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Updates on HTPE Propellant Service Life

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Background of HTPE Propellants

•ATK developed HTPE propellants for improved insensitive munitions (IM) response

– Rocket motors manufactured from HTPE propellants have demonstrated improvements in IM performance

– IM response improved further when coupled with a composite case

– HTPE passed 6-inch diameter zero card gap test

  • non-detonable for motors with webs up through six inches

•Based on hydroxyl-terminated polyether (HTPE) polymer with an energetic plasticizer

– Uses ammonium perchlorate and ammonium nitrate oxidizers

– Uses BuNENA energetic plasticizer

•Both aluminized and reduced smoke formulations are in production for Evolved Sea Sparrow Missile (ESSM)

•Under development or qualification for several other applications

– Mongoose, Japanese 21-inch motor demonstration, RAM Block II, Japanese ESSM

Introduction to HTPE Aging

Service life for HTPE propellant is sufficient for deployment according to typical tactical motor requirements

- equals or exceeds service life of currently fielded NG/BTTN-based propellants

Long-term aging study being conducted on reduced smoke HTPE propellant

- Currently in year 13
- 10-year data presented here (next planned withdrawal at 15 years)
- Gas generation, stabilizer depletion, mechanical and ballistic properties demonstrate exceptional stability
- Better than current minimum smoke (NG/BTTN-based) propellants used in TOW and Hellfire

Gas Generation and MNA Depletion

Gas Generation -- HTPE and Minimum Smoke Propellants

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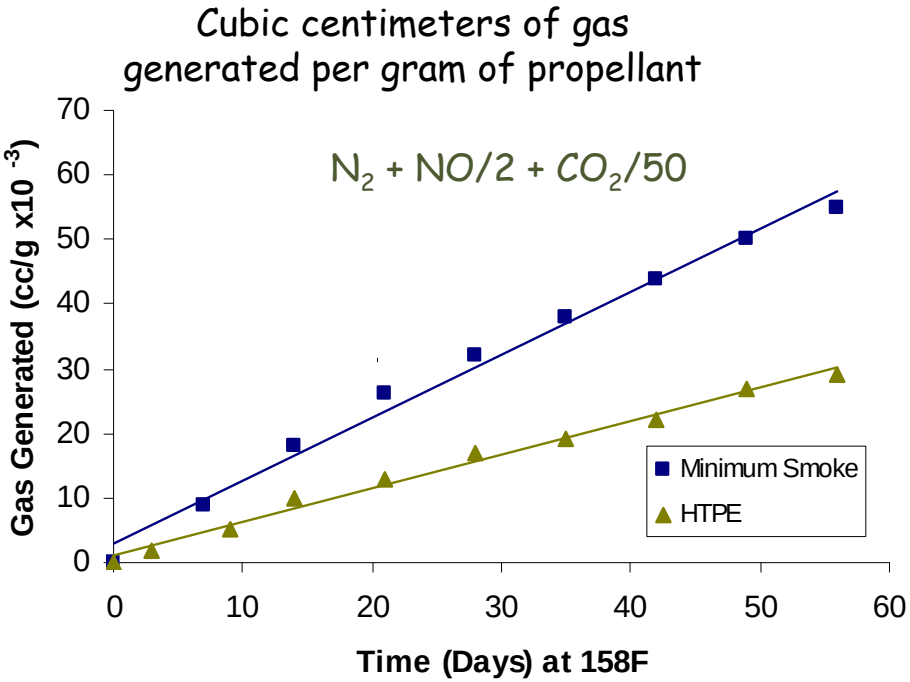

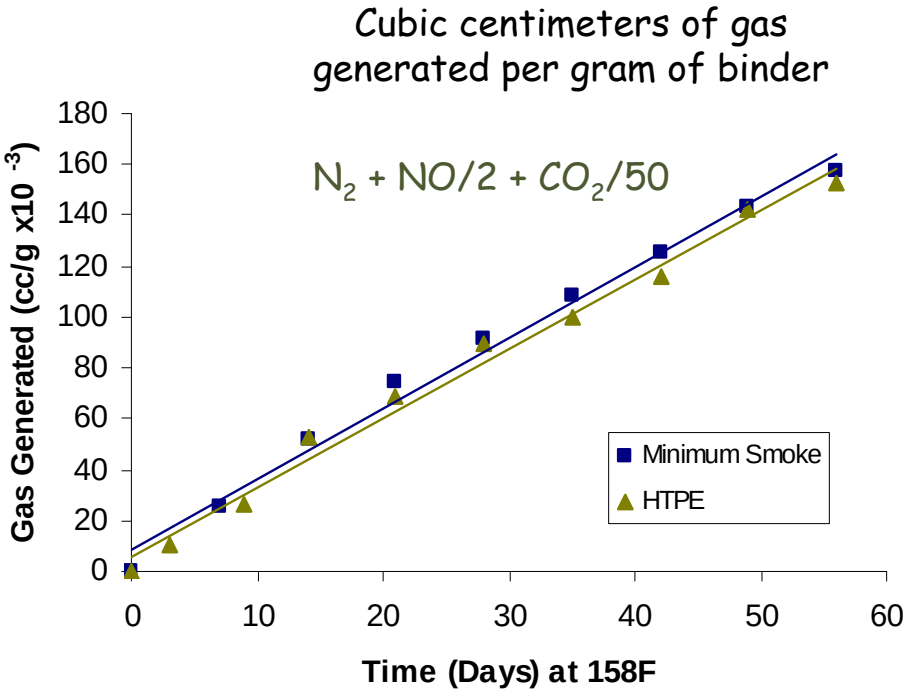

Rate of gas generation by HTPE propellant is about half that of minimum smoke propellant in cc of gas per gram of <u>propellant</u>

Rate of gas generation by HTPE propellant is the same as minimum smoke propellant in cc of gas per gram of <u>binder</u>

HTPE and minimum smoke propellants generate the same gases during aging

Service life criterion is time to generate total normalized quantity of gas equal to $100x10^{-3}$ cc/gram of propellant or $300x10^{-3}$ cc/gram of binder

Stabilizer Depletion --Aluminized HTPE Propellant

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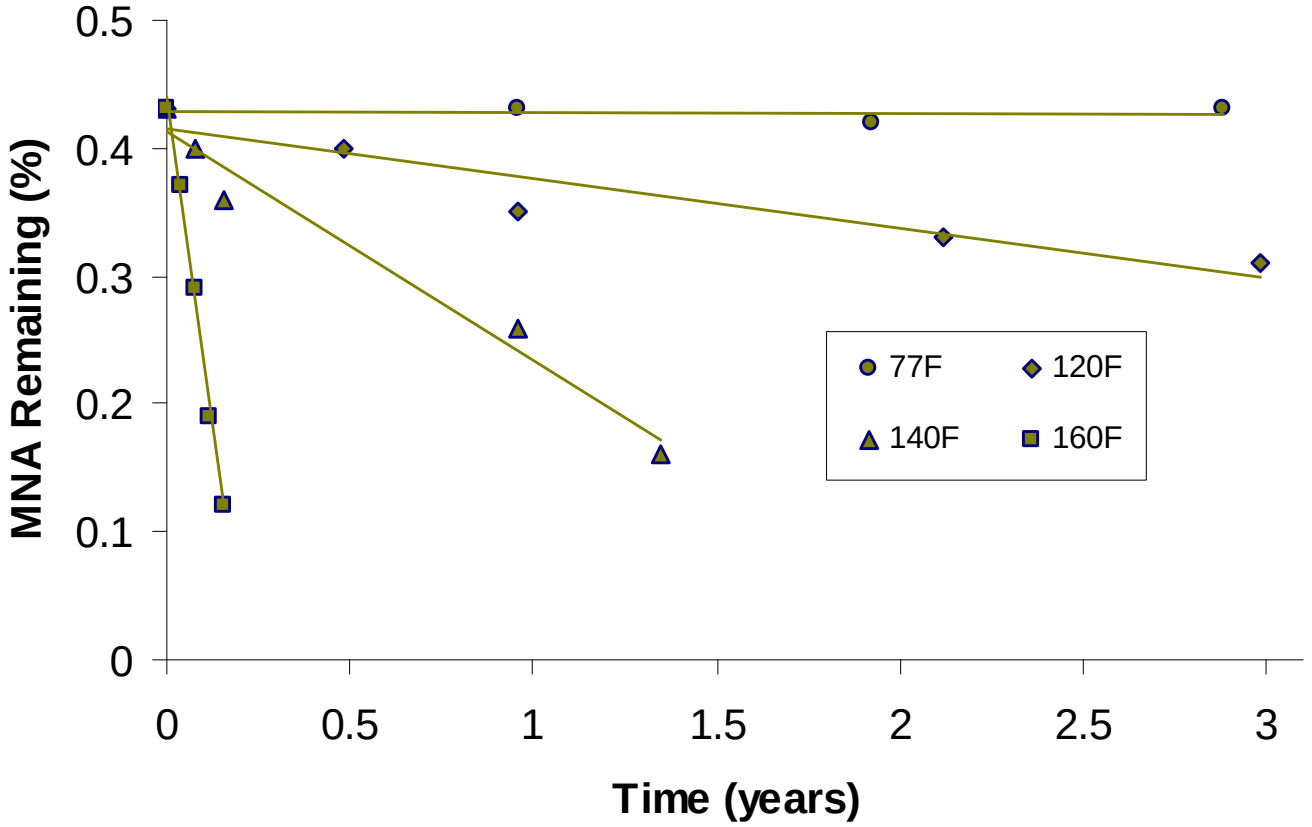

Service life criterion is the time for the MNA concentration to reach 0.1%

Beyond this point gas generation accelerates and grain cracking occurs or propellant softens

Sufficient data available for calculation of activation energy

Stabilizer Depletion -- Reduced Smoke HTPE Propellant

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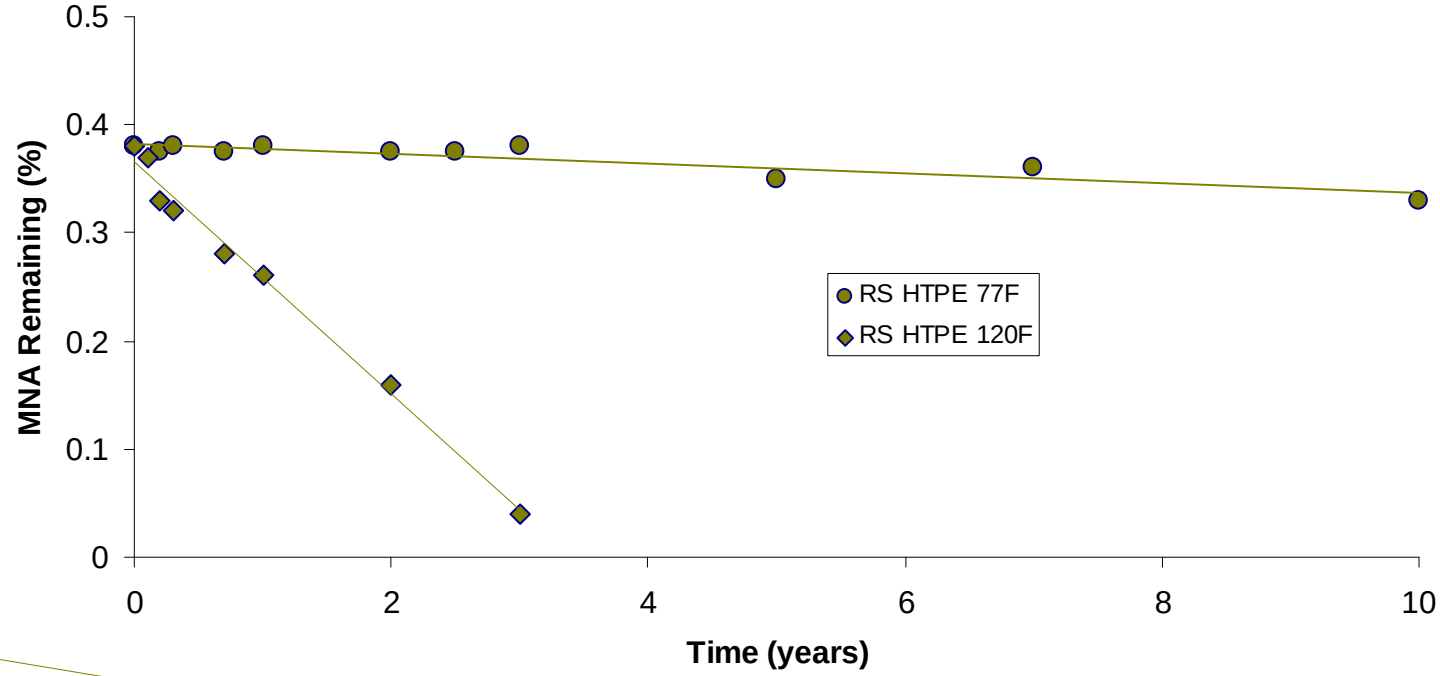

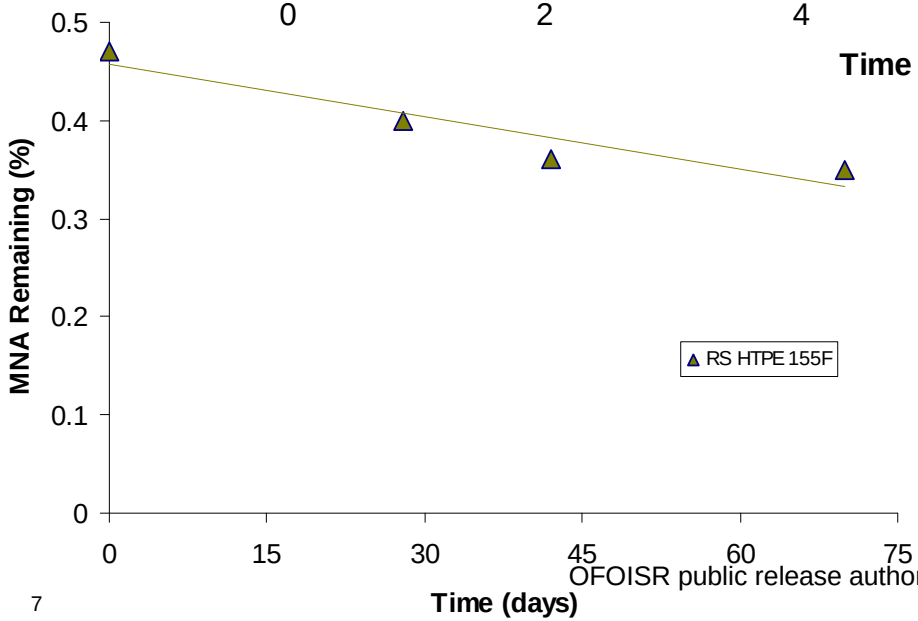

Small amount of MNA stabilizer depleted in ten years at 77 F

Propellants had excellent properties after aging

Stabilizer Depletion -- Aluminized HTPE and Min Smoke Propellants

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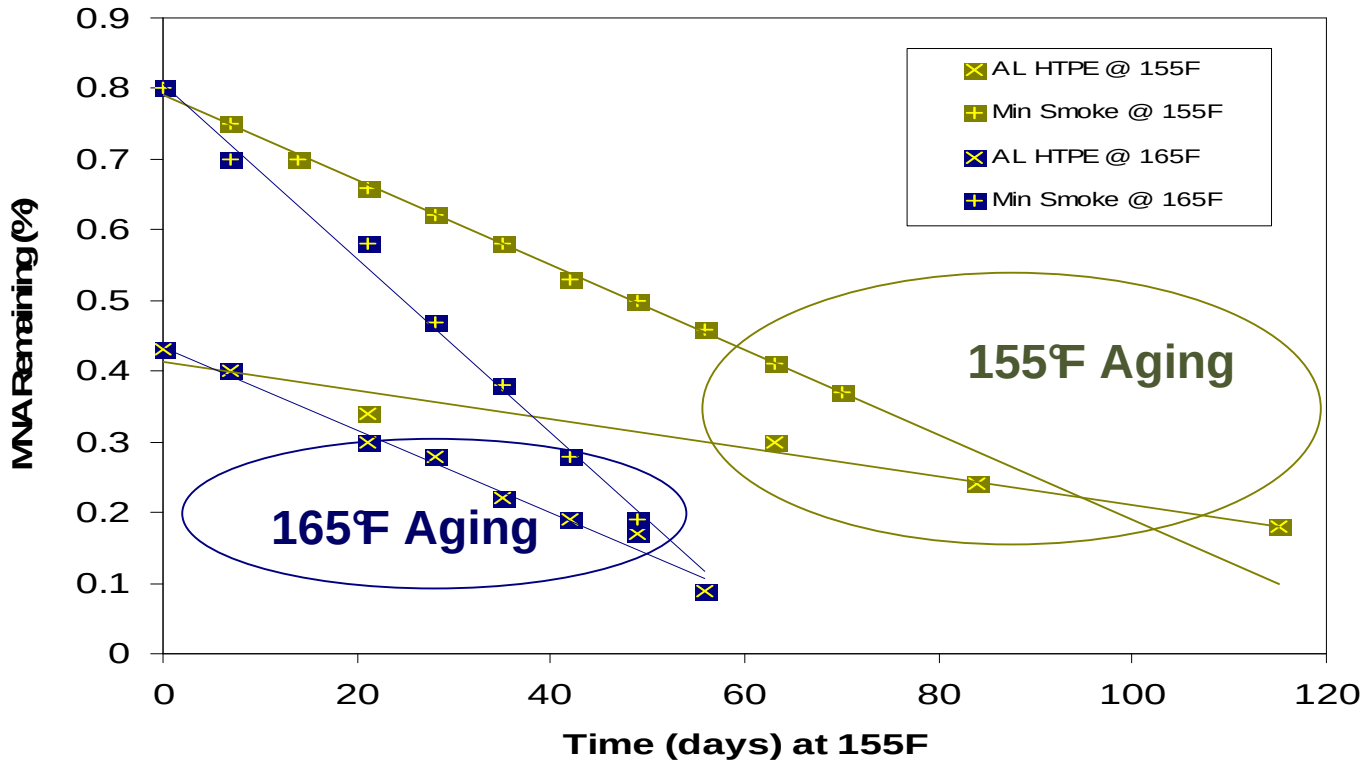

Aluminized HTPE propellants formulated with about half the initial stabilizer content of minimum smoke propellants

MNA stabilizer depletes at about half the rate in HTPE propellant as it does in minimum smoke TOW and Hellfire propellants

Time to reach 0.1% MNA is the same or longer for HTPE propellant

Stabilizer Depletion -- Aluminized HTPE and Min Smoke Propellants

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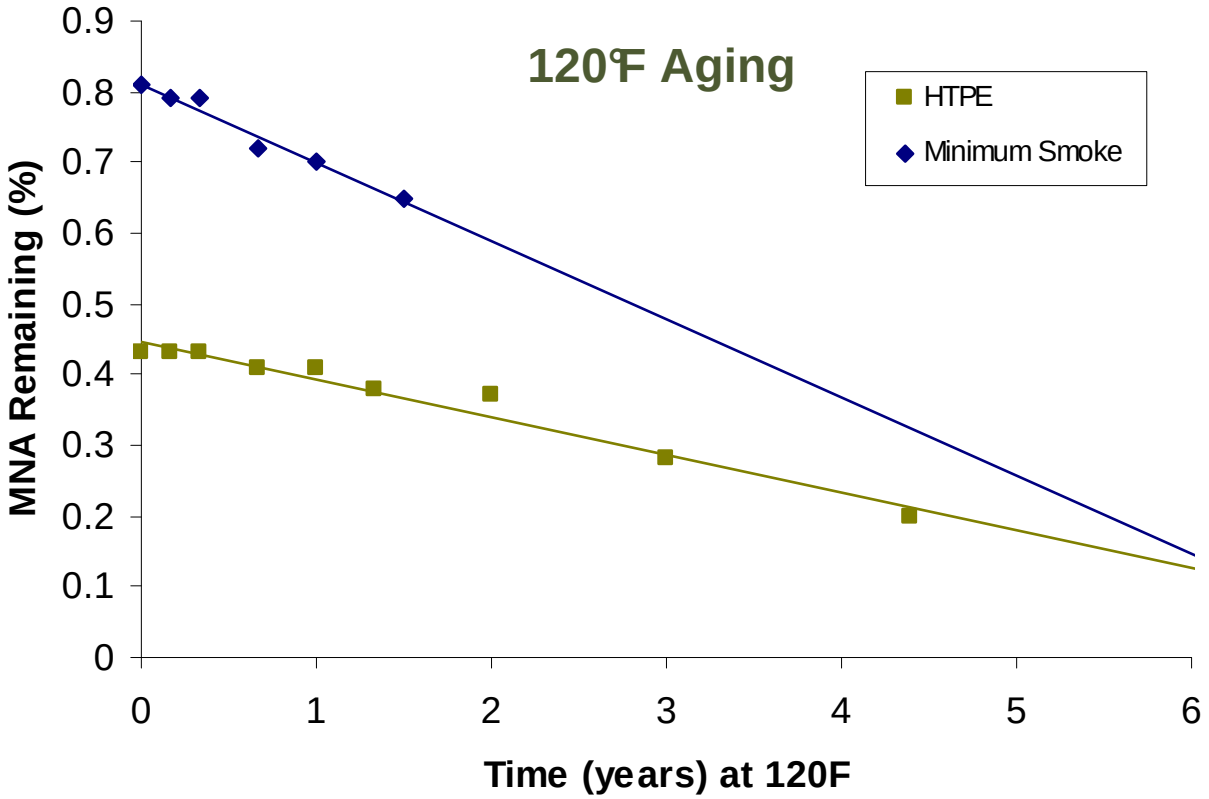
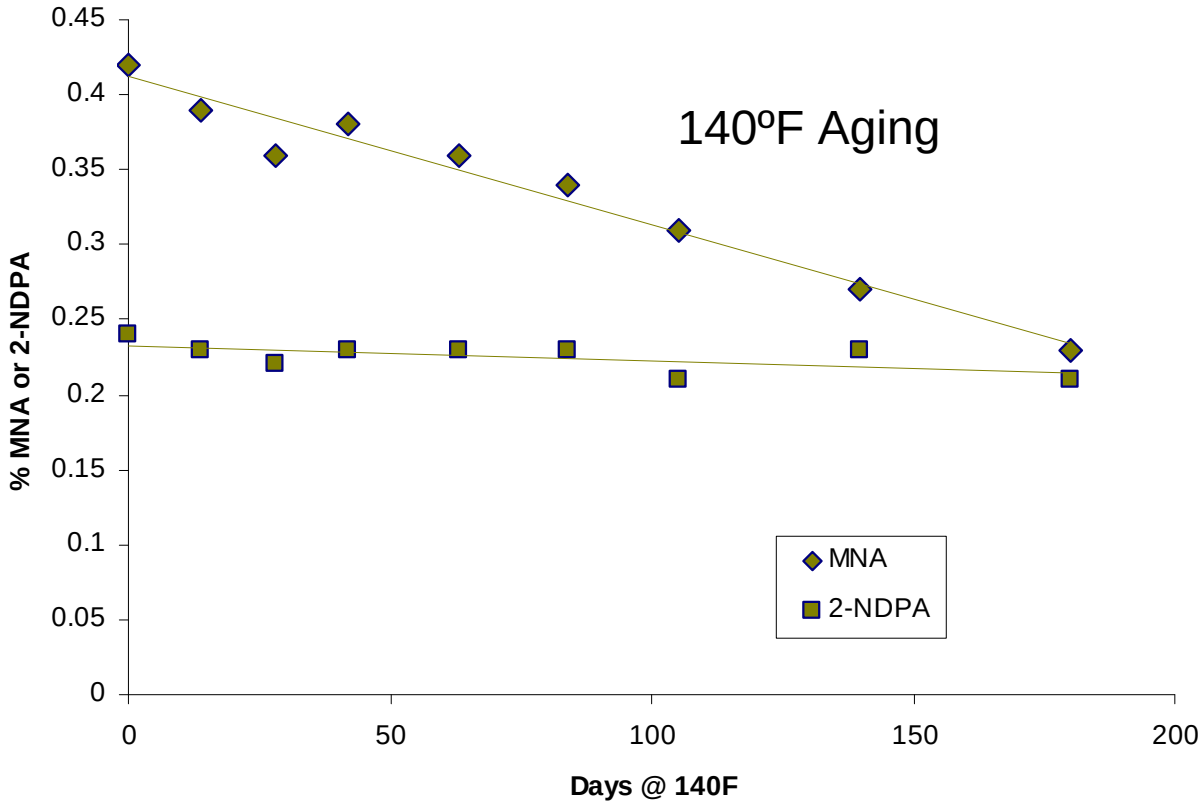


MNA depletion time to 0.1% is about six years at 120℉ for both aluminized HTPE and minimum smoke prop ellants

Expect to have the same service life based on stabilizer depletion

Minimum smoke propellants have demonstrated acceptable service life in a variety of tactical storage conditions

MNA and 2-NDPA Depletion -- Reduced Smoke HTPE Propellant

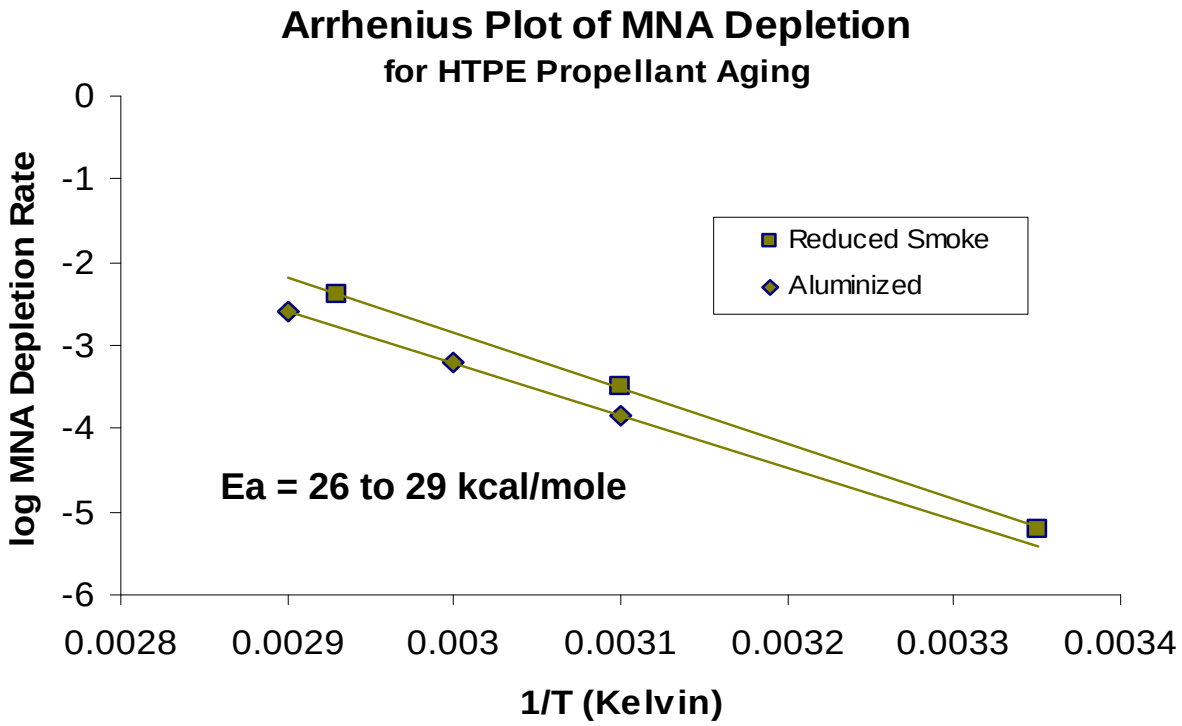


2-NDPA stabilizer concentration remains nearly constant during MNA depletion

MNA depletion to 0.1% signals end of service life

2-NDPA remains to allow safe handling of propellant between end of service life and demil

Stabilizer Depletion -- Arrhenius Plot of HTPE Aging Data

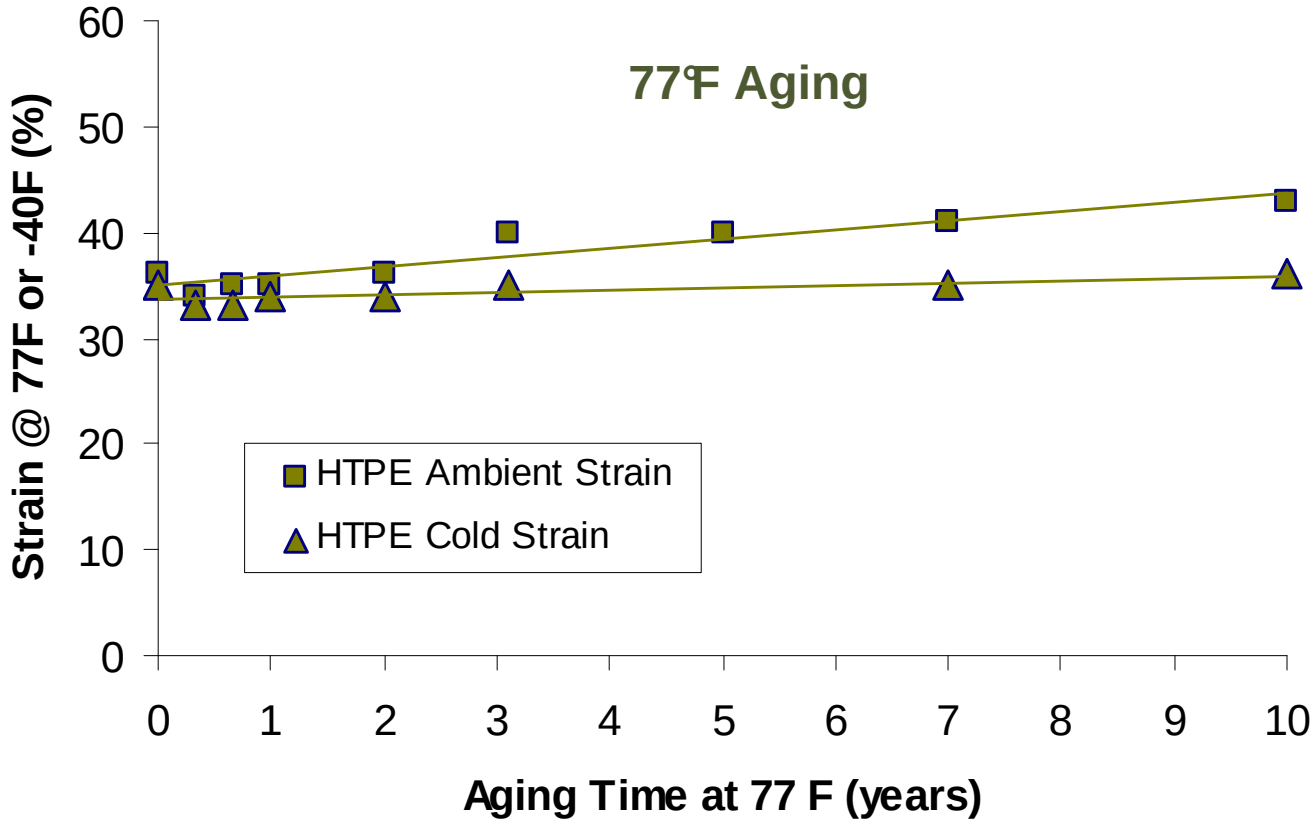


Same activation energy range as for minimum smoke propellants

Can calculate MNA depletion time at any temperature or temperature cycle

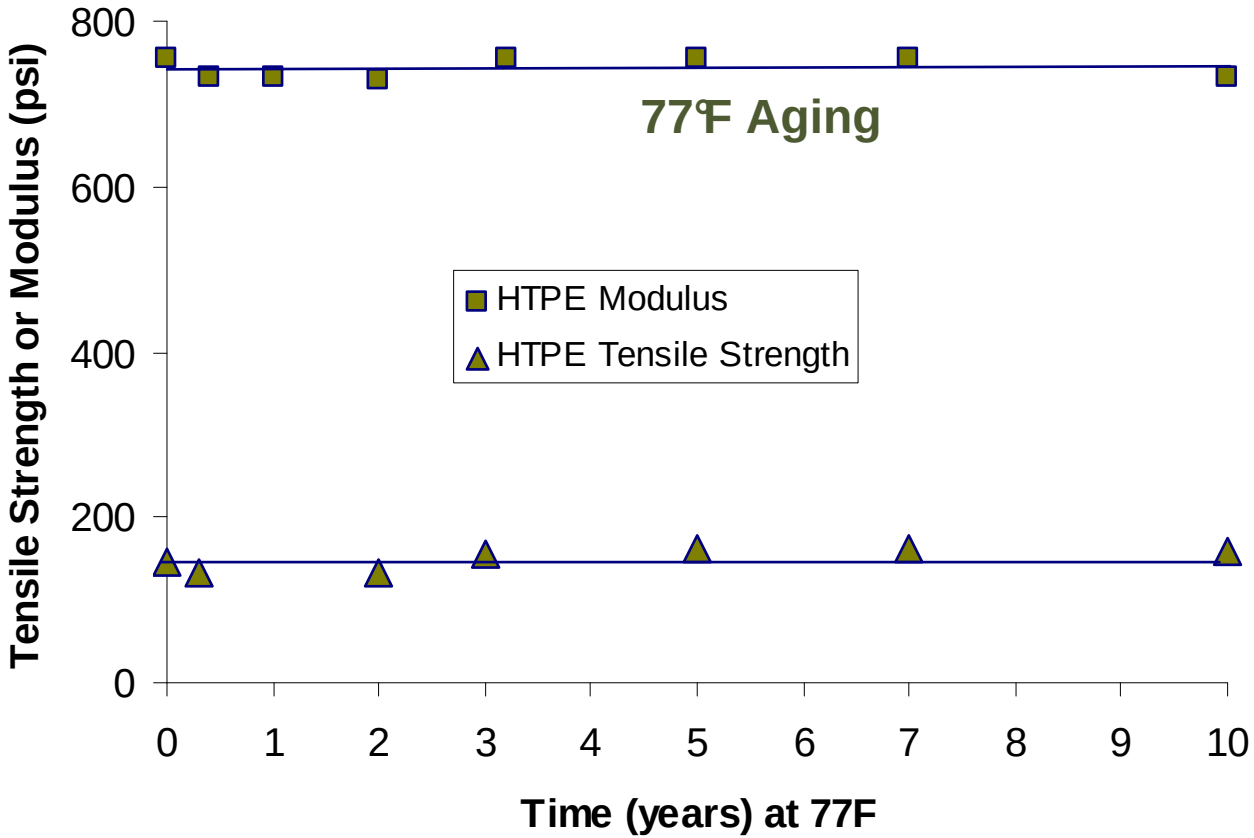
Mechanical Properties

Ambient and Cold Strain -- Reduced Smoke HTPE Propellants



Ambient and cold allowable strain increase slowly during ten-year ambient storage for HTPE propellant

Tensile Strength and Modulus -- Reduced Smoke HTPE Propellant



Tensile strength and modulus for reduced smoke HTPE propellant unchanged after ten years storage

Cold Ignition Simulation -- RS HTPE Propellant Strain

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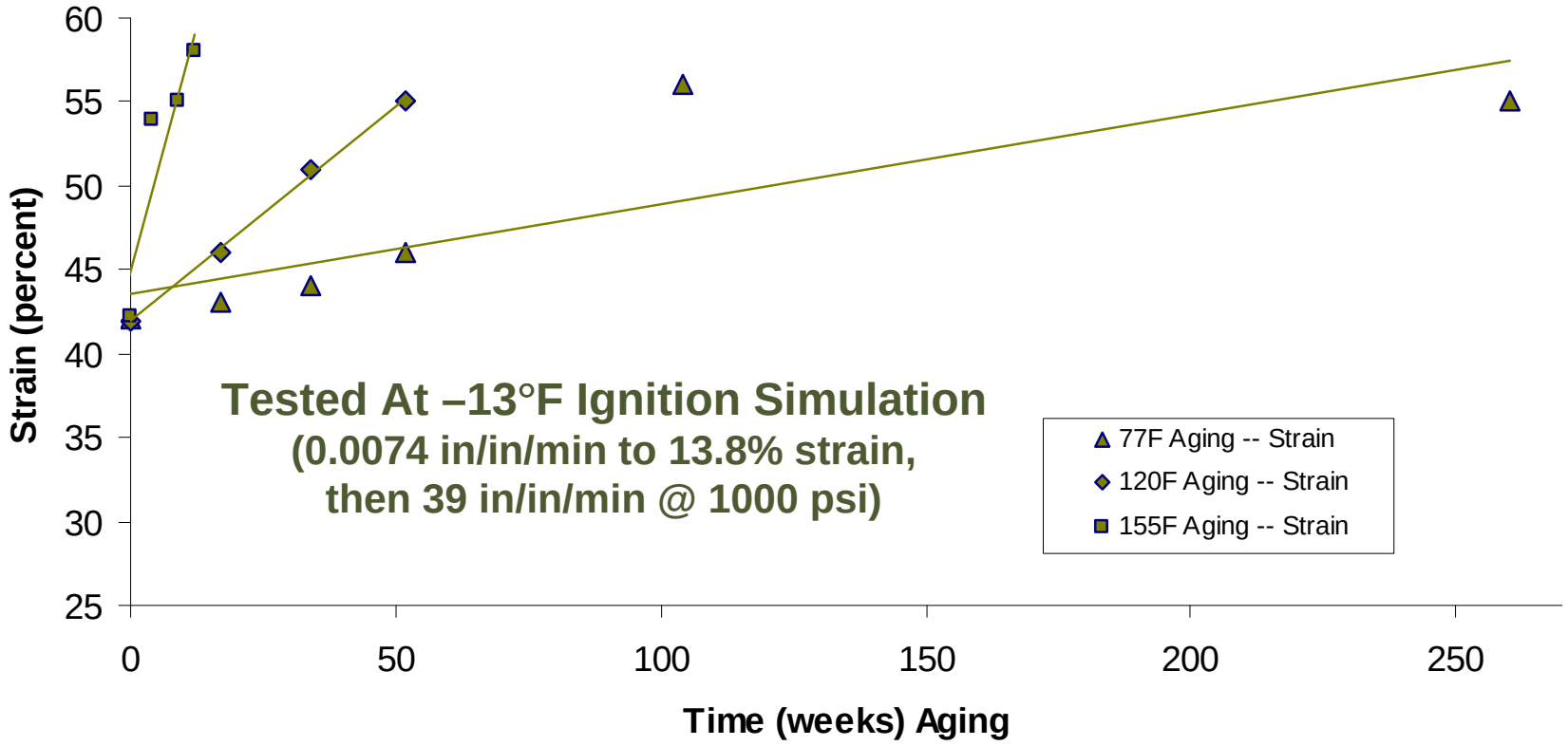

Slow increase in cold ignition simulation strain during elevated temperature aging

Cold Ignition Simulation -- RS HTPE Propellant Tensile Strength

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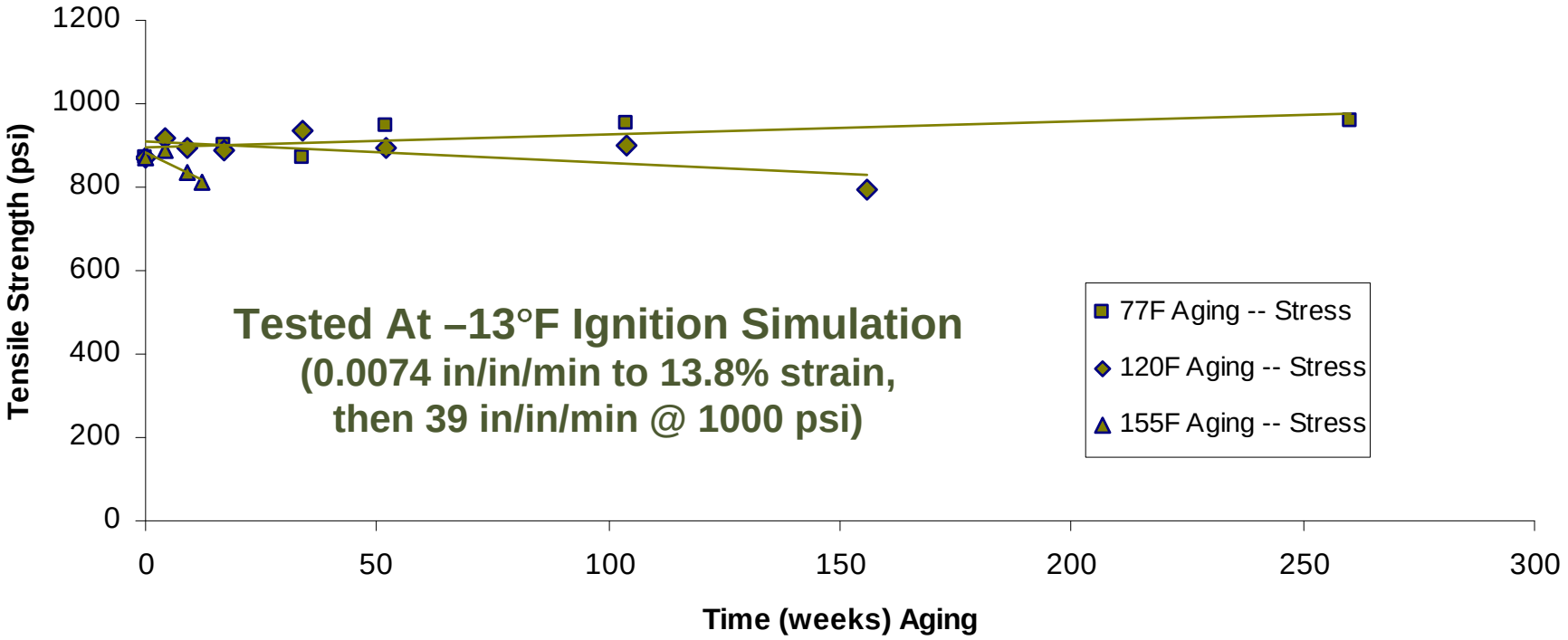

Slow decrease in cold ignition simulation tensile strength during elevated temperature aging

HTPE propellant still serviceable after aging three years at 120℉

Ambient Stress -- Aluminized HTPE and Min Smoke Propellants

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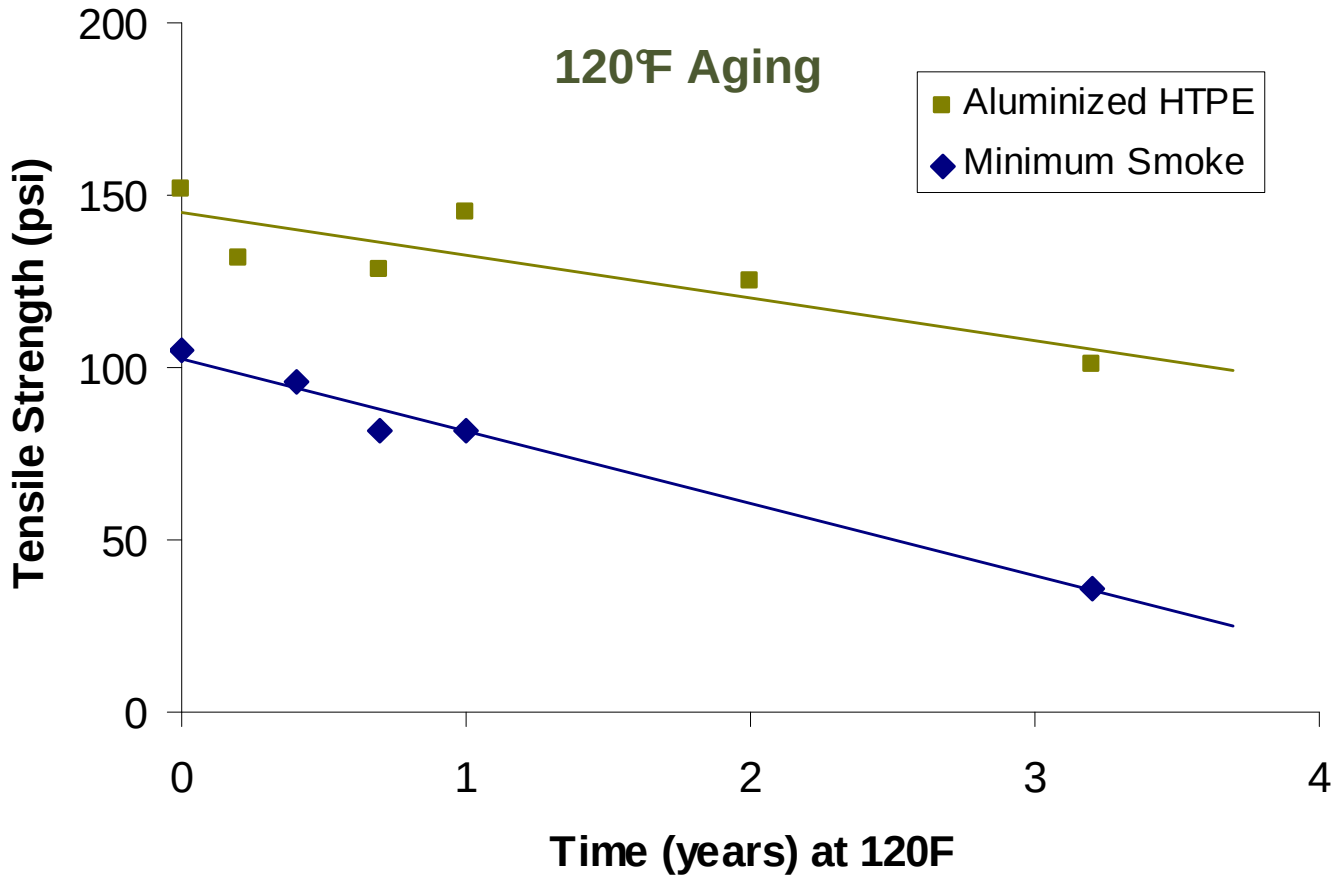

Slow decrease in tensile strength during aging for both propellants

HTPE propellant still serviceable after aging three years at 120℉

Ambient Modulus -- Aluminized HTPE and Min Smoke Propellants

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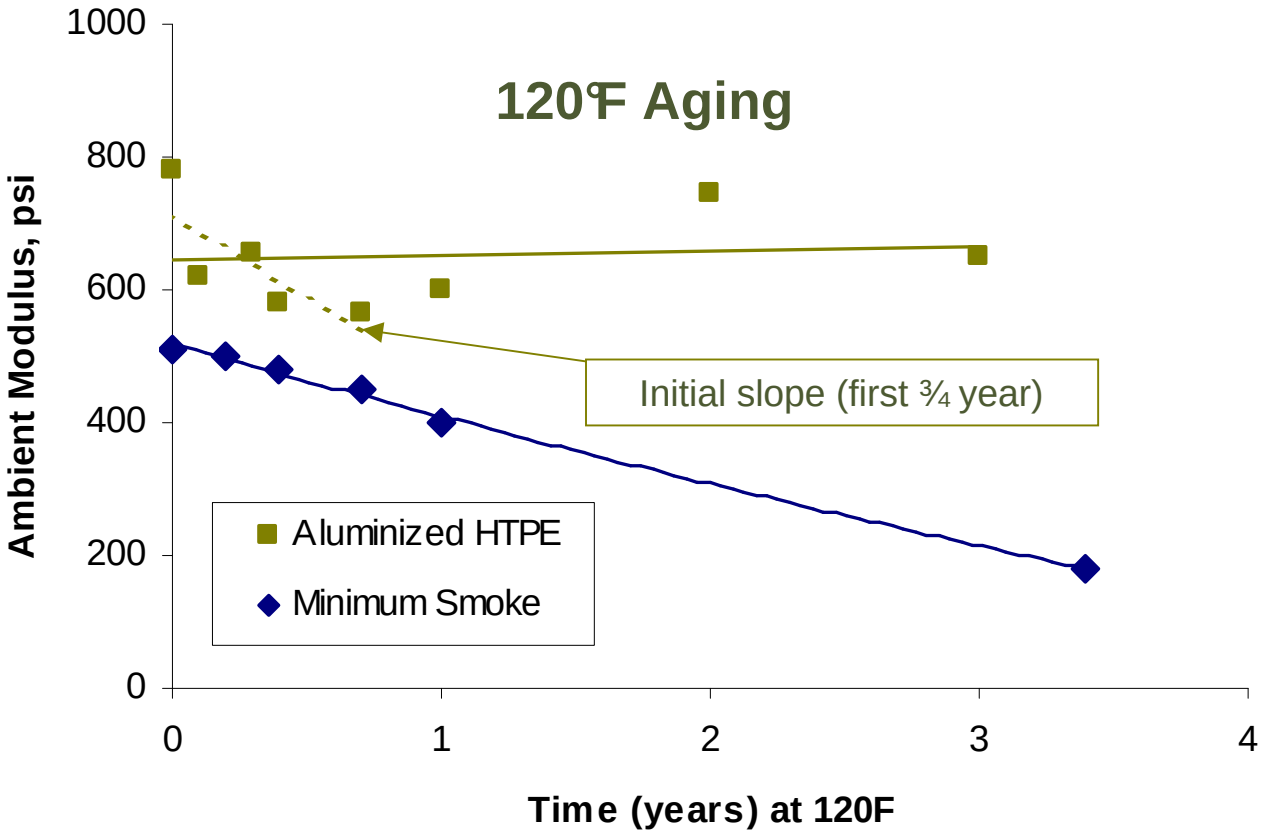
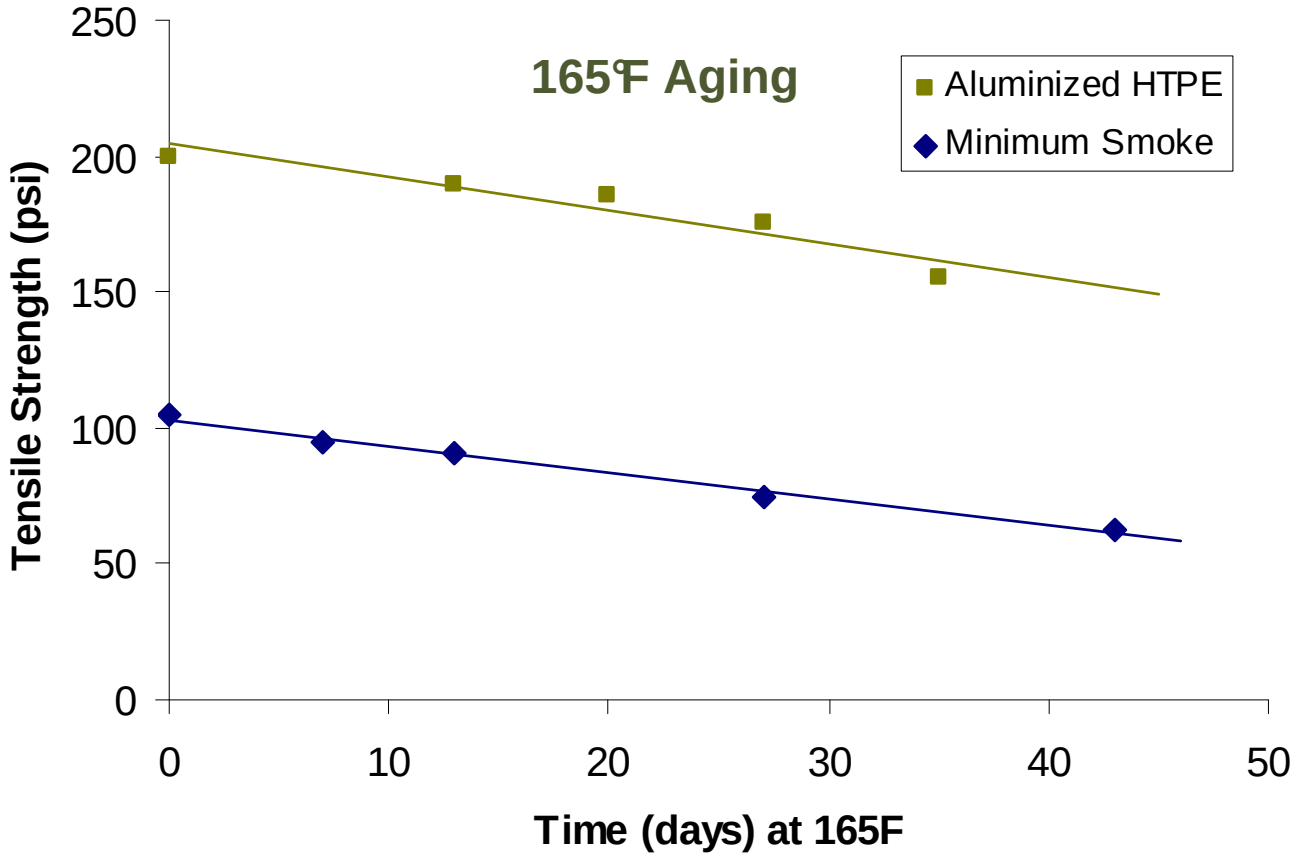


Slow decrease in modulus during aging for minimum smoke propellant; HTPE propellant trend relatively flat

Initial changes in HTPE modulus cannot be extrapolated to later times

HTPE propellant still serviceable after aging about three years at 120℉

Ambient Stress -- Aluminized HTPE and Min Smoke Propellants



Slow decrease in tensile strength during aging for both propellants

HTPE propellant still serviceable after aging about two months at 165℉

Burning Rates of HTPE Propellants -- 155℉, 120℉, a nd 77℉ Aging

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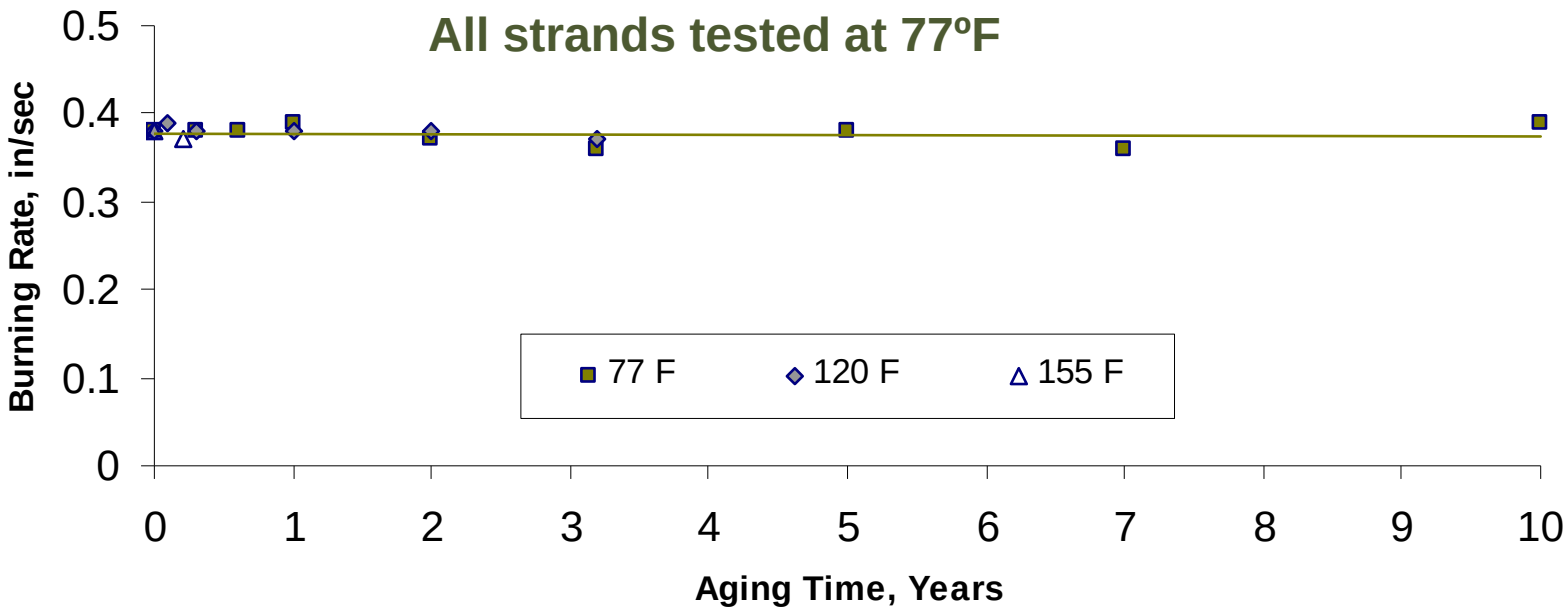

No change in strand burn rate during aging process

Service Life Summary for HTPE Propellant

Service life is equal to or longer than presently deployed minimum smoke propellants in TOW and Hellfire

- Gas generation comparable to or better than that of minimum smoke propellant
- Mechanical property stability is superior to minimum smoke propellants
- Stabilizer depletion time is the same or longer than minimum smoke

Ten-year aging showed no change in tensile strength or modulus

- Small increase in strain capability
- Small loss in stabilizer
- No change in burn rate