an initial rapid utilization of CO_2, followed by a slower loss of radioactivity. Apparently at least two enzymic reactions are present, one involving the uptake and the second the release of carbon dioxide.

A further simplification of the CO_2 utilizing system can be effected by using an acetone powder of pigeon liver as the starting material. This source is the most promising we have obtained for study of the initial carbon fixation reaction. Extraction of acetone dried minced pigeon liver with water or with buffered solutions yields upon centrifugation a deep-red, cell-free supernatant which shows active CO_2 uptake. In such extracts, with increasing time there is a steady increase in the amount of CO_2 taken up and it appears that the reactions leading to the release of radioactive CO_2 are either absent or inhibited. Both fumaric and pyruvic acids are necessary for the complete activity of these extracts. There is an increase in the amount of carbon dioxide utilized with increasing quantities of pyruvic acid, and we are undoubtedly concerned with a reaction involving both CO_2 and pyruvate. At intervals during the reaction we have tested for the formation of oxaloacetic acid. The results, however, were entirely negative and if oxaloacetic acid is formed during the process of pyruvate utilization by these extracts, its existence must be extremely transitory and at concentrations below those we can detect by present methods. The utilization of CO_2 proceeds to the same extent in nitrogen and carbon dioxide as in the presence of O_2 and CO_2.

When pyruvate is added to these extracts under anaerobic conditions, a slow production of CO_2 can be observed. Whether this reaction is involved in the fixation of CO_2 remains open to further investigation, but in itself it is of interest since it constitutes an example of anaerobic decarboxylation of pyruvic acid by animal tissues. The preparation of an enzyme from pig heart muscle capable of effecting the anaerobic decarboxylation of pyruvic acid was described in 1941 by Green *et al.*[24] Pigeon liver extract apparently contains a second enzyme of this type, although, unlike the pig-heart-muscle enzyme, acetyl methyl carbinol is not formed as the reaction product.

These cell-free extracts, then, readily utilize CO_2 from pigeon liver. They show increased utilization of CO_2 on the addition of pyruvic acid and of fumaric acid. The reaction proceeds anaerobically and there is no evidence of the accumulation of oxaloacetic acid.

I may be excused for presenting this brief summary of our preliminary experiments with cell-free extracts on the ground that they open the way to a purely chemical approach to the problem. It is to be hoped that the characterization and isolation of the components of such extracts will resolve the mechanism of CO_2 utilization in animal cells. The clarification that this may afford our knowledge of carbohydrate metabolism, and of the mechanism of carbon dioxide reduction in photosynthesis serves as both a stimulus and a goal.

It is necessary to modify our former ideas which contrasted the synthesis of organic molecules from CO_2 in plants to the uni-directional reverse breakdown of these molecules to CO_2 in the animal world. Rather, it is necessary to believe that the fixation and reduction of CO_2 may be as biologically important in the animal cell as it is in the plant.

THE RECENT EXPANSION OF THE ALUMINUM INDUSTRY[1]

By T. D. JOLLY

THE ALUMINUM COMPANY OF AMERICA

UNDER present conditions, most of us have our noses so firmly pressed against our own grindstones that our range of vision doesn't extend much beyond our own jobs.

Because this is true in my own case, this will not be a scientific address on proper methods to be followed in purchasing for construction in war times, but simply a recital of our experience during the past two or three troublesome years—in other words, a case history of expansions in the aluminum industry and, in particular, in Aluminum Company of America.

Two months after the Munich conference of 1938, the company initiated a study of its ability to meet any demand which might come from Britain or France, should war suddenly break out. A six-man committee, representing various departments within the company, was appointed. That committee made frequent reports to the management as conditions changed throughout 1939. Based on these reports, and disregarding both the large stock of aluminum on hand and the apparent small requirements of the armed forces of this country, the company inaugurated an expansion program which, with the additions since made to it, calls for a capital expenditure of

[1] Address delivered before the convention of the National Association of Purchasing Agents, Waldorf-Astoria, New York, May 26, 1942.

[24] D. E. Green, W. W. Westerfeld, B. Vennesland and W. E. Knox., *J. B. C.*, 140: 683, 1941.

about $250,000,000 of the company's money. This expansion is now substantially completed.

On February 12, 1940, the Russo-German economic treaty was signed, and on March the eighth we started construction of a plant to produce 30 million pounds of aluminum ingot per year. A month later, Germany invaded Denmark, and on April 16, 1940, we decided to increase our new plant to 60 million pounds capacity.

On September 1, 1940, our National Guard units mobilized, and on the third the Navy Department announced the transfer of 50 United States over-age destroyers to Britain in exchange for air bases; while on September 14 the compulsory draft bill passed. With the United States embarked on a defense program, we again increased the size of the new plant—this time to 160 million pounds capacity.

Other aluminum metal-producing plants were expanded to the limit of the power available, and two new hydro-electric power developments were started. Mining operations, ore refining and fabricating facilities kept pace with these increases and continued to expand as the defense program developed. But both funds and credit of any privately owned industry are limited, and by midsummer of 1941 it was quite obvious that no company could finance the full requirement of aluminum.

On August 19, 1941, we signed a contract with Defense Plant Corporation to design and construct at cost, but without fee or profit to the company, one ore-refining plant and three aluminum metal-producing plants. By a supplemental agreement of December 12, 1941, we agreed to build two additional metal-producing plants.

Months before any contracts were signed, we became convinced in our own minds that these additional government aluminum plants would have to be built and that we would have to build some of them. Accordingly we obligated the company for something over $16,000,000 worth of equipment to be used in their construction. This enabled us to save many weeks, and two of the metal-producing plants are now in operation; three others will come along in the very near future.

We have now started on a new program for Defense Plant Corporation. Censorship rules do not permit us to disclose the type, capacity or location of new plants, but we can say that we are building, for Defense Plant Corporation, a total of fifteen plants and that they are located in eight states.

With our own program, this gives us a total of thirty-five major projects now under way. These bring our total acreage of floor space put under roof since January 1, 1940, to 335 acres.

By May 2 of this year, we had placed 108 subcontracts for Defense Plant Corporation, only eight of which were negotiated. Four hundred bids were obtained for the hundred competitively awarded contracts, and of course there are still quite a few not closed. On May 2 we had 7,920 men engaged directly on construction and had placed 17,500 purchase orders.

Summing up: By the end of 1943, the United States production of aluminum will be approximately 2,100,000,000 pounds—six and one-half times its 1939 production. Each of several of the new plants will produce more aluminum than the entire nation made at its World War I peak—and still there will not be a pound available for civilian use.

How much is 2,100,000,000 pounds of aluminum? It is sufficient to rebuild every railroad passenger car in the United States three times a year. Or it could be utilized, were we not at war, to put a 30-piece cooking utensil set in every one of America's 34,000,000 homes, with enough metal left over to make 5,000,000 miles of aluminum transmission cable of the type used in 1936 to 1940 for the electrification of rural America.

It might help to understand the purchasing problems involved if we rather briefly review the processes employed in the production of aluminum.

We start with a mineral called bauxite, which contains about 55 per cent. aluminum oxide and less than 7 per cent. silica. The bauxite is ground to a fine powder and digested in a hot caustic solution under pressure. The aluminum hydrate is dissolved in the hot caustic liquor and passes with it through a filter press, leaving the balance of the bauxite, commonly called red mud, to go to waste disposal. The liquor is then cooled and passes into large tanks, where aluminum hydrate is precipitated. This is washed, to remove soda, thickened, then calcined and shipped to the reduction plants as alumina. This ore-refining process requires large quantities of pure water, steam, soda ash and lime, as well as two pounds of bauxite for each pound of alumina produced.

The alumina, or aluminum oxide, is reduced to metallic aluminum in the metal-producing plants in long rows of electrolytic cells. The cell consists of a steel shell lined with carbon, which serves as the cathode. Electricity is led into each cell through carbon anodes suspended from above the cells on overhead busbars.

In the operation of the cell, the aluminum oxide, dissolved in a bath of molten cryolite, is decomposed by the passage of the electric current. Cryolite is found in commercial quantities only in far-away Greenland; however, we have facilities in this country for making a synthetic material which is the chemical equivalent of natural cryolite, and we can use either in the production of aluminum. At the present time, additional electrolyte plants are being built so that we will be entirely independent of Greenland cryolite.

The cryolite bath material is first introduced into the cell. When it has been melted by the electric current, the alumina is added to the bath and dissolved in it. The low voltage direct current separates the aluminium oxide into aluminum and oxygen. The oxygen liberated during the reaction combines with the carbon anode to form gas, which escapes, while the aluminum is deposited on the bottom of the cell where it remains as a molten layer until tapped off. When the bath becomes exhausted in alumina, more alumina is added and the cycle of operation is repeated.

In the production of one pound of aluminum, two pounds of alumina—made from four pounds of bauxite—are consumed. In addition, ten kilowatt-hours of electricity are required to separate the aluminum from the oxygen, and three quarters of a pound of carbon electrode is burned. In fact, if we take into account all the materials used in the different steps, from the mining of the ore to the manufacture of metallic aluminum, it will be found that nine pounds of raw material are required to make one pound of aluminum.

Carbon electrodes are an important item. They are made by forming a hot mixture of coal-tar pitch and calcined petroleum coke in molds under hydraulic pressure. These electrodes must then be baked to remove the volatiles from the binding material, and after cleaning they are ready for use. Such large quantities of carbon electrodes are consumed in the aluminum industry that it is necessary to provide facilities for their manufacture to supply the metal-producing plants.

The major item of consideration is, of course, electricity. To produce the 2,100,000,000 pounds of aluminum will require annually more electricity than was consumed in 1940 in 27 of the 48 states. Yes, the aluminum industry in one *day* will draw more current than a city of 60,000 homes consumes in one *year*.

This large amount of electricity means considerable planning and investment in power developments. Power comes from three sources: (1) company-owned hydro plants; (2) government-owned hydro plants; and (3) from steam and hydro plants of privately owned public utilities. For every dollar we have invested in plant and equipment at our large Tennessee Works, there is another dollar invested in the mountains in hydro plants. In addition, we are drawing from TVA there as well.

It is interesting to look back and see how conditions and purchasing problems have changed in the comparatively short time we have been engaged in this expansion program. It started before we even thought of serious shortages of materials; then came the defense program and voluntary priorities on some materials. Then, as defense plans developed, so did mandatory priorities. And I might add, we can well appreciate the meaning of priorities, since the aluminum industry was the first to be placed on priorities! Then came allocations, restrictions and prohibitions on the use of materials, and frozen price levels.

In the case of our company expansion program, it was cheaper and quicker to expand existing plants and, where possible, build new plants near old ones in order to utilize the supervision and experience of our existing personnel in developing new operating organizations. We are building to-day an aluminum industry seven times the size of our peacetime industry and that spreads our personnel pretty thin.

The first Defense Plant Corporation sites were selected four to six months before Pearl Harbor. OPM recommended the locations after a study of markets, source of raw material, power and labor. The actual sites were selected on the basis of accessibility, foundation conditions and surroundings.

Because of the enormous quantity of power required and the shortage of materials, it has been necessary to locate the new plants so as to consume the least possible amount of copper in transmission lines. This reverses the old theory of locating aluminum plants in sparsely settled areas where a plentiful supply of power is available at low prices because there are few if any customers. Under present conditions, there is a greater amount of power available in the large metropolitan districts than in any other.

Since it has been officially announced, it is all right to say that the largest aluminum metal-producing plant in the country is now under construction about ten minutes by automobile from this hotel (Waldorf-Astoria, New York City). A unique feature of this plant will be its pure silver busbar and silver-wound transformers. The Conservation Branch of WPB solved our copper purchasing problem by arranging this substitution.

The government-owned metal-producing plants require about 36,000 tons of copper busbar. If we add the requirements for light and power wiring, motors and other miscellaneous uses, this becomes entirely too much copper for these days of heavy military demand. On the new program, the United States Treasury will loan DPC silver from the vaults at West Point. It will be fabricated by the copper companies and shipped to us ready to install. Present plans call for the use of about 13,000 tons for heavy busbar. At the end of the emergency it is to be returned to the Treasury.

Before we started building for the government, we decided that it would be necessary to standardize buildings and equipment as much as possible in order to complete our construction and obtain production as soon as possible. This has paid big dividends, not only on our work, but has spread out and benefited many people who never heard of us. For example, we have purchased from one crane manufacturer since January 1, 1940, one hundred and seventy-five cranes, all of the same span and capacity. The only change in specifications for these cranes was on a few motors, which had to be 50 cycle. The crane builder was able to set up a production line system and claims 50 per cent. more efficiency than if he had the shop filled with miscellaneous specification cranes. The foundries supplying castings and all the other suppliers were able to produce more because of the duplication.

We had 72 buildings from the same shop drawings and many other duplications, but the most interesting one is in one of the powerhouses. At this plant, we were being supplied with natural gas at a very low price. No amount of standardization will obtain quick delivery of 35,000-kw. steam-driven turbo-generators. We were to be supplied with temporary power until we could get a steam power station in operation, but because of the long delivery on steam power equipment and the need for a quick source of power, other arrangements had to be made.

We are installing 60 gas engines, each driving a 750-kw. generator, and 18 equipped with 2,250-kw. generators. These are direct current generators and the power is transmitted directly to the production line. The conventional procedure is to convert A.C. to D.C. by means of mercury arc rectifiers. The elimination of this equipment makes the price of the gas-engine power compare favorably with that from other sources, and with low-priced gas we believe it will be a very economical installation, in spite of the large number of units required.

Every operation required for each construction job is scheduled before the job is started. This requires careful planning to have each unit arrive at the proper time for installation when needed. The aluminum reduction plants can not operate without alumina, carbon electrodes or electrolyte. As we are building plants to produce all three of these, the three types of plants must be kept in step in order to obtain the maximum aluminum production.

To correlate the efforts of the purchasing, engineering and construction departments to keep their jobs on schedule, we have set up a coordinating department in the general office. This department has copies of all schedules, purchase orders and weekly construction reports. In each of our sales offices we have selected a veteran salesman as a regional coordinator, and he has available to him, on a first demand duty basis, the services of each of the other salesmen in his office. This gives us speedy person-to-person contact with our suppliers.

The coordinator's office does not assume the prerogatives and responsibilities of the purchasing department. It merely acts for the responsible buyer and relieves him from the duty of following up his purchases. It works with the general construction superintendent to have needed materials and equipment on the job when required.

This is not an expediting department. It is not its job to worry suppliers into making shipments. Its duty is to help suppliers obtain materials from their suppliers, and sometimes the suppliers of their suppliers. It is a cooperative organization and no small part of its work is with the priority division.

At first our priority certificates were handled through one man. This was more or less a spare-time job, but as the number of forms and reports increased, so did the priority division, until at present it consists of sixteen employees. In addition to handling our own priority problems, this division is ready and anxious to render any possible assistance to our suppliers.

I was drafted by the committee, over my protest, to fill this space on the program. In these days of censorship, it is hard to make a story interesting, and with priorities, allocations and prohibited uses of materials, it is difficult to give any information regarding purchasing for construction which would be of value to a purchasing agent. If I have stressed what my own organization is doing to the point where it may seem boastful, my apologies for wasting your time.

There is, however, one thought I would like to leave with you. Aside from our operating expenditures, we will have spent for construction from January 1, 1940, to the middle of 1943, just about 600 million dollars. We have not yet been seriously behind schedule and have been ahead in some cases. No organization the size of ours could have handled this work without the cooperation of every one connected with it. Engineering, purchasing, construction, operating, coordinating and priority divisions all feel that it is their job. Every one from the blueprint boy up is anxious to see the schedules kept and takes personal pride in beating them. We have always had a purchasing policy of fair treatment to suppliers, and it is paying big dividends under to-day's rather difficult conditions, as some of our suppliers are as anxious as we are to keep our jobs up to date.