

[Shock Wave Science and Technology Reference Library, Vol. 5](#)

Non-Shock Initiation of Explosives

Bearbeitet von
Blaine Asay

1st Edition. 2010. Buch. XVIII, 618 S. Hardcover

ISBN 978 3 540 87952 7

Format (B x L): 15,5 x 23,5 cm

Gewicht: 1221 g

[Weitere Fachgebiete > Technik > Sonstige Technologien, Angewandte Technik > Militärtechnik, Waffen, Pyrotechnik](#)

Zu [Leseprobe](#)

schnell und portofrei erhältlich bei

The logo for beck-shop.de features the text 'beck-shop.de' in a bold, red, sans-serif font. Above the 'i' in 'shop' are three red dots of increasing size. Below the main text, the words 'DIE FACHBUCHHANDLUNG' are written in a smaller, red, all-caps, sans-serif font.

beck-shop.de
DIE FACHBUCHHANDLUNG

Die Online-Fachbuchhandlung [beck-shop.de](#) ist spezialisiert auf Fachbücher, insbesondere Recht, Steuern und Wirtschaft. Im Sortiment finden Sie alle Medien (Bücher, Zeitschriften, CDs, eBooks, etc.) aller Verlage. Ergänzt wird das Programm durch Services wie Neuerscheinungsdienst oder Zusammenstellungen von Büchern zu Sonderpreisen. Der Shop führt mehr als 8 Millionen Produkte.

Contents

1 Introduction

<i>Blaine W. Asay</i>	1
1.1 Background.....	3
1.2 What Are We Able to Predict?.....	5
1.3 What Are We Unable to Predict?	7
1.4 Numerical Approaches	9
1.5 Motivation for This Text	11
1.6 Purpose of This Book	11
1.7 Final Word of Caution	13
References	14

2 Transport Phenomena for Nonshock Initiation Processes

<i>W. Lee Perry</i>	15
2.1 An Overview of Transport Theory in Explosives Problems	15
2.2 The Origins of Transport Theory in the Field on Nonshock Initiation	19
2.3 Physical Properties Used in Transport Theory Analysis	22
2.4 Transport Theory Equations	27
2.5 Selected Examples of Transport Theory Applied to Explosive Problems	30
2.6 Summary.....	41
References	42

3 The Chemical Kinetics of Solid Thermal Explosions

<i>Bryan F. Henson and Laura B. Smilowitz</i>	45
3.1 Introduction	45
3.2 General Considerations.....	49
3.2.1 Chemical Kinetics and Explosives Modeling	49
3.2.2 Types of Models	73
3.2.3 Modeling Objectives	76

X Contents

3.3	Specific Example: A Global Chemistry Model for HMX	76
3.3.1	HMX Thermal Decomposition	77
3.3.2	HMX Thermal Ignition	88
3.3.3	HMX Thermodynamics	96
3.3.4	HMX Thermodynamics and Ignition	103
3.3.5	Global Kinetic Models of PBX 9501 (HMX)	109
3.4	Conclusions	119
	References	121

4 Classical Theory of Thermal Criticality

	<i>Larry G. Hill</i>	129
4.1	Introduction	129
4.1.1	Spontaneous Combustion	132
4.1.2	Thermal versus Physical Explosions	134
4.1.3	The Three Fundamental Cookoff Safety Questions	135
4.1.4	The Nature of Preignition and Post-Ignition Cookoff Modeling	136
4.1.5	Historical Development of Thermal Explosion Theory	137
4.1.6	Definition, Scope, and Modern Relevance of Classical Theory	138
4.1.7	Emphasis and Outline	139
4.1.8	Additional Resources	141
4.2	Reaction Rate	141
4.2.1	Homogeneous and Heterogeneous Chemical Reactions	142
4.2.2	Spatial Averaging Over Heterogeneous Solid-Phase Reactants	143
4.2.3	The Law of Mass Action	144
4.2.4	Arrhenius Reaction Rate	145
4.2.5	Reaction Order	146
4.2.6	Reaction Rate Expressed as Mass Fraction	147
4.2.7	Reaction Progress Function Behavior for Arbitrary Reaction Order	148
4.2.8	Zero-Order Reaction versus Negligible Depletion	149
4.2.9	Autocatalytic Reactions	150
4.2.10	Hot-Spot-Initiated Reaction	154
4.2.11	Reaction Progress Function for an Ideal Hot-Spot-Initiated Reaction	157
4.2.12	Modeling Complex Thermal Decomposition Behavior	162
4.2.13	The Arrhenius Function and its Calibration	163
4.2.14	Activation Energy as a Measure of HE Sensitivity	165
4.2.15	Thermal Decomposition Parameters for PBX 9501	169

4.3	Semenov Theory of Criticality	171
4.3.1	Volumetric Heat Generation and Surface Heat Loss	171
4.3.2	Heat Flux Balance and the Semenov Graphical Construction	172
4.3.3	Semenov Criticality Condition	175
4.3.4	Explicit Solutions for the Critical Temperatures	177
4.3.5	Semenov Universality	180
4.3.6	Semenov Steady-State Solution Space	181
4.4	Semenov Criticality Theory with Reactant Depletion	184
4.4.1	The Path to Ignition	184
4.4.2	Generalized Semenov Critical State	186
4.4.3	Example: First-Order Reaction with Constant Heating Rate	187
4.4.4	Behavior of Reaction Runaway Near the Explosion Limit	189
4.4.5	Effect of Reaction Energy Content on the Explosion Limit	190
4.4.6	Sensitivity to Arrhenius Parameters	192
4.5	Reactive Heat Equation and the F-K Approximation	192
4.5.1	Heat Equation with Volumetric Reaction	193
4.5.2	F-K Dimensionless Temperature	194
4.6	Semenov Theory in the F-K Limit: The “SFK” Model	197
4.6.1	Heat Flux Balance, Graphical Construction, Critical Condition	197
4.6.2	Criticality Expressed by the Semenov Number	198
4.6.3	Explicit Solutions for the Critical Temperatures	199
4.7	Basic Frank-Kamenetskii Theory	200
4.7.1	General Methodology	200
4.7.2	Critical Temperature and Critical Size	201
4.7.3	Critical Condition for the Infinite Slab	202
4.7.4	Critical Condition for the Infinite Cylinder	204
4.7.5	Critical Condition for the Sphere	205
4.7.6	Critical Temperature Profiles for the Canonical Shapes ...	207
4.7.7	Relative Critical Temperatures for the Canonical Shapes	208
4.7.8	F-K Critical State for General Shapes: Square Bar Example	210
4.8	F-K Criticality Correlations for General Shapes	213
4.8.1	Correlation for Bodies of Near-Unity Aspect Ratio	214
4.8.2	Comparison of Fk_c Values Obtained by Various Studies	217
4.8.3	Effective Dimensionality of Near-Unity-Aspect-Ratio Shapes	219

XII Contents

4.8.4	Breakdown of the Shape Correlation for Elongated Shapes	220
4.8.5	On Extending the Shape Correlation to Elongated Bodies	222
4.9	F-K Theory with Generalized Boundary Conditions	224
4.9.1	Thermal Conductance/Resistance and the Biot Number	224
4.9.2	Thomas' Generalized Boundary Condition	225
4.9.3	Infinite Slab: Critical Condition versus Biot Number	226
4.9.4	Infinite Cylinder: Critical Condition versus Biot Number	228
4.9.5	Sphere: Critical Condition versus Biot Number	230
4.9.6	Critical State versus Biot Number for the Canonical Shapes	231
4.9.7	Quasi-Self-Similar Scaled Criticality Curves vs. Biot Number	233
4.10	Convergence of the Critical State to the F-K Limit	235
4.10.1	Canonical Shape Criticality for the Full Arrhenius Rate	235
4.10.2	Quasi-Self-Similar Scaled Criticality Curves vs. Temperature	237
4.10.3	Critical State Correction for Finite Activation Energy	237
4.11	Concluding Remarks	239
	References	240

5 Deflagration Phenomena in Energetic Materials:

An Overview

<i>Scott I. Jackson</i>	245
5.1 Introduction	245
5.2 Combustion and Its Modes	249
5.3 The Conductive Deflagration.....	250
5.3.1 A Description of the Conductive Flame Structure	250
5.3.2 Factors Affecting the Burn Rate.....	252
5.3.3 Temperature Dependence	253
5.3.4 Pressure Dependence	253
5.3.5 Quenching and Extinction.....	257
5.3.6 Burning Progression	259
5.4 Convective Burning	260
5.4.1 Gas Flow into Porosity and Isolated Voids	264
5.4.2 Ignition of Porosity	266
5.4.3 The Influence of a Melt Layer on the Critical Pressure ..	272
5.5 Progression of Combustion	273
5.5.1 Across Flat Surfaces	274
5.5.2 Spreading of Convective Combustion.....	275
5.6 Concluding Remarks	284
References	288

6 Mechanical and Thermal Damage

<i>Gary R. Parker and Philip J. Rae</i>	293
6.1 Introduction	293
6.2 Classification of Pertinent Morphologies	294
6.2.1 Porosity	294
6.2.2 Crystal Structure	296
6.3 Techniques	298
6.3.1 Issues of Scale	298
6.3.2 The Representative Elementary Volume	298
6.3.3 Experimental Methods	299
6.4 Pristine Materials	309
6.4.1 Energetic Material Types	309
6.4.2 Examination of Defects in Pure Materials	310
6.4.3 Examination of Defects in Pressed Materials	316
6.4.4 Examination of Defects in Melt-Cast Materials	317
6.5 Insult and Damage	317
6.5.1 Damage From Mechanical Insult	319
6.5.2 Damage From Thermal Insult	337
6.6 The Effect of Pore Morphology on Fluid Transport in Damaged EM	351
6.6.1 Fundamentals of Fluid Transport	352
6.6.2 Transport Models	353
6.6.3 Experiments with EM Measuring Gas Transport in the Preignition Regime	357
6.6.4 Experiments with EM Measuring Gas Transport in the Post-ignition Regime	362
6.7 Nomenclature	374
References	393

7 Cookoff

<i>Blaine W. Asay</i>	403
7.1 Concept of Critical Temperature	406
7.1.1 Semenov's Approach	408
7.1.2 Frank-Kamenetskii's Approach	412
7.1.3 Critical Temperature Determination	413
7.2 Visual Observation of the Cookoff Event	418
7.2.1 Mechanically Confined Cookoff Tests	418
7.2.2 Cindy Test	424
7.3 Small-Scale Instrumented Thermal Ignition Experiments	431
7.4 Quantification of Reaction Violence	441
7.4.1 Experimental	443
7.4.2 A First Law Analysis	445
7.4.3 Violence	447
7.4.4 Energy and Power	449

XIV Contents

7.4.5	Violence and $P^2 \tau$	451
7.4.6	Conclusion	459
7.5	Large, Integrated Experiments	460
7.5.1	LLNL Large-Scale Cookoff Test	460
7.5.2	Scaled Thermal Explosion Experiment (STEX)	460
7.5.3	Large-Scale Annular Cookoff	461
7.5.4	Results	463
7.5.5	Discussion	471
7.5.6	Conclusions	476
7.6	Final Thoughts	477
	References	478
 8 The Deflagration-to-Detonation Transition		
	<i>John Michael McAfee</i>	483
8.1	Introduction	483
8.2	Solids	484
8.2.1	Solid DDT Phenomenology	486
8.2.2	Solid DDT Experimental Evidence	487
8.3	Type I DDT	489
8.3.1	The Phenomenology of Type I DDT	489
8.3.2	Experimental Evidence for Type I DDT	494
8.4	Type II DDT	507
8.4.1	Type II DDT Phenomenology	508
8.4.2	Experimental Evidence for Type II DDT	511
8.4.3	General Discussion of Type II DDT	516
8.5	The Change Between Type I and Type II DDT	518
8.5.1	Experimental Dimension	518
8.5.2	Burn Rate	521
8.5.3	Porosity, Permeability, and Particle Size Distribution	523
8.5.4	Particle Surface Morphology	527
8.5.5	Mechanical Properties	528
8.5.6	Igniter Effect	528
8.5.7	Conclusions	529
8.6	DDT in Gases, Vapors, and Dust	530
8.6.1	Gases and Vapors	530
8.6.2	Dusts	531
	References	533
 9 Friction		
	<i>Peter Dickson</i>	537
9.1	Introduction to Frictional Processes	537
9.2	Significant Accidents Probably Involving Frictional Processes	537
9.3	Classical Friction Theory	538
9.4	Other Factors Affecting Surface Temperatures	540
9.5	Effects of Particulate Contaminants	541
9.6	Frictional Processes Involved in Heating and Ignition of Explosives	542

9.7	Friction Testing Methodology	543
9.8	Powder Explosive Tests	543
9.9	Pressed/Cast Explosive Tests	544
9.9.1	Oblique Impact Testing Revisited	545
9.9.2	LANL Friction Test Apparatus	548
9.10	Drop-Weight Testing	552
9.11	Analysis and Modeling	553
	References	554

10 Impact and Shear Ignition By Nonshock Mechanisms

<i>James E. Kennedy</i>	555
10.1 Effects of Shear in Material-Flow Processes	555
10.2 Drop-Weight Impact Tests	559
10.2.1 Cavendish Laboratory Glass-Anvil	559
10.2.2 Temperature and Flow Sensors	561
10.3 Large-Scale Crushing Impact	562
10.3.1 IITRI Test	562
10.3.2 Susan Test	566
10.3.3 U.S.S. Iowa Explosion	567
10.3.4 XDT Response Mode	568
10.3.5 Two-Step Impacts	570
10.4 Penetrating Impact of Cased Explosives	571
10.5 Shear in Confined Charge Assemblies	572
10.6 Mechanical Properties of Energetic Materials Relevant to Shear Ignition	575
10.6.1 Properties of Unreacted Energetic Materials	575
10.6.2 Mechanical Property Effects on Ignition	575
10.7 Summary	577
References	578

11 Spark and Laser Ignition

<i>James E. Kennedy</i>	583
11.1 Introduction	583
11.2 Spark Detonator: A Vehicle for Study of Loose Powder Response	584
11.3 Initiation Behavior of Secondary Explosive Spark Detonators	586
11.4 Similarities Among EBW, Laser, and Spark Initiation of Detonation	587
11.4.1 EBW Detonators	588
11.4.2 Laser Detonators	590
11.5 Sparks as Sources for Ignition of Explosive Powders	591
11.5.1 Charge Generation and Discharge	591
11.5.2 Electrostatic Discharge (ESD) Sensitivity Testing of Energetic Materials	593
11.5.3 Discharges from Human Body or Handling Equipment	595

XVI Contents

11.6	Electrical Discharges Through High-Density Energetic Materials	596
11.6.1	Conclusions Concerning High-Density Energetic Materials	601
11.7	Other Laser Applications	602
	References	603
	Index	607