal cycles┼ …….. C-103 164:1 = 245 thermal cycles┼

Status

- Flight Proven
- Currently in Production

References

- AIAA-2004-3694, AIAA-1980-1294, AIAA-1979-1331

┼ Performed on different engines.

** At nominal thrust*

11411 139th Place NE • Redmond, WA 98052
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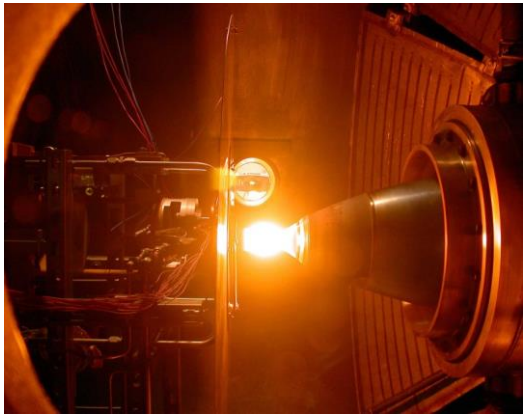
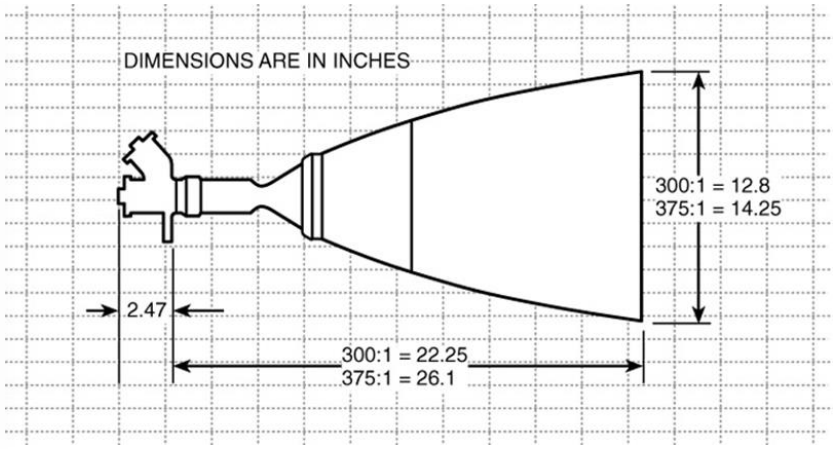
R-4D-15 HiPAT™ 445 N (100 lbf) High Performance Rocket Engine





Design Characteristics

- Propellant . . . . . MMH/NTO (MON-3)
- Nominal Thrust (steady state) . . . .445 N (100 lbf)
- Thrust Range (steady state) . . . . . .378 – 511 N (85-115 lbf)
- Chamber Pressure* . . . . . .9.44 bar (137 psia)
- Inlet Pressure* . . . . . . >14 bar (>205 psia)
- Inlet Pressure Range . . . . . 27.6 - 6.9 bar (400 – 100 psia)
- Valve . . . . . Aerojet Rocketdyne, Dual Coil, Single Seat
- Expansion Ratio . . . . .300:1 or 375:1
- Nominal Mixture Ratio (O/F) 1.65
- Mixture Ratio Range (O/F) . . . . .1.50 -1.80
- Mass . . . . .300:1, 5.2 kg (11.5 lbm) / 375:1, 5.44 kg (12.0 lbm)

** At nominal Thrust*

Performance

- 375:1 Specific Impulse @ 70°F and MR = 1.65 . . . . . .320.6 s (typical for 60 s run) . . . . 322.2 s (typical for 1200+ s run)
- Total Impulse Qualified……13,019,945 N-s (2,927,000 lbf-s)
- Minimum Impulse Bit . . . . 35.6 N-s (8 lbf-s)
- Demonstrated Steady State Firing Duration ……7,200 sec
- Total Number of Pulses Qualified . . . .391 starts ……..85+ thermal cycles

Status

- Flight Proven
- Currently in Production

References

- AIAA-2001-3253, AIAA-2000-3161

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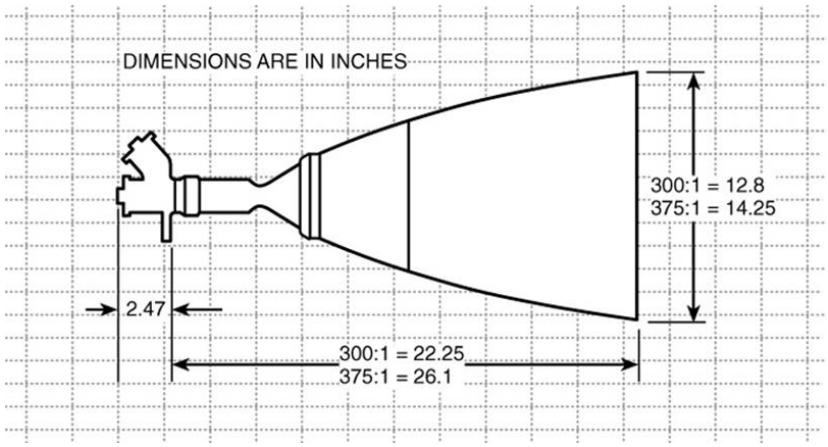
R-4D-15 HiPAT™ 445 N (100 lbf) Dual Mode High Performance Rocket Engine



Design Characteristics

- Propellant . . . . .Hydrazine/NTO (MON-3)
- Nominal Thrust (steady state) . . . . 445 N (100 lbf)
- Thrust Range (steady state) . . . . .329 – 556 N (70-125 lbf)
- Chamber Pressure* . . . . . .9.4 bar (137 psia)
- Inlet Pressure* . . . . . >16.2 bar (235 psia)
- Inlet Pressure Range . . . . .21.4 – 15.2 bar (310 – 220 psia)
- Valve . . . . . .Aerojet Rocketdyne, Dual Coil, Single Seat
- Expansion Ratio . . . . 300:1 or 375:1
- Nominal Mixture Ratio (O/F) 1.0
- Mixture Ratio Range (O/F) . . . . . 0.70 – 1.33
- Mass . . . . . 300:1= 5.2 kg (11.5 lbm), 375:1 = 5.44 kg (12.0 lbm)

Performance

- Specific Impulse @ 70°F and MR = 1.0. . . . . .. 300:1= 326 sec, 375:1 = 329 sec
- Total Impulse Qualified…….. ……...> 9.55 X10^6 N-sec (2.15 X 10^6 lbf-sec)
- Minimum Impulse Bit . . . . 35.6 N-s (8 lbf-s)
- Demonstrated Steady State Firing Duration …….1,800 sec
- Total Number of Pulses Qualified . . . . . 672 starts

. . . . 345 thermal cycles

Status

- Qualified
- Currently in Production

References

- AIAA-2003-4775

** At nominal Thrust*

11411 139th Place NE • Redmond, WA 98052
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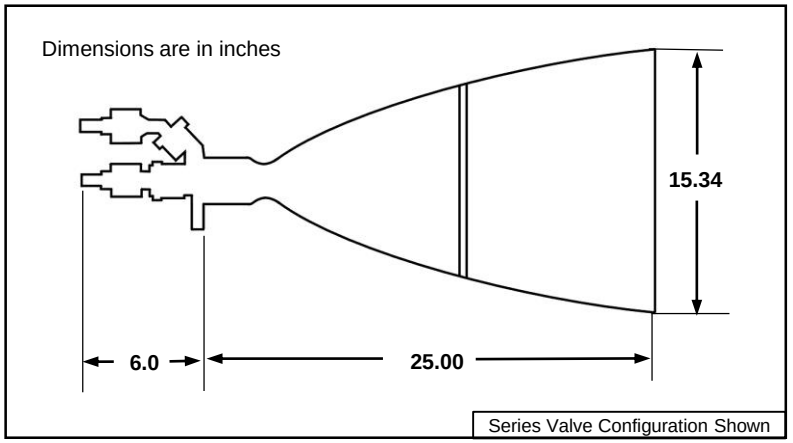
R-42 890N (200 lbf) Bipropellant Rocket Engine



Design Characteristics

- Propellant. . . . . MMH/NTO(MON-3)
- Thrust/Steady State. . . . . 890 N (200 lbf)
- Inlet Pressure Range . . . . . 29.3-6.9 bar (425-100 psia)
- Chamber Pressure*. . . . . 7.1 bar (103 psia)
- Expansion Ratio. 160:1
- Flowrate*.. . . . . 300 g/sec (0.66 lbm/sec)
- Valve . . . . . Aerojet Rocketdyne Single or Dual Seat
- Valve Power……Various
  ……(46 Watts @ 28 Vdc Typical for Single Seat)
- Mass. . . . . .4.53 kg (10.0 lbm)

Performance

- Specific Impulse* . . . . . 305 sec (lbf-sec/lbm)
- Total Impulse . . . . . 24,271,000 N-sec (5,456,700 lbf-sec)
- Total Starts 150
- Minimum Impulse Bit . . . . . 44.48 N-sec (10.0 lbf-sec)
- Steady State Firing Cumulative . . . . . 27,000 sec
- Steady State Firing (Single Firing) . . . . . 3,940 sec

Status

- Flight Proven
- Currently in Production

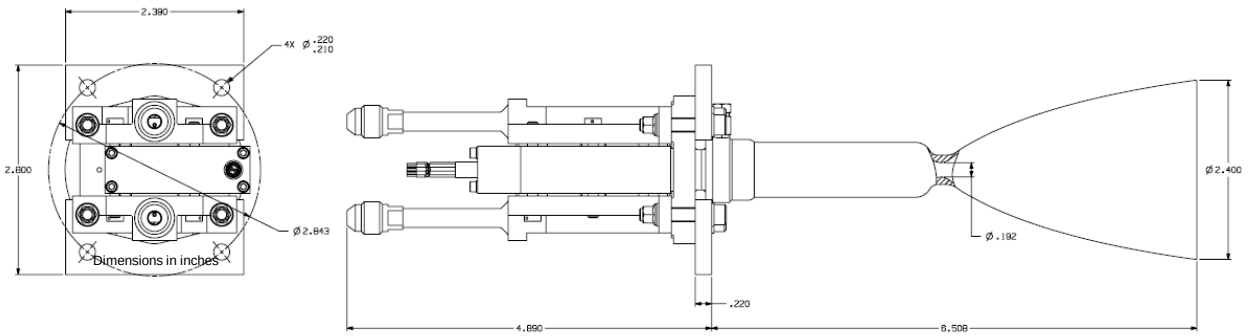
Reference

- AIAA - 1990 - 2055

**At nominal conditions*

11411 139th Place NE • Redmond, WA 98052
(425) 885-5000 FAX (425) 882-5747

R-6F 22N (5lbf) Bipropellant Rocket Engine



Design Characteristics

- Propellant . . . . . MMH/NTO (MON-3)
- Thrust/Steady State . . . . . .22 N (5 lbf)
- Operating Thrust Range . . . . . 13.3 to 27.8 N (3.0 to 6.25 lbf)
- Mixture Ratio/Steady State 1.61
- Operating Mixture Ratio Range . . . . . 1.0 to 2.0
- Expansion Ratio 150:1
- Nominal Flow Rate . . . . . .7.44 g/sec (0.00164 lbm/sec)
- Inlet Pressure. . . . . 6.9 to 20.79 bar (100 to 300 psia)
- Valve . . . . . Bipropellant duel seat solenoid with upstream latching feature
- Valve Power . . . . . .11 watts @ 28 Vdc)
- Mass. . . . . 0.965 kg (2.1 lbm)

Performance

- Specific Impulse . . . . . .305 lbf-sec/lbm
- Total Impulse . . . . . >89,700 N-sec (20,175 lbf-sec)
- Total pulses . . . . . .>19,881
- Minimum Impulse Bit . . . . . 0.53 N-sec (0.12 lbf-sec)
- Steady State Firing . . . . . .0.010 sec to Unlimited

Status

- Ready for flight qualification
- Not in Production

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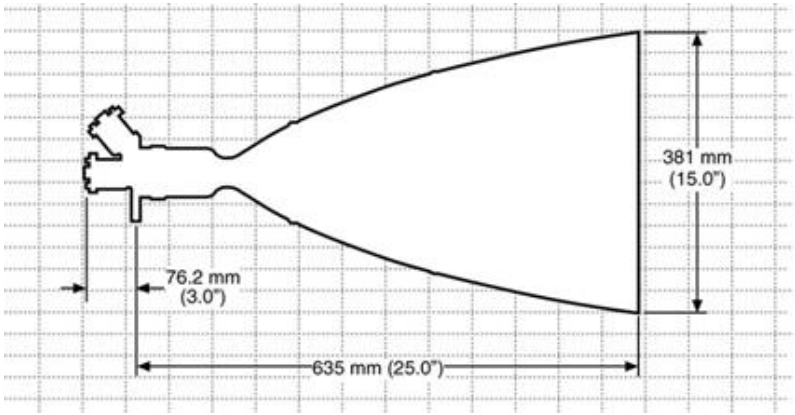
R-42DM 890N (200 lbf) Dual Mode High Performance Rocket Engine



Design Characteristics

- Propellant. . . . . Hydrazine/NTO(MON-3)
- Thrust/Steady State*. . . . . .890 N (200 lbf)
- Inlet Pressure Range . . . . 31.0-5.5 bar (450-80 psia)
- Chamber Pressure*. . . . . 9.6 bar (140 psia)
- Expansion Ratio……..……..200:1
- Oxidizer / Fuel Ratio……..0.8 – 1.30 (1.0 nominal)
- Flowrate*……277 g/sec (0.61 lbm/sec)
- Valve……Aerojet Rocketdyne Single or Dual Seat
- Valve Power…..Various (45 Watts @ 28 Vdc Typical for Single Seat)
- Mass……..with single seat valves 7.3 kg (16.0 lbm)

Performance

- Specific Impulse* . . . . 327 sec (lbf-sec/lbm)
- Total Impulse……..>20,000,000 N-sec (4,500,000 lbf-sec)
- Total Starts . . . .…… ..…….. . . >60
- Minimum Impulse Bit…….... 44.48 N-sec (10.0 lbf-sec)
- Steady State Firing Cumulative . . . . . 6,400 sec
- Steady State Firing (Single Firing) . . . . 1,000 sec

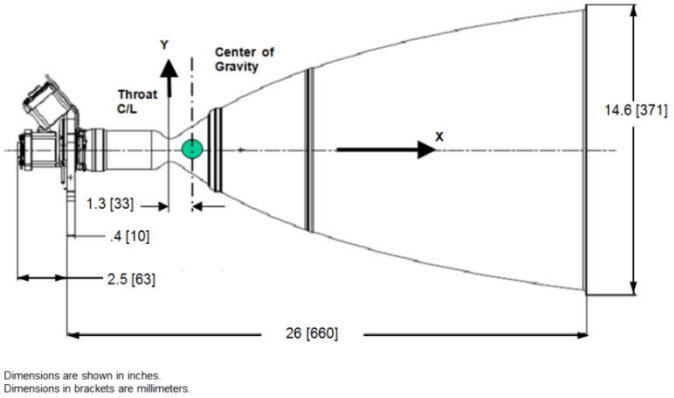
Status

- Ready for flight qualification
- Not in Production

**At nominal conditions*

11411 139th Place NE • Redmond, WA 98052
(425) 885-5000 FAX (425) 882-5747

AMBR 556 N (125 lbf) Dual Mode High Performance Rocket Engine



Design Characteristics

- Propellant . . . . . .Hydrazine/NTO(MON-3)
- Nominal Thrust (steady state) . . . . . .489 – 556 N (110 – 125 lbf)
- Thrust Range (steady state) . . . . . .325 – 645 N (73 – 145 lbf)
- Chamber Pressure* . . . . . 10.3 – 11.7 bar (150 – 170 psia)
- Inlet Pressure* . . . . . >14 bar (>205 psia)
- Valve . . . . . Aerojet Rocketdyne, Dual Coil, Single Seat
- Expansion Ratio 400:1
- Nominal Mixture Ratio (O/F) . . . . . .1.0 – 1.3
- Mixture Ratio Range (O/F) . . . . . .0.62 – 1.96
- Mass . . . . . .4.9 kg (10.8 lbm)

** At nominal Thrust*

Performance

- Specific Impulse @ 70°F and MR = 1.0 . . . . . .329 sec (lbf-sec/lbm)
- Total Impulse. . . . . 5,792,919 N-sec (1,302,300 lbf-sec)
- Demonstrated Steady State Firing Duration . . . . . .2,700 sec
- Total Number of Starts Demonstrated . . . . . .88 total starts

Status

- Ready for final flight design/analysis, and qualification
- Not in Production

References

- AIAA-2007-032, AIAA-2008-4844, AIAA-2010-6883

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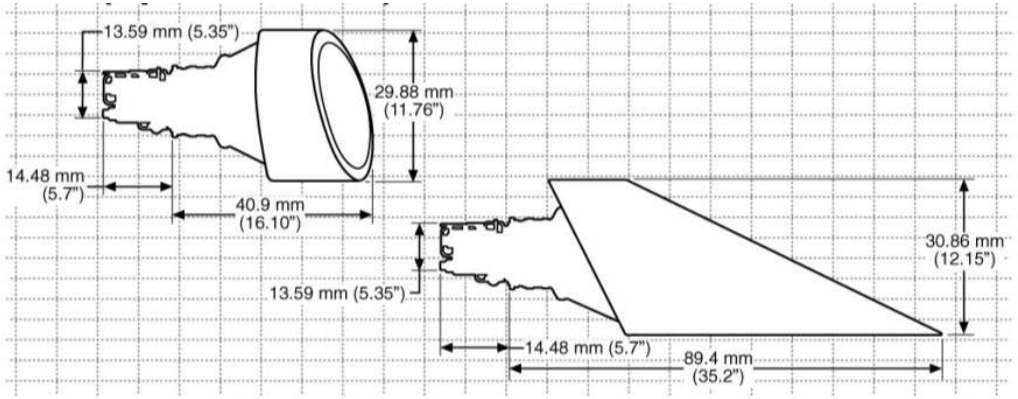
R-40 3,870N (870 lbf) Bipropellant Rocket Engine



Design Characteristics

- Propellant. . . . . MMH/NTO(MON-3)
- Thrust/Steady State*. . . . . 3,870 N (870 lbf)
- Inlet Pressure Range . . . . . 27.6 – 10.3 bar (400 - 150 psia)
- Chamber Pressure*. . . . . 9.9 bar (150 psia)
- Expansion Ratio. 22:1
- Flowrate*.. . . . . .1,400 g/sec (3.07 lbm/sec)
- Valve . . . . . Aerojet Rocketdyne Single Seat
- Valve Power . . . . . .70 Watts @ 28 Vdc
- Mass** . . . . . .10.5 kg (23.0 lbm)

**At rated thrust*

***Varies by configuration*

Performance

- Specific Impulse* . . . . . 281 sec (lbf-sec/lbm)
- Total Impulse . . . . . 92,073,600 N-sec (20,700,000 lbf-sec)
- Total Pulses 50,000
- Minimum Impulse Bit . . . . . 111 N-sec (25.0 lbf-sec)
- Steady State Firing Cumulative. . . . . 23.,000 sec

Status

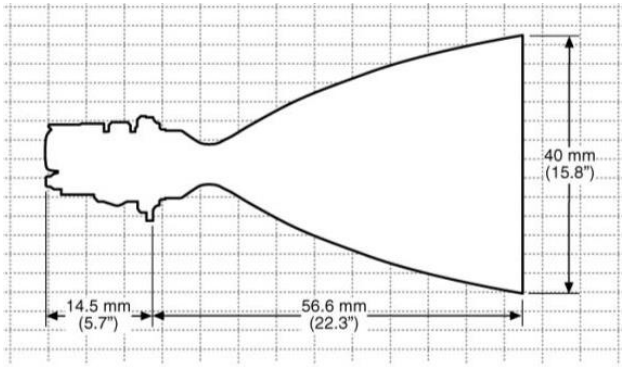
- Flight Proven
- Not in Production; Requires component obsolescence update

Reference

- AIAA-1985-1222
- AIAA-1980-1131
- AIAA-1980-1130
- AIAA-1979-1144
- AIAA-1978-1006
- AIAA-1975-1300
- AIAA-1974-1109
- AIAA-1970-0618

11411 139th Place NE • Redmond, WA 98052
(425) 885-5000 FAX (425) 882-5747

R-40B 4,000N (900 lbf) Bipropellant Rocket Engine



Design Characteristics

- Propellant. . . . . MMH/NTO(MON-3)
- Thrust/Steady State*. . . . . 4,000 N (900 lbf)
- Inlet Pressure Range . . . . . 27.6 – 10.3 bar (400 - 150 psia)
- Chamber Pressure*. . . . . 10.34 bar (150 psia)
- Expansion Ratio. 60:1
- Flowrate*. . . . . .1,400 g/sec (3.07 lbm/sec)
- Valve . . . . . Aerojet Rocketdyne Single Seat
- Valve Power . . . . . .70 Watts @ 28 Vdc
- Mass. . . . . .10.5 kg (23.0 lbm)

**At rated thrust*

Performance

- Specific Impulse* . . . . . 293 sec (lbf-sec/lbm)
- Total Impulse . . . . . 92,073,600 N-sec (20,700,000 lbf-sec)
- Total Pulses 50,000
- Minimum Impulse Bit . . . . . 111 N-sec (25.0 lbf-sec)
- Steady State Firing Cumulative. . . . . 23,000 sec

Status

- Flight Proven
- Not in Production; Requires component obsolescence update

Reference

- IAF-1987-0283

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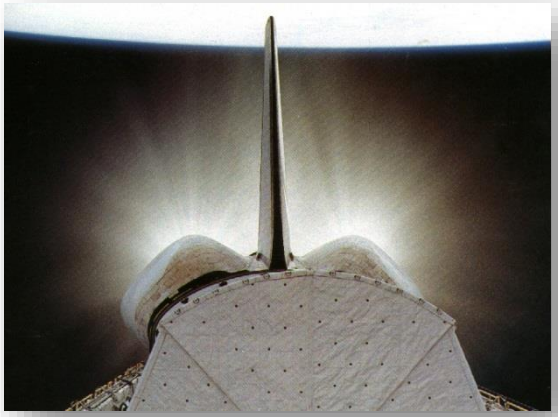
AJ10-190 Space Shuttle OMS Rocket Engine



Design Characteristics

- Propellant……MMH/NTO(MON-3)
- Thrust/Steady State*……N (6,000 lbf)
- Inlet Pressure Range ……16.6 bar (240 psia)
- Chamber Pressure*…….bar (125 psia)
- Expansion Ratio…….55:1
- Flowrate…….8.61 kg/sec (19.0 lbm/sec)
- Valve…….Aerojet Rocketdyne Pneumatic Procured Solenoid Pilot
- Valve Power (all coils energized) ……125 Watts @ 28 Vdc
- Mass…….118kg (260 lbm)
- Engine Length 77 in. / Engine Dia. 46 in.

**At rated thrust*

Performance

- Specific Impulse* ……316 sec (lbf-sec/lbm)
- Gimbal ……..…….± 7 °
- Total Impulse.…1,440 MN-sec (324,000,000 lbf-sec)
- Total Starts ……1,000
- Steady State Firing Cumulative……..…54,000 sec

Status

- Flight Proven
- Not in Production

Reference

- AIAA 2014-3882

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