Personal Reflections on Amateur Experimental Rocketry

presented by

Richard Nakka

http://nakka-rocketry.net

Amateur Experimental Rocketry (AER)

- Rocket motors and propellants are self-designed and self-made.
- Propellant formulations are often unique to AER or "experimental" in nature. New propellant development
- Most or all components of the rocket are self-built

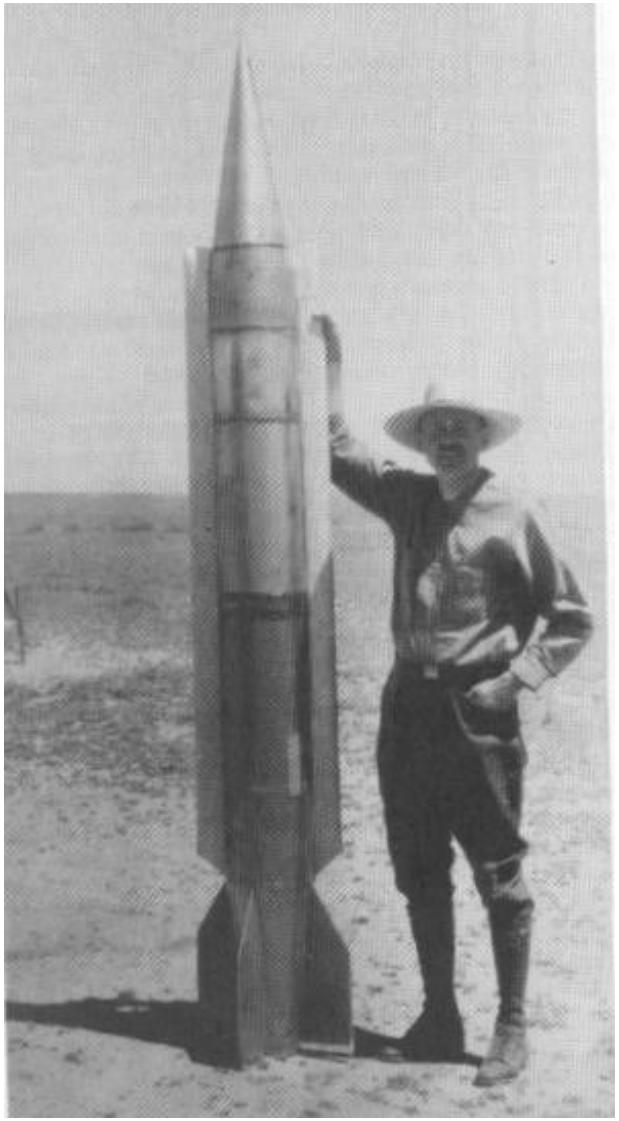
History of AER

- Many of history's great rocket engineers started out as **amateur rocket builders**.

- Robert H. Goddard – launched world's first liquid propellant rocket
- Sergei P. Korolev – A member of GIRD, launched world's first hybrid rocket
- Werhner von Braun – Saturn V moon rocket
- Herman Oberth, Johannes Winkler, Willy Ley & others
- William H. Colburn – invented the "sugar" propellant in 1943.
- Vernon Estes

Robert H. Goddard

1931 Test Rocket # 73



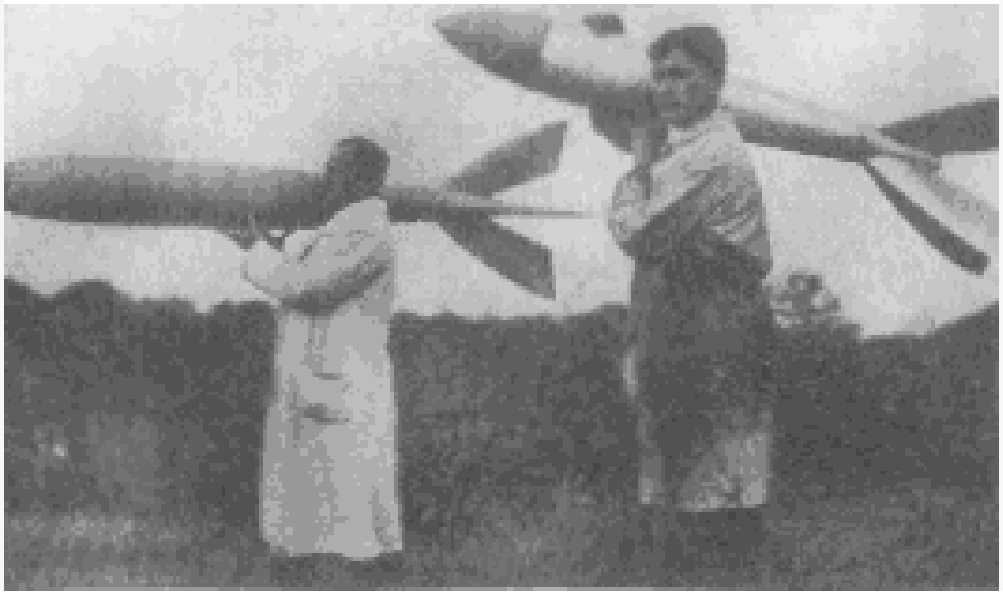
Sergei P. Korolev

1933 GIRD-X rocket

Members of GIRD with the GIRD-X rocket. Sergei Korolev is at the top left. (Novosti photo, also available as Smithsonian

Werhner von Braun

1930 Mirak rocket



Wernher von Braun in 1930, carrying the Mirak rocket to a test at the Raketenflugplatz in Berlin. At left is Rudolf Nebel. *(Courtesy of the National Air and Space Museum)*

William H. Colburn

1956 Sugar propellant rocket

My early experiences with hobby rocketry

- 1971 - built and flew **model rockets**

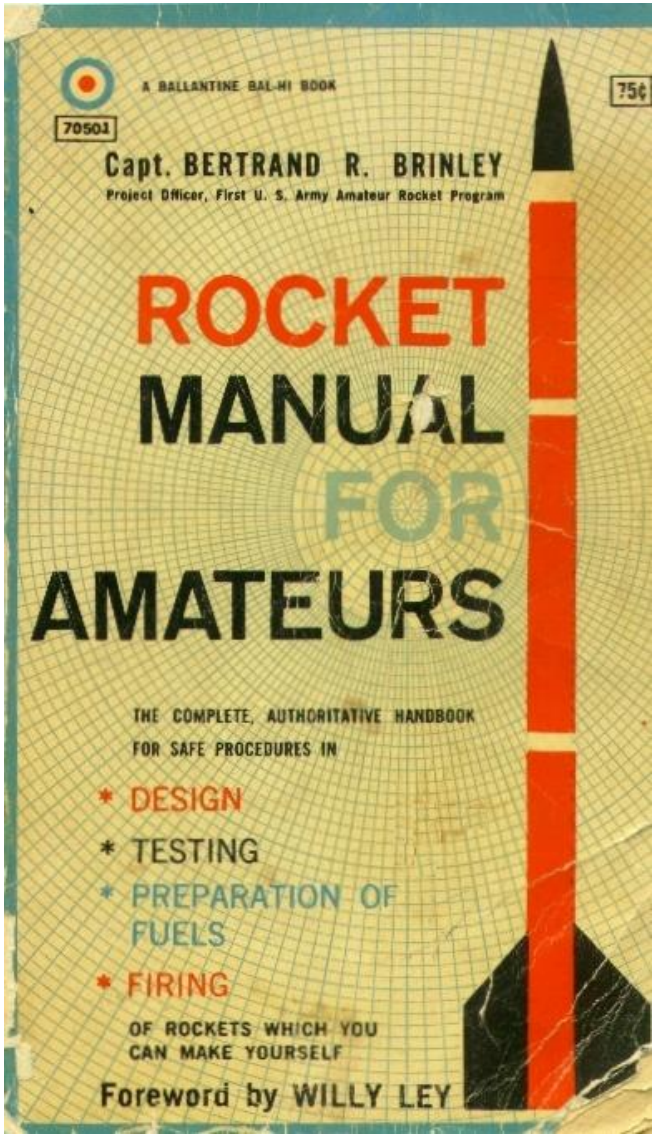

4 ENGINE POWER
UPRATED
SATURN-1
SPECTACULAR FLYING SCALE MODEL
formerly SATURN 1B
$9.50
Specifications
Length ..... 37"
Body Dia. ..... 3.53"
Weight ..... 9.86 oz.
Recommended Engines (All four must be the same.)
A8-3, B6-4, C6-5
3 Parachute Recovery
A thrilling scale model for even the most advanced rocketeer, this bird will be a real challenge to your building and flying skill. A four engine cluster lifts the Saturn 1-B model into the air. Two 24" parachutes on the main body and a 12" parachute on the command-escape structure return it gently. A real beauty, both in the air and on display. A 12 volt car battery and launch control system (such as the Estes 12 volt Launch Control System) is required for ignition. Kit comes complete with all parts, decals, detailed instructions and a copy of Technical Report No. TR-6 (but no engines). Shipping weight 4 lbs.
Cat. No. 671-K-29 . . $9.50

My early experience with AER

- Inspired to learn more about rockets and rocket motors, in particular.
- Very few books available on AER.

Amateur “bible” of the 1960’s

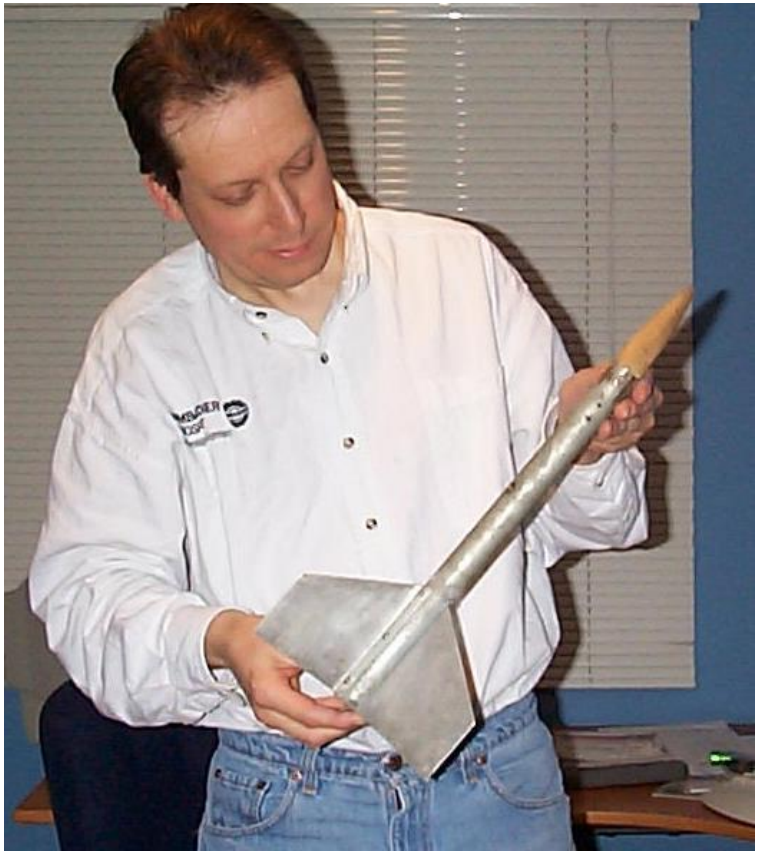
by Capt. B.R.Brinley, published 1960-1968



- Brinley's rockets were powered by zinc + sulfur propellant
- Brinley's book briefly described the "**Sugar Propellant**".
- This led to the development of my first amateur rocket.

First amateur rocket launch, Feb.26, 1972

An old relic…

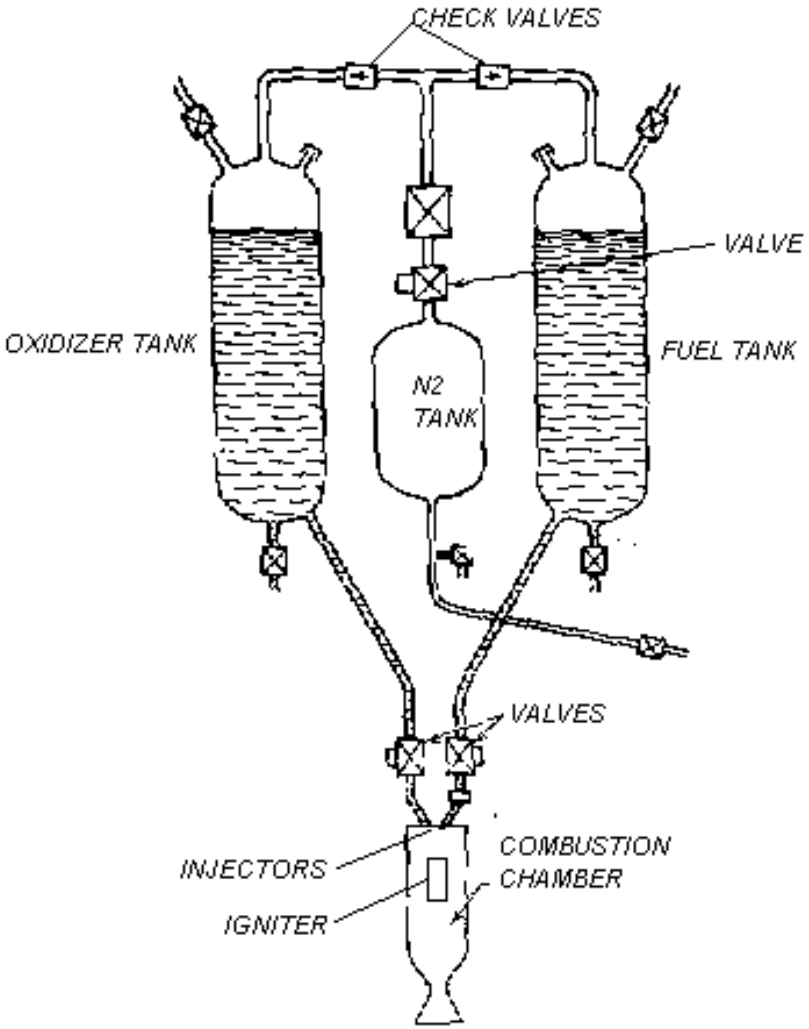


Types of Rocket Motors

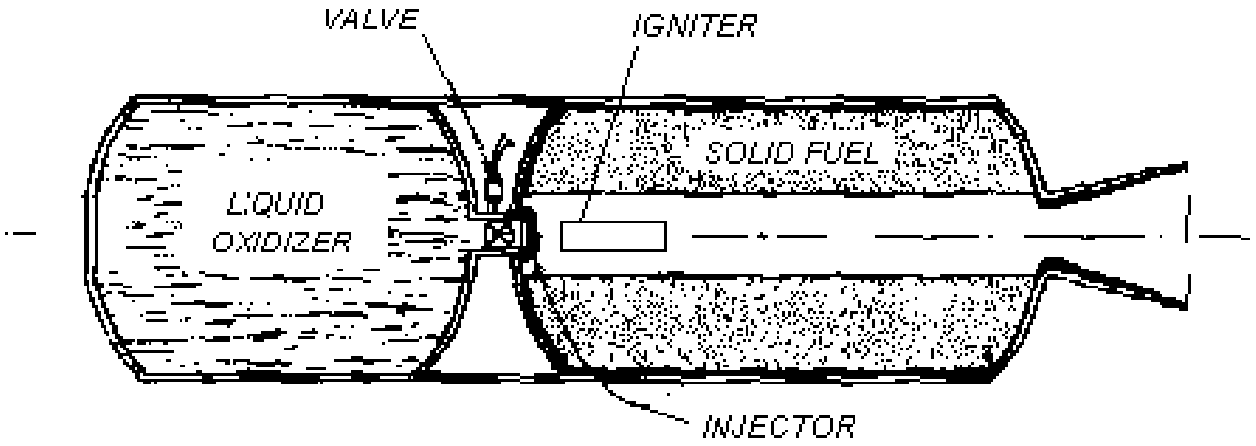
all are applicable to amateur rocketry

- Liquid propellant
- Hybrid
- Solid propellant

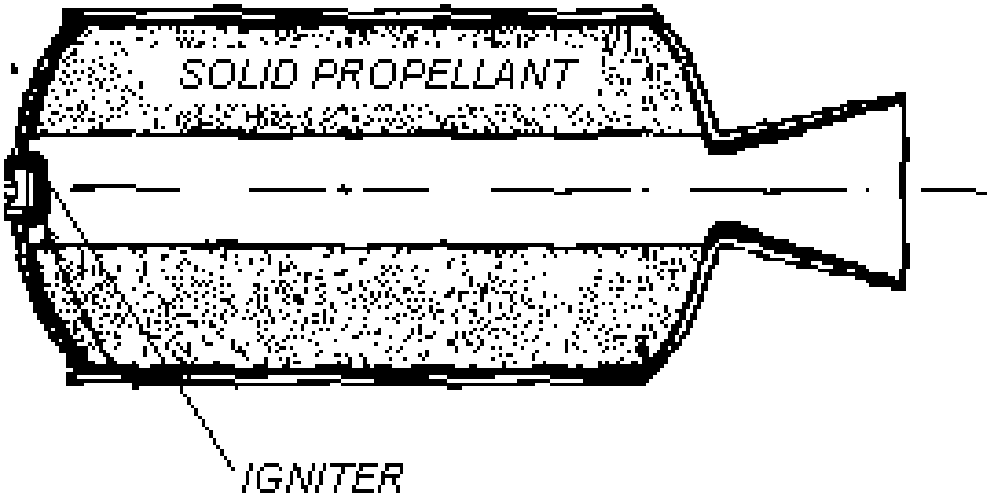
Liquid rocket motor



Hybrid rocket motor



Solid rocket motor



Solid Rocket Motors (SRM)

A-100M (“G” class motor)

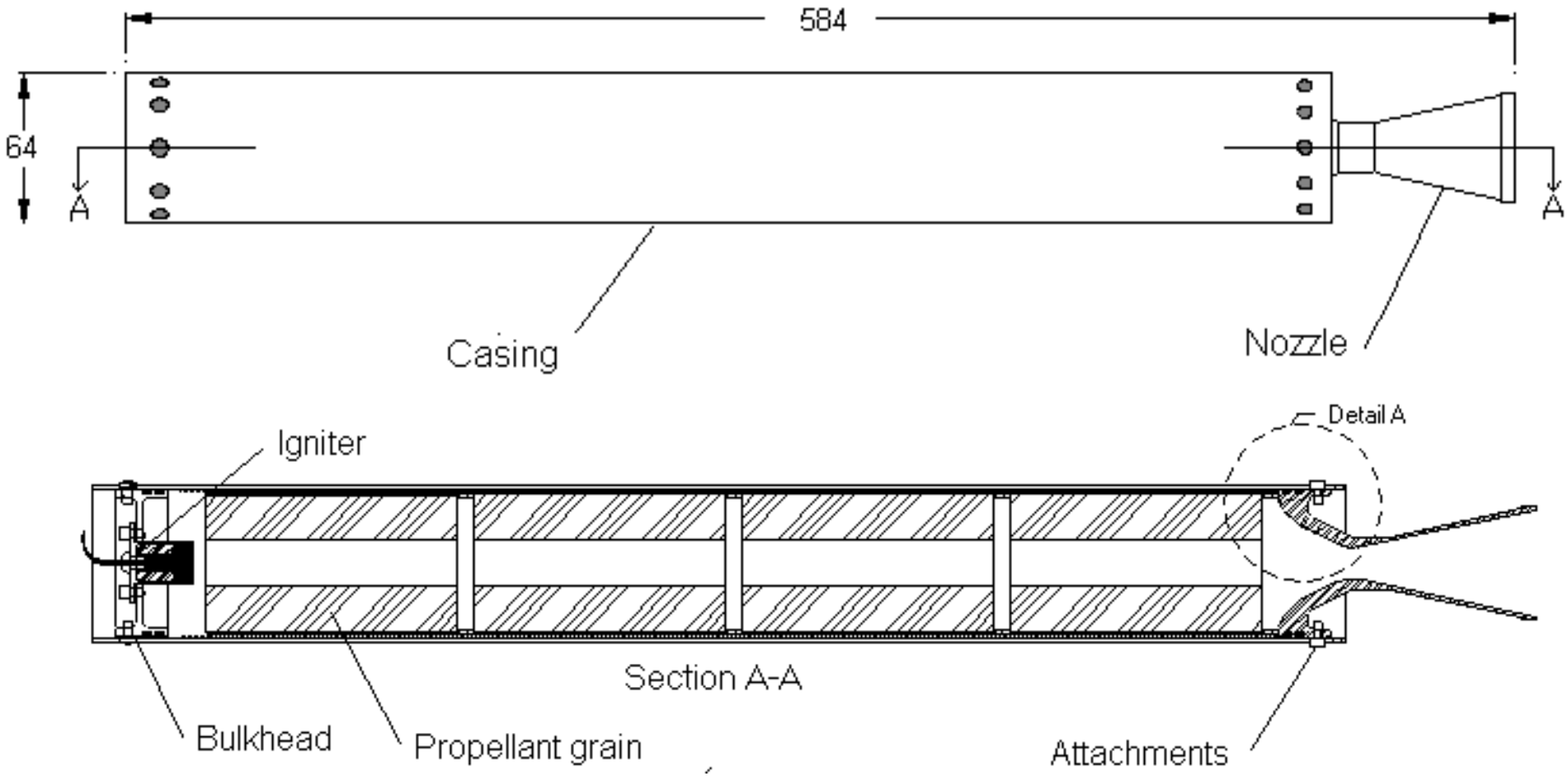
Can be field reloaded in 10 minutes

example: Liberty

"L" Class 3300 N-sec
3.2 kg. RNX propellant

"Rod & Tube" grain

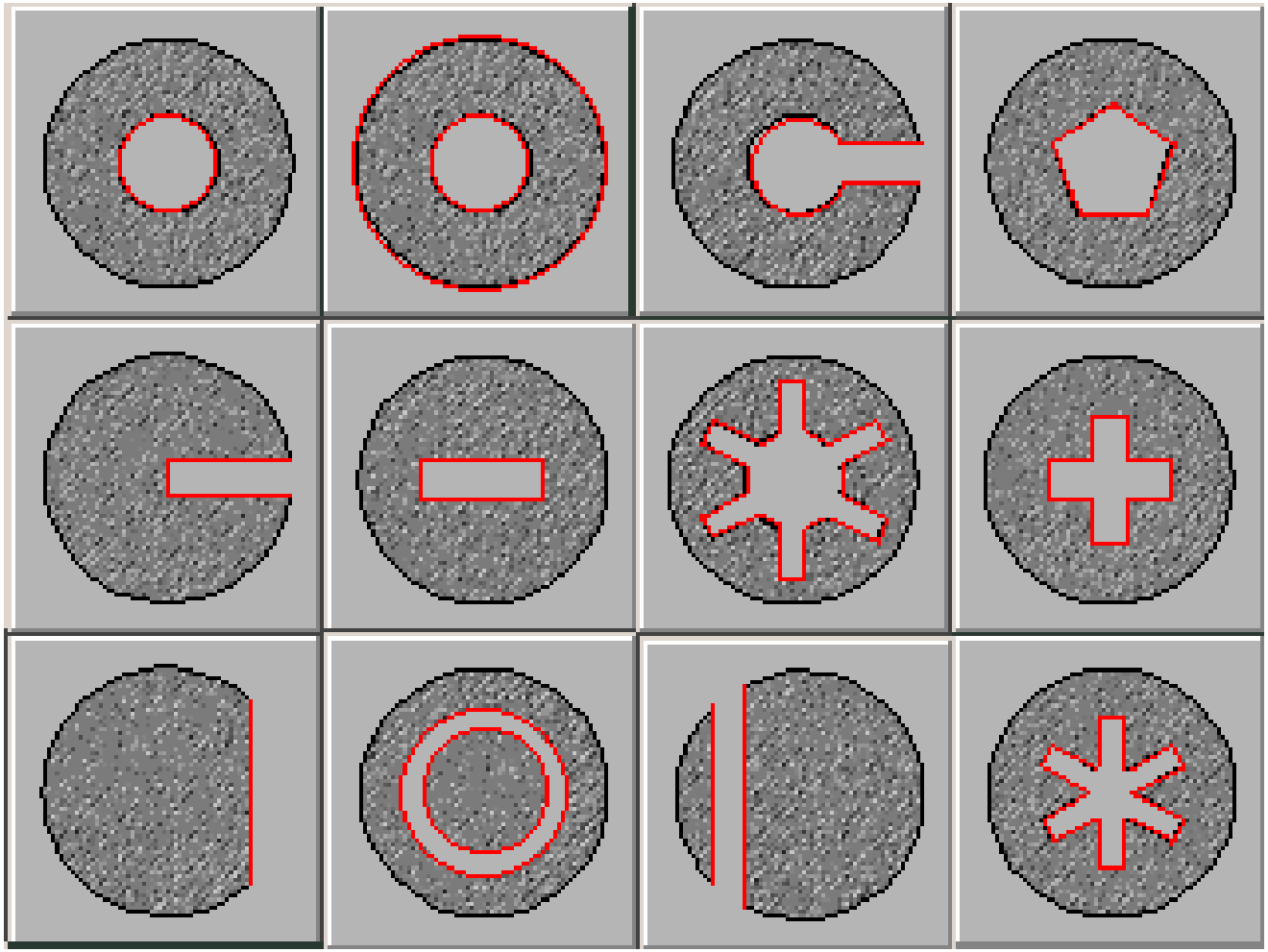
Kappa engineering drawings



Propellant grain

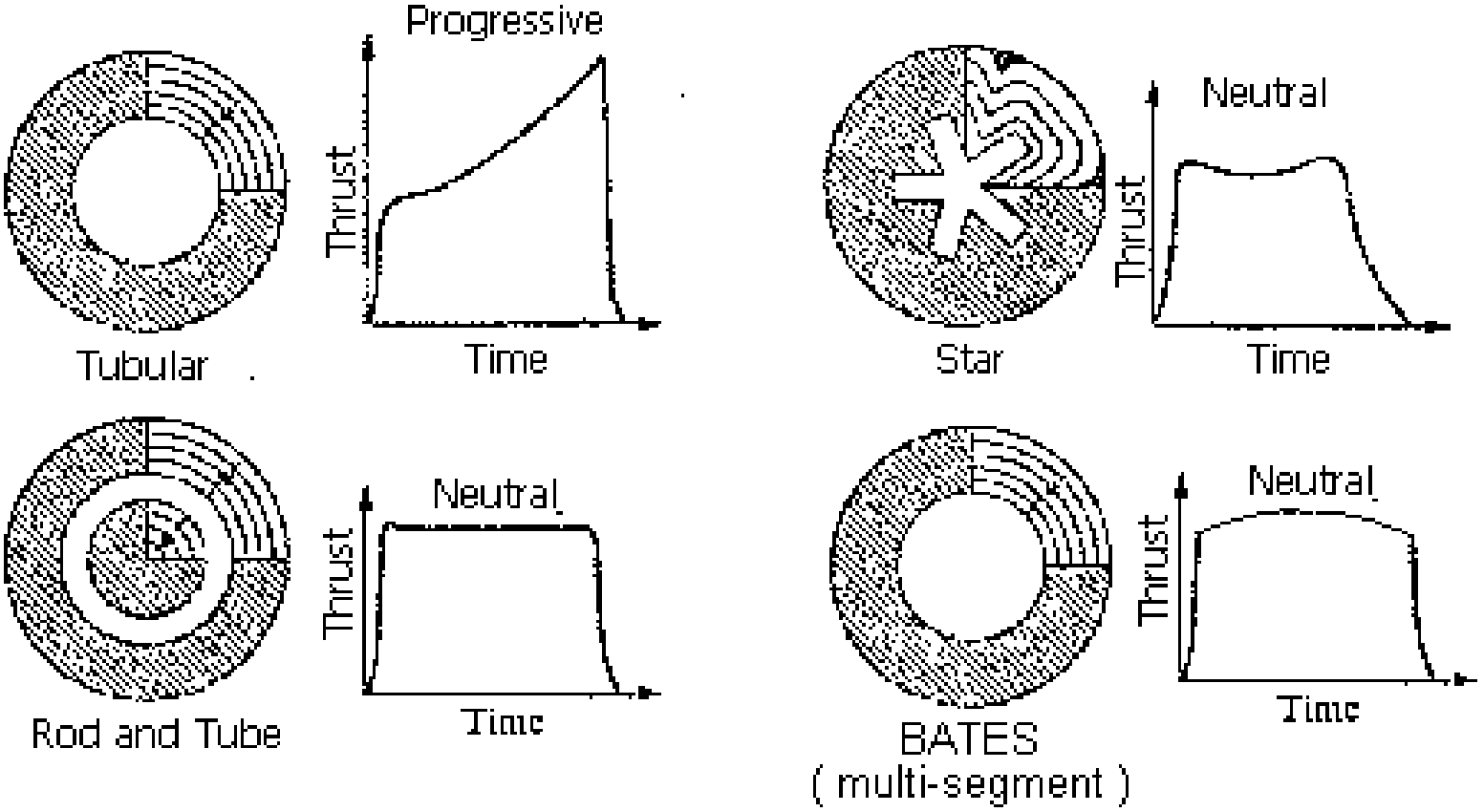
Kappa-DX motor

Grain configurations



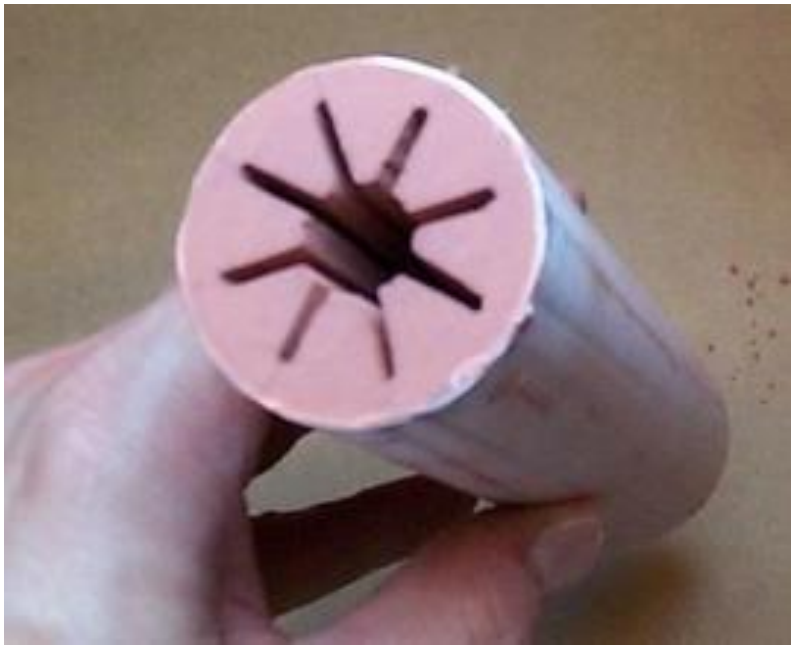
Red is initial burning surface

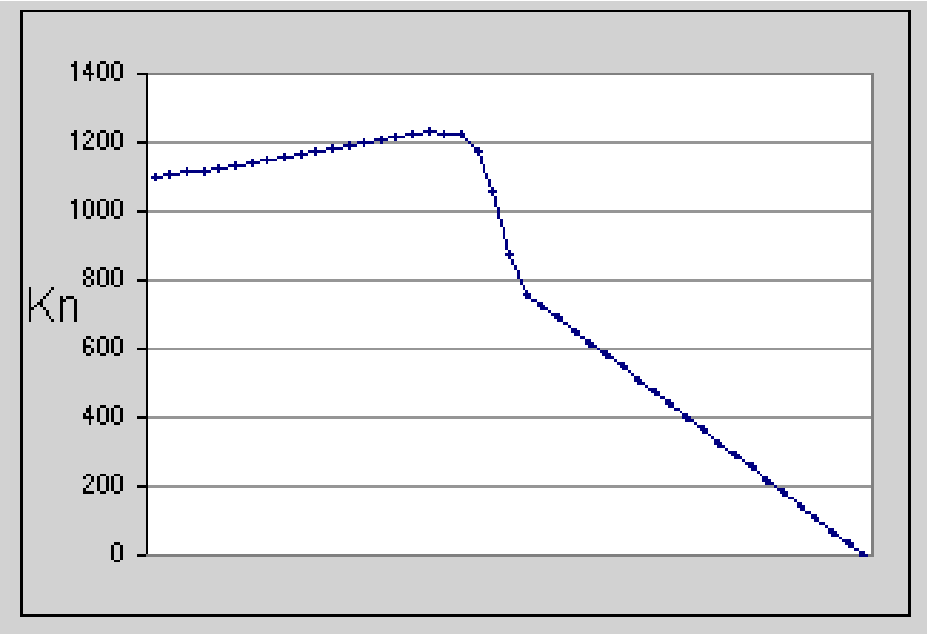
Grain configurations



Grain configurations

Pseudo-finocyl

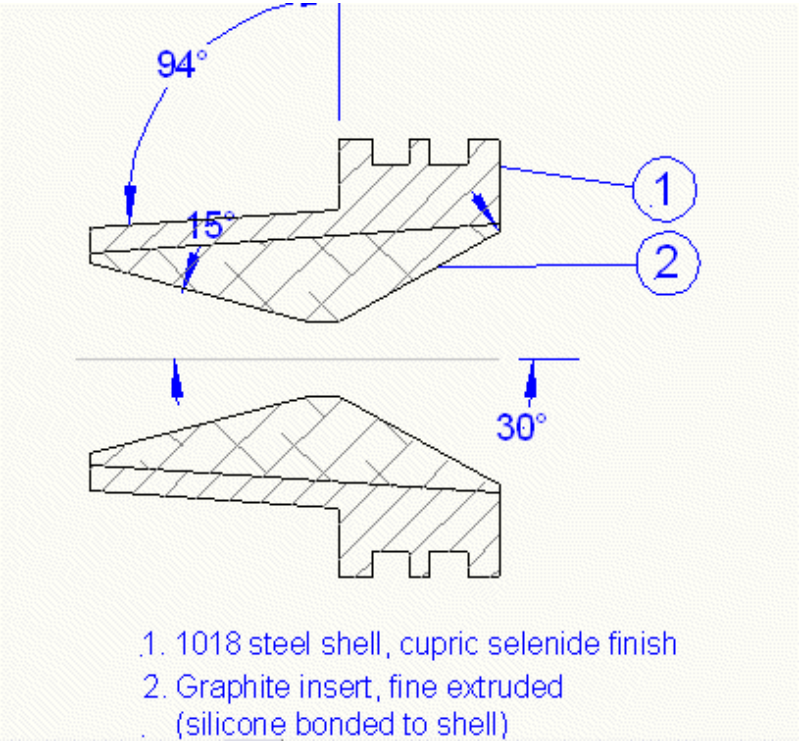




Grain configurations
Rod & Tube

The Rocket Nozzle

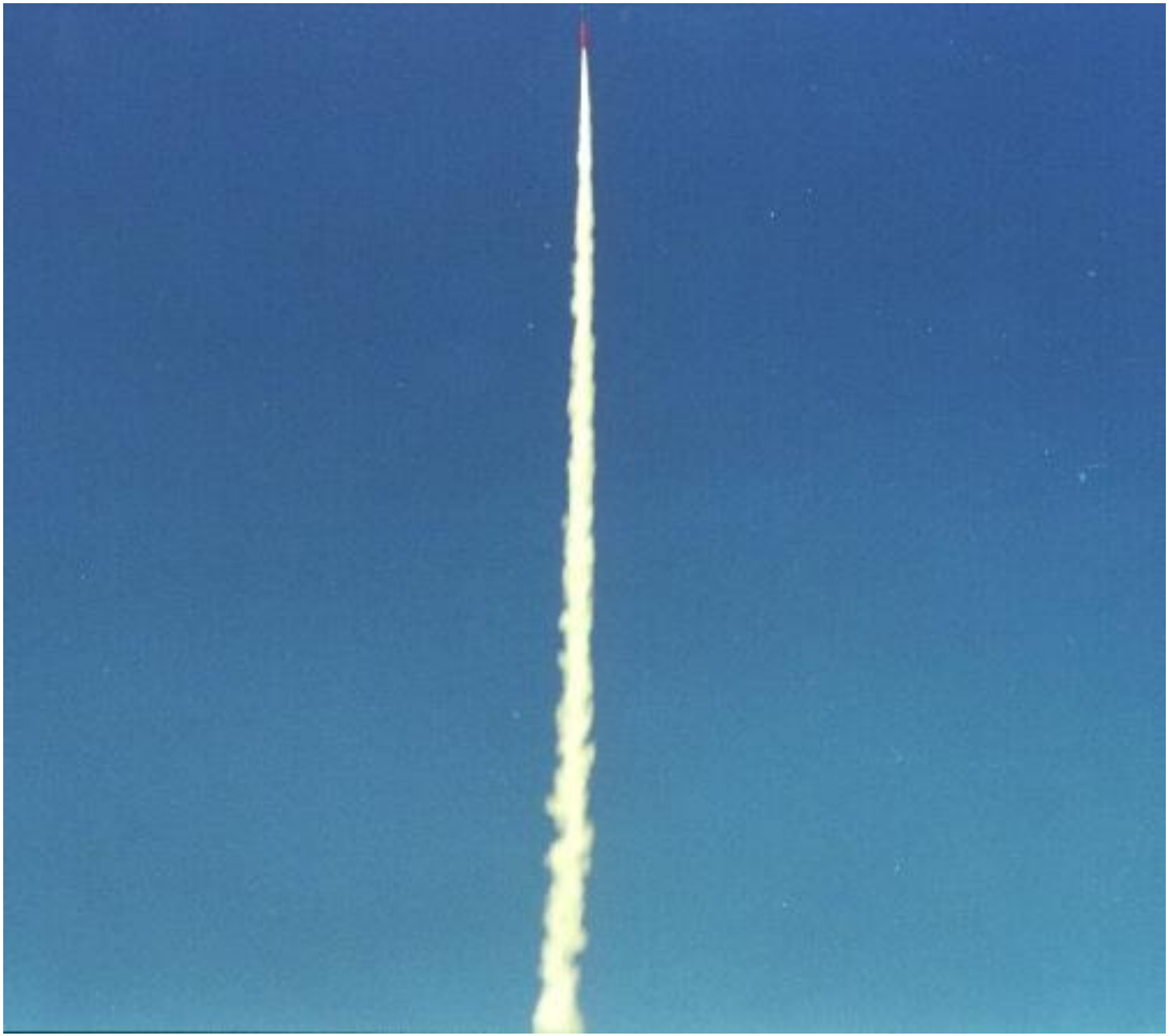
Nozzles with graphite inserts



Rocket Flights

- Cirrus
- Frostfire

Cirrus One with “K” class KNDX propellant



VIDEO-CLIP

Cirrus One (2001)

VIDEO-CLIP

Frostfire 3 (2005)

VIDEO-CLIP

Frostfire 3 SLOW-MOTION

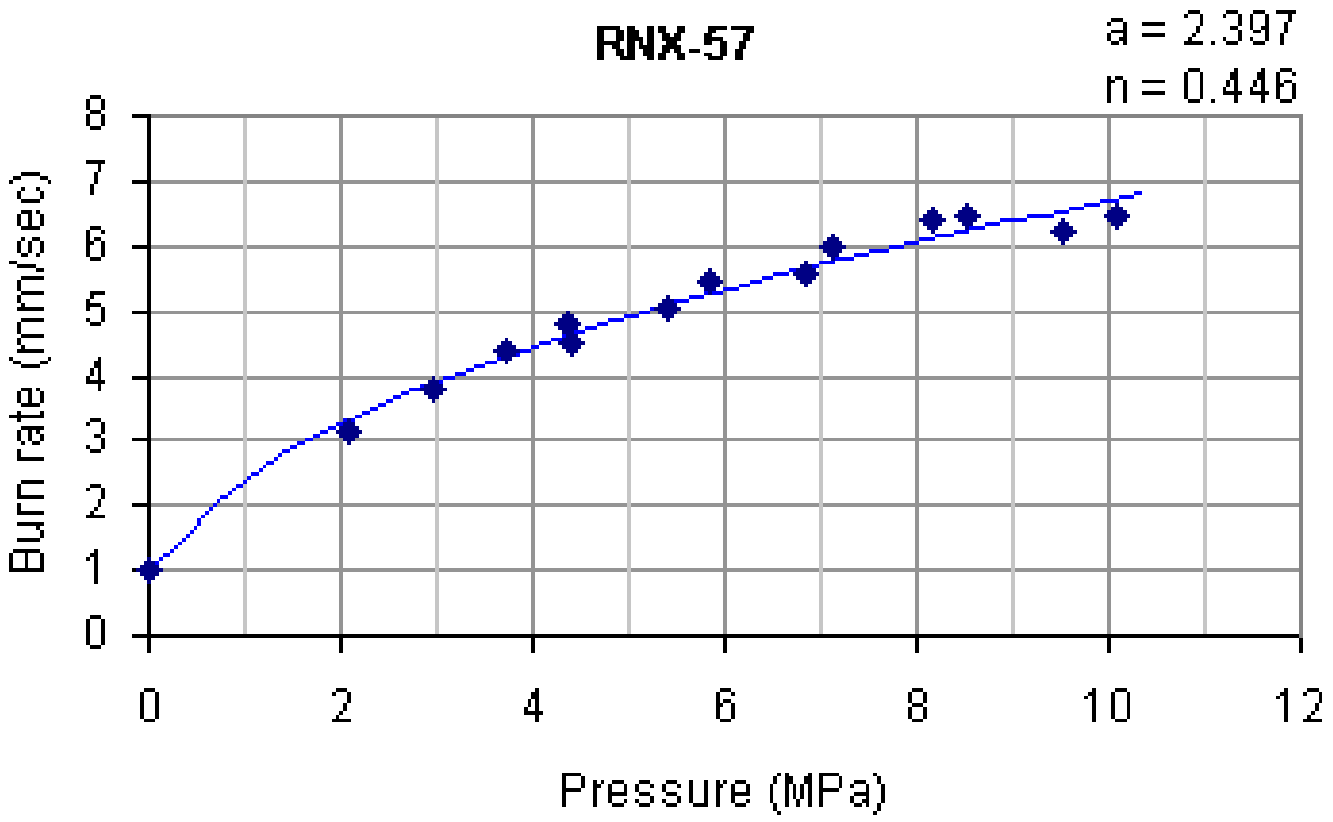
How is propellant burn rate determined?

Burn rate measurement

Crawford Strand Burner

Burn rate measurement

$r = a P_o^n$



Amateur Experimental Propellants:

"**Classic**" formulations:

1. Zinc/Sulfur (Micrograin)
2. Potassium Nitrate/Sucrose ("Sugar Propellant")
3. Blackpowder (KN/Charcoal/Sulfur)

Amateur Experimental Propellants

Formulations that I have experience with

- **Potassium Nitrate/Sucrose (KNSU)**
- **Potassium Nitrate/Sorbitol (KNSB)**
- **Potassium Nitrate/Dextrose (KNDX)**
- **Potassium Nitrate/Fructose (KNFR)**
- **Potassium Nitrate/Epoxy/RIO (RNX)**
- **Ammonium Nitrate/Aluminum/Neoprene (ANAL)**

Sugar Propellants

Oxidizer: Potassium Nitrate , KNO_3

Fuel: Sucrose $C_{12}H_{22}O_{11}$

or Dextrose (glucose) $C_6H_{12}O_6$

or Fructose $C_6H_{12}O_6$

or Sorbitol $C_6H_{14}O_6$

or sugar alloys

RNX Epoxy Propellants

Oxidizer: Potassium Nitrate, KNO_3

Fuel: Epoxy: thermosetting resin

Epoxy consists of liquid Resin and liquid Hardener

Burn rate modifier: Red Iron Oxide: Fe_2O_3

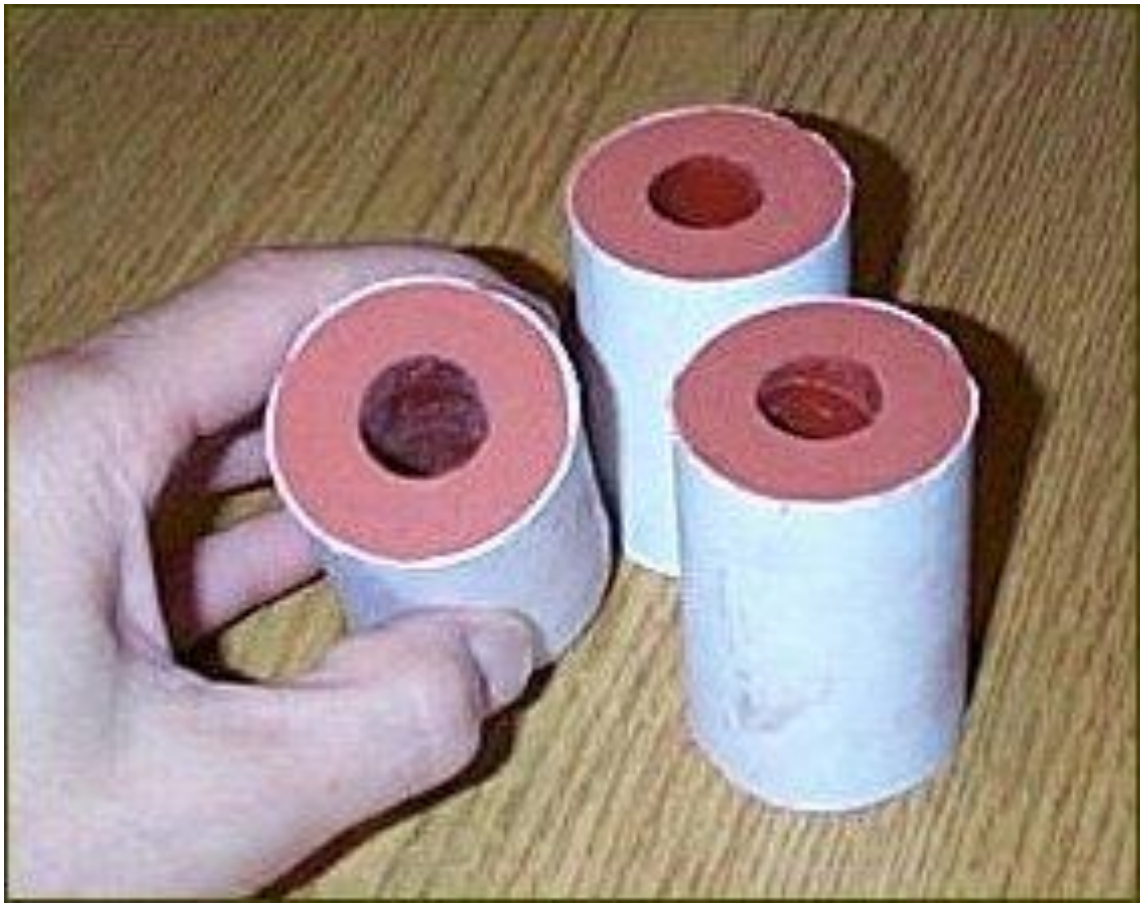
Typical ratios, KN/Epoxy/RIO 70/22/8

RNX Propellant Manufacture

- RNX epoxy propellants are cold cast
- KN and RIO are well blended first using tumbler
- Epoxy (liquid) added and mixed to a “putty” texture
- Packed into mould
- Cured at room temperature for 24 hours
- Can be safely cut, drilled or machined

RNX propellant mixing

RNX propellant finished product



Safety of manufacture

- Due to heat casting of Sugar Propellant, safety concern needs to be addressed.
- "**Overheating experiments**" conducted to address concern. Performed on KNSU, KNDX & KNSB.

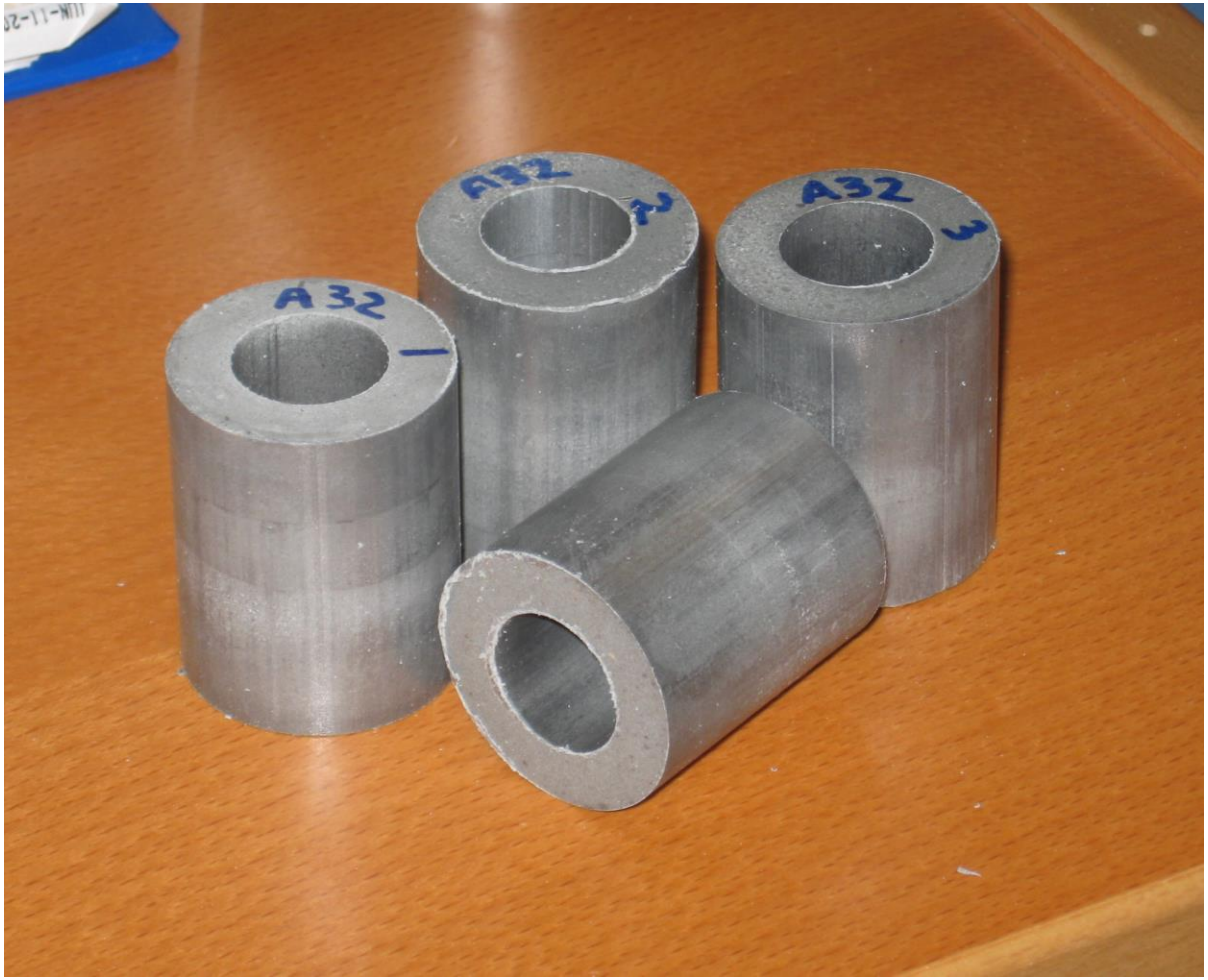
Safety of manufacture

- Thermal energy goes into decomposing the sugar, temperature remains approximately constant at 200^{o} - 220^{o} C. until decomposition is complete.
- Auto-ignition > 300^{o}C.
- Casting: 130^{o} - 185^{o} C
- Large “safety margin” between casting temperature and auto-ignition temperature
- Obvious signs of overheating: discolouration, vapour, smell, etc.

Safety

- RNX propellant is **cold cast**.
- Uncured propellant is difficult to ignite. If ignited, burns weakly.
- Cured propellant is hard to ignite, is not friction or impact sensitive.
- No significant safety issues in manufacturing RNX propellant.

AN-Al Propellants



Rocket Motors

- Design and Testing

Internal Ballistics & Performance

- SRM.xls developed to simply the safe design of amateur rocket motors.

Rocket Motor Structural Design

- Very important, as motor operates under high pressure
- Inadequate design can lead to **CATO**
- Casing *design strength* & *burst strength*
- Nozzle & bulkhead retention

Rocket Motor Structural Design

Closure attachment

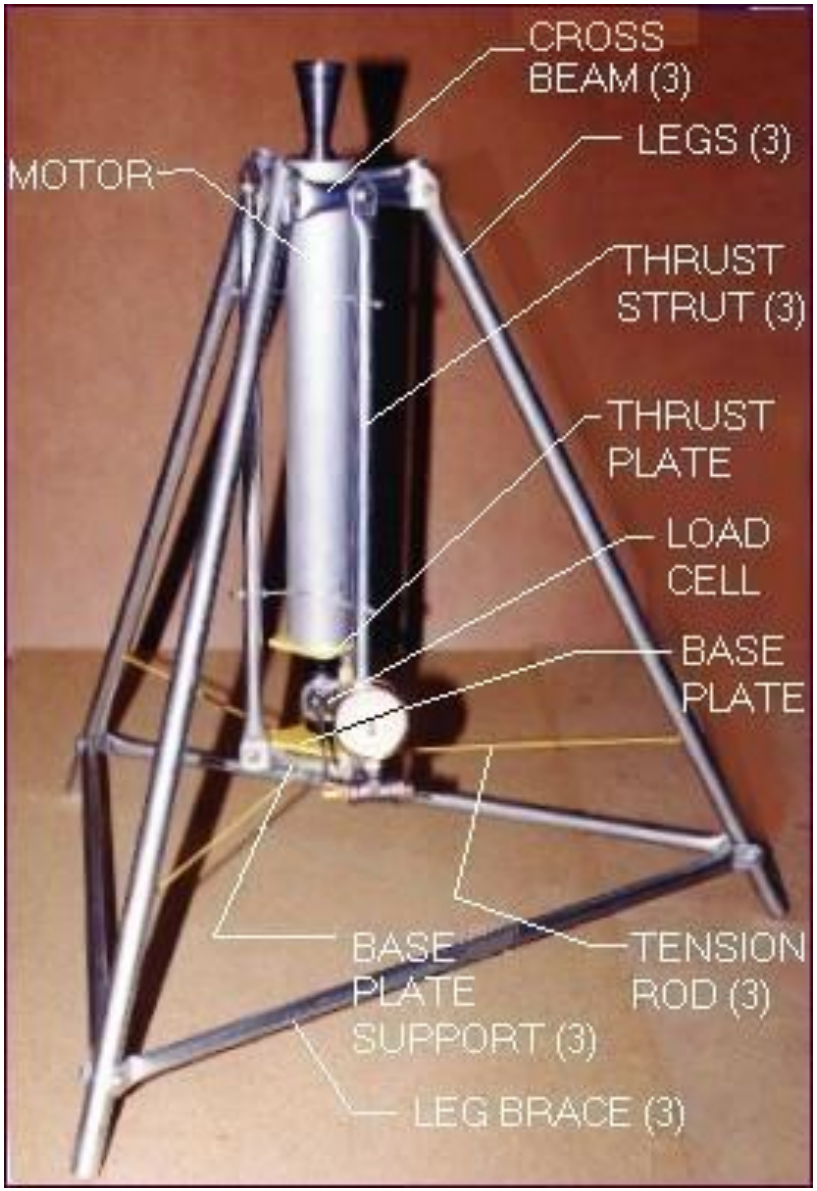
- snap rings
- threaded closures
- radial pattern of machine screws
- bonded

Snap ring closure retention

Rocket Motor Testing

- Verify design
- Provide actual performance numbers
- Reveal flaws in design or construction
- Provide reliability data

STS-5000 static test stand



Setup for Kappa KDX-002, July 22, 2000

VIDEO-CLIP

Kappa_KDX002_static.mpg

Load cells for force (thrust) measurement

Hydraulic

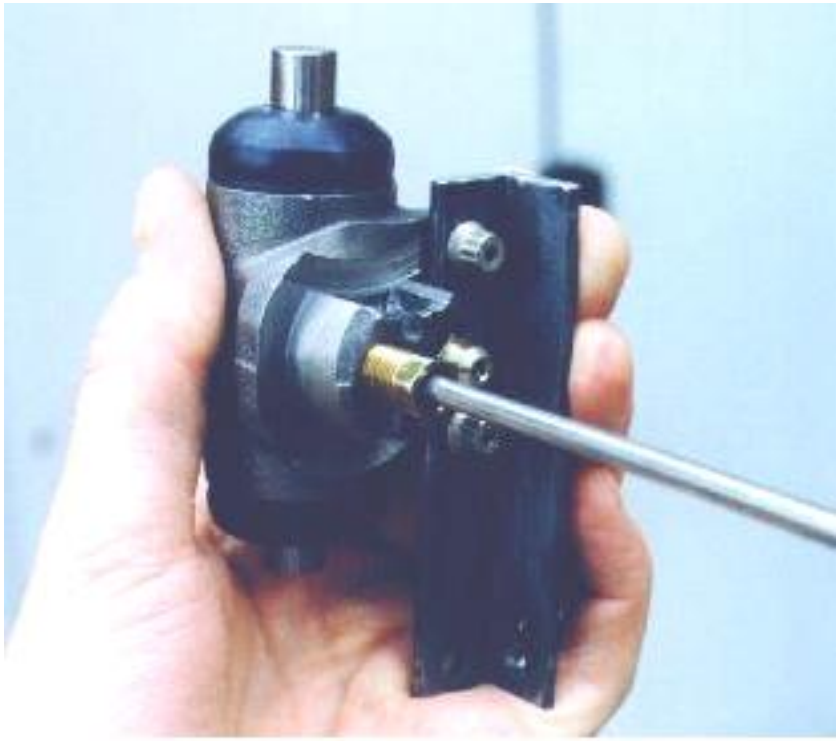
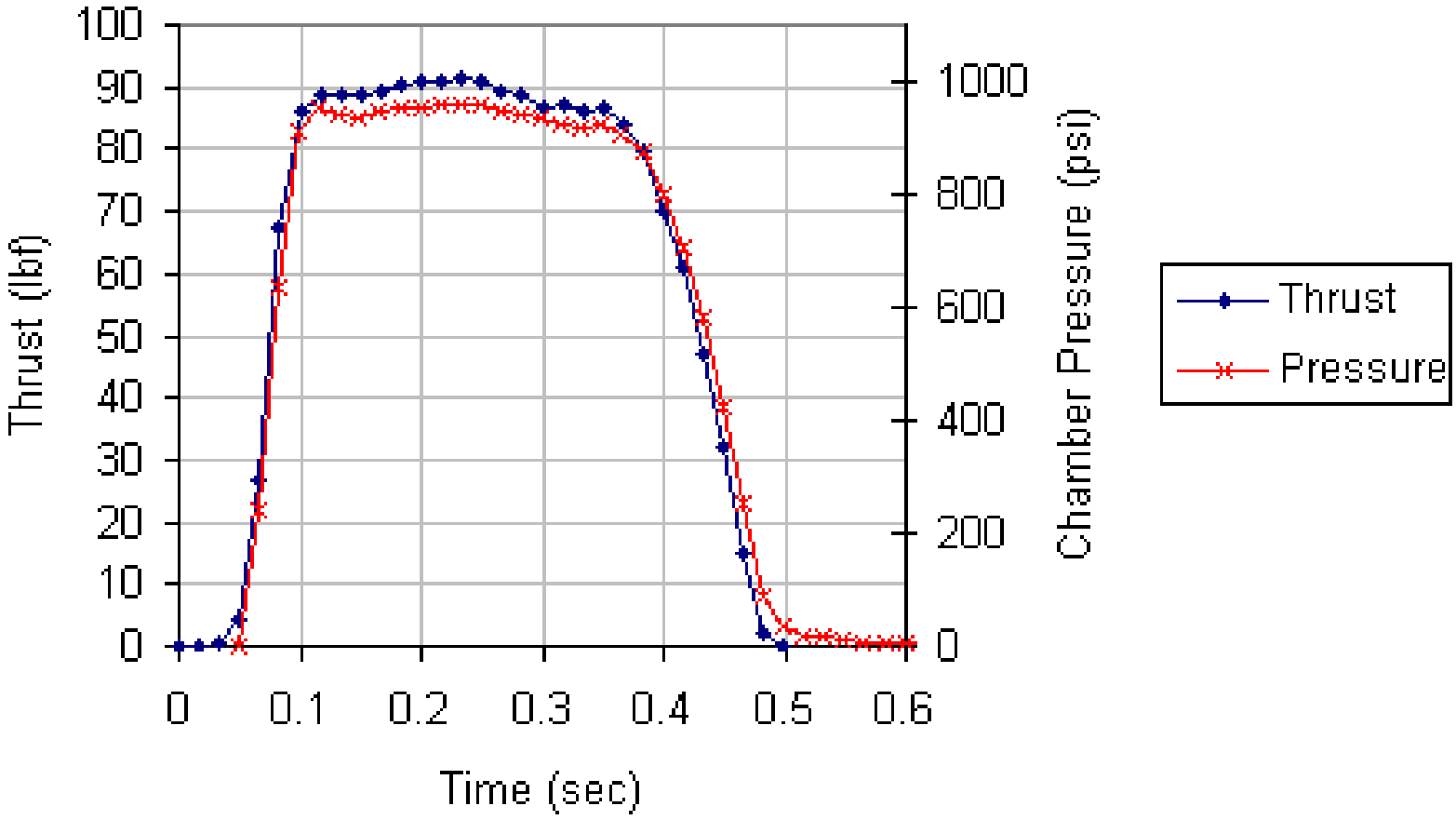


Figure 1 -- Hydraulic Load Cell

Electronic

Test results for A-100M motor, KNDX grain



From static testing, one can determine:

- Thrust as a function of time
- Chamber pressure as a function of time
- Total impulse
- Specific impulse
- Characteristic Velocity (c*)
- Thrust Coefficient (Cf)
- Verify structural capability of motor
- Verify thermal capability of motor (e.g nozzle erosion, casing damage, insulation effectiveness)
- Anomalies in behaviour

Concluding remarks

- What can be gained by involvement in rocketry?

- Rocketry is **multi-disciplinary**
- Chemistry, math, thermodynamics, aerodynamics, strength of materials, electronics, failure analysis, etc., etc.
- Hands-on work: machining, metal working, model building, composite techniques, experimental method, organizational skills
- Team-building amongst fellow enthusiasts.

Rocketry promotes an interest in science & engineering.

- And rocketry experience looks good on a resume.

❖End