AEROJET
A GenCorp Company

NGP
NEXT GENERATION FIRE SUPPRESSION TECHNOLOGY PROGRAM

NAWC
NAVAL AIR WARFARE CENTER

Advanced Propellant/Additive Development for Fire Suppressing Systems

Stephen Fallis and Russell Reed

Research Department, Naval Air Warfare Center Weapons Division, China Lake, CA

Paul Wierenga, Gary F. Holland

Aerojet-Redmond Rocket Center

Redmond, WA

Halon Options Technical Working Conference

May 2003

Outline of Presentation

- Introduction
  - Program Background Information
  - Fire Suppression and GG's
- Propellant Development
  - Cooler, High Nitrogen Compositions
- Effectiveness Testing
  - SPFEs (Solid Propellant Fire Extinguishers)
  - HFEs (Hybrid Fire Extinguishers)
- Summary
- Acknowledgements

But First…

GF Holland
PH Wierenga

S Fallis
R Reed

PRIMEX AEROSPACE COMPANY

Olin Aerospace

Rocket Research

Fire Suppression Mechanistics

$$FE = X_{dil} + X_{cool} + X_{chem} + X_{flow}$$

- X_{dil} ~ dilution effects: $[O_2] \approx 12\text{-}13\%$
- X_{cool} ~ cooling effects: $C_p \approx 40\text{-}50$ cal/°K-mol O_2
- X_{chem} ~ chemical effects: radical traps
- X_{flow} ~ flow rate effects: dec τ_{res} in flame zone

Solid Propellant
Fire Suppression Systems

AEROJET

NAWC NAVAL AIR WARFARE CENTER

Current State of the Art:

- Size competitive w/ Halon-1301 (volume, mass)
- Effective, clean, fast acting
- Environmentally rugged and reliable
- Low human hazard: CO_2, N_2, H_2O
- Environmentally friendly, SNAP-approved
- Temperature compensating designs
- All based on commercial automotive airbag technology

Next Generation Objectives:

- Improve effectiveness via:
  - Increased cooling
    - Cooler burning propellants
    - Hybrid configurations
  - Increased gas output
  - Added chemical activity

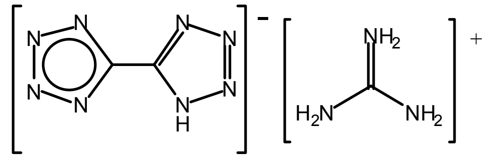
Opportunity:

- 2-5x reduction in agent loads

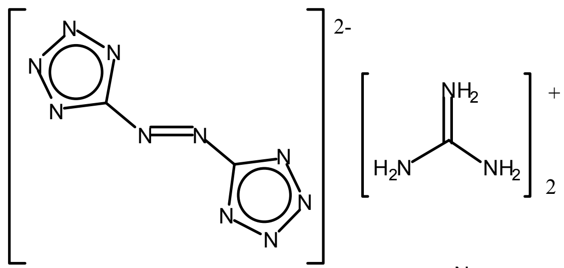
Program Background Information:
Propellant Development

- **Phase I**
  - Developmental Compositions, High-N Compounds
  - Chemically Active Formulations: vary agent
- **Phase II**
  - BTATZ Scale-up
  - Chemical additives incorporated into SPFE, HFE
- **Phase III**
  - BTATZ Formulations: Ballistic Testing
  - Chemically Active Formulations: vary [agent]

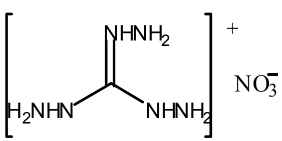
High-Nitrogen Fuels Used in CL/PAC Propellant Development



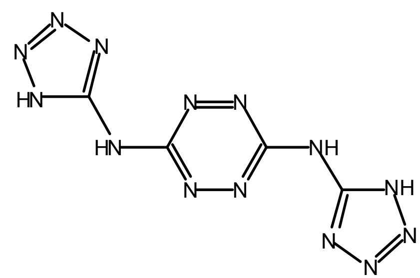
Guanidinium
Bitetrazole
(GBT)



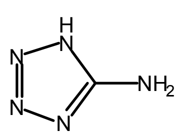
Bisguanidinium
Azotetrazole
(GAZT)



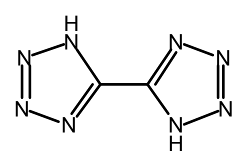
Triaminoguanidium
Nitrate(TAGN)



Bis(aminotetrazolyl)tetrazine
(BTATZ)



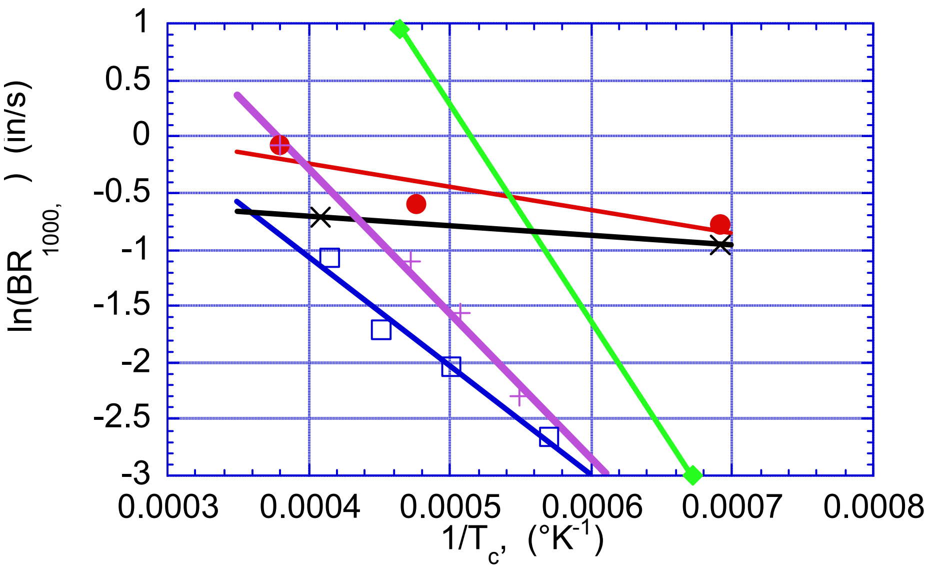
5-Aminotetrazole
(5AT)



Bitetrazole(BT)

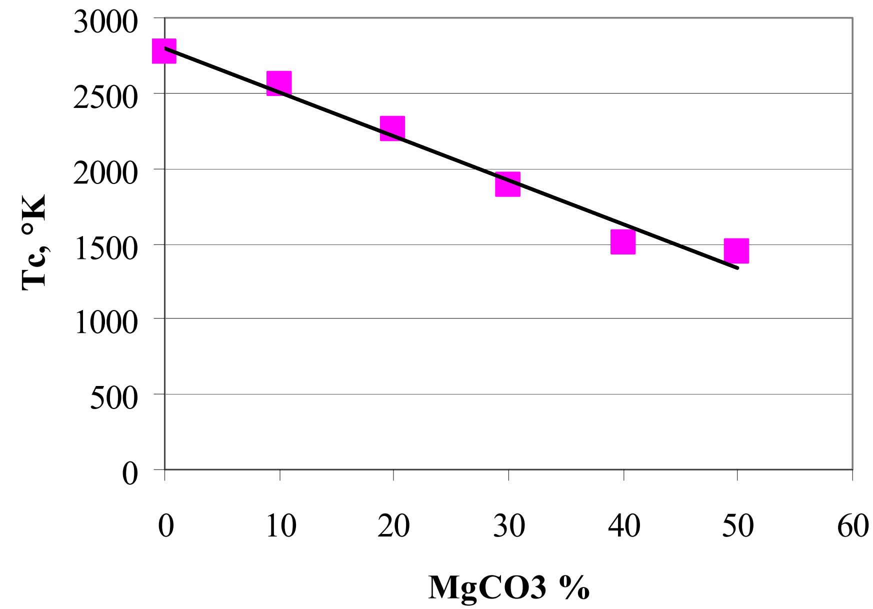
Effect of Combustion Temperature on Ballistics

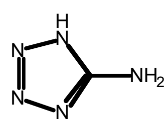
- **Trends**
  - **BR not predictable by T_c alone**
  - **Falloff in BR follows Arrhenius-type activated process**
    - **$\ln(BR) = f(1/T_c)$**
    - **Slopes vary**
- **Predictive tool?**



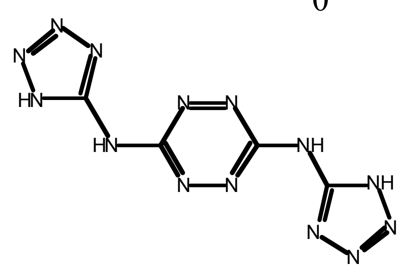
Control of Exhaust Temperatures

- Propellant modifications
  - Vary F, O
    - F+O ——> CO_2, N_2, H_2O
  - Incorporate coolant
  - Calculate T_c (combustion)
  - T_{meas} ~ 200–600 °C
- Hybrid combinations
  - T_{meas} ~ 50 100 °C





5-Aminotetrazole
(5AT)

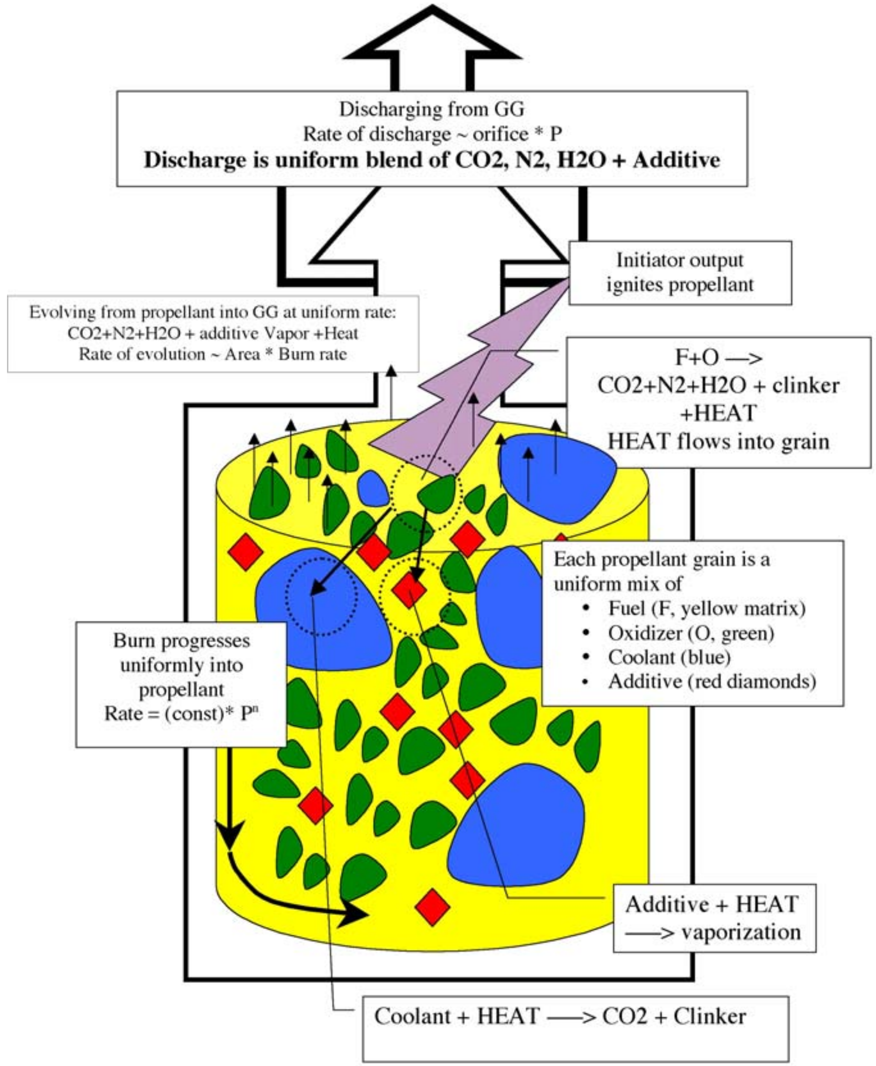


Bis(aminotetrazolyl)tetrazine
(BTATZ)

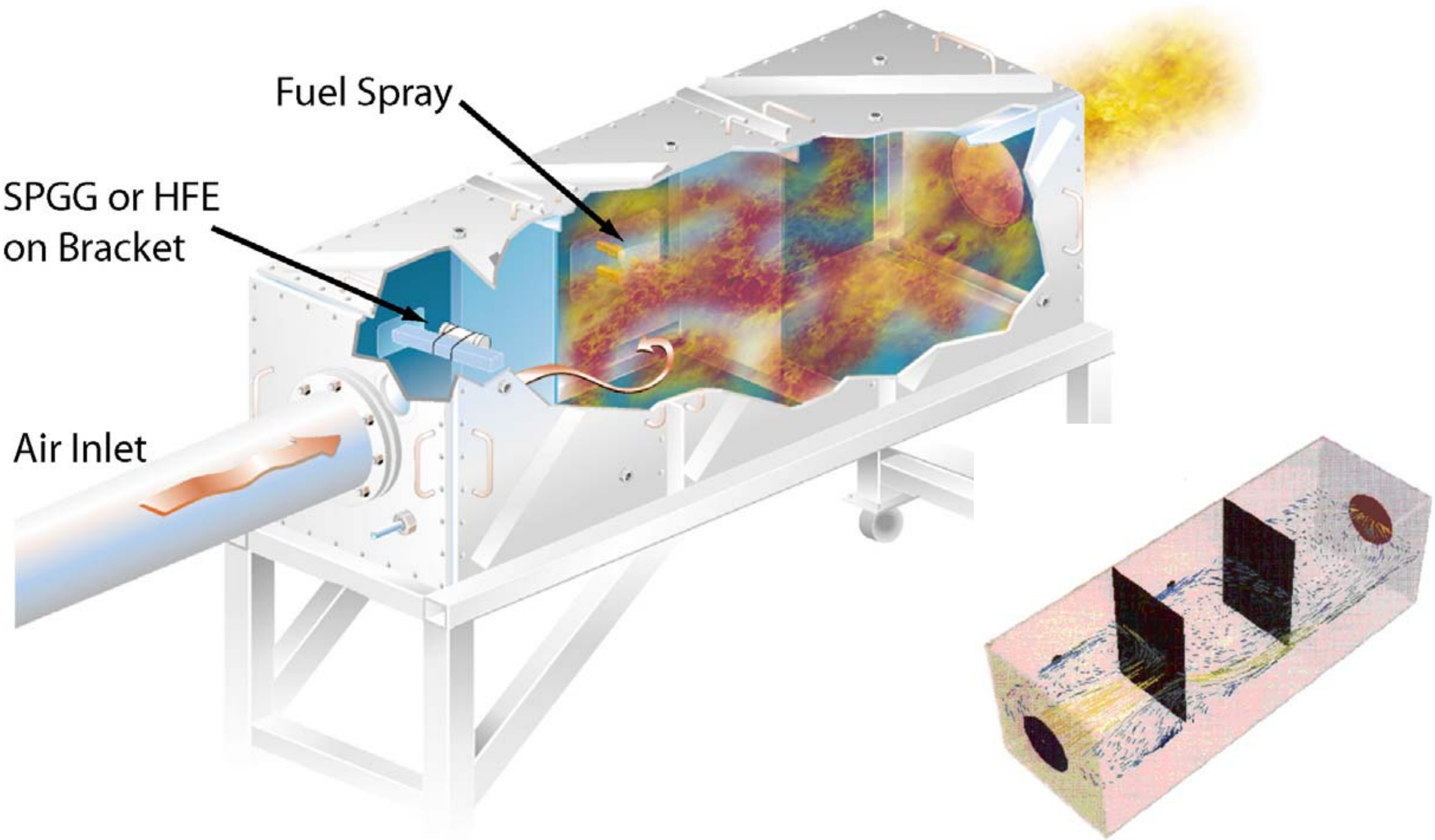
Developmental Propellants:
High Gas, Cooler Gas

Descriptors	T_c, ¡C	Gas, mol/100g	theoretical density, g/cc	BR_{1000}, in/s
BTSN-00	2501	2.27	2.38	1.09
BTSN-10Ê	2289	2.12	2.43	TBD
BTSN-20	2032	2.00	2.49	0.75
BTSN-30	1621	1.89	2.55	TBD
BTSN-40	1537	1.79	2.61	0.35
BTSN-50	1071	1.54	2.67	0.15

Propellant Combustion



Aerojet Fire Test Fixture



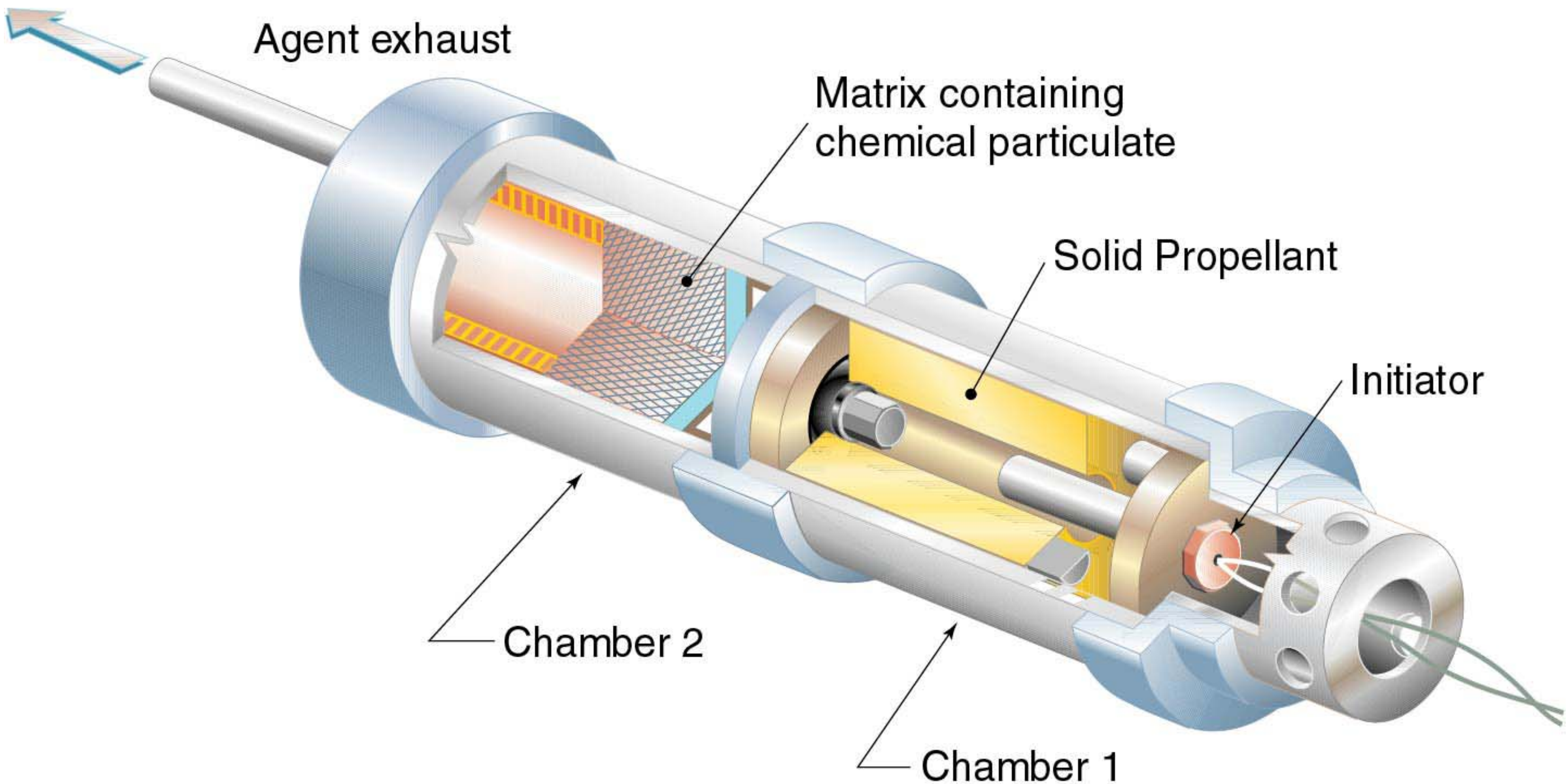
Test Fixture Parameters

- ~700 kW Flame Intensity
  - Flame temperature = ~1000 K (1300 °F)
  - Air flow rate = 450 g/s (1 lb_m/s)
  - Fuel flow rate = 15 g/s (0.033 lb_m/s)
  - Air:fuel ratio = 31
  - Equivalence ratio = 0.5

$$\dot{m}_{air} / \dot{m}_{fuel}$$

- 24 ft^3 Total Volume (16 ft^3 fire zone)
  - Residence time = ~1 s (through fire zone)
- 100-200 ms Discharge Time for SPFEs and HFEs

Aerojet SPFE Active Agent Test Unit



Test Videos: Active Agent Assessment

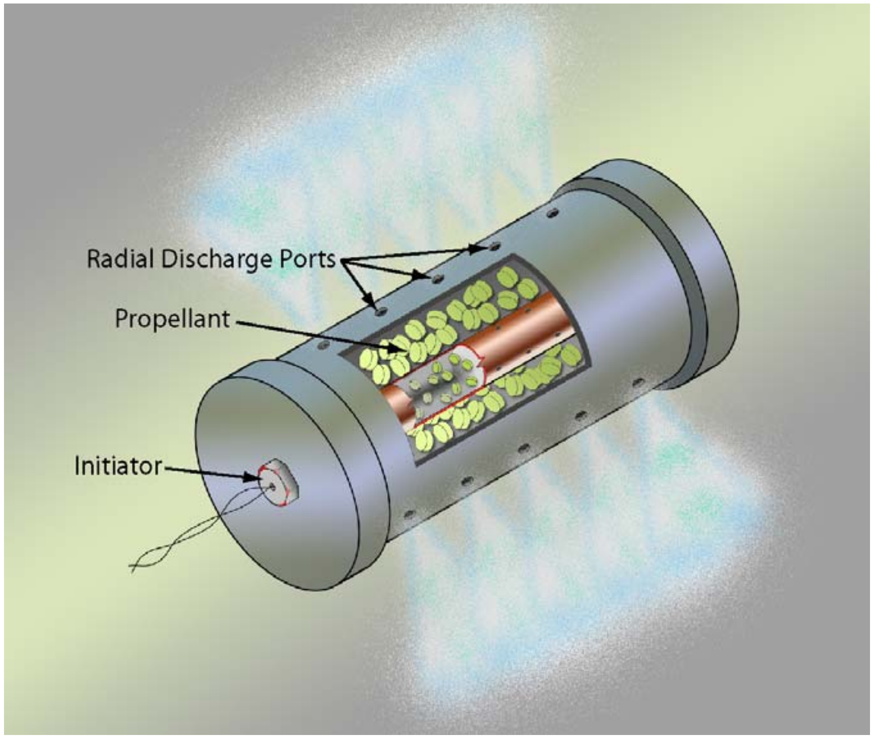
$Fe_2O_3/FeCp_2$

KI/K_2CO_3

Summary of FTF Data

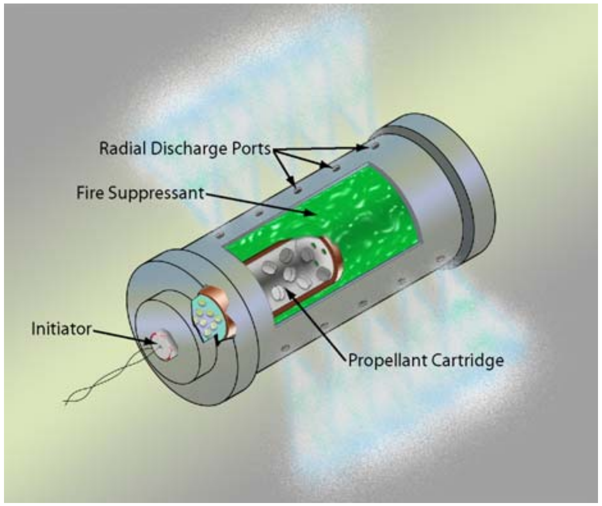
	50% split				50% split		
Neat agent	**Agent mass, g**	**Test No.**	**Result**	**Neat agent**	**Agent mass, g**	**Test No.**	**Result**
KI	20	027-06	fire not out	***Fe_2O_3***	40	038-01	fire not out
	40	027-07	fire not out		80	038-02	fire not out
	40	027-05	fire out				
	60	027-04	fire out				
KBr	40	032-02	fire not out	***Ferrocene***	40	039-01	fire not out
	60	032-03	fire not out		80	039-02r	fire not out
	60	032-01	fire not out				
K_2CO_3	20	035-03	fire not out	***Fe Oxalate***	40	040-01	fire not out
	40	035-02r	fire out				
	60	035-01	fire out	***PBPE***	60	041-01	fire not out

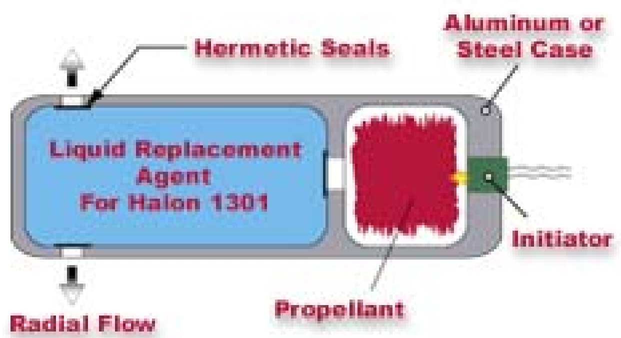
SPFE's



- **Advantages**
  - **Rapid discharge**
  - **No storage pressure**
  - **T-compensating**
- **Applications**
  - **Ballistic & safety fire protection for aircraft.**
  - **Land vehicle engine compartments.**
  - **Electronics bays**

Hybrid Fire Extinguishers

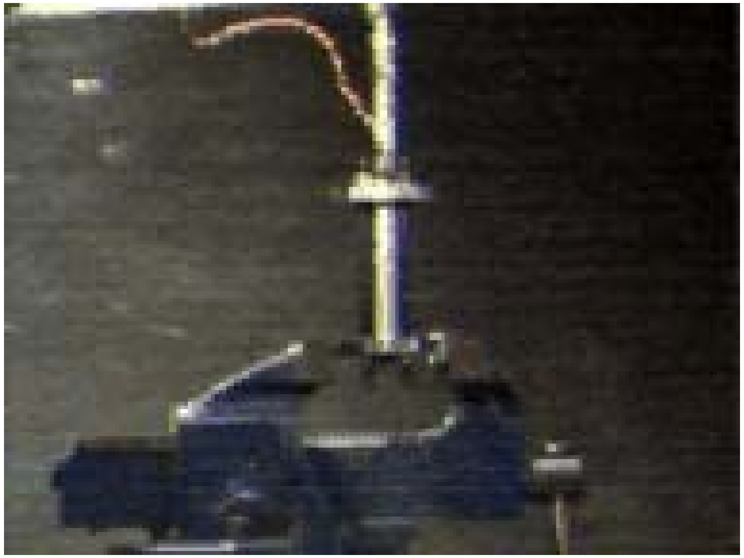




- **Advantages**
  - **Tailorable discharge**
  - **Fits into current Halon 1301 envelope**
  - **Low/No storage pressure**
  - **T-compensating discharge**
- **Applications**
  - **Armored vehicle engine & crew compartments.**
  - **Aircraft engine nacelles.**
  - **Automotive & industrial fire/explosion protection**

SPFE, HFE Testing

Fire Test, active agent



Discharge demo, active agent (100x)

3304/FM200 HFE Fire Out Sequence

HFE Function: T= 0 msec

T= 33 msec

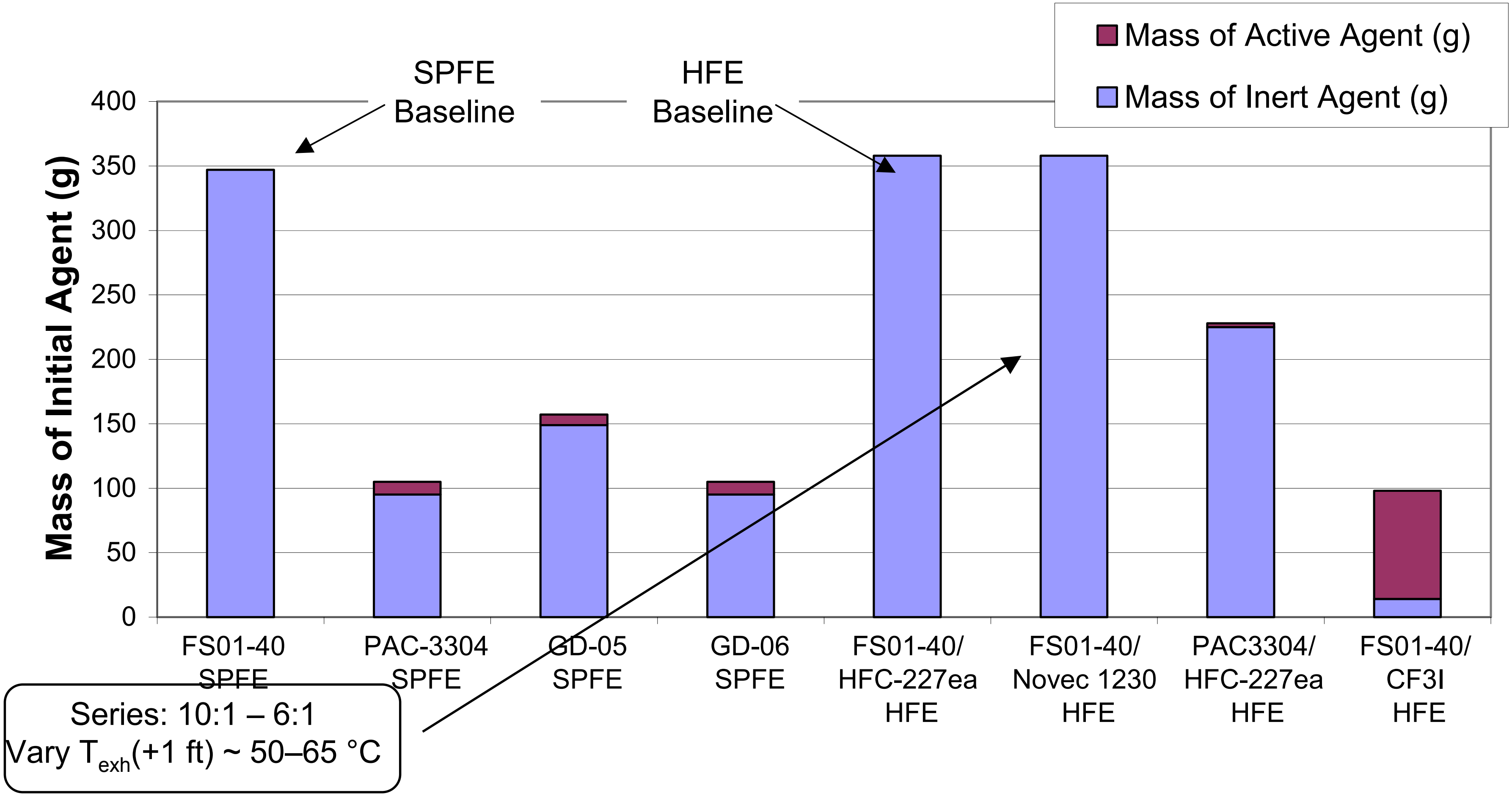
T= 66 msec

T= 99 msec

T= 132 msec

T=165 msec

Performance Summary



Conclusions

- **BTATZ-based formulations provide excellent platform for cooler-burning FS compositions**
- **Increasing the amount of active additive leads to more efficient SPFE and HFE performance.**
  - **Catalysis not yet saturated**
- **HFE's effective for low vapor pressure fluids**
  - **Higher-boiling fluorocarbons**
  - **Water-based systems**

Acknowledgements

- **Suppression and Ballistics Testing:**
  - At China Lake: Dr. T. P. Parr, R. Stalnaker, J. Hitner, P. Curran, A.I. Atwood
  - At Aerojet/GD: Gary Gregg, Jennifer McCormick, Chuck Anderson, Ron Paxton, Ray Nikko

- **Funding**
  - SERDP's Next Generation Fire Suppression Technology Program (NGP)
  - Naval Air Combat Survivability Program