The Theory of Industrial Explosive

Lü Chunxu et al.

兵器工業出版社

The Theory of Industrial Explosive

Lü Chunxu et al.

兵器工業出版社

图书在版编目（CIP）数据

工业炸药理论 = The Theory of Industrial Explosive：英文/吕春绪等著. —北京：兵器工业出版社，2007.10
ISBN 978-7-80172-878-4

Ⅰ.工…Ⅱ.吕…Ⅲ.工业炸药—理论—英文 Ⅳ.TQ564

中国版本图书馆 CIP 数据核字（2007）第 085023 号

出版发行：兵器工业出版社
发行电话：010-68962596，68962591
邮　　编：100089
社　　址：北京市海淀区车道沟 10 号
经　　销：各地新华书店
印　　刷：北京市登峰印刷厂
版　　次：2007 年 10 月第 1 版第 1 次印刷

责任编辑：蒋昌群　李翠兰
封面设计：李　晖
责任校对：仝　静
责任印制：赵春云
开　　本：787×1092　1/16
印　　张：27.75
字　　数：898 千字
定　　价：108.00 元

PREFACE

This book is a theoretical monograph of industrial explosive, which is regarded as the energy of energy source industry and the base of basic industry and plays an important role and occupies an important position in national economic construction. The book "Industrial Explosive" we wrote thirteen years ago, published by The Publishing House of Ordnance Industry, had already been sold out and was in warm welcome at that time. Though the book "Industrial Explosive" systematically expatiated the basic contents of industrial explosive and emphatically discussed its composition designs, performances, manufacturing processes and so on, people had been eagerly longing for a book to describe the theory of industrial explosive in more detail, to summarize theoretically the various industrial explosives, especially those we have studied greatly, to give theoretical explanation to some experimental facts, and to offer further recognition, substantiation, perfection, and promotion to some opinions, views, and theories, so that it can provide certain guidance and promotions to overall studying, manufacturing, application, and development of industrial explosive, which is our intention and purpose of writing the book "Industrial Explosive Theory" as well.

This book is composed of the theories on detonation, formulation design, mixing, expanded ammonium nitrate explosive, emulsion, gel and the safe theory of permitted explosive, the sphere – forming mechanism of bonding explosive, the solution theory of liquid explosive, the theory of source vibrating pellet and so on. The self – sensitization theory of expanded ammonium nitrate and the expansion theory of ammonium nitrate were emphasized, which were invented with our independent intellectual property. Under the guidance of these theories, the expanded ammonium nitrate explosive was invented, which was awarded respectively the special progress prize of science and technology by China North Group Corporation in China, the national second class progress prize of science and technology, one of the ten major patent gold medals for inventions in China awarded jointly by State Intellectual Property Bureau and United Nations World Intellectual Property Organization. By the end of 2006, the expanded ammonium nitrate technique had already been popularized and applied by more than 80 factories in our country. The establishment and the development of the theories provided impetus for industrial explosive in the mainland to catch up with and surpass the international advanced standard. Meanwhile, detailed description on the liquid explosive solution theory, heat resistant explosive and its bonding theory were given in this book. With the guidance of these theories, we developed a SJY high detonation velocity liquid explosive, hexanitrostilbene (HNS) and 3021 bonded explosive, which were respectively awarded the third class prize of national progress of science and technology, the third class prize of national invention, the third class prize of the scientific and technological progress of Jiangsu Province.

The theory of industrial explosive is the main thread of this book. It emphasized the introduction of the theories on detonation, self – sensitization and expansion, the solution theory, the bonding theory, the theory of source – vibrating pellets, and so on. Meanwhile, it described in detail the powdery explosive (ammonium – TNT explosive, ammonium oil explosive, expanded ammonium nitrate explosive), emulsion explosive, powdery emulsion explosive, liquid explosive, heat resistant explosive and other industrial explosive, etc. The novelty of the book is reflected by its integrated and systematic contents. Expanded ammonium nitrate explosive, liquid explosive, heat resistant explosive, bonded explosive, source vibration pellet, etc. have been awarded respectively the national and ministerial level prizes; some related theories had been developed with our own independent intellectual property and 12 invention patents formed. The current achievements and developments in the field were well shown in the book, which was based on the achievements above and lots of domestic and international references. Meanwhile, this book was of great practical values as well. Although it was a theoretical monograph, it was combined with large mount of different techniques of industrial explosive, especially our ten – year scientific researches and the practices on transferring our techniques to the factories. Some designs, processes, and technical questions related with equipments about which technicians in factories have cared much were described in detail in this book, therefore it will provide an important guidance and reference for people to set up related production lines and to enrich their practical experiences.

This book can be used as the teaching material for related disciplines and specialties in higher education institutions; it can also be a reference for people in management, engineering technologies, and production in their areas related to industrial explosive of researching, designing, producing and using.

This book was written by Professor Lü Chunxu, et al. The outlines of the book was examined by Professor Wang Xuguang (An Academician of China Engineering Academy), Professor Xu Gengguang (An Academician of China Engineering Academy), Professor Ye Yupeng, Professor Chi Shuyi, Professor Liu Ronghai, Professor Yan Shilong, Professor Wu Tengfang, Senior Engineer Zhang Jiahao, Senior Engineer Yu Lizhi, Senior Engineer Zhao Guoqiang, et al. Professor Xu Mingzhong, Professor Wang Guilin, Professor Lü Zhaohua and Pakistan Master Ayaza checked the whole book. Professor Xu Mingzhong is the chief umpire. And they provided lots of precious proposals on its structures and contents, hereby great thanks are owed to them.

Chapter 1, 2 and 10 of this book were written by Professor Lü Chunxu; chapter 4, 5 and 6 by Professor Liu Zuliang; chapter 3, 7, 8 and 12 by Professor Lu Ming; chapter 9, 11 and 13 by Associate Professor Chen Tianyun; chapter 14 and 15 by Associate Professor Ye Zhiwen; and chapter 16 by Professor Liu Dabin.

We wrote this book to devote to our readers, in virtue of this chance, we also want to express our sincere gratitude and respect to our leaders, colleagues, friends who guided, subsidized, helped, supported us in the course of our researching, producing and using expanded ammonium nitrate explosive, liquid explosive, heat resistant explosive, bonded explosive and source vibrating pellet.

The Industrial Explosive Group and relevant people have completed a large number of experi-

ments and documents for the successful development of expanded ammonium nitrate explosive, liquid explosive, heat resistant explosive, bonding explosive, source vibrating pellet, etc. and for the writing of this book, especially Professor Sun Rongkang, Professor Hui Junming, Senior Technician Wang Yilin, Senior Engineer Fang Xiuxia, Senior Engineer Qin Weiguo, Master Ding Yun, Doctor Hu Bingcheng, Doctor Zhou Xinli, Doctor Gao Dayuan, Doctor Du Yang, Doctor Chi Bo, Doctor Qian Hua, Master Wu Qiujie, et al. Large amount of their scientific experimental researches, and their dissertations had made great contributions to the birth and development of the achievements listed above, hereby we express our gratitude to them as well.

Because of the limitation in our knowledge and competence, surely there are still some oversights and mistakes in the book. We'd like to appreciate readers for their criticizing and correcting.

Author
March 2007

目　录

1 General Survey of Industrial Explosive

1.1 Industrial Explosive and Its Function

Industrial explosive, with another name of "civil explosive", is an explosive mixture of oxidants, flammable agents, additives, etc. According to the oxygen-balanced principle, it is a non-ideal explosive. It is widely applied in various industries, such as petroleum, coal, traffic, mining, metallurgy, construction materials, chemical industry, water conservancy, electric power, forestry, mechanical manufacturing, urban architecture, disaster recovery, agriculture, etc. Among the industrial products, a few is so widely used as the industrial explosive. So it is considered as "the energy source of energy source industry", "the base of the basic industry".

With the rapid development of our national economy and the increasing of large amount of capital construction, the demand for industrial explosive increases constantly. According to the analysis and prediction of domestic and international authoritative organizations, the next ten to twenty years is still in the high-rise period of our national economy. During this period, the capital construction will be the important motive force to spur the development of our national economy. With more and more high and new techniques entering the field of capital construction, urgent need to develop new types of industrial explosive will be put forward. Therefore, people working in the industrial explosive are facing a good developing environment and a precious historical opportunity. Inevitably, industrial explosive do and will have wider application and developing prospect, and have important and irreplaceable function in the construction of social modernization.

1.2 Compositions, Structures and Characteristics of Industrial Explosive[1~12]

Industrial explosive is a category of special mixture explosive. In the view of their compositions, structures and characteristics, they should first of all possess the structures and characteristics of explosive.

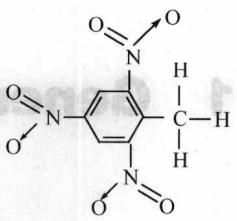
Explosive is a substance, which takes extremely rapid chemical reactions, releases enough heat and gas, and does work to outer environment under certain initiation of external energy.

Single compound explosive is a compound of single ingredient, which has explosion performance. Take TNT as an example to explain the characteristics of such kind of materials from the chemical structures of their molecules.

The structure of the TNT is as follows:

Its approximate equation of explosion reaction is as follows:

$$C_7H_5O_6N_3 \longrightarrow \frac{5}{2}H_2O + \frac{7}{2}CO + \frac{3}{2}N_2 + \frac{7}{2}C + Q_V$$



Here the reaction heat Q_V means the explosion heat of TNT, nearly equals to 884.0 kJ · mol^{-1}. If the influence of agglomeration heat is neglected, we can think that the explosion heat is the difference of the total energy of the chemical bonds of explosion products and the total energy of the chemical bonds of the molecule of TNT. By simple calculation and comparison, we will find the reason why the explosion reaction can release so much heat. It is because among the explosion products the element oxygen (often called oxide element, has greater electro-negativity), is bonded directly with carbon and hydrogen (often called flammable elements, have less electro-negativity). Comparatively, the chemical bond made up by such two atoms, which have greater difference in electro-negativity, has more bond energy (the related bond energy is listed in Table1. 1).

Table 1. 1 Bond Energies for Some Common Chemical Bonds in the Molecules of Explosive

Chemical Bond	C—H	C—C	C=C	C—N<O,O	O—H	C≡O(CO)	N≡N
Bond Energy /kJ · mol^{-1}	405.4	262.9	423.7	1 004.8	480.5	880.9	712.6

In the molecule of TNT, oxygen (oxide element) is not linked with carbon or hydrogen (flammable elements) directly. They are linked by nitrogen (in the form of $—NO_2$), and the electro-negativity of the nitrogen is between oxygen and carbon or hydrogen, and the energy of chemical bonds made up by nitrogen and one of the three (carbon, hydrogen, and oxygen) is relatively small, therefore the total energy of chemical bonds of TNT is small. As a result, the total energy of the chemical bonds of the explosion products is much more than the total energy of the chemical bonds of TNT. That is why the above-mentioned explosion reaction is able to release large amount of heat. It seems that the nitrogen plays the role of isolating the oxide element and the flammable elements in TNT, so it is usually called the isolating element.

All single compound explosive are the same as mentioned above, therefore it can be said that the molecule of single compound explosive is linked by oxide element and flammable element through iso lating element and is in a state of relative balance. Under the action of external energy, the molecule disintegrates rapidly, the oxide element and the flammable element combine directly and release large amount of heat and gaseous products, this process is explosion (with certain brisance or strength).

As far as for a nitro ramification containing carbon, hydrogen, oxygen and nitrogen is concerned, the molecule with proper quantities of nitryl has the explosion performance. If it can reach the basic demand of high explosive, it would be applied in reality as a member in the single compound explosive.

Besides its suitable electro-negativity to play the isolating role, isolating element nitrogen has many advantages. For example, it can produce N_2 with larger specific volume after decomposing, and

give off large amount of energy at the same time (the energy of N≡N is 712.6 kJ · mol^{-1}, six times more than that of N—N, which is 113.0 kJ · mol^{-1}), so it is really much ideal.

In summary, the common single compound explosive is all nitro compound containing carbon, hydrogen, oxygen, and nitrogen. The specific structure of the explosive is that it is usually made up of oxide element, flammable element and isolating element, and the isolating element nitrogen usually exists in the nitryl.

As a mixed explosive, industrial explosive is equally made up of oxidant (oxide element) and combustible agent (flammable element), which generally exists in different materials, for example:

Liquid explosive:

Hydrazine nitrate ($N_2H_5NO_3$)	Hydrazine hydrate ($N_2H_4 \cdot H_2O$)
⇩ Oxidant	⇩ Combustible agent
O (offer the oxide element)	H (offer the flammable element)

To an ammonium oil explosive, ANFO:

Ammonium nitrate (NH_4NO_3)	Diesel fuel ($C_{13}H_{20}$)
⇩ Oxidant	⇩ Combustible agent
O (offer the oxide element)	H (offer the flammable element)

To an expanded ammonium nitrate explosive:

Expanded ammonium nitrate (NH_4NO_3)	Wood powder ($C_{39.2}H_{70.8}$), Diesel oil ($C_{13}H_{20}$)
⇩ Oxidant	⇩ Combustible agent
O (offer the oxide element)	H (offer the flammable element)

Through certain mixing processes, mixed explosive is gained by mixing oxidant and combustible agent together. The higher the mixed degree is, the larger the contact area is, the better performance the mixture has, the closer the explosion reaction between the molecules of the mixed explosive is to the complete detonation reaction state. This is the reason why we should take their composition, structure, and characteristic into account to study the best mixing process route and the best process technological condition when studying the formulation of mixed explosive.

Just like the whole civil demolition equipment, industrial explosive is in a very active field. Much attention has been paid to the types, processes, basic theories, and the research of the technical applications. The new civil demolition equipment and its application technologies have also been listed as one of the important contents of innovative projects. For many years, lots of monographs and treatises have been summarized and expounded systematically the basic problems involved in the industrial explosive from different points of view and different fields. More consideration should be taken that the theory of industrial explosive has important instructive significance to the research and development of industrial explosive; it provides great impetus for industrial explosive in our country to catch up with and surpass the international advanced standard. Meanwhile, the makeup, structures, and characteristics of industrial explosive and the research of its theory is always of great interests to people in this area; any new achievements and accomplishments made in this field will add new pages to the theory of industrial explosive.