fertilizer science and technology series — volume 2

Ammonia

part I

$$3H_2 + N_2 \rightleftharpoons 2NH_3$$

edited by
A. V. Slack
and
G. Russell James

AMMONIA

(in four parts)

Part I

edited by A. V. SLACK

Division of Chemical Development
Tennessee Valley Authority
Muscle Shoals, Alabama

G. RUSSELL JAMES

James Chemical Engineering
Armonk, New York

1973

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Part I

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edited by A. V. Slack

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PREFACE

Ammonia is the basis of nitrogen chemistry . . . the compound from which nitrogen fertilizer is made. Without a continued increase in the manufacture of ammonia and, concurrently, nitrogen fertilizer, the world's crop land will not be capable of keeping up with the population increase.

Nitrogen use is steadily increasing. For the eight years from 1968 to 1976 production projections show an 80% increase. An even greater increase is needed in the developing, populous countries where more ammonia usage means that more people can have food.

Per capita nitrogen usage is highest in Europe and the United States where it is about ten times that of Asia, Africa, and South America. Population concentration is thus not where the nitrogen and fertilizer capacity and usage is and must therefore grow where this demand is located.

Support of the growth required in ammonia and nitrogen fertilizer manufacture requires an educated, experienced engineering and operating cadre who can take the lead in providing and operating the needed facilities. This volume is dedicated to supply information to such technical personnel. It encompasses the entire field of ammonia production, providing in-depth coverage of processes, equipment, and catalysts for use by designers and operators. It is the only broad, detailed reference work available on the manufacture of ammonia.

Technology of ammonia manufacture is not a secret or a series of secrets. It is a combination of known chemical engineering technology, processes, and equipment with proprietary catalyst know-how, processes, and equipment. Newer processes, equipment, and catalyst techniques are generally proprietary. Yet, even the newer techniques are available so that a variety of contractors can supply competitive plants. Both general know-how and proprietary processes are included; the latter perhaps necessarily in less detail.

Through the use of this book, design engineers will have a ready reference to rely upon and operative engineers will have information to assist them in selecting processes and in optimizing plants once they have been erected.

The large amount of data required and the detail needed to accomplish the purpose of this work necessitates a four-part volume. Part I includes a general history of ammonia production as well as a discussion of synthesis gas generation from various raw materials using several different methods. Part II covers CO conversion, CO_2 removal, final purification, and raw material purification. Parts III and IV are still in preparation.

Seventy-five authors participated in the work of writing this monograph. Each one is an expert in the area he covered. Time and space do not allow individual acknowledgment here for each contribution; a general note of thanks is due to every one. Each has put a part of himself into the overall context to make this monograph a comprehensive document. A. V. Slack and myself and the ammonia industry are in their debt.

G. Russell James

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CONTENTS OF PART II

TENTATIVE CONTENTS OF PARTS III AND IV

CONTENTS

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CHAPTER 1

HISTORY AND STATUS OF AMMONIA PRODUCTION AND USE

A. V. SLACK

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Muscle Shoals, Alabama

Ammonia is one of the more important basic chemicals of the world, ranking with materials such as sulfuric acid and sodium carbonate. Unlike these, however, it is a major end product as well as an important intermediate in the production of more complex chemicals. In the fertilizer field, anhydrous ammonia itself has become the major supplier of fertilizer nitrogen in the United States and its use is growing in other parts of the world.

The major use of ammonia, both directly and as an intermediate, is in the fertilizer area. In the United States, for example, 89% of the ammonia produced in 1968 was used one way or the other in fertilizers. There are many other uses, although relatively minor, in both inorganic and organic chemical production; examples are in the manufacture of explosives and acrylonitrile.

The main function of ammonia, both as an end product and as an intermediate, is to supply nitrogen in a reactive form. Actually, ammonia plays the role of an intermediate even in direct use as a fertilizer because the chemical processes within the growing plant convert it to many other compounds, including protein, the end product. For this the plant must have nitrogen in a form that will react easily at relatively low temperature and pressure.

Ammonia is unique in that, unlike the other basic chemicals, the main constituent, nitrogen, is readily available without need for transport and in unlimited quantities. It is estimated that over 36,000 tons of elemental nitrogen hang in the atmosphere over every acre of the earth's surface, in contrast to the raw materials for other basic chemicals that usually exist as deposits beneath the surface.

Unfortunately, elemental nitrogen is a very unreactive and inert material, of little use unless converted to a chemically reactive form. To accomplish such conversion, it has been necessary to adopt extremes of temperature and pressure that are not required for the other basic materials. As a result, full development of ammonia production technology has lagged, waiting for construction and engineering techniques to catch up. In the 1960s, however, plant and process design reached a level that appears to be an advanced state of the art, comparable or superior to that for other heavy chemicals.

Conversion of atmospheric nitrogen to a usable form is often referred to as "nitrogen fixation," meaning that it is converted to a solid or liquid form that is reactive enough to be useful. This form does not have to be ammonia; atmospheric nitrogen has been fixed as nitrogen oxides, metal nitrides, and complex organic nitrogen compounds in growing plants. The last of these forms is quite important because it represents a source of fertilizer

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