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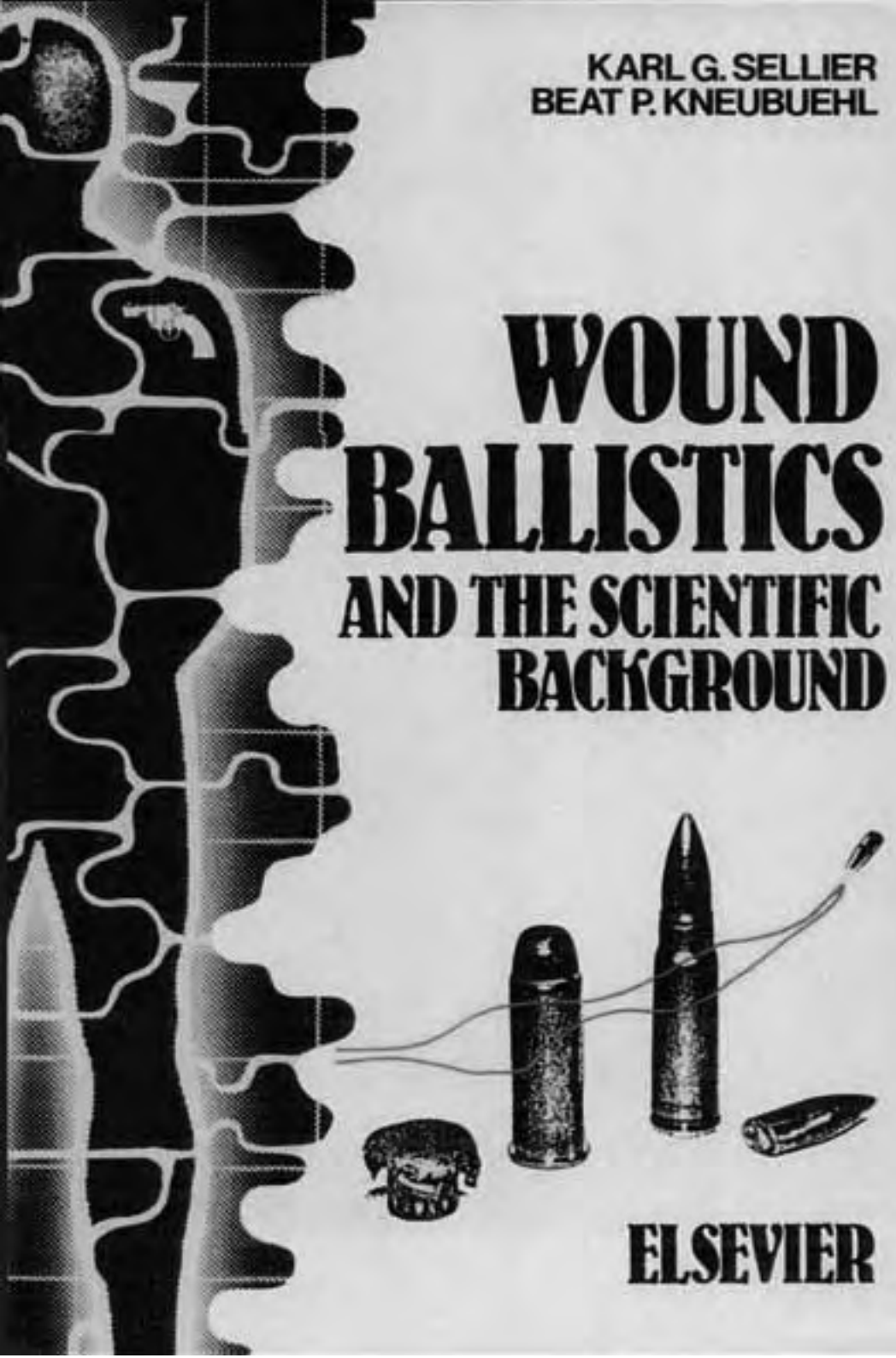
WOUND BALLISTICS

AND THE SCIENTIFIC BACKGROUND



ELSEVIER

Wound Ballistics
and the Scientific Background

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ELSEVIER
Amsterdam – London – New York – Tokyo 1994

Preface

Six international symposia on Wound Ballistics have been held, giving to permanent participants the impression that the mechanical basics of Wound Ballistics have been discovered and are understood. But some important experimental facts still lack a correct physical interpretation and many biological phenomena and body reactions on the mechanical trauma have required (and still require) scientific explanations.

A clear need was thus felt for an extensive and up-dated book on the whole knowledge on the mechanical and hydrodynamical effects of a bullet moving in biological tissue, indicating areas of uncertainty and showing practicable directions for future research.

A group of Swedish researchers (under the Secretary-General Bo Rybeck) deserves credit for having called into existence the above-mentioned symposia, following the objective:

"To create an inter-disciplinary forum for the exchange of knowledge regarding the wounding mechanisms and the biological effects of missile trauma."

The first International Symposium took place at Gothenburg in 1975. Others followed at the same place in the years 1977, 1978, 1981 and 1985. The sixth symposium took place at Chongqing in 1988 and was organized by the People's Republic of China.

Wound Ballistics covers many scientific fields and requires extensive knowledge of many sciences such as, for example, mechanics, ballistics, weapon science, medicine, physiology, neurology and traumatology. We hope we have written a comprehensive and understandable textbook. The famous astrophysicist Stephen W. Hawking wrote in his bestseller "*A Brief History of Time*" that someone had told him that each equation included in a book would halve the sales. This looks bad for us because our purpose was not only to describe but also to quantify the processes, so that the use of some mathematical formulations from time to time was unavoidable. However, skipping over the equations should not affect the comprehension of the processes since the text includes many figures and tables.

We consistently follow the present-day valid International (metric) Unit System (SI) in which length is measured in metres, mass in kilograms, and time in seconds. Since, in the ballistics field, the US unit system is still in common use,

we have added in Chapter 8 the necessary conversion tables. In addition the most important tables are printed twice, once in metric and once in US units.

We are deeply grateful to Dr. Edward H. Ezell, Curator at the National Museum of American History in Washington, for the critical reading of some chapters and for many valuable references. In the preparation of this book we have been much helped by Rosemarie Sellier, the wife and collaborator of the first-named author, and by Mr. Schoska, collaborator of the Institute of Forensic Medicine, University of Bonn.

We are also grateful to Mrs. Ruth Rufer, Kehrsatz/Switzerland, who translated the text into English. This book is based on the revised and extended manuscript of the German edition, published by Springer, Berlin in 1992.

K.G. Sellier and B.P. Kneubuehl
Bonn / Thun, Autumn 1993

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List of Symbols

A	area [mm², m²]
A_{os}	overshooting
a	acceleration [m/s²]
C_D	drag coefficient [–]
C_F	friction coefficient [–]
C_L	lift force coefficient [–]
C_M	overturning moment coefficient [–]
C_P	pressure coefficient [–]
c	sound velocity [m/s]
c_p	specific heat (constant pressure) [J/(kg·K)]
c_v	specific heat (constant volume) [J/(kg·K)]
d	diameter (general) [mm]
E	energy [J]
E_a	impact energy [J]
E_{kin}	kinetic energy [J]
E_{pot}	potential energy [J]
E_{rem}	residual energy after exit [J]
E_{tr}	transmitted energy [J]
E_{tsh}	threshold energy [J]
E'	energy density [J/mm²]
E'_{tr}	transmitted energy per cm path [J/cm]
E'_{tsh}	threshold energy density [J/mm²]
e	basis of the natural logarithm (2.71828..)
F	force [N]
f	form number [–] and tractability [–]
f_n	natural frequency [s^{-1}]
f_r	resonant frequency [s^{-1}]
J_a	longitudinal moment of inertia of projectile [kg·m²]
J_q	transversal moment of inertia of projectile [kg·m²]
k	caliber [mm]
L	angular momentum [N·m·s] or [kg·m²/s]
$\mathcal{L}$	twist length [mm]
ℓ	length (general) [mm, cm]
ℓ_g	length of projectile [mm]

ℓ_s	length of shooting channel [mm]
ℓ_{NC}	length of narrow channel [cm]
ln	natural logarithm (basis e = 2.71828)
$\mathfrak{M}$	Mach number [–]
m	mass [g, kg]
m_c	powder mass, charge (interior ballistics) [g]
md	mass of debridement [g]
p	linear momentum (mechanics) [N·s]
p	pressure (thermodynamics) [N/m², bar]
Q_{ex}	specific explosion heat [J/g, J/kg]
$\mathfrak{R}$	retardation coefficient [1/m]
$\mathfrak{Re}$	Reynolds number [–]
r	radius [mm, m] or correlation coefficient [–]
r	reflexion coefficient (shock wave) [–]
S	sectional density [g/cm²]
s	path [m], standard deviation or number of stability [–]
T	torque, moment of a force [N·m]
V	volume [cm³, m³]
v	velocity [m/s]
v_0	muzzle velocity [m/s]
v_a	impact velocity [m/s]
v_{ck}	crack velocity [m/s]
v_e	exit velocity [m/s]
v_{stk}	stuck velocity [m/s]
v_{tsh}	threshold velocity [m/s]
v_s	sound velocity [m/s]
x,y,z	space coordinates (cartesian frame of reference) [m]
z	burning rate of powder (interior ballistics) [mm/s]
α	angular acceleration [rad/s²]
Γ	angle of twist [degree]
γ	isentropic exponent, c_p/c_v [–]
δ	angle of attack [rad]
η	viscosity [Pa·s]
θ	angle of motion (trajectory) [rad]
θ_0	angle of descent [rad]
κ	compressibility [1/Pa]
μ	proportionality between energy and volume (temporary cavity) [J/ml]
ν	rotations per s [1/s] or kinematic viscosity [m²/s]
ρ	density [kg/m³]

σ	stress (mechanics) [N/m²]
τ	time [ms, s]
φ	angular displacement [rad]
ψ	angle of incidence [rad]
ψ_0	angle of incidence on the point of impact [rad]
ω	angular velocity [rad/s]
~	proportional to
≈	approximatively equal to
<	less than
<<	much less than
>	greater than
>>	much greater than

Prefixes indicating decimal multiples and submultiples of a Unit

Power	Prefix	Symbol	Power	Prefix	Symbol
10^{12}	tera	T	10^{-1}	deci	d
10^{9}	giga	G	10^{-2}	centi	c
10^{6}	mega	M	10^{-3}	milli	m
10^{3}	kilo	k	10^{-6}	micro	μ
10^{2}	hecto	h	10^{-9}	nano	n
10^{1}	deca	da	10^{-12}	pico	p