

Contents

Introduction	1
1 Equations of State, Initial and Boundary Conditions	7
1.1 Equations of State for Water	7
1.2 Equations of State for Detonation Products	15
1.3 Conservation Laws, <i>PU</i> -Diagrams, and Transition Formulas	18
1.3.1 Transition in a Shock Wave	19
1.3.2 Transition in a Simple Wave	21
1.4 Generalized Equation of Pulsations of an Explosive Cavity ...	23
References	26
2 Underwater Explosions, Shock Tubes, and Explosive Sound Sources	29
2.1 Kirkwood–Bethe Approximation, Cylindrical Symmetry	29
2.1.1 Basic Assumptions, Initial Conditions	29
2.1.2 Dynamics of an Explosive Cavity, Riemann’s Function, Delay Integral	32
2.1.3 Calculation of the Delay Integral (for $\nu = 1, 2$)	34
2.1.4 Shock Waves (Cylindrical Symmetry, Comparison with Experiment)	35
2.1.5 Dynamics of Exponent Index, $\theta(r_{\text{fr}})$	36
2.1.6 SW Parameters (Trotzyl, Calculation and Experiment)	38
2.1.7 Asymptotic Approximation for Weak Shock Waves ($\nu = 1, 2$)	39
2.2 Hydrodynamic Shock Tubes	42
2.2.1 Filler’s Conical Shock Tube	42
2.2.2 Glass’s One-Diaphragm Shock Tube	43
2.2.3 Electromagnetic Shock Tube	45
2.2.4 Two-Diaphragm Hydrodynamic Shock Tubes	47
2.2.5 Shock Tube Application: High-Rate Reactions in Chemical Solutions	53
2.3 Explosive Hydroacoustics	57
2.3.1 Basic Characteristics of Explosive Sound Sources	57
2.3.2 Hydrodynamic Sources of Explosive Type	60
2.3.3 Wave Field, Spectral Characteristics	63

2.3.4	Array Systems	67
2.3.5	Explosion of Spiral Charges, Wave Structure	69
2.4	HE-Nuclear-Tests, Explosive Acoustics and Earthquakes	74
	References	78
3	Explosion of Cylindrical and Circular Charges	83
3.1	Dynamics of a Cylindrical Cavity	83
3.2	Cylindrical Cavity: Approximated Models for Incompressible Liquid	87
3.2.1	Generalized Equation (for $c \rightarrow \infty$)	87
3.2.2	Cylindrical Cavity under Free Surface	89
3.2.3	The Model of Liquid Cylindrical Layer	90
3.2.4	Oscillation Period of a Cylindrical Cavity	91
3.3	Circular Charges	93
3.4	Dynamics of a Toroidal Cavity, Numerical Models	101
3.4.1	Ideal Incompressible Liquid	101
3.4.2	Compressible Liquid	105
3.4.3	Comparison with Experiments	110
3.4.4	Basic Characteristics for Toroidal Charges	112
3.5	Comparative Estimates for Spherical Charges	112
3.6	Oscillation Parameters	115
3.7	Explosions of Spatial Charges in Air	116
3.7.1	Experimental Arrangement	116
3.7.2	Test Measurement Results	117
	References	123
4	Single Bubble, Cumulative Effects and Chemical Reactions	125
4.1	Passive Gas Phase	125
4.1.1	Short Shock Waves	125
4.1.2	Formation of a Cumulative Jet in a Bubble (Experiment)	127
4.1.3	Real State of a Gas	130
4.1.4	Viscosity and the Effect of Unbound Cumulation	131
4.1.5	Spherical Cumulation in a Compressible Liquid	134
4.1.6	Oscillation Parameters	136
4.2	Chemical Reactions in Gas Phase	137
4.2.1	Todes' Kinetics, Initiation of Detonation by a Refracted Wave	137
4.2.2	Generalized Kinetics of Detonation in Gas Phase	139
4.2.3	Dynamics of Bubbles Filled with a Reactive Mixture ..	141
4.3	Mass Exchange and Chemical Reactions	142
4.3.1	Instant Evaporation of Microdrops	143
4.3.2	Continuous Evaporation	148
	References	151

5	Shock Waves in Bubbly Media	153
5.1	Nonreactive Media, Wave Structure, Bubbly Cluster Radiation	153
5.1.1	Shock-Gas Layer Interaction	157
5.1.2	Shock Waves in Bubble Layers	158
5.1.3	Two-Phase Model of a Bubbly Liquid: Three Estimates of Wave Effects	170
5.1.4	Amplification, Collision, and Focusing of Shock Waves	177
5.2	Generation of Radiation by Free Bubble Systems	185
5.2.1	Toroidal Bubble Cloud, Mach Disks	186
5.2.2	Spherical Bubbly Clusters: SW Cumulation with a Pressure Gradient Along Front	192
5.3	Reactive Bubble Media, Waves of Bubble Detonation	196
5.3.1	Shock Waves in Reactive Bubbly Systems	197
5.3.2	Shock Tube with Changing Cross Sections	210
	References	217
6	Problems of Cavitative Destruction	223
6.1	Dynamics of Liquid State in Pulsed Rarefaction Waves	223
6.1.1	Real Liquid State (Nucleation Problems)	224
6.1.2	Formation Mechanism of Bubble Clusters	229
6.1.3	Mathematical Model of Cavitating Liquid	233
6.1.4	Dynamic Strength of Liquid	234
6.1.5	Tensile Stress Relaxation (Cavitation in a Vertically Accelerated Tube)	236
6.1.6	Transition to the Fragmentation Stage (Experimental Methods)	238
6.1.7	“Frozen” Mass Velocities in a Cavitation Zone	245
6.1.8	Model of “Instantaneous” Fragmentation	248
6.2	Disintegration of a Liquid, Spalls	257
6.2.1	Cavitative Destruction of a Liquid Drop	257
6.2.2	Cavitative “Explosion” of a Liquid Drop	259
6.2.3	Spall Formation in a Liquid Layer	262
6.2.4	Initial Stages of Disintegration: Solids and Liquids	264
6.3	Cluster, Cumulative Jets, and Cavitative Erosion	267
6.3.1	Single Cavity and Cumulative Jets: Experiment and Models	270
6.3.2	Bubble Cluster Effect	273
6.4	Cavitative Clusters and Kidney Stone Disintegration Problem	278
6.4.1	Shock Waves, Bubbles and Biomedical Problems	278
6.4.2	Some Results on Modelling of ESWL Applications	283
6.4.3	Hydrodynamic Model of the Disintegration in the Cavitation Zone	286

6.4.4	Rarefaction Phase Focusing and Cluster Formation . . .	290
	References	292
7	Jet Flows at Shallow Underwater Explosions	297
7.1	State-of-the-Art	297
7.1.1	Irregular Reflection and Bubbly Cavitation	298
7.1.2	Directional Throwing Out on the Free Surface (Sultans)	299
7.2	Tensile Stress, Structure of Cavitation Region, Spalls	300
7.2.1	Development of Cavitation Zone, Spalls (Experimental Studies)	301
7.2.2	Two-Phase Model of Cavitation Region	303
7.2.3	Parameters of Rarefaction Wave in the Cavitation Zone	310
7.3	Formation of Jet Flows and Their Hydrodynamic Models	313
7.3.1	Formation of Vertical Jets on the Free Surface (Experiment, $H < R_{\max}$)	317
7.3.2	An Analog Model of a Sultan	325
7.3.3	Hydrodynamic Model of a Sultan: Pulsed Motion of a Solid from Beneath the Free Surface	330
7.3.4	Abnormal Intensification Mechanism of the First Pulsation	333
7.3.5	Two Models of Formation of Radial Sultans	339
7.3.6	Basic Parameters of Sultans	343
7.3.7	Structure of Sultans: Jet Tandem, Analogy with a High-Velocity Penetration of a Body into Water	344
7.4	Jet Flows: Shallow Explosions of Circular Charges	346
7.4.1	Gravity Effect	347
7.4.2	Flow Structure Produced by Explosions of Circular Charges	350
7.5	Shallow Underwater Explosions, Surface Water Waves	353
	References	356
8	Conclusion: Comments on the Models	359