A STUDY OF THE ALUMINUM INDUSTRY
WITH AN INDUSTRIAL ARTS STUDY GUIDE

THESIS

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CHAPTER I

INTRODUCTION

Need for the Study

The Aluminum Industry is the second largest metal industry and one of the fastest growing industries in the United States.[1] In terms of age, it is the youngest of the common metals industries. In less than a hundred years, it has grown from infancy to a giant. It has grown from a metal that chemists and experimentors studied to a metals industry second only to steel. It has grown from a day when Napoleon III used an aluminum fork for dining while his guests used goldware, to a day of throw-away candy wrappers,[2] and from an experimental metal to one with more than 4,000 applications. It has grown from an industry of one producer of primary metal in 1940, to three in 1955, and to eleven primary producers in 1970. This fantastic growth is the direct result of the technological era

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[1]The Aluminum Association, Aluminum Statistical Review; 1967 (New York: The Aluminum Association, 1968), p. 11.

[2]John L. Feirer, General Metals (2nd ed.; New York: McGraw-Hill Book Company, Inc., 1959), p. 322.

of our society. It is difficult to envision our way of life without aluminum.

Industrial arts has the responsibility in education to reveal this industry to the oncoming generation. Gordon O. Wilber has said that one objective of industrial arts is "to explore industry and American industrial civilization in terms of its organization, raw materials, processes and operation, products and occupations".[3] Robert G. Hammond in quoting from the American Vocational Association states that the general educational scope of industrial arts should include ". . . materials, tools and processes of industry; science and inventions applicable to industry; the social and economic contributions of industry; and the human relation patterns fostered by the industry. . .".[4] Delmar W. Olsen has said that the mission of industrial arts is ". . . to enlighten boys and girls and men and women as to the role of industry in, and the influences of the technology on their living and to enable them to live to capacity in an industrial civilization".[5]

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[3]Gordon O. Wilber, Industrial Arts in General Education (2nd ed.; Scranton, Pa.: International Textbook Company, 1954), p. 42.

[4]Rex Miller and Lee H. Smalley, Selected Readings for Industrial Arts (Bloomington, Ill.: McKnight & McKnight Publishing Company, 1963), p. 162.

[5]*Ibid.*, p. 341.

The aluminum industry reflects his statement, "the cultural function for industrial arts has as its major concern the development of understandings and appreciations of American culture as it is and has been influenced by man's mastery of materials".[6] Marshall Schmitt and James Taylor define industrial arts as "a phase of the curriculum in general education; the body of courses organized to develop an understanding of the technical, consumer, occupational, recreational, organizational, social, historical, and cultural aspects of industry and technology".[7]

R. Lee Hornbake points to another phase of general education through industrial arts in his statement: "Brought up to date in a modern setting, many of the keys to understanding the problems among nations, matters of national defense, of community and personal health, of communication, of transportation beside in knowing something about the ways of industry. No one can read effectively the daily newspaper, the weekly news magazine, or an annual stockholder's report without some understanding of productivity, of the origins and applications of inventions, of production techniques. Similarly, the pleasures of everyday life are withheld

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[6]Delmar W. Olson, Industrial Arts and Technology (Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1963), p. 181.

[7]U.S. Department of Health, Education and Welfare, Planning and Designing Functional Facilities for Industrial Arts Education, by Marshall Schmitt and James L. Taylor (Washington, D.C.: Government Printing Office, 1968), OE-51015, p. 2.

from those who do not appreciate the finest of man's ceramics, silverware, furniture, graphic arts, as well as the precision products of a modern industry".[8] Thus, industrial arts does contribute to the numerous facets of general education in many ways.

The one term that most closely describes the current period of human history is "an accelerated changing world". "New" is the key word for this changing world. In attempting to label this change, we are using such phrases as: a technological society, super-industrial culture, industrial society, industrial orientated, new age, and space-age technology. Never before has man experienced such an accelerated change in his way of life. This change is reflected in all segments of our way of life. Educational and professional literature is filled with articles on new approaches in teaching all disciplines. For many years, industrial arts has professed to include those phases of general education which deal with technology--its evolution, utilization and significance with industry--its organization, materials, occupations, processes and products, and with the problems and benefits resulting from the technological and industrial nature of

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[8] U.S. Department of Health, Education and Welfare, Improving Industrial Arts Teaching: A Call to the Profession, by Marshall L. Schmitt, (Washington, D.C.: Government Printing Office, 1960), Conference Report, O.E. 33022, Circular No. 656, p. 7.

society.[9]

If one were to analyze the subject matter and programs of industrial arts education in the United States, the results would probably indicate a curricular content of the basic traditional woods, metals, drawing, etc. Emphasis is on the project method with little time devoted to in-depth study of the industry.[10]

The current Texas Education Agency Bulletin 615[11] lists the curriculum for industrial arts and it is project oriented. Further, the problems stemming from obsolete subject matter, growth of technology and an increase in the percentage of people in industrial occupations, and the growing number of industrial products requiring consumer evaluation have contributed to an outdated curriculum which is not meeting the needs of students in the state.[12] In assuming its responsibility in education, the Texas Industrial Arts Association

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[9]Donald Maley, "How Industrial Arts Relates to Occupational Education," Industrial Arts and Vocational Education, February, 1970, p. 16.

[10]Edward Kabakjian, "Change; The Unchangeable Law of Progress," Man/Society/Technology, April, 1971, p. 206.

[11]Texas Education Agency, Principles and Standards for Accrediting Elementary and Secondary Schools and Description of Approved Courses, Grades 7-12, (Austin, Tex.: Texas Education Agency). Bulletin 615, pp. 140-168.

[12]John R. Ballard and M. D. Williamson, "Texas Industrial Arts Curriculum Study, Six-Phase Interdisciplinary Study," (A study prepared for the Texas Industrial Arts Association, 1971), p. 1.

has presented a Six-Phase Interdisciplinary Study to update the industrial arts curriculum.[13] An updated curriculum in industrial arts would include those statements of objectives as proposed by many current leaders in the industrial arts area. Most of these people propose objectives that include those stated by Wesley L. Face and Eugene R. Flug: (a) the study of tools, materials, processes, and occupations of industry; (b) the study of life needs created by technological advance; (c) the study of the applications of mathematics and sciences to the solution of technical problems (problem solving) and (d) the study of industry.[14]

The metals industry is a basic industry in our society and as such it deserves to be placed in the curriculum of industrial arts study. Further, the aluminum industry is the second largest metals industry in the United States and many aluminum products directly relate to our industrial-technological society; therefore, it should have a place in the modern industrial arts curriculum.

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[13]Ballard and Williamson, Curriculum Study. p. 1.

[14]Wesley L. Face and Eugene R. Flug, "A Conceptual Approach to the Study of American Industry," Approaches and Procedures. Fourteenth Yearbook of the American Council on Industrial Arts Teacher Education. (Bloomington, Ill.: McKnight & McKnight Publishing Company, 1965), p. 118.

Statement of the Problem

Most industrial arts curriculum, as now exist, is based on the project concept--an analysis of job activities and tools which is centered around the woods, metals or drawing industries rather than around the broad industrial spectrum as outlined by our state and national professional leaders.[15,16] Most industrial arts teachers agree with the professional leaders that a change is needed but there are two major problems they should face. The first problem is determining the source of current, up-to-date information for teaching the modern curriculum in industrial technology as no textbooks contain this information. The second problem is allocating the time for developing a teaching unit which is applicable to todays' industrial arts concept.[17,18] This study will provide much of the current,

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[15]Face and Flug, "Conceptual Approach," p. 60.

[16]Donald Maley, "Industrial Arts--A Study of Industry and Technology of Contemporary Man," Industrial Arts and Technology--Past, Present, and Future, AIAA Convention Proceedings, (Washington, D.C.: American Industrial Arts Association, Inc., 1967), pp. 5-6.

[17]U.S. Department of Health, Education and Welfare, Industrial Arts Education: A Survey of Program, Teachers and Curriculum, by Marshall Schmitt and Albert L. Pelley, O.E. 33038, Circular No. 791 (Washington, D.C.: Government Printing Office, 1965), pp. 28-29.

[18]Robert L. Woodward, "High School Industrial Arts Teachers' Problems," Industrial Arts and Vocational Education, September, 1967, p. 30.

up-to-date information and a possible teaching unit on the aluminum industry that a teacher can adapt to his local needs to help up-date his metals class into a study of the metals industry.

Sources of Data

The bibliographical approach was the primary method used in developing this study. Sources used were of both primary and secondary nature. Pamphlets and publications published by The Aluminum Association, The Aluminum Industry, and the United States Department of Commerce, Bureau of Domestic Commerce were augmented by books and periodicals of the college library.

Telephone calls and letters of inquiry were used to help collect information and to clarify some items of information. Interviews with industrial arts teachers were beneficial in collecting some information.

Limitation of the Study

This study is limited to supplying current, up-to-date information about the aluminum industry in the United States for use in an industrial arts teaching unit as part of the study of the metals industry. An in-depth technical study would be lengthy and of little use to an industrial arts teacher. This study has been limited to the aluminum industry in the United States and world production is shown only for comparison. Also, the study is limited to the production and supply of aluminum and aluminum mill products.

Scope of the Study

This study will include the major points in the history and the development of the aluminum industry in the United States from the experimental stage through 1970. The history shows how the industry has grown in terms of companies producing aluminum, production capacities and products produced. The technical processes involved in aluminum production are discussed in major terms but with sufficient details for an understanding of the processes involved. The competitive aspects of the industry are limited in nature because there was no competition within the industry for so long a period and information is not available.

Definitions

Company--incorporated or not is a firm, concern or business, a financial entity to make money. A manufacturing company must have at least one plant.[19]

Establishment--a single factory, mill or plant. A physical entity which produces some tangible goods or useful service.[20]

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[19] E. B. Alderfer and H. E. Michl, Economics of American Industry (3rd ed.; New York: McGraw-Hill Book Company, Inc., 1959), p. 12.

[20] Ibid.

Industry--a homogeneous group of enterprises or companies.[21] An institution in our culture which, through the application of knowledge and utilization of men, money, machines, and materials, produces goods or services to meet the needs of man.[22]

Mill--a building or collection of buildings with machinery by which the processes of manufacturing are carried on; can produce more than one item.[23]

Plant--factory or shop for producing a particular product. The size may vary.[24]

Industrial Arts--those phases of general education which deal with industry--its organization, materials, occupations, processes and products--and with the problems resulting from the industrial and technological nature of society.[25] Industrial arts as a curriculum area is defined as those phases of general education which deal with technology--its evolution, utilization, and significance with industry--

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[21]Alderfer and Michl, American Industry, p. 3.

[22]Face and Flug, "Conceptual Approach," p. 117.

[23]Alderfer and Michl, American Industry, p. 8.

[24]Ibid.

[25]Gordon O. Wilber and Norman C. Pendered, Industrial Arts in General Education (3rd ed. Scranton, Pa.: International Textbook Company, 1967) p. 2.

its organization, materials, occupations, processes and products, and with the problems resulting from industrial and technological nature of society.[26] Industrial arts--an activity-oriented curriculum area in general education. It is concerned with developing concepts of function, organization and management, and socioeconomic influences of industry.[27] Industrial arts--as (a) the study of life needs created by technological advance; (b) the study of tools, materials, processes, and occupations of industry; (c) the study of the applications of mathematics and the sciences to the solution of technical problems and (d) the study of industry.[28]

Place and Structure of the Industry

The metals industry is recognized as a major industry in our society and; therefore, deserves to be included in the curriculum for industrial arts. The aluminum industry should be studied because it is the second largest metals industry, by tonnage produced, in the United States.[29] To further define the place and

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[26]Maley, "Industrial Arts Relates to Vocational Education." p. 30.

[27]A. Bruce Hartung, "We've Crossed our Rubicon," The Journal of Industrial Arts Education, (March-April, 1970), p. 11.

[28]Face and Flug, "Conceptual Approach," p. 115.

[29]Alderfer and Michl, American Industry, p. 107.

structure of the aluminum industry in our economic order, Alderfer and Michl have suggested several ways and measures that may be used.[30] (As with any measure, care must be used to insure correct comparison. Measurements used in one type industry may not be valid when used in a different industry or situation.)

One measure suggested is "value of products shipped" and may be used in a limited way.[31] A second and better test of importance suggested is "number of workers" but it has limitations because it shows only one view of our complex structure.[32] Suggested as a better way but not perfect single measure of the importance to the economy by a manufacturing industry is "value added".[33] This one measurement may achieve more importance in our economy in the future in terms of taxation. Some countries are currently taxing "value added" in production of goods for sources of revenue. Table 1, page 13, gives the figures for these three measures for the years 1967 through 1971.[34]

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[30] Alderfer and Michl, American Industry, p. 8.

[31] Ibid., p. 4.

[32] Ibid.

[33] Ibid.

[34] U.S. Department of Commerce, Business and Defense Services Administration, U.S. Industrial Outlook, 1971, (Washington, D.C.: Government Printing Office, 1972), p. 186.

TABLE 1

Aluminum Industry: Trends 1967-1971
(in millions of dollars except as noted)

	1967	1968	1969	1970	1971[a]	Per Cent Increase 1970-1971
Value of shipments[ab]	4,300	4,800	5,400	5,200	5,300	2
Total employment (000)[a]	185	192	204	192	180	-6
Value added (SIC 3334, 3352, 3361)[b]	2,267	2,463	2,592	n.a.	n.a.	n.a.
Value added per production worker man-hour ($).....	10.39	10.91	10.89	n.a.	n.a.	n.a.

a. Estimated by BDC (Bureau of Domestic Commerce).

b. Represents shipments to consuming industries and exports: includes shipments of aluminum products made by all industries as well as imports.

c. Total for three SIC industries only; not comparable with value of shipments estimated in the first line of the table.

Source: U.S. Department of Commerce, Business and Defense Services Administration, U.S. Industrial Outlook--1972 (Washington, D.C., Government Printing Office, 1972) p. 186.

A more technical and detailed breakdown on total numbers of employees, production workers, manhours, wages, value added, cost of materials, value of shipment and ratios of these are available in the book, Profile of an Industry.[35, 36] Several additional ways that Alderfer and Michl suggest for comparing industries are: (1) cost of labor, (2) cost of material and (3) size of establishment.[37] In examining these factors, individually, the cost of labor will vary throughout the different types of aluminum industry. Two examples shown place the production of primary aluminum in the "medium labor" bracket. The aircraft industry is a part of the transportation industry, a part of the "direct and indirect demand" part of the aluminum industry, and also a part of the "consumer products" as shown in Figure 6, page 68. It is a high labor cost industry. The classification of such a large industry is difficult; however, different aspects of it are more easily compared. The cost of materials is in the "low raw materials cost" while the primary aluminum industry is in the "medium raw materials" category. Their table for "average

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[35]Metals Week, Aluminum--Profile of an Industry (New York: Metals Week. 1971), pp. 165, 167, 169 and 172.

[36]U.S. Department of Commerce, Industrial Outlook. pp. 15, 23.

[37]Alderfer and Michl, American Industry, p. 5.

number of workers per establishment" places both industries in the "large-scale industries" bracket. See Table 1, page 13 for the total number of workers in the industry.

Alderfer and Michl suggest that the product be examined for place in the economic order in relationship to the demand for the product.[38] They state that, generally, products of manufacturing industries fall into one of two categories; producers goods or consumers goods.[39] Primary aluminum is a producers goods. It is sold basically to other establishments to make consumer products. However, an aluminum extrusion would be classified as a producers goods or a capital goods to be sold to make a building or an aircraft, which are consumers goods.

Further, the consumers goods may be classified according to their durability as defined by the National Bureau of Economic Research. "Durable" goods are those that will last three years or more, "semi-durable" goods are those that last for six months to three years and items lasting less than six months are classified as "perishable".[40] Most aluminum goods would be classified as

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[38]Alderfer and Michl, American Industry, p. 5.

[39]Ibid.

[40]Ibid.

"durable"; however, because of their nature and use, they could be classified as "semi-durable" or as "perishable". Foils and some containers could be in these two classifications.[41] Demand for a product can be further classified from the affect that a change in the price has on the sale of the product. A product in which the change in price has very little affect on its demand is classified as "inelastic" while one in which the demand will change as related to a change in price is "elastic".[42] Generally, most aluminum products would be within the "elastic" classification. The demand for a product of goods may also be classified as direct or derived. A goods or item used directly as it is made is a direct demand item. Aluminum cable, used for power transmission or aluminum siding would be examples of direct demand. An extrusion that is bought to make a screen door is an example of indirect demand.[43]

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[41] Alderfer and Michl, American Industry, p. 7.

[42] Ibid.

[43] Ibid.

CHAPTER II

THE HISTORY OF THE ALUMINUM INDUSTRY

Donald Maley has said that part of industrial arts curriculum should include the history of the industry.[1] This chapter concerning the history of the aluminum industry will include the early experimental period, the discovery of a practical refining process, the development of the modern aluminum industry by ALCOA, and the period of accelerated expansion in the industry.

Alderfer and Michl develop the theory that there are definite growth period patterns in industries.[2] Figure 1, page 18, illustrates these periods graphically.[3] According to their curve, the years prior to 1888 were the period of experimentation for the aluminum industry and the period of rapid progress would include the years from 1888 to possibly 1970. Figure 2, page 34, shows there have

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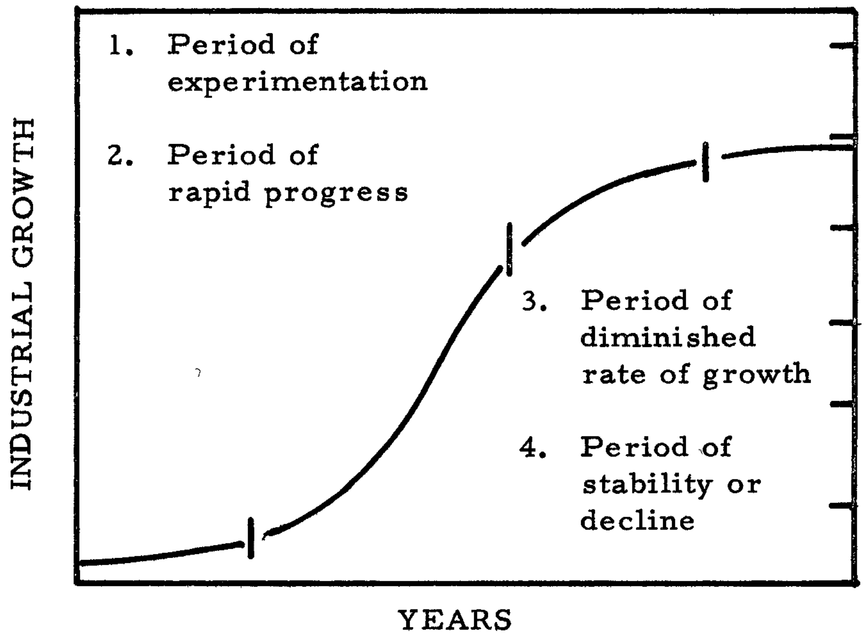
[1]Maley, "Industrial Arts Relates to Vocational Education." p. 30.

[2]Alderfer and Michl, American Industry, p. 13.

[3]*Ibid.*, p. 14.

FIGURE 1

CURVE OF INDUSTRIAL GROWTH



SOURCE: Alderfer and Michl, American Industry, p. 14.

been some downturns in aluminum production but it has always recovered and pushed upward. Only the future will tell if the industry has reached the third period on the curve, the period of diminished rate of growth, or if it is still in the period of rapid progress.

The history of aluminum can be divided into three distinct periods. The first may be named the experimental period for it was the time that man searched for a way to isolate and produce the bright and shining metal that was more expensive than gold, selling for $545.00 in 1852.[4] The second period is the development of the aluminum industry. This period is basically the history of the Aluminum Company of America. The third period is the one of accelerated expansion due to advanced technology and wide use of aluminum in many applications.

The Early Experimental Period

Craftsmen started forming metals very early in history. Probably early man observed that metals ran out of the rocks from around his fires and he found he could form these metals by hammering them when they were hot. The art of hardening steel was well developed in Greece over 3,000 years ago. In fact, Homer wrote about it some

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[4]Aluminum Company of America, Facts About Alcoa (Pittsburgh: Aluminum Company of America, 1968). p. 11.

time between 1100 and 600 B.C.[5] Copper and bronze pieces were found in the tombs of Egypt. Silver and gold have been worked by man since his earliest records. All of these metals have one thing in common, they all occur in the metallic state in nature.

A striking contrast with these ancient metals is aluminum. It is the most abundant metal and, in fact, the third most abundant element on the earth's surface, exceeded in amount only by oxygen and silicon. It has been estimated that the outer ten miles of the earth's crust contains about 8 per cent aluminum by weight or about 15 per cent aluminum oxide (alumina). Compounds of aluminum are found in a greater or lesser extent in rocks, vegetation and animals.

Aluminum is unlike most other metals in that it is never found in nature in the metallic form. In fact, one might say it is a man-made metal. Aluminum is always tightly locked up with other elements in compounds that hold tenaciously onto it. The surprising contrast between the ancient metals and aluminum is that aluminum was not introduced to the public until the Paris Exposition in 1855 and did not come into general commercial use until 1891--only 81 years ago.

Sir Humphry Davy first attempted to produce pure aluminum

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[5]Alfred Cowles, The True Story of Aluminum (Chicago: Henry Regnery Company, 1958), p. 2.

by electricity in London in 1807. His attempt to produce pure aluminum failed although he did produce an alloy of aluminum with iron in 1809. Alexander Volta had produced the first battery in 1800 which made it possible to produce the current of an effective magnitude required for these experiments, but Sir Humphry Davy's production of the alloy was not feasible commercially because of the number of batteries consumed.

Aluminum was first isolated in 1825 by Hans Christian Oersted, a professor at the University of Copenhagen in Denmark, using a chemical process. A small amount was produced by causing diluted potassium amalgram to react with an excess of anhydrous aluminum chloride, which produced aluminum combined with mercury. The mercury was then distilled away, leaving a small residue of slightly impure aluminum. Accounts of his experiments were published in a Swedish journal.

In 1827, Friedrich Wohler described the production of aluminum as a powder by the direct reaction of potassium upon anhydrous aluminum chloride. In 1845 he was able to produce slightly larger amounts of the metal (some particles being as large as a big pin head) and he was able to determine some of aluminum's properties.

H. Sainte-Claire Deville improved on Wohler's method in 1854 by using cheaper sodium for the potassium. This developed into a successful but expensive commercial process that was used in France and other countries for a few years until the coming of a cheaper electrolytic process. Many people worked trying to produce aluminum by electrolysis of aqueous solutions but hydrogen and aluminum hydroxide are formed at the cathode and prevents aluminum from forming. The modern process of producing aluminum by an electrolytic method was discovered almost simultaneously by Charles Martin Hall in the United States and by Paul L. T. Herould in France in 1886.[6] Although living on different continents, their lives strangely paralleled each other. Both developed essentially the same process for producing aluminum even though they had no knowledge of the other or of his work. They were both 22 years old when they made their discovery at almost the same date, and both died in 1914.

Hall became interested in this shining "new metal" while a student in Oberlin College in Ohio. His chemistry professor, Frank Jewett, encouraged him in his work and lent Hall equipment from time to time to continue his experiments after he finished college. In February of 1886 and using an old woodshed at his

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[6]A more detailed history of Heroult is found in The Aluminum Industry, McGraw-Hill Publishing Company, 1930.

parent's home for a converted laboratory and his sister for help, Hall succeeded in isolating pure aluminum by his electrolytic process.[7]

Hall knew immediately that he had found the process for which he had been searching but there were many problems ahead for him to solve. The first major problem was finances. Being the son of a preacher, he needed outside financial help to develop his process. The second major problem was the litigation that was to arise from the nearness in time of his discovery with that of Heroult. Hall did have the vision to establish proof of his discovery by writing letters to other members of his family and to show the new metal to professor Jewett at Oberlin College.[8] In the patent suits that were to follow, Hall succeeded in proving priority over Heroult by the narrow margin of two months.[9] Other major problems with which he was to cope were the refinement of the technical process and the development of a market for the new metal.

After a short period of working with a brother as a financial sponsor, Hall teamed with Alfred and Eugene Cowles (Kolz). The

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[7]Junius Edwards, The Immortal Woodshed (New York: Dodd, Mead and Company, 1955), p. 48.

[8]Ibid.

[9]Charles C. Carr, Alcoa: An American Enterprise (New York: Rinehart & Co., Inc., 1952), p. 13.

two brothers had invented the Cowles Electric Furnace in 1884 (this is basically the same design used today for reduction of metal from ore), in hopes of having the backing and facilities to develop his process. Hall worked with the Cowles Electric Smelting and Aluminum Company at Niagara Falls, N.Y. for about two years. This Company had been producing some aluminum alloys but they were unable to produce pure aluminum. Hall became disenchanted with the Cowles brothers when it appeared that they were more interested in other production and kept him only to suppress his work on producing pure aluminum commercially. He terminated his work with the Cowles and went back to Oberlin, Ohio to work and look for financing.[10]

The ALCOA Period

The history of the aluminum industry is basically the history of the Aluminum Company of America. The Aluminum Company of America--ALCOA--was founded on a dream of Charles Martin Hall less than 81 years ago. From this dream has grown an industry that has made a major change in man's way of life with its more than 4,000 valuable applications.[11] The electrolytic process

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[10]Carr, Alcoa: American Enterprise. p. 14.

[11]Leonard M. Fanning, Charles Martin Hall, Father of the Aluminum Industry (New York: The Mercer Publishing Company, 1956).

discovered in 1886 by Hall was the key that opened the door to volume production and the use of aluminum.

Finding businessmen with money to finance this new but untried aluminum was finally rewarded in 1888 when Hall, Captain Alfred E. Hunt and a group of farsighted Pittsburgh businessmen founded the Pittsburgh Reduction Company. Later, Andrew W. and Richard M. Mellon personally invested in the firm which gave the young company the needed boost to make needed improvements and increase production. All was not easy for the young company. New markets were needed for this new metal that was competing with well established iron and copper. Aluminum made its bow to the public in 1890 in the form of pots and pans. In 1907, the Pittsburgh Reduction Company was renamed Aluminum Company of America. The infant company, faced with financial problems and frustrations in developing markets for the metal, pushed forward under their first President, Arthur Vining Davis. Davis' aggressive salesmanship and Hall's inventive genius combined to make and market the metal.

The original fledging company began operation in a two-room building on Smallman Street in Pittsburgh, Pennsylvannia and the world's first commercial aluminum ingot was poured by Hall and Davis on Thanksgiving Day of 1888. This small plant used its own steam generated electricity for the production process and the plant soon proved too small for demands. In 1891, a new plant was built on the Allegheny River at New Kensington, Pennsylvannia. In 1896, the company bought mechanical power from the turbine shafts of the Niagara Falls Power Company and converted it into electricity for a new plant at Niagara Falls. Thus, the aluminum industry became the first customer for power at the Falls which was the nations first major hydroelectric plant.[12]

Alcoa established its own fabricating mills where the company could demonstrate new industrial and consumer uses for the metal. During this period, processes for alloying, rolling, forging, drawing, extruding and casting were developed in order to widen the market for aluminum. Also, during this early phase in developing the industry, it was all Alcoa. No one else entered the business of making primary aluminum although there were numerous independent fabricators. Alcoa owned all the primary aluminum production facilities, the best ore--bauxite--deposits, and it had the best aluminum technicians. Even with these advantages the company continued to try and expand the market by a consistent price reduction policy.

From the founding of the industry until 1940 was truly the Alcoa Period for the aluminum industry. They were synonymous and in 1937 the United States Government started anti-trust suits

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[12]Alcoa, Facts About Alcoa. p. 13.

TABLE 2

AVERAGE ANNUAL PRICE FOR U.S. PRIMARY ALUMINUM UNALLOYED INGOT

Year	Cents per Pound	Year	Cents per Pound	Year	Dollars per Pound*
1970.......	28.7	1960.......	27.2	1890.....	2.25
1969.......	27.7	1959.......	24.6	1888.....	5.25
1968.......	25.6	1958.......	24.8	1886.....	7.85
1967.......	25.0	1957.......	25.4	1885.....	11.33
1966,.,,,..	24.5	1950.......	16.7	1857.....	27.20
1965.......	24.5	1940.......	18.7	1855.....	113.30
1964.......	23.7	1930.......	23.8	1854.....	272.00
1963.......	22.6	1920.......	30.6	1852.....	545.00
1962.......	23.9	1910.......	23.0		
1961.......	25.5	1900.......	32.7		
		1895.......	58.7		

*Price on a worldwide basis prior to effective establishment of U.S. aluminum industry.

Source: Alcoa, Facts About Alcoa; 1971, p. 11.

against Alcoa. These were long, lengthy suits and although Alcoa was a monopoly, it had not used its position to eliminate competition. No one had ever attempted any competition. Although the courts did rule that Alcoa had a monopoly in primary metal production because it produced 100 per cent of the nation's metal, no punitive judgment was granted. Before all court decrees were issued, the issue became moot in that other companies did enter into aluminum production; however, Alcoa remained under court observation until 1956 and Alcoa is no longer a monopoly.[13]

Nothing should take away from the importance of Alcoa to the aluminum industry. Alcoa's importance may be summarized in its four major contributions to the industry: (1) development of the technology of the aluminum processes; (2) development of the sources of raw materials; (3) development of power sources for the industry; and (4) development of the market for aluminum products.

Period of Accelerated Expansion

Growth in Primary Producers

The industry made a steady and profitable growth through Alcoa by expanding its markets. This growth was interrupted by cyclical downturns. There was no major growth until World War II

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[13] Carr, Alcoa: American Enterprise. Chapters 15-17.

and its demand for aircraft that started a spiraling demand for aluminum. This period really established aluminum in our way of life. Aluminum had competed with iron, steel and copper and had created a place for itself. From the start of production, it took only 52 years, until 1940, for annual primary aluminum production to reach 412 million pounds. The next 15 years production increased to 3,200 million pounds. By 1970, production had reached 7,952 million pounds.[14] Per capita consumption of aluminum in the United States was 3 pounds in 1938 compared with more than 27 pounds today. Approximately one million people earn their living directly or indirectly through the output of aluminum products.[15] With World War II's demand for more aluminum products, Alcoa could not supply all of the industries demands for primary metal. Alcoa built and operated, for the government, aluminum production plants to help fill the war's demand. After the war, with the government selling off its sponsored facilities and with the court's mandate for competition in the industry, Alcoa continued to expand its operation but the Alcoa period was ended.[16] Other companies

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[14] The Aluminum Association, Statistical Review; 1967. p. 12.

[15] Isaac F. Marcosson, Anaconda (New York: Dodd, Mead & Company, 1957), p. 322.

[16] Alcoa, Facts About Alcoa. p.18

entered into production of primary aluminum and to compete for the ever expanding market of aluminum.

In 1941, the Reynolds Metal Company, an aluminum fabricator, could not get enough pig aluminum to fill their demands. With no place to turn for more aluminum, Reynolds Metal built their own reduction and ore refining plants. Later they borrowed more money and built another reduction plant. Thus; the second aluminum producer was on the scene.

Kaiser Aluminum and Chemical began aluminum production after World War II. Since the government had furnished the money for Alcoa to build plants during the war, it sold these facilities at a reduced cost in order to foster competition. The government sold some of them to Kaiser Aluminum in 1946 and the third aluminum producer in this country was started. The three major producers of primary aluminum were after their share of the market. At the end of 1948 there were three producers of primary aluminum in the United States with a combined annual capacity of 641, 500 tons. Capacity increases were frequent and by 1959 three new producers had entered the field to boost production to 2, 402, 750 tons.[17] The well-established metals company, Anaconda, came into the

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[17]The Aluminum Association, Statistical Review; 1967. p. 13.

primary aluminum production in 1955 as the fourth producer.[18] At this time, the government had sold all of its aluminum plants and was no longer in the aluminum business. The Ormet Corporation (jointly owned by Olin Mathieson and Revere Copper and Brass, Incorporated) entered production in 1958 with an annual production of 144,000 tons. This represented more than twice that of Anaconda.[19] Harvey Aluminum Incorporated also entered primary aluminum in 1958 but not in size as did Ormet. Harvey's first year of production was only 54,000 tons.[20]

During the next five years, through 1964, only one new producer appeared, but total annual capacity increased only 8.2 per cent. This new company was The Consolidated Aluminum Corporation and it started out with an annual production of only 20,000 tons of primary aluminum in 1963.[21] The Intalco Aluminum Corporation (owned jointly by Amax Aluminum Company, Howmet Corporation, and Pechiney Enterprises, Inc.) began production in 1966 with 152,000 tons of primary aluminum.[22] By the end of 1970, three

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[18] Marcosson, Anaconda. p. 325.

[19] The Aluminum Association, Statistical Review; 1967. p. 13.

[20] Ibid.

[21] Ibid.

[22] Ibid.

more producers had entered the market bringing the total number of primary aluminum producers to eleven. The National-Southwire Aluminum Company started production in 1969 and produced 7,300 tons of primary aluminum but then production jumped to 180,000 tons in 1970. Eastalco Aluminum Company began production in 1970 by producing 85,000 tons of primary aluminum. Revere Copper and Brass started a separate production from its joint ownership in Ormet Corporation and produced 56,000 tons of primary aluminum in 1970.[23]

The eleven primary producers are:

1. Alcoa (Aluminum Company of America)
2. Reynolds Metals Company
3. Kaiser Aluminum & Chemical Corporation
4. Intalco Aluminum Corporation
5. Ormet Corporation
6. Anaconda Aluminum Company
7. Consolidated Aluminum Corporation
8. Harvey Aluminum (Incorporated)
9. National-Southwire Aluminum Company
10. Eastalco Aluminum Company
11. Revere Copper and Brass Incorporated.

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[23] The Aluminum Association, Statistical Review; 1967. p. 17.

Growth in Primary and Total Supply of Metal

Its growth with the eleven primary aluminum producers does not complete the picture of the rapid expansion in the industry. At least three other areas need to be examined to get a more complete picture of the growth in total production of primary aluminum: the total supply; growth in production of milled products; and the expansion in the number of plants.

Figure 2, page 34, is a semi-log graph that illustrates the rapid growth in the production of primary aluminum covering production that started with the Pittsburgh Reduction Company in 1893. This chart illustrates a record aluminum production of 7,952 million pounds in 1970 and the average annual growth rate of 14 per cent since 1893 and 9.9 per cent since 1946. To some, the 7.0 per cent growth rate in the past decade is of more interest because it illustrates a continued expansion in recent times. The industry contributes this development to a growing economy, technological progress and increasingly wide acceptance of aluminum for many applications because of its many desirable characteristics.[24]

Further expansion and growth in the industry is reflected in its production of primary aluminum but the total United States supply

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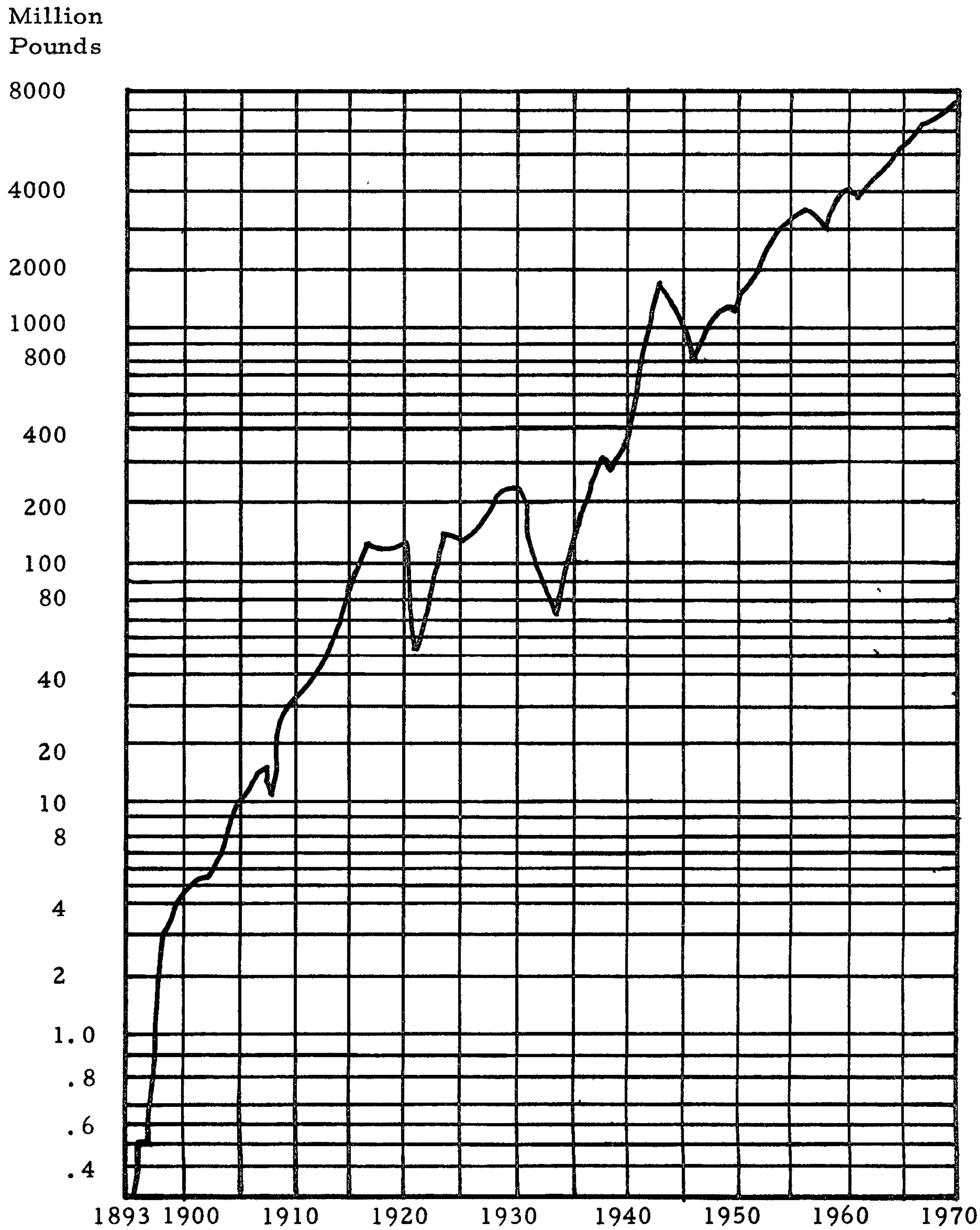
[24]The Aluminum Association, Statistical Review; 1970. p. 14.

FIGURE 2

PRODUCTION OF PRIMARY ALUMINUM
1893-1970

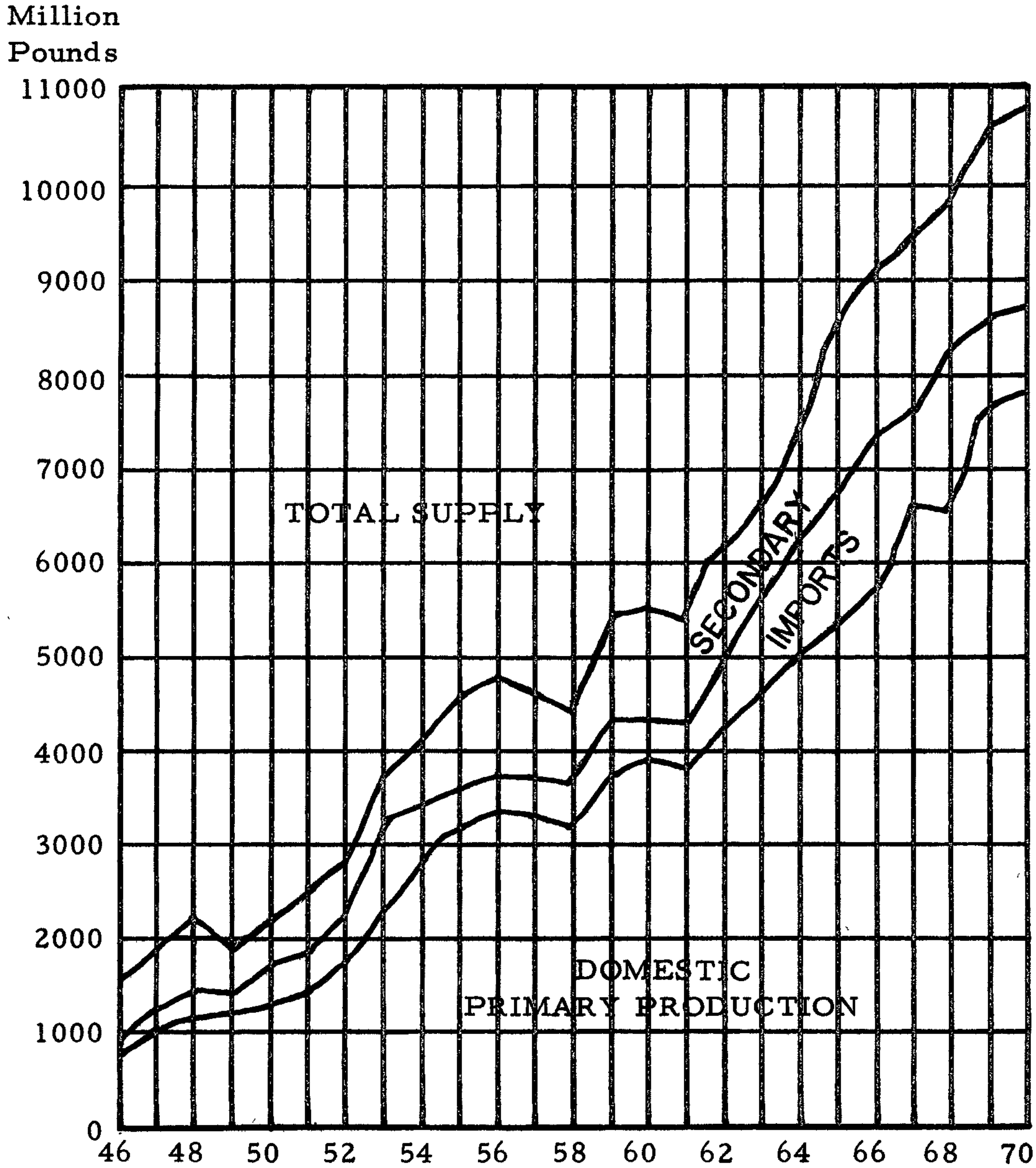


Source: The Aluminum Association, Statistical Review: 1970. p. 14.

of aluminum consists of metal from other sources. Figure 3, page 36, shows the total supply and it consists of domestic primary production, primary import, metal recovered from domestic scrap and imported scrap, and imported mill products. This chart makes no adjustments for inputs or withdrawals from government stock piles. As has been shown in 52 years, the industries production reached 400 million pounds per year. World War II distorted the overall supply conditions for aluminum and figures for these years are not usually considered. Alcoa's has been shown, the number of primary aluminum producers increased from two to eleven during the 1946-1970 period. The total supply expanded at an average rate of 8.6 per cent annually. Since World War II, annual domestic production rose 9.9 per cent per year, primary and mill product imports rose 10.3 per cent and secondary recovery rose 5.2 per cent annually. The growth rate of the total supply averaged 7.0 per cent annually from 1960 to 1970. Domestic production showed a gain of 7.0 per cent annually, imports 8.6 per cent and secondary recovery 8.3 per cent. Total supply increased to a record 10,816 million pounds in 1970 from the 10,767 million pounds in 1969, an increase of 0.5 per cent. The industry contributes the increase of primary production to: increased capacity; operating efficiencies and the absence of labor stoppages. Primary ingot imports were down 25.3 per cent

FIGURE 3

TOTAL ALUMINUM SUPPLY
1946-1970



Source: The Aluminum Association, Statistical Review: 1970. p. 11.

to 700 million pounds, reflecting a slowdown in U.S. economy.[25]

Growth in the Number of Plants

The period of rapid expansion has been marked by increased production and to support this production there has been an expansion in plants producing aluminum and aluminum products. The increase in the number of plants will not follow the production percentage increase because a plant may increase production within itself or through modernization of its' facilities. However, the figures speak for themselves and are impressive.

Table 3, page 38, shows the number of plants for each product and not the companies, which in many cases operate more than one plant. Totals are not shown because some plants produce more than one product, also, Table 3 shows that since World War II there has been a substantial increase in the number of product producing plants. The greater percentage increases have occurred in ACSR (aluminum covered steel reinforced) and bare cable, bare wire, insulated or covered wire, powder, rods and bar materials. The significant increases reported in 1970 for bare wire, ACSR and bare cable, and insulated or covered wire and cable were primarily as a result of a recent survey made by the Bureau of Domestic

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[25] The Aluminum Association, <u>Statistical Review; 1970.</u> p. 14.

TABLE 3

NUMBER OF ALUMINUM PLANTS
IN THE UNITED STATES

SELECTED YEARS

PRODUCT	1970	1969	1968	1967	1960	World War II
Primary Ingot	28	27	24	24	22	14
Secondary Ingot	85	89	90	89	92	46
Sheet and Plate	61	61	59	57	44	13
Foil	27	26	27	26	22	8
Rod and Bar, Rolled and Continuous Cast	33	31	23	21	12	4
Wire, Bare, Conductor and Nonconductor	99	83	75	67	37	10
ACSR and Aluminum Cable, Bare	61	39	34	36	26	NA
Wire and Cable, Insulated or Covered	80	77	71	61	48	12
Extruded Products	206	208	180	177	155	17
Drawn Tube	23	23	23	24	22	16
Welded Tube	23	24	24	21	11	NA
Powder	21	21	19	19	13	12
Forgings	70	67	54	52	49	59
Impacts	28	29	NA	NA	NA	NA

NA--Not available.

SOURCE: The Aluminum Association, Statistical Review: 1970. p. 8.

Commerce. This special survey of aluminum wire mills uncovered a number of plants not previously reported.

Summary

The period since World War II and two primary producers, to 1970 and eleven primary producers, has truly been a period of accelerated expansion for the aluminum industry. It has been a period marked by steady growth with few downtrends. However, the acceleration appears to be leveling off. The 1967 Aluminum Statistical Review stated the average annual growth rate since 1893 was 18.6 per cent with an increase of 9.1 per cent in primary production per year for the past 20 years. The 1970 Aluminum Statistical Review shows these figures to have changed to 14.7 per cent and 9.9 per cent respectively and a 7.0 per cent growth rate for the past decade.[26]

The industry continues to grow. The Gulf Coast Aluminum Company and the Noranda Aluminum Incorporated are constructing new facilities and should be in their first year of production soon. Alcoa, Anaconda, Harvey and Reynolds have all announced plans for increasing production and modernization for the near future.[27]

Alderfer and Michl have said that there are several measures

[26] The Aluminum Association, Statistical Review; 1970. p. 7.

[27] Ibid., p. 17.

for growth in an industry.[28] Aluminum meets all of these requirements adequately. First, the number of establishments; Table 3, page 38, shows this growth. Table 4, pages 41 and 42, shows the expansion of the capacities for plants. Though this may be an imperfect way to measure growth, the sheer numbers indicate an accelerated growth. A second way suggested for measuring growth, though it, too, may be defective is "capital invested". With the capital investment involved for building an intergrated aluminum plant shown and the number of new producers entering production, from three in 1948 to eleven in 1970, there is no doubt that the industry is expanding. The third and more reliable way suggested for measuring growth is the "number of workers" employed. When the Alcoa Rockdale plant was producing 175,000 tons of aluminum annually in 1968, they were employing about 1,550 employees. When they added two pot lines, approximately 250 more employees were added. When applying these figures to the industry as a whole, we get a good yardstick of the growth in the number of employees for the industry. Actual numbers of employees for the industry as a whole, including fabricators, will fluctuate too much to give a complete picture.

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[28]Alderfer and Michl, American Industry, pp. 12-13.

TABLE 4

PRIMARY ALUMINUM CAPACITY

Selected Years
Short Tons

Year(1)	Total	Alcoa	Reynolds	Kaiser	Intalco	Ormet	Anaconda
1948	641,500	325,000	188,000	128,500	--	--	--
1951	800,750	371,250	259,500	170,000	--	--	--
1952	1,155,700	484,250	353,250	318,200	--	--	--
1954	1,413,200	570,500	414,500	428,200	--	--	--
1955	1,634,700	706,500	440,000	428,200	--	--	60,000
1957	1,839,000	792,500	488,500	498,000	--	--	60,000
1958	2,194,250	798,250	601,000	537,000	--	144,000	60,000
1960	2,468,750	853,250	701,000	609,500	--	180,000	65,000
1962	2,488,750	853,250	701,000	609,500	--	180,000	65,000
1963	2,510,750	853,250	701,000	609,500	--	180,000	67,000
1965	2,758,284	950,000	725,000	650,000	--	184,284	100,000
1966	3,165,284	1,050,000	815,000	670,000	152,000	184,284	100,000
1969	3,888,300	1,325,000	935,000	710,000	265,000	240,000	175,000
1970	4,217,000	1,325,000	945,000	710,000	265,000	240,000	180,000

(1) Capacities shown are as reported for December 31.

SOURCE: The Aluminum Association, Statistical Review: 1970. pp. 16-17.

TABLE 4

PRIMARY ALUMINUM CAPACITY
(Continued)

Selected Years
Short Tons

Year[1]	Total	Consolidated	Harvey	National-Southwire	Eastalco	Revere
1948	641,500	--	--	--	--	--
1951	800,750	--	--	--	--	--
1952	1,155,700	--	--	--	--	--
1954	1,413,200	--	--	--	--	--
1955	1,623,700	--	--	--	--	--
1957	1,839,000	--	--	--	--	--
1958	2,194,250	--	54,000	--	--	--
1960	2,468,750	--	60,000	--	--	--
1962	2,488,750	--	80,000	--	--	--
1963	2,510,750	20,000	80,000	--	--	--
1965	2,758,284	62,000	87,000	--	--	--
1966	3,165,284	106,000	88,000	--	--	--
1969	3,888,300	140,000	91,000	7,300	--	--
1970	4,217,000	140,000	91,000	180,000	85,000	56,000

(1) Capacities shown are as reported for December 31.

SOURCE: The Aluminum Association, Statistical Review: 1970. pp. 16-17.

In the light of the fluctuation of the money market and overall decline in business, the "value of product" as a measure has almost lost its importance in measuring growth of the industry. Suggested as the best test of growth is in the trend of physical quantity output. Table 4, pages 41 and 42, shows, also, the output of primary aluminum production for the selected years to give this continued growth. The industries annual growth rate of 8.4 per cent makes it one of the fastest growing industries in the nation.

CHAPTER III

THE TECHNOLOGY OF THE INDUSTRY

The Smelting Process

Introduction

Industrial arts professional literature contains many articles about modern curriculum for our discipline. While some may differ on a few items to be included, our state and national leaders agree that industrial arts should include the technology of the industry.[1, 2, 3] In following with their views, this study is not intended to make the student a technician in the industry but it will give him a general understanding of the processes, procedures, equipment and scope of the industry's involvement.

Aluminum is valuable to man because of its many outstanding

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[1]Maley, "Industrial Arts Relates to Vocational Education." p. 13.

[2]Leslie H. Cochran, "Charting the Changing Directions of Industrial Arts, School Shop, October, 1969, pp. 53-56.

[3]Wilber and Pendered, Industrial Arts in General Education. p. 2.

properties. Light weightness is its primary virtue. Aluminum weighs about two-fifths as much as zinc, one-third as much as steel, three-tenths as much as copper and one-fourth as much as lead.[4] Its weight is about one-fourth to one-third that of the other common commercial metals, with a specific gravity of 2.70. A cubic foot of aluminum weighs 168 pounds. The advantages of lightness and resistance to corrosion makes it of great value for architectural applications in building construction and for all forms of transportation. The advantages of lightness and thermal conductivity make it valuable for cooking utensils, and when combining these features with corrosion resistance, aluminum is very good for containers and packaging. Another outstanding virtue of aluminum is its electrical conductivity. Pound for pound it has twice the conductivity of copper. This feature plus its light weightness makes it of great value for electrical applications. Other economic advantages of aluminum are: high conductivity for heat, high reflectivity for light and radiant heat, workability, non-toxicity, strength in alloys, non-sparking, non-magnetic, appearance, and high scrap and re-use value.[5]

One would assume that it would be an easy matter to obtain aluminum since it is the third most abundant element on the earth's

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[4]Stanley V. Marlcuit, The Aluminum Industry, (Boston: Bellman Publishing Co., Inc., 1946), p. 1.

[5]Ibid.

surface and about 15 per cent of the earth's crust is alumina. This was one of the things that led Charles Martin Hall in his quest--that any clay bank could be a rich source of aluminum. But this is not so! Aluminum never occurs in its pure state in nature and because of its many impurities, its ores cannot be made directly into metal as can the ores of many other metals.

Unlike other common industrial metals (iron, copper, zinc, lead) pure aluminum is not produced by the direct smelting of its ores. In the first place, its affinity for oxygen is so much greater than that of the principal metallic impurities in the ore (iron, silicon, titanium) that their oxides are more readily reduced to the metallic state than is alumina. If direct smelting methods were used to reduce the ore, other oxides would also be reduced and a resulting alloy produced would be too impure to use. The second problem is that very high temperatures are required to produce aluminum from alumina and if other less volatile materials such as iron or copper are not present to absorb some of the temperature, the aluminum will vaporize and disappear or if carbon is present the aluminum will convert into worthless aluminum carbide. Likewise, aluminum cannot be produced by the electrolysis of aqueous solutions of its salts, hydrogen and aluminum hydroxide are formed at the cathode instead of aluminum.

The modern electrolytic method of producing aluminum is a two-step procedure. The first step is to convert the bauxite into pure alumina, aluminum hydroxide. Bauxite, the name for aluminum ore, derived its' name from a small town in France--LeBauex--where the ores were exceptionally rich in alumina. This is done using the Bayer process. The second step is to separate the aluminum and the oxygen. This step is Hall's contribution to the industry.

First Step: The Bayer Process, Bauxite to Alumina

The bauxite must be first made into aluminum oxide or alumina.[6] The bauxite is mined mostly with large powered shovels in open pit mines which are located in the Dominican Republic, Jamaica, Suriname (Dutch Guiana), British Guiana, Brazil, Western Australia and some low grade ores are mined in Arkansas. The bauxite is crushed, washed to remove much of the clay and silica waste, kiln dried in rotary kilns and then shipped to the United States by boat and arrives as a white to reddish brown powder, according to its content. This bauxite is converted to alumina, usually by the Bayer process. The powdered bauxite is measured into a mixer where it is mixed with lime, caustic soda and hot water. The

[6]Aluminum Company of America, A Brief Story of Aluminum and Alcoa (Pittsburgh: Aluminum Company of America. n.d.). p. 3.

mixture is pumped to a digester where it is heated with steam. When the mixture is heated under pressure, only the hydrated alumina (alumina hydroxide) contained in the bauxite is dissolved while the solids and other remaining impurities (a red mud) are filtered out in a filter press. The filtered solution is then cooled in a cooling tower and pumped onto hugh precipitation tanks, that are about five to six stories high, where a "seed" charge of hydrated alumina is added to precipitate hydrated alumina from the solution. The precipitate is combined with water and it crystallizes, after which the caustic soda is washed out in a washing thickener. The water is removed and the precipitate is dried in rotating calcining kilns at 1800^{o} F. and then cooled. The resulting white powder--pure alumina--is then shipped to smelting plants for the second process. About two tons of bauxite are required to produce one ton of alumina.[7]

Second Step: The Hall Process, Alumina to Aluminum

The second step in the making of aluminum is the smelting procedure, which is done by an electrolytic smelting process. This is Hall's contribution to the industry and in it metallic aluminum is produced by an electrolytic process that separates alumina into its component parts--oxygen and aluminum. In this process, pure alumina is dissolved in a bath of molten cryolite (sodium aluminum

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[7]More details and other processes are discussed in: U.S. Department of Commerce, Materials Survey: Aluminum, Nov. 1956, p. VI-2 to VI-6.

flouride), a Greenland mineral that looks like ice, in large electrolytic furnaces called reduction "pots". The metal pot itself is lined with carbon anodes suspended in the cryolite, electric current is passed through it, generating heat and causing the cryolite to fuse. After the cryolite fuses, alumina is added and the electric current continues to pass through this mixture of cryolite and alumina, causing metallic aluminum to be deposited on the cathode, the carbon lining of the pot, where it settles to the bottom of the cell. The heat generated by the passage of electric current keeps the cryolite bath molten so that alumina can be added as necessary to make the process continuous. Additional alumina is stirred into the electrolyte from time to time. At intervals, the molten aluminum is syphoned from the pots, and the molten metal is transferred to holding furnaces for removal of impurities or alloying with other ingredients. It is then cast into ingots of various sizes for further fabrication. The cells are arranged in rows and wired in series to form what is called "pot lines".[8] Most commercial cells for the production of aluminum use currents of 50,000 to 100,000 amps. Since each cell requires only five to six volts, it is customary to connect a large number (often 100 or more) of such cells in series, and supply the necessary power from

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[8] U.S. Department of Commerce, Materials Survey: Aluminum (Washington, D.C.: Government Printing Office, 1956), pp. VI-6 to VI-10.

a group of rotary converters, mercury arc rectifiers, or large direct current generators. In many plants, large Soderberg self-baking electrodes (one or two per cell) are used instead of the numerous smaller prebaked carbon anode blocks or rods which are employed in the older plants. The box for 50,000 amp. cells may be 20 ft. long, 6 ft. wide, and about 3 ft. deep and made of steel about 0.5 in. thick. Such cells are arranged in a line or several lines in suitable buildings (often 700 ft. or more in length) supplied with equipment to collect and remove the fumes and minimize the effect of the radiated heat. Aluminum fluoride is added to the molten electrolyte from time to time to neutralize the soda in the alumina (derived from the Bayer process), and some cryolite is added to make up for the absorption by the cell lining, losses caused by spillage, etc. Plants may be expanded simply by adding more "pot lines".

The process to produce a ton of aluminum requires two tons of alumina, one-half ton of carbon (the carbon electrodes burn up very fast), 18,000 Kwh. of electricity and 16 manhours of labor.[9]

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[9] Alderfer and Michl, American Industry, p. 105.

The only commercial quantities of cryolite were found in Ivigtut, Greenland but these deposits were depleted in 1963 after 100 years of mining. Artificial cryolite, made from flourspar, is preferred and used today because of its purity.

Mill Processes

Aluminum lends itself to many milling processes easily. However, like most metals, aluminum is usually worked as an alloy. Commercial aluminum usually ranges between 99.0 and 99.6 per cent pure and technically should be considered as an alloy. Iron and silicon are the usual impurities present and they will change the properties of aluminum. The usual alloying metals are copper, magnesium, manganese, zinc and nickel. Special alloys may contain varying small amounts of many other metals or elements.

In 1946, the U.S. Bureau of Census compiled data on ingots and four groups of mill products. Because of their growth, the industry now shows twenty-three separate categories of these mill products. The U.S. Census grouping continues to be satisfactory in that many of the statistics are still reported in this method.

These groups are: (1) ingots, (2) sheet, plate and foil, (3) extrusions and tube, and (4) other. This "other" group includes conductors, rod, bar, wire, forgings, impacts and powder.

Figure 4, page 53, contains pie charts that show the percentage of production in selected years for these groupings. Table 5, pages 54, 55, and 56, shows net shipments for these groups. Since these groupings are general, it is necessary to identify how each group is used.[10]

The ingot group is that aluminum which is for export, destructive uses and used in casting. Ingot is the basic form of primary aluminum and may be cooled for shipment in that form. Many intergrated plants move the hot ingot directly to other processes where it is often alloyed with other metals which gives it a wide variety of desirable characteristics and then feed it directly to mills for processing while still hot. Ingots are made available in a range of sizes and shapes for customer use. Castings can be made by most of the general casting procedures used: sand, plaster, permanent mold and die process. Most permanent mold castings contain 7 per cent to 10 per cent copper, although heat-treated alloys contain varying amounts of copper, magnesium and silicon

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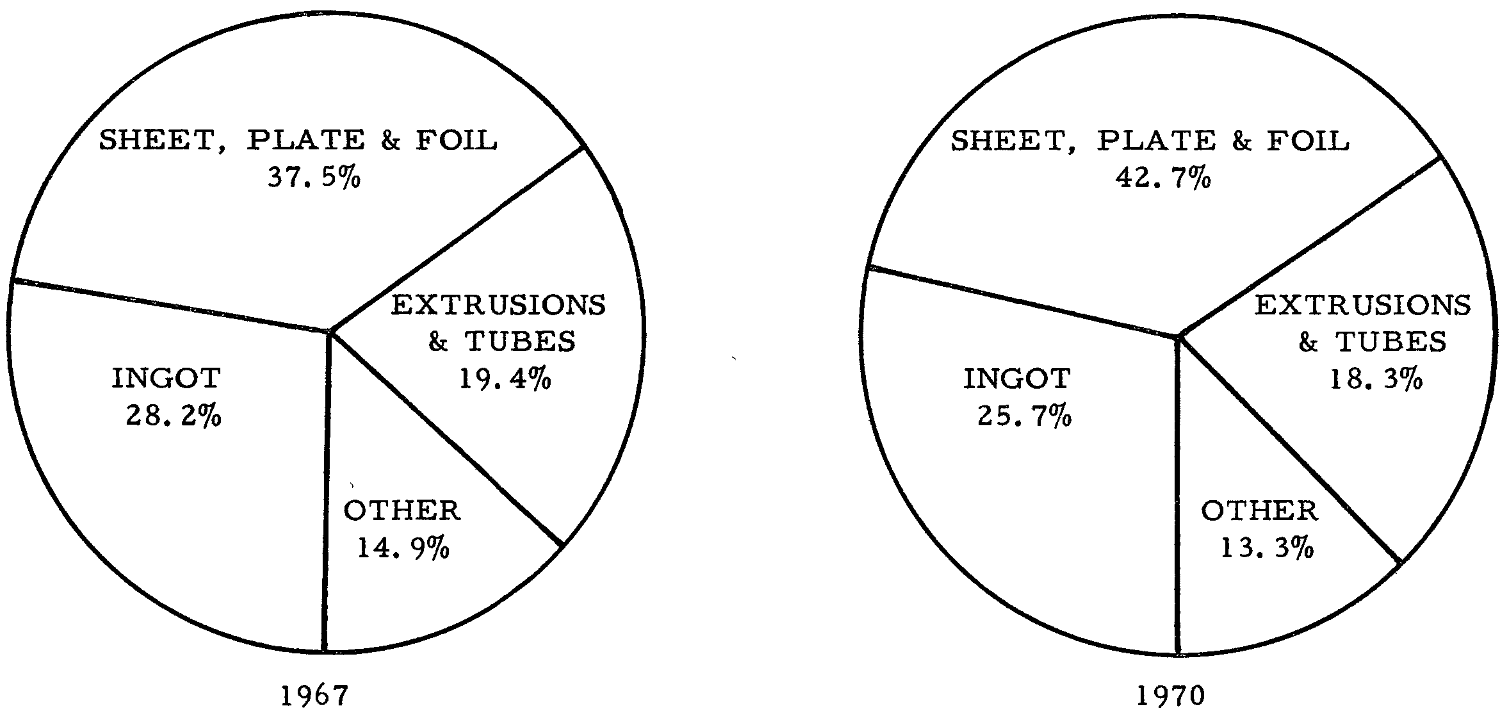
[10]The Aluminum Association, Statistical Review; 1970. p. 24.

FIGURE 4

PERCENTAGE DISTRIBUTION BY MAJOR PRODUCTS



Source: The Aluminum Association, Statistical Review: 1970. p. 26.

TABLE 5

SHIPMENTS OF INGOT AND MILL PRODUCTS*

Excludes Mill Product Imports to Consumers
1946-1970 Millions of pounds, Net Shipments

Year	Total Aluminum	Total Ingot	Primary Ingot	Secondary Ingot	Extrusion Ingot	Total Mill Products
1946	1,670.0	529.2	--	--	--	1,140.8
1948	2,270.0	629.8	--	--	--	1,640.2
1950	2,438.0	724.6	--	--	--	1,713.4
1952	2,661.6	811.2	339.8	471.4	--	1,850.4
1954	3,006.8	920.2	425.7	494.5	--	2,086.6
1956	4,109.3	1,223.4	520.1	703.4	--	2,885.8
1958	3,571.1	974.0	368.6	605.4	--	2,597.1
1960	4,657.7	1,608.6	852.3	665.2	91.1	3,049.1
1962	5,669.8	1,858.6	768.9	848.7	241.0	3,811.3
1964	7,063.5	2,228.6	946.5	995.1	287.0	4,834.9
1966	8,797.6	2,340.1	987.2	1,190.4	162.6	6,457.5
1968	9,861.8	2,694.8	1,154.2	1,284.3	256.3	7,167.0
1969	10,717.5	3,051.2	1,569.4	1,264.9	216.9	7,666.3
1970	9,941.9	2,555.7	1,269.9	1,126.0	159.7	7,386.2

*Producers Goods. Detail may not add to totals due to rounding.

SOURCE: U.S. Department of the Interior, Aluminum: Reprint from the Bureau of Mines Minerals Yearbook (Washington, D.C.: Government Printing Office. Years selected).

TABLE 5--Continued

Year	Total Aluminum	Plate, sheet & strip			Rod, bar & wire			
1946	1,670.0	867.0			130.6			
1948	2,270.0	1,268.3			183.0			
1950	2,438.0	1,163.1			269.8			
		Sheet & Plate nonheat-treatable	Sheet & Plate heat-treatable	Foil	Rod & Bar	Wire, bare	ACSR & bare cable	Ins. or Cov. wire & cable & wire, bare
1952	2,661.6	641.4	288.0	85.4	197.3	42.7	174.7	23.4
1954	3,006.8	768.2	243.6	153.3	143.7	45.6	147.1	25.0
1956	4,109.3	1,050.6	327.0	190.5	117.8	59.9	187.4	56.1
1958	3,571.1	944.4	209.1	199.6	75.6	44.2	174.8	51.0
1960	4,657.7	1,203.4	184.8	249.0	92.9	55.4	183.1	60.4
1962	5,669.8	1,470.7	240.2	297.4	136.4	55.0	253.2	76.9
1964	7,063.5	2,027.2	246.8	356.7	146.8	63.1	309.2	103.2
1966	8,797.6	2,508.1	428.7	432.2	151.9	103.2	507.4	165.3
1968	9,861.8	3,014.3	390.2	508.7	130.0	100.4	492.2	214.0
1969	10,717.5	3,405.1	321.7	559.9	144.3	94.7	475.1	250.5
1970	9,941.9	3,470.5	218.1	558.7	138.2	93.5	499.5	260.2

Consumer Goods.

TABLE 5--Continued

Year	Total Aluminum	Extruded shapes, tube blooms and tubing					Powder	
1946	1,670.0	126,1					17.2	
1948	2,270.0	171.9					17.0	
1950	2,438.0	258.1					22.5	
		Extruded shapes Soft alloys	Extruded shapes Hard alloys		Tubing Soft alloys	Tubing Hard alloys		
1952	2,661.6	206.2	81.0		46.4	14.2	49.7	
1954	3,006.8	385.8	63.8		53.5	10.1	46.9	
					Drawn tube	Welded tube		Forgings Impacts
1956	4,109.3	641.0	63.5		60.2	27.6	28.4	75.7
1958	3,571.1	693.5	49.8		59.8	18.7	25.6	50.8
1960	4,657.7	812.1	38.9		60.3	25.9	32.8	50.1
		Extruded rod & bar	Extruded Shapes	Extruded pipe & tube				
1962	5,669.8	67.4	827.2	144.7	78.4	40.7	43.7	79.4
1964	7,063.5	83.1	1,057.4	162.5	66.9	77.4	46.3	88.4
1966	8,797.6	88.7	1,433.0	197.5	99.7	91.2	111.4	139.2
1968	9,861.8	58.4	1,433.0	182.0	92.6	106.9	276.4	167.8
1969	10,717.5	63.3	1,532.5	196.1	89.0	101.6	276.0	156.6
1970	9,941.9	56.5	1.412.6	176.9	84.2	92.5	204.5	120.4

where higher strength and ductility are required. Typical strengths for ordinary sand cast alloys are in the range of 19,000-30,000 lbs. per square inch (p. s. i.) while heat-treated alloys may show 30,000-45,000 p. s. i. As a general rule, an alloy cast in permenant (metal) molds will show tensile strengths of 5,000-10,000 p. s. i. higher than when sand cast.

In the sheet, plate and foil group, the sheet ingots are reduced to sheet or plate by continuous passes through rolling mills. Plate becomes sheet when it is reduced to a thickness of .249 inch. Sheet becomes foil when rolled to less than .006 inch. Sheet is used for building products, cans, cooking utensils, automotive trim, truck-trailer bodies, airframe skins, welded furniture, tube and other products. The foil can be rolled to .0002 inch for special cases. Aluminum is ideal as a household wrap but it has other uses. It is also used for electric motor windings, capacitors and honeycomb structures used in many aerospace applications.[11] Foil is generally made from somewhat higher purity aluminum than commercial "pure aluminum" sheet, ranging upward to 99.99 per cent for foil used in electrolytic condensers.

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[11]Alcoa, Story of Aluminum and Alcoa. p. 8.

Extruded shapes and tubular group products are made by forcing heated aluminum ingots through a die opening. Aluminum extruded shapes permit engineers, architects and manufacturers almost unlimited latitude of design. More than 100,000 different cross sections have been extruded by one manufacturer.
Tubular products also are further fabricated by drawing operation. Common uses for extrusions and tubes range from furniture, doors and hand rails to automotive trim, product pipeline and a variety of heavy structural shapes. Cold working (rolling, forging, drawing through dies, etc. at ordinary temperatures) hardens the metal, increasing both tensile and yield strength. Most extrusions are, however, made by using hot ingots (700° F.-950° F.) 6-8 inches in diameter and of various lengths, placed in hydraulic "extrusion-press" and forced through dies to form the desired shape or "bloom" for further shaping. Small amounts of alloying materials also will increase the strength of the metal.[12]

The products produced in the "other" category use several different processes which should be noted. Rod, bar and wire mills take "blooms" and pass them through rolls and are frequently cold-finished or drawn to obtain desired size or shape. The product size

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[12]Alcoa, Story of Aluminum and Alcoa. p. 9.

and shape are controlled by the shapes of the rolls or drawing dies. Rod and bars are widely used as screws, machine and other forging stock, for drawing into wire and many other applications, while structural shapes are used throughout the electrical, construction and highway industries. Since it is one of the better conductors of electricity, coupled with the high cost of copper, aluminum conductors are being used for high-voltage power transmission lines, power distribution, in residential areas and to and within industrial plants and commercial buildings. Over five million miles of aluminum transmission lines are in use by the electrical industry along with aluminum towers for cable-supports. Again, alloying is the key to obtaining the workability and strength required of the product being made.

Aluminum forgings and impacts of the "other" group have been developed from the ancient art and is a highly versatile production process employing hammers, presses and specialized machines. Hydraulic presses ranging up to 35,000 and 50,000 ton giants have been the impetus to forging changes that have greatly expanded the use of large aluminum forgings. Impact extrusions have been developed for use in both simple and complex design methods. The process that makes aluminum products for aerospace, missiles, electronic parts and many other uses, requires equipment that includes presses almost three stories high and produces impacts up to five feet long.

Aluminum powder and paste are made from finely ground aluminum and used mostly in paints and roof coatings. They are also used in printing ink, lubricants and rocket fuel. With the development of the technological processes completed by Alcoa, others were to enter the competition.

CHAPTER IV

THE COMPETITIVE ASPECTS OF THE INDUSTRY

It has been shown in Chapter I that there was no competition within the aluminum industry for producing primary metal during the Alcoa period, however, there were independent fabricators. In this period Alcoa developed sources of bauxite, power, processes and markets. Competition during this period was from the established steel and copper industries. Alcoa was dedicated to reducing the price of aluminum and the price of aluminum did decrease steadily from $5.28 per pound in 1888 to fifteen cents per pound in 1942.[1] Table 1, page 13, shows the average annual price of aluminum. Prices have increased from the low in 1942 but this rise is from a general inflation in the economy and not because of the industry itself.

Steel and copper, the main competitors of aluminum, were widely used and, often, little consideration was given to weight or

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[1]Alcoa, Facts About Alcoa. p. 11.

bulk in developing machines, equipment or structures. World War II and the need for aircraft brought a new technology and created a new, widely expanded need for aluminum. Although the steel industry is much larger than the aluminum industry, aluminum has made inroads into some areas of it where the character of aluminum has an advantage.

The expanded use of electricity created a greatly expanded network of high voltage transmission and lines and allied products. Many of these new networks incorporated either ACAR (aluminum conductor alloy reinforced) or ACSR (aluminum conductor steel reinforced) cables. The ASCR cable is 50 per cent stronger and 28 per cent lighter than electrically equivalent copper cable.[2] Although aluminum is not cheap, its cost per pound fell below that of copper in 1947. Aluminum tonnage production surpassed that of copper in 1954 and because of its light weight in relation to volume, aluminum goes about three times as far as copper.[3]

Aluminum has competed for its place with the metals and it is not likely to be replaced by other metals. Competition in primary aluminum production actually started in 1941 when the Reynolds Metals Company, then a fabricator, could not get enough

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[2] Alderfer and Michl, American Industry, p. 113.

[3] Ibid., p. 107.

pig aluminum to keep its fabricating plants busy and built its own ore refining and reduction plants. Kaiser Aluminum and Chemical Corporation became a competitor in 1946 when it bought some of the government sponsored and built plants operated by Alcoa during the war.

Now there were three primary aluminum producers in the United States, and at the end of 1948 they had a combined capacity of 641,500 tons. Alcoa's capacity was 325,000 tons or slightly over 50 per cent. Reynolds' capacity was 188,000 tons or slightly over 29 per cent, while Kaiser's capacity was 128,500 tons for just under 21 per cent of the total supply. There were annual capacity increases frequently through 1959.[4]

By 1959 there had been annual increases in production and three new producers had entered the competition: Anaconda, Ormet and Harvey Aluminum Companies. Production had increased to 2,402,750 tons. During the next five years, through 1964, only one new producer appeared and production was up 8.2 per cent to a total of 2,599,100 tons. Since 1964 producers have increased their capacities by 1,617,900 tons or 62.2 per cent or an annual rate of 8.2 per cent and four new producers have brought the total production up to 4,217,000 short tons at the end of 1970. Table 4, pages 41 and 42,

[4]The Aluminum Association, Statistical Review; 1970. p. 17.

shows production for selected years for the companies in production at that time and that while all producers have continued to increase their capacities and production, some are increasing at a faster rate than others.

Also, while not shown, it is interesting to note that Alcoa's Rockdale, Texas plant production capacity of 275,000 tons annually is more than that of eight of the eleven primary aluminum producers total capacity.

Figure 5, page 65, is a chart that shows percentage of production by producers in 1948 and 1970. These charts illustrate that while Alcoa is still the leading producer of primary aluminum its per cent of lead is decreasing as more producers enter the industry.[5]

Major markets for aluminum.--The aluminum industry has continued to grow and markets for aluminum continue to change. As one market may decrease in overall demand for aluminum another will increase in demand and take up the slack in the market. Competition for these markets is the result of the growth of the industry. The major markets, as identified by the aluminum industry in the United States, have a wide range of uses within them. These major markets and uses are identified as: (1) the building construction market which

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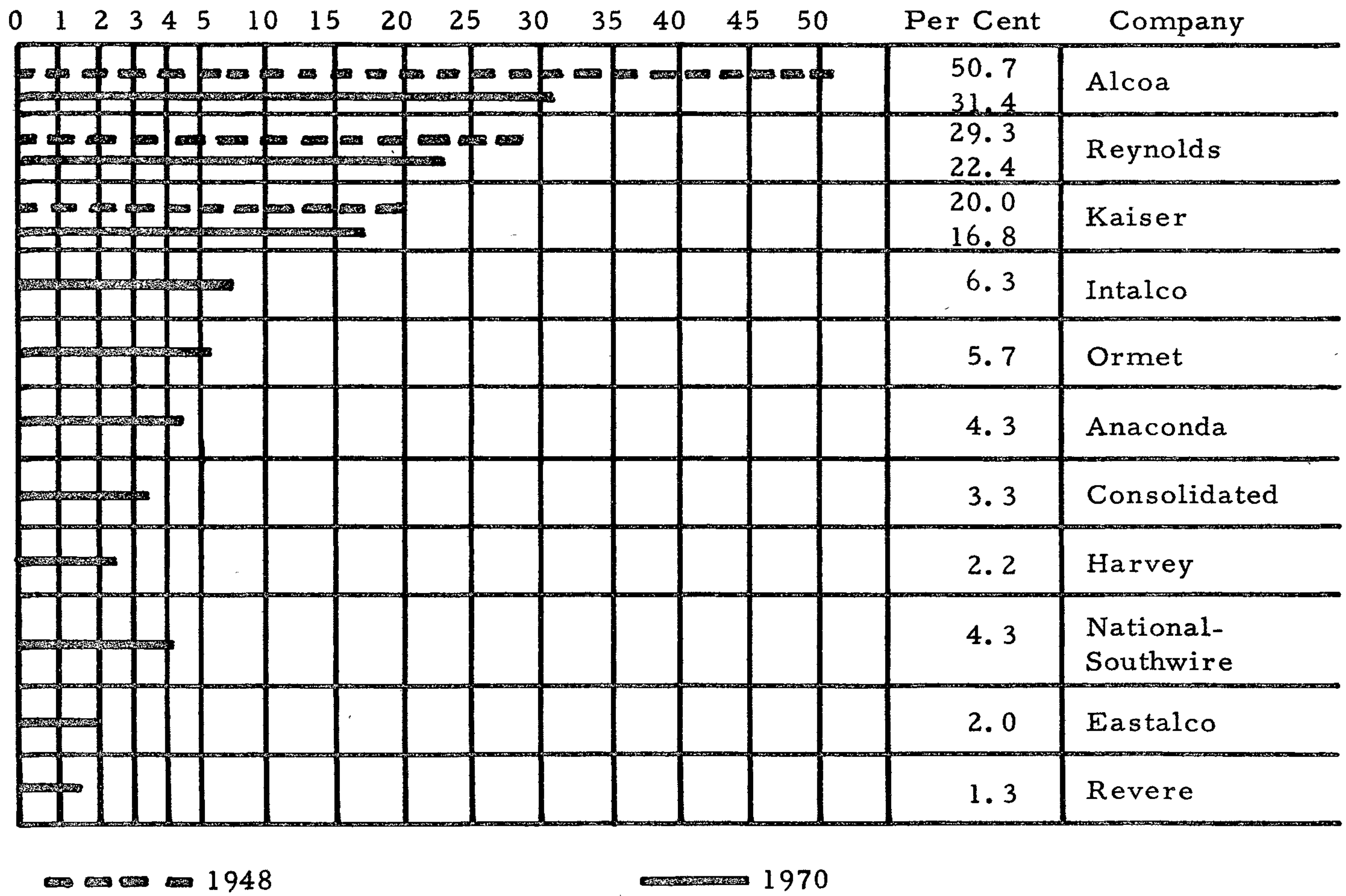
[5]The Aluminum Association, Statistical Review; 1970. p. 17.

FIGURE 5

PERCENTAGE OF PRIMARY ALUMINUM CAPACITY



uses aluminum in residential, industrial, commercial, farm and highway applications. These include doors, windows and screening, awnings, and canopies, roofing and siding, curtain walls and store fronts, gutters and downspouts, bridge and guard rail, lighting standards and mobile homes. (2) Cans, caps and closures, collapsible tubes, household and industrial foils, semi-rigid food containers and the many flexible packagings are part of the components of the containers and packaging market. (3) The market of consumer durable goods includes the market for air conditioning, cooking utensils, furniture, pleasure boats, personal and recreational goods and refrigeration. (4) The electrical industry comprises electrical machinery and equipment, lighting fixtures and lamps, power transmission and distribution equipment and communications equipment. (5) The market for machinery and equipment uses include agricultural, construction, industrial and mining machinery, irrigation pipe, storage tanks, sewage disposal process industries equipment, fasteners and other general components. (6) Transportation end uses are found for aluminum in the aircraft and aerospace industry, marine, rail and automotive applications, travel trailers and recreational vehicles and cargo containers. (7) The "other" market consists of the miscellaneous end uses not included in the other categories while the export group is self-explanatory.[6]

Figure 6, page 68, shows the percentage of the major markets of aluminum for selected years and the fluctuating as the market has shifted and the total amount of aluminum actually used in each category. Figure 7, page 69, shows the annual growth rate percentage changes for the years 1960-1970 in the market changes, During this ten year period all major markets continued to grow. Containers and packaging had the largest percentage of growth in this period. They reported a gain of 1, 146 million pounds which was almost four times its 1960 shipments. Competition within an industry often effects the location of the industry's plants. Industries with favorable locations have an edge on their competition.

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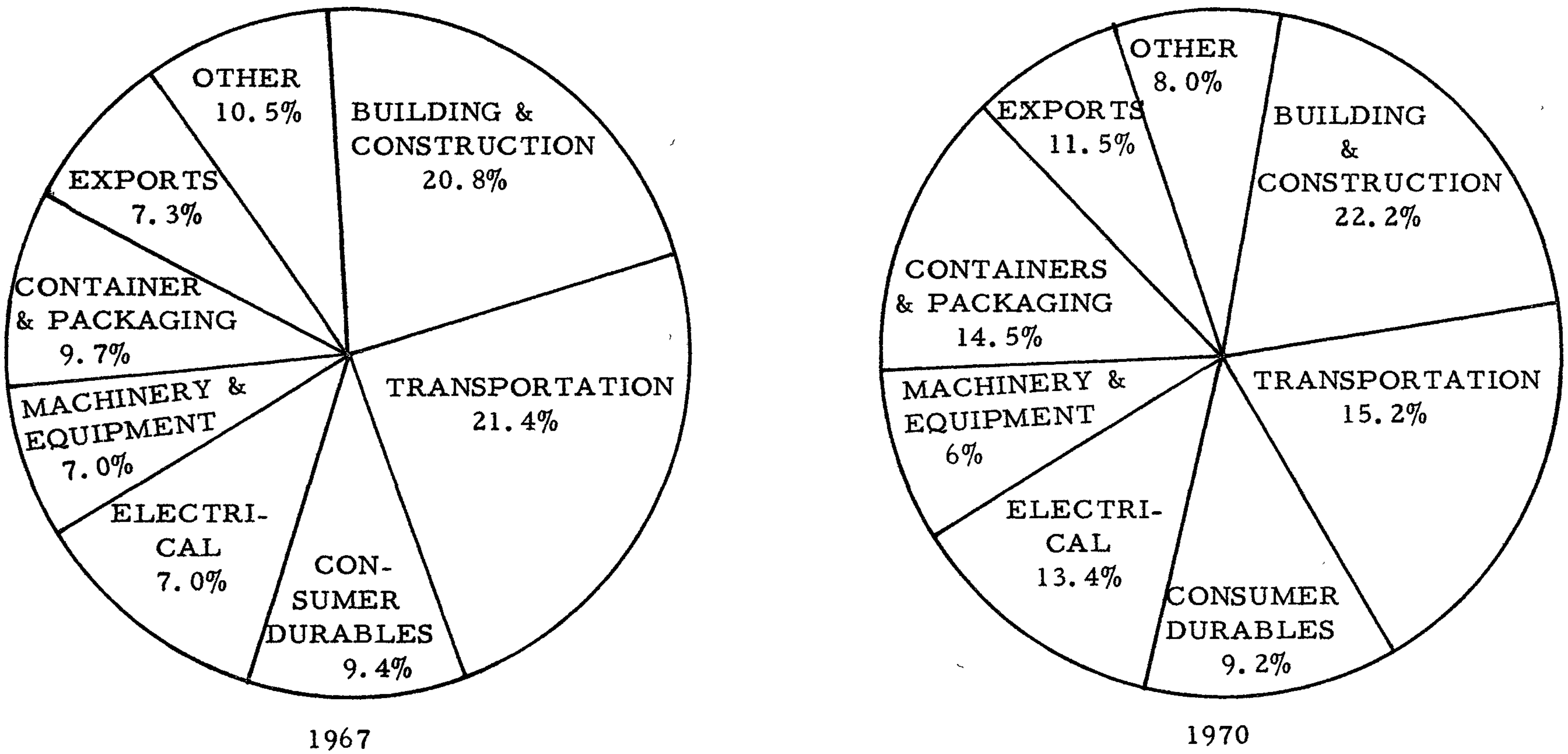
[6] The Aluminum Association, Statistical Review; 1970. p. 32.

FIGURE 6

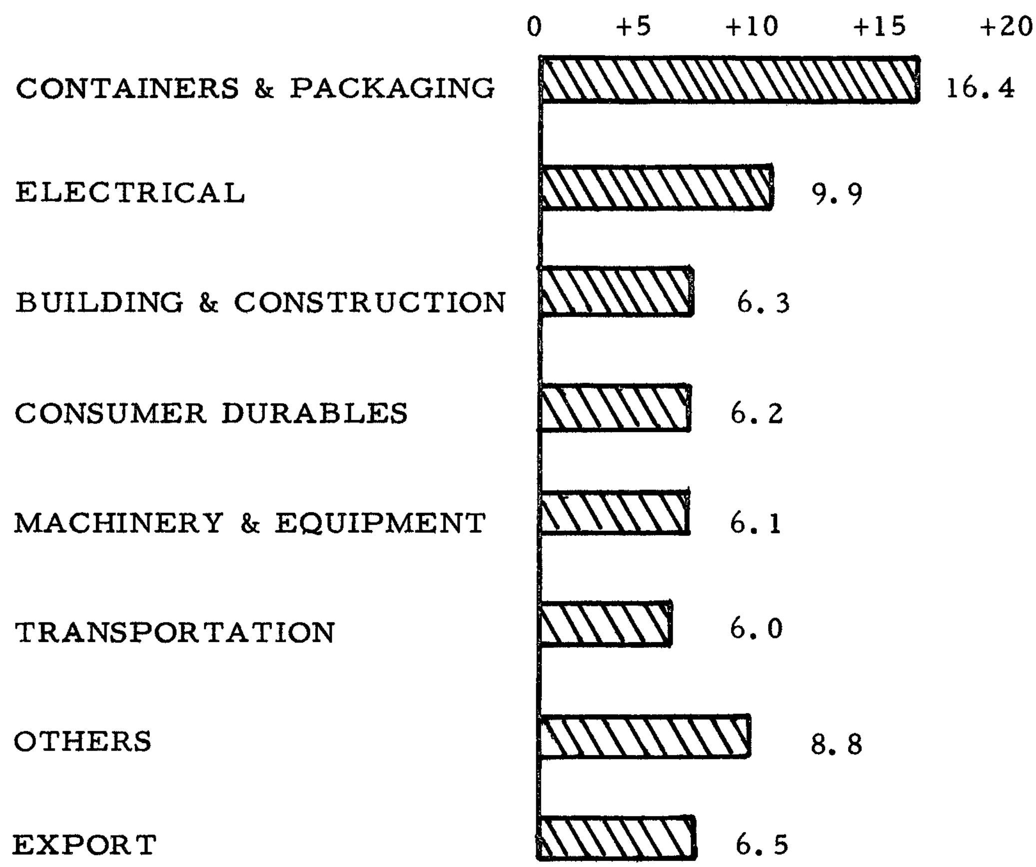
SHIPMENTS DISTRIBUTION BY MARKET



SOURCE: Estimated by the Aluminum Association, Statistical Review: 1967 and 1970. p. 32.

FIGURE 7

MARKET CHANGES
1960-1970 ANNUAL GROWTH RATES
PER CENT CHANGE



SOURCE: The Aluminum Association, Statistical Review; 1970. p. 33.

CHAPTER V

LOCATION OF THE ALUMINUM INDUSTRY

It may be natural to assume that, like most of the steel industry and because Alcoa originated in Pittsburgh, the aluminum industry is centered in the Pittsburgh area, but that is not the case. The location of plants apparently follows two separate patterns. One pattern is for the primary aluminum smelting and the other is for mill products. The location of aluminum smelters is determined, basically, by two major production factors--the cost of transportation and of electricity. Since practically all of the bauxite must be imported and processed into alumina, these plants are usually located near a source of low cost water transportation and most are on the coast or on navigable rivers. The transportation of the alumina to the smelter is another factor to influence the location of the smelter and it becomes a compromise in its location. It is the cost of transporting the alumina versus the cost of transporting the power required for the smelting process and usually the cost of transporting the alumina is cheaper. Therefore, the smelter is located near the source of the electricity.

The plant location for mill products is determined, primarily, by markets for the products and therefore follows the pattern of other manufacturing industries in the United States in location. The largest per cent of these plants is located in the Eastern half of the United States. None are in the West but some are on the Pacific Coast with a concentration of plants in parts of California.

Forty of the forty-eight Continental United States have plants for producing primary aluminum or mill products. Those eight states that are the exception are: Arizona, Idaho, New Mexico, North Dakota, South Dakota, Utah, Vermont and Wyoming. [1]

Figure 8, page 72; Figure 9, page 73; Figure 10, page 74; Figure 11, page 75, and Figure 12, page 76, show the location of the plants, by product, but it must be pointed out that many plants are intergrated and they produce more than one product. These locations for the products are only that, and since more than one product may be produced in a plant, it may appear that there are many plants in one location when in reality there is only one plant. Refer to Table 2, page 27, for the number of plants in the United States.

There are two factors that have made the Pacific Northwest most suitable for aluminum smelting; they are accessible to ocean

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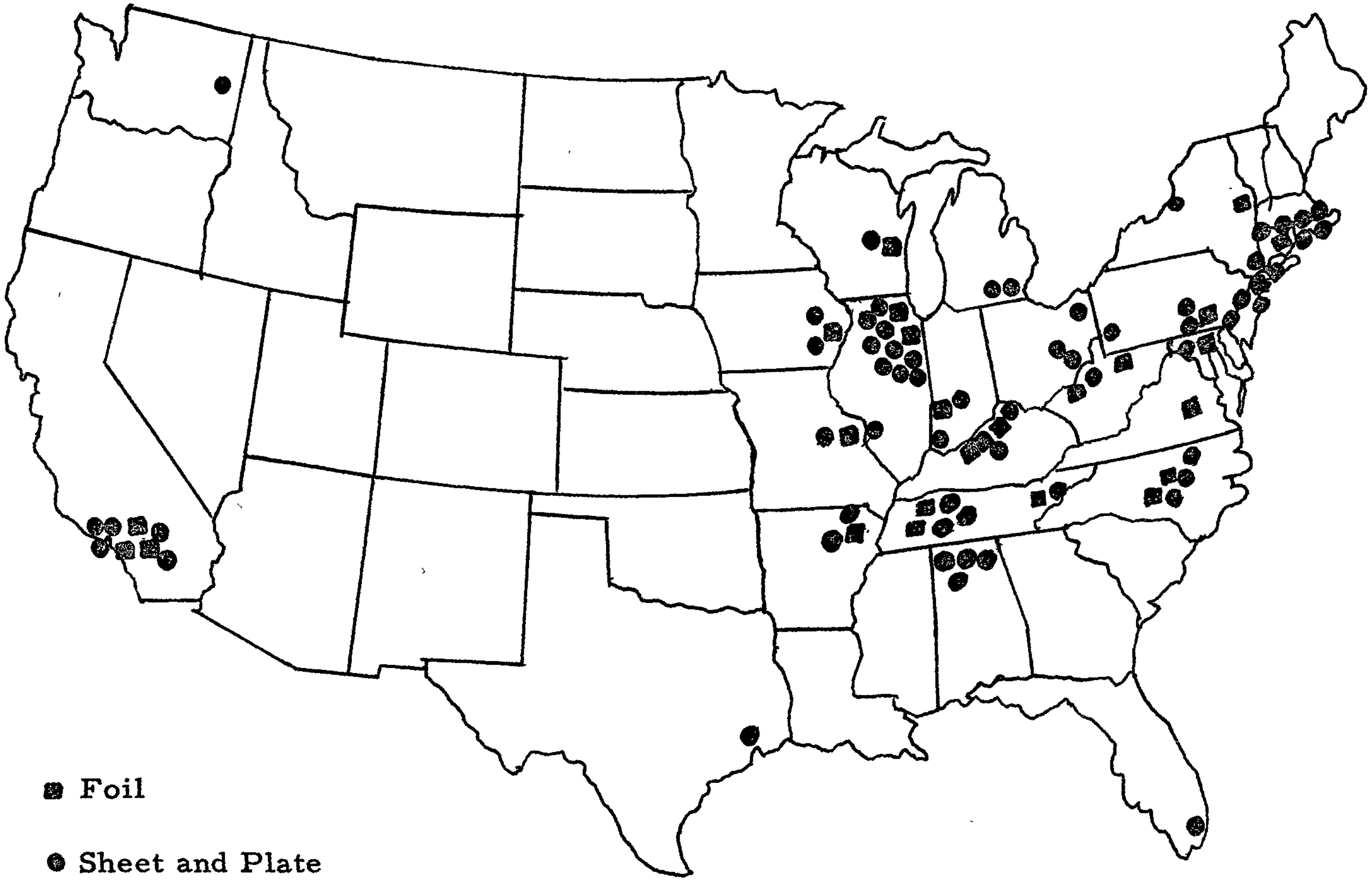
[1] The Aluminum Association, Statistical Review; 1970. pp. 8-9.

FIGURE 9

GEOGRAPHIC DISTRIBUTION OF ALUMINUM PLANTS

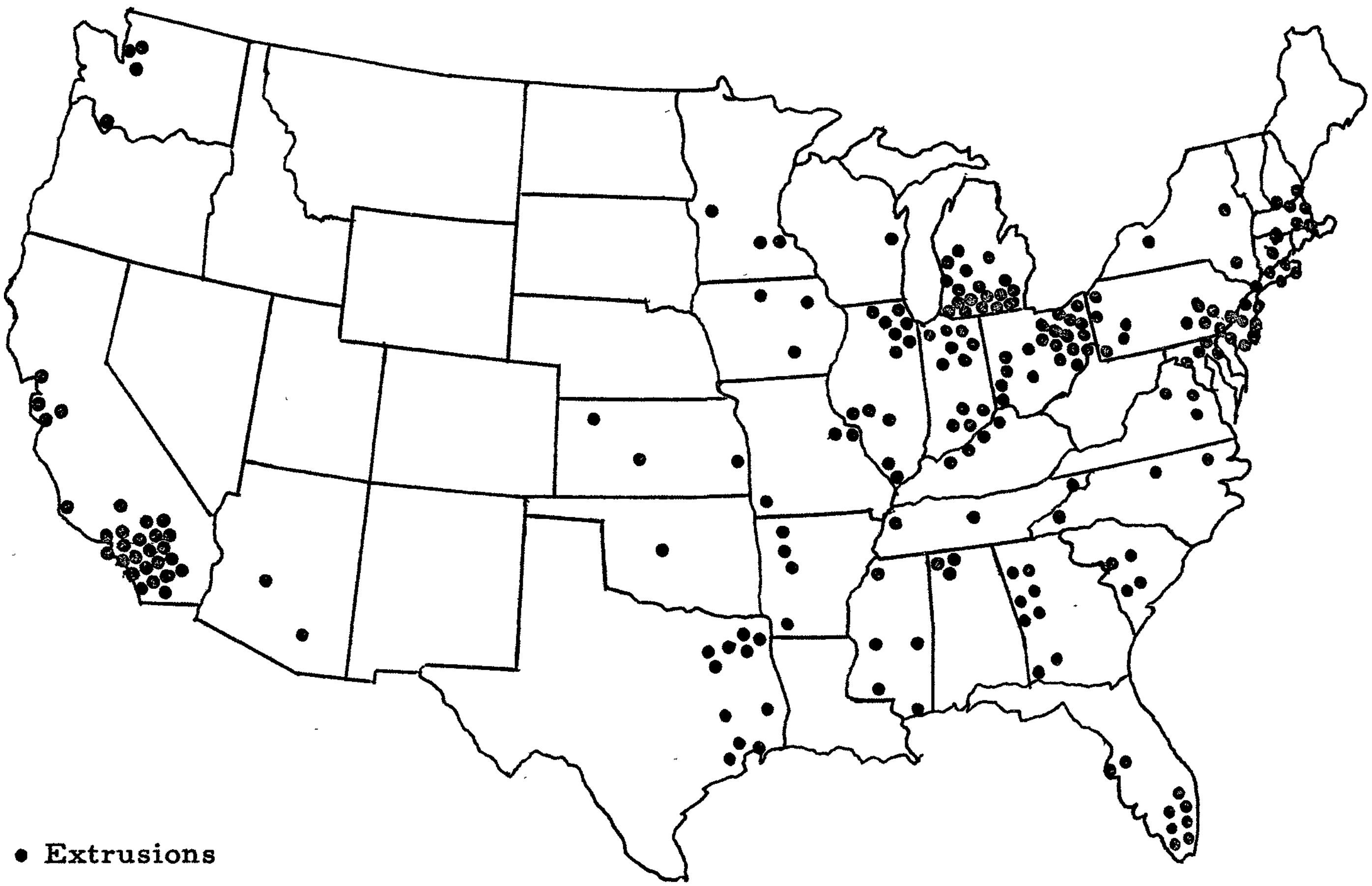
FOIL; SHEET AND PLATE



Source: The Aluminum Association, Statistical Review; 1970. pp. 9-10.

FIGURE 10

GEOGRAPHIC DISTRIBUTION OF ALUMINUM PLANTS
Extrusions

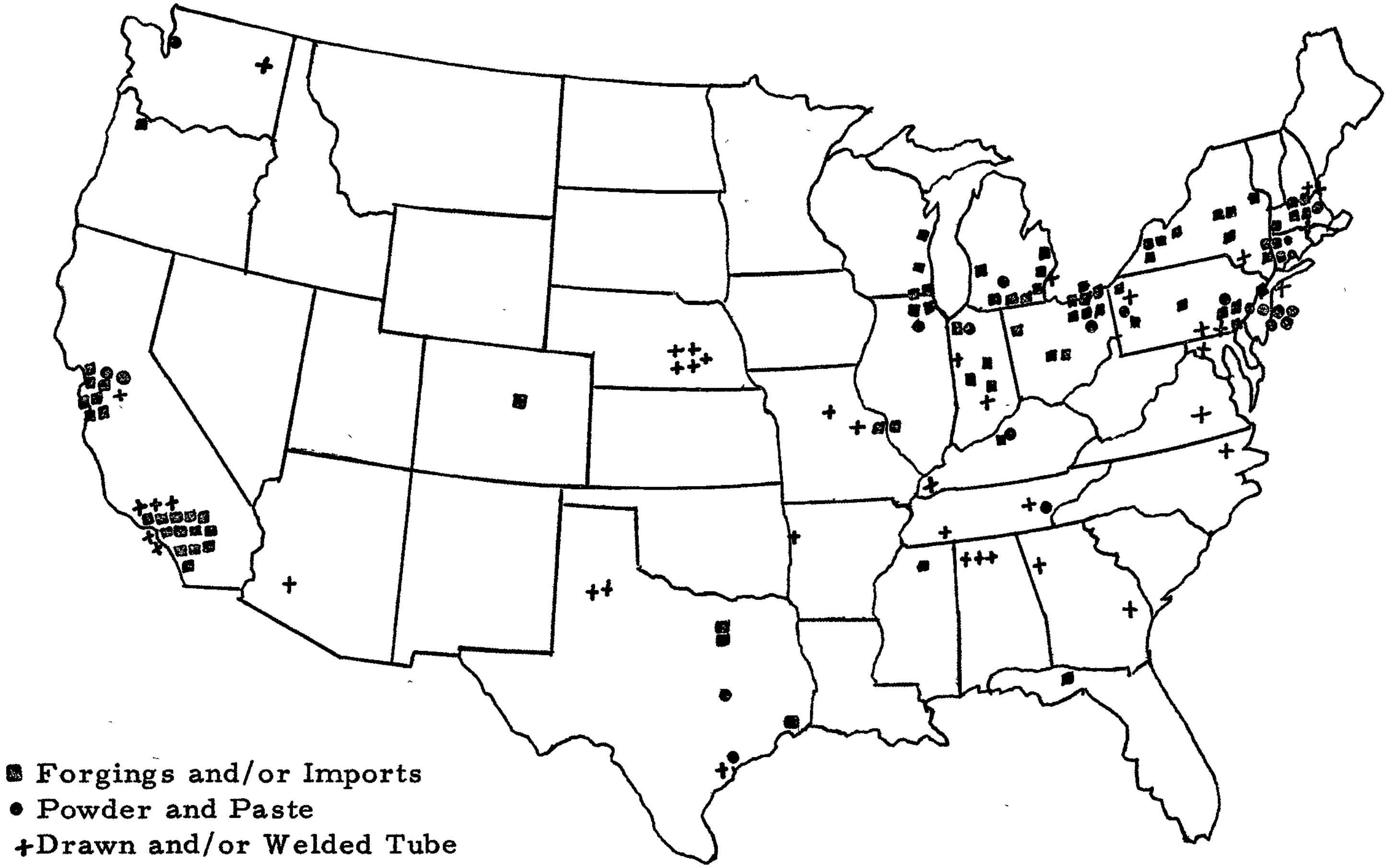


• Extrusions

Source: The Aluminum Association, Statistical Review; 1970. pp. 9-10.

FIGURE 11

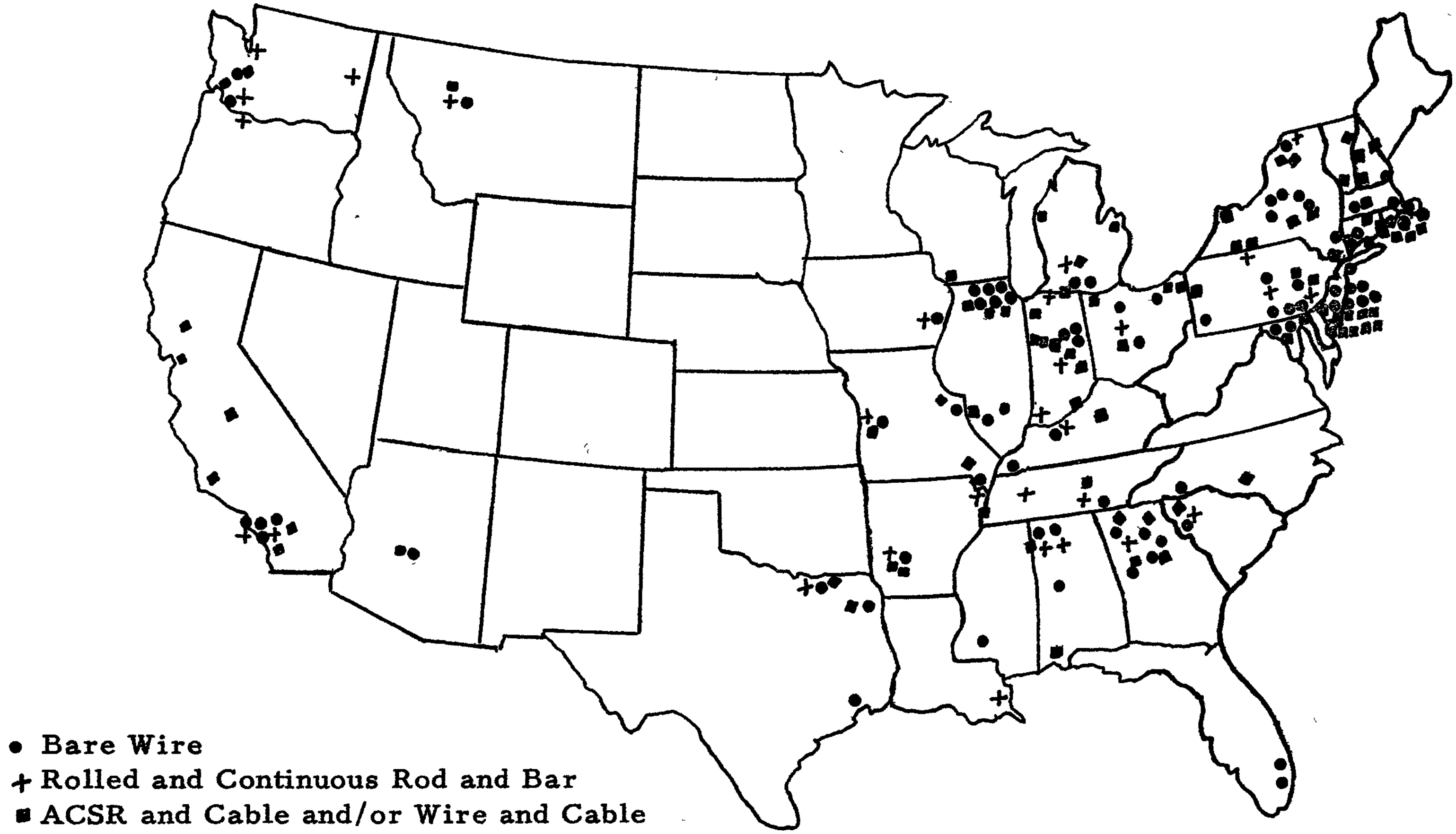
GEOGRAPHIC DISTRIBUTION OF ALUMINUM PLANTS
Forgings and/or Imports; Powder and Paste;
Drawn and/or Welded Tube



Source: The Aluminum Association, <u>Statistical Review; 1970.</u> pp. 9-10.

FIGURE 12

GEOGRAPHIC DISTRIBUTION OF ALUMINUM PLANTS
Bare Wire; Rolled and Continuous Rod and Bar;
ACSR and Cable and/or Wire and Cable



Source: The Aluminum Association, Statistical Review; 1970. pp. 9-10.

vessels bringing in the bauxite and hydroelectric power is relatively nearby.

Alderfer and Michl state that "aluminum follows power--and geographically, it is essentially a Southern and Pacific Northwest industry".[2] Basically this remains true but there has been some shift in the geographical location for many of the new plants for producing primary aluminum. In 1956 when Alderfer and Michl made the above statement there were seven primary aluminum smelters in the Pacific Northwest, nine in the South and one in the Northeast. In 1970, there were nine smelters in the Pacific Northwest, eleven in the South and seven in the North. Although the shift in the geographical location for many new smelters has been to the North, their location still follows the power source theory in that they are situated near power sources. Hydroelectric power is still the prime power source, however, some plants rely on fossil fuels: gas, coal and lignite.

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[2] Alderfer and Michl, American Industry, p. 110.

CHAPTER VI

WORLD ALUMINUM SUPPLIES

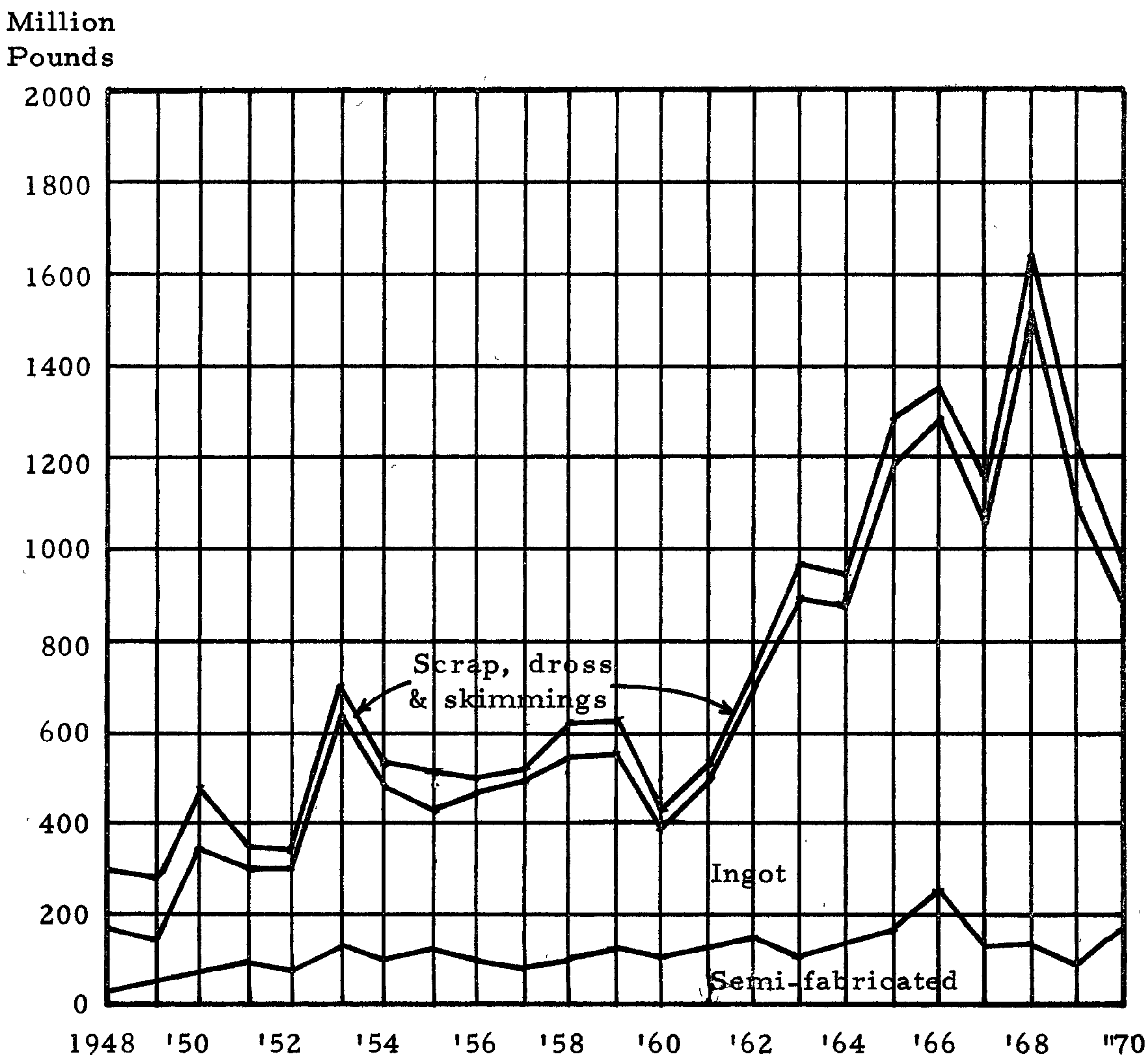
The United States has been a leader in world technology and as would be expected is a leader in the world aluminum industry. United States' imports and exports and the world production of primary aluminum by country illustrates the United States position in this world-wide industry.

United States Imports.--Figure 13, page 79, shows the United States aluminum imports of ingot, scrap, dross, skimmings and semi-fabricated products for the years 1948-1970. This graph illustrates the general trend of the United States aluminum imports. From 1948 to 1968 there have been some down cycles but the general trend has been upward to a high of slightly over 1,600 million pounds. Between 1968 and 1970 these imports have declined to under 1,000 million pounds. The 1970 figures include 115 million pounds of reimports or 11.8 per cent. Ingots accounted for 71.5 per cent of the imports while semi-fabricated products took 20.1 per cent and 8.4 per cent was scrap, dross and skimmings.

The six largest sources of United States imports for 1970 were:

FIGURE 13

UNITED STATES ALUMINUM IMPORTS



NOTE: Includes reimports in 1970.

SOURCE: The Aluminum Association, Statistical Review; 1970. pp. 44.

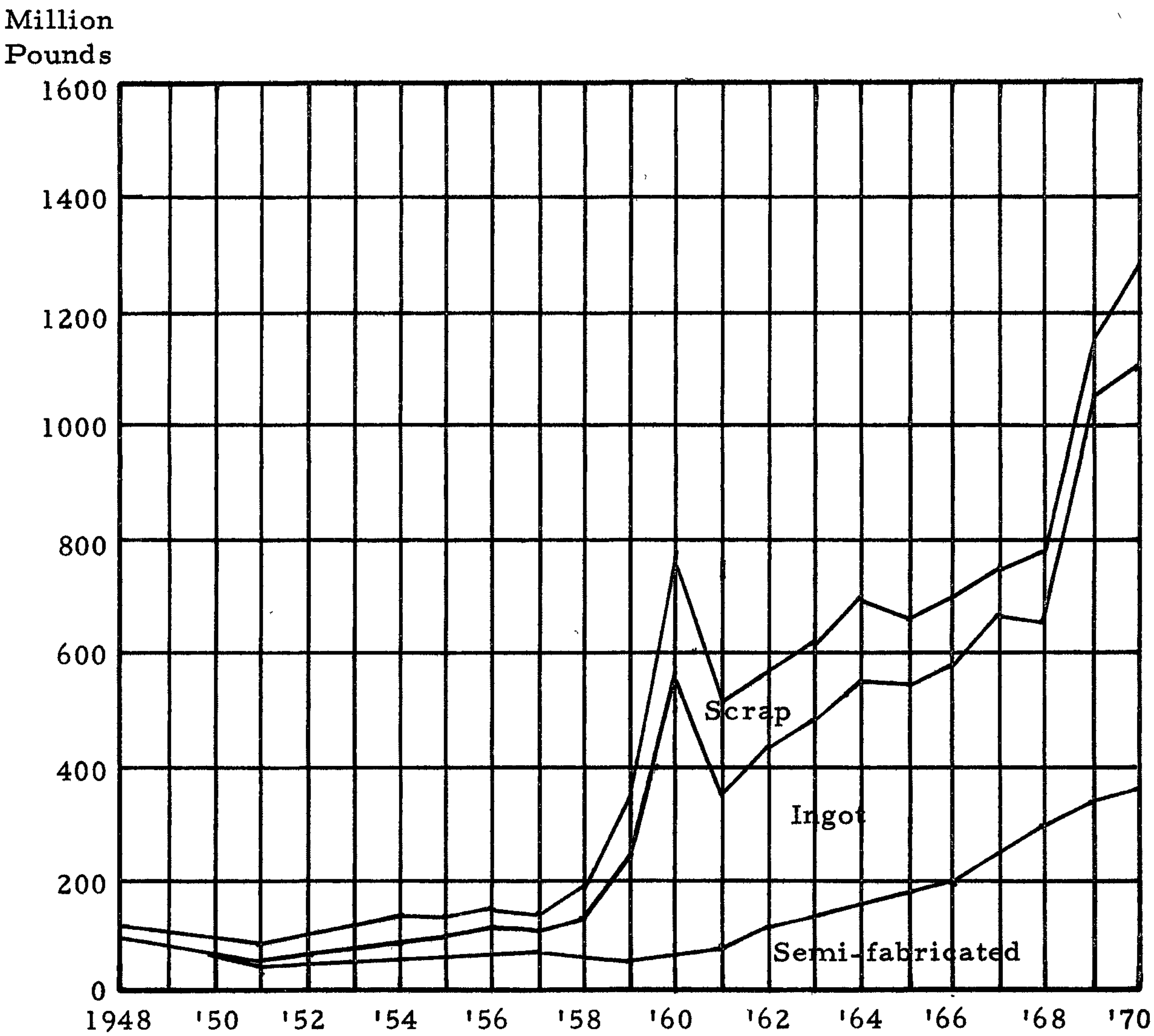
Canada, 75.0 per cent; Belgium, 5.7 per cent; Norway, 4.3 per cent; France, 3.4 per cent; Japan, 3.2 per cent and West Germany, 2.4 per cent.

United States Exports.--Figure 14, page 81, illustrates the United States exports for the years 1948-1970. As with the imports, there are some down turns but the general trend in the United States exports of aluminum products is upward and in 1970 the total exports were up to 1,276 million pounds or 8.1 per cent. Ingot aluminum accounted for 64 per cent of the exports, up 18.6 per cent in 1970 and semi-fabricated products accounted for 27 per cent, while scrap accounted for another 9 per cent. In 1970 Canada received the largest part of our exports with 15.2 per cent followed by West Germany with 13.7 per cent; Japan, 12.3 per cent; France, 11.8 per cent; Italy, 5.9 per cent and Belgium, 5.5 per cent. It should be noted that under "imports" an item listed as "reimports" and the two listings of countries verify this "exchange" of aluminum.

World Primary Aluminum Production.--The world production of aluminum rose from 4,950 thousand short tons to 10,655 thousand short tons or 115 per cent from 1960 to 1970. During this same period the United States' production rose 97 per cent. North American production accounted for 47.6 per cent of the world's total primary aluminum production.

FIGURE 14

UNITED STATES ALUMINUM EXPORTS



SOURCE: The Aluminum Association, Statistical Review; 1970. p. 45.

Table 6, pages 83 and 84, shows world primary aluminum production by country for years selected to demonstrate continued growth and competition. In 1960, there were 23 countries producing primary aluminum and in 1970 there was an increase of the countries to a total of 33 countries in production of aluminum.

U.S.S.R. led the communist countries in 1970 and accounted for 1,210,000 short tons, 11.4 per cent of the world's production. Total communist country production was 1,771,000 short tons or 16.6 per cent of the world's production.

TABLE 6

WORLD PRIMARY ALUMINUM PRODUCTION

Thousands of short tons

COUNTRY	1970p	1968r	1966	1964	1962	1960
World Total(1)	10,644	8,839r	7,583	6,553	5,580	4,950
North America--Total	5,076	4,259r	3,881	3,415	2,808	2,777
Canada	1,063	979r	890	843	690	762
United States	3,976	3,255	2,968	2,553	2,118	2,014
Mexico	37	25	22	19	--	--
South America--Total	146	102r	58	29	22	20
Brazil	63	43r	30	29	22	20
Surinam	58	48	28	--	--	--
Venezuela	25	11	--	--	--	--
Asia--Total(1)	1,172	785r	593	487	350	264
China(1)	140	100r	110	110	110	88
India	178	132	92	62	39	20
Japan	808	531r	372	293	189	147
South Korea	17	--	--	--	--	--
Taiwan	30	22	19	21	12	9
Africa--Total	183	170	54	57	58	48
Cameroon	58	50	54	57	58	48
Ghana	125	120	--	--	--	--
Oceania--Australia	225	107	101	88	18	13

TABLE 6--Continued

Thousands of short tons COUNTRY	1970p	1968r	1966	1964	1962	1960
Europe--Total(1)	3,852	3,416r	2,897	2,477	2,325	1,827
Common Market						
Countries--Total	1,003	898r	833	718	613	541
France	419	403	401	348	325	263
Germany, West	340	284r	269	242	196	186
Italy	162	157	141	127	91	92
Netherlands	82	54	22	--	--	--
European Free Trade						
Association--Total	901	800r	592	513	419	350
Austria	99	95	87	86	82	75
Norway	584	516	357	288	227	182
Sweden	73	62	32	34	18	18
Switzerland	101	85	76	71	55	44
United Kingdom	44	42	41	36	38	32
Other--Total(1)	1,948	1,718r	1,472	1,245	1,293	936
Czechoslovakia(1)	72	72	68	65	65	44
Germany, East(1)	55	55r	88	72	50	44
Greece	96	84	40	--	--	--
Hungary	73	69	67	63	58	55
Iceland	41	--	--	--	--	--
Poland (includes secondary)	109	103	61	53	53	29
Rumania(includes secondary)	112	84	52	--	--	--
Spain	127	98	70	55	46	32
U.S.S.R.(1)	1,210	1,100r	980	900	990	705
Yugoslavia	53	53	46	38	31	28

r--Revised p--Preliminary (1) Estimated by the Bureau of Mines, Department of Interior.
Detail may not add to totals due to rounding.
Source: U.S. Department of the Interior, Aluminum: Minerals Yearbook. Years Selected.

CHAPTER VII

AN OUTLINE OF STUDY FOR AN INDUSTRIAL ARTS METALS COURSE

The Aluminum Industry

Unit Objective.--A study of the Aluminum Industry including the history of the industry, the technological processes, and the way aluminum has grown into our society through production and consumer products.

I. The History of Aluminum

Objective.--to explore the history of the aluminum industry through library research and determine:

TOPIC	ACTIVITIES
A. Metals of the ancient times	A. Theories of how man may have found metals. Aluminum was not one of them.
B. Early scientist who experimented with aluminum: 1. Sir Humphry Davy	B. Make advanced assignments for students to work in pairs or teams to research these men and

2. Hans Christian Oersted
3. Frederich Wohler
4. Sainte-Claire DeVille.

C. The modern aluminum process discovered by Hall and Heroult.

D. Charles Martin Hall's work:

1. A student in Oberlin College when he became interested in aluminum.
2. Experimenting at home.
3. Discovery of the modern process.

to make a brief report to the class about their work with aluminum.

C. Similarity in life and work. Heroult's work confined to Europe.

D. For extra credit, student to read: Junius Edwards, The Immortal Woodshed, Dodd, Mead and Company, N.Y., 1955.

A condensed pamphlet giving the highlights of his life and works: Leonard M. Fanning, Charles Martin Hall, Father of the Aluminum Industry. Distributed by Aluminum Company of America, Pittsburgh, Pa.

E. The Alcoa Period.	E. Class discussion of Alcoa.
1. The founding of Alcoa.	1. Locating backers (Hunt and others), establishing the Pittsburgh Reduction Company, name changed to Alcoa in 1907. Formed on capital of $20,000.00.
2. Growth through:	2.
a. Expanding markets	a. Markets had to be made since there were none to start with. Sold aluminum wire when there were no facilities to produce it.
b. Expanding facilities	b. Show how the first small plant started and others followed. Let students do this as a

part of book reports for outside assignments.

c. Reducing the price of aluminum.

c. Show the price of aluminum for the years 1888-1941. Have students discuss the affect of this policy.

F. History of aluminum in media form.

F. A documentary film about the history of aluminum, Unfinished Rainbows, Wilding Pictures Productions, 1941. Available from Alcoa Film Library.

II. Aluminum and Our Society

Objective.--To determine how the aluminum industry has grown into and affects our society through production and consumer products.

TOPIC	ACTIVITIES
A. The Alcoa Period: 1888 through 1940:	A. Use class discussion and reports.

	1. The growth of Alcoa		1. From founding to a major industry.
	2. The growth of markets		2. From an experimentor's item to more than 4,000 applications.
	3. Competition		3. Public acceptance and competition from other metals.
	4. The monopoly question		4. Alcoa had not abused its' position as a monopoly.
	5. Price policy.		5. A policy to sell aluminum at the cheapest possible price caused the industry to grow.
B.	World War II and the 1940's:	B.	Class discussion using team assignments.
	1. The affect of World War II and the advancing technology on the industry.		1. Caused a demand for aluminum that the industry could not meet by itself.

2. Growth in producers and in production:	2.
a. Government built plants and policy	a. Government owned: Alcoa operated; to be sold, after the war, to others at a reduced price.
b. Entry of Reynolds and Kaiser Aluminum.	b. Reynolds in 1941; Kaiser in 1946.
c. Post war slump in production.	
3. Competition in the industry:	
a. Domination of Alcoa	
b. Price of aluminum.	
4. Location of the industries plants.	4. The "aluminum follows power" concept.

C. The 1950's:	C.
1. Entry of three more primary aluminum producers.	
2. Production increases.	2. Production of aluminum surpasses that of copper in 1954.
3. Competition:	3.
a. Alcoa's position in leadership	a. Although Alcoa is still the leader, its percentage of leadership is not as great.
b. More producers.	
c. With other metals.	
4. Location of the industry.	4. New areas opening in the Northwest.

D. The 1960's:

1. Entry of five more primary aluminum producers.
2. Expanding number of aluminum mills.
3. Increased production in almost all areas.
4. Effect of these increases on competition.
5. The affect of the national economy on the industry.

   5. A depressed economy resulted in a decrease in production in many areas and an inflated economy caused an increase in price of aluminum and aluminum products.

6. The location of smelters, intergraded plants and mills.

E. The United States aluminum industry in relationship to worldwide production of aluminum.	E. Discussion continued. World leader.

III. The Technology of Aluminum

Objective.--To explore and determine the basic technology of aluminum through classroom discussion, outside readings and research and laboratory experiments.

TOPIC	ACTIVITIES
A. Advantages of aluminum:	A. Laboratory experiments and class discussions.
1. Light weightness	1. Compare with steel and copper by volume. Discuss how this can be an advantage.
2. Corrosion resistant	2. Compare with other metals and discuss where this advantage is an asset.
3. Thermal conductivity.	3. Compare with other common metals.

4. Electrical conductivity.

4. Compare with other metals and discuss how aluminum can compete with copper as a conductor.

B. Aluminum in nature.

B. Discuss: never found in pure state; per cent of earth's crust that is aluminum; always alloyed with other elements.

C. Problems encountered in smelting.

C. Use a very brief discussion on the problems encountered in using direct heat or an electrolysis of an aqueous solution method.

D. The modern smelting process:

1. The Bayer process, converting bauxite into alumina.

D. A more detailed discussion using diagrams, drawings or pictures to show the steps in the process. A good simple diagram is in the pamphlet distributed by Aluminum Company of

	America: Leonard M. Fanning, <u>Charles Martin Hall, Father of the Aluminum Industry</u>.
E. Mill Processes.	E. Forgings; castings; extrusions; sheet, plate and strip; and wire. Discuss examples.
F. Laboratory experiments:	F. In addition to those listed in "A" above:
1. Castings	1. Make sand and permanent castings using aluminum. For in-depth study vary the alloy content for comparison.
2. Machine shop processes	2. Lathe and mill machine work to make useful objects.
3. Sheet metal processes	3. Riveting and bending processes.
4. Spinning processes.	4. Spin disc into bowls or other objects.

5. Craft processes	5. a. Foil for tooling pictures. b. Hand shape and design serving pieces, etc.
6. In-depth study: a. Heat-treating b. TIG welding c. Use of foils in applications	6. For advanced work use in-depth study c. Make electrical components as: transformers, electro-magnetics or coils, capacitors.
7. Field trips to plants or mills that process aluminum.	

APPENDIX

Glossary

Alcoa--the abbreviation for Aluminum Company of America. They are now synonymous.

Alumina--aluminum hydroxide, resembles powdered sugar.

Annode--a pre-baked or pressed carbon cylinder varying in size and number that is the positive (+) terminal in a cell.

A. C. S. R. Cable--aluminum conductor-steel reinforced cable used as electrical transmission line.

Bath--the molten cryolite in a pot. May contain 6-10 per cent alumina and 5 per cent calcium flouride from impurities. The operating temperature is between 950°C. to 1,000° C.

Bayer Process--a process used to convert bauxite into alumina. Developed by the German scientist, Bayer.

Bauxite--a hydrated aluminum oxide with oxides of iron, silicon, and titanium. Preferred grades contain 55 per cent or more alumina and a maximum of 7 per cent silica. Name is derived from LeBauex, France; a source of high grade bauxite.

Carbon Electrodes--the anode or cathode of a cell made from petroleum, coke or pitch.

Cathode--the pre-baked or pressed lining that is the negative pole for a cell.

Cooling Tower--a unit used in the Bayer Process; used to cool the material after it leaves the filter press.

Cryolite--a double flouride of sodium and aluminum ($3NaF. AlF_3$) contains 60 per cent sodium flouride and 40 per cent aluminum flouride by weight. A Greenland mineral of icy appearance.

Dross--the skim that forms on the molten metal.

Digester--a unit used in the Bayer Process where the materials passed from the mixer are heated with steam under pressure to dissolve the aluminum hydroxide.

Electrolytic Reduction--the process that separates a metal from its oxide. A direct electrical current is passed through the ore. The heat generated causes it to melt and the electrolytic process separates the metal from the oxygen.

Extrusion Press--a press that forces heated aluminum through a die opening to form the shape of the die.

Filter Press--a unit used in the Bayer Process that receives the materials from the mixer. Here the solid and impurities (a red mud) are filtered out.

Foil--when aluminum sheet is rolled to a thickness of .006 inch or less.

Hall's Process--the reduction of aluminum by passing a current through alumina dissolved in a bath of cryolite.

Ingot Aluminum--the basic form of primary aluminum that comes from the pot and has been treated and adjusted to a specific chemical composition. The metal is blended to the required composition, fluxed, skimmed and poured into ingot bars.

Intergrated Plant--one which contains units to refine and mill metals in a continuing process.

Mixer--a unit used in the Bayer Process where the crushed bauxite, lime, soda, ash and hot water are mixed and passed to the digester.

Pig Aluminum--aluminum as it comes from the pot and contains some dross and electrolyte.

Pot--an electrical cell used in the reduction of aluminum. It is rectangular shaped and lined with carbon that acts as the cathode.

Pot line--a row of up to one hundred pots or cells connected in series. Consumes 100,000 amps. at 5 V.D.C.

Primary Aluminum--the metal in ingot aluminum and is usually 99-99.6 per cent pure.

Rotating Calcining Kilns--used in the Bayer Process to dry the alumina; operates at 1,800° F.

Secondary Aluminum--usually scrap aluminum that may contain other elements or alloys. It is usually used to make alloys.

Seed Charge--the alumina induced in the precipitator tank to start the liquid alumina to precipitate.

Sheet--when the plate has been reduced to a thickness of .249 inches.

Washing Thickener--a unit in the Bayer Process that washes and thickens the aluminum hydroxide.

Aluminum Chronology

1886	Charles Martin Hall discovered electrolytic process for the reduction of metallic aluminum from aluminum oxide, thus making possible economic commercial production of aluminum.
1888	Pittsburgh Aluminum Company founded by Charles Martin Hall, Captain Alfred Hunt and other Pittsburgh industrialists. Name of the firm changed two weeks later to The Pittsburgh Reduction Company.
	World's first commercial aluminum ingot poured by Charles Martin Hall and Arthur Vining Davis on Thanksgiving Day, using the Hall Process.
1889	First aluminum cooking utensil (a tea kettle) manufactured.
1890	Electrical conductor (EC) grade alloys developed.
1892	Produced first rolled aluminum sheet and plate.
	Pittsburgh Reduction Company became first user of hydroelectric power for the production of primary aluminum and first industrial user of Niagara Falls hydroelectric power.
	Small, aluminum portable boat used on expedition into Egypt's Nile Valley.
1894	Aluminum parts for bicycle frames. First use of aluminum pigments in paint.

1895 First commercial installation of electrical bus bar made of aluminum.

First dividend paid to Pittsburgh Reduction Company's shareholders.

First aluminum pleasure boat.

1896 Aluminum canteens and tent pegs first used by the U.S. Army.

1897 Aluminum wire first used as electrical conductor.

First architectural use of aluminum sheet on roof cupola of the St. Gioacchino Church in Rome.

1898 Aluminum conductor first used in overland electric power transmission line.

First aluminum jar closures.

1901 Aluminum sheet used in automobile bodies.

The Aluminum Cooking Utensil Company organized as a wholly owned subsidiary of Alcoa, to manufacture "Wear-Ever" cookware.

1903 Supplied aluminum parts for use in the Wright Brothers' airplane.

1904 First aluminum extruded shape produced.

1905 Panels made of aluminum sheet first used on street cars.

1906 First commercial production of cast aluminum parts for automobile engines.

1907 The Pittsburgh Reduction Company renamed Aluminum Company of America (Alcoa).

1909 Development of ACSR (aluminum conductor, steel reinforced) for high voltage transmission lines.

1910 Aluminum foil rolled commercially for the first time.

Introduction of aluminum paint for commercial use.

1913 First commercial use of foil packaging.

1915 Aluminum permanent mold automobile pistons introduced.

1916 Heat-treatable aluminum alloys for wrought applications developed.

1917 Extensive use of aluminum castings in famous Liberty engine for World War I military aircraft.

1918 Establishment of Alcoa's formal aluminum research organization, now known as Alcoa Research Laboratories.

1919 First use of aluminum sheet for airplane fuselage and wing skin.

Heat-treatable aluminum alloys for forgings and sheet developed.

1920 Introduction of aluminum collapsible tubes.

1921 First aluminum-skinned airplane, CO-1 observation aircraft.

1922 Aluminum furniture first manufactured.

1923 Patent filed by Alcoa Research Laboratories for coloring aluminum by using dyes with anodized coatings.

High-strength aluminum alloys first used in structural members of railroad rolling stock.

1925 Aluminum Company of America reincorporated by merger with Canadian Manufacturing and Development Company.

Aluminum foil insulation introduced.

1926 Alclad sheet developed, using a dissimilar aluminum alloy cladding on aluminum for superior resistance to corrosion.

1927 Aluminum truck bodies developed.

1928 Color anoidized finishing introduced commercially by a U.S. processor.

1929 Large, rolled structural aluminum shapes made commercially available.

Anodized aluminum spandrels first used, on the Koppers Building in Pittsburgh, Pennsylvannia.

1930 First extensive use of aluminum in architectural applications. Empire State Building, New York City, New York.

First aluminum curtain wall, A. O. Smith Building, Milwaukee, Wisconsin.

1931 Development of aluminum copper alloy 2024 with substantially greater strength than Duralumin (the widely used German aircraft alloy). The new alloy became the primary aircraft material during World War II.

Introduced the sealing process for anodic coatings.

1932 Aluminum household foil introduced.

1934 Aluminum used extensively in first streamlined train in the U.S.

1935 Development of DC (Direct Chill) ingot casting process.

1942 Development of Alcoa Combination Process for production of alumina from low-grade bauxite ore.

Natural gas first used as fuel for generating electric power to produce primary aluminum.

Beginning of Alcoa wartime program to build and operate over 20 aluminum smelters and fabricating plants for the U.S. Government.

1951 Inert gas, shielded arc welding introduced for aluminum alloys.

1953 First use of solid fuel (lignite) in U.S. to generate power for an aluminum smelter.

Completion of 30-story Alcoa Building in Pittsburgh, first multi-story office building with aluminum curtain wall.

Brazed aluminum automobile radiator successfully fabricated.

1959 Ballistic aluminum armor plate for military vehicles.

Ultrasonic welding of aluminum introduced.

1960 Aluminum radiator first used on mass-produced U.S. automobile (Corvette sports car).

Introduction of aluminum strip conductor for use as secondary windings on distribution transformers.

Introduction of the "composite" rigid aluminum container, utilizing a foil-fiber can body and aluminum ends.

Development of aluminum easy-open can end.

1962 Installed industry's first continuous heat-treating line for high-strength aluminum sheet.

1964 Powder-metallurgy forged pistons.

New fluxless aluminum-alloy brazing process.

Heat-treated forged aluminum armor, permitting design of more efficient military vehicles with rounded contours.

1965 Adhesive-bonded highway sign system.

Air-formed foil products.

1966 Safe impact sign structure.

Flame soldering for heat-exchanger coils.

1967 First extensive use of "air-expanded" electrical conductor for EHV overhead transmission lines.

Hot batch dip method (Alvanize process) for coating of ferrous parts with aluminum.

1969 Began operation of world's largest primary aluminum potline, 100,000 tons a year at Alcoa, Tennessee.[1]

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[1]Alcoa, Facts About Alcoa. pp. 14-15.

BIBLIOGRAPHY

Alderfer, E. B., and Michl, H. E. Economics of American Industry. 3rd ed. New York: McGraw-Hill Book Company, Inc., 1959.

Aluminum Company of America. A Brief Story of Aluminum and Alcoa. Pittsburgh: Aluminum Company of America, n. d.

Aluminum Company of America. Facts About Alcoa. Pittsburgh: Aluminum Company of America, 1968.

Aluminum Company of America. Facts About Alcoa. Pittsburgh: Aluminum Company of America, 1971.

Ballard, John R., and Williamson, M. D. "Texas Industrial Arts Curriculum Study, Six-Phased Interdisciplinary Study." A study prepared for the Texas Industrial Arts Association, 1971.

Carr, Charles C. Alcoa: An American Enterprise. New York: Rinehart & Co., Inc., 1952.

Cochran, Leslie H. "Charting the Changing Directions of Industrial Arts." School Shop, October, 1969.

Cowles, Alfred. The True Story of Aluminum. Chicago: Henry Regnery Company, 1958.

Edwards, Junius. The Immortal Woodshed. New York: Dodd, Mead and Company, 1955.

Face, Wesley L., and Flug, Eugene R. "A Conceptual Approach to the Study of American Industry." Approaches and Procedures. Fourteenth Yearbook of the American Council on Industrial Arts Teacher Education. Bloomington, Ill.: McKnight & McKnight Publishing Company, 1965.

Fanning, Leonard M. Charles Martin Hall, Father of the Aluminum Industry. New York: The Mercer Publishing Company, 1956.

Feirer, John L. General Metals. 2nd ed. New York: McGraw-Hill Book Company, Inc., 1959.

Hartung, A. Bruce. "We've Crossed Our Rubicon." The Journal of Industrial Arts Education, (April, 1970).

Kabakjian, Edward. "Change; The Unchangeable Law of Progress." Man/Society/Technology, April, 1971.

Maley, Donald. "Industrial Arts--A Study of Industry and Technology of Contemporary Man." Industrial Arts and Technology--Past, Present, and Future. AIAA Convention Proceedings. Washington, D.C.: American Industrial Arts Association, 1967.

Maley, Donald. "How Industrial Arts Relates to Occupational Education." Industrial Arts and Vocational Education, February, 1970.

Marcosson, Isaac F. Anaconda. New York: Dodd, Mead & Company, 1957.

Marlcuit, Stanley V. The Aluminum Industry. Boston: Bellman Publishing Co., Inc., 1946.

Metals Week. Aluminum--Profile of an Industry. New York: Metals Week, 1971.

Miller, Rex and Smalley, Lee H. Selected Readings for Industrial Arts. Bloomington, Ill.: McKnight & McKnight Publishing Company, 1963.

Olson, Delmar W. Industrial Arts and Technology. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1963.

Texas Education Agency. Principles and Standards for Accrediting Elementary and Secondary Schools and Description of Approved Courses, Grades 7-12. Austin, Tex.: Texas Education Agency. Bulletin 615.

The Aluminum Association. Aluminum Statistical Review; 1967. New York: The Aluminum Association, 1968.

The Aluminum Association. Aluminum Statistical Review; 1970. New York: The Aluminum Association, 1971.

U.S. Department of Commerce. Materials Survey: Aluminum. Washington, D.C.: Government Printing Office, 1956.

U.S. Department of Commerce, Business and Defense Services Adminstration. U.S. Industrial Outlook--1971. Washington, D.C.: Government Printing Office, 1972.

U.S. Department of Health, Education and Welfare. Improving Industrial Arts Teaching: A Call to the Profession, by Marshall Schmitt. O.E. 33022, Circular No. 656. Washington, D.C.: Government Printing Office, 1960.

U.S. Department of Health, Education and Welfare. Industrial Arts Education: A Survey of Program, Teachers and Curriculum, by Marshall Schmitt and Albert L. Pelley. O.E. 33038, Circular No. 791. Washington, D.C.: Government Printing Office, 1965.

U.S. Department of Health, Education and Welfare, Planning and Designing Functional Facilities for Industrial Arts Education, by Marshall Schmitt and James L. Taylor, O.E. 51015. Washington, D.C.: Government Printing Office, 1968.

U.S. Department of Interior. Aluminum: Reprint from the Bureau of Mines Yearbook, selected years (Washington, D.C.: Government Printing Office, selected years.

Wilber, Gordon O. Industrial Arts in General Education. 2nd ed. Scranton, Pa.: International Textbook Company, 1954.

Wilber, Gordon O., and Pendered, Norman C. Industrial Arts in General Education. 3rd ed. Scranton, Pa.: International Textbook Company, 1967.

Woodward, Robert L. "High School Industrial Arts Teachers' Problems." Industrial Arts and Vocational Education, September, 1967.