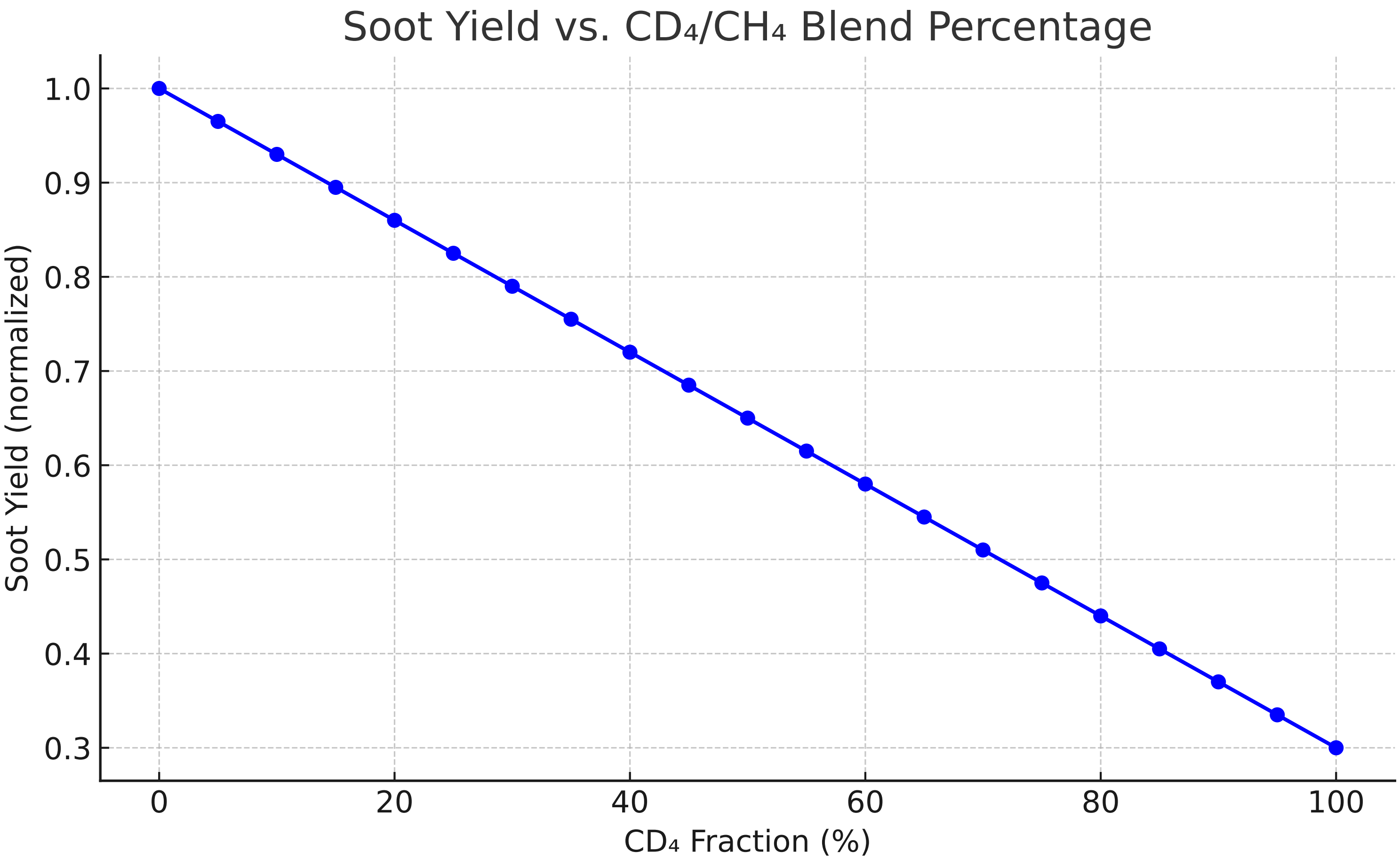
Soot Yield vs. CD₄/CH₄ Blend Percentage
Soot Yield (normalized)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0
20
40
60
80
100
CD₄ Fraction (%)

CD_4/CH_4 BLEND SOOT REDUCTION ANALYSIS

Overview:
Methane (CH_4) is widely used as a clean-burning rocket fuel, especially in the Raptor eng
However, soot formation from incomplete combustion remains a challenge, contributing to:
- Hot spots
- Throat erosion
- Chamber degradation
- Reduced engine reusability

Key Insight:
Substituting hydrogen with deuterium (CD_4) dramatically suppresses soot due to:
- Reduced hydrogen abstraction rates
- Lower production of soot precursors (e.g., acetylene, PAHs)

Model:
Soot Yield $Y = (1 - x) * Y\_CH_4 + x * Y\_CD_4$
Where:
- x is the CD_4 mole fraction (0 to 1)
- Y_CH_4 = 1.0 (normalized soot yield for pure methane)
- Y_CD_4 = 0.3 (empirical estimate from literature)

Findings:
- A 50% CD_4 blend reduces soot yield by 35%
- A 100% CD_4 burn could cut soot by 70%

Implications for SpaceX:
- Longer chamber life (lower ablation & wear)
- Reduced turnaround time
- Cleaner optics and sensors
- Enables higher combustion pressures with fewer fouling constraints

Engine Life Projections (hypothetical):
Assuming soot is the dominant degradation factor:
- 0% CD_4: Baseline engine life = 10 cycles
- 50% CD_4: +50–70% cycle extension (15–17 cycles)
- 100% CD_4: Up to 2.5x improvement (25+ cycles)

Conclusion:
CD_4 blends offer a low-complexity, high-impact pathway to soot suppression and longer eng
Given the relative simplicity of isotopic methane production (via D_2O electrolysis or gas
this could be a near-term fix for high-performance staged combustion engines.

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