

Preface to Three Reviews of *Pyrotechnics* by A. Hardt

On occasion, when a book to be reviewed has special significance, we have included more than one reviewer's comments about it. In the present case we are including three reviews by authors with differing backgrounds, and thus viewing the book from differing perspectives. The first short review was written by one of the persons participating in the publication of the book, and for that reason he thought it inappropriate for him to write a detailed technical review. The second short review was written by a pair of authors relatively new to the field of military pyrotechnics. The third review was written as a more complete technical review of the book.

Generally, as a courtesy, book reviews to be published in the *Journal of Pyrotechnics* are sent to the author, with an offer to publish any comments or response they wish to make. In this case, since the primary author is deceased, the reviews were sent to the book's publisher. Although, comments were received from a representative of the book's publisher, permission was not granted for those comments to be published.

Review of:

Pyrotechnics

Alexander P. Hardt
Pyrotechnica Publications
[ISBN 0-929388-06-2] 2001

Bernard E. Douda, PhD

A General Review

In his preface to *Pyrotechnics*, Alexander Hardt indicates that his objective is to present an overview of significant advances. Initially, his effort began as a collaboration with Herbert Ellern in preparing an updated edition of *Military and Civilian Pyrotechnics*. For this reason, the reader will observe similarities between Hardt's book and Ellern's. However, the reader will also note that information in the new book has been updated and significantly expanded. Included are new comprehensive chapters on "Fireworks" and on "Statistical Tests and Analysis Methods."

The book is quite impressive, and very attractive. No other book on pyrotechnics has covered so wide a scope as thoroughly as this one does. Details abound within. The page size is 7 × 10 inches, as compared to other pyrotechnics books where the page size of which is typically 5-1/2 × 8-1/2 inches. Within its thirty pages of introductory material, 430 pages of text, and 24 plates, are 23 chapters including a glossary, 79 tables of data, 42 line illustrations, 45 photographic illustrations, four appendices, a bibliography, and 263 references. The typography, printing, and binding are of exceptionally high quality.

Hardt's draft was begun in 1985, and his personal contributions ended with his untimely death in 1989, still incomplete. The manuscript languished with another publisher for some time before being "rescued" by Pyrotechnica Publications. It is to be expected that a few of the subjects covered do not reflect information and developments subsequent to that period. This is consistent with the publisher's and the editorial team's desire to produce the book without de-

grading the goals and vision that Hardt had for his book. Nevertheless, a number of topics were added and a great number of areas were updated in an effort to fulfill his desire for quality, correctness and completeness.

The chapter on "Statistical Tests and Analysis Methods" is a major contribution toward satisfying Hardt's goal for completeness. Barry T. Neyer, Ph.D., a noted expert in the field, wrote this chapter. He provides a summary of the evolution of tests and analysis starting with the Probit test in 1935, the later Bruceton test, through the current Neyer D-Optimal test. This information will guide the reader when making a choice of which method to apply and the relative advantages of each.

Barry Bush, recipient of the Pyrotechnics Guild International's 1992 Grand Master award, contributed the chapter on "Fireworks." In a comprehensive review of Hardt's book, Kurt Medlin, author of numerous fireworks articles, past PGI competitor and award winner, display operator, and Trustee of the Fireworks Foundation, recognized the great value of the fireworks chapter and emphasizes its completeness, accuracy, thoroughness and up-to-date contents. His complete review, and the Table of Contents of the book, were published in the November 2001 *PGI Bulletin* (No.126) and on the web at <http://www.ipsusa.org/review.pdf>.

Just as Medlin points out that many aspects of military pyrotechnics are applicable to fireworks, so there is much information in the fireworks chapter directly applicable to military pyrotechnics. Of particular value are the descriptions of material incompatibilities and associated safety and handling, the precautions needed in dealing with moisture in compositions and high humidity in the processing areas, and the impact of low humidity on electrostatic sensitivity.

The chapter on "Matches" has changed considerably from the Ellern version. Stig Johansson, Ph.D., a leading expert on matches, and author of numerous articles on this subject, provided assistance in ensuring that the information was current and correct. The discussions of the safe mixing of potassium chlorate and phosphorus provide insights into the processing of extremely sensitive materials.

The developer of military pyrotechnics will find many useful tables of relevant material attributes and updated information about colored and obscurant smokes, colored and illuminating flames, generation of light and sound. Delays, primers, igniters, ignition concepts, sample thermodynamic calculations, and characteristics of the principal materials used in pyrotechnics are included as well as discussions of toxicity, hazards, and safety. I am in total agreement with many of my colleagues who have already expressed their desire to have a copy of this book at work and at home for ready reference.

Review of:

Pyrotechnics

Alexander P. Hardt

Pyrotechnica Publications
[ISBN 0-929388-06-2] 2001

Sara K. Poehlein, PhD and
Caroline K. Wilharm, PhD

Dr. Poehlein is an analytical chemist & Dr. Wilharm is a chemical engineer. Both have nearly three years of experience with military pyrotechnics.

A Brief Review

This book exceeded the author's intent to be an introductory volume on pyrotechnics. It is a reasonably extensive overview of the field. The thoroughness with which each subject is covered varies, with some subjects briefly touched upon, and others covered in more detail than necessary for this type of text. In many cases, the lack of detail stems from the fact that most of the book was written more than 10 years ago. For instance, Chapter 3. Disposal of Hazardous Materials is obsolete, as the field of demilitarization has grown extensively over the past dec-

ade. Also, the reference for the toxicity guidelines for pyrotechnic ingredients presented in Chapter 2 is from 1963.

This book is easy to read and follow, written in a language that is clear and flows well. The author's subtle humor interspersed throughout the book (see the Glossary) enhances its readability and enjoy-ability. The list of references is quite extensive, giving the reader many opportunities to learn more about a topic.

The inclusion of safety and handling as the second chapter of the book appropriately emphasizes this important subject. There are also references to safety throughout the other chapters, further stressing its importance. However, it would have been advantageous to present some of the other topics in a different sequence. For instance, Chapter 16. Materials Used in Pyrotechnics, should have been placed toward the beginning of the book, rather than the end.

The colorful pictures in the book are of excellent quality, but the reader tends to lose his train of thought when flipping back and forth between the pictures and the text, particularly for Chapter 15. Fireworks. This chapter was added to Hardt's original work to supplement his material, and it covers materials, safety, applications, formulas, assembly instructions, packaging, and history for numerous display fireworks. This chapter is far too long when compared to the other chapters, and much of the material covered here, though informative, would have been better discussed in shorter, specific chapters.

The lists of formulas for pyrotechnic items provided throughout the book are an excellent reference, as is the glossary. The chapters on matches and on materials are also well done. The chapters on mechanisms and rates and on thermochemical calculations have some minor errors, so the reader should be cautious if these methods are to be used.

Having read this book in its entirety, we have a better perspective about the breadth of the field of pyrotechnics. Good information about any area of interest is available, whether your interest is in creating displays, theatrical effects, or military applications.

Review of:

Pyrotechnics

Alexander P. Hardt
Pyrotechnica Publications
[ISBN 0-929388-06-2] 2001

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The introductory pages of *Pyrotechnics*^[1] reveal that Dr. A. P. Hardt died in 1989. We are told that during a long career as a scientist with Lockheed Missiles and Space Co., Inc. Dr. Hardt published extensively in the field of pyrotechnics and became “a good friend” of both Dr. H. Ellern and Dr. T. Shimizu. At the time of his death Dr. Hardt was working on the manuscript of a book intended to be a “revised and updated adaptation” of Dr. Ellern’s *Military and Civilian Pyrotechnics*.^[2] According to the Publisher’s Preface, Dr. Hardt finished the first draft of his manuscript a few weeks before his sudden death. The manuscript “rested for rather a long time with a large publisher” and eventually was retrieved by Dr. Hardt’s widow, who requested that the present publisher, Robert G. Cardwell, should “see the manuscript to publication”. *Pyrotechnics* is the result of that effort.

This is a beautifully produced book. Its size is similar to that of Brock’s classic *Pyrotechnics*^[3] and Plimpton’s *Fireworks*.^[4] Like those books, it has decorative endpapers adorned with historical images that remind the reader that the subject has a long tradition. The front and back boards are tastefully enhanced with borders impressed into the material. The spine is decorated in gold, with the title in gold on a red background, most elegant against the cream cloth of the binding. There is gold decoration above and below the title, and the edges of the pages are red. The book opens easily and stays open on the table with no tendency for the pages to stand up or turn by themselves. The paper has a pleasingly non-glossy finish and the type is clear. A colleague who has won prizes for bookbinding

confirmed that the design and construction of this book is of an unusually high standard, rarely found in mass-produced books. A note at the back of the book indicates that the book “has been designed, printed on acid-free paper, and durably bound by the Smyth-sewn process, by Bayport Printing House, Inc, Bayport, Minnesota, United States of America.”

The same note discusses the type used for the text. “Grace and legibility, without distracting ornament” are stated to be characteristic of the work of the designer of the typeface. The type is certainly legible, and is indeed free of distracting ornament. One minor aspect of the type setting, however, seemed odd. The word “aerial” is frequently written as “ærial”, and “aerosol” as “ærosol”, and even “aeroplane” as “æroplane”. This looks rather quaint, but it is distracting, and is also, as far as this reader can ascertain, inconsistent with conventional usage.^[5-7]

The Table of Contents indicates that the topics covered are appropriate:

- Chapter 1 Definitions, Scope and Literature
- Chapter 2 Safety and Handling of Hazardous Materials
- Chapter 3 Disposal of Hazardous Materials
- Chapter 4 Statistical Test and Analysis Methods
- Chapter 5 Mechanisms and Rates of Pyrotechnic Reactions
- Chapter 6 Color Creation
- Chapter 7 Thermochemical Calculations
- Chapter 8 Some Words on Instrumentation
- Chapter 9 Ignition
- Chapter 10 Primary Ignition
- Chapter 11 Matches
- Chapter 12 Primers and Ignition Mixtures
- Chapter 13 Miscellaneous Ignition Devices
- Chapter 14 Miscellaneous Pyrotechnic Devices
- Chapter 15 Fireworks
- Chapter 16 Materials Used in Pyrotechnics
- Chapter 17 Generation of Light
- Chapter 18 Delay Trains

- Chapter 19 Incendiaries and Tracer Munitions
- Chapter 20 Generation of Smoke
- Chapter 21 Generation of Sound
- Chapter 22 Gas Generators and Heating Devices
- Chapter 23 Glossary
- Appendix I Selected Further Resources for Pyrotechnics
- Appendix II Normal Distribution, Mean and Standard Deviation
- Appendix III Sieve Sizes
- Appendix IV KDNBF and DXN-1 (DXW-1)
- Bibliography
- Index

A Note about the Type and Printing

The content is of extremely variable quality. The best part by far is the chapter on fireworks contributed by B. L. Bush. It is comprehensive, well written and clearly reflects the author's knowledge and enthusiasm for his subject. This chapter alone would certainly justify the purchase of the book. It takes up over one third of the book, and is lavishly and appropriately illustrated with line drawings and colour and monochrome photographs. It seems highly likely that Mr. Bush could have written much more, to judge from his recent excellent contribution to the *Pyrotechnics Guild International Bulletin*.^[8] It is greatly to be hoped that he will do just that. A book as well presented as this one, but filled with an even more complete treatment of fireworks by Mr. Bush, would be a delight for any firework enthusiast.

The chapter on statistical test and analysis methods, contributed by Dr. B. T. Neyer, is also of an appropriate standard for a book of this type. One of the services that the writer of a technical book performs for the reader is to act as an interpreter of material from the primary literature. The original papers usually make no concessions to the needs of non-specialists and can be very intimidating for the general reader. The author of a technical book can help make this material more accessible by stating the important facts and providing clarifying explanations. Dr. Neyer's chapter on statistical test and analysis methods is a good example. It is well

referenced and provides explanations that would assist the reader in working with those references. It would perhaps have been useful to provide a worked example showing the calculations for each of the methods discussed.

These two chapters contributed by guest authors are consistent with the expectations raised by the impressive presentation of the book. It is unfortunate that much of the rest of the book falls short of the standards set by these two chapters. Dr. Hardt wrote "Pyrotechnic literature is commonly characterized by fragmentation and a lack of a comprehensive outlook." That would be a very fair comment on this book.

The glossary is very good; it is curious, however, that it contains no definition of 'pyrotechnic' or 'pyrotechnics'. The first sentence of the first chapter states that "Pyrotechnics is distinguished from the closely related technology of explosives and propellants, though their functions frequently overlap." It would have been useful to see a clarification of what is to be considered "pyrotechnics" and what is not. The content of the book would suggest that Dr. Hardt's definition would be very broad indeed, including such things as spontaneously flammable liquids and gases, pyrophoric metals, white phosphorus, and various primary explosives. Outlines for the synthesis of two of the latter are presented as Appendix IV. This Appendix is of only marginal relevance and might well have been omitted, especially as the original references are cited.

Appendix I provides lists of "Selected Further Resources for Pyrotechnics". It is strange that the list of publications has no reference to *American Fireworks News*.^[9] One can only wonder what selection criteria led to the exclusion of this valuable source of information.

Over 13 pages of Appendix I are given to a list of companies providing "Services and Supplies". If these companies sponsored the book, well and good; if not, it is hard to see the value of listing them. Companies, or at least their contact details, tend to be very ephemeral. A list that is up-to-date today is likely to be of much less use in a year or two.

A bibliography of 263 titles is a useful feature of this book. The remaining contents can be divided into two categories: chapters of descrip-

tive material about various devices and applications and chapters on scientific matters related to pyrotechnics.

The best that can be said for the science-related chapters is that they provide some useful references. Mostly, they do very little to assist the reader to make sense of those references. They present a few equations; some of them, unfortunately, are gravely misquoted. This can only cause confusion. There is no point in publishing equations just for the sake of displaying them. Equations are of value only if they allow something useful to be calculated or if they aid the understanding. Many of the equations published in this book are useless, either because they are wrong or because an adequate explanation is lacking.

The errors in the published equations are not, it would seem, mere typographical errors. Regrettably, comparison with the corresponding equations in the original papers suggests that the author apparently did not adequately understand the material. This conclusion was in every way contrary to this reader's expectations and was reached reluctantly. It is, of course, completely inconsistent with Dr. Hardt's reputation and with the standard of his co-authored papers in technical journals. Yet, the material is here for all to see. In the section "Kinetics of Reaction" in Chapter 8, the rate of reaction is given by equation 8.1:

$$\frac{dx}{dt} = A(1-x)^n$$

where the exponent

$$n = \frac{-E_a}{RT}$$

There is no need to define the meaning of the various symbols; the point is that the corresponding equation in the original reference^[10] is different:

$$\frac{dx}{dt} = r_0 (1-x)^n e^{\frac{-E_a}{RT}}$$

where the exponent n is the order of the reaction. The symbol e (for the number 2.71828...) ^[11] does not appear in the version published in this book. If there had not been the explicit statement that the exponent

$$n = \frac{-E_a}{RT},$$

one might attribute the error to the typesetter and the proof reader.

Similar examples of incorrectly transcribed equations are to be found in Chapter 9. Equation 9.1 is

$$\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial x^2} + \left(\frac{Q}{C\rho} \right) A_0^{\frac{-E_a}{RT}}$$

The corresponding equation in the original^[10] is

$$\frac{\partial T}{\partial t} = \alpha \frac{\partial^2 T}{\partial x^2} + \left(\frac{Q}{C\rho} \right) K_0 \exp\left(\frac{-E}{RT}\right)$$

The expression

$$\exp\left(\frac{-E}{RT}\right)$$

is just another way of writing

$$e^{\frac{-E}{RT}}$$

Can one avoid the conclusion that whoever wrote this material did not understand the difference between ne^x and n^x ?

Equation 9.4 is evidently Merzhanov and Averson's equation 25,^[12] transformed in accordance with the incorrect assumption that $ne^x = n^x$. The same error is evident in equation 9.5, which is adapted from Merzhanov and Averson's definition of a dimensionless variable giving the scale of the width of a chemical reaction zone.^[12] The error is also to be found in equation 5.1 on page 33.

An author writing about the scientific subjects treated in this book ought to know about e^x . A look at two of Dr. Hardt's co-authored publications^[13,14] showed that he certainly did know about it. Furthermore, the 1974 paper by Phung and Hardt^[14] on ignition characteristics of gasless reactions is vastly better than any scientific chapter in this book. What went wrong between that work and this?

The chapter on thermochemical calculations is disappointing. It would have been useful to include a general introduction to the subject. For example, I. Barin's *Thermochemical Data of*

Pure Substances^[15] provides a concise overview in a 19-page chapter, followed by 9 pages explaining how to calculate the thermodynamic functions and 13 pages giving many worked examples of practical applications. It might be objected that 41 pages on thermodynamics would be excessive in a book about pyrotechnics. However R. H. Parker's *An Introduction to Chemical Metallurgy*^[16] is of similar length to Hardt's book, and Parker devotes his first chapter (37 pages) to an introduction to chemical thermodynamics and a second (47 pages) to entropy and free energy. Thermodynamics is certainly as relevant to pyrotechnics as it is to metallurgy, yet this book gives the subject only five pages, including a whole page of conversion factors between various units, many of which are of historical interest only. This page would have been more appropriately placed as an Appendix.

The brief treatment of thermodynamics is confusing. Symbols and equations are used with almost no comment or explanation. The author correctly indicates that changes in the Gibbs free energy have to be calculated from the enthalpy and entropy changes at the temperature of interest, but then proceeds to use values for 298 K in his example for a high-temperature reaction. The example of the application of the Gibbs free energy is made more confusing by an error in the table of numerical values (page 48) that gives the units of entropy as kilocalories/mole instead of calories/mole. The correct units are used (but not mentioned) in the calculation, so a credible temperature is calculated. A reader unfamiliar with the subject would be left wondering where the factor of 0.001 came from. Such a reader would probably leave this chapter thinking that thermodynamics is just too difficult and obscure. Better leave such things to the clever fellows who can handle all those impressive equations.

The chapter on colour creation combines brevity and inaccuracy to create confusion. The subject is obviously important; furthermore, its scientific and practical aspects have been discussed in some detail, and there are interesting differences of opinion that could have been reviewed.^[17-23] Yet, here it is given merely five pages, including one page for a table of wavelengths and another showing a monochrome sketch of the C.I.E. chromaticity diagram. The value of the table of wavelengths is question-

able, as no comment is given on the possibilities and limitations of using the various species as colour emitters in pyrotechnics. The sketch of the C.I.E. chromaticity diagram is nowhere near as informative as that presented by Dr. Shimizu.^[20] A coloured plate of the chromaticity diagram appears as Plate 1. Something has gone badly wrong with this plate. The region that ought to appear orange and yellow is a sickly green, the green region is brown, and blue is rendered as violet. The standard of this plate is, regrettably, consistent with the three-page treatment of pyrotechnic color creation. It seems incredible that an author who has cited Dr. Shimizu's writings on the subject^[20,21] could produce such vague and misleading work. The author cites *Pyrotechnica* as a source of information on the subject, but does not refer to any specific articles. He does his readers a disservice. Anyone seeking an introduction to pyrotechnic color creation would do well to read the two-part article in *Pyrotechnica* on the physics and chemistry of colored flame.^[22,23] Had the author studied and understood these articles, he would have been able to provide a far clearer explanation of the nature of molecular emission spectra. He wrote: "Many ionized species exist in the gaseous phase as bi- and tri-atomic molecules which give off molecular band spectra that arise from the ability of the molecule to absorb vibrational and rotational energy. Because molecules have fixed masses, sizes and interatomic spacing their rotational and vibrational energies are also quantized and so can take up and emit energies in discrete wavelengths. To the extent that these band spectra are in the visible range, they are of interest to pyrotechnics." One has to wonder about the use of the word "ionized". As indicated in Table 6.2, the species of interest as molecular band emitters in pyrotechnics are simple neutral molecules, not "ionized species". The importance of molecular vibration and rotation in the generation of molecular bands in the visible is, as clearly explained in reference 22, a consequence of the effect of these quantized molecular motions on the electronic energy states. The rotational and vibrational motions produce a great many more electronic energy states than there would otherwise be. Consequently the electronic spectrum of a molecule is a set of "bands" of closely spaced "lines" rather than the set of well-separated lines seen

in the electronic spectrum of an atom. A reader seeking a more detailed discussion will find it in any textbook on molecular spectroscopy.^[24]

It is hard to believe that the person who wrote this inadequate exposition on colour generation was also responsible for the related chapter on light generation. This chapter is quite good. It would have been useful to include a sketch of the black body spectrum at various temperatures, to complement the table of subjective colours (Table 17.1, p 277), and to have provided some explanation of the difference between radiometric and photometric units. Nonetheless, this chapter seems free from obvious errors and provides some interesting technical details. Even here, however, one gets the feeling that the information might not always be reliable. Referring to the use of organic solvents to dilute the binder when combining metal powder and binder in the manufacture of magnesium flares, the author writes: "The older literature mentions trichloroethane but the current practice of blaming half the world's ills on chlorinated hydrocarbons has probably made this practice a thing of the past". Yet, as noted earlier in the book, "Reactive metals reduce chlorinated hydrocarbons... chlorinated hydrocarbons may be excellent degreasing agents, but they must never be used in place of hydrocarbon solvents." One does not have to blame "half the world's ills on chlorinated hydrocarbons" to feel that it is probably wise not to mix trichloroethane with powdered magnesium.

Enough shortcomings have been mentioned to indicate that this is not a book to be completely relied upon. It would have benefited from a highly critical editor, willing to take the time to check everything against the references. Understandably, that would have been a mammoth task. Some of the chapters, however, do not just need editing – they deserve to be rewritten and some irrelevant material ought to be removed. Were it not for the two excellent chapters by the guest authors, this book would best be left on the shelf. As it is, it is still worth purchasing and will certainly make a very handsome addition to the pyrotechnic library.

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