Solid Propellant Selection

Solid Design Team

Andrew Reid, Zach Anderson, Derek Bean, Tony Irvine, Mayra Flores, Afiq Ashiran

The Story of Selection

Our Story

- The learning process
- Gathering all possibilities
- Refinement
- Final Selection

Double Base

- Binder: Nitrocellulose
- Reactive Plasticizer: Nitroglycerine
- Burn rate modifiers
- Nearly Smokeless Exhaust
- **Not Commonly Used**

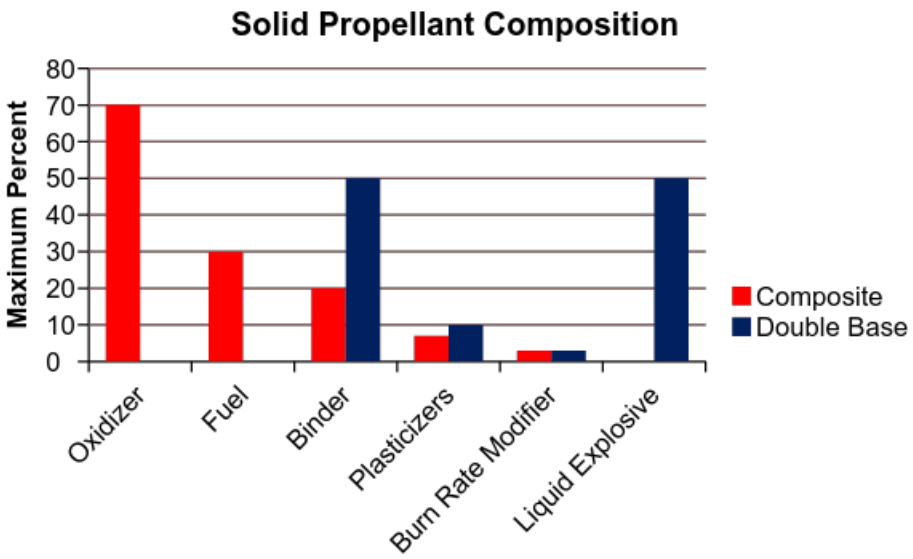
Nitrocellulose Clip

Nitroglycerine Clip

Textbook Reference: Table 13-6

Composite

- Oxidizers
- Fuels
- Binders
- Burning Rate Modifiers
- Plasticizers
- Most Commonly Used



Textbook Reference: Table 13-7

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Propellant Type[a]	I_s Range (sec)[b]	Flame Temperature[c] (°F)	Flame Temperature[c] (°K)	Density or Spec. Gravity[c] (lb/in^3)	Density or Spec. Gravity[c] (sp. gr.)	Metal Content (wt %)	Burning Rate[c,e] (in./sec)	Pressure Exponent[e] n	Hazard Classification[d]	Stress (psi)/Strain (%) −60°F	Stress (psi)/Strain (%) +150°F	Processing Method
DB	220–230	4100	2550	0.058	1.61	0	0.05–1.2	0.30	1.1	4600/2	490/60	Extruded
DB/AP/Al	260–265	6500	3880	0.065	1.80	20–21	0.2–1.0	0.40	1.3	2750/5	120/50	Extruded
DB/AP–HMX/Al	265–270	6700	4000	0.065	1.80	20	0.2–1.2	0.49	1.1	2375/3	50/33	Solvent cast
PVC/AP/Al	260–265	5600	3380	0.064	1.78	21	0.3–0.9	0.35	1.3	369/150	38/220	Cast or extruded
PU/AP/Al	260–265	5700	3440	0.064	1.78	16–20	0.2–0.9	0.15	1.3	1170/6	75/33	Cast
PBAN/AP/Al	260–263	5800	3500	0.064	1.78	16	0.25–1.0	0.33	1.3	520/16 (at −10°F)	71/28	Cast
CTPB/AP/Al	260–265	5700	3440	0.064	1.78	15–17	0.25–2.0	0.40	1.3	325/26	88/75	Cast
HTPB/AP/Al	260–265	5700	3440	0.067	1.86	4–17	0.25–3.0	0.40	1.3	910/50	90/33	Cast
PBAA/AP/Al	260–265	5700	3440	0.064	1.78	14	0.25–1.3	0.35	1.3	500/13	41/31	Cast
AN/Polymer	180–190	2300	1550	0.053	1.47	0	0.06–0.5	0.60	1.3	200/5	NA	Cast

[a] Al, aluminum; AN, ammonium nitrate; AP, ammonium perchlorate; CTPB, carboxy-terminated polybutadiene; DB, double-base; HMX, cyclotetramethylene tetranitramine; HTPB, hydroxyl-terminatd polybutadiene; PBAA, polybutadiene–acrylic acid polymer; PBAN, polybutadiene–acrylic acid–acrylonitrile terpolymer; PU, polyurethane; PVC, polyvinyl chloride.

[b] At 1000 psia expanding to 14.7 psia, ideal or theoretical value at reference conditions.

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Table 12-1 Sutton/Biblarz

Specific Application

- Tactical Missile
- Space Launch Booster
- High-Altitude Motors
- Ballistic Missile Defense
- Gas Generator

Table 11-3 Sutton/Biblarz

TABLE 11–1. Major Application Categories for Solid Propellant Rocket Motors

Category	Application	Typical Characteristics
Large booster and second-stage motors	Space launch vehicles; lower stages of long-range ballistic missiles (see Figs. 11–2 and 14–2)	Large diameter (above 48 in.); L/D of case = 2 to 7; burn time t = 60 to 120 sec; low-altitude operations with low nozzle area ratios (6 to 16)
High-altitude motors	Upper stages of multistage ballistic missiles, space launch vehicles; space maneuvers	High-performance propellant; large nozzle area ratio (20 to 200); L/D of case = 1 to 2; burn time t = 40 to 120 sec (see Fig. 11–3)
Tactical missiles	1. High acceleration: short-range bombardment, antitank missile	Tube launched, L/D = 4 to 13; very short burn time (0.25 to 1 sec); small diameter (2.75 to 18 in.); some are spin stabilized
	2. Modest acceleration: air-to-surface, surface-to-air, short-range guided surface-to-surface, and air-to-air missiles	Small diameter (5 to 18 in.); L/D of case = 5 to 10; usually has fins and/or wings; thrust is high at launch and then is reduced (boost-sustain); many have blast tubes (see Fig. 11–4); wide ambient temperature limits: sometimes minimum temperature −65° F or −53°C, maximum temperature +160°F or +71°C; usually high acceleration; often low-smoke or smokeless propellant
Ballistic missile defense	Defense against long- and medium-range ballistic missiles	Booster rocket and a small upper maneuverable stage with multiple attitude control nozzles and one or more side or divert nozzles
Gas generator	Pilot emergency escape; push missiles from submarine launch tubes or land mobile cannisters; actuators and valves; short-term power supply; jet engine starter; munition dispersion; rocket turbine drive starter; automotive air bags	Usually low gas temperature (< 1300°C); many different configurations, designs, and propellants; purpose is to create high-pressure, energetic gas rather than thrust

Table 11-1 Sutton/Biblarz

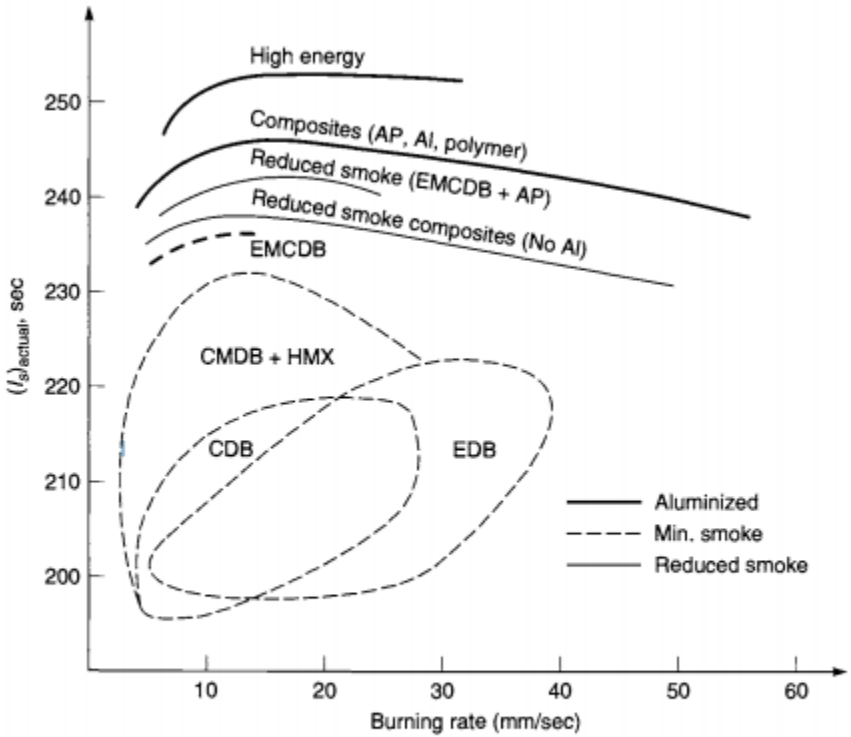

FIGURE 12–1. Estimated actual specific impulse and burning rate for several solid propellant categories. (Adapted and reproduced from Ref. 12–1 with permission of the American Institute of Aeronautics and Astronautics [AIAA].)

Figure 12-1Sutton/Biblarz

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Safety Rating

- Detonable (Class 1.1)
- Non Detonable (Class 1.3)

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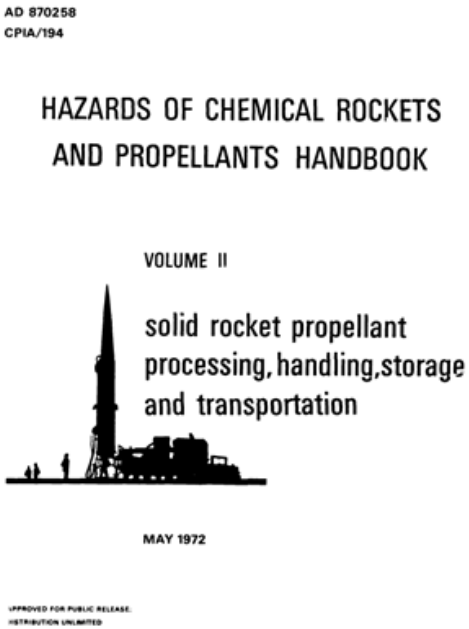
Safety Rules

Train all personnel

Design Safe experiments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VOLUME II

solid rocket propellant processing, handling, storage and transportation

MAY 1972

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Follow and enforce all safety rules

Toxicity

- Toxic
- Nontoxic

http://en.wikipedia.org/wiki/STS-27

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TABL-E 12–2. Characteristics of Selected Propellants

Propellant Type	Advantages	Disadvantages
Double-base (extruded)	Modest cost; nontoxic clean exhaust, smokeless; good burn rate control; wide range of burn rates; simple well-known process; good mechanical properties; low temperature coefficient; very low pressure exponent; plateau burning is possible	Free-standing grain requires structural support; low performance, low density; high to intermediate hazard in manufacture; can have storage problems with NG bleeding out; diameter limited by available extrusion presses; class 1.1
Double-base (castable)	Wide range of burn rates; nontoxic smokeless exhaust; relatively safe to handle; simple, well-known process; modest cost; good mechanical properties; good burn rate control; low temperature coefficient; plateau burning can be achieved	NG may bleed out or migrate; high to intermediate manufacture hazard; low performance; low density; higher cost than extruded DB; class 1.1
Composite-modified double-base or CMDB with some AP and Al	Higher performance; good mechanical properties; high density (sp. gr. 1.83–1.86); less likely to have combustion stability problems; intermediate cost; good background experience	Storage stability can be marginal; complex facilities; some smoke in exhaust; high flame temperature; moisture sensitive; moderately toxic exhaust; hazards in manufacture; modest ambient temperature range; the value of n is high (0.8 to 0.9); moderately high temperature coefficient
Composite AP, Al, and PBAN or PU or CTPB binder	Reliable; high density; long experience background; modest cost; good aging; long cure time; good performance; usually stable combustion; low to medium cost; wide temperature range; high density; low to moderate temperature sensitivity; good burn rate control; usually good physical properties; class 1.3	Modest ambient temperature range; high viscosity limits at maximum solid loading; high flame temperature; toxic, smoky exhaust; some are moisture sensitive; some burn-rate modifiers (e.g. aziridines) are carcinogens
Composite AP, Al, and HTPB binder; most common composite propellant today	Slightly better solids loading % and performance than PBAN or CTPB; widest ambient temperature limits; good burn-rate control; usually stable combustion; medium cost; good storage stability; widest range of burn rates; good physical properties; good experience; class 1.3	Complex facilities; moisture sensitive; fairly high flame temperature; toxic, smoky exhaust
Modified composite AP, Al, PB binder plus some HMX or RDX	Higher performance; good burn-rate control; usually stable combustion; high density; moderate temperature sensitivity; can have good mechanical properties	Expensive, complex facilities; hazardous processing; harder-to-control burn rate; high flame temperature; toxic, smoky exhaust; can be impact sensitive; can be class 1.1; high cost; pressure exponent 0.5–0.7

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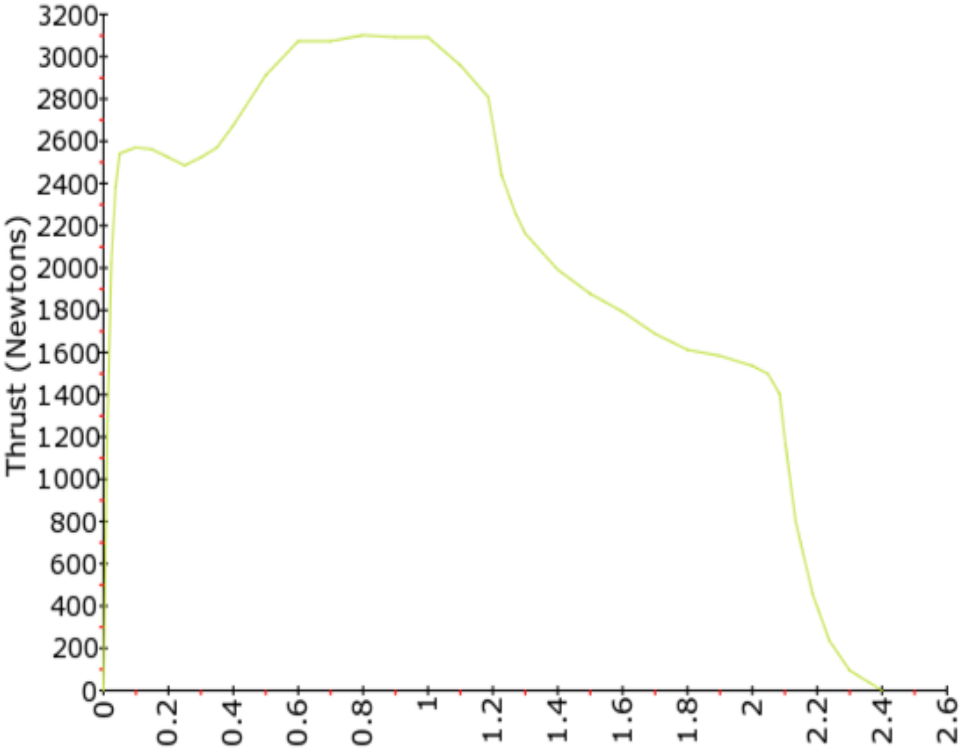
Manufacturer: Aerotech
Aerotech L2200G-P

List Price: ~~$249.99~~
Price: $237.99



[Newtons] [Pounds]

- Class: 76-100% L
- Diameter: 75.0000 mm
- Length: 665.0000 mm
- Letter: L
- Manufacturer: Aerotech
- Name: L2200
- Type:

- Designation: L2200G
- Delays: 0,6,10,14,18 seconds
- Propellant Weight: 2516.0000 g
- Total Weight: 4751.0000 g
- Average Thrust: 2,104.9852 N
- Peak Thrust: 3,101.7700 N
- Total Impulse: 5051.9644 Ns
- Class: 97% L
- Thrust Duration: 2.4000 s

Take Aways & Future Steps

- HTPB/AP/AL
- Buy Motor
- Target mass
- Calculations
- Simulations
- Calculations
- Simulations

"Oh, come on, they wouldn't sell it if it wasn't safe."

http://lowres.cartoonstock.com/military-bomb-naive-missile-rocket-explosive-aton4830_low.jpg