Experimental procedure to obtain burn rate coefficient and pressure exponent for a one grain motor.

1. Summary

This report proposes a static test campaign for a one-grain solid rocket motor using KNSB (65:35 potassium nitrate and sorbitol). The test will record chamber pressure and thrust over time to derive:

- Propellant burn rate
- Burn law constants a and n
- Kn ratio and web regression
- Total impulse and motor performance

The procedure is based on the work of Richard Nakka, who conducted extensive experiments on sugar-based propellants. Tools such as **SRM.XLS**, the **Burn Rate Calculator**, and **OpenMotor** will support analysis and simulation.

2. Theory

2.1 Burn Rate Law

The burn rate is governed by Saint Robert's law:

$$r_b = a \cdot P^n$$

where:

- r_b: burn rate (mm/s)
- a: burn rate coefficient
- n: pressure exponent
- P: chamber pressure (MPa)

From Nakka's KNSB tests at 25°C:

- $a = 5.0$ mm/s/MPa^n
- $n = 0.35 - 0.38$

2.2 Chamber Pressure Estimation

$$P_c \propto \left(\frac{A_b}{A_t}\right)^{\frac{1}{1-n}} \quad \Rightarrow \quad P_c = \left(\frac{a \cdot \rho_p \cdot A_b}{C^* \cdot A_t}\right)^{\frac{1}{1-n}}$$

where:

- A_b: burn area
- A_t: throat area
- C^*: characteristic velocity ($\approx 1250\,\mathrm{m/s}$)
- ρ_p: propellant density ($\approx 1800\,\mathrm{kg/m^3}$)

2.3 Kn and Web Regression

$$Kn = \frac{A_b}{A_t}, \quad w = \frac{D_{\text{outer}} - D_{\text{core}}}{2}$$

These parameters govern pressure evolution and are simulated using **SRM.XLS** and **OpenMotor**.

3. Apparatus and Tools

3.1 Propellant Grain

Propellant:	KNSB (65:35)
Grain Type:	BATES-style
Outer Diameter:	86 mm
Core Diameter:	33 mm
Length:	145 mm
Inhibition:	Outer surface and both ends

3.2 Instrumentation

- Pressure transducer (rated $\geq 1000\,\mathrm{psi}$)
- Load cell (thrust sensor)
- Data acquisition system
- Remote ignition system

3.3 Software Tools

- **SRM.XLS** – for pressure simulation and Kn tracking
- **Burn Rate Calculator** – for tuning a and n
- **OpenMotor** – for grain geometry and simulation

4. Calculations and Procedures

4.1 Test Procedure

1. Manufacture and inhibit grain
2. Mount motor on test stand
3. Connect sensors and verify calibration
4. Fire the motor and record pressure and thrust vs. time
5. Conduct two tests with different nozzle throat diameters

4.2 Data Analysis

Burn Rate:

$$r_b = \frac{w}{t_{\text{burn}}}$$

Log–log Regression:

$$\log(r_b) = \log(a) + n \cdot \log(P)$$

Software Integration:

- Use **SRM.XLS** to simulate Kn and regression over time
- Use **Burn Rate Calculator** to validate a, n
- Use **OpenMotor** to visualize regression and simulate thrust

4.3 Thrust and Impulse

$$I_t = \int_0^t F(t)\,dt$$

Total impulse will be computed by integrating the measured thrust curve.

5. Discussion Plan

Following testing:

- Compare derived a, n to Nakka's values
- Evaluate agreement between measured and simulated Kn and pressure
- Investigate any signs of erosive burning
- Assess performance scalability to multi-grain motors

6. Conclusion (To be completed post-test)

This section will summarize:

- Accuracy of experimental setup
- Comparison of empirical and predicted results
- Effectiveness of SRM.XLS, Burn Rate Calculator, and OpenMotor
- Suggestions for improved design or further study

7. References

1. Nakka, R. *Sugar Propellant Burn Tests – KNSB*. `https://www.nakka-rocketry.net/bntest.html`
2. Nakka, R. *SRM.XLS Internal Ballistics Calculator*
3. OpenMotor: `https://openmotor.io`
4. NASA SP-125: *Solid Propellant Fundamentals*
5. Sutton, G. P., *Rocket Propulsion Elements*, 9th Edition

Appendices (To be added post-test)

- A: Raw pressure and thrust data
- B: Log–log regression plots
- C: SRM.XLS and OpenMotor outputs
- D: Burn Rate Calculator input/output