Chapter 1

Book Review

§ 1.0 *Introduction*

It is as well to begin this book by a review of other books that address the same subject matter which are frequently cited in the literature, or which are otherwise enlightening, and for which a student of the subject might wish to find room in his (or her) library.

This will necessarily be a review of English language publications. On the one hand, the Internet has meant that it is now easier than ever to access a vast amount of literature – so long as it is in the English language. All the books described below are available online, for free. On the other hand, the increasing stringency of copyright law means that obtaining copies of literature from foreign libraries is now more difficult than ever. Ballistics too has developed in parallel, but in isolation, in three distinct regions. The English speaking world (Britain and the United States), Europe (France and Germany) and the Soviet Union. In consequence, each region has its own repertoire of literature upon which it draws.

After WWII, there was a period of consolidation and recapitulation where the research efforts of the war were set down in a systematic way as the 'state of the art' in a number of publications by British and American ballisticians. By this time, what Corner (see below) called, "the classical problem of interior ballistics" - by which he meant the calculation of maximum pressure and muzzle velocity from the characteristics of the propellant and loading properties of the gun - had essentially been solved. Much of the literature reviewed here will therefore be from this era.

Since WWII, research on internal ballistics went on to address a number of pressing problems, primarily concerned with instabilities as the propellant burned, in both guns and rockets, but this is beyond the definition of "classical" internal ballistics. Too, it has to be said that China has emerged as the nation most interested in internal ballistics research. Journals and conferences dedicated to internal ballistics are either Chinese owned or heavily Chinese influenced.

J. Hayes, "Elements of Ordnance", John Wiley & Sons, New York (1938)
This is styled as "A textbook for use by cadets of the United States Military Academy" but stands as a surprisingly thorough exposition of weapons technology of that time. In particular, the early chapters on the manufacture and theory of propellants and explosives is still of relevance today and this book is worth seeking out on that account alone. The chapter on internal ballistics concentrates on the Leduc equations, which had been the mainstay of quantitative internal ballistics in the United States for the previous thirty years and would continue to be used for another thirty years, despite the fact that more sophisticated descriptions of the internal ballistics processes would be developed within a very few years of this book's publication.

M. E. Serebryakov, "Interior Ballistics of Tube Weapons and Solid Propellant Rockets", State Scientific and Technical Publishing House, Moscow (1942)
This was published in Russian as a text book. It was revised in 1949 and again in 1962. It covers a large range of subjects pertaining to internal ballistics in considerable detail across more than 670 pages. It is evidently revered by Russian and Eastern European ballisticians in much the same way as Corner's book (see below) is in the West, in that it is often a starting point in the introduction and first among the references of their publications. It is included here as there was an abridged translation into English by V. A. Nekrassoff of the Catholic University of America in 1965. A translation by the Air Intelligence Center at Wright-Patterson Air Force Base, Ohio, was also carried out in 1968. It is generally agreed that there is little that is novel in this book compared to the literature in the West. It is interesting, though, for its account of the history of internal ballistics research in Russia, also the fact that the references and research upon which it draws is Russian (Soviet Union) casting a light on the parallel-but-separate research that was being done in the Soviet Union on internal ballistics, but which is scarcely known in the West.

C. S. Robinson, "Thermodynamics of Firearms", McGraw-Hill, New York (1943)
This book concentrates on the thermochemistry of propellants and explosives, which is approaches in a thorough if pedantic way. On the actual thermodynamics of firearms, it is surprisingly poor. Résal's equation, for example, is never mentioned. It has relatively little to say on the modelling of the projectile's trajectory up the barrel. The description and analysis of the 'dynamite guns' on the USS Vesuvius is clearly in error.

J. S. Burlew, "Hypervelocity Guns and the Problems of Gun Erosion" Summary Technical Report of Division 1, National Defence Research Committee, Vol. 1 (1946)
This was the American rendering of "the state of the art" of internal ballistics after the research effort brought about by WWII. This was a compendium of articles covering the subject matter by writers who had been active in that research, edited by John S. Burlew. Despite its title, this book covers a broad range of theoretical, practical, technical and experimental aspects of internal ballistics across 650 pages.

J. Corner, "Theory of the Interior Ballistics of Guns" John Wiley & Sons, New York (1950)
John Corner was a mathematician who worked at the Armaments Research Establishment in the UK during WWII. This is the 'classic' text on internal ballistics and even today, this book is amongst the first two or three references in many papers on internal ballistics. This book is unique for the wide range of subjects which it covers, and the depth and detail in which it covers them. It deals with the thermochemistry of propellants and the nature in which propellants burn. It develops several variants of an analytic internal ballistics system, which are still used today to check more sophisticated numerical systems. It deals with 'leaky' guns, recoilless guns, squeeze-bore guns and much else besides. It is not, however, an introductory text to internal ballistics, rather it is a statement on the knowledge as it existed at the end of WWII. It is also dated in that it was written at the dawn of the computer age and so does not benefit from a description of the numerical techniques which would transform the ability to model realistic internal ballistic system. It concentrates heavily on mathematical descriptions at the expense of reporting on the experimental work which supports the theory.

F. R. W. Hunt, "Internal Ballistics", The Philosophical Library, New York (1951)
Colonel Hunt was the editor of this book, which is a collection of essays on various topics on internal ballistics written by a number of the researchers at the Armaments Research Establishment in the UK. It is also a "state of the art" statement – from a British perspective - of what the huge research effort during WWII had achieved. It is a more complete book than Corner's (above) in that it describes experimental methods and experimental results along with a well structured theoretical exposition. It includes a description of the Hinds-Hunt analytic internal ballistics system. There is a detailed description of numerical methods using Bush differential analysers, which were mechanical forerunners of the digital computers whose development was just starting when this book was published, and which makes this section of historical interest only.

"Oerlikon Pocket Book" Zurich-Oerlikon (1958)
This little handbook is a treasure trove of facts and figures on explosives, propellants, internal ballistics and much else. It gives details on the construction and use of small cannon – principally anti-aircraft guns – for which the company is famous. This book is often referenced as the source of the Vallier-Heydenreich equations and tables, which are a quick and easy method by which the internal ballistics of a gun can be described, given the maximum pressure and the muzzle velocity. The book was revised for a second edition in 1981.

Waldemar Wolff, "Innere Ballistik" Deutscher MilitarVerlag, East Germany (1961)
Waldemar Wolff was the chief ballistics expert at the German armaments giant, Krupp, during WWII. In 1946 he was forcibly relocated to work in the embryonic Soviet rocket base at Gorodomlya Island where he was part of a team trying to build V2 rockets from parts discovered scattered about in Soviet occupied Germany. He was allowed to return to Dresden in 1952 where he taught in various military institutions. This little book of 160 pages was published in 1961 and would have passed into obscurity except that it was partly translated by L.E. Brownell of the University of Michigan and published as **"Elements of Internal Ballistics - Russo-German Methods" Appendix III, University of Michigan Technical Reports in Internal Ballistics (1966)** This was written in some frustration by Brownell, who could not find any printed works on internal ballistics in English. Brownell wrote, "*When Michigan investigators looked for unclassified U.S. literature on ballistics they found it to be almost non-existent. The reasons for this seem to be that 1) the United States Army classifies nearly all of its ballistic research; and that 2) there is no journal in the United States which is suitable for printing technical articles on ballistic research. Therefore, the Appendices are an attempt to alleviate this problem in part by presenting technical articles from the University of Michigan*" It is a pity that this text is not more widely known as it still stands as probably the best introduction to internal ballistics ever written, hence its inclusion here. Since that time, the United States Army has had a change of heart and a significant effort has been made to make freely available much of the ballistic research of that era and of WWII.

"Interior Ballistics of Guns", Engineering Design Handbook – Ballistics Series, Army Material Command, Washington D.C. (1965)
From the theory and experimental methods it describes it would be easy to conclude this book was written at the end of WWII and not twenty years later. This work is similar in content, scope and detail to that of Hunt's "Internal Ballistics" above and this work actually makes a very useful companion to Hunt, as it essentially gives an account of the WWII internal ballistics research efforts from the American perspective. It appears to

have originally been written in report form, but was then re-issued as an optical character recognition (OCR) copy of that report in a bound booklet, in which format it is generally available today. It is a pity that sufficient care was not taken to correct all the OCR errors. This is particularly evident in the equations, which makes it generally difficult - and in some places impossible - to follow the mathematical argument.

H. Krier and M. Summerfield, "Interior Ballistics of Guns", Progress in Astronautics and Aeronautics, Vol. 66, (1979)

As a number of books described above set down the "state of the art" at the end of WWII, then this book gives an overview of how matters stood at the end of the 1970s. It was widely disseminated, being printed in the United States, the UK, Germany, France and China. It has contributions by many of the top US ballisticians of the day, though much of the material is recycled from earlier reports and publications from the contributors. The book starts with a review of internal ballistics theory and the use of computer models. The book then moves on to a detailed look at propellants, and then particularly concentrates on the problem of pressure waves and uniform ignition of the propellant bed which was the major preoccupation of that time.

"Handbook on Weaponry", Rheinmetall GmbH (1982)

Rheinmetall had published handbooks on artillery and weaponry since 1936, but after persistent requests they were finally prevailed upon to publish an English version of their handbook in 1982. It is similar to the Oerlikon Pocket Book (see above) in that it covers all aspects of the theory and design of weapons and ammunition, but on a much grander scale across 730 pages. Of this, some sixty pages are dedicated to internal ballistics, which it covers methodically in some detail. An analytic system is developed and an example is given for its use, but there is no description of numerical methods.

C. L. Farrar and D. W. Leeming "Military Ballistics – A Basic Manual", Brassey's Battlefield Weapons Systems & Technology, Vol. X, Brassey's Battlefield Publishers, New York (1983)

This book covers internal ballistics, external ballistics and terminal ballistics in just 200 pages. It was written as a text book for army officers and technical specialists to give a good grounding in ballistics in general, and it is interesting to contrast this slim book to the weighty tomes written for US officer cadets in the early 20th century. The subject matter is well laid out and despite the necessary abbreviation, it is covered effectively. The description of an analytic system is not attempted. A numerical system is described, and is regularly cited, but unfortunately the ballistic equations to be solved are not properly ordered in the description, which would lead to poor performance of the model as detailed. It is surprisingly thorough on how the ballistic parameters of propellants are

derived from closed bomb measurements. One criticism is that the typesetting for the equations is crude, which hinders the readability of this book.

D. E. Carlucci and S. S. Jacobson, "Ballistics" 2nd Ed. CRS Press, New York (2013)
This modern text book covers all the branches of ballistics: internal ballistics, transitional ballistics, external ballistics and terminal ballistics. The topic of internal ballistics is covered in just over 100 pages and is rather perfunctory in consequence, with much basic groundwork left as an 'exercise for the reader'. It is also curiously dated, and so for a modern text book, rather unbalanced. For example, Corner's analytic system developed during WWII is described in great detail. In fact, a more detailed description will not be found anywhere else in the literature. But numerical systems, as used by today's ballisticians, are accorded little more than an overview in less than three pages. The modern ballistician who hopes to develop a numerical model to illuminate some internal ballistics problem will have to look elsewhere for guidance on this quest. In that regard, it would be hoped that there would be numerous references to steer the student to where such material is well covered, but there is only one – Baer and Frankle's report of 1962 on the very first efforts to run a numerical internal ballistics model on a digital computer. This is a poor choice as the approach to a numerical simulation is not as generally used today. Then again, burning rate coefficients and form functions are discussed in detail, but these days propellant powder companies issue vivacity charts as the key descriptor of the burning rates of their powders, and 'vivacity' is never once mentioned in the book.