PLASTICS ADDITIVES and MODIFIERS HANDBOOK

Edited by
JESSE EDENBAUM

Plastics Additives and Modifiers Handbook

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Plastic Industry Consultant

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Preface

A handbook, by definition, is "a book of instruction or guidance, as for an occupation; manual: a handbook of ——, a reference book in a particular field."*

In the long early years of my career as an industrial chemist, first in textiles, where I was involved in the field of yarn-covered rubber thread, and then in rubber compounding for drug sundry and medical applications, I searched for "handbooks." When I began to work in the thermoplastics area with polyvinyl chloride, polyolefins, and styrenics, I thirsted for knowledge. There had to be "technology in a book"! There wasn't much.

The young working industrial chemist in the 1950s was part practical chemist, theoretical chemist, process engineer, inventor and artist, supervisor, and student. I attended many technical courses at nearby colleges and universities about polymers, both rubber and plastics, and attended meetings of all of the technical societies such as the Rubber Clubs, SPE, ASTM, ACS, and others in order to continue learning.

There was never enough knowledge available for the industrial chemist, and when a "handbook" became available, it was gobbled up. I learned "plastics" at the Society of Plastics Engineers local section meetings, RETEC's, ANTEC's, plastics magazines; from salesmen who were technically adept, and from the literature of the pioneering companies. Some of them produced excellent "handbooks" as literature for their customers.

I always wanted a handbook that was *complete.* I decided to prepare one that was to answer *all* the questions. However, it didn't work out that way. This one is not complete, as none can ever be. But I wanted to assemble a book about compounding, and this is as close as I can come. This *Plastics Additives and Modifiers Handbook* has a singular purpose. It is designed to

* *The Random House Dictionary of the English Language.* The Unabridged Edition, 1967, Edited by Jess Stein.

discuss and supply fundamental information about the predominant additives for the principally compounded thermoplastics. It presents the fundamentals of compounding those most usable additives into these thermoplastics by virtue of introducing the reader to the background, preparation, usage, effect, and manufacturing techniques of both the additives and the polymers.

It also has an unusual flavor because it has allowed the contributors to state their opinions. The information published is often based upon the author's experience and art. There is a "feel" to industrial chemistry, and it is my wish that the reader experience that sensitivity to the contributors' history.

I have also pressed my contributors to supply a significant bibliography and a good key word index. Use the index, and if you need to learn more than we have presented here, please use the Bibliography and Recommended Reading lists. Industrial chemistry, especially plastics compounding, is *fun*. Enjoy your chosen field. There is significant pleasure in the accomplishment of the preparation of usable materials with new and novel properties. Enjoy!

Acknowledgments

The many men and women who contributed to the writing of this book range from the veterans of our profession to the dynamic newcomers. Their driving interest in whatever corner of the plastics industry each has made his or her own was my most persuasive reason for recruiting their expertise.

In every instance I urged authors to share opinions and personal experiences when writing their chapters. Most of them did exactly that. Others took a more scholarly approach. No one gave me any less than the most current picture of the technology they undertook to report.

I would be negligent if I did not single out several authors who "gave back" to the profession in this instance as in many others. Dr. Richard F. Grossman (a/k/a "Doctor Dick") of Synthetic Products Company volunteered for the challenge of preparing eight chapters on specialized subjects necessary for the overview of this book. Robert H. Lindner of Allied-Signal Company set out to author a single chapter on Lubricants which grew in the course of lively discussion to three. Dr. Dennis Sekutowski of Engelhard Industries contributed the entirety of Section 4: "Inorganic Additives, Fillers, Extenders, and Reinforcing Agents." His eight chapters are amplified by the many excellent photographs, charts, and plastics application data he was at pains to provide.

I tried not to be too demanding or "pesky," but at times all my authors endured inconvenient phone calls and nagging messages. I too have grown to hate answering machines, but they do work, and eventually so did all of you.

I thank you all for a monumental effort resulting in a handbook of impressive proportions.

Contents

I

Fundamentals of Polymers and Formulation

1

The History of Polyvinyl Chloride

Mark E. Bruner

INTRODUCTION

The early development of the industry based on polymers of vinyl chloride differs from the origins of most polymer industries. First, the discovery of the useful properties of plasticized high-molecular-weight polyvinyl chloride (PVC) was accidental. Second, the PVC industry in the United States was not developed by a plastics manufacturer, but through efforts in the rubber and chemical industries.

The growth of this industry, which began as a laboratory curiosity more than half a century ago, has been phenomenal. As indicated in Figure 1-1, in 1955, the U.S. production of PVC was slightly more than 500 million pounds; 1990 production was in excess of 9 billion pounds. Currently, there are some 65 manufacturers of PVC resin worldwide. In 1989, they produced an estimated 39 billion pounds of PVC resin. This reflects an annual growth rate of 5.5% since 1983 and constitutes an approximate current total industry value of approximately $16 billion.

Figure 1-2 demonstrates that despite periods of decreased prices spurred by a burgeoning supply, the price curve of PVC since 1955 has been counterbalanced by demand and the effect of inflation, plus the increased costs of raw material, labor, and energy.

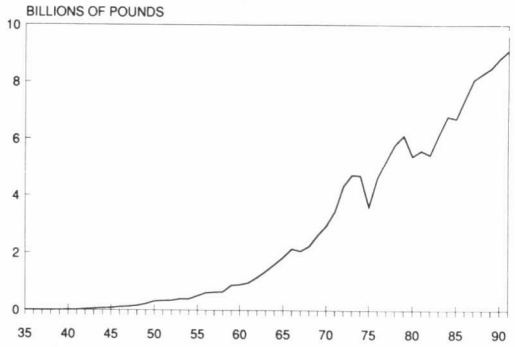

Figure 1-1. U.S. PVC production, 1935 to 1991.

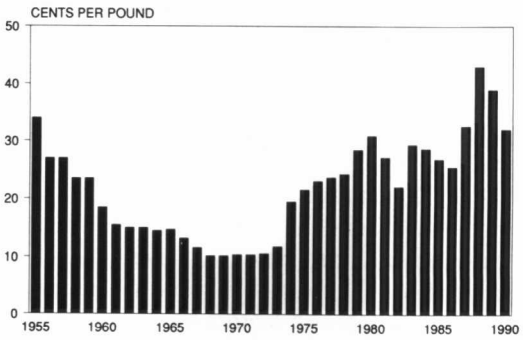

Figure 1-2. PVC resin prices, yearly average.

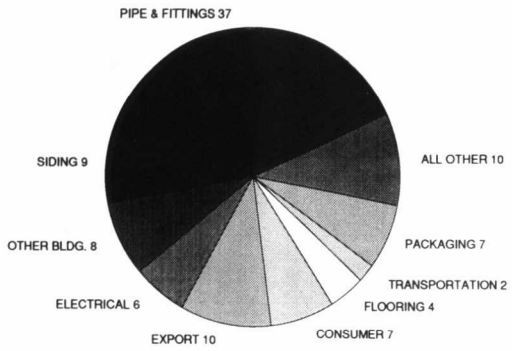

Figure 1-3. Major PVC end markets—percentage of total.

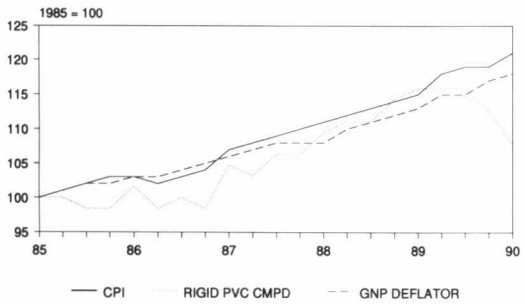

Figure 1-4. Price comparison—PVC rigid vs. GNP/CPI.

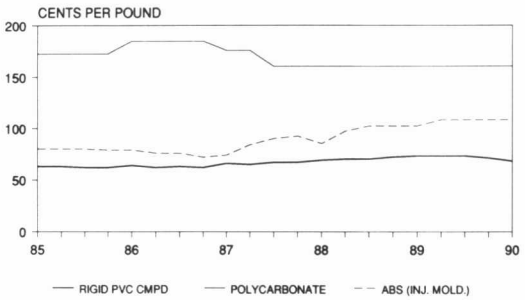

Figure 1-5. Price comparison—PVC rigid vs. ABS and PC.

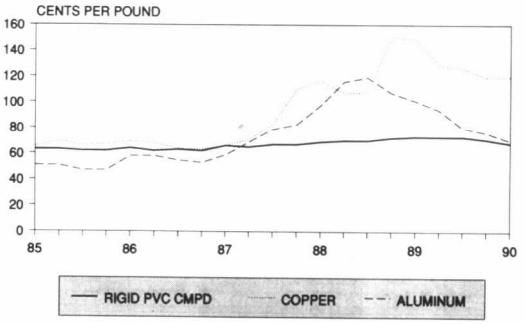

Figure 1-6. Price comparison—PVC rigid vs. aluminum and copper.

Few materials, natural or manufactured, can compete with vinyl as a material that is cost-effective for thousands of applications. Figure 1-3 apportions consumption of PVC according to its major markets. In addition to its high potential for penetration into markets normally served by traditional materials such as wood and metal, PVC competes favorably with low-cost plastics on a cost-per-cubic-inch basis. The principal reason for this is that most plastic materials are entirely dependent on hydrocarbon-based feedstocks, whereas the PVC molecule is more than half chlorine—an abundant natural resource. Cost benefits can be measured over time as examples in Figures 1-4, 1-5, and 1-6 indicate.

Many important factors have contributed to the growth of PVC. Some are technical and others are service in nature. These contributions will be reviewed in the following.

DISCOVERY AND EARLY HISTORY

The story of vinyl chloride started nearly 200 years ago. In 1795, chemists working in Holland heated ethyl alcohol with sulfuric acid and obtained a gas, ethylene. They then reacted ethylene with chlorine and obtained a liquid that for many years was called "oil of Dutch chemists" and is now known as ethylene dichloride. The French chemist M. V. Regnault (1834), while working with this oil, allowed it to stand with alcoholic potassium hydroxide, whereupon crystalline potassium chloride was precipitated and a sweet-smelling gas, liquifiable at $-15°C$, was evolved. He analyzed the material and showed it to