Appendix B

“Muscle Shoals”

The Kansas Engineer

THE KANSAS ENGINEER

VOL. X. January, 1925 No. 4

Muscle Shoals

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IN addition to the military engineering functions allotted to the Corps of Engineers, U. S. Army, there are certain civil engineering projects with which this branch of the army is charged by Congress.

In the past there. may be listed among such projects the lay-out and construction of some of the first railroads in America, the Panama Canal, the Alaskan railroad and all the major river and harbor improvement throughout this country. At present, river and harbor improvement constitutes most of the civil engineering work of this corps. The hydraulic development at Muscle Seals on the Tennessee river is an instance of this class of work.

The Muscle Shoals project is a culmination of three important situations: first, the shortage of nitrates in this country; second, the necessity for improvement of the Tennessee river for navigation; third, hydro-electric development. We shall consider each of these contributing factors in order.

NITRATES

Nitrogen, forming four-fifths of our atmosphere is one of the commonest elements in our daily life. However, it is of little value in its pure state and is valuable only in the form of its chemical compounds such as nitrates. Vegetable life, and consequently human life, cannot exist without them.

In explosives, the same situation relative to the need of nitrates exists. Nitrogen in some of its chemical compounds is an essential constituent of almost every explosive necessary in warfare. Regardless of "the millions of men, who" to quote William Jennings Bryan "will spring to arms overnight," if there are no arms, explosives or equipment with which to arm, train and equip, they would be helpless under a swift attack by any modern European or Asiatic power.

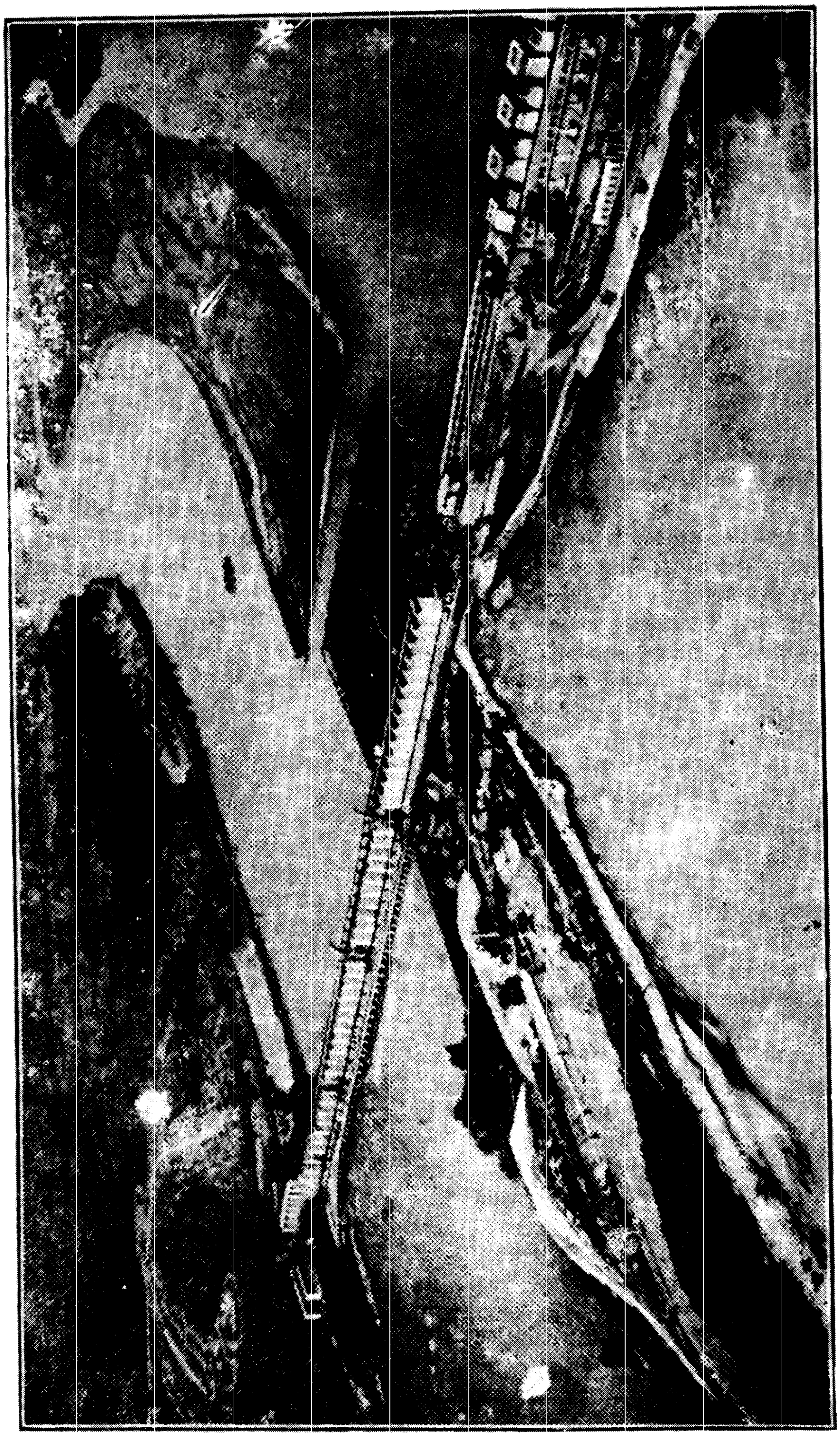
Before the construction 01 l-J. S. Nitrate Plants Nos. 1 and 2 at Sheffield, Alabama, close to Muscle Shoals, our nation was dependent on a foreign country for its supply of nitrates. In the northern part of Chile, lie vast fields of sodium nitrate upon which we have depended for our nitrate supply. This meant that in the event of war with a superior naval power or with a power conducting a ruthless submarine campaign, our freighters and transports would be cut off from communication with Chile and our supply of nitrates would cease. Without nitrates, our surrender would be but a matter of time. Nitrogen may be obtained in the form of ammonia and ammonia sulphate as a by-product in the process of making coke or gas. However, it would not be feasible to construct and hold in times of peace the additional coke ovens necessary to furnish sufficient nitrates for war requirements. Animal and vegetable refuse furnishes another source for nitrates but in insufficient quantities. It is better adapted for agricultural demand as a fertilizer.

There are at present three commercial processes for the obtaining of nitrogen compounds.

The arc process burns the nitrogen in the air by using a number of large electric arcs in an air current, thereby forming the base for nitric acid. A great quantity of cheap electric power is required to make this process commercially practical.

The Haber process, which was Germany's salvation in the World War, consists of the uniting of nitrogen and hydrogen under very high temperatures and pressures to form ammonia. This is the process used in Nitrate Plant No. 1 but it was not commercially successful. Since the construction of this plant several improvements have been perfected in the Haber method, so that with certain alterations in the plant, nitrates may be commercially produced there.

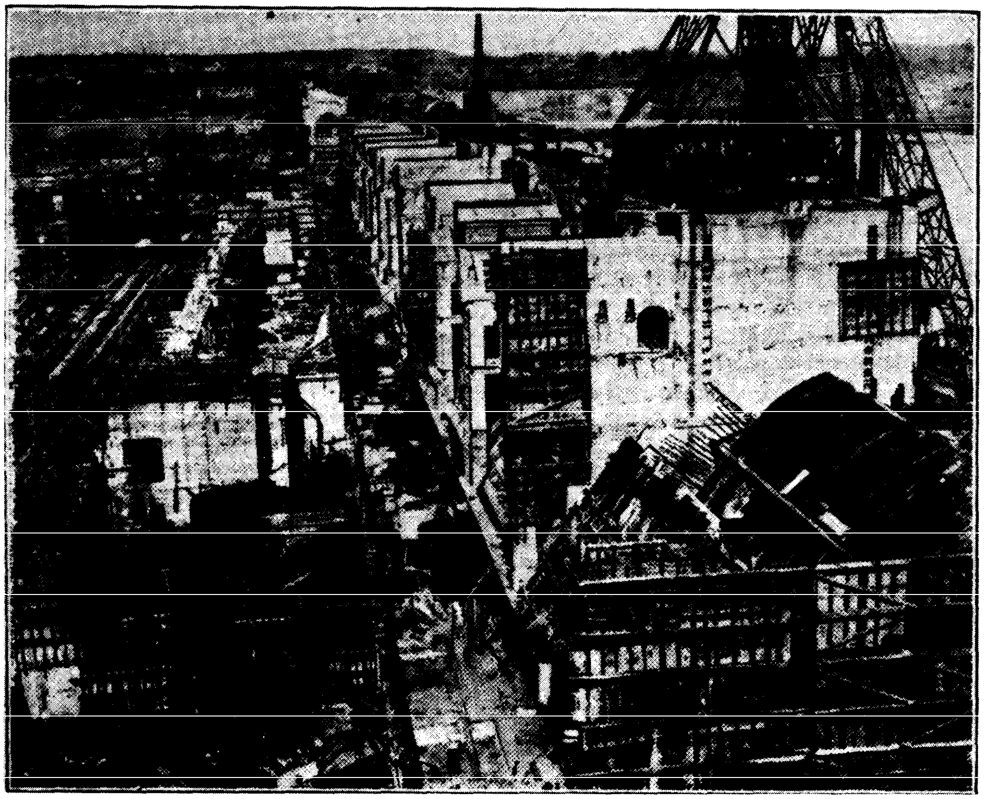
The cyanamide process, which is that used at Nitrate Plant No. 2, is as follows. Limestone, $CaCo_3$, obtained from the government quarry at Waco, a short distance away, is burned in rotary kilns to form lime, CaO. Coke, made from coal obtained in the mines of this region, if mixed with the lime and heated to very high tempera. tures in electric furnaces, to form calcium carbide, CaC_2. This is ground to a fine powder.



Aerial Photograph of Wilson Dam

Pure nitrogen is then obtained by liquefying the air and boiling off the nitrogen which boils at —195.5 degrees C., whereas oxygen boils at —182.5 degrees C. The nitrogen then passes thru the carbide which is heated to 2000 degrees l?. by an electrically heated carbon pencil, forming calcium cyanamide, $CaCN_2$. This after being washed is ground to a fine powder and charged into heavy walled steel cylinders, called autoclaves, containing caustic soda solution. Steam is then introduced and the pressure raised to fifty pounds to form ammonia, NH_3. Ammonia and air are then passed thru a platinum guaze catalyzer which is kept heated to a red heat thereby forming nitric oxide, NO, which on cooling forms nitrogen peroxide, NO,. This gas is passed thru large towers in contact with water to form nitric acid, HNO_3. Ammonia gas, NH_3, and nitric acid, $HN0_3$, unite to form ammonium nitrate, NH_4NO_3,

Explosives such as smokeless powder, dynamite, nitroglycerine, triton, picric acid, and ammonium nitrate and commercial fertilizers such as ammonium nitrate, ammonium sulphate and ammonium phosphate are manufactured from the above derivatives.



View of Construction Work on Wilson Dam

The above process requires over 6800 kilowatt-hours of electrical energy per ton of ammonium nitrate produced. Therefore, in order to maintain such a war-reserve plant in time of peace for the manufacture of commercial fertilizer, a source of cheap electric power in addition to the raw materials, limestone and coal, was necessary. The site at Muscle Shoals combined these essentials and was selected for the above reasons.

With the supplies maintained as a war reserve and those turned out at this plant, an army of 1,250,000 men may be continuously supplied with ammunition. Additional plants may be erected on this site after the declaration of war should the need therefore arise.

NAVIGATION

The question of water transportation is another vital factor in this project.

The Tennessee river extends from about 41,2 miles above Knoxville, Tennessee, for a distance of 652 miles to where it joins the Ohio river at Paducah. It is a vast, potential navigation systern.

With an adequate means of water transport, the tributary territory is capable of very intensive development. The lowlands are fertile and capable of raising huge crops. The mountainous or broken country contains timber, great mineral wealth in iron, coal, limestone and lead. Chat anooga, Knoxville and Harriman are manufacturing centers which would be further developed with improved transportation facilities on the Tennessee river.

The greatest obstruction to navigation on this river is the system of shoals extending to Florence, Alabama. In this relatively short distance, the river falls 134 feet. These shoals are commonly known as the Muscle Shoals. They consist of a hard flinty rock strata which has resisted erosion and has caused the river to widen out to two miles in places with a resultant shallow depth.

At this point, a word about the two general systems of river improvement might not be amiss. One method is that of channeling in which the object is to so direct and regulate the channel of the river that it will scour out its own path and furnish sufficient depth for navigation. This is accomplished principally by dredging and by bank revetment. The Mississippi river is an example of this method of river improvement. The other principal method is that of damming the stream at intervals thruout its length so as to raise the water level of the river. This is accomplished by a system of locks and dams, weirs or wickets. An excellent example of this type of improvement is the Ohio river. Combinations of both methods are frequently used.

As early as 1831, the state of Alabama with funds derived from a Federal grant of land of 400,000 acres tried to improve the Muscle Shoals section of the Tennessee by putting a detour system of canals and locks around this obstruction but it was not successful,

The present plan of improving the Tennessse river was adopted by President Wilson, Feb. 23, 1918. A six foot channel at ordinary low water will be maintained from the mouth of the river up to Florence where the Muscle Sheds system is encountered. At Florence, Dam No. 1 will be constructed to provide six feet depth of water between it and Dam No. 2, two miles upstream, It is purely a navigation project as no power will be developed.

WILSON DAM

Dam No. 2, or Wilson Dam, is the major project in this system, It is the largest dam in the world, being almost a mile long and one hundred and thirty-seven feet high. Thirty-six million cubic feet of masonry go to make up its vast bulk.

It will provide a lake of a minimum depth of six feet for a distance of eighteen miles upstream, thereby taking navigation over the worst obstacles of the Tennessee river shoals.

The dam is made up of a power house 1250 ft. long, a dam or spillway section 3050 ft. long and a two stage lock system having a total lift of 93 feet.

CONSTRUCTION

In the construction of the dam, six temporary coffer-dams of a total length of two miles had to be constructed. These coffer-dams were made up of timber cribs loaded with rock and sealed with clay.

Numberless water-bearing seams and clay pockets were encountered in the foundation and adjoining bluffs. In one instance alone, a tunnel 1400 feet long had to be dug thru a water-bearing seam. All the clay encountered was cleaned out and the cavities were filled with concrete to make all waterproof.

A large central concrete plant was erected on Jackson Island in the center of the river. A construction bridge was built paralleling the dam site, bearing railroad tracks and tracks for seven huge construction derricks to facilitate the transportation and handling of materials. A lumber yard was erected to handle the millions of board feet of form-work necessary. Five thousand men are working day and night on the construction of this dam. The question of systematic supply of cement, lumber, sand and the thousand and one other essentials was a huge problem in itself.

LOCKS

The locks are located on the north bank of the stream, each being 60 feet wide, 300 feet long, and providing a lift of 461/.. feet for vessels up to 7 1\2 feet draught.

The gates on the upstream end of these locks are of unique construction. Watertight steel boxes, 60 feet long, 14 feet high and 6 feet wide span the lock. When empty, these boxes float keeping the headwaters out of the locks. When filled, they sink in their recess and permit the passage of vessels entering the lock.

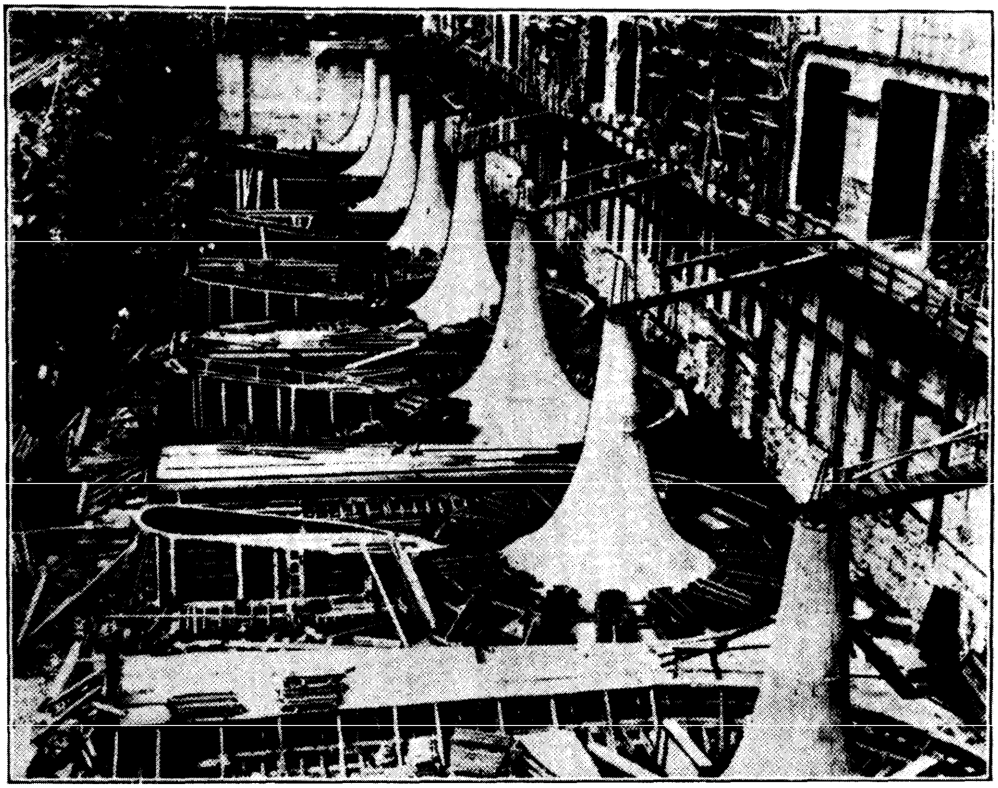
A pair of standard mitering lock gates is used between the locks. They are hinged on the inner sides of the locks and meet in the center. When opened, they are contained in recesses on each side.

All gates and valves are operated by compressed air and are controlled from one central point in the operator's house.

DAM

The dam is made up of non-overflow sections and the spillway section. Both sections are unreinforced gravity structures, the foundations of which extend fifteen to sixteen feet into total width of 160 feet at the base. It extends to a height of 140 feet from the foundation to the operating bridge.

A non-overflow section extends for 180 feet from the locks. The spillway section is 3050 feet bed rock. At bed rock, the dam has a width of 101 feet which with an apron of 59 feet gives a long and contains the gates and controls to take care of normal and flood overflow. When it is considered that the Tennessee fluctuates from a flow of 10,000 c.f.s to almost 500,000 c.f.s, it is seen that extensive provision must be made for flood control.



SPREADING DRAFT TUBES—POWER HOUSE CONSTRUCTION

Flood waters are passed thru a series of 58 steel flood control gates, each 38 feet long and 18 feet high. A very unique system of controlling these gates allows one operator to open or close all of them within two hours.

To take care of normal flow in excess of power requirements, thirteen sluices are located in the five non-overflow sections near the power house. These sluices are circular conduits nine feet in diameter. They are protected by large screens upstream and controlled by a butterfly valve at the downstream end. When fully opened, a sluice discharges a stream of water eight to nine feet in diameter at a velocity of 45 feet per second. Special precautions have to be taken to prevent destructive scouring action from these streams. A bed of concrete a yard thick and covered with huge granite blocks extends some distance downstream and serves to break up this torrent.

The power house containing the hydro-electric generators makes up the remainder of the dam. Over all of this runs the Dixie Highway which allows all forms of traffic to cross the river on this dam bridge. (Literal interpretation.)

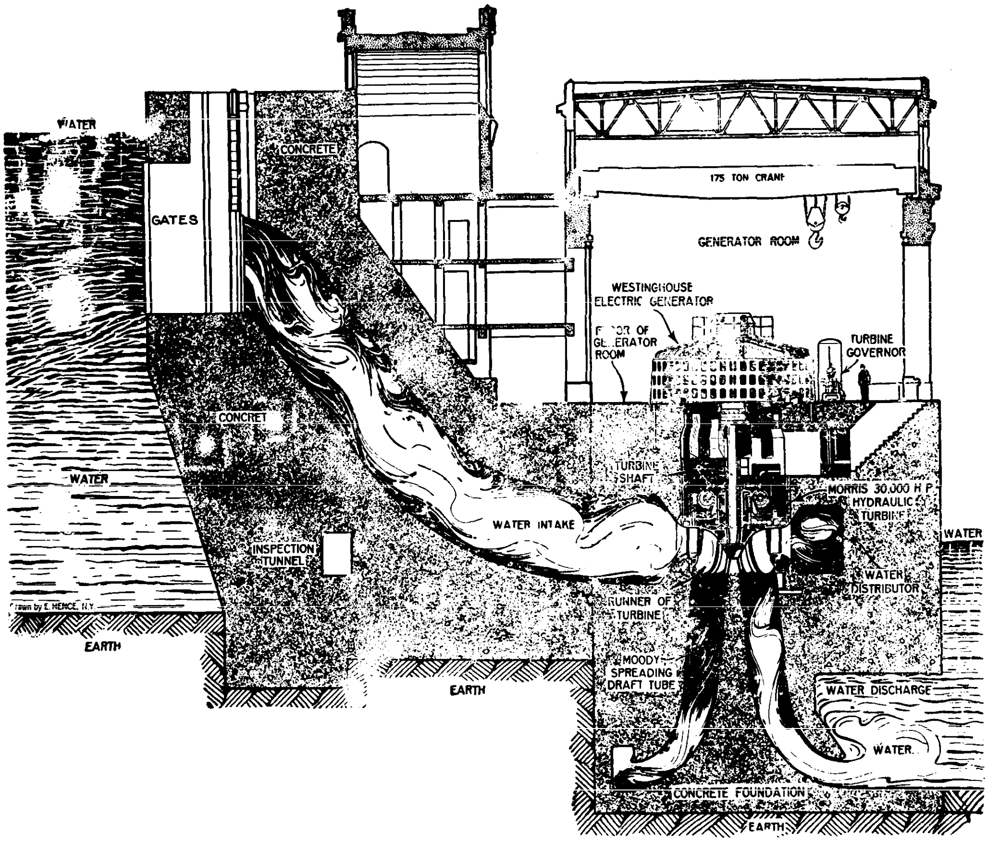
About eighteen miles above Wilson Dam, it is planned to construct Dam No. 3. This dam will raise the water 45 feet and allow navigation 65 miles further upstream. It will cost about $25,000,000 and will develop from 34,000 primary horse-power to 250,000 secondary H. P. It will be longer than Wilson Dam but not as high. Several smaller dams will provide navigation for 156 miles up to Holes Bar. Above this point to Knoxville, the river is navigable to light draft vessels.

Even without nitrates or power development the increased water transport facilities provided on the Tennessee will be worth the total expenditures. It will furnish a necessary means of cheap transportation for a great industrial region.

HYDRO-ELECTRIC DEVELOPMENT

One thousand two hundred fifty feet of the southern end of Wilson Dam go to make up the power house. This building is 160 feet wide and 134 feet high. It will contain the turbines and generating apparatus for the hydro-electric development.

With the completion of this dam, 260,000 horsepower of hydro-electric generating apparatus will reinstalled. Tailrace excavation, draft tubes and the necessary construction of the power house sub-structure will be provided for the ultimate installation of additional generating apparatus sufficient to develop the total power to 610,000 H. P. It is believed that with the intensive industrial development going on in this region that a market will soon be developed that will absorb all this power.



POWER HOUSE SECTION

POWER UNITS

A total of eighteen power units will eventually be installed, four of 30,000 H. P. and the remainder of 35,000 H.P. Each unit consists of a water turbine of the Francis type set vertically with a Westinghouse electrical generator rotated on the same shaft above it. Three water intakes, large enough for a truck to drive through, conduct the water to each turbine. These intakes join to form a scroll case where the water is distributed into the turbine buckets.' Control gates are provided at the head of each intake to regulate or cut off the flow of water. Steel screens prevent debris from entering and harming the turbines. A turbine governor regulates a system of wicket gates located around the runner so that the amount of water delivered to the turbine is regulated according to the amount of power required and distributed from each generator.

DRAFT TUBES

In order to discharge the water with minimum back pressure, a form of draft tube is necessary. In tests carried out in miniature, the Moody spreading draft tube gave the best efficiency. One each of two other types have also been installed to determine under identical conditions the rela-

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ing magazines represented there, thus showing the weaknesses of each publication. Each delegate was given a style book for E. C. M. A. which had been carefully worked out by members of the group. Professor Gardner of the School of Commerce, spoke on advertising methods and practices. The talks by Professors Hyde and Gardner were to the point, full of practical information of real use to every publication, and gave the delegates something to take back to their staff. The discussion on advertising took up most of the time allotted to group business as it was the subject of greatest importance to the delegates. The regular committee reports and election of officers had to be rushed slightly because of the intense interest in the advertising discussion. It was a great convention and one the delegates will always remember.

Compare this issue of the Kansas Engineer, in which the staff has tried to embody the principles recommended by E. C. M. A., with the Jan., 1924, issue, and you will agree that there have been great strides toward the improvement of your publication.

Muscle Shoals

(Continued from page 10)

tive efficiency so that the results may be available to the engineering profession.

ELECTRICAL EQUIPMENT

The initial installation of generators w 11 consist of 25,000 K. V. A., and 32,000 K. V. A., 60-cycle, 3-phase, 12,000-volt, 100 R. P. M. Westinghouse type. The exciters for each will be a 250-volt direct connected and equipped with voltage regulators for their own control.

A house generator 940 K. V. A., 60-cycle, 3-phase, 2300-volt, 515 R. P. M. will provide power for the lighting system and station auxiliaries. A large storage battery is also provided for switch operation and emergency lighting.

With the installation of all eighteen units, 100,000 H. P. may be developed over 97 per cent of the year, over 300,000 H. P. for six months and over 600,000 H. P. for two and a half months.

AUXILIARY POWER PLANTS

In addition to the hydro-electric generating system, there is a steam plant at Gorgas, about 90 miles southeast of Nitrate Plant No. 2, capable of generating about 40,000 H. P., with a transmission line for this amount of power to the plant. There is also an auxiliary steam plant at Nitrate Plant No. 2 adjoining Wilson Dam where 80,000 additional horsepower may be generated, Coal is plentiful in this region so that these plants may be economically run during low water periods should extra power be required.

GENERAL

It is seen that Muscle Shoals is a project of vast importance to this country It is a very essential unit in the national defense system of this country due to its potential nitrate production. In peace times it will be a great aid to the agricultural industry in providing a necessary fertilizer at a cheap price. It will generate a great amount of electrical energy and furnish it at a low price to the industries in this section, thereby helping to develop another great industrial region in the south. It will open Up to navigation an important waterway which will become more and more important as this region develops.

Muscle Shoals is only one other successful accomplishment in the peace-time activities of the U. S. Army.

When a shop foreman in England, France, or Italy tells a workman how to do a job, the chances are that he will be understood and that the man will follow out the instructions.

But when a foreman in an American shop tells a man how to do a job he may understand or he may not, depending on whether the workman understands the English language.

The advantages of a working force using a common language are so many that other nations wonder how we are able to get any production. In some of our large cities there are as many as twenty different nationalities under a single factory roof.

Where there is a problem, there is a solution.

In this instance, American manufacturers who have been assimilating foreign labor over a period of fifty years have partially solved their problem by the extensive use of machinery and the subdivision of labor.

The task of making foreign labor productive has contributed largely to the development of standardized articles and processes. Workmen in these plants go through the same motions month in and month out.

This is the way out, but not the final answer.

The answer will not be obtained until we make some provision for the compulsory acquirement of the ability to speak and write English.

The universal use of a common language will do more than any one thing for the political and industrial development of the United States. We should all apply ourselves to its realization.

—Through the Meshes,