Accelerated Aging of the M864 Baseburner Assembly

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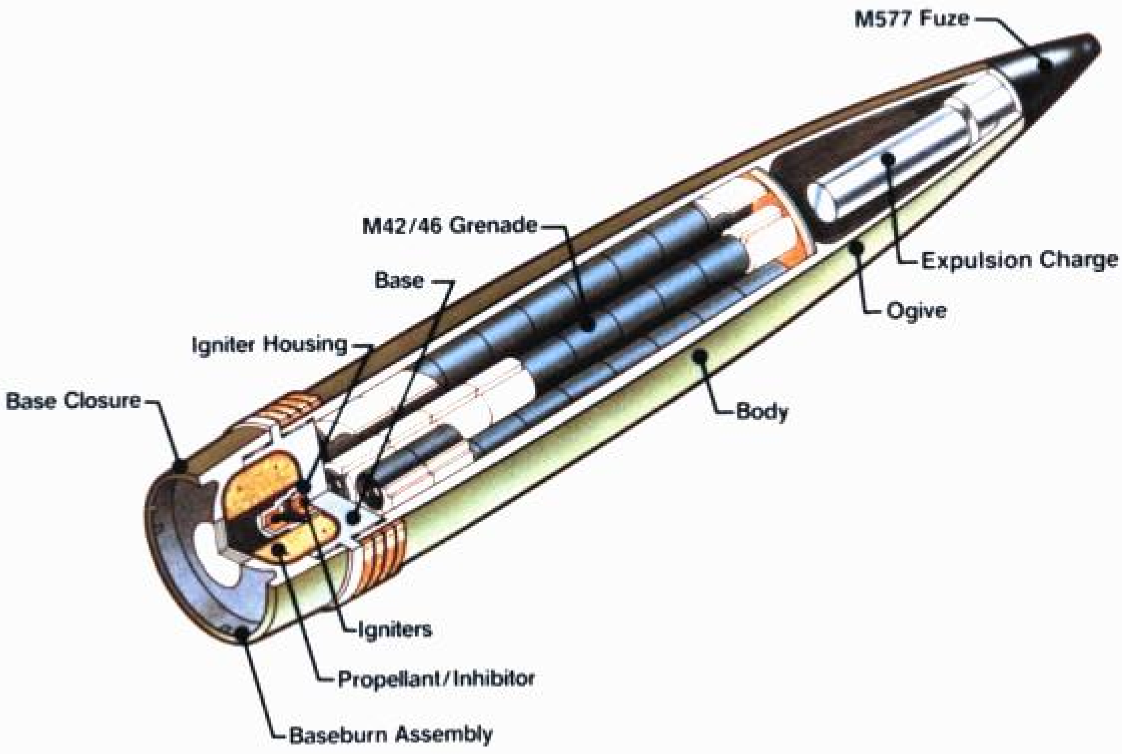
ABSTRACT

- ***An accelerated aging program and a surveillance program were conducted to evaluate the lifetimes of the baseburner assembly for the M864.***

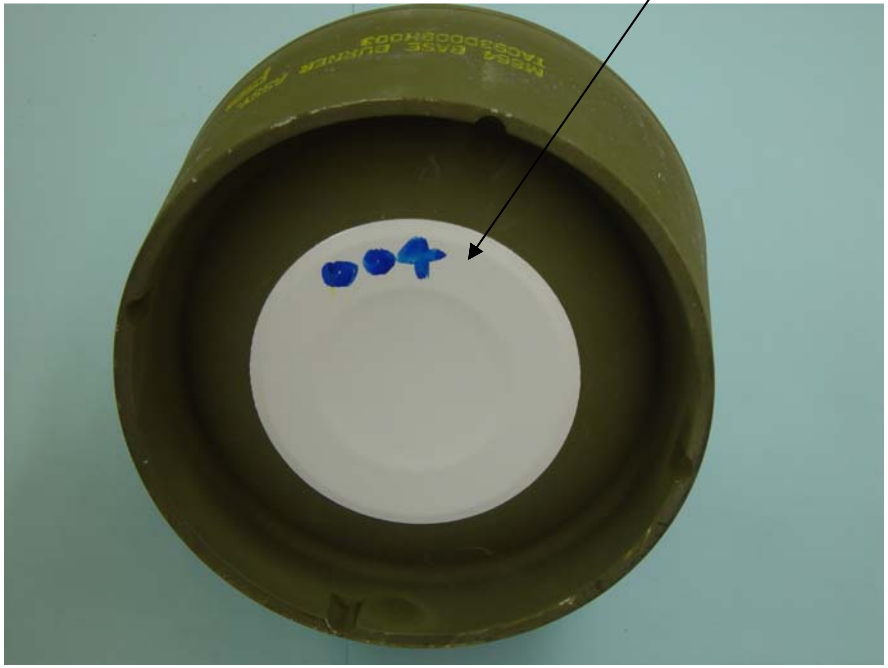
155mm M864 MAJOR COMPONENTS



Baseburner Assembly with weatherseal

EXCELLENT ADHESION UNLESS REMOVED INTENTIONALLY

Weatherseal



Mathematical Models

Theoretical Development

$$C_A = C_{A0} - k*t$$

Zero Order

$$C_A = C_{A0}*e^{(-k*t)}$$

First Order

$$k = \{k_0*e^{(-Ea/RxT)}\}$$

Arrhenius

$$k = \{k_0*e^{(-Ea/RT)}\} \times \{e^{(B * \%RH)}\}$$

Eyring

$$F(t,V) = 1 - R(t,V)$$

Cumulative Damage Model

$$\Delta C_A = C_{Af} - C_{A0}$$

Change in Property based on Surveillance Data

Nomenclature Used in Reaction Kinetic Modeling of variables data

- C_{A0} = Initial value of property
- T = absolute temp
- t = time
- C_A = Property value as a function of time
- k = rate constant
- V = Stress level

Accelerated Aging Conditions for Baseburner Assembly

Temperature (°F)	Humidity (% RH)	Weatherseal Present
225 °F	0 % RH	Yes
200 °F	90 % RH	Yes
200 °F	90 % RH	No
200 °F	55 % RH	No
175 °F	90 % RH	No

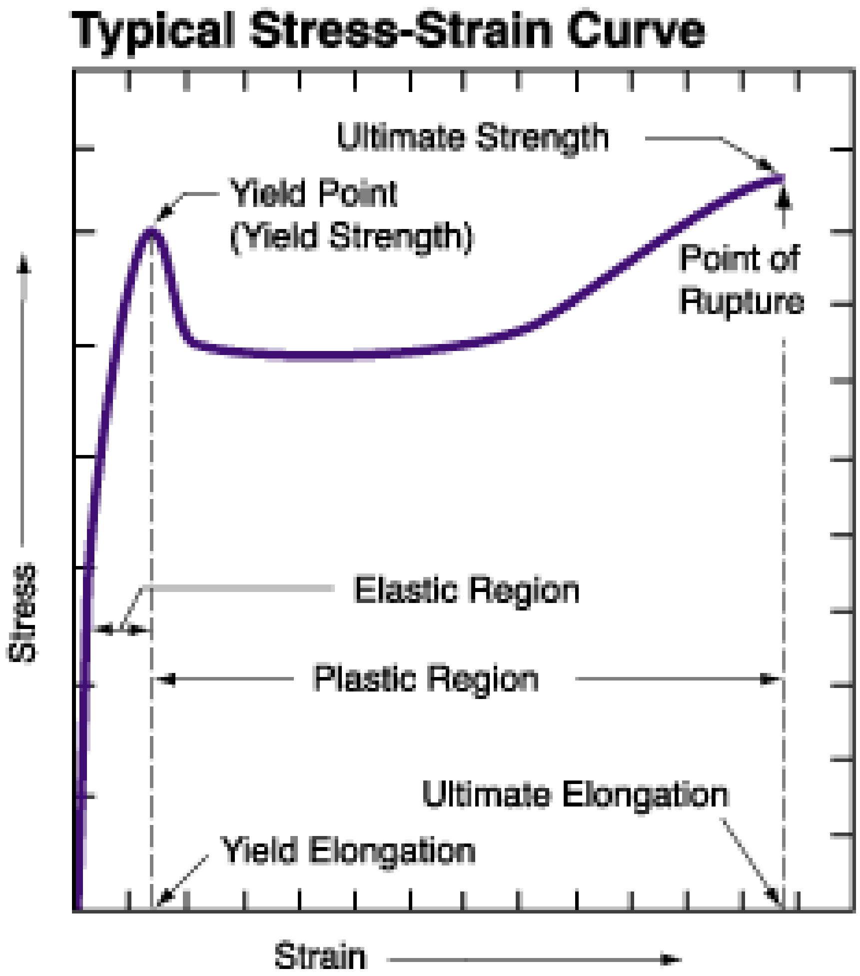
5 baseburner assemblies in chamber prior to conditioning

Samples were periodically withdrawn from the conditioning chamber

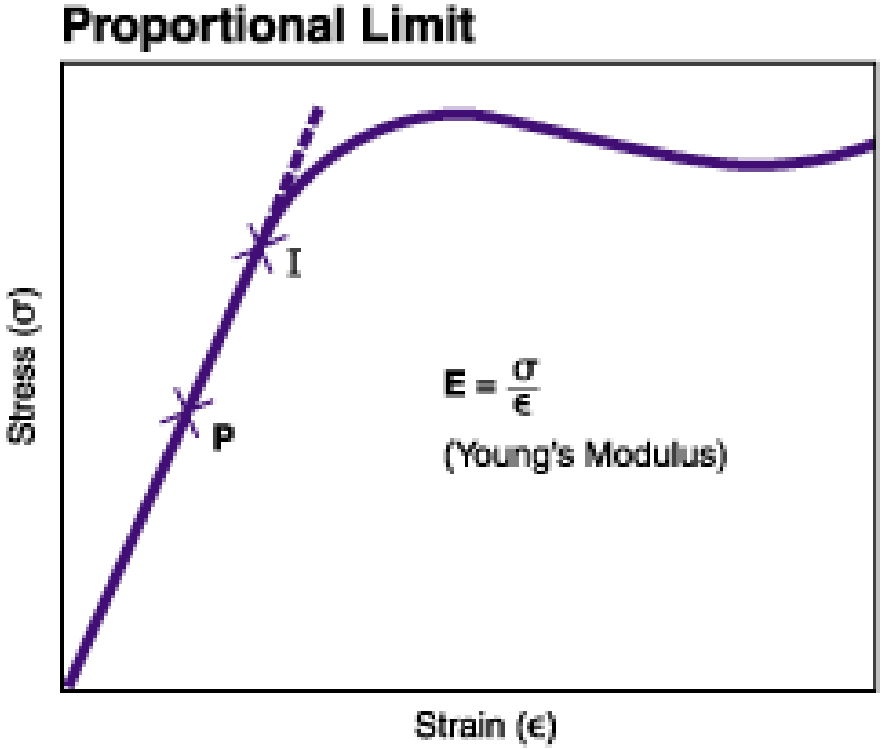
Hot and Humid Cycle Used for Uncontrolled Storage Simulations

Local Time	T in °C	%RH	Local Time	T in ° C	%RH
0100	35.00	67.00	1300	66.00	16.00
0200	34.00	72.00	1400	69.00	15.00
0300	34.00	75.00	1500	71.00	14.00
0400	34.00	77.00	1600	69.00	16.00
0500	33.00	79.00	1700	66.00	18.00
0600	33.00	80.00	1800	63.00	21.00
0700	36.00	70.00	1900	58.00	29.00
0800	40.00	54.00	2000	50.00	41.00
0900	44.00	42.00	2100	41.00	53.00
1000	51.00	31.00	2200	39.00	58.00
1100	57.00	24.00	2300	37.00	62.00
1200	62.00	17.00	2400	35.00	63.00

Mechanical Property Definitions



Young's Modulus or Modulus of Elasticity



Testing Procedure

- “dogbones” were fabricated from the baseburner assembly propellant grains
- Properties were measured prior to conditioning
- Samples were periodically withdrawn from the conditioning chamber
- Properties were measured on the samples

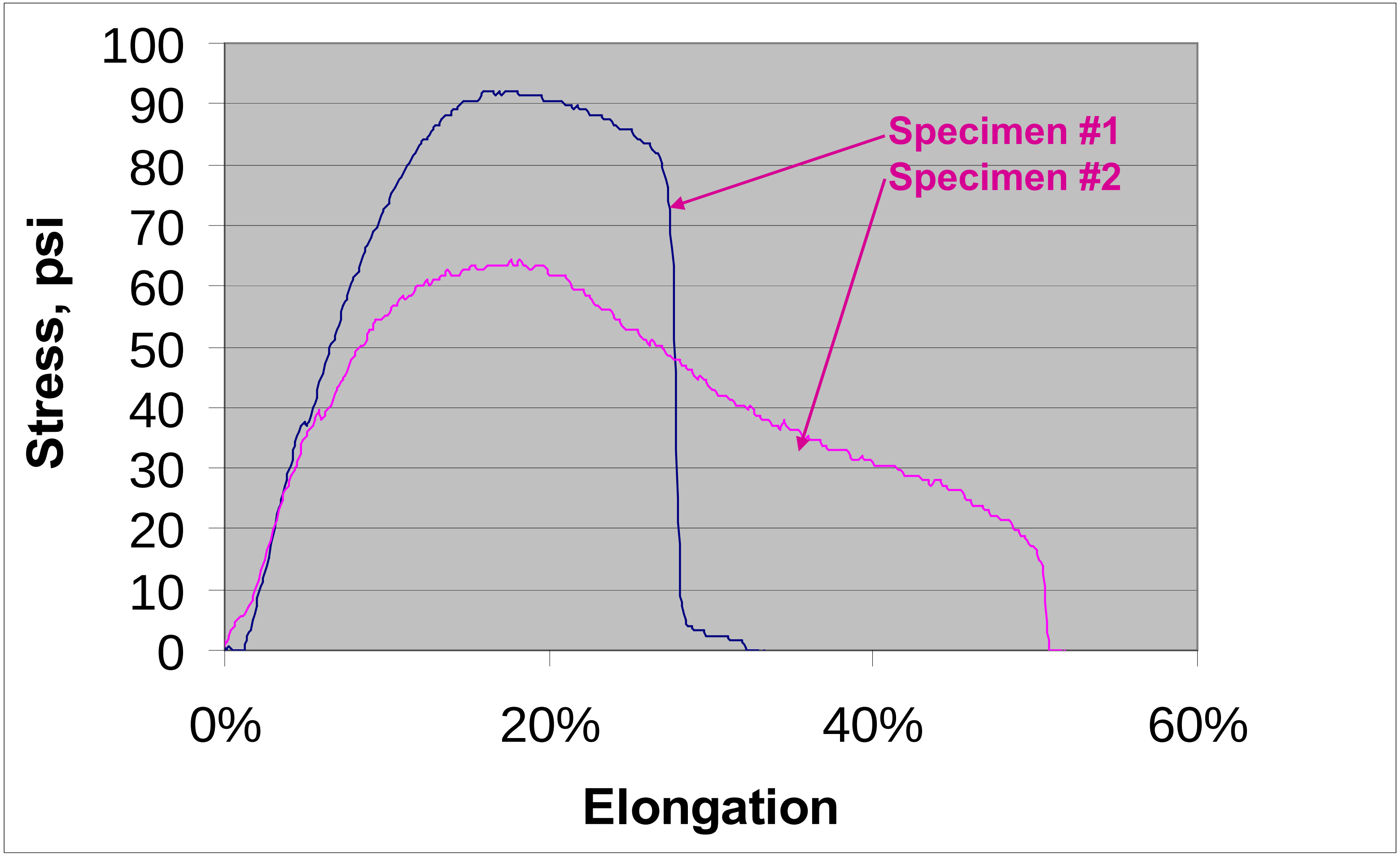
Mechanical Property Test Method for propellant grain

- Conformed to the JANNAF "CLASS B" uniaxial Tensile Specimens
- Dogbones fashioned from propellant grain and tested on an Instron tensile testing machine

Dogbones were cut from the propellant grains

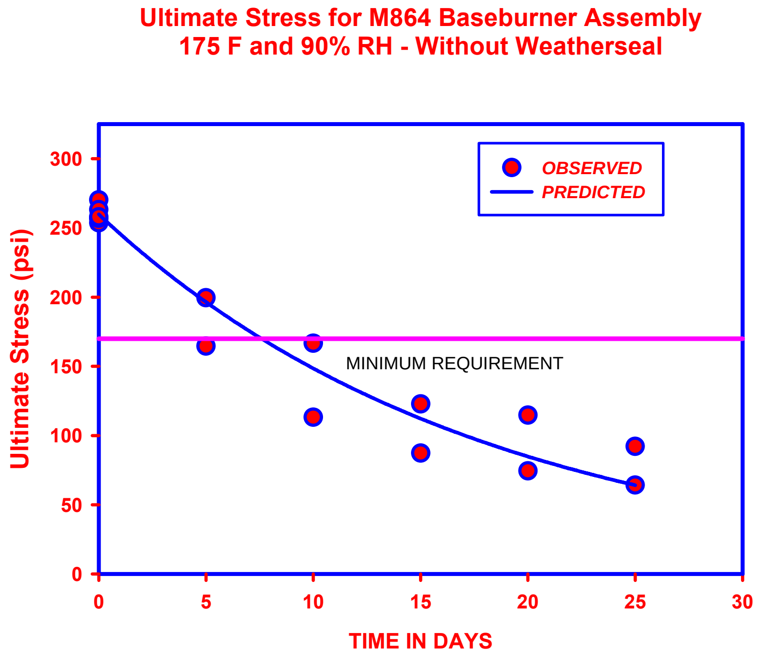
Mechanical properties of the dogbones were tested using an Instron tensile testing machine.

STRESS / STRAIN PLOT
Sample AGE-028 (25 Days @ 175F & 90% R.H.)



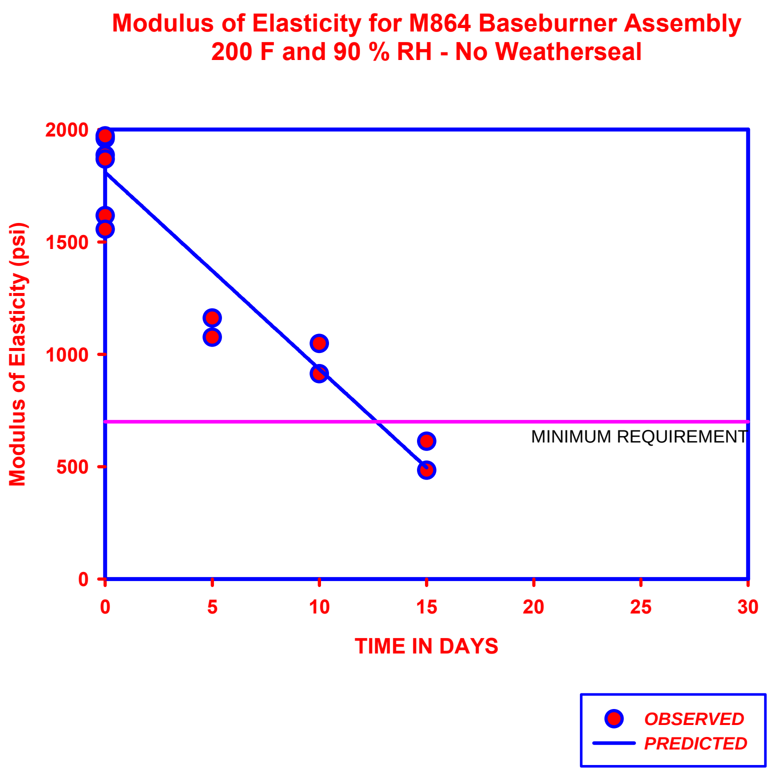
Specimen #2, taken from propellant closest to exposed surface.

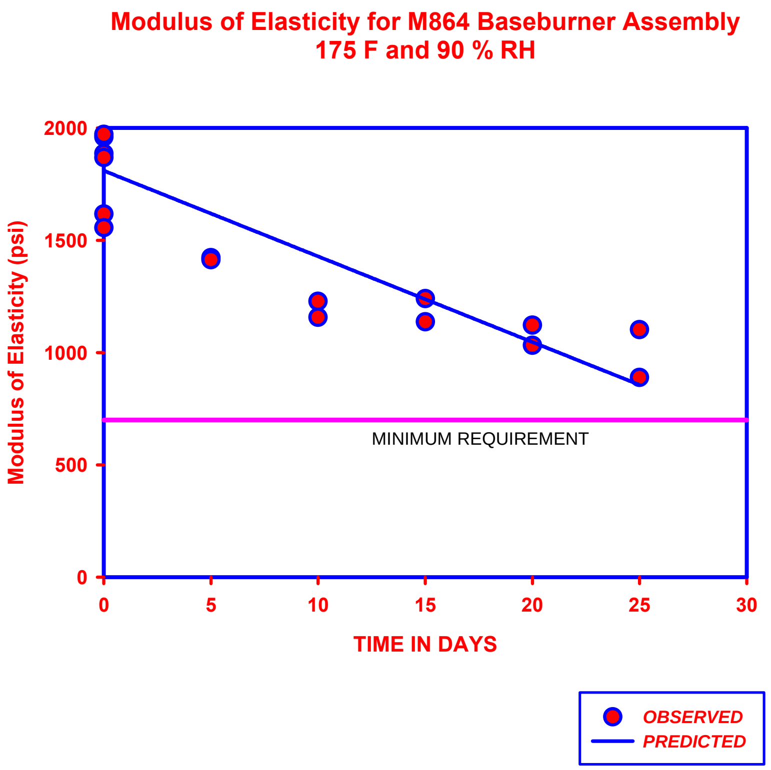
Ultimate Stress as a function of time at 175 F and 90 % RH



Data Fitted with First Order Kinetic Model

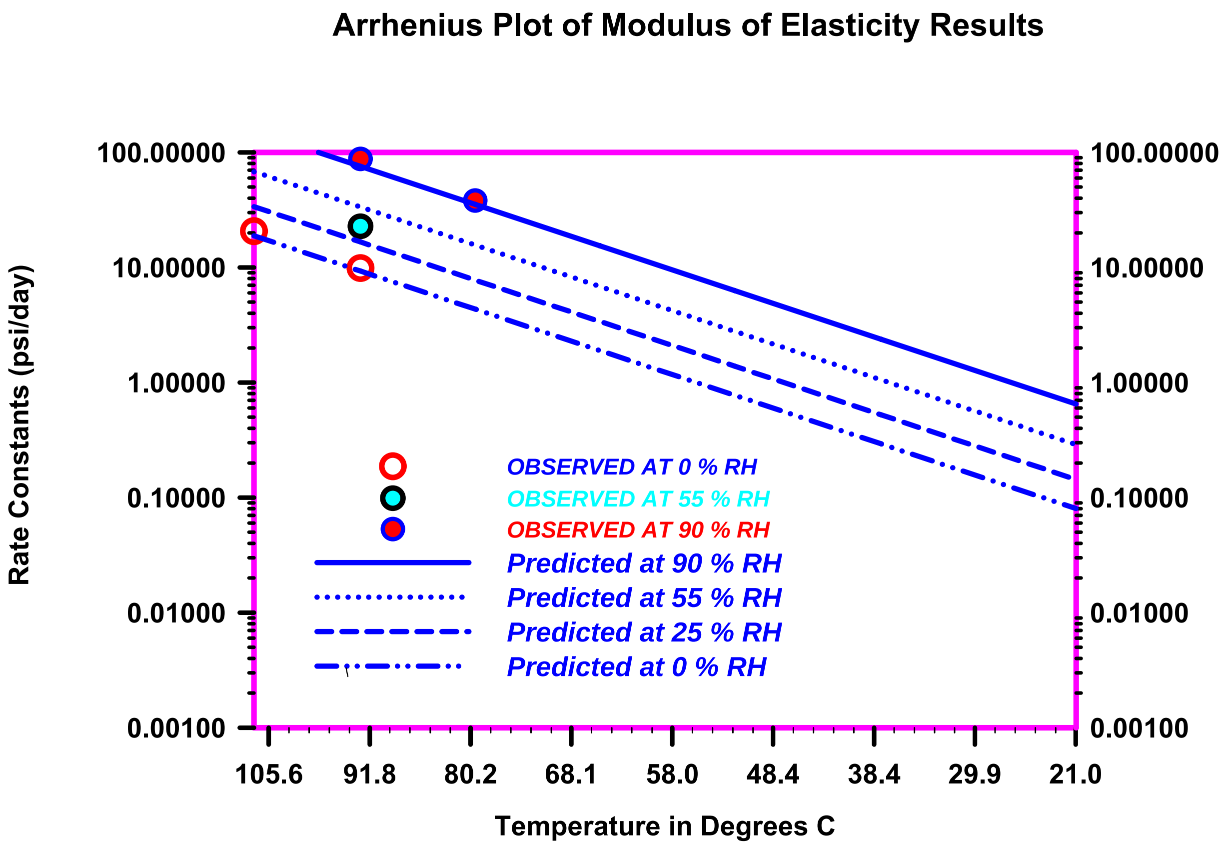
Modulus of Elasticity as a function of time at 200 F and 90 % RH





Zero Order Kinetic Model

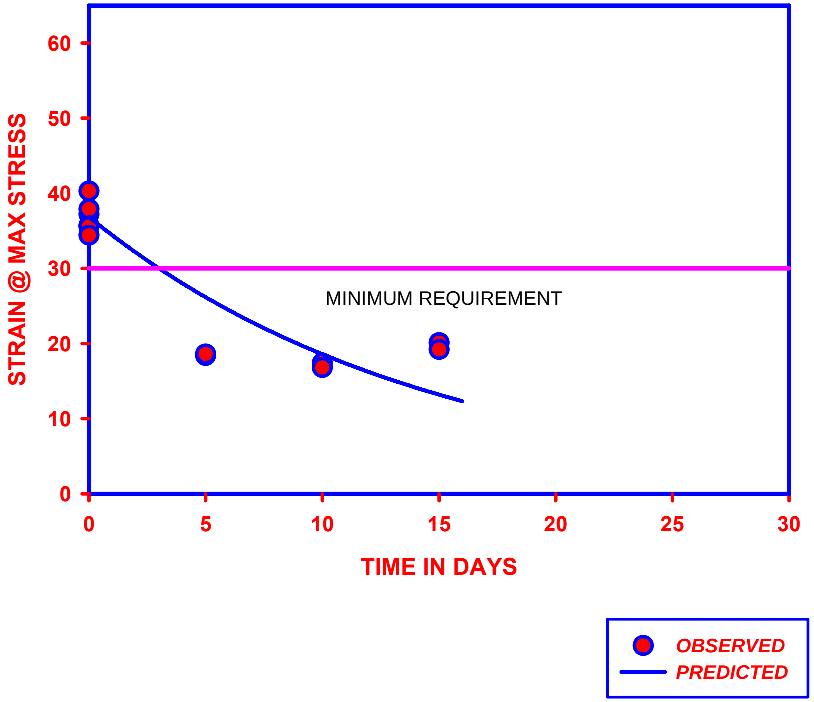
Modulus of Elasticity
Rate Constants - Correlated Using Eyring Equation – All Samples used for this correlation

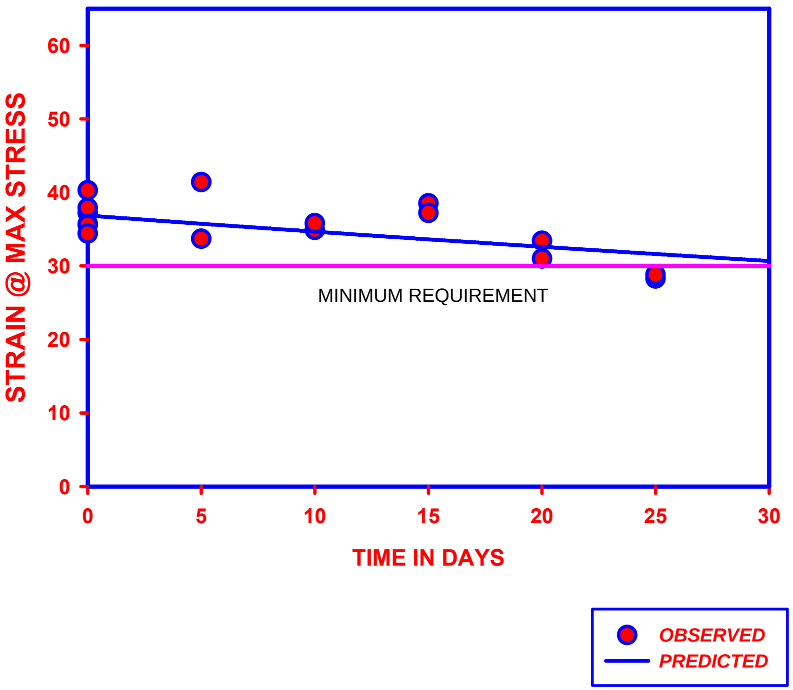


Life Predictions based on Modulus of Elasticity

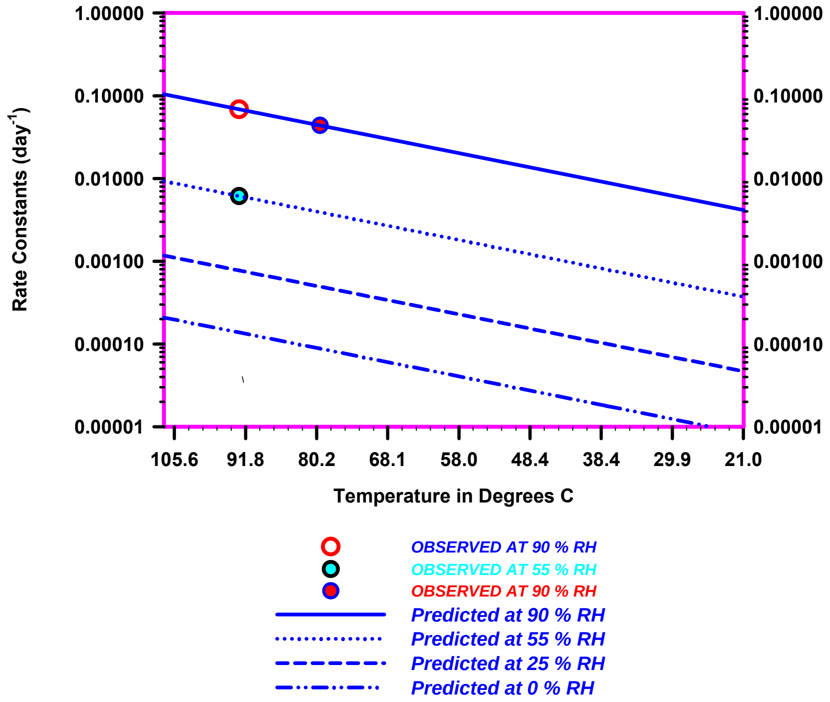
RELATIVE HUMIDITY LEVEL (%)	Controlled Storage (years)	Uncontrolled Storage (years)
90	4.67	.414
55	10.55	.936
25	21.22	1.883
0	38.0	3.37

Degradation of the Mechanical Property "Strain at Maximum Stress"





First Order Degradation Rates of the Strain at Maximum Stress Correlated Using the Eyring Equation



Lifetimes in Years of the Propellant Grain based on the Strain at Maximum Stress

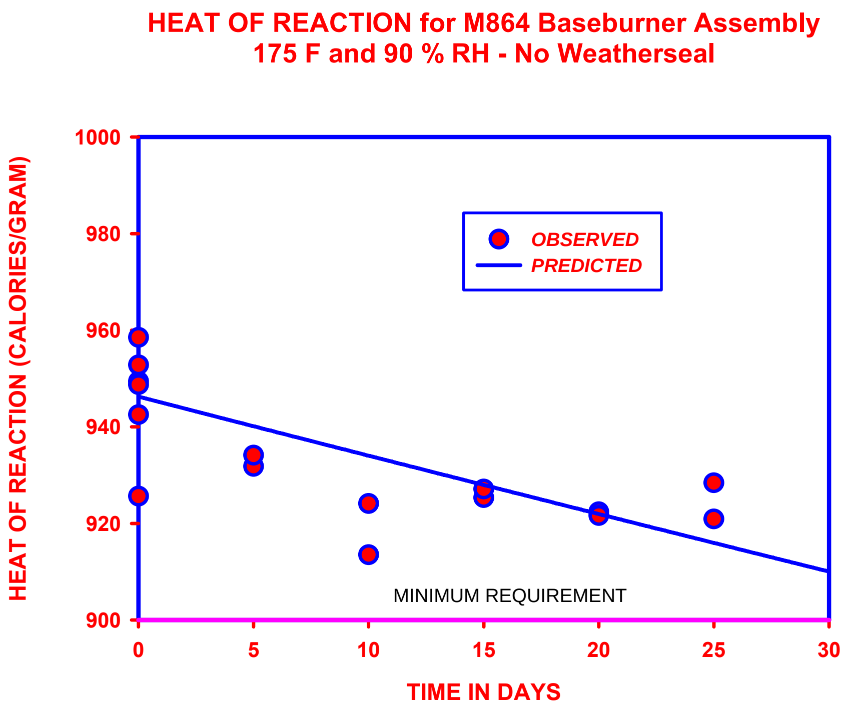
First Order Kinetic Model

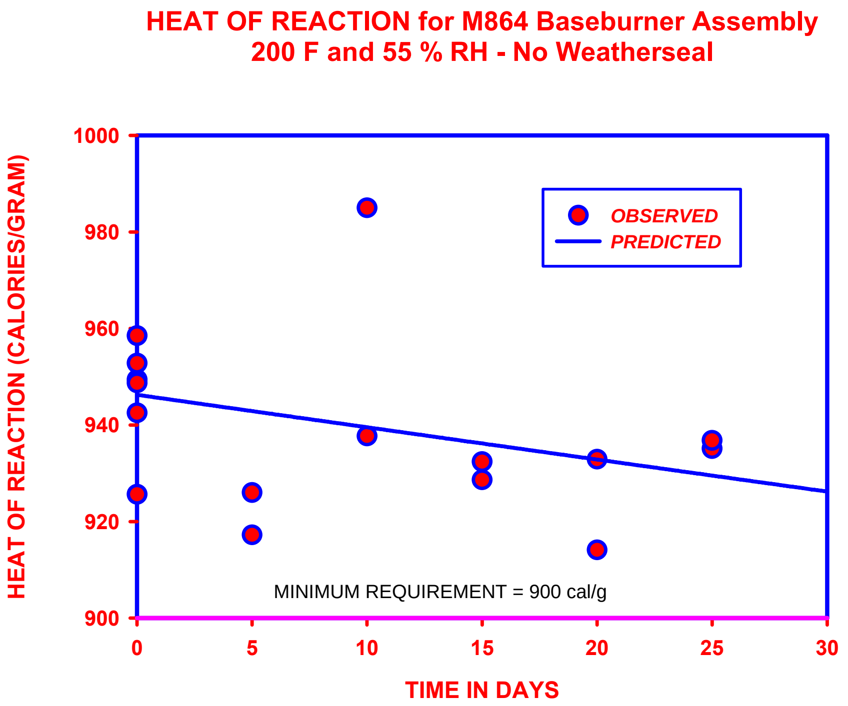
% RH	Controlled Storage	Uncontrolled Storage
0	67.6	17.9
25	12	3.19
55	1.52	.402
90	.136	.0358

Thermal Properties

Heat of Reaction

- *Minimum Value of 900 cal/gram*
- *Degraded in both stockpile and accelerated aging study*

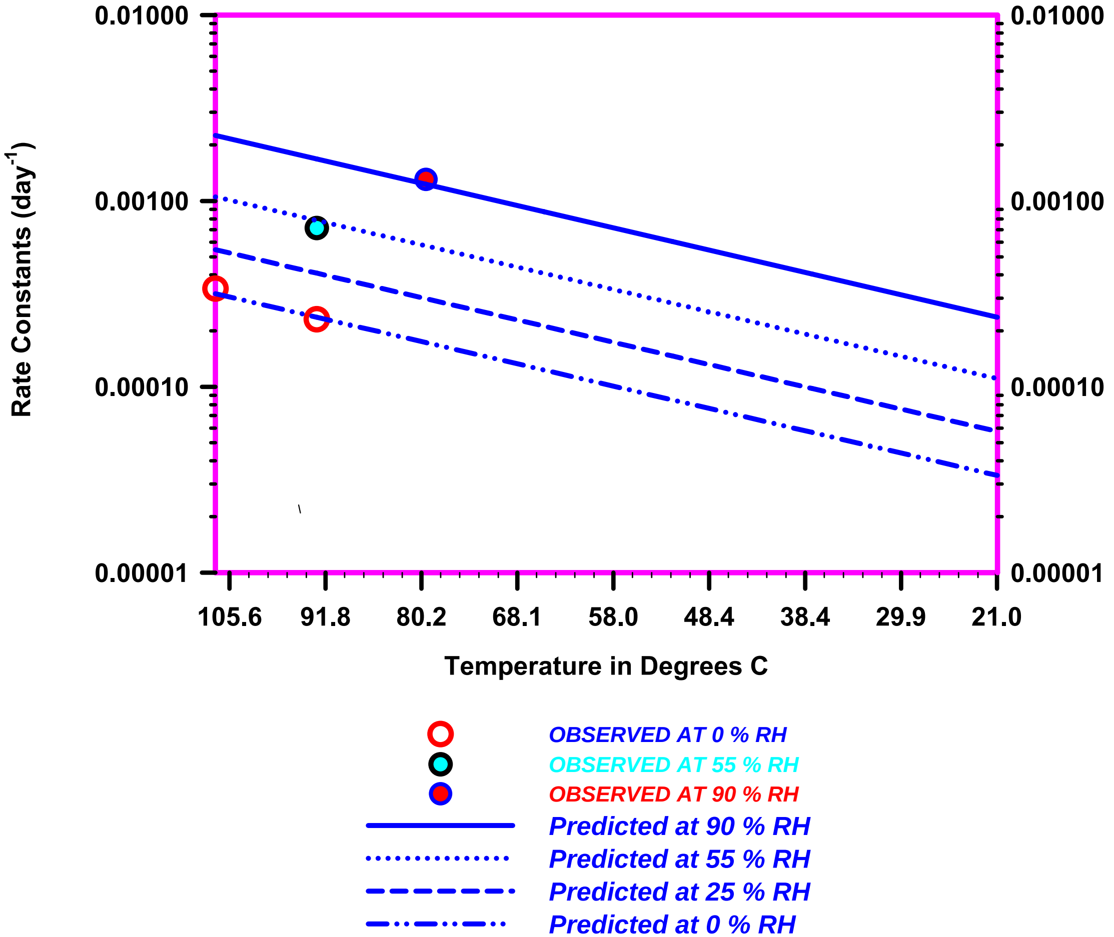




Life Predictions based on Heat of Reaction from the Accelerated Aging Experiments

Kinetic Model	ZERO ORDER		FIRST ORDER	
RELATIVE HUMIDITY LEVEL (%)	Controlled Storage (years)	Uncontrolled Storage (years)	Controlled Storage (years)	Uncontrolled Storage (years)
0	4.07	1.65	4.13	1.68
25	2.37	.961	2.39	.975
55	1.24	.501	1.24	.507
90	.578	.234	.580	.236
Eyring Equation Parameters	ZERO ORDER		FIRST ORDER	
k_0	683 cal/g-day		.697 day^{-1}	
E_A	5846 cal/mol		5817 cal/mol	
B	.0217 ($\%RH^{-1}$)		.0218 ($\%RH^{-1}$)	

Heat of Reaction rates correlated using Eyring Equation

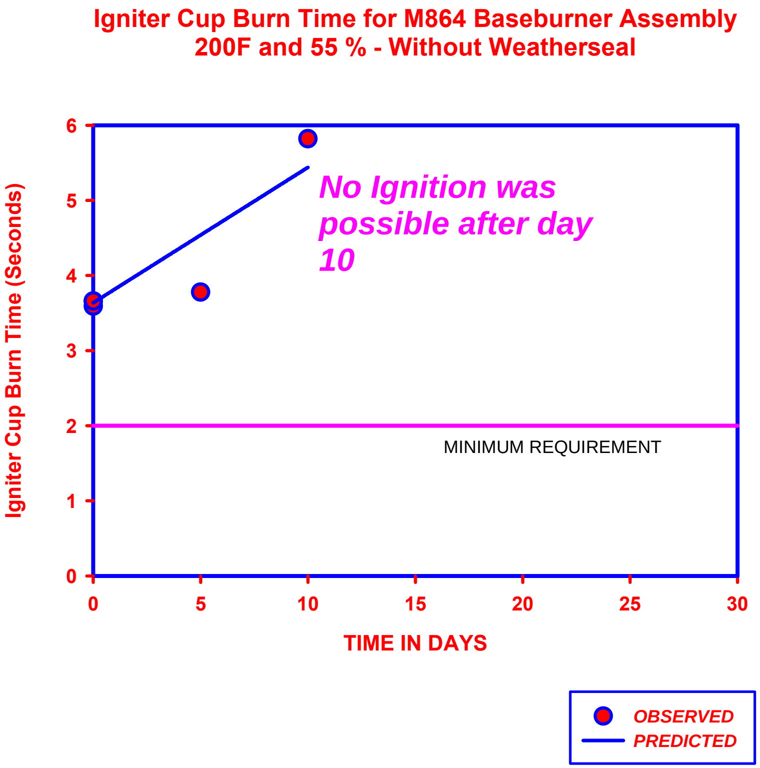


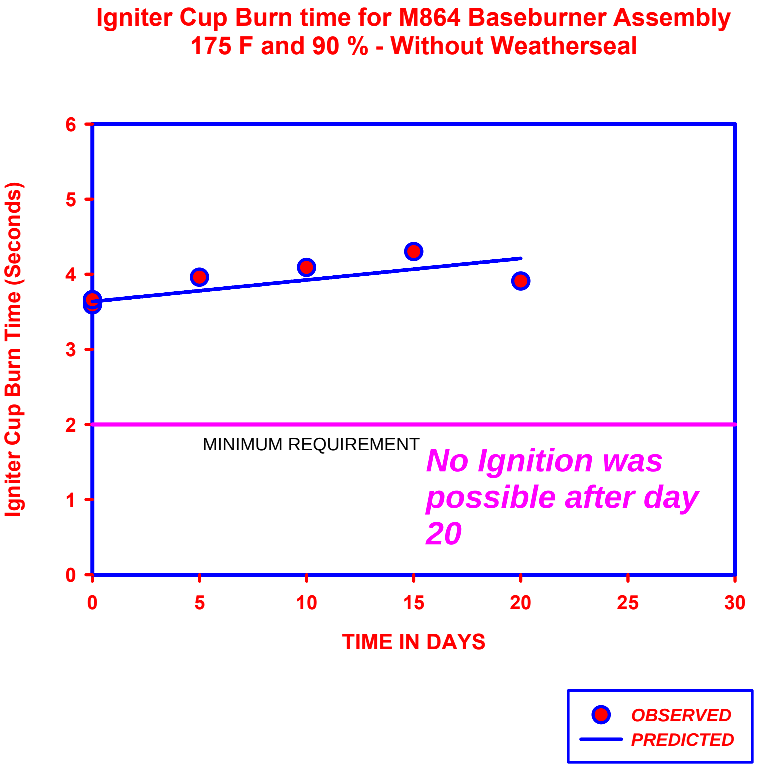
Igniter Failure Modes

- ***Igniter tended to fail due to the effect of moisture. It would not light.***

- ***Very long life predictions for this failure mode were calculated from the data***

Igniter Cup Burn Times – No Weatherseal





Summary

- *Variables and attribute data used to estimate controlled and uncontrolled storage lifetimes for baseburner assembly of the M864*
- *Accelerated Aging and Real Time Aging data both used to provide estimates*

Summary

- Weatherseals were removed to accelerate degradation of baseburner
- Heats of reaction showed degradation both in accelerated testing and real time aging
- Accelerated aging lifetime estimates were generally shorter than real time aging lifetime estimates – Models used for Accelerated Aging are conservative – They provide a margin of safety.

Lifetime Predictions

- ***Controlled and uncontrolled storage.***
- ***For each property measured in the study***
- ***For accelerated aging data as well as depot storage (surveillance) data.***

Lifetime Predictions by Property

DATA TYPE	Stress Required	Property	Uncontrolled Storage	Controlled Storage
Stockpile –	Depot Storage	Ultimate Stress	----------	40.8
Accelerated Aging	55 % RH	Ultimate Stress	.877	10.8
Accelerated Aging	Depot Storage	Modulus of Elasticity		Unlimited Lifetime – No Degradation
Accelerated Aging	55 % RH	Modulus of Elasticity	.936	10.6
Accelerated Aging	25 % RH	Modulus of Elasticity	1.883	21.22

Lifetime Predictions by Property

DATA TYPE	Stress Required	Property	Uncontro lled Storage	Controlled Storage
Stockpile –	Depot Storage	Heat of Reaction	-----------	9.76
Accelerated Aging	55 % RH	Heat of Reaction	.507	1.24
Accelerated Aging	25 % RH	Heat of Reaction	.975	2.39
Stockpile –	Depot Storage	Strain at Maximum Stress	-----------	2.10
Accelerated Aging	55 % RH	Strain at Maximum Stress	.402	1.52
Accelerated Aging	25 % RH	Strain at Maximum Stress	3.19	12
Accelerated Aging	0% RH	Strain at Maximum Stress	17.9	67.6
Accelerated Aging	75 % RH	Igniter Cup Reliability*	3.10 years	12000 years

CONCLUSIONS

- *The weatherseal integrity is fundamental to survivability of base burner assembly*

- *Heat of reaction, mechanical properties and igniter cup reliability all adversely affected by moisture*

- ***Although some of the properties have degraded slightly, there has been no effect on ballistic performance or reliability***

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