# HARVARD ECONOMIC STUDIES

I. The English Patents of Monopoly. By William H. Price.

II. The Lodging House Problem in Boston. By Albert B. Wolfe.

III. The Stannaries: A Study of the English Tin Miner. By George R. Lewis.

IV. Railroad Reorganization. By S. Daggett.

V. Wool-Growing and the Tariff. By Chester W. Wright.

VI. Public Ownership of Telephones on the Continent of Europe. By A. N. Holcombe.

VII. The History of the British Post Office. By J. C. Hemmeon.

VIII. The Cotton Manufacturing Industry of the United States. By M. T. Copeland.

IX. The History of the Grain Trade in France. By Abbott Payson Usher.

X. Corporate Promotions and Reorganizations. By A. S. Dewing.

XI. The Anthracite Coal Combination in the United States. By Eliot Jones.

XII. Some Aspects of the Tariff Question. By F. W. Taussig.

XIII. The Evolution of the English Corn Market From the Twelfth to the Eighteenth Century. By N. S. B. Gras.

XIV. Social Adaptation: A Study in the Development of the Doctrine of Adaptation as a Theory of Social Progress. By L. M. Bristol.

XV. The Financial History of Boston, from May 1, 1822, to January 31, 1909. By C. P. Huse.

XVI. Essays in the Earlier History of American Corporations. By J. S. Davis. 2 vols.

XVII. The State Tax Commission. By H. L. Lutz.

XVIII. The Early English Customs System. By N. S. B. Gras.

XIX. Trade and Navigation between Spain and the Indies in the Time of the Hapsburgs. By C. H. Haring.

XX. The Italian Emigration of Our Times. By R. F. Foerster.

XXI. The Mesta: A Study in Spanish Economic History, 1273–1836. By Julius Klein.

XXII. Argentine International Trade under Inconvertible Paper Money: 1880–1900. By J. H. Williams.

XXIII. The Organization of the Boot and Shoe Industry in Massachusetts before 1875. By Blanche E. Hazard.

XXIV. Economic Motives. By Z. C. Dickinson.

XXV. Monetary Theory before Adam Smith. By Arthur E. Monroe.

XXVI. Canada's Balance of International Indebtedness, 1900–1913. By Jacob Viner.

XXVII. The History of the United States Post Office to the Year 1829. By W. E. Rich.

XXVIII. The Theory of International Prices. By James W. Angell.

XXIX. Forests and Sea Power. By Robert G. Albion.

XXX. Banking Theories in the United States before 1860. By Harry E. Miller.

XXXI. Karl Marx's Interpretation of History. By Mandell Morton Bober.

XXXII. Grain Growers' Coöperation in Western Canada. By Harald S. Patton.

XXXIII. The Assignats. By S. E. Harris.

XXXIV. Economic and Social History of an English Village. By N. S. B. Gras and E. C. Gras.

XXXV. Direct Taxation in Austria. By John V. Van Sickle.

XXXVI. The Greenbacks and Resumption of Specie Payments, 1862–1879. By D. C. Barrett.

XXXVII. The Street Railway in Massachusetts. By Edward S. Mason.

XXXVIII. The Theory of Monopolistic Competition. By Edward Chamberlin.

XXXIX. Interregional and International Trade. By Bertil Ohlin.

XL. The French International Accounts, 1880–1913. By Harry D. White.

XLI. Twenty Years of Federal Reserve Policy. By S. E. Harris. 2 vols.

XLII. The Illinois Central Railroad and Its Colonization Work. By Paul W. Gates.

XLIII. American Treasure and the Price Revolution in Spain, 1501–1650. By Earl J. Hamilton.

XLIV. German Monetary Theory, 1905–1933. By Howard S. Ellis.

XLV. Wages in Eighteenth Century England. By Elizabeth W. Gilboy.

XLVI. The Theory of Economic Development. By J. A. Schumpeter.

XLVII. The Supply and Control of Money in the United States. By L. Currie.

XLVIII. British International Gold Movements and Banking Policy, 1881–1913. By W. Edwards Beach.

XLIX. State Control of Local Finance in Massachusetts. By Royal S. Van de Woestyne.

L. Fluctuations in American Business, 1790–1860. By Walter B. Smith and Arthur H. Cole.

LI. Money, Prices, and Wages in Valencia, Aragon, and Navarre, 1351–1500. By Earl J. Hamilton.

LII. The Development of the Business Corporation in England, 1800–1867. By B. C. Hunt.

LIII. Exchange Depreciation. By S. E. Harris.

LIV. A Study of Fluid Milk Prices. By John M. Cassels.

LV. Location Theory and the Shoe and Leather Industries. By Edgar M. Hoover, Jr.

LVI. Federal Subsidies to the Provincial Governments in Canada. By J. A. Maxwell.

LVII. Studies in Massachusetts Town Finance. By Eugene E. Oakes.

LVIII. Market Control in the Aluminum Industry. By Donald H. Wallace.

LIX. The New York Bond Market, 1920–1930. By Charles Cortez Abbott.

LX. The Commercial Paper House in the United States. By Albert O. Greef.

HARVARD UNIVERSITY PRESS

# HARVARD ECONOMIC STUDIES

## VOLUME LVIII

AWARDED THE DAVID A. WELLS PRIZE FOR THE YEAR 1933–34 AND PUBLISHED FROM THE INCOME OF THE DAVID A. WELLS FUND. THIS PRIZE IS OFFERED ANNUALLY, IN A COMPETITION OPEN TO SENIORS OF HARVARD COLLEGE AND GRADUATES OF ANY DEPARTMENT OF HARVARD UNIVERSITY OF NOT MORE THAN THREE YEARS STANDING, FOR THE BEST ESSAY IN CERTAIN SPECIFIED FIELDS OF ECONOMICS

THE STUDIES IN THIS SERIES ARE PUBLISHED BY THE DEPARTMENT OF ECONOMICS OF HARVARD UNIVERSITY, WHICH, HOWEVER, ASSUMES NO RESPONSIBILITY FOR THE VIEWS EXPRESSED

LONDON : HUMPHREY MILFORD
OXFORD UNIVERSITY PRESS

# MARKET CONTROL IN THE ALUMINUM INDUSTRY

BY

DONALD H. WALLACE
ASSISTANT PROFESSOR OF ECONOMICS IN HARVARD UNIVERSITY


CAMBRIDGE
HARVARD UNIVERSITY PRESS
1937

PRINTED AT THE HARVARD UNIVERSITY PRESS
CAMBRIDGE, MASS., U.S.A.

*To*

MARCIA

# PREFACE

THE present study first took partial form as a doctoral dissertation (presented in 1931) upon the aluminum monopoly in the United States. Thereafter, the scope of the inquiry was widened to include market control in Europe and international relations in this industry. It was my hope that study of the industry in Europe, where producers have at times competed and at times united in cartel organization, might enable a surer assessment of the market results here, where there has been but one producer of primary aluminum, as well as furnish some conclusions about the consequences of cartel control and of "oligopoly," to use Professor Chamberlin's expression for the condition where sellers are few, which appear to be the practicable alternatives in this industry. The grant of a traveling fellowship for the year 1931–32 from the Social Science Research Council gave me the opportunity to study in Germany, France, and Switzerland, where much of the material for the analysis of European experience was gathered. Since then nearly all of the original thesis has been completely revised in accordance with changes in the conception of some of the problems involved and in the light of additional material; and an attempt has been made to unify the analysis of both American and European experience relating to the fundamental problems presented by the alternative possible mixtures of competitive and monopolistic elements in this industry.

I have benefited much from conversations with many officials of companies engaged in producing aluminum or its products in various countries. In accordance with their wishes, acknowledgment is made anonymously, and the information and ideas which they have contributed appear without citation. The following gentlemen have provided me with courteous and valuable assistance: Mr. Richard Whitely, attorney for the Federal Trade Commission; Messrs. Furness and McGrath of the Bureau of Foreign and Domestic Commerce; Dr. Martin Doering of the Verein der deutschen Maschinenbauanstalten in Berlin; Dr. Thews and Dr.

Regensburg, Berlin journalists; Dr. Josten of the Reichswirtschaftsministerium; Dr. Apfelstädt of the Statistisches Reichsamt; Dr. Rudolf Schwarzmann of the Statistisches Amt in Bern; and M. Thibaud of the Ministère des Travaux Publics in Paris.

I owe much to Professors Taussig and Ripley, whose encouragement and guidance were of great aid in carrying the project through the troublesome early stages. Professors W. L. Crum and A. P. Usher of the Department of Economics and Professors R. S. Meriam and Samuel S. Stratton of the Graduate School of Business Administration of Harvard University have aided me with valuable criticism. I have also benefited from the suggestions of members of two discussion groups at Harvard to whom I presented in their original form parts of the analysis of Chapters XV, XVI, and XX. My greatest debts are to Professor Edward Chamberlin, as will be apparent to all who are familiar with his *Theory of Monopolistic Competition* (Cambridge, 1933), and to Professor Edward Mason, whose thinking upon the sort of problems treated in this book has exercised an immeasurable influence upon my ideas. Responsibility for the views expressed in this volume is, of course, entirely my own.

I am indebted to the Bureau of International Research of Harvard University and Radcliffe College for permission to reproduce here much of the material contained in my chapter on aluminum contributed to the study entitled *International Control in the Nonferrous Metals,* directed by Professor W. Y. Elliott, which is about to be published by the Bureau as this book goes to press. Much of that chapter represents a brief condensation of several portions of Parts I-III of the present book, and contains several tables and charts which are reproduced here in similar or more elaborate form. As a result of better information obtained since that chapter was completed some time ago, the statistics and other information presented in this book differ in some instances from what was given there.

The major part of the tedious work of preparing the manuscript for the press has been done by my wife, who has also assisted in proofreading. Her criticism of ideas and expression has aided me greatly in many instances. Financial assistance from the A. W. Shaw Fund, administered by the Committee on Research in the Social Sciences of Harvard University, facilitated the latter stages

of preparation of the manuscript. I am very grateful to Miss Margaret Ballard for her meticulous care in this part of the work.

Statistics of production and foreign trade in aluminum ordinarily appear in pounds or short tons for the United States and in metric tons or long tons for Europe. In order to facilitate comparison I have reduced the figures for all countries to a metric ton basis. In Part IV, which deals only with relations within the aluminum industry of the United States, the pound unit has been retained.

My original hope of making the book equally understandable to the economist and to the general reader, whose lack of familiarity with the tools of economic analysis is overborne by an interest in the nature of modern market processes, is not, I fear, well realized. The endeavor to put certain parts of the argument in non-technical language has resulted in a style of exposition demanding the forbearance of the trained economist, to whom it will seem unduly tedious and awkward; while a frank resort to technical exposition in those parts dealing with more complicated phases of the problem requires the forgiveness of others.

For the benefit of the general reader I wish to stress the fact that many words and phrases of ordinary language are here used in the special meanings given to them in economics, and, in some instances, with a particular sense of my own. I hope I have avoided misunderstanding by defining terms in cases where ambiguity seemed to threaten. It should be quite clear that, unless otherwise specified, the word "monopoly" in all its forms has been used in an economic sense — signifying complete control of supply, or sufficient control to affect appreciably the fundamental market relations between investment, output, price, earnings, and demand — and not in the legal sense attached to it by the antitrust laws of the United States. Such terms as "discrimination" and "unfair methods of competition" are also used with particular economic meanings rather than their legal meanings, except where the contrary is stated. Questions of discrimination in the aluminum price structure have not been related to the Robinson-Patman Act, which was passed after most of the analysis of discrimination had been concluded.

In several instances terms which sound quite "academic," such as "ideal investment" and "best utilization," have been employed

in order to give precision to the analysis. The reader must not draw the mistaken inference that it is implied that ideal conditions can necessarily be obtained under some form of market control. Such phrases are merely technical terms used to designate certain market relationships which represent useful standards by which to measure the results of different sorts of market control.

The present work is an attempt to appraise critically the limited material bearing upon several important economic problems. Inasmuch as the material available has proved in some respects inadequate, the statements in the text must be regarded merely as the considered judgments of the author. I also wish to make it plain that the economic conclusions are not intended to express any moral or ethical judgment on the conduct of persons in this industry. At the present time an understanding of economic processes sufficient to distinguish those business policies which promote general economic welfare from those which tend in the opposite direction is not widespread enough to exert any very salutary influence upon the general scale of moral values and standards of conduct.

One symptom of the tardy appreciation of the range of alternative mixtures of competitive and monopolistic elements in modern markets is the absence of any term for the structure of market forces which does not imply the predominance of either competitive or monopolistic elements. I have used the term "market control" to fill this gap. In this sense market control may be of various types, ranging from pure competition to single-firm monopoly. The phrase selected is not entirely satisfactory, for it is often convenient to employ it, as I have sometimes done, in the older and more limited sense of substantial monopoly control.

Those who are chiefly interested in the reasons for existence in the aluminum industry of a few producers only will find a unified treatment of this topic in Part II. The main conclusions about the actual results of oligopoly in this industry are contained in Chapters XII–XIV. The analysis in these chapters will be better understood if Chapter X is also read. Section 1 of Chapter XV embodies a unified theoretical essay comparing the probable results of oligopoly and single-firm monopoly under certain assumed conditions, the most important of which are a rapid forward movement of demand and great uncertainties about the rate of movement and the sorts of new adaptations of a basic product that can

be made. This section can be read apart from the rest of the book by those interested in the pure theory of oligopoly.

As this book goes to press I discover that Professor Arthur R. Burns's new book, *The Decline of Competition* (New York, 1936), contains several ideas about oligopoly under dynamic conditions, price stabilization, and the relations between monopoly and vertical integration which are similar to ideas worked out here.

CAMBRIDGE, MASSACHUSETTS
*December, 1936*

D. H. W.

# CONTENTS

## PART III

### SOME CONSEQUENCES OF VARIOUS KINDS OF MARKET CONTROL



## PART IV

### RELATIONS BETWEEN MONOPOLY OF THE BASIC PRODUCT AND INDEPENDENT COMPETITORS AT LATER STAGES — SOME ASPECTS OF AMERICAN EXPERIENCE

# TABLES

## CHARTS

## ABBREVIATIONS

AG = *Les Assemblées générales*

BMTC appellant v. ACOA = Baush Machine Tool Company, appellant, v. Aluminum Company of America

BMTC v. ACOA appellant = Baush Machine Tool Company v. Aluminum Company of America, appellant

BR = Benham Report, Department of Justice

EMJ = *Engineering and Mining Journal*

FTC = Federal Trade Commission

HR = Henderson Report, National Recovery Administration

JFE = *Journal du four électrique*

KFR = Kitchen Furnishings Report, Federal Trade Commission

MI = *The Mineral Industry . . . in the United States*

MR = *The Mineral Resources of the United States*

MW = *Metallwirtschaft*

NRA = National Recovery Administration

# INTRODUCTION

FOR the student of monopolistic and competitive forces the aluminum industry presents an unusually interesting specimen. The Aluminum Company of America has remained the only producer of virgin aluminum ingot in the United States since its organization in 1888 to work the patent which gave birth to this new industry. The activities of the company affecting the domestic market for virgin ingot have never been held, in a final proceeding, to violate the antitrust laws, nor does it appear that they have infringed accepted notions of business ethics. How explain the lack of domestic competitors? Except during periods of depression imports over the tariff duty have usually been rather small relative to the sales of the domestic firm. No marked separation of ownership and control has existed in the Aluminum Company to vitiate direct motivation. Here seems to be an opportunity to test at once the pessimism of the older monopoly theory and the optimism infused into the discussion of monopoly by the rationalizers. In Europe some degree of competition has existed at times in national and international markets, while national monopolies and international cartel control have prevailed for periods of several years. Analysis of the consequences of oligopoly and of cartel control abroad in this industry may be of interest in this country, where the violent death of NRA is not likely to allay the appeals for permanent revision of the antitrust laws to permit cooperative self-government of business for "planned" control of production and marketing in each industry.

This study is an inquiry into the nature of monopoly and oligopoly, with and without agreements, under dynamic conditions. Its purpose is to explain the continued existence of single-firm monopoly[1] of the basic product in the United States and of strong

[1] Owing to the presence of foreign producers in the market for virgin aluminum in the United States the condition is, strictly speaking, one of oligopoly. Apparently, however, the foreign companies have not set up capacity for large exports to this country; and much of the time their sales here have been quite small. Since we have no simple phrase to describe this sort of oligopoly, it will be convenient to use the term "single-firm monopoly."

monopolistic elements abroad (Part II), to evaluate the consequences and assess the relative merits of alternative mixtures of competitive and monopolistic elements (Part III), and to examine some of the intricate problems created by the existence in some fabricating stages of independents competing with the firm or firms from whom they obtain their raw materials (Part IV). No attempt is made to consider the effects of monopolistic elements upon labor, bankers, different classes of investors; no questions are raised concerning working conditions or the division of gross earnings among all those who have claims to a part. The chapters in Part I are designed to give sufficient knowledge of technology, markets, public relations, and international relations for the analysis which follows. Two chapters upon the early history of scientific discovery and inventive activity centering about aluminum are printed as Appendices A and B in the hope that others may share my lively interest in this hitherto neglected chapter of economic history.

The study was undertaken with the aim of adding to our knowledge of the workings and results of competitive and monopolistic forces in present-day economic organization. I share with many others the belief that we need more studies of the different mixtures of competitive and monopolistic forces in particular industries, of the various sorts of markets which make up that part of the economy in which the conditions of pure competition—that is, complete absence of monopoly elements—are not even approximated. Unfortunately it has been impossible in the present study to reach assured conclusions upon several points. In large degree this has been due to inability to obtain adequate and accurate information; but the limitations of economic method and the unavoidable employment of hypothesis must bear part of the responsibility. With the exception of some financial and technical data, little information of basic economic importance has been voluntarily published by the aluminum companies. In the last ten years there has appeared a tendency towards more publicity on the part of the Aluminum Company of America and some of the other firms. They do not yet, however, ordinarily give out the sort of information required for analysis of the kind of questions raised in this book. Government reports and the records of private litigation contain a large amount of information, but

much of it is inadequate for the treatment of such questions. The material available in trade and scientific journals and the yearbooks of private organizations falls far short of remedying this lack. For statistical data on production and capacity it has been necessary to rely largely upon the estimates appearing in such sources. Requests addressed directly to the aluminum companies have yielded some important information; but the companies have been unwilling to give me the sort of data desired for many parts of this study, doubtless partly through fear that disclosure of such information might hurt their business. Even the sketch of the historical development of the industry has suffered from the lack of information of certain sorts. While there is a vast literature in trade and scientific journals dealing with the technical aspects of aluminum, few articles attempt to survey the changing industrial importance of this metal or to provide the quantitative materials for such study. Finally, it is particularly unfortunate that the government investigations of the position and competitive methods of the Aluminum Company of America in the fabricating stages of the industry do not provide sufficient information of the sort required to resolve the true economic issues.

Furthermore, it must be recognized that economic method has not yet designed tools of analysis keen enough to dissect neatly the results of various mixtures of competitive and monopolistic forces operating under the dynamic conditions of the real world. Until the recent advances made by Professor Chamberlin, Mrs. Robinson, and others forced recognition of the limitations of theoretical analysis based upon assumptions of pure competition, most students of the kind of problems treated in this book had employed the apparatus of purely competitive theory (if not indeed of perfectly competitive theory!) to block out the questions or issues for factual study. The most serious shortcoming of this procedure was the conception of evils of monopoly as evils in the sense of much less desirable results than would accrue with pure or simple competition. The obvious requirements of comparison between the consequences of monopolistic forces and the results of some kind of competitive control were met by comparing the former with the outcome under hypothetical conditions of pure competition. Actually, however, the choice which public policy must usually make is between alternative mixtures of com-

petitive and monopolistic elements, with or without different sorts of public control. The conditions of pure competition are neither a practicable nor a desirable alternative in many industries. For, although the great size attained by many industrial corporations is doubtless to be explained in substantial part by considerations of "power politics," advances in the technique of capital and administration have extended the most efficient scale for a firm in many industries to the point where it produces a sufficient portion of the total output to affect price or quality by its policy. Under these circumstances the appropriate comparison is between the results of simple oligopoly, oligopoly with agreements, single-firm monopoly, and each of these with different sorts of government control. Since the outcome with oligopoly may, as Professor Chamberlin has shown, vary all the way from that of pure competition to that of monopoly, the older measuring stick of "competitive" results turns out to be an elastic rod! It is necessary to study the particular sorts of market control which represent real alternatives to those actually in existence, to compare them with the latter, and to determine as well as can be which is best. It is plain, I think, that the technique for economic analysis of concrete problems of this kind needs improvement. It is my hope that the present volume may be of some stimulus to others who are interested in redesigning analytical tools for future study of these questions.

I had hoped to be able to deal more adequately with the issue of progressiveness. Unfortunately, difficulties with evaluation of standards and inability to obtain adequate material have made it impossible to devote to this problem the amount of space which its importance warrants. Treatment of this issue has been limited for the most part to consideration of progressiveness in the development of new alloys, fabricating processes, and finished goods.

In several instances, particularly in Part IV, the problems presented by concrete situations which were of relatively little importance have been subjected to detailed analysis because of the significance of the principles involved. Since government agencies often failed, in my judgment, to use correct principles in their analysis of competitive methods, it seemed important to devote considerable space to the development of the proper principles.

No plan for economic reform in the aluminum industry is advocated here. More adequate information is required to determine whether the undesirable consequences of the existing types of market control are of sufficient magnitude to make some sort of change worth while. Moreover, examination of the more purely governmental problems attending various kinds of public control — a task for which the economist is often not well fitted — is necessary before any final pronouncement on the relative merits of alternative schemes for improvement. In Chapters XV and XX, however, I have considered the economic problems presented by different devices for bettering the relations between investment, output, and demand in this industry, and have appraised the relative merits of the several alternatives according to economic considerations. In this analysis some schemes, particularly of government regulation in the narrow sense, have been discussed in detail which their seeming impracticability might not appear to warrant. But it is of the utmost importance to realize fully the breadth and complexity of the problems and the extent of detail in measurements and in policies which would be required for successful regulation. We must recognize that in an industry of this sort regulation according to simple rules is not likely to produce desirable results and that serious difficulties are to be encountered in the formulation and administration of complex rules.

# APPENDICES

# APPENDIX A

## ALUMINUM AND THE ELECTROCHEMICAL REVOLUTION

SCIENTIFIC study of the general principles governing the relations between electric currents and chemical changes originated with the science of electricity. The successful economic adaptation of these principles to particular problems, which proceeded rapidly in the last quarter of the nineteenth century, altered technical operations in some industries, and introduced several new products which have assumed considerable economic significance. The role played by aluminum in this electrochemical revolution was twofold. It was among the most important of the new products; and the search for a successful method of reducing it from refractory ores advanced the knowledge of electrochemical technique and contributed to the development of several other new products. The following survey describes the development of some of the chief principles of electrochemistry and the results of the work of several inventors who attempted to apply them to the reduction of aluminum.

Shortly after the invention of the voltaic pile, which first provided electric currents of effective magnitude, Sir Humphry Davy succeeded in isolating potassium and sodium by electrolysis. Then, turning his battery of one thousand plates upon aluminum oxide, he attempted a number of experiments which, though failing to yield pure aluminum, had, by 1809, established the fact that alumina can be decomposed while fluid in the electric arc, and its metal reduced as an alloy of iron. Davy also decomposed other oxides and hydrates, but his work did not extend far into the realm of analysis and explanation. His pupil, Michael Faraday, eclipsed the master by his comprehension and formulation of the fundamental principle that there exists a definite quantitative relation between the amount of current passing in any electrolyte and the chemical effect produced. The chemical effect upon each substance was explained by Faraday as being directly proportional to its equivalent weight and to the time during which the current passed. Elucidation of these laws led Faraday to believe that

the dissolved molecules of an electrolyte consisted of oppositely charged atoms which he called ions. Under the influence of the electric current the positively charged atom (cation) was attracted to the negatively charged pole (cathode) of the circuit and the negatively charged atom (anion) migrated to the positively charged pole (anode). At the pole each gave up its charge. Thus there collected at each pole groups of neutralized atoms, each of which constituted a molecule of the substance or element now existing in a free state. When metallic compounds were electrolyzed the atoms of the metals became cations, and their migration to the cathode resulted in the free existence of metal at that pole, where it could be collected.[1]

Less than a decade after Faraday's communications on electrolysis Joule formulated the principle that there is a definite mathematical relation between the quantity of electricity passing in a conductor and its heating effect. "By these two laws (Faraday's and Joule's) nearly all of modern practice of electrochemistry and electrometallurgy is governed." [2]

In 1819 Hans Christian Oersted, professor at the University of Copenhagen, found the relationship between electricity and magnetism which philosophers had long suspected. This epochal discovery at once attracted the attention of Ampère of France, Professor Joseph Henry of the United States, and Faraday in England. Ampère and Henry worked out the relationship in detail. It was the English genius who, aided by their researches, discovered that an electric current could be induced in a coil of wire by revolving it in a magnetic field, and thus revealed the fundamental principle of the dynamo. Several magneto machines were constructed upon this principle during the thirties and forties. The typical machine consisted of a permanent steel magnet between or near the poles of which rotated an armature composed of wire coils wound about iron cores. By multiplying the number of coils and magnets, and utilizing steam power, currents of sufficient strength to produce illumination for lighthouses were generated, but it was found impossible to obtain steel magnets of

[1] Of course, theories of electricity and electrolytic action have changed and expanded since Faraday's work, but the fundamental principles which he formulated remain valid.

[2] E. A. Ashcroft, *A Study of Electrothermal and Electrolytic Industries* (New York, 1909), Pt. I, p. 6.

strength enough to induce powerful currents. The true dynamo did not make its appearance for several decades.

Thus, before the century was half over, some of the fundamental principles of electrochemistry were thoroughly understood, and the magneto machine had been demonstrated as a practical success. But the scientific achievements of the laboratory could not emerge into the economic world until the dynamo made its momentous appearance. Investigations of the effects of electric current upon various chemical compounds continued, however, with some important results. Professor Bunsen of Heidelberg succeeded in obtaining barium, chromium, and manganese solutions with the battery. He also decomposed fused magnesium chloride by the electric current.

Aluminum had been first isolated in 1825 by the Danish chemist, Oersted, who reduced aluminum chloride with potassium amalgam. Two years later Friedrich Wöhler, professor of chemistry at the University of Göttingen, secured the white metal by a slightly different chemical process. Henri St. Claire Deville of the École Normale in Paris is, however, entitled to the honor of first obtaining fairly large amounts of aluminum in a state of almost perfect purity and determining its true properties. Deville employed potassium as the reducing agent. Encouraged to continue his researches by a financial grant from the Academy, he directed his attention to electrolysis, since potassium was both dangerous to handle and very expensive. Bunsen's success with electrolysis of magnesium chloride stimulated Deville to try the same experiment with aluminum chloride. After a few weeks of experiment he obtained aluminum in March 1854. Scientific discoveries often have a habit of descending upon two men in different places at nearly the same time. Bunsen had published in Poggendorf's *Annalen* an electrolytic process quite similar to that of Deville just a week before the latter, in complete ignorance of Bunsen's success, read a paper to the Academy describing his own results. The reduction of aluminum by electrolysis was clearly the stimultaneous discovery of both of these men. Neither of them, however, attempted to apply the discovery to industrial production. Deville, who was seriously interested in promoting an aluminum industry, realized that the large consumption of zinc in the battery would entail a prohibitive cost. He reverted to

chemical methods and invented the sodium process, which gave birth to an aluminum industry of small proportions. Professor Richards, writing in 1896, when electrolytic aluminum had been on the market for several years, observed that

> . . . the great advances made in dynamo-electric machinery in the last decade have led to the revival of the old methods of electrolysis discovered by Deville and Bunsen, and to the invention of new methods of decomposing aluminum compounds electrolytically. It will be recalled that the first small pencils of aluminum made by Deville were obtained by electrolysis and that he turned back to the use of alkaline metals solely because the use of the battery to effect the decomposition was far too costly to be followed industrially. This fact still holds true, and we cannot help supposing that if Deville had had dynamos at his command such as we have at present, the time of his death might have seen the aluminum industry far ahead of where it now is.[3]

Just three years previous to the successful experiments of the French savant and Bunsen upon aluminum Charles Watt in England had taken out what one authority refers to as "the master patent of the electrochemical and electrometallurgical industries in the United Kingdom." [4]

> In this patent, Watt described in some detail how the electric current might be employed for producing alkali hydrates and chlorine, hypochlorites, or chlorides, and how it might be utilized for refining copper, silver, or other metals, or for separating these from their ores. . . .
>
> Watt's ideas, as put forth in this patent of 1851, could not, however, receive practical trial until the dynamo was developed and improved, and it was not until 1869, when Elkington erected the first electrolytic copper refinery at Pembrey, in South Wales, that the industrial development of the facts and ideas gathered during the previous years of the century commenced.[5]

Just why there was such a long time lag between the understanding of scientific principle and the adaptation to industry in the instance of the dynamo is not altogether clear. It would appear, however, that the possibilities of utilizing powerful electric currents in industry must have been manifest; so one would

[3] J. W. Richards, *Aluminium*, p. 24. See also R. J. Anderson, *The Metallurgy of Aluminium and Aluminium Alloys*, p. 3; MI, 1, 12 (1892); *Engineering News*, LXXIII, 177 (1915).

[4] J. B. C. Kershaw, *Electro-metallurgy*, p. 6.

[5] Apparently this was one of the first electrochemical patents. It is not without significance that until at least the middle of the century most of the discoveries appeared in the transactions of the learned societies rather than in the patent office. The number of patents for electrochemical processes and equipment appears to increase through the sixties and seventies to a veritable outbreak in the eighties.

infer that the chief resistance was found in the difficulties of overcoming serious technical problems. The magneto machine maundered along through the fifties and sixties with no startling change. The Siemens armature designed in 1856 increased the maximum current strength, but this could not remove the main obstacle, which was the weakness of the magnetic sphere of influence. It was in the latter part of 1866 that Siemens of Berlin and Wheatstone in London independently made a change in the construction of the machine which provided the necessary improvement. In place of the permanent steel magnet they substituted an electromagnet consisting of a core of soft iron wound with insulated wire which was connected to the revolving coils of the armature. Although soft iron possesses but a trace of magnetism, this trace is sufficient to induce a feeble current in the coils of the armature. A portion of this current passes through the wire wound around the iron, thus magnetizing it. This increased sphere of influence enhances the strength of the current in the armature, with the reciprocal result of a further access of magnetism in the iron, and so on. By the cumulative action of this process the dynamo, as the machine was called after this change, generates currents of far greater strength than the magneto machine was able to produce. The perfecting of the dynamo in the following years was due largely to the work of Gramme.

As is indicated in the passage from Kershaw quoted above, the first important development of industrial electrochemistry followed close on the heels of the appearance of the dynamo. But the electrolytic copper refinery mentioned was for some years the only important electrochemical works. Although electrolytic refining of copper was inaugurated twenty years earlier it did not expand substantially until it had caught the contagion which spread from the electrochemical outbreak in the eighties.

Progress in dynamo construction in the seventies, by cheapening cost as well as increasing the electric horsepower available for industrial application, aroused more interest in practical experiments aiming at the reduction of highly refractory metallic compounds. The results of this experimentation were twofold. In the first place the electric furnace was developed and adapted to many particular industrial applications. Secondly, several electrochemical processes were discovered and perfected which could

be carried out successfully in the electric furnace. The natural consequences of the two related achievements appeared in the birth of several new industries, of which the aluminum industry was the first and most robust infant. The experimental and developmental work done upon aluminum compounds in the eighties possessed also a wider significance. In 1891 a writer describing the early achievements in electrochemistry referred to the development of electrometallurgy [6] as "largely due to the attempts to produce aluminum economically." [7]

During the eighties a large number of inventors were at work upon the problem of electrolytic or electrothermal reduction of aluminum. The first proposal to use the dynamo for electrolytic reduction of aluminum was made in Berthaut's patent in 1879. His process was similar to that of Deville. Grätzel in 1883 and Kleiner in 1886 each proposed an electrolytic process using a dynamo. Although none of these processes proved successful in industrial application, they were significant in showing that attempts were being made to utilize the possibilities of the new power generators. The first successful industrial work was accomplished by the brothers Alfred and Eugene Cowles of Cleveland. In 1883 they purchased with their father a zinc mine in New Mexico. The extreme refractoriness of the zinc ores led them to an investigation of electric-furnace reduction which resulted in the designing of a successful electric furnace. For this initial task and the long series of inventions, experiments, and practical achievements in electrometallurgy which followed, the brothers possessed a rare combination of qualities. Alfred brought an alert mind and a training in science which were evidenced by a distinguished career of several years' study at Cornell University. Eugene, also resourceful and ingenious, had acquired much practical experience in metallurgy and electrical engineering, in addition to executive experience as manager of an electric-lighting plant.

Encouraged by the success in smelting refractory zinc ores in their electric furnace, the brothers turned their energetic en-

[6] Electrometallurgy is, of course, one branch of electrochemistry. The early development was largely metallurgical.

[7] R. L. Packard, MR, 1891, p. 147. Cf. E. E. Slosson, *Creative Chemistry* (New York, 1919), p. 245: "The industrial development of the electric furnace centered about the search for a cheap method of preparing aluminum."

thusiasm upon aluminum at about the time when Charles M. Hall was graduating from Oberlin College after a classical course which had left him with a passion for chemical experiment. The Cowleses appeared to have the prize within their grasp when they developed a commercially successful method of obtaining copper-aluminum alloys in the electric furnace; but it was wrested away overnight when Hall discovered an electrolytic process which yielded pure aluminum.

The Cowleses' attack upon the problem of adapting their electric furnace to aluminum smelting and finding a suitable reagent had consumed only a few months when their success was announced by Professor Charles F. Mabery, one of their associates, in a paper before the American Association for the Advancement of Science.[8] The process was simple. In a furnace of the so-called resistance type a high temperature was obtained by introducing coarsely pulverized carbon, which presented a great resistance to the electric current. Carbon was, at the same time, the most easily available substance for the reduction of oxides. The attempt to secure pure aluminum by this method was unsuccessful because the aluminum combined with the carbon to form a useless carbide. However, it was found that by introducing another metal into the furnace a useful alloy of aluminum would be yielded at a cost per pound of aluminum equivalent to a third of the price at which the pure metal was then selling. For the production of aluminum bronze there was placed between the electrodes of the furnace a charge of alumina in the form of granulated corundum, mixed with charcoal and granulated copper. The most successful Cowles furnace was, of course, adapted for continuous working. Aluminum-alloy production was undertaken in a plant at Lockport, New York, where cheap water power was available from a tailrace of the Niagara overflow. The Cowleses also built and put into operation a plant at Milton, England. At one of these plants (reports seem to divide the honor) there was installed a dynamo of almost 400 h.p. capacity which aroused so much interest, by virtue of its novel magnitude, that it became famous under the sobriquet of "the Colossus." The alloy business flourished for a few years until the advent of pure aluminum announced its doom. Metal mixers preferred to make their

[8] August 28, 1885.

own alloys when the pure metal became available at a favorable price.

While aluminum was for some years their primary interest and their first industrial venture with the electric furnace, the Cowles brothers did not confine their early experiments or their later commercial activities to this one metal. A committee of the Franklin Institute of Philadelphia in recommending the award of two medals [9] to the Cowleses in 1886 reported in part:

> The essential and valuable novelty of the process is the ingenious application of the intense heat obtained by the passage of a powerful current of electricity through a conductor of great resistance, to the reduction, in the presence of carbon, of the most refractory ores, some of which have hitherto resisted all similar attempts at reduction. . . .
>
> This process is applicable to the reduction of all kinds of ores, but particularly to those unreducible by other means . . .; already aluminum alloys of iron, silver, tin, cobalt, and nickel have been prepared; silicon, boron, potassium, sodium, magnesium, calcium, chromium, and titanium as well as aluminum have been obtained in a free state.[10]

Albert W. Smith in a brief biographical sketch of Professor Mabery credits the Cowleses with even more discoveries.

> In this work, the development of the electric furnace, they were the first to produce all the many electric-furnace products which have since become such important items in industrial chemistry — calcium carbide, carborundum, fused alumina, and artificially-made graphite — although they did not interest themselves in the commercial development of these products.[11]

Perhaps the claims made in these statements are somewhat exaggerated. A few years later Moissan in his researches on the electric furnace showed that many of the first conclusions regarding electrothermal carbon smelting to secure pure metals required important modification, because useless carbides were the typical yield. Very likely the Cowleses and their employees did produce

[9] The John Scott Legacy premium and medal given by the City of Philadelphia to encourage science in the arts, and awarded on recommendation of the Franklin Institute; and the Elliott Cresson gold medal, the highest honor given by the Franklin Institute.

[10] Report of the Committee on Science and the Arts on the process and furnace for reduction of refractory ores, and the production of metals, alloys, and compounds invented by Eugene D. and Alfred H. Cowles (*Journal of the Franklin Institute*, CXXII, 51, July 1886).

[11] *Journal of Industrial and Engineering Chemistry*, XV, 314 (March 1923).

in one form or another most of the products which Smith credits to them. For the most part, however, they did not produce these products with commercial success until others had demonstrated their economic usefulness.

The part played by these innovators in the electrochemical revolution may be summed up as follows. They built and operated several electric furnaces which were not only successful in industrial application but also provided an arresting demonstration of the possibility of utilizing the electric furnace in a wide range of industrial activities. In their electric furnace they decomposed for the first time many metallic oxides which had previously resisted the most determined efforts of the fuel furnace. They were responsible for the first commercial production of aluminum in the form of alloys on a fairly large scale at a cheap cost. Their work possessed great significance for the development of the dynamo. "In the early days of the Cowles Company their experiments and improvements did important pioneer work for the United States and other countries in the use of large dynamos." [12] The success of the Cowles furnaces was followed by a broadcast of their results in the leading scientific journals of Europe and America. Literature concerning aluminum was widely disseminated by the Cowles company. In attracting world-wide attention to the potentialities of electric smelting by furnishing other workers with both knowledge and stimulus, the Cowles brothers played a leading part in the industrial development of electrochemistry.[13] As far as aluminum itself is concerned, although they did not obtain the metal in pure form, their attainments with the electric furnace were doubtless of aid to the inventors of the electrolytic process, while their prosperous business in aluminum alloys presented a stimulus to those who were still at work upon the more difficult problem. It should be added that, while the Cowles company found it unprofitable to operate the electrothermal reduction of aluminum after 1892, Alfred Cowles continued his

[12] *Electro-chemical Industry*, I, 56 (October 1902). Another authority declares that "the Cowles process attracted much attention, as it was the pioneer of dynamo-electrometallurgy in the United States" (R. L. Packard, in MR, 1894, p. 359, being *Annual Report of the United States Geological Survey*, XVI, Part III).

[13] Cf. Dr. Leonard Waldo's supplementary note in his translation of Adolphe Minet, *The Production of Aluminium and Its Industrial Use*, p. 255.

interest in aluminum in particular and electrometallurgy in general for many years.[14]

The progress of the Cowleses in electrometallurgy was closely paralleled on the other side of the Atlantic by a brilliant Parisian inventor, M. Paul L. T. Héroult. In 1886 M. Héroult began a long career of experiment and industrial application characterized by achievements in nearly every department of electrometallurgy. His attention, also, was first claimed by aluminum. In 1886 he independently discovered and patented in Europe an electrolytic process yielding pure aluminum which was in all essentials precisely similar to the Hall process. At the time he did not realize the possibilities attaching to the metal in its pure state. Speaking at the Metallurgical Congress in Paris during the World's Fair in 1900, he explained how it came about that he did not immediately attempt to perfect his process for industrial production.

> My practical knowledge of chemistry was at the time [1886] that of a student of twenty-three; of special knowledge I had as good as none at all. Under these circumstances, it is needless to say that after I had taken out my first patent I sought the counsel and encouragement of those men who were then considered authorities on this subject. Péchiney (Salindres), whom I first approached, explained to me that aluminum was a metal of restricted usefulness; at most it might be used for opera-glasses; and whether I wanted to sell the kilogram for 10 or 100 francs, I would not be able to dispose of one kilogram more. It was otherwise in the case of aluminum bronze, of which considerable quantities were handled commercially, if I could produce it cheaply; I would then, beyond a doubt, come out even in my reckoning.
>
> I had then already in this connection undertaken some successful experiments; and I therefore laid aside for the time being the production of pure aluminum and turned to a series of new researches which in the year 1887 led to a second patent.
>
> In this additional patent a system of electric furnaces and a process were described which made possible a continuous production of alloys of aluminum, and particularly of all metals difficult to melt and reduce.[15]

The furnace and process of the 1887 patent were essentially like the Cowles apparatus for aluminum alloys. Héroult's European patents for production of aluminum and its alloys were purchased by the Schweizerische Metallurgische Gesellschaft, formed in October 1887 by Swiss industrial interests.[16] During 1888 and

[14] Eugene Cowles died in 1893.

[15] Quoted in Minet, *op. cit.*, pp. 115–116.

[16] Schulthess, *op. cit.*, p. 4.

a part of the following year aluminum alloys were produced with the aid of Héroult himself in a small plant at Neuhausen, Switzerland. In 1888 this company and the Deutsche Edison Gesellschaft (later the Allgemeine Elektrizitätsgesellschaft) organized the Aluminium Industrie A. G., which thenceforth operated the aluminum patents in an enlarged plant at Neuhausen. Dr. Martin Kiliani, who had experimented upon the production of pure aluminum for the AEG was largely responsible for the successful industrial adoption of the Héroult process for producing pure aluminum to which attention was turned in 1889. Héroult returned to France, where he aided in perfecting electrolytic production of aluminum by the Société Électrométallurgique Française, founded in 1888 with the aid of the Neuhausen company.

Héroult next turned his attention to the electrothermal production of calcium carbide, which had been discovered in 1892 and 1893 by Willson and Moissan. The furnace which had served for aluminum alloys was used for calcium-carbide production at La Praz and perhaps at other plants of the Société. The later and more important accomplishments of this versatile inventor were concerned with ferroalloys and steel refining. A passage in *The Electric Furnace* by J. N. Pring is particularly apt in that it shows, by tracing the repercussions of Héroult's early work in connection with aluminum upon other fields in electrometallurgy, a trend which was characteristic of the activities of several aluminum experimenters.

> The work of Héroult on the production of steel in the electric furnace followed as an outcome of the aluminum process which had been established in 1887. The possibility of producing various ferroalloys was shown in a similar type of furnace consisting of a metallic casing of crucible form, the bottom of which is carbon lined to form one pole, whilst the movable carbon electrode making contact with the surface of the charge forms the second electrode. . . .
>
> The production of low-carbon ferrochromium led to work on the production of steel and to the establishment of a furnace in which, by the use of special slags, high-grade steel can be obtained directly from highly impure iron. Furnaces for this purpose were brought into operation at La Praz and Froges in France at the aluminium works of P. Héroult, and in 1906 the process was applied at Remscheid, in Germany.[37]

[37] J. N. Pring, *The Electric Furnace* (London: Longmans, Green & Co., 1921), p. 210. Héroult also developed the electric-furnace smelting of iron ores.

If it be said that the Cowles brothers introduced the electric furnace to the industrial world, it must be said that Héroult assisted at the introduction and took a leading part in its subsequent adaptation for several important uses. The popularity of the Héroult steel furnace in the early years of electric steel was testified to by Wright in 1910.[18] Figures on electric furnaces in the British steel industry in 1919 show that the Héroult installations outnumbered those of every other type by a substantial margin.[19]

Another American inventor who first studied aluminum reduction, but made his real contributions to the development of electrochemistry through his work on other materials, was Thomas L. Willson. In 1885 Mr. Willson was an employee of the Brush Company of Cleveland, manufacturers of dynamo machines for the Cowles brothers. Willson's interest was caught by the experiments of the latter with their electric furnace. He left the Brush Company and began experiments upon aluminum reduction in an electric furnace at Spray, North Carolina, which was situated near deposits of corundum. These experiments resulted in a patent for the reduction of aluminum alloys in 1890, just as they were beginning to be supplanted by Hall's electrolytic aluminum. Willson discontinued further work on aluminum soon after he had accidentally discovered calcium carbide while attempting to obtain metallic calcium in the electric furnace for the purpose of trying this metal as a reducing agent upon aluminum.[20] Willson and Moissan, who obtained calcium carbide at about the same time in France, were the first to perceive the economic usefulness of this compound for the production of acetylene gas. Industrial

[18] J. Wright, *Electric Furnaces and Their Industrial Application* (London, 1910), p. 118.

[19] Pring, *op. cit.*, p. 272. Héroult furnaces numbered 49 of the 144 electric furnaces installed. Total capacity of these 49 was 195 tons compared with 79 tons capacity of the 34 furnaces of the next most common type.

[20] The honor of this discovery must be shared with Moissan in France, who announced his results at about the same time as Willson (the end of 1892). Willson appears to have been the first to manufacture calcium carbide, beginning as early as 1891 in Spray. Moissan's researches, which continued for several years, were the more scientific and the more valuable for the economic utilization of this product. The discovery of calcium carbide by these two men was in fact a rediscovery, for Robert Davy, cousin of Sir Humphry, had discovered this compound originally in 1855, and Wöhler had repeated Davy's experiment in 1862 and engaged in further study of the compound. This is another example of the time lag between laboratory discovery and industrial development.

production of calcium carbide and acetylene gas was inaugurated on a fairly large scale in the United States and England under the Willson patents, and on the Continent under patents taken out in the name of Bullier, an assistant of Moissan.

Calcium carbide, which had appeared as an indirect result of experiments upon aluminum, was also destined to lead into further developments in electrometallurgy. In the last three years of the century calcium carbide and acetylene developed an inflationary boom complex in England and upon the Continent. Capital and enterprise poured into these new industries with cautionless optimism, and acute overcapacity was rapidly created. In 1900 the collapse occurred with even more swiftness. The difficulties of the new companies were increased by court actions in which the patents of Bullier and Willson were declared invalid in most of the European countries. Under the influence of manifold troubles the owners of many carbide plants with cheap water power turned their interest to the production of ferroalloys or sold their plants to persons who had been experimenting in this field.[21] In the United States Willson saw his second venture with the electric furnace end without great financial success to himself when, as a result of the patent litigation, the control of carbide manufacture was awarded to the owners of the Bradley patents.[22] Willson likewise turned to the production of ferroalloys in plants at Holcomb Rock and Kanawha Falls, Virginia, and Ste. Catherine in Canada. In 1900 *The Mineral Industry* reported that the Virginia plants were devoted exclusively to the manufacture of ferrochromium. Subsequently other ferroalloys were produced, but ferrochromium continued to be the chief product. A few years later the Electro-Metallurgical Company was formed to take over the Willson patents and Virginia furnaces. A new plant was built at Niagara Falls by this company. One authority on the develop-

[21] France was the leader in the development of electric-furnace ferroalloy production.

[22] It is interesting to note that this owner was none other than the Cowles Electric Smelting and Aluminum Company, which henceforth owned an interest in the Union Carbide Company. A part of the fortune which Willson had failed to win from his early experiments upon aluminum came to him later through Saguenay water power, which is now used for aluminum production. J. B. Duke acquired a large part of the Saguenay water rights from Willson, who, it is said, had bought them from the Quebec government in 1912 for one thousand dollars.

ment of the electric furnace summarizes the evolution of the ferroalloy industry as follows:

> It is in the manufacture of ferroalloys that the electrochemical industry met with its greatest success and most rapid development. The main incentive which led originally to the progress of this work was the decline in the calcium-carbide industry which followed its early extension. Thus in 1900, experiments were made in France on the production of ferrochromium, ferrosilicon, and other ferroalloys. Carbide furnaces were found applicable for this manufacture, and the success obtained has finally led, in the case of many of these alloys, to the complete replacement of the older processes by electric-furnace manufacture. Large works manufacturing ferroalloys are now in operation mainly in Savoy, and Isère in the South of France and in the United States, Switzerland, and Scandinavia.[23]

With the exception of Héroult's electrolytic process for aluminum reduction the achievements so far described involved the use of the electric furnace in electrothermal processes — that is, the electric current was used to produce heat of a sufficient intensity to allow chemical reactions which would not occur at a lower temperature. During the eighties a few men perceived that successful reduction of the alkali and alkaline earth metals and aluminum would be attained by electrolysis rather than electrothermal methods. Charles S. Bradley became convinced by experiments that many of the highly refractory metallic ores or compounds which were nonconductors in an unfused state could be reduced by electrolysis when the electric current was at the same time used to fuse the electrolyte and maintain it in a state of fusion.[24] The peculiar feature of Bradley's work was the use of electric current to fuse and maintain fusion, thus making it possible to dispense with external heat. Bradley seems to have been the first, in America, at least, to recognize the significance of internal heating of the electrolyte.

Almost contemporaneous with Bradley's work were the experiments of Charles M. Hall upon the electrolysis of aluminum. Before his graduation from Oberlin College in 1885 this brilliant young man became vitally interested in the possibilities of wresting the ubiquitous metal aluminum from its useless compounds. While

[23] Pring, *op. cit.*, p. 14. This book was published in 1921.

[24] Three-quarters of a century earlier Davy had reduced potassium and sodium by employing the electric current for simultaneous fusion and decomposition.

still an undergraduate studying the classics, he found time to experiment with the effects of the electric current upon aluminum compounds, and after graduation his whole interest became absorbed in this problem. He was shortly convinced that the chief requirement for an electrolytic reduction process capable of commercial development was an effective solvent for alumina, the cheapest aluminum compound.

As he has several times explained to the writer, he had in mind the analogy to dissolving a salt, such as copper sulphate, in water and obtaining the ingredients of the salt at the two electrodes without decomposition of the water.[25]

Hall's next experiments were directed toward the discovery of a substance which would dissolve alumina as water dissolved the copper sulphate in the illustration given.[26] He worked with many salts to find one which would (1) dissolve alumina fully, (2) conduct electricity, (3) yield only aluminum and oxygen from electrolysis, and (4) not volatilize or deteriorate on continued use.

A few months of elimination work sufficed to arrive at the discovery which was the essential part of Hall's invention. He found that the double fluoride of aluminum and the more electropositive metals possessed the qualifications for an effective solvent of alumina. It was on February 10, 1886, that he was delighted to remark that cryolite, the double fluoride of aluminum and sodium, readily dissolved considerable amounts of alumina. Using a gasoline burner to heat his crucible, he applied the electric current from a galvanic battery to a bath of alumina dissolved in cryolite. The result was not at first successful. A suspicion that the difficulty lay not in the bath but in the presence of silica in the lining of his clay crucible was proved to be correct when he lined the crucible with a mixture of ground carbon and tar. On February 23, 1886, he obtained his first button of pure

[25] J. W. Richards, in *Electro-chemical Industry*, I, 159 (January 1903).

[26] Aqueous solutions are unsatisfactory for the electrolysis of aluminum salts because the aluminum possesses such a great affinity for oxygen that the hydroxide of aluminum is yielded rather than the metal itself. See Minet, *op. cit.*, p. 57. Richards states (MI, XIV, 13, 1905) that Hall's earlier attempts at Oberlin convinced him that electrolysis from aqueous solutions was out of the question because the nascent aluminum at the cathode was immediately oxidized. The critical pressure for decomposition of water is lower than that of aluminum.

aluminum. Patents were applied for in July, and during the next two years Hall was engaged in the work of adapting his process for industrial production and securing financial backing. Throughout the experimental period, and apparently for a few months after industrial production had actually begun at the plant of the Pittsburgh Reduction Company, Hall relied upon external heating. It is not clear whether he really intended to continue external heat when the process was conducted upon a commercial scale, or whether he believed that as a natural consequence of larger-scale operations the electric current would maintain the bath in a fused state. It does not appear that Hall appreciated the principle of fusion by the electric current simultaneous with electrolysis until after some experience with industrial operation of his process. His patent claims did not specify this; on the contrary, they definitely mentioned external heating. In the absence of Bradley's work Hall would, of course, have adopted internal heating when operation demonstrated its advantage. It should be recognized, however, that Bradley was the first of the many investigators of this decade to appreciate the significance of the principle of simultaneous fusion and electrolysis by the electric current. It was Hall who overtopped his many competitors and carried electrolysis from the laboratory to its first successful application in the industrial world.

It may be asked why Hall and other inventors worked with alumina, which exists in nature (as corundum) in a very limited amount, rather than with some of the common aluminous ores such as bauxite, gibbsite, or kaolin. Any reduction of its ores which will yield aluminum will also reduce the metals associated with it in the ores and thus destroy all the valuable qualities of the aluminum. The refining of impure aluminum presented great obstacles. Alumina seemed the most promising point of attack. The alumina used in the Hall process has until recently been produced only by an expensive chemical treatment from the ore bauxite.

Hamilton Y. Castner, a chemist from Columbia University, also turned his attention to aluminum at the same time as the others. His attack, however, was upon the chemical method which reduced aluminum at a high cost by the chemical action of sodium, which was itself obtained only at great expense. It was stated in

1883 that 57 per cent of the cost of aluminum was attributable to the sodium. Castner invented a process of reducing sodium which lowered its cost from one dollar a pound to about twenty or twenty-five cents. A new aluminum company was set up in England by Castner and an English associate in 1887. Four years later the competition of electrolytic aluminum forced this company to discontinue aluminum manufacture and write its capital down from £400,000 to £80,000. The firm continued to produce sodium, and Castner, perhaps disgruntled by his failure in trying to patch up an obsolete process, began to experiment with electrolysis. His ability was both recognized and rewarded a few years later when he invented an electrolytic method for reducing sodium from common salt, which soon replaced the chemical methods.[27] Castner also contributed to the industrial application of electricity to the production of caustic soda and chlorine and cyanides.

The development of the electric furnace and the rapidly increasing knowledge concerning its application in the industrial arts had other repercussions before the turn of the century. In 1891 E. G. Acheson, while experimenting on artificial production of diamonds in an electric furnace, accidentally secured an extremely hard crystalline material which he supposed to be a compound of carbon and alumina (corundum). It was only after he had given it the name carborundum that he identified it definitely as the simplest compound of carbon and silicon — CSi or silicon carbide. After investigation had shown the usefulness of this material, which is next to the diamond in hardness, Acheson proceeded to produce and sell it under the name of carborundum. A small factory in Pennsylvania was superseded in 1895 by larger works at Niagara Falls, where furnaces absorbing 1,000 h.p. were set up. This represented a significant development, for until this time only small furnaces had been used in applied electrometallurgy. A few years later Acheson founded successful industrial processes for the manufacture of artificial graphite and refractories (siloxicon and aloxite) in the electric furnace.

Up to this point we have surveyed the early course of the electrochemical revolution, which received its stimulus from the search for a practical process of reducing pure aluminum on a

[27] This was similar to the method used by Davy in 1807.

large scale. Laboratory discovery and the formulation of the fundamental principles of electrochemistry in the first half of the century brought no immediate industrial consequences owing to the absence of cheap electric power in large amounts. The introduction of effective dynamos in the late sixties and seventies precipitated an outbreak of experimentation aimed at the use of the electric power now made available for electrochemical processes. Electrolytic copper refining, although first upon the scene, did not reach sizable proportions until after further advances in industrial electrochemistry, which resulted in the birth and growth of several new industries. Most of the experimentation of the eighties was concerned with aluminum reduction and somewhat incidentally with the reduction of other refractory oxides. The invention and development of the electric furnace by the Cowles brothers in this country, and by Héroult and Moissan among others abroad, marked the first important step. Alloys of both aluminum and silicon were produced industrially by the Cowleses in the latter eighties. After Hall and Héroult had seized the aluminum prize with their successful electrolytic process, Willson, Moissan, the Cowleses, and others, who had been working upon electrothermal processes in the electric furnace, developed the manufacture of calcium carbide and acetylene and ferroalloys. During the first decade of the present century these industries became firmly established. Under the influence of ferroalloy production a beginning had been made in the production of electric furnace steel. This decade also witnessed the growth of additional industries which seemed to appear naturally once the applicability of the electric furnace had been established — e.g., carborundum, artificial graphite, and refractories. While the existence of an effective dynamo was a necessary condition for the birth of electrochemical industries, their growth in turn demanded the further cheapening of power which was obtained by hydroelectric developments. The early promotion of hydraulic electricity at Niagara Falls in the nineties found about half its market in electrochemical plants which were built there to use this cheap power. The rapid progress of industrial electrochemistry in this decade and an aroused interest in its development are testified to by the simultaneous establishment in 1902 of the *Electro-chemical Industry*,[28] a scientific

[28] Now *Chemical and Metallurgical Engineering.*

and trade journal, and of the American Electrochemical Society, whose membership embraced both industrial and academic men.

It is interesting to note that in addition to his earlier achievements already described, Alfred Cowles and his associates had by this time come to hold the most prominent position in electric smelting in the United States. By patent litigation or purchase the following companies had become more or less subsidiary to the Electric Smelting and Aluminum Company: the Union Carbide Company, the Willson Aluminum Company, the Electric Gas Company, the Acetylene Illuminating Company, the Acetylene Company.[29] In 1913 the Cowles company won an infringement suit against the Carborundum Company over the Cowles electric-furnace patents. Although these had already expired, the decision legally established the Cowles brothers as pioneers in electric smelting.

While it would be beyond the purposes of this essay to describe the further development of electrochemistry, it may be of interest to indicate briefly the economic significance connected with the later development of the industries whose birth has been noticed, and to mention the more recent electrochemical applications.

Since the early nineties the electrolytic copper-refining industry has shown an enormous expansion, principally in America. The inadequacy of the supply of "lake" copper to fill the rapidly growing demand for metal of high purity for electrical uses necessitated the exploitation of the great deposits of the western states. Ordinary metallurgical methods could not secure the metal from these ores in pure enough form for the electrical industry. As a consequence, electric refining of the raw copper obtained by smelting these ores developed rapidly with the expansion of the electric industry. This development was facilitated by the presence of silver and gold in American raw copper, the recovery of which materially reduces the cost which must be borne by copper. The absence of these valuable constituents in the European copper ores has been adduced as the main reason why the growth of electrolytic refining in Europe was so slow by contrast.[30]

Calcium carbide, which was earlier employed chiefly as a base for acetylene manufacture, has not lost its importance with the

[29] MR, 1903, p. 267. [30] Kershaw, *op. cit.*, p. 109.

waning of acetylene illumination. Oxyacetylene cutting and welding has exerted a marked influence upon the development of the metal industries. Furthermore, acetylene, $C_2H_2$, is useful as a starting point in building up higher compounds of carbon and oxygen by synthetic chemistry. Some of the products thus derived are alcohol, acetic acid, acetone, and methyl. The largest use of calcium carbide in recent years has been in the manufacture of calcium cyanide, now employed extensively as a fertilizer.

It was pointed out above that the production of ferroalloys in the electric furnace received part of its initial stimulus from the overcapacity of calcium-carbide furnaces. Since then the furnaces used for ferroalloy production have been modified in details, and the ferroalloy industry has enjoyed a tremendous expansion under the influence of an increasing interest in the development of ternary and quaternary steel for special purposes. Ferroalloys serve two purposes in the manufacture of steel. First, they act as purifiers and deoxidizers by combining with elements which would lower the quality of the steel unless removed. Ferrosilicon and ferromanganese are the principal alloys used for this purpose. For many years these two alloys were prepared by ordinary blast-furnace methods. The electric furnace, which yields alloys of much higher manganese and silicon content, has largely superseded the older methods in the preparation of ferromanganese and to a lesser extent in the making of ferrosilicon. Secondly, ferroalloys are employed to introduce into the steel a certain proportion of the alloyed metals, with the purpose of increasing the quality of the steel for special uses. Of the several alloys used in this way ferrochromium was the first to be produced in large amounts by the electric furnace, which has almost completely replaced the crucible process for this alloy. By virtue of its extreme hardness, steel with a small percentage of chromium has been instrumental in the development of gear machinery and cutting tools. Ten to twelve per cent chromium has given us "stainless steel." Ferrotungsten has had a remarkable growth as an electric-furnace product. It is utilized in making high-speed steel for cutting tools which, by retaining their edge even at the red heat induced by rapid machining, have revolutionized machine-tool performance. Ferromolybdenum added to steel imparts qualities similar to those of tungsten steel. Ferrovanadium is made largely

in the electric furnace. Steel possessing very small amounts of vanadium resists shock and vibration more satisfactorily, and hence is used for axles, cranks, connecting rods, and so on. Ferrotitanium, ferrouranium, and ferrophosphorus are alloys of lesser importance which are produced to some extent in the electric furnace.

It has already been explained that the use of the electric furnace for steel refining was suggested by the success with the production of ferroalloys. About 1900 Héroult in France and Kjellin in Sweden successfully applied many of the carbide plants to the production of high-quality steel as well as ferroalloys. Since then, because it is more economical and gives larger masses of metals of uniform composition than the crucible process, the electric furnace has almost entirely replaced the crucible process for the production of "fine steels" [81] — i.e., high-grade carbon steels and the highly complex alloy steels, such as tungsten steel. The electric furnace is also constantly encroaching upon the domain of the open-hearth fuel furnace in the production of structural alloy steels for automobile and airplane parts. There is a growing tendency toward the adoption of the "cold melt." Further, the electric furnace has also been used somewhat to replace or supplement the open-hearth and converter processes for producing "tonnage" steel. In general, the advantage of the electric furnace is that it allows the use of less pure materials, while producing higher quality steel than the fuel furnace. But for "tonnage" production the electric furnace is economical as an alternative to fuel heating methods only in situations where fuel is quite dear and electric power relatively cheap. Actual replacement of fuel furnaces has been rare. However, there has come into increasing use a "duplex" process whereby steel is produced in bulk by subjecting it first to a preliminary refining in open-hearth furnaces or Bessemer converters and then transferring it in liquid form to the electric furnace for further refining.[82] The electric energy is usually generated by

[81] Professor S. S. Stratton is responsible for the term "fine steel." He has supplied much of my information on the electric furnace in various branches of the steel industry. See his unpublished doctoral dissertation, "Some Chapters on the Development of the Fine Steels Industry in the United States," Harvard University, 1930.

[82] In 1908 there was but one electric furnace in the United States. Pring reported 287 in operation in January 1919 (*The Electric Furnace*, p. 272).

gas engines driven by blast furnace gas. Most of the steel rails made in this country are now manufactured by this "duplex" process. It has enabled the Bessemer process to hold its own as a competitor of the open-hearth in the face of more exacting requirements in the quality of steels for rails and other products. Stassano, Héroult, Keller, and others built successful furnaces for electric smelting of iron ores, but industrial application has remained small, owing to the high efficiency of the fuel process already in existence. Large-scale operations have been carried on for several years in Norway, Sweden, and California, however, and electric smelting of iron ores appears to be gaining slowly.

Metal grinding and polishing has been revolutionized by carborundum, which has also enjoyed wide application as a refractory for lining various types of furnaces in which high temperatures are developed. Its high thermal conductivity renders it useful in the construction of furnace muffles which are required to transmit heat. Fused alumina or artificial corundum (sold under such names as alundum and aloxite) has proved a more satisfactory abrasive than the natural compound. Though less hard than carborundum, it is also less brittle, and therefore more efficient in grinding steel and malleable iron. It is also receiving increasing employment as a refractory in the form of crucibles and tubes. The Carborundum Company has lately reduced silicon in the electric furnace and now manufactures it for use in steel production, in the chemical industries, where its high resistance to acids is advantageous, and in the making of hydrogen. "Pyrex" dishes are electric-furnace products containing 80 per cent silica. Artificial graphite, because it is infusible and incombustible except at extremely high temperatures, is used extensively for crucibles and electrodes. It can be employed in the form of electrodes in fused alkali and aqueous solutions, and possesses electrical conductivity four times that of the best carbon electrodes. Furthermore, it can be readily machined with accurate threads, so that it can be connected up for structural purposes. Colloidal graphite in a medium of water or oil presents a useful lubricant for bearings.

Electrolytic reduction of sodium from fused sodium hydroxide drove out the chemical process for sodium products soon after Castner's invention. Sodium, however, has only restricted uses, and it is in the development of the production of chlorine and

caustic soda that electrolysis of the alkalis has gone farthest. Electrolytic decomposition of common salt (sodium chloride) in aqueous solution yields chlorine and caustic soda. Chlorine is used largely in making bleaching powders. Many paper mills and other large users of bleaching powders have installed electrochemical plants to produce chlorine. Electrolytic caustic soda has largely replaced the products of the older methods. Electrolysis of salt also produces sodium hypochlorite, which is employed as a bleaching agent and for disinfecting purposes. The decomposition of potassium chlorate, used extensively where a strong oxidizing agent is needed, is obtained by electrolysis.

The most important of the more recent developments of electrochemistry seem to be the various electric furnaces for the fixation of atmospheric nitrogen into cyanides, cyanimides, or nitrides. Oxidation of ammonia to produce nitric acid is another electrochemical industry of growing significance. The electric current has a wide use to produce ozone from oxygen for use in water-purification plants. The attempts to apply electrometallurgy to metals other than those already mentioned have not met with success until quite recently. Electrolytic extraction of zinc from aqueous solution has lately begun to achieve a considerable degree of success, especially with complex ores containing lead and silver. An extensive development has also occurred in the electrolytic reduction of copper from aqueous solutions of copper ore. Electric smelting of copper and tin ores has been carried on to a slight extent only. Electrolytic gold refining now finds a wide range of employment. Electroplating of several metals has developed into an important industry. Magnesium is produced solely by electrolysis. This light metal is useful in alloys (e.g., magnalium, an aluminum-magnesium alloy, and Elektron) and will probably have an increased demand as aviation develops. The preparation of phosphorus and carbon bisulphide is now conducted almost wholly by electrothermal processes.

An interesting by-product of electrochemistry was described by Professor Richards in his presidential address to the American Electrochemical Society in 1903.

> Such organizations as research companies, formed explicitly to combine research with practical application, are novelties in the industrial world which have originated with, and are almost peculiar to, electrochemistry. They in-

vent, investigate, and develop electrochemical processes, and furnish facilities to would-be experimenters whose ideas might otherwise remain stillborn.

Industrial electrochemistry has thus branched far in many directions since the beginnings which were occasioned by interest in aluminum reduction. Some of the more important products and their applications have been noticed here, but it would require several volumes to describe all the ramifications and the repercussions upon the industrial structure. The importance of this new group of industries for the development of the most spectacular child of the twentieth century is well explained by Mr. Tone of the Carborundum Company.

The mechanical perfection of the automobile and the interchangeability of its parts have been made possible by the modern grinding wheel. Practically every part of the automobile must be ground with artificial abrasives at some stage of its manufacture. Take away from the automobile industry artificial abrasives and other products which the chemist has made available to it by the electric furnace, such as aluminum, alloy steel, and high-speed steel, and the labor cost of building a car would become prohibitive. The industry would cease to exist on its present lines.

# APPENDIX B

## PATENT LITIGATION IN THE UNITED STATES

THE first fifteen years of the electrolytic aluminum industry witnessed continuous litigation in the United States to settle conflicting claims to participation in the profits of the new industry. This litigation is of interest in connection with the question of the participation of several persons in the same invention and the distribution of rewards. It also bears upon the relation of patents to monopoly.

Charles M. Hall succeeded in reducing pure aluminum by electrolysis in February 1886. He filed his first patent application in the following July. In the course of correspondence between Hall and the Patent Office several apparatus claims were disallowed as being mere aggregations of well-known apparatus. S. C. Mastick, lecturing on chemical patents, states:[1]

> We have seen that the various parts of his apparatus were all old and that the essence of his invention consisted in fusing a compound composed of the fluorides of aluminum and of a metal more electropositive than aluminum, dissolving alumina therein and passing an electric current through the fused mass. It may be that at this point of time Hall himself did not appreciate that the process, regardless of the form of apparatus used, was the broad and valuable invention.[2]

During the correspondence with the Patent Office an interference was declared between the application of Hall and one filed by Héroult, who had independently discovered the same process in France. It was settled in favor of Hall because the date of actual success with his process (February 23, 1886) preceded the filing of Héroult's application. Patent number 400,766 was issued to Hall on April 2, 1889.[3] It contained three claims, all process

[1] For this discussion of the patent litigation I have drawn heavily upon a series of lectures given in 1915 by Seabury C. Mastick, special lecturer on chemical patents, Department of Chemical Engineering, Columbia University. The aluminum litigation was treated quite fully in these lectures, which are reprinted in *Industrial and Engineering Chemistry*, VII, 789, 879, 984, 1071 (September to December 1915).

[2] *Ibid.*, VII, 881 (October 1915).

[3] In the interim Hall had amended his original application in some respects. The only change of importance seems to have been specifying carbonaceous anodes

claims, viz.: (1) a bath of "fluorides of aluminum and a metal more electropositive than aluminum," and passing an electric current through the fused mass; (2) fluoride of sodium as the metal more electropositive than aluminum, and the use of a carbonaceous anode; (3) fluoride of lithium as an additional or alternative ingredient of the bath.

In the meantime Hall, who was without resources, had made several attempts to secure the financial backing necessary to perfect his invention for industrial operation. In the summer of 1886 he worked in Boston, where his brother had been able to raise a little money to defray expenses. After four rather discouraging months the inventor found his backing withdrawn and returned to Oberlin, where he used a large bichromate-sulphuric acid battery constructed by himself. The results of his work there were so encouraging that he went to Cleveland in December and attempted to raise funds for work on a larger scale. A decided lack of interest upon the part of Cleveland capitalists combined with the interference declared about this time by the Patent Office, and not immediately settled in his favor, led the disheartened inventor to enter into an optional agreement to sell his patent to the Cowles brothers, whom he had met during the preceding summer. Hall was to have current and facilities for experiment at the Cowles works at Lockport, and was to receive one-eighth interest in the Cowles company in the event that they decided to purchase. He worked at Lockport from the summer of 1887 until July 1888, endeavoring to perfect his process. It was during these months that there emerged a difference which may at first have been merely a difference of opinion, but which later developed into an acrimonious dispute between Hall and the Cowles brothers over the right to fundamental parts of the reduction process as it was finally developed. Previous to his Lockport work Hall had employed external heat to fuse the bath in his crucible and keep it in fusion. His patent applications specified an externally heated crucible, although he had included a statement similar to the following quotation from a letter written to his sister in August 1886. "Also it is evident from the experiments that the waste heat of electricity, which must be used anyway, will be nearly, if not quite, enough

rather than copper, which had not proved satisfactory. Four other patents covering minor details of the process were issued at the same time.

to keep the solvent melted." [4] At Lockport he continued to use external heat. Furthermore, at this time he was employing copper anodes, as he had done from the beginning. According to Mr. Mastick, the Cowleses believed that internally heated crucibles with carbon anodes were necessary, and internal heating was alleged to be within the scope of certain prior Cowles patents and applications.[5]

Testimony concerning the results of Hall's work at Lockport is contradictory. He himself relates that he experienced difficulties with his process for a time, but "after finally overcoming the difficulties which I have mentioned, I made several pounds of aluminum in small crucibles which I showed to Mr. Alfred Cowles and gave him all the facts in relation to the same, but he was not interested." [6] Mr. Cowles is reported as stating that the results, as far as they saw, were not sufficiently encouraging; [7] while it is said that Hall alleged that the current at his command was so small that he could not show the results which would come with larger-scale processing.[8] However this may be, the Cowleses allowed the option to lapse in July 1888.

One of their metallurgists, Romaine Cole, was interested, however. Before Hall left Lockport, Cole resigned and went to Pittsburgh, where he was able to gain the support of Captain Alfred E. Hunt of the Pittsburgh Testing Laboratory. Hall's arrival in Pittsburgh at the close of July was followed within a few weeks by the organization of the Pittsburgh Reduction Company, with Captain Hunt as its president. A capital of $20,000 was subscribed by Hunt and his associate, Mr. Clapp of the Pittsburgh Testing Laboratory, and four other Pittsburgh men. On the following Thanksgiving Day production was begun in a small plant in Pittsburgh. Apparently, external heating was employed for a short time, during which no startling success attended, and then was abandoned in favor of internal heating by electric current, which

[4] 111 Fed. Rep. 754.

[5] *Industrial and Engineering Chemistry*, VII, 986 (November 1915).

[6] Remarks of Mr. Charles M. Hall in acknowledgement of the Perkin Medal (*ibid.*, III, 148, March 1911). Cf. also Hall's report to the Cowles company, printed in *Aluminum Industry*, I, 21; and statement in an anonymous biography of Hall that he was able to produce aluminum at Lockport "in nearly as large a quantity, in proportion to the power employed, as had ever been done since" (*Aluminum World*, I, 66, January 1895).

[7] *Electrochemical Industry*, I, 10 (September 1902).

[8] *Ibid.* Cf. also report of Hall cited above.

immediately proved more effective.[9] Carbon anodes were substituted for copper by Hall at some time during the early months of his work with the Pittsburgh Reduction Company. Progress during 1889 and 1890 was rapid.

Probably the future success of electrolytic aluminum was perceptible to the Cowleses, experienced as they were in electrometallurgy. As soon as Hall departed they had begun experiments with cryolite and alumina, keeping the bath fused by electric current. For a while attempts were made to merge the two companies. When this failed, the Cowles company threw down the gauntlet with a determined gesture. First they brought suit against the Pittsburgh company, alleging infringement of certain Cowles patents. They claimed prior invention and application of the use of electric energy to fuse ores preparatory to reduction.[10] Their next move is described by Judge Taft.

> The evidence leaves no doubt that the defendant company [the Cowles company] began their manufacture of pure aluminum in January 1891, with the aid of one Hobbs, who had been the foreman of the complainant company, and engaged for it in superintending the manufacture of aluminum by the Hall process.[11]

Hitherto the Cowleses had made and sold only aluminum alloys. Now they began to advertise pure aluminum at prices which undercut the Pittsburgh company's charge of $1.50 a pound. A short price war ensued, bringing the price down to $1 by the middle of March. At this juncture the Pittsburgh Reduction Company entered the legal arena with a countersuit alleging infringement of the Hall patent and praying for a preliminary injunction. Judge Ricks, of the Circuit Court of the Northern District of Ohio, denied a complete injunction but issued an order restraining the Cowles company from increasing its output during the trial of the suit and from selling below a price to be named by the complainant.[12]

[9] Mastick, in *Industrial and Engineering Chemistry*, VII, 986 (November 1915). Cf. *Aluminum Industry*, I, 24.

[10] E. P. Allen, "The Production of Aluminum," *Cassier's Magazine*, I, 419 (February 1892). This suit never went beyond the filing of bills in the Circuit Court at Pittsburgh.

[11] Opinion in Pittsburgh Reduction Company v. Cowles Electric Smelting and Aluminum Company; quoted from Mastick, *op. cit.*, p. 989.

[12] The Pittsburgh company named $1.50 as the price, but this was lowered to 50¢ in August to meet foreign competition.

The outcome of the suit was favorable to the Hall interests. Judges Taft and Ricks handed down an opinion on January 11, 1893, holding the Cowles company to be infringers and ordering the payment of $292,000 damages to the Pittsburgh Reduction Company. This sum was never paid because attempts to secure a rehearing lasted until another suit had turned the pecuniary tables. The results of this first case established the Hall company as the sole producers of aluminum in the United States by the electrolytic method, the only method then in commercial use for producing pure aluminum.

Nevertheless, the Cowleses were not willing to regard this defeat as final. Rather they pushed the struggle in the courts for another decade. The litigation concerned the ownership of the Bradley patents, which were believed to dominate the Hall patent, and the infringement of the Bradley patents by the Pittsburgh Reduction Company. Apparently the Cowleses had concluded after the adverse decree of 1893 that their own patents could not be used successfully in fighting the Pittsburgh company. At that time they had certain claims to two patents which had just been issued to Charles S. Bradley. The brothers had come into contact with Bradley in 1895 when the Patent Office declared an interference between some of their respective patent applications. Bradley sold out to the Cowleses. At this time there stood rejected at the Patent Office an earlier application of Bradley's, filed February 23, 1883, relating to the separation of metals from highly refractory ores which were nonconductors in an unfused state, by using the electric current to fuse, maintain fusion, and decompose by electrolysis. The use of this process for aluminum reduction was specifically claimed. The rejected application was brought to the attention of the Cowleses, and was the subject of a discussion between them and Bradley before a contract was finally signed which, in quite broad language, conveyed to the Cowleses "all interest in any and all discoveries and inventions relating to electric smelting processes and furnaces, and all patents they [Bradley and an associate] have obtained therefor and all applications now pending, and caveats on file, in the United States Patent Office, relating to electric smelting processes and furnaces, which do or may interfere with any application for patents made by Eugene H. and

Alfred H. Cowles of Cleveland, Ohio, now pending in the United States Patent Office." [13]

Bradley's application of 1883 lingered on in the Patent Office, with no interest shown in it by the Cowleses, until 1892, when the Board of Examiners-in-Chief allowed the issuance of two patents which Bradley promptly assigned to G. P. Lowrey.[14] The latter brought suit to restrain the Cowles company from claiming title to these patents, to which the company replied with a cross-bill praying that Lowrey be enjoined from claiming the title. Judge Taft held in the Circuit Court decision, rendered April 23, 1895, that the Bradley patents were not intended to be conveyed by the assignment of May 18, 1885.[15] The Circuit Court of Appeals, Judge Severenz delivering the opinion, reversed the lower court, holding that the inventions were intended to be included in the terms of the contract of 1885.[16] Immediately upon receiving title, the Cowles interests again took up the legal cudgels against the old rival in Pittsburgh, alleging infringement of the Bradley patents.[17] The Circuit Court finally dismissed the bill in October 1901, holding that the Hall process did not infringe.[18] Having become used to defeat in the lower courts, the Cowleses at once appealed the suit, and were rewarded two years later with a verdict that one of the Bradley patents had been infringed.

The judges of both courts were in apparent agreement that the novelty of Hall's process or the essence of his invention consisted in the discovery that alumina would dissolve freely in cryolite. The process actually operated by the Pittsburgh Reduction Company

[13] Quoted by Mastick, *op. cit.*, p. 1072..

[14] Patents no. 464,933, issued December 8, 1891, and no. 468,148, issued February 2, 1892. Lowrey, a shrewd patent attorney, had evidently hunted out this Bradley application and pushed it through. When the patents issued, Lowrey immediately notified both the Pittsburgh and the Cowles companies that they were infringers. An interesting side issue in the struggle between this attorney and the Cowleses over the Bradley patents was a shift from the Cowleses to Héroult, engineered by Lowrey, on the part of a group of Berlin capitalists whom the Cowleses had got together for the erection of an aluminum works in Switzerland which was to be operated under Cowles patents.

[15] 68 Fed. Rep. 354 (1895).

[16] 79 Fed. Rep. 331 (1897).

[17] Electric Smelting and Aluminum Company v. Pittsburgh Reduction Company, 111 Fed. Rep. 742. The Electric Smelting and Aluminum Company had been recently formed by the Cowles interests. The old Cowles Electric Smelting and Aluminum Company continued its existence as a subsidiary of the new company.

[18] 111 Fed. Rep. 742 (1901).

involved also simultaneous fusion and electrolysis by the electric current. Did this constitute infringement of the Bradley patent? The chief issues stressed in both opinions were two: (1) whether the construction to be placed on Bradley's patent should be broad or narrow; (2) whether the Hall process as operated employed electric energy in excess of the amount necessary for electrolysis, the excess being used for heating to fuse and maintain fusion. The judges of neither court were altogether successful in avoiding confusion with respect to the electrochemical relations which continually intruded upon the legal domain. In a muddled opinion which occasionally confused the two issues, Judge Hazel of the lower court concluded that the proper construction to be placed on the Bradley patent was too narrow to cover Hall's process, and that "the heat required to maintain fusion is obtained by the heat radiation, and from such sources as are incidental to the use of the process, and not from any independent process of electric heating."

Judge Coxe of the Circuit Court of Appeals, with his two associates concurring, delivered a clearer opinion, well ordered, more careful in logic.[19] After a survey of the prior art, which seems to be more penetrating if no more exhaustive, he concluded that the Bradley patent should have a liberal construction. Starting with the undisputed fact that before Bradley's work no one had ever been able to separate aluminum from its compounds solely by the use of electricity — i.e., without the employment of external heat — Judge Coxe went on to show that although it was previously known that metals contained in ores which were conductors could be separated therefrom by electricity, the problem of dissociating metals from nonconductors by this method had not been solved. The ores of aluminum are nonconductors at ordinary temperatures.

The principal expert for the defendant, Dr. Chandler, whose reputation for learning and ability is well known to the courts, although of the opinion that slight modifications of the previous methods would produce the Bradley process, nevertheless admits frankly, "I do not recall any one process which, when applied to the ore of aluminium, would without any modification whatever have produced aluminium, in which process both the fusion and the electrolysis would have been accomplished by the electric current."[20]

[19] Electric Smelting and Aluminum Co. v. Pittsburgh Reduction Co. on appeal (125 Fed. Rep. 926), decided October 20, 1903. [20] 125 Fed. Rep. 932.

From Davy to Bradley no one had been able to produce any aluminum by electricity alone. The efforts of inventors were directed to the perfection of external heating processes, even after the introduction of dynamos; and, indeed, these efforts continued for several years after the Bradley invention. Hall himself employed external heat until 1889. The Court disposed of the first issue by concluding:

> We are unable to discover anything in the prior art describing this process or anything closely approximating thereto. The patent is, therefore, not anticipated, and its claims are entitled to a liberal construction.
>
> The Judge of the Circuit Court, after a careful and painstaking research, reached the conclusion that Bradley had made a valuable invention, but failed to grant relief to the complainant upon the theory that the process which the defendant uses was an entirely separate invention, neither dependent upon nor subsidiary to the invention of Bradley. In this we think there was error. Hall's achievement should be considered in the light of an improvement upon Bradley's fundamental discovery.[21]

In taking up the second issue Judge Coxe stated that consideration of the Hall patent to which the court below had devoted much time was irrelevant, since the patent was not issued until 1889 and did not disclose the process which the Pittsburgh company used and of which the complainant complained. The material fact was that Hall's discovery that he could dispense with external heat came at least three years after Bradley's invention. Upon the question of excess energy beyond that necessary for electrolysis the Court believed that a current which fuses, maintains fusion, and electrolyzes must be of greater power than one which electrolyzes alone. The fact that the Bradley process was actually operated commercially in the United States and abroad is adduced.[22] In sum, when the proper construction is placed upon the Bradley patent, it was seen to be infringed because some of the electric energy was used to fuse and maintain fusion.

It is, of course, an indisputable fact that a substantial portion of the electric energy is converted into heat which results in constant fusion.

> There are, however, certain electrochemical processes in which electrical energy is used both for heating and for effecting electrolytic resolution; the

[21] 125 Fed. Rep. 932 (quoted by Mastick, *op. cit.*).

[22] Probably the reference was to operation by the Cowles firm before it had acquired legal title to the Bradley patent.

most noteworthy instance is in the manufacture of aluminium by electrolysis of alumina dissolved in a double fluoride of aluminium and sodium. The bath is not only decomposed electrolytically, but is also kept fused by heat obtained at the expense of electrical energy passing between the electrodes.[23]

Indeed the conversion of electric energy into heat is inevitable in this electrolytic process. Professor Richards has explained that:

. . . it is impossible to pass any current whatever through an electrolyte without generating some internal heat in it, and therefore the question as to whether the heat thus generated internally shall be sufficient alone to keep the bath melted, at the proper temperature, is merely a question of increasing the size of the pot and the scale of the operation.[24]

It is clear that Hall obtained internal heat by this expedient. Either Hall's invention was not a complete one in the first instance, because he failed to realize that the electric current would fuse and maintain fusion as well as decompose,[25] and hence continued for some time to employ external heating, the use of which hindered him from increasing the size of the pot and the scale of the operation to the point where this principle would be made manifest;[26] or, recognizing the principle, with or without knowledge of Bradley's work, Hall was unable at first to apply it satisfactorily, and hence did not specify it in any of the patents which were issued to him in 1889; or else he did not consider that it could be or should be patented.[27] Whatever was true of Hall, Bradley — and perhaps the Cowleses — had recognized the importance of this principle earlier.

The question whether Hall had benefited from Bradley was

[23] Bertram Blount, *Practical Electro-chemistry* (New York, 1903), pp. 24, 167 ff. See also A. J. Allmand and H. J. T. Ellingham, *The Principles of Applied Electrochemistry* (New York, 1924), pp. 521 ff.; J. W. Mellor, *A Comprehensive Treatise on Inorganic and Theoretical Chemistry* (London, 1924), I, 166; Richards, *Aluminium*, p. 383; Minet, *The Production of Aluminium*, pp. 19 ff.

[24] *Aluminum World*, VIII, 132 (April 1902).

[25] This opinion was expressed by Professor F. Haber in reporting to the Bunsen Society of Germany upon the industrial development of electrochemistry in the United States after a visit to this country sponsored by the Society.

[26] Dr. F. Regelsberger says that of the four inventors Hall, Minet, Kiliani, and Héroult, the latter two alone recognized early that external heating could be replaced by means of a stronger current. Héroult specified this in his British patent. See *Aluminium*, VII, Heft 9, p. 1 (May 16, 1925).

[27] Upon one occasion Hall characterized this principle as resulting "from a law of nature and not from any invention." See his remarks in acknowledgement of the Perkin Medal, reported in *Industrial and Engineering Chemistry*, III, 148 (March 1911).

immaterial to a decision upon infringement. The same may be said of the question whether, at the scale upon which the Hall process was being operated, just the amount of energy required for electrolysis would necessarily generate just the amount of heat necessary to maintain fusion properly. The only possible construction for the Bradley patent, except a construction which would have nullified it, would appear to be that it covered any use of the electric current to secure internal heat for fusion simultaneous with electrolysis of aluminum and other substances specified, whether such generation of heat was unavoidable or not. The fundamental question is whether Bradley should ever have been granted a patent for his process.[28] As issued, the patent, if construed to mean anything, must necessarily have been infringed by the Hall process.

The final decision in this suit involved a judgment of nearly $3,000,000 against the Pittsburgh Reduction Company as infringers since 1892. A few months prior to this holding the Cowles group had succeeded in having the old case, in which Judge Taft had enjoined the Cowles company from manufacturing pure aluminum, reopened for the introduction of new testimony and reargument. The sum decreed against them by Judge Taft had never been paid because of litigation. Now a final agreement between the two companies settled the whole controversy. The Pittsburgh company paid a sum of money somewhat less than the damages awarded. It was agreed that this company should have the monopoly of aluminum manufacture until the expiration of the Bradley patent in February 1909, and should work under a license, paying royalties. The Cowles companies agreed not to manufacture pure aluminum but could buy and sell all grades of aluminum.[29] As far as the inventors were concerned the outcome was not, perhaps, far removed from the attainable optimum of human justice. Hall and his associates, who had actually made a commercial success of electrolytic alu-

[28] This is a question upon which I am not competent to pass judgment. In the view of this controversy given by J. D. Edwards in *Aluminum Industry*, I, chap. II, it is stated that Bradley never operated his process and it is implied that in the light of this fact and the state of the prior art this "paper patent" should not have been issued.

[29] The Cowles companies were, of course, free to continue the manufacture of aluminum alloys.

minum, remained alone in the field. The Cowleses, who had played a conspicuous part in the early development of electrochemistry, and who may have had some influence upon Hall's success, received a cash reward. And Bradley, who at least seems to have been the first in this country to grasp the importance of the idea of simultaneous fusion and electrolysis of aluminum, received recognition.

The patent controversy and its outcome were a typical instance of the industrial development of inventions under a system of patent law. As the *Engineering News* remarked:

> The situation is simply one which constantly recurs in the history of inventions, in which an inventor whose work reaches commercial success finds that he must settle with the owner of some earlier pioneer patent, whose claims are entitled to a broad construction.[89]

In its relation to monopoly the result of this litigation was of considerable significance. What may have seemed to the Pittsburgh Reduction Company a severe blow was transformed some time later into an undisguised blessing. The license to operate the Bradley patent extended the period of legal monopoly past the business boom of 1906–1907 into the middle of the succeeding depression, and really gave the company three extra years in which to become so well fortified against competition that none developed. Furthermore, the decision of the victors to refrain from the manufacture of pure aluminum removed the most logical competitor. Mr. Alfred Cowles and his associates were probably better fitted by experience to enter this new industry than any other group of men in the country, except those already operating the Pittsburgh enterprise. A study of the patent struggle also makes it clear that the electrolytic process was so simple in its elements as to permit no possibility of patenting modifications or variations upon the basis of which a competing enterprise might operate.

[89] *Engineering News*, L, 390 (1903).

# APPENDIX C

## INVESTMENT AND EARNINGS OF THE ALUMINUM COMPANY OF AMERICA, 1909–1935

ANNUAL financial reports have been published by the Aluminum Company of America only since the year 1926. Materials from which estimates of investment and earnings may be derived for the years 1909–1926 are composed of the following sorts of information: (1) approximate figures for particular years given to government bodies by the company; (2) general statements in security advertisements that earnings, before or after interest as indicated, exceeded, equaled, or did not fall below certain sums in certain periods or particular years; (3) balance sheets for the years 1920–1924 submitted to the Department of Justice and printed in the Benham Report, p. 92; (4) records of interest and dividend payments, and fragmentary records of capital expenditures; (5) study of market conditions. The object of the study is to ascertain approximately the average ratios of earnings to investment in certain periods. Earnings signify net earnings of capital *after* operating expenses, including depreciation, depletion, taxes, and interest on current debt, and *before* interest on funded debt. Investment is equivalent to total assets less depreciation and depletion.[1] In order to obtain average investment during each year, investment at the beginning and end of each year has been averaged, except in the case of years during which assets or securities were bought or sold. In such instances averages of investment during appropriate periods of each year have been computed.

With regard to the period prior to 1927 there have appeared figures of investment at the end of 1908, 1910, 1911, 1912, 1916, each year 1920–1924, and 1926, and data on earnings for the years 1909–1912, 1916, 1921, and 1924–1926.[2] Other information about earnings is as follows:

[1] No good-will item or other questionable asset account appears on the balance sheets of the Aluminum Company. Assets of "non-consolidated" subsidiaries are represented in the investments account.

[2] Sources are given in the notes to Table 37.

(1) 1915–1924 — Average annual earnings after interest were $9,843,133.33.[3]

(2) 1917–1926 — Average annual earnings before interest exceeded $12,000,000.[4]

(3) 1911–1920 — Average annual earnings after interest exceeded $10,000,000.[5]

(4) 1916–1919 — Earnings after interest were in no year less than $10,000,000.[6]

(5) 1915–1918 — Earnings were in no year less than $8,000,000.[7]

The general method used is shown in the following summary of figures.

| | | | |
|---|---|---|---|
| | Total earnings after interest, 1915–1924 | | $98,431,333[8] |
| | Total earnings paid as interest on funded debt, 1915–1924 | | $9,297,500[9] |
| | Total earnings, 1915–1924 | | $107,728,833 |
| Less | Earnings, 1915 | $9,000,000 (estimated) | |
| | Earnings, 1916 | $20,000,000 (official) | |
| | Total earnings, 1915-1916 | $29,000,000 | $29,000,000 |
| | Total earnings, 1917–1924 | | $78,728,833 |
| Less | Total earnings, 1921–1924 (figures for 1921–1923 derived from comparing balance sheets; figure for 1924 given by the company) | | $30,425,300 |
| | Total earnings, 1917–1920 | | $48,303,533 |
| | Total earnings after interest, 1911–1920, equal at least to | | $100,000,000 |
| | Total interest paid on funded debt, 1911–1920 | | $1,500,000[8] |
| | Total earnings, 1911–1920 | | $101,500,000 |
| Less | Total earnings, 1917–1920 | $48,303,533 (above) | |
| | Total earnings, 1915–1916 | $29,000,000 (above) | |
| | Total earnings, 1911–1912 | $9,560,000 (official) | |
| | | $86,863,533 | $86,863,533 |
| | Total earnings, 1913–1914 | | $14,636,467 |

[3] *New York Times*, October 29, 1925, p. 38. [4] *Ibid.*, February 7, 1927, p. 28.
[5] *Wall Street Journal*, October 3, 1921, p. 3.
[6] *Commercial and Financial Chronicle*, CXI, 1853 (November 6, 1920).
[7] *Ibid.*, CVIII, 880 (March 1, 1919).
[8] This figure represents ten times the annual earnings after interest officially reported for that period. It does not appear whether the operating loss of about
[9] (See page 540 for note 9.)

The indicated total net earnings for each of the several periods were distributed over the individual years in accordance with considerations suggested by changing conditions. Growth in investment was estimated by calculation of reinvested earnings and additions to assets from sales of new securities. Recent testimony implies that there has been no substantial revaluation of any assets upward in the period covered by this study.[10] Some discussion of estimates of investment and earnings in certain periods is appropriate.

## 1913–1920

Figures of investment at the end of the years 1912, 1916, and 1920, and of earnings in the year 1916 have been given by the company. Figures for other years have been estimated according to the method just described. Investment grew from about $30,000,000 at the end of 1912 to about $80,000,000 at the end of 1916. The sum of the indicated reinvested earnings in these years is only $39,000,000. Apparently no new securities were sold. At the end of 1920 investment had increased to approximately $158,000,000. During the four years 1917–1920 reinvestment totaled $38,000,000, according to my estimates, and the sale of notes added about $24,000,000. The indicated increase in investment is only $62,000,000, while the actual increase was $78,000,000. During the whole period 1913–1920 investment increased about $128,000,000, according to the company's figures. Only $101,000,000 of this increase is accounted for by my estimates of reinvested earnings plus the proceeds of security sales.[11] The balance sheet for December 31, 1920, shows current payable items equal to $16,000,000. If current payables stood at zero at the beginning of 1913 the part of the growth in investment

---

$5,000,000 in 1921 was taken into consideration in computation of the average. If it was, the total earnings after interest during the period 1915–1924 were $5,000,000 larger.

[9] Calculated from data published in financial manuals.

[10] BMTC v. ACOA appellant, fol. 5707. A small write-up in 1925 is referred to on the next page.

[11] According to figures supplied by the company the total capital expenditures by the Aluminum Company and its subsidiaries in this period amounted to about $102,000,000. See *Hearings before Senate Committee on Investigation of Bureau of Internal Revenue,* 68 Cong., 2 Sess., Part 10, p. 1852.

which is unaccounted for in this study would be reduced to $11,000,000. Evidently the estimates of earnings presented here for the period 1913–1920 are too low by at least this amount.

## 1921–1935

Figures of investment at the end of each year (except 1925) have been given by the company. An operating deficit of about $5,000,000 is reported for 1921. To this has been added an inventory loss of $5,000,000 suggested by examination of balance sheets, price data, and other information, on the chance that this loss may not have been included in the operating deficit. Earnings for 1922 and 1923 have been estimated after comparing balance sheets and studying other relevant material. Comparison of balance sheets was rendered difficult by lack of information to explain changes in inventory items and reduction in plant account. If the reduction in plant account of about $9,000,000 in 1922 represented a simple write-down, the estimated earnings for the period 1921–1924 are too low by about that amount. Figures for earnings before interest in the years 1924–1926 were given by the company. Net earnings for each year thereafter have been computed by adding to the published figure of earnings after interest and taxes the annual interest payments required for the average amount of bonds outstanding in the year. Total investment increased approximately $75,000,000 during the period 1921–1929. Of this, $70,000,000 can be accounted for by the algebraic sum of indicated reinvestment of earnings, net proceeds from security sales, and the diminution in current liabilities and sundry other items. This small discrepancy is about equal to an increase in the book value of marketable securities made at the time of the merger with the Canadian Manufacturing and Development Company in 1925.[12] Examination of financial reports for the years since 1929 does not indicate any substantial write-down of assets or recapitalization other than bond retirements.

In addition to the fact that the full growth of investment during the period 1909–1920, at least, does not seem to be accounted for with the estimates of earnings given in Table 37,

[12] BMTC v. ACOA appellant, fol. 5707.

there are other indications that the annual earnings and rates of return on investment were actually somewhat greater, during part of the time, at least, than the figures shown in the table. (1) The method used in making estimates of earnings in those years for which no official earnings figures appear has probably tended to understatement because lower rather than higher figures have been used in all cases of doubt. (2) The figures of Table 37 do not include interest paid on current liabilities which is part of true earnings of total capital investment. Since payments on this item could be computed for a few years only, they were uniformly excluded. (3) The investment and income of several partially or wholly owned subsidiaries were evidently not included in the consolidated balance sheets and income accounts of the Aluminum Company.[13] Only such part of the earnings of these subsidiaries as was paid to the parent in dividends would appear in the income account of the latter. At the end of 1924 (the latest date for which we have information) the non-consolidated group included several important subsidiaries or affiliates, such as foreign bauxite companies, the Norwegian aluminum firms, Aluminum Manufactures, and the Aluminum Goods Manufacturing Company. (4) It appears that during the years 1912–1925 the Aluminum Company spent several millions of dollars in the acquisition and development of foreign ore properties, particularly in South America. At the beginning of 1925 the aggregate capitalization of these subsidiaries seems to have been not much more than $1,000,000.[14] It is possible that some true earnings were used for these bauxite properties without entering the income or capital accounts of the parent or subsidiaries. (5) At the end of 1927 the reserve for amortization, depletion, and depreciation was equivalent to about 32 per cent of the undepreciated book value of land, plants, and facilities. Three years later the corresponding figure was about 35 per cent, and at the end of 1934 it was about 37 per cent. More than three-quarters of the present capacity represented by dams and powerhouses seems to have been added since 1912, and at least half of the present capacity since 1925. Other facilities have been greatly enlarged in the last ten or fifteen years. True annual depreciation on hydro-

[13] BR, pp. 92–96.
[14] *Ibid.*

electric dams, powerhouses, and equipment is, of course, very small.[15] Furthermore, the company has accumulated large reserves of bauxite. Although the annual charges to depletion and depreciation may not have exceeded true charges since 1926 — they averaged slightly less than 3 per cent of undepreciated book value of land, plants, and facilities during the years 1927–1934 — it is quite possible that the large reserve for depletion and depreciation contains a substantial amount of reinvested earnings which have not been included in the income figures.

Sales and cost data appearing in the Benham Report[16] enable rough computation of earnings at the ingot stage — i.e., earnings upon all ingot, which is made up of ingot sold in that form and ingot sold in the form of later products. When the average price received for the metal sold as ingot is considered as the average price received for all ingot, the difference between this figure and the average cost of producing ingot (exclusive of any profit) constitutes the average profit per pound of ingot. Net earnings at the ingot stage may then be estimated by multiplying the total amount of metal sold in all forms by the average profit per pound of ingot. This computation indicates that in 1923 earnings at the ingot stage represented about 45 per cent of the total net earnings estimated for that year. In 1924 earnings at the ingot stage appear to be almost equal to the amount which the company reported as its net earnings on all operations, while in 1925 earnings at the ingot stage during the first half year apparently represent more than 40 per cent of the total net earnings reported for the whole year, or perhaps 80 per cent of the net profit in the half year.[17] It is not specified whether the cost figures, which have been used in the computation here, include selling cost and general expense or not. If they do not, profit at the ingot would, of course, be less. If one quarter of the total selling cost and general expense for 1925[18] is included in cost of ingot

[15] J. D. Justin and W. G. Mervine estimate that the annual depreciation for typical hydroelectric plants will vary from 0.7 per cent to 1.5 per cent (*Power Supply Economics*, p. 150).

[16] Pages 47 and 118.

[17] The company may, of course, keep its books in such manner that a higher rate of earnings is shown on the investment in fabricating facilities.

[18] These expenses for 1925 appear in Exhibits 58 and 258 of BMTC v. ACOA appellant.

TABLE 37

INVESTMENT, EARNINGS, AND RATE OF RETURN OF THE ALUMINUM COMPANY OF AMERICA, 1909–1935

| Year | Investment at End of Year [a] ($1,000) | Average Investment during Year [b] ($1,000) | Net Earnings [c] ($1,000) | Rate of Return (per cent) |
|---|---|---|---|---|
| 1908 | $24,000 [d] | | | |
| 1909 | 27,000 [e] | $25,500 | $3,600 [f] | 14.1 |
| 1910 | 30,000 [d] | 28,500 | 4,590 [f] | 16.1 |
| 1911 | 26,300 [d] | 28,150 | 5,100 [f] | 18.1 |
| 1912 | 30,000 [d] | 28,150 | 4,463 [g] | 15.9 |
| 1913 | 36,750 [e] | 33,380 | 7,500 [e] | 22.5 |
| 1914 | 43,130 [e] | 39,990 | 7,500 [e] | 18.8 |
| 1915 | 50,900 [e] | 47,015 | 9,000 [e] | 19.1 |
| 1916 | 80,000 [h] | 65,450 | 20,000 [h] | 30.6 |
| 1917 | 91,750 [e] | 85,880 | 14,000 [e] | 16.3 |
| 1918 | 100,650 [e] | 101,200 | 11,230 [e] | 11.1 |
| 1919 | 120,880 [i] | 114,830 [j] | 10,500 [e] | 9.1 |
| 1920 | 157,723 [k] | 127,500 [j] | 12,500 [e] | 9.8 |
| 1921 | 145,331 [k] | 150,220 [u] | def. 10,000 [l] | –6.7 |
| 1922 | 134,188 [k] | 139,760 | 3,000 [e] | 2.1 |
| 1923 | 145,016 [k] | 139,600 | 14,000 [e] | 10.0 |
| 1924 | 155,515 [k] | 150,510 | 13,425 [m] | 8.9 |
| 1925 | 190,000 [n] | 170,000 [o] | 22,892 [m] | 13.5 |
| 1926 | 209,716 [n] | 203,260 [j] | 19,747 [m] | 9.7 |
| 1927 | 250,170 [p] | 248,100 [j] | 18,160 [q] | 7.3 |
| 1928 | 215,320 [p] | 235,000 [r] | 23,390 [q] | 10.0 |
| 1929 | 232,517 [p] | 223,220 [s] | 27,330 [q] | 12.2 |
| 1930 | 240,778 [p] | 235,940 [s] | 13,630 [q] | 5.8 |
| 1931 | 245,133 [p] | 242,240 [s] | 6,495 [q] | 2.7 |
| 1932 | 237,438 [p] | 240,500 [s] | def. 510 [q] | –0.2 |
| 1933 | 233,452 [p] | 234,660 [s] | 3,400 [q] | 1.4 |
| 1934 | 228,317 [p] | 229,610 [s] | 8,100 [q] | 3.5 |
| 1935 | 221,703 [p] | 221,000 [v] | 10,820 [q] | 4.9 |

[a] Total assets, except as otherwise noted.

[b] Average of investment at beginning and end of year; or, in the case of years in which assets were sold, securities sold or retired, or the like, average of investment at different periods of the year.

[c] Net earnings before interest on funded debt but after interest on current debt and taxes.

[d] Approximate figures given by an officer of the company (Tariff Hearings, 1912–1913, House Document no. 1447, II, 1491 ff.).

[e] Estimate by author.

[f] Testimony of an officer of the company that earnings were approximately 15 to 17 per cent of investment in these years (Tariff Hearings, *loc. cit.*). It has been assumed that this meant 15 to 17 per cent of investment at the beginning of each year.

[g] Figure given in bond advertisement, *Wall Street Journal*, Oct. 3, 1921, p. 3.

[h] Approximate figure given by an officer of the company. See *Congressional Record*, LV, 4592.

[i] Includes $12,000,000 increase in assets from sale of notes in 1919.

[j] Average of investment at beginning of year and that amount plus reinvested earnings, adjusted for increase or decrease in assets due to sale or retirement of securities during year.

[k] Figure from balance sheet in Benham Report, p. 92.

[l] This deficit consists of an operating loss of about $5,000,000 (FTC Docket 1335, Record, p. 5240) and an estimated inventory loss of about the same amount.

[m] Figure given in bond advertisement, *New York Times*, Feb. 7, 1927, p. 28.

[n] No official figure for Dec. 31, 1925, is obtainable. Figures for Sept. 30, 1925, and Dec. 31, 1926, appear in Exhibits 249 and 250, BMTC v. ACOA appellant. The figure for Dec. 31, 1925, has been computed by deducting from the investment at the end of 1926 the sum of the cash obtained by sale of notes in 1926 and the indicated reinvestment of earnings in 1926.

[o] The figure for 1925 represents an approximate average of investment during several periods of the year separated to reflect changes in investment occasioned by the merger of the Aluminum Company and the Canadian Manufacturing and Development Company on July 29 and retirement of $12,000,000 of notes on Nov. 1.

[p] Figure taken from annual report with deduction of preferred dividend payable next day.

[q] Net earnings after all expenses incident to operations and reserves for depreciation, depletion, income and franchise taxes from annual report, plus interest paid on funded debt computed from data in financial manuals.

[r] The figure for 1928 represents the average of average investment in the periods before and after exchange of certain assets for stock of Aluminium Limited and distribution of that stock to shareholders of the Aluminum Company.

[s] Average of investment at beginning and end of year adjusted for retirement of bonds on March 1.

[t] Average of investment at beginning and end of year adjusted for retirement of bonds on March 1 and purchase of $924,000 of bonds during 1934 for retirement in January 1935.

[u] Average of investment at beginning of year and that amount less deficit of $10,000,000, adjusted for retirement of notes.

[v] Average of investment at beginning and end of year adjusted for retirement of $6,000,000 of bonds, September 1, 1935.

for the half year, net profit at the ingot would approximate 35 per cent of the net for the whole year, or perhaps 70 per cent of the half year's earnings. Similar calculations have been made for the years 1926 and 1928.[19] When about half of the total sales and general expenses are added to the plant cost of ingot — probably a substantial overestimate — net earnings at the ingot stage appear to represent about 40 per cent of net on all operations in 1926 and about 60 per cent in 1928. It is questionable whether the plant cost figures, taken from an exhibit of the Aluminum Company do not include some items which are not a part of true cost from the standpoint of the question raised here.

[19] From data in Exhibits 58, 106, 117, 258, 291, 293, *ibid.*

## APPENDIX D

### DECREE

In the United States District Court, Western District of Pennsylvania

Session of 1912

---

UNITED STATES OF AMERICA, Petitioner,

*v.*

ALUMINUM COMPANY OF AMERICA, Defendant

---

DECREE

This cause coming on to be heard on this 7th day of June, 1912, before the Hon. James M. Young, District Judge, and the petitioner having appeared by its district attorney, John H. Jordan, and by Wm. T. Chantland, its special assistant to the Attorney General, and having moved the court for an injunction in accordance with the prayer of its petition, and it appearing to the court that the allegations of the petition state a cause of action against the defendant under the provisions of the act of July 2, 1890, known as the Anti-trust Act, that it has jurisdiction of the subject matter, and that the defendant has been regularly served with proper process, and has appeared in open court, by George B. Gordon, its counsel, and has given its consent to the entering and rendition of the following decree:

Now, therefore, it is ordered, adjudged, and decreed:

1. That sections 2, 4, and 5 of the agreement entered into as of date September 25, 1908, between the Société Anonyme pour l'Industrie de l'Aluminum of Neuhausen and the Northern Aluminum Co. (Ltd.), acting on behalf of the defendant corporation, as follows, to wit:

§ 2. The N. A. Co. agree not to knowingly sell aluminum directly or indirectly in the European market.

§ 3. The A. J. A. G. agree not to knowingly sell aluminum directly or indirectly in the American market.

§ 4. The total deliveries to be made by the two companies shall be divided as follows:

European market, 75 per cent to A. J. A. G., 25 per cent to N. A. Co.

American market, 25 per cent to A. J. A. G., 75 per cent to N. A. Co.

Common market, 50 per cent to A. J. A. G., 50 per cent to N. A. Co.

The Government sales to Switzerland, Germany, and Austria-Hungary are understood to be reserved to the A. J. A. G.

The sales in the U. S. A. are understood to be reserved to the Aluminum Co. of America.

Accordingly the A. J. A. G. will not knowingly sell aluminum directly or indirectly to the U. S. A. and the N. A. Co. will not knowingly sell directly or indirectly to the Swiss, German, and Austria-Hungarian Governments.

§ 5. The N. A. Co. engages that the Aluminum Co. of America will respect the prohibitions hereby laid upon the N. A. Co.

be, and the same are hereby, declared null and void, and that the defendant Aluminum Co. of America, and all its agents and representatives in whatever capacity, are hereby perpetually enjoined from directly or indirectly requiring the parties to said contract to abide by its terms, and defendant is further enjoined from either directly or indirectly entering into, through said Northern Aluminum Co., or any other person or corporation, and from making or aiding in making any agreement containing provisions of the nature of those hereinbefore set out, in so far as they relate to the sale of aluminum in the United States, or its importation into or exportation from the United States, or any contract or agreement, either verbal or written, the purpose and effect of which would be to restrain the importation into the United States, from any part of the world, of aluminum, or alumina, or bauxite, or any other material from which aluminum can be manufactured, or to fix or illegally affect the prices of such aluminum, alumina, bauxite, or other material, when imported.

2. That the fourth and eighth paragraphs of the agreement en-

tered into, under date of July 5, 1905, between the defendant Aluminum Co. of America, under its former name, Pittsburgh Reduction Co., and the General Chemical Co., a corporation, which paragraphs read as follows:

"Fourth. Said Chemical Co. further expressly covenants and agrees that it will not use or knowingly sell any of the bauxite sold to it by the said Bauxite Co. hereunder, or any other bauxite, or the products thereof for the purpose of conversion into the metal aluminum, and that upon proof that any of said bauxite or products thereof have been put to any such use it will not make any further sales or deliveries to the purchaser thereof.

"Eighth. It is understood and agreed that the bauxite sold hereunder by the said Bauxite Co. to the said Chemical Co. shall be used by the said Chemical Co. and by companies under its control or whose stock is largely held by it, and by no other person or party, and only for the manufacture of alum, alum salts, alumina sulphate or alumina hydrate for alum and its compounds, and for no other purpose whatsoever —"

be, and they are, hereby declared null and void, and are stricken out of said contract; and that the fifth section of said contract which reads as follows:

"Fifth. The said Reduction Co. agrees to use its good offices in the interest of said Chemical Co. so far as relates to promoting the trade of the latter in alum and alum products in the United States and in foreign countries; and said Chemical Co. reciprocally undertakes and agrees to use its good offices in the interest of said Reduction Co. so far as relates to promoting the metal business of the latter in the United States and in foreign countries — " in so far as it may be considered as an agreement upon the part of the General Chemical Co. to antagonize the interests of the competitors of the defendant company, be and it is hereby declared to be null and void, and that defendant and all its agents and representatives be, and they are, hereby perpetually enjoined from in any manner, and to any extent, requiring an enforcement of said provisions, and from entering into or acting in pursuance of any contract or agreement the purpose and effect of which would be to place any restraint upon the General Chemical Co. with reference to the right of said company to

acquire and sell, or the quantity which it may acquire and sell, or the price at which it may acquire and sell any bauxite, alumina or aluminum of which it may become the owner by purchase, manufacture, or otherwise.

3. That the tenth and eighteenth sections of the contract entered into under date of April 20, 1909, between the defendant Aluminum Co. of America and the Norton Co., which sections read as follows to wit:

"Tenth. Norton Co. may mine and use bauxite from the said 40-acre tract of bauxite land referred to in paragraph D above, which shall be used for the purpose of manufacturing alundum, and may mine and sell from the said property bauxite or other mineral taken therefrom for any purpose except for the manufacture of aluminum, and Norton Co. shall not sell or otherwise dispose of said 40-acre tract except subject to the above restrictions.

"Eighteenth. Norton Co. shall not at any time during the continuance of this agreement use or sell any of the bauxite contained on the said 40-acre tract described in paragraph D above, or any other bauxite, or the products thereof, hereafter acquired by Norton Co., in the United States of America or the Dominion of Canada for the purpose of conversion into aluminum — " and all other parts of said contract, in so far as they restrain or seek to restrain the Norton Co. from exercising its free and independent will in using and disposing of the bauxite which it may receive under the provisions of said contract, or any other bauxite which it may obtain, be, and the same are hereby, declared null and void and are abrogated; and that the defendant, and its officers and agents, be perpetually enjoined from in any manner or to any extent enforcing or requiring recognition by the Norton Co. of such provisions, and from hereafter entering into any contract with said Norton Co., the purpose and effect of which would be to restrain said Norton Co. in the disposition of any bauxite which may be obtained from any source, or of any alumina or aluminum which it may manufacture from such bauxite, or may otherwise obtain.

4. That the following clause in a contract between defendant and the Pennsylvania Salt Manufacturing Co., to wit:

"The Pennsylvania Salt Manufacturing Co. agrees not to enter

into the manufacture of aluminum as long as this agreement is in force — "

and the ratification and extension of said clause contained in a letter from the Pennsylvania Salt Manufacturing Co. to defendant, dated January 1, 1907, be, and the same are hereby, declared null and void; and that defendant Aluminum Co. of America and its officers and agents be, and they are hereby, perpetually enjoined hereafter from in any manner or to any extent enforcing or relying upon said clause and its ratification, and from entering into any contract with said Pennsylvania Salt Manufacturing Co., the purpose and effect of which would be to restrain said Pennsylvania Salt Manufacturing Co. from freely making any disposition that it may see proper, and at any price it may deem proper, of any bauxite, alumina, or aluminum the ownership of which it may acquire from any source.

5. That that part of the agreement entered into as of date November 16, 1910, by defendant Aluminum Co. of America and Gustave A. Kruttschnitt, of Newark, N. J., and James C. Coleman, of Newark, N. J., which provides that —

"As part consideration for the execution of this agreement by Aluminum Co., Kruttschnitt and Coleman hereby severally agree that for the period of 20 years from the date hereof, in that part of the United States east of a north and south line through Denver, Colo., neither Kruttschnitt nor Coleman will directly or indirectly engage or become interested in the manufacture or fabrication or sale of aluminum, or any article made substantially of aluminum, provided that either or both the said Kruttschnitt and Coleman may be employed by or become interested in the Aluminum Co. or said Aluminum Goods Manufacturing Co., without committing a breach of this contract — "

in so far as it constitutes a restraint upon said Kruttschnitt and Coleman from freely engaging in any part or branch of the aluminum business, be, and the same is hereby, declared to be null and void, and that the defendant and its officers, agents, and representatives be, and they are hereby, perpetually enjoined from entering into a contract with said Kruttschnitt or Coleman or with any other individual, firm, or corporation of a like or similar character to the above-quoted provisions of said contract,

except as the same may be a lawful incident to the purchase of good will.

6. That the defendant and its officers, agents, and representatives be, and they are hereby, perpetually enjoined from entering into a contract with any other individual, firm, or corporation of a like or similar character to the above-quoted provisions in the contracts between the Aluminum Co. of America and the General Chemical Co., between said Aluminum Co. and the Norton Co., between said Aluminum Co. and the Pennsylvania Salt Manufacturing Co., and between said Aluminum Co. and Kruttschnitt and Coleman, or either of them, and from entering into or participating in any combination or agreement the purpose or effect of which is to restrict or control the output or the prices of aluminum or any material from which aluminum is directly or indirectly manufactured, and from making any contract or agreement for the purpose of or the effect of which would be to restrain commerce in bauxite, alumina, or aluminum, or to prevent any other person, firm, or corporation from or to hinder him or it in obtaining a supply of either bauxite, alumina, or aluminum of a good quality in the open market in free and fair and open competition, and from themselves entering into, or compelling or inducing, under any pretext, or in any manner whatsoever, the making of any contract between any persons, firms, or corporations engaged in any branch of the business of manufacturing aluminum goods the purpose or effect of which would be to fix or regulate the prices of any of their raw or manufactured products in sale or resale.

7. To prevent all undue discriminations upon the part of defendant and its officers and agents, or upon the part of any firm or corporation in whose business defendant owns or hereafter acquires a financial interest by stock ownership or otherwise, against any competitor of defendant and thus to prevent the unlawful acquisition by defendant of a monopoly in any branch of manufacturing from crude or semifinished aluminum, defendant and its officers, agents, and representatives, are hereby perpetually enjoined from committing the following acts, to wit:

(*a*) Combining either by stock ownership or otherwise with any one or more manufacturers for the purpose or with the effect

of controlling or restraining the output of any product manufactured from aluminum, or fixing or controlling the price thereof.

(*b*) Delaying shipments of material to any competitor without reasonable notice and cause, or refusing to ship or ceasing to continue shipments of crude or semifinished aluminum to a competitor on contracts or orders placed, and particularly on partially filled orders, without any reasonable cause and without giving notice of same, or purposely delaying bills of lading on material shipped to any competitor, or in any other manner making it impossible or difficult for such competitor promptly to obtain the material upon its arrival, or from furnishing known defective material.

(*c*) Charging higher prices for crude or semifinished aluminum from any competitor than are charged at the same time under like or similar conditions from any of the companies in which defendant is financially interested, or charging or demanding higher prices for any kind of crude or semifinished aluminum from any competitor for the purpose or which under like or similar conditions will have the effect of discriminating against such manufacturers in bidding on proposals or contracts to the advantage of said defendant or any company in which it is financially interested.

(*d*) Refusing to sell crude or semifinished aluminum to prospective competitors in any branch of the manufacturing aluminum goods industry on like terms and conditions of sale, under like or similar circumstances, as defendant sells such crude or semifinished aluminum to any firm or corporation engaged in similar business in which defendant is financially interested.

(*e*) Requiring, as a condition precedent to selling crude or semifinished aluminum to a competitor, that such competitor divulge to defendant the terms which such competitor proposes to make in order to secure the work in which the desired aluminum is to be used, and from imparting to any one the purpose or purposes for which said competitor is intending to use said metal.

(*f*) Requiring or compelling the making of agreements by competitors not to engage in any line of business nor to supply any special order in competition with defendant or with any company in which it is financially interested as a condition precedent to the procurement of aluminum metal.

(*g*) Representing or intimating to competitors that unless they dealt with defendant or with companies in which defendant has a financial interest for their supply of metal such competitor will not be able to obtain a sufficient supply of metal or obtain it at a price that will permit them to engage in competition with defendant or with companies in which defendant is financially interested; or in like manner representing or intimating to consumers of aluminum in any stage of manufacture that unless they deal with defendant or with a company in which it is financially interested, their supply of material or manufactured products will be cut off for that reason.

(*h*) Taking the position with persons, firms, or corporations engaged in the manufacture of any kind of aluminum goods that if they attempt to enlarge or increase any of their industries or engage in enterprises that are or will be competitive with defendant or with the business of any firm or corporation in which defendant is financially interested, such persons, firms, or corporations will for that reason be unable to procure their supply of material from defendant or any of the companies in which it is financially interested.

The term "competitor," as used above, shall be construed to mean all persons, firms, or corporations engaged in or who are actually desiring or about to engage in the manufacture of any kind of products or goods from crude or semifinished aluminum, whose business is not controlled or not subject to be controlled by defendant, its officers and agents, either by virtue of ownership of all or a part of the capital stock of such concerns, or through any other form or device of financial interest.

Provided, however, That nothing contained in this decree shall be construed to prevent or restrain the lawful promotion of the aluminum industry in the United States.

Provided, further, that nothing herein contained shall obligate defendants to furnish crude aluminum to those who are not its regular customers, to the disadvantage of those who are, whenever the supply of crude aluminum is insufficient to enable defendant to furnish crude aluminum to all persons who desire to purchase from defendant, but this proviso shall not relieve defendant from its obligation to perform all its contract obligations, and neither shall this proviso, under the conditions of insufficient

supply of crude aluminum referred to be or constitute a permission to defendant to supply such crude aluminum to its regular customers mentioned with the purpose and effect of enabling defendant or its regular customers, under such existing conditions, to take away the trade and contracts of competitors.

Provided, further, that nothing in this decree shall prevent defendant from making special prices and terms for the purpose of inducing the larger use of aluminum, either in a new use or as a substitute for other metals or materials.

Provided, further, that nothing in this decree shall prevent the acquisition by defendant of any monopoly lawfully included in any grant of patent right.

Provided, further, that the raising by defendant of prices on crude or semifinished aluminum to any company which it owns or controls or in which it has a financial interest, regardless of market conditions, and for the mere purpose of doing likewise to competitors while avoiding the appearance of discrimination, shall be a violation of the letter and spirit of this decree.

This decree having been agreed to and entered upon the assumption that the defendant, Aluminum Co. of America, has a substantial monopoly of the production and sale of aluminum in the United States, it is further provided that whenever it shall appear to the court that substantial competition has arisen, either in the production or sale of aluminum in the United States, and that this decree in any part thereof works substantial injustice to defendant, this decree may be modified upon petition to the court after notice and hearing on the merits, provided that such applications shall not be made oftener than once every three years.

It is further ordered that the defendants pay the cost of suit to be taxed.

JAMES M. YOUNG,
*Judge.*

# APPENDIX E

UNITED STATES OF AMERICA
BEFORE FEDERAL TRADE COMMISSION

IN THE MATTER OF
Aluminum Company of America,
a corporation.

DOCKET NO. 1335

## COMPLAINT

I

Acting in the public interest, pursuant to the provisions of an Act of Congress approved October 15, 1914 (the Clayton Act) entitled "An Act to supplement existing laws against unlawful restraints and monopolies, and for other purposes," the Federal Trade Commission charges that the Aluminum Company of America, a corporation, hereinafter referred to as respondent, has been and is violating the provisions of Section 2 of said Act, issues this complaint and states its charges in that respect, as follows:

PARAGRAPH ONE: Respondent, Aluminum Company of America, is a corporation organized, existing and doing business under and by virtue of the laws of the State of Pennsylvania, with its principal or executive offices in the City of Pittsburgh, in said State. The said respondent owns extensive bauxite deposits from which the aluminum ore is secured in Saline County, Arkansas, and in British and Dutch Guiana, South America, and also owns or has a controlling interest in bauxite deposits in France and Jugo-Slavia. Said respondent owns and operates crushing and drying apparatus in Saline County, Arkansas, a refining plant in East St. Louis, Illinois, reduction works where aluminum is made at Niagara Falls and Massena, New York, Maryville (Alcoa), Tennessee, and Badin, North Carolina; it owns and operates a wire and cable mill at Massena, N. Y.; a general fabricating plant at New Kensington, Penna.; a plant for the manufacture of aluminum bronze powder and aluminum foil at New Kensington,

Penna.; and rolling mills at Niagara Falls, N. Y., at Maryville (Alcoa), Tennessee, and at Edgewater, New Jersey. Respondent is the sole producer of virgin aluminum ingots in the United States and, since March, 1923, has produced over 95 per centum of the virgin sheet aluminum manufactured in the United States, the present sole competitor in this branch of the industry, the United States Smelting & Refining Company, of New Haven, Connecticut, producing not more than one per centum of said virgin sheet aluminum at higher prices for spot delivery. Respondent owns 36 per centum of the stock of the Aluminum Goods Manufacturing Company, the largest manufacturer of aluminum cooking utensils in the United States, and 100 per centum of the stock of the United States Aluminum Company, the second largest manufacturer of cooking utensils in the United States, these two companies producing not less than 65 per centum of the total output of said cooking utensils in the United States; 75 per centum of the stock in the American Body Company, which manufactures aluminum bodies for automobiles; 64 per centum of the stock of the Aluminum Manufactures, Inc., which company makes sand castings for automobile parts; 89 per centum of the stock in the Aluminum Die Castings Corporation; and 80 per centum of the stock of the Aluminum Screw Machine Products Company. Respondent owns a 50 per centum stock interest in the Norsk Aluminum Company of Norway, a one-third interest in Norske-Nitrid Company of Norway, and also is the sole owner of the Northern Aluminum Company, Ltd., of Canada, the only other manufacturer of virgin aluminum ingots in North America. The total holdings of respondent on December 1, 1922, comprised a 100 per centum stock ownership in 34 corporations, a greater than 50 per centum stock ownership in nine corporations, and a less than 50 per centum stock ownership in 17 corporations, engaged in various enterprises.

The said respondent, Aluminum Company of America, is now and has been for more than two years last past, engaged in the manufacture and sale in interstate commerce of pig aluminum ingots and aluminum ingots, aluminum sheet, tubing, moulding, wire, cable, foil and powder and, through affiliated subsidiaries and/or leased companies, is engaged in the manufacture and the sale in interstate commerce of fabricated aluminum products, and alu-

minum alloy products, in particular cooking utensils, aluminum sand castings, permanent mould castings and die castings, causing its aforesaid products, when so sold, to be transported from the place of manufacture in one State to purchasers thereof located in other States of the United States.

The sole sources of supply of aluminum metal required by foundries and/or manufactories engaged in the manufacture and the sale in interstate commerce in the United States of fabricated aluminum products, and/or products manufactured from aluminum alloy, in particular aluminum cooking utensils, aluminum automobile bodies, aluminum sand castings and permanent mould and die castings are (1) respondent, Aluminum Company of America, and its subsidiary, the Northern Aluminum Company, Ltd., of Canada, the estimated capacity for production of said companies annually, being about 175,000,000 pounds; (2) foreign companies engaged in the production of aluminum ingots and/or aluminum sheets, importations from which during the calendar year 1923 for companies other than respondent and its subsidiaries being about 28,000,000 pounds; and (3) domestic manufacturers of fabricated aluminum products who have for disposition scrap aluminum resulting from the aforesaid manufacturing. In recent years the supply of scrap aluminum available to foundries and manufactories in competition with respondent for use in remelting into secondary ingots and in the production of aluminum cooking utensils and aluminum castings has been very extensive. In the year 1922 the recovery of secondary aluminum as pig aluminum or in alloys amounted to slightly more than 32,000,000 pounds. Since that time and as a result of competitive practices of respondent of which complaint is made herein, practically all of this secondary aluminum has been removed from the market by respondent, for the purpose and/or effect of preventing its competitors from securing this secondary or scrap aluminum and in order to make respondent's monopoly of the aluminum raw material more certain and complete.

In the course and conduct of its said business the respondent was at all times hereinafter mentioned, and still is, in competition with other individuals, firms, partnerships and corporations likewise engaged in interstate commerce.

PARAGRAPH TWO: Respondent, Aluminum Company of America,

for more than two years last past, in the course and conduct of its business —

(a) Has adopted and maintained the practice of entering into contracts or agreements for the sale and is now selling and making contracts for the sale in interstate commerce of virgin sheet aluminum to manufacturing foundries at prices less than they have been and are selling said virgin sheet aluminum to jobbing foundries; and/or

(b) Has adopted and maintained the practice of entering into contracts or agreements for the sale, and are now selling and making contracts of sale with certain manufacturers of automobile bodies, of cooking utensils, and/or of other fabricated aluminum products, for the sale in interstate commerce to said manufacturers of virgin sheet aluminum at prices less than they have been and are selling said virgin sheet aluminum to other manufacturers of automobile bodies, of cooking utensils, and/or of other fabricated aluminum products, on the condition, agreement, understanding or contract that the said manufacturers to whom the lower selling price is made shall sell all the aluminum scrap resulting from their manufacturing operations to the Aluminum Company of America; and said discrimination in price between purchasers of virgin sheet aluminum engaged in the manufacture of automobile bodies, of cooking utensils and/or of other fabricated aluminum products by respondent, Aluminum Company of America, was not made on account of differences in the grade, quality or quantity of the commodities sold, nor did it make only due allowance for difference in the cost of sale or transportation, nor was it made in good faith to meet competition nor in the selection of customers in bona fide transactions.

The effect of such sales and/or contracts for sale, and agreements, conditions and understandings may be and is to substantially lessen competition and tends to create a monopoly.

PARAGRAPH THREE: The above alleged acts and things done by respondent, Aluminum Company of America, are all in violation of Section 2 of the Act of Congress entitled "An Act to

supplement existing laws against unlawful restraints and monopolies, and for other purposes," approved October 15, 1914.

II

Acting further in the public interest, pursuant to the provisions of an Act of Congress approved September 26, 1914, entitled "An Act to create a Federal Trade Commission, to define its powers and duties, and for other purposes," the Federal Trade Commission charges that the Aluminum Company of America, a corporation, hereinafter referred to as respondent, has been and is using unfair methods of competition in commerce in violation of the provisions of Section 5 of the said Act, issues this complaint and states its charges in that respect as follows:

PARAGRAPH ONE: Proceeding in the public interest and as a further cause of action in violation of Section 5 of the above Act, the Commission charges and relies upon the matters and things set forth in Paragraphs One and Two under the First Count of this complaint to the same extent as though the allegations thereof were set out at length herein and the said Paragraphs One and Two of the First Count are incorporated herein by reference, and adopted as a part of the allegations of this Count.

PARAGRAPH TWO: Respondent, Aluminum Company of America, for more than two years last past has employed, and still employs, a scheme the effect of which was and is to gain a monopoly of the aluminum sand castings industry of the United States, and, in order to carry out said scheme, respondent has adopted, and used, and is now using the following practices, to-wit:

(a) It arbitrarily fixes a differential between the selling price of virgin aluminum ingots and the purchase price of scrap aluminum;

(b) It pays higher prices for scrap aluminum than it costs the respondent to manufacture virgin aluminum ingots;

(c) It makes concessions to automobile body manufacturers and/or to manufacturers of other fabricated aluminum products in the price of virgin sheet aluminum to said manufacturers upon the agreement, understanding, or contract that said manufacturers sell respondent their total

available supply of scrap aluminum at prices fixed by respondent approximating the actual cost of manufacture or at prices higher than it cost the respondent to manufacture the virgin aluminum ingots; and/or at prices higher than competing foundries engaged in manufacturing and jobbing fabricated aluminum products or aluminum castings or aluminum alloy products could pay for such metal and more than its intrinsic value when compared with virgin aluminum metal.

(d) It transfers virgin aluminum metal to its agents and/or its subsidiaries, at an arbitrary price below the cost of production and below the selling price of said metal to competitors of its said agents or subsidiaries engaged in the manufacture and the sale of aluminum sand castings;

(e) It makes sales of aluminum sand castings to manufacturers of automobiles or automobile products at prices approximating the actual cost of manufacture or at prices less than it cost the respondent to manufacture the aforesaid sand castings; and/or at prices less than competing foundries can sell aluminum sand castings at a profit taking into consideration the cost to the said competing foundries of virgin aluminum and scrap aluminum.

(f) The practices of respondent as set out in subparagraphs "(a)" to "(e)" of this paragraph, both inclusive, have been made and are being made with the purpose and/or effect of curtailing the supply of raw material used by independent and/or competing jobbing foundries or manufactories and of compelling said independent and/or jobbing foundries or manufactories to purchase virgin aluminum ingots and aluminum sheets from respondent at prices arbitrarily fixed by respondent and with the purpose and/or effect of eliminating as a source of supply for independent and/or competing jobbing foundries or manufactories the scrap aluminum theretofore available; in that the domestic source of supply of aluminum metal of the aforesaid independent and/or competing jobbing foundries or manufactories, with the exception of the aforesaid scrap aluminum, is limited to and dependent upon the supply obtainable from respondent; and that the effect

of the aforesaid practices of respondent as herein set out has been and is to suppress competition and to tend to create a monopoly.

PARAGRAPH THREE: Respondent, Aluminum Company of America, for more than two years last past, in the course and conduct of its business as described in Paragraph One hereof, has employed and is still employing, a scheme the purpose and/or effect of which was and is to gain and maintain a monopoly of aluminum raw material, of aluminum ingots and sheets, of secondary aluminum, and of aluminum fabricated products and/or aluminum alloy products, throughout the United States, and, in order to carry out such scheme, respondent has adopted and used and is now using, the following practices, to-wit:

(a) It arbitrarily neglects or refuses to supply to manufacturers of aluminum goods and/or aluminum fabricated products, and/or aluminum castings the aluminum sheet metal or ingots required by said manufacturers, who are in competition with respondent or its subsidiaries.

(b) It arbitrarily fails to make shipment of aluminum ingots to its competitors or to the competitors of its subsidiaries at the time said products are ordered, and/or at the time specified for shipment;

(c) It arbitrarily makes deliveries of aluminum or aluminum ingots to its competitors or to the competitors of its subsidiaries in insufficient quantity and in amounts or quantities less than ordered;

(d) It makes deliveries of aluminum sheets, and/or aluminum ingots to its competitors or to the competitors of its subsidiaries of quality inferior to that required.

(e) The practices of respondent as set out in subparagraphs "(a)" to "(d)" of this paragraph, both inclusive, have been made and are being made for the purpose and/or effect of unfairly harassing the competitors of respondent or of respondent's subsidiaries and with the effect of suppressing competition between respondent and its competitors and of creating or tending to create or maintain a monopoly.

PARAGRAPH FOUR: The above alleged acts and things done by respondent, Aluminum Company of America, are all to the prejudice of the public and of respondent's competitors and constitute unfair methods of competition in commerce within the intent and meaning of Section 5 of an Act of Congress entitled "An Act to create a Federal Trade Commission, to define its powers and duties and for other purposes," approved September 26, 1914, and/or with the effect of suppressing competition and tending to create a monopoly.

WHEREFORE, THE PREMISES CONSIDERED, The Federal Trade Commission, on this 21st day of July, 1925, now here issues this its complaint against said respondent.

NOTICE

Notice is hereby given you, Aluminum Company of America, respondent herein, that the 9th day of September, 1925, at 10:30 o'clock in the forenoon, is hereby fixed as the time, and the offices of the Federal Trade Commission, in the City of Washington, D. C., as the place, when and where a hearing will be had on the charges set forth in this complaint, at which time and place you shall have the right, under said Act, to appear and show why an order should not be entered by said Commission requiring you to Cease and Desist from the violation of the law charged in this complaint.

IN WITNESS WHEREOF, The Federal Trade Commission has caused this complaint to be signed by its Secretary, and its official seal to be hereto affixed at Washington, D. C., this 21st day of July, 1925.

By the Commission:

Otis B. Johnson,
Secretary.

(SEAL)

L. A. R.

UNITED STATES OF AMERICA
BEFORE THE FEDERAL TRADE COMMISSION

IN THE MATTER OF
Aluminum Company of America, a corporation. } DOCKET NO. 1335

ANSWER OF THE ALUMINUM COMPANY OF AMERICA
TO THE COMPLAINT OF THE COMMISSION,
DATED THE 21ST DAY OF JULY, 1925.

And now, to wit, September 21st, 1925, comes the Aluminum Company of America, the respondent in this case, and makes the following answer to the complaint filed against it by the Federal Trade Commission, dated the 21st day of July, 1925.

FIRST. The respondent denies that any or all of the averments set forth in the complaint disclose any violation of law, or that the same, if true, would justify the making and issuing of any decree by the Commission against the respondent, and therefore prays that the complaint be dismissed.

---

SECOND. In answer to the averments and allegations contained in COMPLAINT I respondent avers:

1. In so far as PARAGRAPH ONE sets up the corporate organization of the respondent and the location of its principal office, the same is admitted. In so far as the complaint avers ownership of bauxite deposits, the same is admitted. Bauxite is the principal raw or natural material used in the production of the metal aluminum, and the bauxite owned by respondent is necessary in the reasonable conduct of respondent's business. It is true that the respondent, either directly or through subsidiary corporations, is the owner of bauxite deposits, refining plants, reduction works and fabricating plants as set forth in Paragraph One of Complaint I. It is also true that respondent is the sole manufacturer in the United States of aluminum ingots made from the ore (bauxite). It is not true that respondent has since March, 1923, produced over 95% of the virgin sheet manufactured in the United States, neither is the United States Smelting

& Refining Company at present respondent's sole competitor in the manufacture of such sheet aluminum.

The statements contained in said paragraph as to the ownership of stock by respondent in certain manufacturing companies whose names are given therein, are substantially correct. The United States Aluminum Company is and always has been a hundred per cent. subsidiary of the respondent. The Aluminum Manufactures, Inc. is not engaged in business; all its plants are leased to and operated by the United States Aluminum Company. In regard to the companies referred to whose names are not mentioned, those in which respondent owns one hundred per cent. stock are purely subsidiaries engaged in the holding of real estate or production of power or raw materials necessary and useful for the respondent in the conduct of its business or in the fabrication of the materials manufactured by respondent or in the transportation or sale of said raw materials or finished products. The other unnamed companies referred to in the complaint are engaged in business which has a direct relationship to the business conducted by the respondent and respondent's ownership in the stock thereof is lawful and useful and to a great degree consists of investments made by respondent in corporations engaged in the fabrication of materials manufactured by respondent entered into for the purpose of promoting the aluminum industry in the United States and to some degree represent temporary investments of surplus funds.

It is admitted that the respondent is engaged in interstate commerce.

It is admitted that the supply of aluminum metal in the United States consists of the primary aluminum manufactured by the respondent in the United States, the primary aluminum manufactured by the respondent and others outside of the United States, and scrap of various kinds, both from within and without the United States.

As to the annual production of ingots, sheets and scraps available in the United States, respondent has no precise knowledge. It varies from year to year, and if said facts are material to the present controversy, respondent demands proof of same.

It is not true that as a result of any practices, competitive or otherwise, practically all the secondary aluminum referred to in the said paragraph has been removed from the market by respon-

dent, nor is it true that any purchases of secondary aluminum that the respondent may have made were made either for the purpose or had the effect of creating a monopoly or preventing any of its competitors from securing secondary aluminum, or to make respondent's alleged monopoly of aluminum raw materials more certain or complete.

It is admitted that in the course and conduct of its business the respondent was at all times and now is in competition with other individuals, firms, partnerships and corporations engaged in interstate commerce.

2. In answer to PARAGRAPH TWO of COMPLAINT I, the averments of subparagraph (a) are denied. The averments of subparagraphs (b) are denied. It is particularly denied that if it had been true (which it is not) that any such sales or practices as those referred to in this paragraph either had been in the past or were now in existence, such practices or sales, could, would or do have any effect upon competition or tend in any way to create a monopoly.

3. PARAGRAPH THREE of COMPLAINT I is denied.

---

THIRD. In answer to the averments and allegations contained in COMPLAINT II, respondent avers:

1. The same answer is made to PARAGRAPH ONE of COMPLAINT II as is made to Paragraphs One and Two of Complaint I, and with the same force and effect as though said answers were set forth herein at length.

2. The averments of PARAGRAPH TWO of COMPLAINT II as therein stated are denied; subject, however, to the following explanations:

Respondent admits that it sometimes pays higher prices for certain qualities of scrap aluminum than it costs the respondent to manufacture primary aluminum; in so far as respondent may transfer primary aluminum to subsidiaries at arbitrary prices, said conduct is purely one of bookkeeping and is a customary and convenient way of handling such transactions on the books of a parent company and its subsidiaries.

3. The allegations of PARAGRAPH THREE of COMPLAINT II are denied.

4. The allegations of PARAGRAPH FOUR of COMPLAINT II are denied.

FOURTH. In further answer to the complaint filed in this case, respondent avers that it engaged in the manufacture of aluminum in the year 1888 in accordance with the methods set forth in certain letters patent of the United States, which respondent lawfully acquired and respondent had, during the life of said patents, a lawful monopoly in the manufacture of aluminum by the methods set forth in said letters patent. The process set forth in said letters patent and so used by the respondent is the only method by which aluminum could be manufactured at a cost which made it possible to use the metal commercially. Although the last of the patents used by the respondent expired in the year 1907 the same processes are the methods still in use by the respondent and all other manufacturers of aluminum in the world. At the time when the respondent began the manufacture of aluminum there was no commercial market for aluminum, and it became necessary for the respondent, in the development of its business, to fabricate the metals into shapes in which it could be used and to induce the public to use it as a substitute for other metals. The respondent explicitly avers that since the expiration of said letters patent there has been nothing to prevent any person who so desired from engaging in the manufacture or fabrication of aluminum in the United States, and respondent never has done, neither has it attempted to do, anything which in any way prevented or embarrassed others from engaging in said business, but, on the contrary, has devoted its time to producing aluminum in quantities which the public needed and of the best quality that could be produced, and has encouraged and aided others to embark in the fabrication and use of articles in which aluminum is the sole or a constituent part. It has been its policy to give to consumers of aluminum the lowest possible prices, and respondent avers and charges that whatever complaints have been made as to respondent's prices and methods are largely, if not wholly, confined to complaints of middlemen who naturally have found their profits more or less interfered with by said policy of respondent.

WHEREFORE respondent prays that the complaint be dismissed.

ALUMINUM COMPANY OF AMERICA,
By Gordon, Smith, Buchanan & Scott
Its Attorneys.

UNITED STATES OF AMERICA
BEFORE FEDERAL TRADE COMMISSION

At a regular session of the Federal Trade Commission, held at its office in the City of Washington, D. C. on the 7th day of April, A. D., 1930

COMMISSIONERS:

Garland S. Ferguson, Jr., Chairman
C. W. Hunt,
William E. Humphrey,
Charles H. March,
Edgar A. McCulloch.

IN THE MATTER OF

Aluminum Company of America, a corporation.

DOCKET NO. 1335

ORDER OF DISMISSAL

The above-entitled proceeding coming on for consideration by the Commission upon the complaint of the Commission, the answer of respondent, the record, briefs and oral argument of counsel for the Commission and for the respondent, and the Commission having duly considered same and being fully advised in the premises,

IT IS ORDERED that the complaint herein be and the same hereby is dismissed for the reason that the charges of the complaint are not sustained by the testimony and evidence.

By the Commission.

Otis B. Johnson
Secretary

(SEAL)

SOURCES OF DATA OF TABLE 58 *

*United States* —1883–1903, *Mineral Resources;* 1904–1909, *Mineral Industry;* 1910–1912, given by A. W. Mellon, *Senate Judiciary Committee, Hearings on Aluminum Company of America,* p. 410; 1913–1919, given by Aluminum Company, *Hearings of Senate Committee investigating the Bureau of Internal Revenue,* Exhibit H; 1920–1924 given by Aluminum Company, *Federal Trade Commission,* Docket 1335; 1925–1931, given by Aluminum Company, Baush v. Aluminum Company, appellant, Exhibit 126; 1932–1935, *American Bureau of Metal Statistics.*

*Canada* — Canadian production is included in the figures for the United States until 1909. The figures for 1909–1913 represent Canadian exports; for 1914–1919, estimates of the *Mineral Industry.* These figures are probably overestimates, for this yearbook overestimated output in the United States in these years. For 1920–1924 and 1933–1935, *American Bureau of Metal Statistics.* For 1925–1932, estimates from a private source.

*Europe* — There seem to be no reliable government statistics of aluminum production except in Italy. Statistics have been given in government publications in England, France, and Norway, but there is reason to believe that they have often been incorrect. After some consideration of the statistics published by private institutions it was decided to use those of the *Metallgesellschaft* for all the countries of Europe. Until 1920 the production of Germany, Switzerland, and Austria appeared as one figure. Estimates of the output of Germany, 1916–1919, were taken from German press reports. The figures for Swiss output in these four years were corrected by subtracting the estimates of German production. Until 1920 the figures for Switzerland include the small production of Austria. Estimates of European output in 1935 are taken from the *American Bureau of Metal Statistics,* which reports the estimates of the *Metallgesellschaft* for Germany, Great Britain, Switzerland, and Austria.

* Pages 570–571.

# APPENDIX F

## TABLE 38

ESTIMATED WORLD PRODUCTION OF PRIMARY ALUMINUM BY COUNTRIES, 1890–1935 *

(*Thousands of Metric Tons*)

| Year | United States | Canada | Total America | Total Europe | France | Germany | Switzerland | Austria | Great Britain | Norway | Italy | Russia | Other Countries | Total World |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1890 ..... | 0.03 | | 0.03 | 0.15 | 0.04 | | 0.04 | | 0.07 | | | | | 0.18 |
| 1891 ..... | 0.07 | | 0.07 | 0.26 | 0.04 | | 0.17 | | 0.05 | | | | | 0.33 |
| 1892 ..... | 0.12 | | 0.12 | 0.35 | 0.07 | | 0.24 | | 0.04 | | | | | 0.47 |
| 1893 ..... | 0.15 | | 0.15 | 0.58 | 0.14 | | 0.44 | | | | | | | 0.73 |
| 1894 ..... | 0.25 | | 0.25 | 0.87 | 0.27 | | 0.6 | | | | | | | 1.12 |
| 1895 ..... | 0.42 | | 0.42 | 1.0 | 0.36 | | 0.65 | | | | | | | 1.42 |
| 1896 ..... | 0.59 | | 0.59 | 1.2 | 0.37 | | 0.7 | | 0.13 | | | | | 1.79 |
| 1897 ..... | 2.0 | | 2.0 | 1.58 | 0.47 | | 0.8 | | 0.31 | | | | | 3.58 |
| 1898 ..... | 2.4 | | 2.4 | 1.68 | 0.57 | | 0.8 | | 0.31 | | | | | 4.08 |
| 1899 ..... | 2.9 | | 2.9 | 3.15 | 1.0 | | 1.6 | | 0.55 | | | | | 6.05 |
| 1900 ..... | 3.2 | | 3.2 | 4.1 | 1.0 | | 2.5 | | 0.6 | | | | | 7.3 |
| 1901 ..... | 3.2 | | 3.2 | 4.3 | 1.2 | | 2.5 | | 0.6 | | | | | 7.5 |
| 1902 ..... | 3.3 | | 3.3 | 4.5 | 1.4 | | 2.5 | | 0.6 | | | | | 7.8 |
| 1903 ..... | 3.4 | | 3.4 | 4.8 | 1.6 | | 2.5 | | 0.7 | | | | | 8.2 |
| 1904 ..... | 3.5 | | 3.5 | 5.4 | 1.7 | | 3.0 | | 0.7 | | | | | 8.9 |
| 1905 ..... | 5.1 | | 5.1 | 7.0 | 3.0 | | 3.0 | | 1.0 | | | | | 12.1 |
| 1906 ..... | 6.5 | | 6.5 | 8.5 | 4.0 | | 3.5 | | 1.0 | | | | | 15.0 |
| 1907 ..... | 11.8 | | 11.8 | 11.8 | 6.0 | | 4.0 | | 1.8 | | | | | 23.6 |
| 1908 ..... | 5.9 | | 5.9 | 12.6 | 6.0 | | 4.0 | | 2.0 | | 0.6 | | | 18.5 |
| 1909 ..... | 6.8 | 2.8 | 9.6 | 15.2 | 6.0 | | 5.0 | | 2.8 | 0.6 | 0.8 | | | 24.8 |
| 1910 ..... | 15.4 | 3.5 | 18.9 | 24.2 | 9.5 | | 8.0 | | 5.0 | 0.9 | 0.8 | | | 43.1 |

TABLE 38 — *Continued*

| Year | United States | Canada | Total America | Total Europe | France | Germany | Switzerland | Austria | Great Britain | Norway | Italy | Russia | Other Countries | Total World |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1911 ..... | 16.8 | 2.3 | 19.1 | 24.7 | 10.0 | | 8.0 | | 5.0 | 0.9 | 0.8 | | | 43.8 |
| 1912 ..... | 18.1 | 8.3 | 26.4 | 34.8 | 13.0 | | 12.0 | | 7.5 | 1.5 | 0.8 | | | 61.2 |
| 1913 ..... | 21.5 | 5.9 | 27.4 | 36.4 | 14.5 | | 12.0 | | 7.6 | 1.5 | 0.8 | | | 63.8 |
| 1914 ..... | 26.3 | 6.8 | 33.1 | 35.9 | 10.0 | | 15.0 | | 7.5 | 2.5 | 0.9 | | | 69.0 |
| 1915 ..... | 41.1 | 8.5 | 49.6 | 28.3 | 6.0 | | 12.0 | | 7.1 | 2.3 | 0.9 | | | 77.9 |
| 1916 ..... | 52.2 | 8.5 | 60.7 | 43.5 | 9.6 | 5.0 | 15.8 | | 7.7 | 4.3 | 1.1 | | | 104.2 |
| 1917 ..... | 58.9 | 11.8 | 70.7 | 53.5 | 11.1 | 10.3 | 15.7 | | 7.1 | 7.6 | 1.7 | | | 124.2 |
| 1918 ..... | 56.6 | 15.0 | 71.6 | 62.9 | 12.0 | 14.1 | 19.9 | | 8.3 | 6.9 | 1.7 | | | 134.5 |
| 1919 ..... | 58.3 | 15.0 | 73.3 | 59.4 | 15.0 | 11.2 | 20.3 | | 8.1 | 3.1 | 1.7 | | | 132.7 |
| 1920 ..... | 62.9 | 12.0 | 74.9 | 53.1 | 12.3 | 12.0 | 12.0 | 2.0 | 8.0 | 5.6 | 1.2 | | | 128.0 |
| 1921 ..... | 24.7 | 8.0 | 32.7 | 43.1 | 8.4 | 11.0 | 12.0 | 2.0 | 5.0 | 4.0 | 0.7 | | | 75.8 |
| 1922 ..... | 33.4 | 10.0 | 43.4 | 49.2 | 7.5 | 16.0 | 13.0 | 2.0 | 5.0 | 4.9 | 0.8 | | | 92.6 |
| 1923 ..... | 58.4 | 10.0 | 68.4 | 70.6 | 14.3 | 17.0 | 15.0 | 1.5 | 8.0 | 13.3 | 1.5 | | | 139.0 |
| 1924 ..... | 68.3 | 12.5 | 80.8 | 88.8 | 18.5 | 20.0 | 19.0 | 2.2 | 7.0 | 20.0 | 2.1 | | | 169.6 |
| 1925 ..... | 63.5 | 15.0 | 78.5 | 104.1 | 20.0 | 27.2 | 21.0 | 3.0 | 9.7 | 21.3 | 1.9 | | | 182.6 |
| 1926 ..... | 66.9 | 18.0 | 84.9 | 112.2 | 24.0 | 30.6 | 21.0 | 3.0 | 7.3 | 24.4 | 1.9 | | | 197.1 |
| 1927 ..... | 74.2 | 36.0 | 110.2 | 108.6 | 25.0 | 28.4 | 20.0 | 4.0 | 7.9 | 20.8 | 2.5 | | | 218.8 |
| 1928 ..... | 95.5 | 36.0 | 131.5 | 120.7 | 27.0 | 31.7 | 19.9 | 4.0 | 10.7 | 22.8 | 3.6 | | 1.0 | 252.2 |
| 1929 ..... | 103.4 | 31.0 | 134.4 | 132.7 | 29.0 | 32.7 | 20.7 | 4.0 | 13.9 | 24.4 | 7.0 | | 1.0 | 267.1 |
| 1930 ..... | 103.9 | 34.0 | 137.9 | 128.2 | 26.0 | 30.2 | 20.5 | 3.5 | 14.0 | 24.7 | 8.0 | | 1.3 | 266.1 |
| 1931 ..... | 80.5 | 31.0 | 111.5 | 107.5 | 18.0 | 26.9 | 11.4 | 3.3 | 14.2 | 21.4 | 11.1 | | 1.2 | 219.0 |
| 1932 ..... | 47.6 | 18.0 | 65.6 | 88.3 | 15.0 | 19.0 | 8.5 | 2.1 | 10.3 | 17.8 | 13.4 | 1.0 | 1.2 | 153.9 |
| 1933 ..... | 38.6 | 16.2 | 54.8 | 86.3 | 14.3 | 18.3 | 7.5 | 2.0 | 11.0 | 15.5 | 12.1 | 4.4 | 1.2 | 141.1 |
| 1934 ..... | 33.6 | 15.5 | 49.1 | 119.6 | 16.0 | 37.2 | 8.1 | 2.1 | 12.5 | 15.5 | 12.4 | 14.4 | 1.4 | 168.7 |
| 1935 ..... | 54.1 | 20.6 | 74.7 | 178.9 | 21.8 | 70.7 | 11.7 | 2.1 | 15.1 | 16.0 | 14.0 | 24.5 | 7.0 † | 257.6 † |

* For sources of data, see p. 569.

† Includes 4,000 tons produced in Japan. No information is available concerning output in Hungary.

## TABLE 39

ESTIMATED PRODUCTION AND FOREIGN TRADE IN ALUMINUM OF THE UNITED STATES, 1900–1935 *

(*Metric Tons*)

| Year | Production of Primary Aluminum Ingot | Production of Secondary Aluminum Ingot | Total Production of Aluminum Ingot | Imports of Aluminum Ingot | Exports of Aluminum Ingot | Exports of Fabricated Aluminum |
|---|---|---|---|---|---|---|
| 1900 ..... | 3,240 | | | 116 | | |
| 1901 ..... | 3,240 | | | 256 | | |
| 1902 ..... | 3,310 | | | 338 | | |
| 1903 ..... | 3,400 | | | 226 | | |
| 1904 ..... | 3,490 | | | 234 | | |
| 1905 ..... | 5,150 | | | 241 | | |
| 1906 ..... | 6,510 | | | 350 | | |
| 1907 ..... | 11,790 | | | 396 | | |
| 1908 ..... | 5,900 | | | 211 | | |
| 1909 ..... | 6,800 | | | 2,318 | | |
| 1910 ..... | 15,420 | | | 5,566 | | |
| 1911 ..... | 16,780 | | | 1,893 † | | |
| 1912 ..... | 18,140 | | | 10,324 | | |
| 1913 ..... | 21,450 | | | 10,517 | | |
| 1914 ..... | 26,300 | 4,110 | 30,410 | 7,367 | | |
| 1915 ..... | 41,050 | 7,730 | 48,780 | 3,871 | | |
| 1916 ..... | 52,210 | 17,550 | 69,760 | 3,015 | | |
| 1917 ..... | 58,890 | 14,640 | 73,530 | 27 | | |
| 1918 ..... | 56,580 | 13,680 | 70,260 | 766 | 9,141 | 1,806 ‡ |
| 1919 ..... | 58,270 | 17,000 | 75,270 | 8,003 | 2,022 | 255 ‡ |
| 1920 ..... | 62,890 | 14,090 | 76,980 | 18,178 | 3,348 | 919 ‡ |
| 1921 ..... | 24,740 | 8,090 | 32,830 | 13,870 | 477 | 519 ‡ |
| 1922 ..... | 33,400 | 14,820 | 48,220 | 18,122 | 698 | 3,342 § |
| 1923 ..... | 58,360 | 19,360 | 77,720 | 19,534 | 531 | 4,433 § |
| 1924 ..... | 68,280 | 24,550 | 92,830 | 13,333 | 1,523 | 4,432 § |
| 1925 ..... | 63,550 | 40,000 | 103,550 | 19,690 | 3,688 | 4,978 § |
| 1926 ..... | 66,850 | 40,180 | 107,030 | 33,965 | 266 | 4,156 |
| 1927 ..... | 74,200 | 42,000 | 116,200 | 32,744 | 1,599 | 5,682 |
| 1928 ..... | 95,500 | 43,450 | 138,950 | 17,189 | 1,084 | 6,505 |
| 1929 ..... | 103,400 | 44,000 | 147,400 | 21,961 | 278 | 8,566 |
| 1930 ..... | 103,900 | 35,090 | 138,990 | 11,112 | 276 | 8,431 |
| 1931 ..... | 80,530 | 27,550 | 108,080 | 6,261 | 688 | 2,033 |
| 1932 ..... | 47,600 | 21,820 | 69,420 | 3,631 | 1,771 | 622 |
| 1933 ..... | 38,600 | 30,460 | 69,060 | 7,580 | 2,501 | 294 |
| 1934 ..... | 33,646 | 42,180 | 75,826 | 8,333 | 3,653 | 375 |
| 1935 ..... | 54,113 | 46,730 | 100,843 | 9,560 | 1,525 | |

* Sources of statistics of production of primary aluminum are given in the note to Table 38. Estimates of the recovery of secondary aluminum have been published in *Mineral Resources* (now *Minerals Yearbook*) since 1914. The figures underestimate the actual recovery because some firms do not report. It is believed that coverage has become increasingly broader in the last decade. Import statistics are general imports of aluminum in crude form and alloys, including scrap, for calendar years. (Figures for calendar years during the period 1900–1917 are given in the *Mineral Industry*.) The figures for 1934 and 1935 are imports for consumption. Before 1918 exports were reported by value only. The total quantity of fabricated aluminum exported was reported only for the four years 1922–1925. The classes covered in other years are indicated in the footnotes. The figures do not include small amounts of foreign metal exported from the United States. Imports of fabricated aluminum have rarely exceeded 500 tons.

† July–December only.

‡ Plates, sheet, bar, etc. Does not include tubes, castings, utensils, and other manufactures.

§ Total exports of semifinished and manufactured aluminum products.

|| Plates, sheet, bar, etc. and tubes, molding, and castings. Does not include utensils and other manufactures.

# BIBLIOGRAPHY

# BIBLIOGRAPHY

THIS bibliography includes literature on the aluminum industry and a few books and articles on economic theory or its application. The larger part of it consists of those sources of information about the aluminum industry which have been useful for this study. The best known government publications, such as annual statistical abstracts and statistics of foreign trade, have been omitted. Only a small part of the vast literature on the technology of the industry has been included. No attempt has been made to present an exhaustive list of books, articles, and government publications treating the industrial history and economics of this industry. I believe, however, that I have discovered most of the substantial works of this sort in English and German. Owing to the inadequate indexing of French economic and business literature, which is particularly manifest in the lack of an index of periodical material, I may have failed to discover some sources which would have been helpful. The paucity of cross references in French articles and books suggests, however, that the number of works of this sort in French is quite limited.

The short list of books and articles on economic theory or its application is included with a twofold purpose. It will afford the economist familiar with this literature an indication of some of the principal influences which have led me to the particular formulation of the problems and the type of analysis appearing in this book. It may also serve as a useful reference list for any lay reader whose interest may be attracted because of or in spite of inability to understand those portions of this book where the technical apparatus of economic theory is most obtrusive.

## I. THE ALUMINUM INDUSTRY

### BOOKS AND ARTICLES

#### *Technology*

Allmand, A. J., *The Principles of Applied Electrochemistry* (New York, 1912).

Allmand, A. J., and Ellingham, H. J. T., *The Principles of Applied Electrochemistry* (revised and enlarged ed.; New York, 1924).

"Aluminum Alloy Progress," *Iron Age,* CXXVI, 1455 (1930).
Aluminum Company of America, *Strong Aluminum Alloys* (Pittsburgh, 1928).
Anderson, R. J., *The Metallurgy of Aluminium and Aluminium Alloys* (New York, 1925).
——, *Secondary Aluminum* (Cleveland, 1931).
Ashcroft, E. A., *A Study of Electrothermal and Electrolytic Industries* (New York, 1909).
Barrows, H. K., *Water Power Engineering* (New York. 1927).
Berg, Hans, *Aluminium und Aluminiumlegierungen* (Frankfurt a.M., 1924).
Blount, Bertram, *Practical Electro-Chemistry* (New York, 1903).
Edwards, J. D., Frary, F. C., and Jeffries, Zay, *The Aluminum Industry,* 2 vols. (New York, 1930).
Fox, Cyril S., *Bauxite and Aluminous Laterite* (2nd ed.; London, 1932).
Gregory, R. A., *Discovery, or the Spirit and Service of Science* (London, 1916).
Higgs, Paget, ed., *Magneto- and Dynamo-Electric Machines* (London, 1884).
Howe, H. E., ed., *Chemistry in Industry* (New York, 1924).
Justin, J. D., and Mervine, W. G., *Power Supply Economics* (New York, 1934).
Kershaw, J. B. C., *Electro-Metallurgy* (London, 1908).
Mastick, S. C., "Lectures on Patents," *Industrial and Engineering Chemistry,* VII, 789, 874, 984, 1071 (1915).
Melchior, Paul, *Aluminium — die Leichtmetalle und ihre Legierungen* (Berlin, 1929).
Mellor, J. W., *A Comprehensive Treatise on Inorganic and Theoretical Chemistry,* vol. I (London, 1924), chap. V.
Pannell, E. V., *High Tension Line Practice* (London, 1925).
Perrine, F. A. C., *Conductors for Electrical Distribution* (2nd ed.; New York, 1907).
Pring, J. N., *The Electric Furnace* (London, 1921).
Py, Gaëtan, *Progrès de la métallurgie et leur influence sur l'aéronautique* (Paris, 1928).
Richards, J. W., *Aluminium: Its History, Occurrence, Properties, Metallurgy, and Applications, Including its Alloys* (3rd ed., rev.; Philadelphia, 1896).
——, "Conditions of Progress in Electrochemistry," presidential address, American Electrochemical Society, April 18, 1905.
Rosenhain, Walter, "Some Steps in Metallurgical Progress, 1908–1933," *Engineering,* CXXXVI, 725 (1933).
Schulz, Bruno, *Das Aluminium, seine Herstellung, Eigenschaften und Verwendung* (Berlin, 1926).
Slosson, E. E., *Creative Chemistry* (New York, 1919).
"Twenty Years in the Metal Industries," *Metal Industry,* XXI, 1 (1923).
Whyte, A. G., *The Electrical Industry* (London, 1904).
Wright, J., *Electric Furnaces and their Industrial Application* (new ed.; London, 1910).
Zeerleder, A. von, *Das Aluminium und seine Legierungen* (Zurich, 1927).

*Industrial History and Economics*

"The Aluminum Company of America," *Fortune*, March 1930.
"The Aluminum Company of America," *Fortune*, September 1934.
"Der Aluminiumzoll als Waffe im Internationalen Quotenkampf," *Magasin der Wirtschaft*, V, 1728 (1929); and other articles in this journal in 1929.
Anderson, R. J., "The Aluminum Industry," chap. I in *Representative Industries in the United States* (New York, 1928), ed. by H. T. Warshow.
Bannert, Hans, *Der Rohaluminiumweltmarkt und die deutsche Rohaluminiumindustrie* (Halle, 1927).
Barut, Victor, *L'Industrie de l'électro-chimie et de l'électro-métallurgie en France* (Paris, 1924).
Benni, A. S., and others, *Review of the Economic Aspects of Several International Industrial Agreements* (League of Nations, Industrial and Financial Section, Geneva, 1930).
Buschlinger, Heinrich, "Entwicklung und Aufbau der Aluminiumwirtschaft" (unpublished dissertation, Hamburg, 1924).
Chiati, M. B., *Les Ententes industrielles internationales* (Paris, 1928).
Clark, V. S., *History of Manufactures in the United States*, vols. II, III (New York, 1929).
Collins, H. C., and Loudon, D., "The Aluminum Industry," *Harvard Business Review*, VIII, 1 (1929).
Costa, J. L., *Le Rôle économique des unions internationales de producteurs* (Paris, 1932).
Czimatis, Albrecht, *Rohstoffprobleme der deutschen Aluminiumindustrie im Rahmen ihrer wirtschaftlichen Entwicklung* (Dresden, 1930).
Debar, Rudolph, *Die Aluminiumindustrie* (Braunschweig, 1925).
Dejean, Pierre, *Petite Histoire de la métallurgie dans le Sud-est* (Grenoble, 1929).
Dux, C., *Die Aluminium-Industrie-Aktiengesellschaft Neuhausen und ihre Konkurrenz-Gesellschaften* (Lucerne, 1913).
Ertel, Erich, *Internationale Kartelle und Konzerne der Industrie* (Stuttgart, 1930).
Escard, Jean, *L'Aluminium dans l'industrie* (2nd ed.; Paris, 1925).
Gautschi, Alfred, *Die Aluminiumindustrie* (Zurich, 1925).
Guillet, Léon, *L'Évolution de la métallurgie* (Paris, 1928).
Günther, Georg, *Die deutsche Rohaluminiumindustrie* (Leipzig, 1931).
Kossmann, Wilfried, *Über die wirtschaftliche Entwicklung der Aluminiumindustrie* (Frankfurt a.M., 1911).
Kupczyk, Edwin, "Zur Lage der Aluminiumindustrie," *Wirtschaftsdienst*, XVI, Heft 7, 281 (1931).
Marcus, Alfred, *Grundlagen der modernen Metallwirtschaft* (Berlin, 1928).
Minet, Adolphe, *The Production of Aluminum and its Industrial Use* (1st ed., rev.; New York, 1905), trans. by Leonard Waldo.
Pannell, E. V., "Aluminum: Its Present and Future Status," *Metal Industry*, XXVII, 72 (1929).

"Pittsburgh and the Pittsburgh Spirit." Addresses before Chamber of Commerce of Pittsburgh, 1927–1928.

Rousiers, Paul de, *Les Industries chimiques* (Paris, 1928), vol. V of *Les Grandes Industries modernes.*

Schoenebeck, *Das Aluminiumzollproblem* (Berlin, 1929).

Schulthess, M. von, "Die Entwicklung der Aluminiumindustrie in der Schweiz und ihre Beziehungen zur Wasserkraftnutzung," *Schweizerische Technische Zeitschrift,* Jahrgang 1926, no. 34/35.

Schwarzmann, R., "Die internationale Verflechtung der schweizerischen Aluminiumindustrie," *Weltwirtschaftliches Archiv,* XXXV, 585 (1932).

Sonnenberger, Erna, *Wirtschaftliche Bedeutung der Aluminium Herstellung in Deutschland* (Dissertation, Cologne, 1925).

Spurr, J. E., *Political and Commercial Geology and the World's Mineral Resources* (New York, 1920).

Tiedmann, H., "Die Standortsfrage in der Aluminiumindustrie," *Metallwirtschaft,* XIII, 36 (1934).

PERIODICALS

*Scientific, Trade, and Financial*

United States

*Automotive Industries*
*Boston News Bureau*
*Cassier's Magazine*
*Chemical and Metallurgical Engineering* (before 1902, *Electrochemical Industry*)
*Commercial and Financial Chronicle*
*Engineering and Mining Journal*
*Engineering News*
*Foundry*
*Industrial and Engineering Chemistry*
*Iron Age*
*Journal of the Franklin Institute*
*Manufacturers' Record*
*Metal Industry* (New York; before 1902, *Aluminum World*)
*Mining and Metallurgy*
*Power*
*Wall Street Journal*

Europe

*Aluminium* (Berlin)
*Deutsche Oekonomist* (Berlin)
*Economist* (London)
*Engineering* (London)
*Hauszeitschrift der Vereinigte Aluminiumwerke und der Erftwerk A. G. für Aluminium* (Berlin)
*Journal du four électrique* (Paris)

*Kartellrundschau* (Berlin)
*Magazin der Wirtschaft* (Leipzig)
*Metall und Erz* (Halle)
*Metallwirtschaft* (Berlin)
*Mining Journal* (London)
*Nachrichten des Vereins deutscher Ingenieure* (Berlin)
*Revue de l'aluminium* (Paris)
*Weltwirtschaftliches Archiv* (Jena)
*Wirtschaftsdienst* (Hamburg)

*Miscellaneous*

Aluminiumindustrie A. G., Neuhausen, Switzerland. Annual Reports.
Aluminium Limited, Toronto. Annual Reports.
Aluminum Company of America, Pittsburgh. Annual Reports.
American Bureau of Metal Statistics. Yearbook.
*American Metal Market.* Daily.
*Les Assemblées générales.*
*The British Guiana Handbook.*
Compagnie de Produits Chimiques et Électrométallurgiques, Alais, Froges, et Camargues, Lyon. Annual Reports.
*Handbuch der deutschen Aktiengesellschaften.*
Metallgesellschaft, *Statistische Zusammenstellungen über Aluminium, Blei, Kupfer, Nickel, Quecksilber, Zink und Zinn* (Frankfurt a.M.). Annual.
*Metal Statistics* (New York). Annual.
Minerais et Métaux, Société Anonyme, *Renseignements statistiques concernant les métaux cuivre, plomb, zinc, aluminium, argent, or* (Paris). Annual.
*The Mineral Industry . . . in the United States* (New York). Annual.
*Moody's Manual.*
Poor's Cumulative Index.
Vereinigte Aluminiumwerke A.G., Berlin. Annual Reports.
Vereinigte Industrie-Unternehmungen A.G., Berlin. Annual Reports.
Yearbook of the Bermudas, Bahamas, British Guiana, Etc.

GOVERNMENT DOCUMENTS

Canada

Department of Mines:
*Economic Minerals and Mining Industries of Canada* (Ottawa, 1913).
Dominion Bureau of Statistics:
*Mineral Production of Canada.* Annual Reports.

France

Ministère des Travaux Publics:
*Statistique de l'industrie minérale.* Annual.

Germany

Ausschuss zur Untersuchung der Erzeugungs- und Absatzbedingungen der deutschen Wirtschaft:

*Die Versorgung der deutschen Wirtschaft mit Nicht-Eisen Metallen* (Berlin, 1931).

Preussische Geologische Landesanstalt:

*Weltmontanstatistik* (2 vols., Stuttgart, 1929, 1932).

Great Britain

British Guiana, Combined Court:

*Report on the Condition of the Colony of British Guiana during the Great European War* (Georgetown, Demerara, 1919).

*Report of the Land and Mines Department.* Annual.

Imperial Institute:

*Bauxite and Aluminium* (London, 1925), by W. G. Rumbold.

*Bulletin.* Quarterly.

*The Mineral Industry of the British Empire and Foreign Countries.* Annual.

Switzerland

Statistisches Bureau des eidgenössichen Departments des Innern:

*Betriebszählung vom 9 August 1905.*

*Schweizerische Fabrikstatistik vom 26 September 1923; Schweizerische Statistische Mitteilungen,* VI Jahrgang, 1924, 6 Heft.

*Betriebszählung vom 22 August 1929.*

*Gewerbebetrieben in den Kantonen; Statistische Quellenwerke der Schweiz,* Heft 15, 1929.

United States

Congress

House

Committee on Military Affairs:

Hearings on the Tennessee Valley Authority, 74th Congress, 1st Session.

Committee on Ways and Means:

Tariff Hearings, 60th Congress, 2nd Session; House Document no. 1505, Schedule C., 1908–1909.

Tariff Hearings, 62nd Congress, 3rd Session; House Document no. 1447, vol. II, Schedule C., 1913.

Tariff Hearings, 67th Congress, 2nd Session, Part II, Schedule C., 1921.

*Comparison of Tariff Acts of 1909, 1913, and 1922 (revised to June 1, 1924) prepared for Committee on Ways and Means under the direction of Clayton F. Moore* (Washington, 1924).

Senate

Committee on Finance:

Replies to Tariff Inquiries, 53rd Congress, 2nd Session; Report no. 423, Bulletin no. 13.

Tariff Hearings, 62nd Congress, 2nd Session; Senate Document no. 5, Schedule C., 1921–1922.

Committee on Judiciary:

*Hearings, 69th Congress, 1st Session, pursuant to Senate Resolution 109 directing an inquiry by the Committee on Judiciary as to whether due expedition has been observed by the Department of Justice in prosecuting the inquiry in the matter of the Aluminum Company of America* (1926).

Report of Committee on Judiciary pursuant to Senate Resolution 109, Senate Report no. 177. February 15, 1926.

Select Committee on Investigation of Bureau of Internal Revenue:

Hearings, Part 10, 68th Congress, 2nd Session.

Department of Commerce

Bureau of Foreign and Domestic Commerce:

Commerce Reports.

*Mineral Raw Materials* (Washington, 1929), by J. W. Furness and L. M. Jones. Trade Promotion Series, no. 76.

*Representative International Cartels, Combines and Trusts* (Washington, 1929), by W. F. Notz. Trade Promotion Series, no. 81.

Bureau of Mines:

*Mineral Resources of the United States*, 1882–1931. (Published by the United States Geological Survey until 1925.)

*Minerals Yearbook*, 1932–1936. A continuation of *Mineral Resources.*

Department of the Interior

United States Geological Survey:

Political and Commercial Control of Mineral Resources of the World, no. 19, *Bauxite and Aluminum*, by J. M. Hill.

Department of Justice

*Aluminum Company of America, Report of Special Assistant to the Attorney General, William R. Benham, concerning alleged violations by the Aluminum Company of America of the decree entered against it in the United States District Court of the western district of Pennsylvania on June 7, 1912* (February 22, 1926). Senate Document no. 67, 69th Congress, 1st Session, 1926.

Department of the Treasury

Tariff of 1897 on Imports into the United States to 1899; Document no. 2099.

Federal Trade Commission

Annual Reports.

Docket 248. Federal Trade Commission v. Aluminum Company of America. Complaint, answer, briefs, findings of fact, order to divest stock.

Docket 1335. In the Matter of the Aluminum Company of America. Complaint, answer, briefs, order, record of testimony, exhibits.

*Report of the Federal Trade Commission on House Furnishings In-*

*dustries,* vol. III, *Kitchen Furnishings and Domestic Appliances, October 6, 1924* (Washington, 1925).

National Recovery Administration

Report on the Aluminum Industry, submitted by Leon Henderson, Director of Research and Planning Division (1935).

Tariff Commission

*Digest of Tariff Hearings before the Committee on Finance, United States Senate* (1922)

*Summary of Tariff Information . . . on Tariff Act of 1922,* Schedule 3 (1929).

*Tariff Information Survey, C–16, Aluminum, Magnesium, etc.* (1921).

United States Court Papers

Aluminum Company of America v. Federal Trade Commission. 284 Fed. Rep. 401 (1922).

Petitioner's Brief, Petitioner's Reply Brief.

Re application by Federal Trade Commission for injunction and modification of order. 299 Fed. Rep. 361 (1924).

Brief on Behalf of Aluminum Company of America.

Reply of Aluminum Company of America.

Petitioner's Memorandum of Testimony on Special Points.

Baush Machine Tool Company, appellant v. Aluminum Company of America. 72 Fed. Rep. (2) 236 (1934).

Record of Pleadings, Testimony, Exhibits, Charge, and Exceptions.

Baush Machine Tool Company v. Aluminum Company of America, appellant. 79 Fed. Rep. (2) 217 (1935).

Record of Pleadings, Testimony, Exhibits, Charge, and Exceptions.

Haskell v. Perkins et al. 31 Fed. Rep. (2) 54 (1929).

Record of Pleadings, Testimony, Exhibits, Charge, and Exceptions.

United States v. Aluminum Company of America. United States District Court, western district of Pennsylvania, session of 1912.

Petition and Decree.

War Industries Board

*History of Prices during the War; Prices of Ferroalloys, Nonferrous and Rare Metals* (1919), Price Bulletin no. 34, by H. R. Aldrich and Jacob Schmuckler.

## II. Economic Theory and Method

Beckerath, Herbert von, *Modern Industrial Organization* (New York, 1933).

Chamberlin, E. H., *The Theory of Monopolistic Competition* (Cambridge, 1933).

——, "Duopoly: Value Where Sellers are Few," *Quarterly Journal of Economics,* XLIV, 63 (1929).

Clark, J. M., *Studies in the Economics of Overhead Costs* (Chicago, 1923).

Crum, W. L., *Corporate Earning Power* (Stanford University, 1929).

Epstein, R. C., *Industrial Profits in the United States* (New York, 1934).

Harrod, R. F., "The Law of Decreasing Costs," *Economic Journal*, XLI, 566 (1931).

——, "Doctrines of Imperfect Competition," *Quarterly Journal of Economics*, XLVIII, 442 (1934).

Jewkes, John, "Factors in Industrial Integration," *Quarterly Journal of Economics*, XLIV, 621 (1930).

Lederer, Emil, "Monopole und Konjunktur," *Vierteljahrshefte zur Konjunkturforschung*, 2. Jahrgang (1927), Ergänzungsheft 2.

Pigou, A. C., *The Economics of Welfare* (3rd ed.; London, 1929).

Robertson, D. H., *The Control of Industry* (New York, 1923).

Robinson, Joan, *The Economics of Imperfect Competition* (London, 1933).

——, "What is Perfect Competition?" *Quarterly Journal of Economics*, XLIX, 104 (1934).

Schneider, Erich, *Reine Theorie monopolistischer Wirtschaftsformen* (Tübingen, 1932).

Shove, G. F., "The Representative Firm and Increasing Returns," *Economic Journal*, XL, 94 (1930).

Taussig, F. W., *Principles of Economics* (3rd ed.; New York, 1921).

Tschierschky, Siegfried, *Kartellpolitik* (Berlin, 1930).

Viner, Jacob, "Cost Curves and Supply Curves," *Zeitschrift für Nationalökonomie*, III, 26 (1931).

Wolfers, Arnold, *Das Kartellproblem im Lichte der deutschen Kartell-literatur* (Munich, Leipzig, 1931).

Zeuthen, Frederik, *Problems of Monopoly and Economic Warfare* (London, 1930).

# INDEX

# INDEX