JACOBS & DAVIES, INC., CONSTRUCTION ENGINEERS, HALES BAR, TENN.

D E S C R I P T I O N - O F - H A L E S - B A R - D A M.

- HISTORY OF PROJECT -

Original Scheme of Government.

The construction of a dam on the Tennessee River in this neighborhood was first proposed by the United States Government; primarily, for the purpose of improving navigation on one of the worst sections of the river.

Since the early part of the last century, the United States Government has been desirous of improving the navigation of the Tennessee River; the mountain section, of which in the neighborhood of Chattanooga, most loudly called for improvement. From Chattanooga to Hales Bar includes what is known as the mountain section and contains a larger number of obstructions to navigation than any other similar length of the river. As the river here passes through the Cumberland Mountains, its character is quite different from the parts above and below, and in some parts of this section it has eroded a canon eight hundred to one thousand feet deep. In this mountain section there are ten shoals as well as narrow places, where the stream is exceedingly swift, making navigation difficult at all times and impossible at low water for boats drawing morethan three feet.

The Government had up to now confined itself to such improvements as could be made by dredging the channel or removing some of the larger obstructions; but, on the whole, these minor efforts were not of much value, The difficulty facing the Government was that to build a dam adequate to permanently inprove navigation was prohibitive in cost.

In 1900, several plans for improving navigation by a dam were taken up and considered, among which were the following:-

(1) A dam to back the water up over Tumbling Shoals only.

(2) A dam to improve the entire distance between the Skillet and Chattanooga.

(3) The construction of a lock and dam near Savannah Towhead.

(4) A plan for a single lock and dam near the Skillet, calculated to back the water up, and thus secure at the lowest stage of the river a depth of not less than five feet for navigation.

Much difficulty was experienced in the effort to find a suitable site; and, after examination of many pääces, Scott's Point was finally selected, and plans were made for a timber crib dam and a masonry lock.

Owing to the vast improvements made in hydro-electric developments about this time, it was suggested that these works, for the betterment of river traffic, might be allied with the production of electrical power, thereby making the expenditure subserve the double end. Thisput fresh life into the matter, and an act of Congress, approved April 26th, 1904, authorized the Secretary of War to grant permission to the City of Chattanooga to build a lock and dam at Scott's Point. This act provided that, if the City of Chattanooga within four months failed to nitify the Secretary of War of its intention to construct the lock and dam, then the Secretary of War was empowered to offer the franchise to C. E. James and J. C. Guild of Chattanooga. These gentlemen accepted the offer and organized the Chattanooga & Tennessee River Power Company.

The Scheme of the Chattanooga & Tennessee River Power Company.

The Chattanooga & Tennessee River Power Company engaged Mr. John Bogart of New York as Chief Engineer, and Mr. Thomas Murray of the same city as Consulting Engineer.

On examination the Scott Point project was not considered the most favorable after consultation between the Government Engineer and the Company's Engineer; and other points attracted the Engineers' attention as better fitted to provide, not only more power, but also to improve navigation over a longer stretch of the mountain section. Accordingly, an amendment to the act was presented and passed January 2nd, 1905, authorizing the location of the dam at such other point in the mountain section below Scott Point as the Secretary of War might approve.

Combination of the Two, Involving Lock and Governmental Inspection.

Hales Bar, was, therefore, finally selected as the most favorable site inasmuch as it rendered possible the production of, not only a large amount of power, but very largely increased the length of river improvement. The first reason was important for the Power Company inasmuch as the contract for the Government put the entire expense of the project on the Company in return for the use of the power for ninty-nine years.

As the Tennessee is a navigable river, and, therefore, under the control of the War Department, this combination entailed Governmental inspection of all construction work that could in any way, shape or form be construed to affect navigation; so that, although the work is being carried on and the money provided by private interests, it is at the same time subjected to the severe and most exacting scrutiny and control that is always applied to Government construction.

GEOGRAPHICAL SITUATION.

General Situation.

Hales Bar is situated on the Tennessee River close to the southern border of the State of Tennessee. The distance from Chattanooga is thirty-three miles by river, twenty-two miles by roads, and fifteen miles on an air line. The main line of the Nashville, Chattanooga & St. Louis, R. R. at Ladds' Switch is three miles from the site of the dam, and the proposed and partly constructed branch of the Southern Railroad is three miles up the stream.

The Tennessee River - General Description.

The Tennessee River is the third largest river in the United States, and takes its rise in the states of Virginia, North Carolina and Tennessee, flowing in a southwestly direction until it enters the northern part of the State of Alabama, which it traverses from east to west. It just touches the northeasterly corner of the State of Mississippi and re-enters the State of Tennessee running due north, and in the State of Kentucky it joins the Ohio River at Paduca. There are only two other rivers in the United States which carry more water than the Tennessee, namely the Mississippi and the Missouri. The Tennessee at its junction with the Ohio carries slightly more water than does the Ohio itself.

Description of the Country at Hales Bar.

In the immediate neighborhood of Hales Bar and northward, the country is termed mountainous; more correctly, it is a plain that has been eroded by the river and its tributaries during the course of ages. The so-called mountains are about fourteen hundred to sixteen hundred feet above the sea level and about eight hundred to one thousand feet above the present river level. These elevations are covered with red oak, pine and a small amount of red cedar; and it is only in the river bottoms and the wider valèeys that any arable land exists.

The drainage area of the Tennessee River above Chattanooga is 21,418 square miles; the rainfall per annum in the neighborhood of 47.6 inches. This rainfall would produce an average flow the year round of 74,600 cubic feet per second if all the water reached the river; but, as the observed mean flow in only 41,500 cubic feet, 33,100 cubic feet per second is lost by evaporation as well as some in all probability by subterraneous channels.

Hydraulic Conditions of the Tennessee River.

The minimum flow of the Tennessee River, observed during the last eighty years, is 4,300 cubic feet per second; the mean flow is 41,500 cubic feet per second, and the maximum flow is about 500,000 cubic feet per second. A flood reaching thirty-five feet on the Chattanooga gauge means a river discharge of 220,000 cubic feet per second. During a period of twenty-five years this stage has been reached seventeen times,, amd has held for an average of three days a year. A few instances of the fifty foot stage having been reached is on record, and the maximum stage ever known is one of sixty. This enormous variation between the high and low water periods, while it causes considerable difficulty in the development of power, at the same time promises great things in the future when these flood-waters are impounded further up stream. Every such up-river improvement, inasmuch as it decreases the amount of water in the flood period and increases the amount in the dry season, will be of enormous advantage to the Hales Bar project.

The following table shows the relation of water horsepower to the stage of the river:-

Chattanooga Gauge Readings	R. Discharge Cubic Feet Per Second	Elevation Tail Water	Elevation Head Water	Head On Wheels	Power in H. P. of Current On Switchboard Av. 14 Hrs.	Av. 10 hrs.
0.1	6700	598.5	638.0	39.5	16800	40000
0.5	7900	598.7	638.0	39.3	16700	42000
1.0	9400	599.0	638.0	39.0	16600	52000
2.0	13000	600.2	638.45	38.25	30500	50800
3.0	17800	601.0	638.75	37.75	53800	53800
5.0	27000	602.7	639.5	36.8	58800	58800
10.0	53400	607.0	641.5	34.5	58800	58800
15.0	84000	611.2	643.4	32.2	58800	58800
20.0	120000	615.5	645.33	29.83	58800	58800
25.0	159000	619.7	647.25	27.55	58800	58800
35.0	249000	628.2	651.1	22.9	46800	46800
40.0	295000	632.5	652.85	20.33	36500	36500

General Description of the Geology of the District.

The foundation of the dam is in what is known as Bangor limestone, lying in nearly level strata and seventy to one hundred feet below the coal measure. Above the limestone there are alternate layers of clay shale, sandstone and coal up to the tops of the mountains; the whole being covered more or less thickly with a blanket of of gravelly red clay.

The Bangor limestone, in which the foundation of this dam is constructed, is honeycombed with crevices; the explanation, that geologists give of this crevices conditions of this limestone, is that it is slightly soluble in rain water, so that in the course of ages the solid rock has been dissolved, following lines of greater solubility, into crevices and cavities, which have been later filled with gravel, sand and clay. Springs of clear cold water are encountered in some of these crevices while excavating, the majority are completely filled with clay and gravel. The source of the springs, discovered while excavating the foundation, is undoubtedly rain water that lies in the crevices under pressure from the water in similar and connecting crevices in the mountains; in proof of which the following comparative analysis of water is given:-

Parts per 100,000.
All samples turbid. Filtered water analyzed.

	Sample #1 Caisson C 37' below river bed	Sample #2 River	Sample #3 Driven Well 170' Deep.	Sample #4 Natural Spring
Alkalinity	12.50	5.00	15.00	5.00
Lime	5.50	2.60	7.30	2.60
Magnesia	0.88	0.16	0.88	0.24
Total Solids	14.16	6.68	18.88	10.00
Calcium Carbonate	11.00	4.63	13.00	4.63
Magnesium Carbonate	1.84	0.61	1.84	0.49

It will be noticed in the above analyses that the sample taken in Caisson C, thirty-seven feet below the river bed, was almost identical with that taken from the driven will, 170 feet deep; and, again, the sample taken from the river and the natural spring were almost identical in their mineral contents.

It was contended by some persons that the water encountered in these foundation springs was river water, but the above analyses conclusively proved this not to be the case. In addition to the analyses, there was a difference in temperature between the springs and the river water amounting to more than ten degrees fahrenheit, warmer in winter and colder in summer, which also points to the same conclusion that the water in the crevices is spring and not river water.

The advocates of the river water theory made an experiment to try and ascertain if there were any direct connection between the river water outside the coffer and the water coming in through the spring in the bottom of Caisson C. For this purpose they put some permanganate of potash in a sack and dragged it along the bottom of the riverthrough the water on the upstream side of the coffer. They then took samples of the water coming into Caisson C and claimed to have found traces of the permanganate in the water. They forgot, however, to note two facts which vitiate this conclusion.

Permanganate of Potash

In the first place the air pressure in Caisson C was at the time two pounds higher than was necessary to meet the hydrostatic head of water on the upper side of the Dam; and, if their conclusion is correct, the permanganate of potash must have forced its way into the caisson against the pressure.

The second point is that the spring water coming into the caisson did and does flow into the caissons in spite of this higher pressure, conclusively proving that the spring was subjected to sufficient pressure from its sources in the hills on either side of the river to overcome the head of air in the caissons.

Another point is that the flow of gravel, sand and mud in this river invariably fills up every crevice in the bottom of the river except those in which spring water from the hills forces its way in under the head from the mountains. From this point of view the permanganate of potash must have exerted itself to travel against the pressure of water in an open crevice and obstinately persisted in reaching the desired objective point under the caissons in spite of the natural obstacles of spring water under head and compressed air.

This conclusion that the water in the caissons was spring water and not river water is of great importance; for, were this water from the river, its presence within the caissons during construction would imply that direct leaks under the dam might occur after the dam was built, which, in the low water season, might seriously diminish the amount of water available for power.

Description of Hales Bar Dam.

- DESIGN -

Original Proposal of Government.

The original proposal of the Government was to build a crib dam and a masonry lock. (See History of Project).

Final Design Adopted.

The final design was for a cyclopean concrete masonry dam with a cross section as shown in sketch No. 1. In the dam proper further modification was made in the cross section after Jacobs & Davies, Inc., took hold of the work by adding 4'3" to the thickness of the dam and a change of the surface over which the water flowed, as shown in sketch No. 2. Both of these designs for a concrete dam were intended to be built on solid rock foundation which, as a matter of fact, existed for only a small portion of the dam. The rock actually encountered was not solid as expected, but very much broken up and creviced, as will be described later on.

The Leading features of the Whole Design.

The dam is 2,376 feet long from shore to shore, including Lock, Spillway, Power House, Transformer House and Core Wall Masonry. The dam proper is built of cyclopean concrete, 1,200 feet long between the Power House and the Lock, 58' to 72' wide at the base, 11'6" wide at the top and the extreme depth of concrete below the crest varies from 50' to 82' according to the depth it was necessary to go to secure adequate foundation. The upstream face is vertical and the downstream face is battered nine on twelve with a curve at the foot of 20' radius. When solid rock was encountered the concrete base was keyed into the rock both on the upstream and downstream faces. A longitudinal gallery running through the upper part of the dam provides space for inspection and installation of electric ducts, etc., by means of which power can be conveyed to the right bank of the river to work the gates and for other purposes.

Power House. Each bay of the power house contains two power units, consisting of three vertical turbine water wheels, directly connected to one vertical 3-phase, 60-cycle 6600-volt, 3133-kilowatt, alternating current generator, which revolves at 112½ revolutions per minute and develops over 4000 horsepower. There are ten of these units already installed and fourteen will be the ultimate installation.

Ten feet below the main floor of the power house is the basement floor on which are installed the thrust bearings which support the revolving portions of the wheels and generators. Here are also the delicately-controlled water wheel regulators which open and close the gates to the wheels and maintain a constant speed.

The two lower 72-inch wheels will develop the full normal 4200 horsepower at all stages of the river and the upper third wheel comes into service only when the effective head of water is decreased during floods. So full power can be obtained with all stages of the river within wide limits from low water to high water. When all wheels are in service, they will generate 58,800 horsepower.

Overlooking the main generating room is a gallery on which is located the operating room from which all of the apparatus in the plant is controlled. The operator has an unobstructed view of all of the generators and signals are made by a gigantic annunciator of steel 9 feet high with numerous windows of porcelain containing the numbers of the units and other symbols

Transformer House. The transformer house, continuous with the power house, four stories high, is a maze of concrete compartments in which every piece of apparatus is installed. On the main floor are ten single-phase transformers of 3133 kilowatts each which are for stepping up the voltage from 6600 volts to 44000 volts at which pressure the current is transmitted to Chattanooga.

Transmission Line. The transmission line consists of two 3-wire circuits of hard-drawn copper cables, one-half inch in diameter, supported on pin type insulators on heavy steel towers spaced, on an average, about 600 feet apart. The line is eighteen miles long from the power house to the sub-station in Chattanooga. It crosses the Tennessee River twice with spans 1400 feet and 1486 feet long on towers 200 feet high. The right-of-way is 1500 feet wide and is cleared of all trees and buildings. All land was purchased outright and it was not necessary in a single instance to resort to condemnation proceedings.

Sub-Station. The substation in Chattanooga has a capacity of 40,000 horsepower. It is a steel and concrete structure similar to the power house and contains the transformers for stepping down the voltage from 40000 to 4000 and 2300 volts, at which voltage the power will be distributed to power users. The sub-station is located at the corner of Nineteenth and Carter Streets at the end of a private right-of-way 150 feet wide and half a mile long from the river.

Pole Lines. The pole lines are the most substantial ever put up in Chattanooga--the main routes having heavy, creosoted pine poles as straight as lead pencils and varying from 50 to 70 feet. Some of these poles cost $40.00 each erected.

The power house, transformer house, sub-station and transmission line and all the electrical work were designed by Thomas E. Murray, consulting engineer for the company. In general, this hydro-electric development is, in every way, far above the average in point of excellence of design, substantial character of the work, provision against damage from floods and in means for obtaining a constant amount of power from the varying stages of the river.

Sluice-Way. A large sluice-way 9 by 13 feet in the river pier of the power house provides for the discharge of 5000 cu. ft. per second, this being the minimum flow of water at zero on the Chattanooga river gauge, necessary to maintain navigation at a time when the turbines are not in operation and no water is going over the dam. The sluice-way was called for by the Government engineers, bit it is not likely it will ever be used.

Core Wall. Eastward from the Power House the dam is extended by means of an embankment about 50 feet maximum height with a battered concrete core wall.

Lock. At the west end of the dam there is a lock with a chamber 60' wide and 312' long, quarried out of solid rock on its land side. It is the highest single life lock in the United States and has a river wall about 630' long and 60' in maximum height. This lock has a lift of 20' to 40', according to the stage of the river. The lower gates are 34' by 59' high and will weigh 130 tons. The upper gates are 37' high. The accompanying plan shows the general arrangement.

Extracts From Specifications Showing Nature and Character of Work required.

Foundations. Cement. To be Portalnd Cement conforming to specifications and tests recommended by Board of Engineer Officers, June 6th, 1901.

Mixture. Proportions of concrete; 1 bbl. of cement to 10 cu.ft. of Sand and 20 cu.ft. of gravel, broken stone.

SAND. 50% to be retained on #50 sieve. If it contains more than 5% earthly matter it must be washed.

Broken Stone or Gravel. Hard & sound; maximum 2½" and minimum 1/4"

Mortar. Face 1½"; proportions 1 bbl. cement to 8 cu.ft. sand.

Large stones, hard & sound, allowed in concrete one foot away from forms and separated 12" horizontally and 9" vertically.

Forms. Not less than 2" planks, dressed for exposed surfaces.

MIXING. By machinery generally.

Placing. Must not be dropped. No slides or chutes permitted. No concrete placed at lower temperature than 34 degrees Fahrenheit.

Lock Gates. Provided and placed by U. S. Government.

Core Wall. Of concrete stepped into rock.

Supervision. The arrangements for supervision of this work were of a somewhat peculiar nature. As this dam was built on a navigable river, the United States Engineer Officer of this district had control of all parts of the work that in any way could be considered as affecting navigation, and the Power Company's Engineers supervised all work outside of this. In compliance with this arrangement the Government Engineers had a Junior Engineer and a staff of inspectors on the job who were supposed to issue their orders to the Contractor through the Power Company's Engineers, but for convenience orders were given direct to the Contractor.

Under the specifications it would have been possible for the Power Company to have appointed their own inspectors, and the Government need not then have had more than the Junior Engineer and perhaps one or two assistants under him. It seems that the arrangement in force was adopted by the Power Company in order to save the expense of inspectors; and this, as it turned out, was a very serious error in matters of dollars and cents, because as is well known, inspectors appointed by the Government do their work with an excess of particularity and precision, which was in this case far beyond the requirements of a good job. The result was that, while the Power Company probably saved the small amount of money paid the inspectors in wages, they were compelled by the severity of this inspection to spend probably several hundred thousand dollars more than was necessary. But this was among the many large increases of cost incurred from the initial failure to test the rock in the bottom of the river, as the time taken to do the work was very much longer than anticipated and the cost incurred enormously greater in all departments of the work.

- CONTRACTORS AND THEIR METHODS UP TO JACOBS & DAVIES PERIOD -

So far, the work of the construction has been in the hands of four separate and distinct organizations, namely:-

(1) October 5th, 1905 to December 14th, 1907 - William J. Oliver.

The work done by this contractor was almost exclusively confined to work on dry land, including the Core Wall and its foundation and part of the Embankment and that portion of the Power House and Transformer House foundations that were on dry land on the east side of the river.

On the west side, a cofferdam was constructed to unwater the main wall of the Lock, which did not include the Upper and Lower Guard Walls. The foundation of the Lock Walls, which was on good rock without crevices, and a considerable amount of concrete was put in.

In the river bed some cofferdaming was done around the site of the Power House and Section One.

(2) March, 1908 to January 1st, 1910 - Firm known as Bailey & Dumary superseded William J. Oliver.

This firm attempted to pump out the section on the east side of the river and added some more cofferdam work around Section Two. They proceeded to do some excavation on the Power House site and also in Section One, but accomplished this with great deal of difficulty through the influx of water through the rock. During the time this firm had charge a small portion of the foundation of the Power House site on the east end was put in, covering about two of the seven bays required. At this east end of the Power House foundation very little water was encountered; but, when they attempted to excavate the foundation rock on the west end of the Power House, large leaks interfered with progress.

In Section One, after very heavy pumping, a portion of rock foundation about 40' by 60' was convered with concrete, but this was all of the Dam proper that any of the contractors were able to build before Jacobs & Davies took hold. During this period three well drills were purchased and some attempt made to grout the leaks through the foundation rock but with very small success; and, during the period of nearly two years in which they continued work, an enormous amount of pumping in the sections enclosed resulted in practically nothing being accomplished. The Tail Race was partly enclosed in coffers, and an attempt was made to remove the river silt by means of a sand pump, but, owing to the clayey nature of the river silt, was partially a failure.

On the west side of the river the concrete construction of the Main Lock Walls was continued with some vigor, but not more than about half the work completed. The coffer was built around part of the site of the Upper Guard Walls, and the foundation of three of these secured.

During this period no attempt was made to ascertain the character of rock in the bottom of the river not yet enclosed in coffers, and comparatively little use was made of the welldrills.

(3) January 1st, 1910 to June 18th, 1910 - William H. Flaherty was in control of the work.

During this period he continued the work of Bailey & Dumary, mainly in the Power House where a portion of the Power House Piers, between bays 3, 4 and 5, was secured, but no work was done in the Dam proper except to continue the pumping that had already been proved to be futile. A portion of the superstructure of the Transformer House was gone on with, the foundation having been previously secured by Bailey & Dumary. In the Tail Race no more work was attempted neither was any attempt made to proceed with vigor in Section One of the Dam proper where considerable foundation might have been secured.

(4) June 18th, 1910 to present time - JACOBS & DAVIES, INC.

- ACCOUNT OF JACOBS & DAVIES' WORK -

General Account of Jacobs & Davies' Work.

Early in June, 1910, A. N. Brady, the original contractor, requested Jacobs & Davies to take over the work, and, on June 18th, 1910, Jacobs & Davies, Inc. took actual control at Hales Bar and proceeded to attack the work vigorously.

It was early realized that the securing of foundation was the crux of the whole affair, and special attention was, therefore, given to this with a view to ascertain what was the character of the rock under the remaining unexplored portion of the river while pushing that portion of the work that was open and in shape to go on with

The work was divided into river sections, 1, 2, 3 and 4, Tail Race, Power Houe & Lock, including the Guard Wall, both above and below, and the necessary excavation and riprapping that goes with it.

In carrying on the work and in view of the large sums of money that had already been spent, expedition of construction was judged to be of prime importance. It was, therefore, decided that Section Four should be attacked early on the west side while the Power House, Tail Race, Sec. One and Sec. Two were progressing on the east side. It would have overloaded the east bank plant facilities had Section Three been started before Section Four; and also, in looking to the future, an extra plant on the west shore would come into play with that on the east shore, and both could be concentrated on the work of Sec. Three, the closing section, and thus provide ample steam, air, water and supplies from both sides of the river at once. About eight hundred horsepower of boilers were purchased and set up on the back of the Land Wall of the Lock; and, as the caisson work calling for compressed air was started in Sec. Four, the first air compressing machinery was installed near these boilers. Derricks were erected on the river coffers at suitable locations to move material as the exigencies of the work required.

A. Brothers' Balanced Cableway, with clear span of about eighteen hundred feet, was thrown across the river, the west end being supported by an "A" frame and the east end going over the top of the Power House and anchored in the ground of the Core Wall Embankment.

A Lidgerwood Cable, with about twelve hundred feet span, was erected, one tower south of the railway on the east bank and the other tower on the north side on the Dam supported by a large crib in the river.

These two cableways by means of the transfer platform, where they crossed, were of the greatest use, especially in flood times, in transferring all kinds of material from the railway on the east bank to all parts of the work as well as loading and unloading material from the floating equipment on the north side of the Dam.

On the east bank of the river the existing power plants were improved and extended. Repair shops were put in efficient working condition, and this part of the outfit was exceedingly useful and busy as most of the repairs to the plant were of necessity done on the job.

At first, it was presumed that the campaign of vigorous drilling and grouting of the river bottom might secure the foundation and avoid adding to the already enormous expense that had been incurred in pumping the sections enclosed. In Sec.

One and in the Power House the well drills were set to work and additional ones, to the number of twelve machines, were purchased in order to both explore the underlying rock and also provide holes through which grout could be forced should open crevices be found. During the late summer and fall of 1910, Section One and Section Two and the Power House were persistently drilled and then flooded and cement grout forced through pipes to refusal. 47,122 bags of cement were used in this way, the bulk of it being taken by Section Two. By this means the pumping was very much reduced and work of excavating loose rock was rendered possible, but frequently the removal of small portions of the rock would open up new crevices bearing water, the influx of which drove the men out of the excavation and rendered a resumption of drilling and grouting methods necessary. In forcing grout into crevices discovered the smallest amount of air pressure was used that would clear the mixer, and it was found that each hole would take a few charges very easily, but, as the cavities got filled, it required higher pressures until the limit was reached of 75 to 80 pounds. Each hole, before grouting, was tried with air pressure alone, to get an idea of the extent and ramification. After this a charge of water was tried because in some cases it was found that, where the hole took air fairly readily, it would not take cement grout, so that a charge of water was tried to avoid a waste of cement in trying to put grout into holes that would not take it.

P. of Potash

It was found that some crevices in Section One were connected with those in the Power House, and the method used to ascertain this was by putting permanganate of potash in the holes in sections One and Two, and it was not many minutes before the red color showed in the pumping out of the Power House excavation.

The Power House excavation was about thirty-five feet into the limestone rock. Some of the horizontal strata encountered were honeycombed with fissures and filled with sand and gravel. In order to avoid breaking into water-bearing crevices, most of the remaining rock was quarried with the use of only small charges of powder. In spite of this precaution, the breaking in of leaks necessitated the flooding and grouting of the foundation before even the balance of the excavation could be gone on with. After a long continued struggle a layer of rock was uncovered sufficiently solid to build foundation on. On this layer the contractors were permitted to put down a slab of about two feet thick of concrete in which were placed vertical short pieces of three inch pipe through which drilling could be done with a view to ascertaining the location of any live water-bearing seams and to provide a cover through which grouting could go on without the necessity of flooding the section. This kind of treatment was continuously carried on for four months before the foundation was accepted by the Government Officers. At one time there were so many of these pipes standing on the floor of this section, there was hardly room to stand up a percussion drill. About 16,083 bags of cement were used for grouting in the Power House foundation alone. After drilling holes, water was forced in under high pressure with a view of washing out the crevices. At the same time compressed air was put in by a hose to another and water and air alternately forced into the crevices with the same object. As soon as the water would run clear from any of these portions, the inspectors would permit grout to be forced in, but this kind of work simply substituted grout for clay which was equally as good for foundation purposes. When, at length, the foundations were accepted it took only a short time to build up the concrete piers carrying the superstructure of the Power House.

Concrete in the Power House is built in layers of varying depths , from five to eight feet usually. The kind of forms used have horizontal two inch planks beveled on the side and one face dressed and laid against six by eight inch vertical posts three or four feet apart, which in their turn are supported by four by six horizontal waling pieces. The waling pieces are held by horizontal bolts which are embeded in the concrete immediately below that about to be laid, where they are held in place by anchor nuts and washers. These bolts are well greased when being set so that no difficulty is experienced in removing them after the concrete is finished, but the nut is left embedded and the bolt hole filled.

Meanwhile, on the west side of the river, Section Four cofferdam was commenced and some of the gravel overlying the foundation of the Dam was dredged out. Immediately quiet water was secured behind the first cribs put in, well drills were put to work on floats and the bottom of Section Four was thoroughly explored. Alarming conditions of foundation were thus disclosed, and for the first time it was ascertained that conditions were worse considerably than those found on the east side. The drill holes, however, showed a difference to those on the east side, which was that the cavities were here filled with gravel and clay, whereas on the east side they had been found to a large extent empty. This curious difference was explained by the fact that for more than two years the heavy pumping in sections One and Two had gradually removed, by means of inrushing leaks, the gravel and clay that originally existed in them. This fact also gave rise to another very serious difficulty which was that grout could not be forced into these holes in Section Four like it had been in sections One and Two. A persistent effort was made by forcing water and air separately and combined into these well holes in the effort to wash out some of these holes so that cement and grout could be forced in and thus block the leaks and enable the section to be pumped out. This scheme partially succeeded because in November this Section Four was dry and could be kept pumped out, and the leaks, both through the coffers and through the bottom, kept under control by one 10 inch centrifugal pump; but, as soon as the overlying gravel, which is impervious to water in its natural state, was removed, the leaks through the bottom continually increased to such an extent as to overcome the available pumps, although at one time no fewer than nine centrifugal pumps, varying from eight to twelve inches in diameter, of discharge, and four six inch Emerson pumps were used at the same time.

All the time this excavation was going on, the well drills were not idle but were used to put down additional holes for grouting, and percussion drills were also called into play wherever any rock could be found on which they could be set up. When the leak water beat the pumps, holes thus prepared were ready to pipe and bring to the surface of the water of the section when flooded, and grouting could be gone on with. After letting the grout stand for forty-eight hours, it was possible to pump out the section once more and resume operations of excavation and redrilling. This process was continuously carried on, working all the men and machines that could be gotton into the area of the section until the winter floods compelled the cessation of the work.

At a meeting held on November 7th, after the well drilling had shown the conditions of the bottom, at which were present Major Harts, Col. Bogart, Mr. Forgie, and Mr. C. J. Crowley, attention was called to the unsuitable design of Dam for the actual foundations discovered. Nothing was done, however, by Major Harts and Col. Bogart, but Jacobs & Davies were requested to continue in the method then being used in the hope that better fortune might attend them. In the early spring, following the winter floods, consequently, this same method was continued; but, after repeated flooding and grouting, it became evident that that method was absolutely hopeless, at least in Section Four.

In the meanwhile on the east side of the river, fairly good progress had been made with securing foundation in sections One and Two, where the grouting method was of some efficiency because the crevices were empty and could be filled with grout.

In the early part of June, 1911, it was suggested by Jacobs & Davies, at a meeting where were present Major Harts, Colonel Bogart, Mr. Forgie and Mr. Crowley, that the use of reinforced concrete caissons and compressed air would probably be required if it was desired to close the Dam within a reasonable period of time. After some consideration, this permission was granted , but six weeks delay was incurred by an objection raised by Major Harts that the Government specifications read that all foundation must be secured "in the open", and that officer did not feel that he could permit the new method to be tried unless approval was first secured from Washington. The permission was promptly requested, but no reply was forthcoming for six week, and that most valuable period in the low water season was entirely lost. In the meanwhile, the whole material, air compressors, and the plant necessary for compressed air work, was located and provisionally bought, so that no more time need be wasted than was necessary while waiting for the Government decision.

The caissons were of reinforced concrete with steel cutting edge. They were of two sizes in sections 3-A and 4; a row of caissons 40' by 40' on the upstream side of the Dam, and a row of 30' by 32' on the downstream side, located so as to break joint, as illustrated in sketch plan. The thickness of concrete was from 8 to 12 feet from the roof of the working chamber, the latter being 4'6" high and affording ample space for the workmen. Two shafts were used in each of these caissons, one for the removal of excavated material and the other for the entrance of themen. The reinforcing used was one inch twisted steel rods, and the cutting edge consisted of 1/2" and 5/8" steel plate. The caisson was built of concrete with proportions the same as that in the Dam; and, after sinking, the working chamber was filled with concrete through the two shafts. After the caisson was sunk until its top was level with the ground withing the cofferdams, an additional lift of concrete was put on varying from 8 to 12 feet in thickness, and thus provided the necessary weight to sink the caisson as greater depths were reached. In some cases two lifts of ten feet each were built on top of the original caisson before foundation satisfactory to the Government Engineers was reached. The shafting and various pipes throughthe concrete were, of course, brought up through the new lifts. These pipes were used for blowing out leakage water, for passing in long drill steel for testing and finally for grouting through the caissons. Fourteen of these caissons were built and sunk in Section Four during the summers of 1911 and 1912.

Locks

The type of air lock used on these caissons was one designed by Jacobs & Davies and used very successfully on the thirty-five caissons sunk under Cortlandt and Fulton streets forming the approach tunnels of the Hudson & Manhattan Terminal Station in New York. These locks have a side door running on hangers and a bottom door worked by levers and weights on the outside. The rope, to which is attached the bucket, runs through a stuffing box on the top of the lock; and, passing over a sheave, runs to a single drum hoisting engine placed at a convenient distance on the outside. These locks are very much quicker in action than any other locks used in caisson work; because, after dumping at the sliding door, the bucket is returned to the laborers below at once, whereas, with the ordinary type of lock a bucket attached to a derrick boom is lowered through a top door, thus at all times either the gang inside the caisson is waiting for a bucket or the derrick is tied up to one lock.

The same type and size of caissons was used in what was known as Section 3-A, where seven caissons were put down during the summer of 1912, in some cases having to be sunk 40 feet before satisfactory foundation was found. Late in 1912 in was decided to build larger caissons of similar type to close the Dam; so, that after Section 3-B was closed with coffers, reinforced concrete caissons of a size 72' by 54' were constructed, these caissons being in every respect like the others except a larger amount of reinforcing rods were used and the thickness of the cutting edge plate was increased to 3/4". Six shafts were built into these caissons, fowr for excavating material and two for men. In was found that these large caissons could be sunk at the same rate of speed that the smaller ones were. Between the smaller caissons a space of a foot to 15 inches was left; between the larger caissons a space of two feet was left with a view to sealing them together with the help of compressed air. In addition, recesses in the concrete of the caissons were left so that the caissons could be solidly bonded together when the spaces between them were cleaned out and filled with concrete. In some cases, in sealing between the smaller caissons, it was found necessary to build a roof of concrete and put on compressed air, because of the large amount of leakage of spring water. In other cases it was possible to clean out to make these seals without serious trouble from water. Sheet piling was driven at the ends of all such joints and clay piled up on the outside so that steam syphons or a small Emerson pump were able to keep the water down until the concrete could be put in. In all cases, before the caisson was back-filled with concrete, all rock and clay was excavated under the cutting edge and under the space to be sealed between caissons. This entailed some loss of air, but the closing by these means of the bottom of the space between caissons with concrete was of the greatest help in making the seals between caissons without air.

The disturbance in the section caused by the sinking of these caissons gradually increased leaks from the springs to such an extent that the pumping capacity of the contractors was tried to the utmost; at one time no less that nine centrifugal pumps, varying from eight to twelve inches in discharge, and five large Emersons pumps were working at one time and still the water could not be drawn below the top of the caissons. In spite of this the caissons were continuously sunk by means of adding shafting, thus allowing the work to go on in conditions of flood that would by any other means have defeated the whole project. While the last few caissons were going down, piping for grouting was put down along the upstream face of the finished caissons and also between caissons and along their downstream face, holes being drilled for the purpose where necessary. These pipes, in addition to those brought up through the shafting of the caissons themselves, the lower end of which were in crevices, were all grouted at the same time. After grout was put in in this way a couple of times, it was found to have secured complete control of the leaks, for two twelve inch pumps, working only part of the time, were found amply sufficient to take care of all water from every source inside the cofferdams.

The rate of sinkage of caissons when working was found to reach about from one to two feet a day in the soft material overlying the rock and in the rock from .6' to one foot per day. The men worked three eight hour shifts in compressed air which did not at any time have to exceed twenty-five pounds to the square inch.

The rock discovered under the caissons in most cases steadily improved with depth and consisted of layers of good limestone lying horizontally where originally laid down by nature, but the dissolving action of the rain water had gradually eaten crevices in them of all shapes and sizes. Some of the layers of rock seemed more susceptible to this dissolving action than others. All the crevices discovered, except those comparatively few in which spring water was discovered, were filled with compact sand, gravel and clay, which in its undisturbed conditions was dry and hard.

The method of procedure in getting foundation passed was as follows:-

When the contractor had cleaned off with the aid of small percussion drills and small charges of dynamite a layer of rock that appeared to be sufficiently good foundation percussion drills were brought in and set to work on a row of holes three to four feet apart, driven eight feet or more deep, all around the inside edge of the caisson. The Government inspecotrs kept close record of these borings and the results were submitted to the engineer officer in charge of the work, who decided by them if the foundation was good enough to build on. If the decision was favorable, all crevices large and small in the layers of rock were cleaned out, sometimes to a depth of fourteen feet, and back-filled with concrete. Grout pipes were put into all test holes or crevices bearing running water and brought up through the caisson's shafts and grouted from the outside, as described above. The crevices thus formed excellent anchorage for the dam foundation.

When it is considered that some ot these foundations are eighty-two feet below the crest of the Dam and thirty-seven feet below the bottom of the river, there does not seem much doubt about the stability of the Dam.

It will be noted that this caisson work was done in sections surrounded by cofferdams. The reasons for this were as follows:-

In the first place, no test drilling in the bottom rock had been done before the work was commenced, and, therefore, no plan of procedure took the creviced rock into consideration. If the condition of the rock had been known, and failing a change of site of dam on establishing its condition, the caisson method might perhaps have been applied to bad sections before any other sections had been attacked, by floating steel caissons out and filling them with concrete and sinking them in the open river in the way usual in putting down bridge piers. The balance of the river channel would, during that time, have permitted the heavy floods to go by without seriously endangering the caisson work. After all caissons were down in the bad sections, then the balance of the foundations might have been secured under cover of cofferdams in the usual way.

As no test of the rock was taken, however, and sections One, Two and Four were already coffered before the caisson method was adopted, there remained only Section Three to finish, and the question arose: Should this be closed with coffers or an attempt made to sink caissons "in the open".

The final space in the Dam to be closed was about 280' with a depth of water in it of 22' at extreme low water running about eight miles an hour and 50' of water during floods running fifteen miles per hour or more.

In addition, another difficulty was that no spillway through the lock had been left by previous contractors, but the cross walls built up without any forethought of the trouble that would arise from inadequate spillway in high water.

Under these adverse circumstances it was felt that it would have been impossible to control caissons of the floating type without building coffers to protect them.

Additional, but minor reasons, lent weight to the decision to the use of cofferdams, among which were the following:-

The design of the Dam rendered it necessary to lower the water below the lowest stage in order to conveniently form the lower curve of the downstream face. This might have been changed by appeal to the Engineering Department at Washington, but the loss of time incurred in getting consent for such changes in other cases on the work had proved so great that the idea of change was abandoned.

Another reason was the desirability and the necessity of grouting around the caissons on the outside after sinking in order to incorporate the concrete with the loose rock in the bottom of the river and thus prevent leaks. This work required a pool of water on both upper and lower sides, so that hydrostatic conditions should prevail during the grouting or the cement could not be held in place long enough to set up.

Another consideration was that large additions to the floating equipment would have been necessary in the absence of the convenient stage afforded by cofferdams for the placing of derricks, mixers, etc.

The still more important point was that the sealing of the caissons one to the other would have been much more difficult and tedious without the protection of cofferdams.

From these various reasons, it was decided that the safest and quickest way was to build and sink caissons under cover of cofferdams. Further than this it was found of great advantage to the rapid carrying on of the construction of caissons to full up the middle of Section Three with gravel and other available material, so that the cutting edge could be built on solid ground above low water or at least at an elevation that reduced the pumping to a minimum. The material for this filling was gravel and sand dredged from the bottom of the river within a few hundred feet of the Dam, and the bulk of it loaded on barges, which were run into the section and unloaded before the lower coffer cribs were built in place.

The work in these caissons went forward continuously except in flood seasons, and every other Sunday, the day after pay day, only a watch shift was employed. The excavation of the material overlying the rock was done by means of pick and shovel. The top layers of rock were separated by crevices caused by the dissolving action of the water, and the pieces looked more like boulders than stratified rock in its original location; in fact, the men were in the habit of calling them boulders, although nothing but limestone rock in its undisturbed original horizontal location was encountered. Small drills of the "Hardsocg Little Wonder " type were used with compressed air to drill shallow holes in which very small charges of powder of 60 percent dynamite were used. The exploding of these charges was done with batteries, or the electric light current, in the usual way, and usually the men simply climbed up into the shafts and closed the bottom door while shooting. This was quite safe and enabled a quick return to be made to work after the powder fumes had dispersed. In order to retain the compressed air in such open work foundations, two or three men were occupied in finding and filling air leaks, when they were large enough, with bags of clay, and the small ones by daubing the surface generally below the cutting edge with clay . This was aided on the outside of the caisson by dumping a heavy red bank clay over where air leaks showed themselves. By this means a comparatively small amount of air was lost. In the river gravel the caissons followed the excavation down by their own weight, but sometimes it was necessary to reduce the air pressure so as to help them down, the red clay dumped on the outside seeming to afford sufficient skin friction added to the compressed air to carry the caisson. The rock under the cutting edges was found to be the greatest obstruction to the sinking of the caissons; and, in this regard, the round edge cutting edge, of the four types in the sketch herewith, was found to be the best. The type of cutting edge with the small channel more than doubled the work of clearing the cutting edge of rocky points on which the caisson hung up. Small charge of dynamite were shot freely in close proximity to and immediately under the cutting edge without seeming to damage it at all; in fact, at no time did the caissons or their cutting edge show signs of weakness, and were in every way admirably efficient for the work required of them. In one or two instances excavation in crevices was followed as far as eight feet outside the area covered by caissons, and fourteen feet vertically was excavated in one crevice below the accepted foundation. From the roof of the caisson's working chamber to the bottom of this crevice was about twenty-five feet. Considerable delay and difficulty was incurred by the requirements of the Government Engineers that test drilling should be done to the depth of eight feet below the rock under the caissons, although it was admitted that clay foundation at such depths would have formed an amply safe foundation. Holes for this purpose were drilled with percussion drills on tripods on a line about four feet from the cutting edge and three feet apart all around the caisson. These holes had to show good solid rock for at least eight feet down before the foundation was accepted. This requirement, it will be readily understood, compelled the hanging up of the caisson a sufficient height above the foundation rock to enable the drill steels to be dropped into the holes; the roof of the working chamber thus being sometimes as much as eleven or twelve feet above the floor. This opened up a very large area in which leaks of air could occur, so that a very efficient "mudding up" with clay had to be maintained to avoid blow-outs on the one hand and avoid the influx of water through the springs in the bottom or around the cutting edge. In a few cases 20' test holes were drilled under these caissons, by percussion drills working in the air chamber, the long drill steel being passed through the top of the caisson by means of the three inch grout pipes, which, for that purpose, acted as air locks.

Most elaborate cleaning processes were insisted on by the Government inspectors, so that the floor of the rock foundation, when concrete was finally allowed to be put on it, was as clean as an asphalt street after a thorough scrubbing. To such a degree was this minute and microscopic particularity carried that it nearly always cost the contractors more to clean off the rock surface than it did to put the concrete in place.

After the foundation rock is accepted by the Government Engineers and before the working chamber is filled with concrete, clay bags and rock under the cutting edge is cleared away little at a time so as to avoid undue loss of air, and a wall of bags of cement built up to the cutting edge from the solid rock. This bag wall sometimes extends outside the cutting edge to the next caisson. A stiff cement mortar is then plastered over the inside of the bags in order to hold air; and, when this work is finished, which goes on at the same time as the cleaning of the crevices, the working chamber is ready for filling with concrete. The quickest way to do this filling was found to be to remove the muck lock and substitute for it an ordinary diaphragm door. There were thus three doors used in carrying out this operation; namely, one at the extreme bottom end of the shaft, one at the top end of the shafting where it showed above the caisson concrete, and one at the top of an extra length of shafting put on on the outside. This center door was left open while most of the concrete was put in, it being used only after the caisson chamber was nearly filled up and there was not room at the bottom shaft for men to work. The process followed was to dump concrete from a bucket delivered by a derrick into a hopper over the top of the shaft; and, with the top door open, the concrete fell to the bottom door which was securely propped from below. On siginal from the outside that the top door was closed, this bottom door was opened by the men in the caisson, the concrete falling to the floor of the caisson and from there it was shovelled to its place. As the roof of the caisson working chamber was horizontal, this method of filling left a small space between the new concrete and the roof of the original caisson, which was subsequently forced full of grout through three inch pipes built in the caisson for the purpose. A pressure as high as 80 pounds, when necessary, of air was used to force the grout into all crevices

Sealing between caissons. The spaces between the caissons was sealed by various methods according to accessibility. In sinking the caissons one or two of them moved one toward the other, so that the space was then smaller than originally designed. The recesses left in the sides of the caissons for anchoring them one to the other provided space enough generally for men to work and for pumps to be lowered, but at the worst a steam syphon could draw out the water. The narrow spaces were filled with grout, the final cleaning being done by means of water delivered at high pressure, which stirs up and thoroughly washes all clay and objection material. This water and clay mixed is removed by one or more steam syphons; and, when the space is sufficiently clean, as evidenced by the wash water running clear, a thick cap of concrete is built over the top, the areas under treatment having previously been divided one from the other by wooden plank bulkheads into convenient sections. In this concrete cap, pipes are left through which grout is forced in at any pressure required, up to 80 pounds to the square inch. The Government Engineers insisted on having these grouted spaces tested with percussion drills, although it was found that very little additional cement could be forced in after the treatment. The larger spaces, where it was possible for men to get down and clean to the bottom, were divided into sections as above described by wooden piling and pumped out either by Emerson pumps or syphons, where leaks occurred, and the filled with concrete. In all these larger spaces, before filling in with concrete, pipes were put as deeply as possible into any crevices found and brought to surface and subsequented grouted. In some of the wider spaces, where it was found difficult to keep the water out, a heavy cap of concrete was built on the upper part of the space to be filled, with its under side sloping down toward the end of the area treated and air locks put on. This method was found to work very satisfactorily as the air enabled the men to get down between caissons below their cutting edge and sometimes into the rock and make just as good a foundation as was secured in the caissons themselves.

In the five last caissons to close the middle section, it is designed to use this method, thereby rendering it feasible to leave spaces between caissons larger than was heretofore thought advisable.

The upstream caissons break joint with the downstream caissons in the first caissons sunk so that wider spaces than usual were left between the new large caissons and the small ones at each end in the middle. It is proposed to treat these spaces, one of which is twelve feet wide and the other six feet wide, by building a cap of concrete and putting on compressed air.

It was found practicable to work three, and on one occasion four, of the smaller caissons at one time, and several of the caissons toward the latter end of the finishing of Section Four were being worked under air while the section was full of water and grouting around the finished caissons was going on. (See photo.)

Tail Race Excavation. The earth excavation overlying the rock was done by traveling derricks using orange-peel buckets which picked the material up and loaded it in six yard dump cars which were hauled away by locomotives running on standard gauge tracks. Some of this material was wasted and some hauled by rope traction to Core Wall Bank. The Rock was handled in the same way, but skips were substituted for orange-peel buckets. The excavation of this Tail Race rock was expensive on account of the large amount of water leaking in and also for the fact that the crevices in the rock were found filled with tenacious clay. This acted in two ways. It not only made the drilling and blasting difficult and ineffective, but it also caused the loose rock to become embedded and mixed up in this clay, which rendered the work of loading the skips very tedious and expensive. Most of the rock excavated was dumped on the river bank a short distance below the Tail Race site. Some of the earth excavation was hauled up to the Core Wall Embankment, and some of the rock was used for riprapping the bank of the Tail Race as well as the north side of the Core Wall Embankment.

Cofferdams. The temporary cofferdams used on this work were in all cases pole cribs filled with stone. These cribs were set in a double row from five to ten feet apart according to the depth of the water; the space between them, after being sheeted with various types of sheet piling, was filled with clay to render the enclosed area water-tight.

These cribs were built, as a rule, on barges and placed by derrick boats. They were set on the gravel bottom of the river, which in itself was water-tight owing to the presence of considerable clay mixed in with the gravel and sand.

The cofferdams were of three types:-

Type No. 1, for shallow water up to nine or ten feet, consisted of two rows of cribs about twelve by fifteen feet in size about six feet apart on the gravel at the bottom of the river. A row of sheet piling on each side of the space between the cribs was driven, breaking joint, about two feet into the gravel. Six by eight waling strips steadied the plank in the driving. Iron rods were put through the waling strips from side to side and the clay chamber was filled to the top of the sheeting with river clay and then covered with small stone or riprap.

Type No. 2 for water twenty feet deep. Two rows of cribs twelve by twenty-six feet were set on the bottom of the river and loaded with stone as before, this time ten feet apart. On either side of this space sheet piling was driven consisting of twelve by six grooved planks with oak splines in the grooves. These sheet piling were pointed and a shoe of light iron plate put on. Waling strips as above were fastened to the cribs as low as the water would permit as a guide in the driving and iron rods were run through from side to side to the clay chambers, size 3/4", spacing 5' center to center.

Type No. 3, special pole cribs twenty-six feet long set in parallel with the axis of the stream, one end ten feet and the othereend fifteen feet wide. These cribs were used to close spillway after the shore sections were finished and ready to have the water pass through them. In this channel, or spillway, there was twenty-two feet of water running twelve miles per hour.

These dovetail shaped cribs were set in place with the small end upstream and every other crib being left out with the object of reducing the rush of the water in the closing space to as small dimensions as possible. This closure work was very easily and quickly carried out by the following method.

The cribs were built on barges and lifted into place by two derrick boats. The large dipper dredge was previously backed up on the downstream side of the opening to be closed and secured in place by lines to the cribs already placed and steadied by its two spuds, and its bucket which was resting on the bottom of the river and acting as a strut. The crib was then lowered and slid down the rear spud of the dredge into its place, where it was held until safely loaded with riprap. This method did away with all necessity for ropes and anchorage upstream. This closure of the coffers caused the river to rise four feet higher while these cribs were being placed.

Jones & Laughlin type of steel inter-locking piling, size 15", 40' long, was then driven on the upstream side of this single row of cribs. A large quantity of clay was then dropped on the upstream side of this piling, and, subsequently, a second row of cribs was set on this clay five feet away from the steel sheet piling, and the clay chamber fill brought up to the height of the cribs.

Crib Work. The crib work consisted of pine poles bought in the neighborhood, size 6" to 8" in diameter of the small end, length 12 to 26' long. These poles were fatened together with drift pins, 5/8" diameter, after being dapped out to fit at the end and bored for the pins, and vertical poles were set in each corner and spiked there. Diagonal struts and ties were used in deep water cribs. All cribs were built bottomless and filled with riprap to their tops after being placed. As a rule the cribs were built on the barges sufficiently high to just reach the surface of the water when placed, and, where they needed any further elevation, poles were built onto them to the desired height. Cost of poles 2 cts. a foot delivered at river bank.

Sheet Piling. The steel sheet piling was Jones & Laughlin inter-locking type, weight per foot 39.75 lbs., cost per foot 72.8 cts., freight rate 44 cents. a hundred pounds from Pittsburg, dimensions 15" in 40' lengths. These piles were driven by a drop hammer, weight 3,000 lbs., and sometimes by an Arnott steam hammer, weight 8,000 lbs. This steel piling was used for the upstream coffer and driven down in the broken up rock and its crevices immediately under the gravel; its purpose being to check any possible deep leaks and also to help anchor cribs, labor cost of driving $0.068 per foot.

Wood sheet piling was of two kinds:-

(1) 12 by 6", length 16 to 26', with groove for oak splines, size of spline 2 x 4". This piling was used where driving into gravel was deemed necessary. These piles were sharpened and a shoe put on the end. Lumber was bought in Chattanooga, price for 26' lengths 15.6 cts. a foot, price for 16' lengths 13.2 cents per foot, price of grooving 1.2 cts., freight rate $5.50 per hundred weight. Splines were made on the job from oak logs bought from the neighboring farmers.

(2) The second kind of wooden sheet piling was two inch planks, double breaking joint, on each side of the clay chambers. These were used where heavy driving in the gravel was not deemed necessary, hammer used "Arnott", weight 1400 lbs, size 2 x 12 x 26". Six by eight waling strips were used to steady all kinds of piling and rods were run through clay chambers to bind the sheeting together, spaced 3 to 5 feet apart.

Riprap. The riprap was quarried in the immediate neighborhood of the Dam, and some of it was secured from foundation rock excavation, cost of quarrying per yard 60 cts. to $1.00. It was loaded on barges and transported to the cribs to be filled in, loaded by hand into skips and dumped in place by derrick boats. Riprap was also used to cover top of clay chambers to prevent the clay from being washed away when flood water rose over the tops of the coffers. In some cases there was eighteen feet of water running five to fifteen miles an hour over the top of these cribs; hence it was necessary to build everything of great strength to stand the long and persistent floods, rendered more destructive by large quantities of drift wood and whole trees brought down from the upper river.

Clay Coffer Filling. The best material for this purpose was found to be clay dredged from the foot of the river banks and loaded onto barges. This material was loaded sometimes by the dipper dredge and sometimes by derrick boats with orange-peel buckets, and transferred by derrick boats with clam-shell buckets to the clay chambers. Bank clay from the shore was tried for this purpose, but it was found it bridged over bottom leaks, whereas the river clay filled in and flowed down where any wash occured at the bottom of the river, thereby showing the location of leaks and materially aided to stop them. In addition, this river clay was in a naturally well puddled state and required no wetting down and tamping as did the bank clay.

Derricks. On top of the coffers stiff-leg derricks were erected in such locations that their booms covered most of the area enclosed by the coffers. Booms 80' to 85' long were used, and all parts of derricks were designed to enable them to handle a load of about four to five tons. Fittings were of various standard makes. Goose necks heavily upset. Stiff-legs anchored in stone filled cribs so places that, where possible, protection from floods and drift was afforded to the hoist engine and mast. In the beginning, in Sections Two and Four, these derricks were set on cribs whose tops were about twelve on the gauge. In Section Three, the closing section, the derricks were set at about elevation 620 on the gauge in order to have them safe above minor floods. During one flood no less than seven derricks were thrown and many of the timbers broken and lost. Two or three drum hoists of various standard makes with swinging gear were used, and dead drums were installed where clam-shell and orange-peel buckets were to be operated. Generally speaking, the masts of the derricks were of pine trees with just the bark removed. They cost about $120.00 F. O. B. job per stick, and were procured from Sunflower Alabama. The bull-wheels used were usually built on the job from timbers with bent railway rails for swinging rope guides. The ropes used were of steel wire, the hoisting 3/4" diameter, falls 5/8" and swinging gear 1/2". Ropes of the American Steel & Wire Co., A. Leschen & Son and Non-Rotating were used. As an additional protection wire ropes were laid from the pin at the head of the mast along the top of the stiff-leg and fastened to the anchor cribs. This precaution saved a good many sticks.

- PLANT, MATERIAL AND TRANSPORTATION -

Stationary and Floating Plant.

The attached list of plant gives the total used on the work the First of January, 1913.

Generally speaking, the plant taken over by Jacobs & Davies was found to be in very bad condition, pumps worn out, boilers leaky and of very inadequate dimensions and kinds. Everything had to be thoroughly overhauled and a great deal of all kinds of plant purchased. Nearly all of the larger and more efficient types of all classes of plant in the accompanying list had to be purchased or built after Jacobs & Davies, Inc. took hold.

When Jacobs & Davies, Inc. took over the work, the floating plant was in exceedingly bad condition and consisted of a gravel dredge of very inadequate capacity, two steamboats, the hulls of one of which was condemned and and had to be rebuilt the first winter, a miscellaneous collection of barges and two derrick boats; most of which were so rotten that almost a complete new floating outfit had to be built before the work could be attacked with full force; so that, with the exception of the steamer "Margaret" and the gravel dredge "Ajax", the whole accompanying list of floating equipment had to be built afresh by Jacobs & Davies.

Ship Yards.

In order to build the new and repair the old floating equipment, a ship yard was started on the west bank of the river and a large force of ship carpenters kept steadily at work. This was the more necessary because the River Tennessee at this point becomes very shallow in the summer months, and the floating equipment generally was constantly going aground and needing repairs. The large dipper dredge "M. A. Gundy" had to be kept busy nearly all summer dredging channel-ways in the bottom of the river in order to make it possible to transport the large quantities of materials necessary.

In the latter part of 1912, a ship ways was graded on the left bank of the river, so that steamers and other heavy parts of the floating equipment could be hauled up and repaired without the necessity of sending them long distances, as below the dam the nearest ship yard was at Decatur, and much time was lost sending steamers down and getting them back besides the possible danger of the water falling so low in the river that the vessel could not be gotten back when finished. In fact, the river is so low in the summer that it was necessary to provide all facilities for repairing and building floating equipment right on the job.

In the quarry on the west bank, the material was loaded by a derrick onto the barges along side and conveyed to the work by steamers. The three floating derrick boats were indispensable in handling material for the construction of cofferdams and the large variety of work needed on the river.

Material.

Cement. The quantity of cement used since Jacobs & Davies started up to

January 1st, 1913, was 175,300 barrels. The cement used on this job is Dixie Portland Cement, manufactured at Richard City, Tennessee, and transported on the N. C. & St. L. R. R. and by company barges. It was tested by the Pittsburg Testing Laboratory under the supervision of Government Engineers.

Coal. Coal was brought in almost exclusively by the N. C. & St. L. R. R. from the various mines on that railroad. This formed the heaviest single item of transportation.

Stone. The stone in the work was taken from a quarry immediately adjoining the Lock on the right bank of the river. A crusher had been provided to crush this stone for use in the concrete, but it was found to be much cheaper to dredge gravel from the river, so its use was abandoned. The stone quarried was used for large dimension stones in the concrete and for riprapping earth slopes and filling cribs for the coffers.

Sand & Gravel. Gravel and sand were excavated from the bed of the river by means of a bucket dredge, built on the job, and delivered on the job by Company barges towed by Company steamers.

Timber. Timber for derricks was brought from Sunflower, Alabama. For forms, lumber was at first bought at Chattanooga, and part of the supply was provided by local saw mills; but, subsequently, the Company installed a saw mill on the right bank of the river and bought logs from the farmers in the mountains between the Lock & Dam and Chattanooga. Both oak and pine were procured this way, and provided an excellent and cheap supply of all classes except where long timber was necessary.

Steel. The reinforcing bars were purchased, some in Birmingham and some in New York, and shipped to the work.

Clay. Clay was provided partly by a dipper dredge, partly from banks on the shore of the river, and delivered on barges. The river clay was found best for clay chambers in cofferdams, but the red clay found on the banks was found to be much more desirable for use around caissons while sinking same.

Transportation.

Transportation to the site of the Dam was provided partly by river, 33 miles from Chattanooga; 14 miles from South Pittsburgh; 21 miles by N. C. & St. L. R. R. to Ladds Switch from Chattanooga, whence, the Company, on their own railroad, 2-3/4 miles long and their own engines, hauled material to the Dam. Considerable material was brought from Chattanooga when river conditions permitted, partly by the Company's own steamers, when available, and more often by the weekly boat of the Chattanooga & Tenn. River Navigation Co.

- ORGANIZATION -

Supervision of the Work.

A general supervision was exercised by a Superintending Engineer, resident on the job, with a staff as indicated by the attached diagram of staff organization

The Chattanooga & Tennessee River Power Company had a Resident Engineer with a small staff of assistants.

The United States Government had a Resident Junior Engineer on the work, who was under orders from the Government Engineer, in charge of this district of the Tennessee River, residing at Nashville. During 1912, a Captain of Engineers was stationed at Chattanooga, to whom was delegated the power of the Major in charge of the district when that officer had other engagements and attention was needed at the Dam. The Resident Junior Engineer had from twelve to eighteen inspectors under him. The Government supervision was limited to work that in any way could be interpreted to have to do with the continuity and safety of navigation on the Tennessee River; and, in the summer of 1912 following decisions of the courts, the enterprise was adjudged to be a Government work and the eight hour law was immediately enforced in all its strictness.

Labor.

The number of men employed on the work varied from eighteen hundred down, and was of every nationality of recent immigration. The largest percentage consisted of negroes from Tennessee and neighboring states. Considerable difficulty was experienced in keeping a sufficient number of men on the work, as it is the habit of other contractors to send agents to the Camp and induce the men to leave on all sorts of fallacious promises. A somewhat higher rate than current wages was maintained and thereby a fairly efficient number of men kept on the work.

The Hours of Work. Three eight hour shifts were maintained for all classes of labor except on floating equipment and those men employed on the railroads. Some difficulty was at first experienced with green hands working in compressed air; but, after a time, the colored laborers got accustomed to it and made fairly good "sandhogs"; although at first alarmed at the occasional flooding of the caissons, they soon got accustomed to the work.

For the safety of the men working in compressed air, the resident physicians examined every man before permitting him to go to work. A hospital lock was provided so that any cases of the bends could be treated promptly. Steam heated dressing rooms furnished with lockers were provided for the men working in air, and free coffee was also given them when coming off shift, and in colder weather in the middle of the shift. No fatal cases of bends have so far occured; very few men have needed to use the hospital lock.

- DIAGRAM OF STAFF ORGANIZATION -

SUPERINTENDING ENGINEER.

Camp Boss (One Assistant)

One Camp Foreman

One Assistant on East Side
One Assistant on West Side

Police - One Deputy Sheriff

Three Assistant Deputy Sheriffs

Engineer

One Assistant

Hospital Doctor

One Assistant

Office Manager

Bookkeeper
Paymaster
Order Clerk
Head Timekeeper
Storeroom
Hotel Manager
Commissary Manager
Poolroom Manager

SUPERINTENDENT

Walking Boss. (1Runner)

Days - East Side

River Equipment	1 Captain - 2 pilots	
Railroad "	1 Gen. Foreman - 1 Assistant	
Ladds Clay Bank	1 Foreman	
River Clay Bank	1 Foreman	
Sec. 3-A Cofferdam	2 Foremen	Driving poles
Sec. 3-A Cofferdam	1 Foreman	Building Cribs
Sec. 3-A Cofferdam	5 Foremen	Blasting, Loading & Unloading Rock &c.
General Carpenter	1 Foreman - 1 Assistant	
Rigging	1 Foreman - 2 Assistants	
Power House	1 Foreman	
Dipper Dredge	1 Foreman	
Bucket Dredge	1 Foreman	
Painting	1 Foreman	
Stable	1 Stableman	

Night Shifts - East Side

Walking Boss (1 Runner)

River Equipment	1 Captain - 2 pilots
Railroad "	1 Foreman
Sec.3-A CofferDam	4 Foremen - Blasting, Loading and Unloading Rock & C.
Dipper Dredge	1 Foreman

Walking Boss (1 Runner)

Days - West Side

Shipyard	1 Foreman - 2 Assistants
Handling Material	1 Foreman - 1 Assistant
General Work	1 Foreman - 1 Assistant
Gen. Carpenter	1 Foreman - 1 Assistant
Bldg. Caissons.	2 Foremen
Compressed Air. Locks &c.	1 Foreman
Sinking Caissons	1 Gen.Foreman, 1 Asst., 6 Foremen
Rigging	1 Foreman

Night Shifts - West Side

Walking Boss (1 Runner)

Handling Material	1 Foreman
General Work	1 Foreman - 1 Assistant
Compressed Air Locks &c.	1 Foreman
Sinking Caissons	1 Gen. Foreman - 6 Foremen

Master Mechanic.

East Side - Days	West Side - Days
1 Gen.Repr.Foreman	1 Asst.Gen. Foreman
1 Boilermaker "	1 Hoisting Engr. "
1 Machine Shop "	1 Power House "
1 Hoisting Engr."	1 Pump "
1 Power Plant "	

Night Shifts-E.S.	Night Shifts - W. S.
1 Asst.Gen.Foreman	1 Asst.Gen. Foreman
1 Machine Shop "	1 Hoisting Engr. "
1 Power Plant "	1 Power House "
	1 Pump Foreman

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- GENERAL DESCRIPTION OF CAMP -

Population.

The Camp grew up on the flats along the river and on the sides of the mountain at the ends of the Dam. The population amounted to about three thousand people who were housed in two room shanties for married, while the single men were provided with accomodation in what were commonly known as "bull pens", being long one story sheds. In addition, the neighboring village of Guild grew considerably in size owing to the presence of the works, and men came to the works from long distances from the various small villages and towns in the neighborhood.

Water Supply.

This was provided partly from a natural spring and partly from a driven well of about one hundred and seventy feet deep. Both of these sources gave a supply of very pure water which contained on organic but a somewhat large proportion of mineral inpurities, but it is a supply better than most cities get and no sickness has been experienced from this source.

Lighting.

Lighting was provided by means of electric arc and incandescent lamps as well as ascetylene lamps on the work, and incandescent electric lighting is in many houses and "bull pens". This latter it was found advisable to afford, as several comparatively large fires were traced to candles and lamps.

Ice Supply.

Ice is manufactured on the job by the Company, and supplied to the employed at a reasonable rate of 25 cts. per hundred pounds. Occasionally in the summer an additional supply has to be hauled in from Chattanooga by railroad, but nine-tenths of the time the Company can supply enough for all Camp purposes.

Fire Protection.

Fire protection is secured by various means. There are pipe lines leading to all parts of the built up section from a tank on the mountain kept full by pumps from the river. In addition, chemical engines are stationed with the necessary hose reels at proper points in the Camp. Some of the employees have been desiginated as firemen, and notice of any fire is given by a steam siren at the Master Mechanic's Office. In addition, watchmen have been put on, who carry watchmen's clocks, making their regular rounds every night.

Food Supply.

Food supply is procured, partly from the farmers in the neighborhood, mainly from Chattanooga by means of a daily delivery of meats and perishable provisions. Sometimes this supply is received by river from Chattanooga. There are several stores in the immediate neighborhood of the Camp in addition to the Company's "commissary", where a good supply of general merchandise is kept for the convenience of the employees.

Police.

The Camp is policed by means of deputy sheriffs appointed by the Sheriff of Marion County, Tennessee, and approved by the management. In addition, watchmen are put on as above noted and extra deputies are appointed whenever any trouble threatens.

Entertainment.

For a short time a moving picture show was running but did not seem to pay. An athletic club was organized in 1911; and, during the winter of 1911 and 1912, boxing bouts were held to keep the men interested and in Camp. During the summer a baseball team was organized and helped to amuse the employees. Of other entertainments, except one white and one colored poolrooms, there are none.

Provisions for Various Religions.

There is a colored church in the colored quarter, and a school house in the white camp in which religious service is occasionally held. On the west side of the river religious service was held for a time in the saw mill.

Hospital Accommodation and Medical Supervision.

Organization. The Hospital is in charge of a physician with one qualified assistant. There are also employed at the Hospital two nurses and two servants.

Duties of Doctors. The doctors take care of all patients in the Camp on both sides of the river and are to make calls on employees in the immediate surrounding country, including the villages of Haletown and Ladd's Switch.

Hospital Patients. The Hospital is carried on for the benefit of the employees of Jacobs & Davies: hence no other patients are admitted unless people injured by the Company or in cases where absolutely necessary. Women are not admitted as patients unless injured by the Company or in cases where it is unavoidable.

Hospital Fees. A charge of 25 cts., except to office men, is made to all employees on the work for medical attendance and medicine. If the employees are sick and are able to call at the Hospital, they are to do so; if they are unable to call at the Hospital, the doctors will call at any place in Camp to give medical attendance. In neither case will there be a charge made. The families, who reside in Camp, of the men who pay the fee of 25 cts. a week for medical attendance, will be treated free of charge. Out of Camp calls are charged at the rate of $1.00 a mile.

Sanitation. It is the duty of the doctor in charge to see that the Camp and immediate surroundings are kept clean of all matter which may cause disease. He is to have all stagnant pools drained or oiled; to see that the water supply is kept uncontaminated; to inspect both commissaries, dairies and ice plant; to know that the "bull pens" are kept sanitary; to see that the Camp grounds are always in a sanitary condition and to have any other unhealthy condition speedily attended to.

Special Charges. Everyone pays the following special charges:-

For circumcision - $10.00

For obstetrics at least $10.00 and not more than $25.00, according to patient.

For male and female veneral diseases and for all operations where disease is not incurred in Company's service and for accidents caused by figting and drinking, everyone is charged according to the physician's judgment.

Reports. The doctor in charge reports to the Superintending Engineer every week. This report contains the number of patients in both white and colored wards, an itemized report regarding sanitation, the number of camp calls made, patients calling and treated at Hospital, number of dressings, births, deaths, and number of pest house cases.

The exact condition of any suspicion, infectious disease is carefully watched and the progress reported daily to the Superintending Engineer.

General. Since April 20th, 1912, to March 1st, 1913, there have been forty-six births and twenty-three deaths. There has been a weekly average of six white patients and four colored patients in the Hospital. The number of pest house cases has been nine.

Health of Camp.

The health of Camp has been excellent, very few cases of dangerous and contagious diseases have developed, but there is a pest house provided in case such should appear. A few cases of smallpox and spinal meningitis have come into Camp, but they have been promptly taken care of.

LIABILITY INSURANCE.

The first policy for Liability Insurance was taken out by William H. Flaherty in the spring of 1910 with the Travellers' Insurance Company, the rate being $1.44 per $100.00 pay roll. This policy was carried until October 31st, 1910, when it was cancelled by the Travellers' Insurance Company account of the large number of accidents.

In the month of November, 1910, while we were negotiating for a new policy, we had no liability insurance, and, during this month, had only one serious accident, viz., H. W. Bird, who was killed on the core wall and whose relatives instituted suit, but were unable to recover. Therefore, we saved the entire month's premium for the month of November, 1910.

On November 30th, 1910, we obtained a policy from the United States Fidelity & Guaranty Company of Baltimore, Md., at the rate of $1.39 per $100.00 pay roll. This rate remained in force until the fifth day of October, 1912.

When we started caisson work, which was in August, 1911, the insurance company took up the matter of increasing the rates of the men employed in the caissons, they claiming that the current rate throughout the country was from $8.00 to $10.00 per $100.00 pay roll for work of this character, but, on our assurance that there was very little danger in the caissons, they agreed to protect us at the same rate, viz., $1.39 per $100.00 pay roll, provided the air pressure did not exceed 20 lbs. per square inch.

In the fall of 1912 the United States Fidelity & Guaranty Company threatened cancellation of our policy account of their losses in handling the business, but, after several conferences and on the advice of Mr. Williams of Messrs. Williams & Lancaster, it was agreed, on and after October 1st, 1912, that the premium should be increased to $2.10 per $100.00 pay roll, we, however, to have the privilege of operating our caissons with no air pressure limit. This removed the danger of the insurance company waiving liability in case an accident occurred if the pressure happened to run a trifle over 20 lbs. per square inch.

The protection on both the Travellers' Insurance Company's and the United States Fidelity & Guaranty Company's policies is for $2,500 for one man and $10,000 for one accident, they to pay all legal expenses for judgements in these amounts, we to pay our proportion on judgements over and above these amounts.

The United States Fidelity & Guaranty Company have been very liberal in their settlements and in only a few cases we have settled, where there was danger of a judgement exceeding the amount for which we were protected, we have paid small amounts to assist in obtaining a settlement, but always on the advice of our attorneys.

Description of Hales Bar Dam.

CLOSURE OF DAM.

The closure of this dam was effected by a somewhat unusual method. As the foundation in each section was secured all the concrete was built up solid to elevations between 598.5 and 600. From that point to the crest the dam was built in detached piers of varying widths longitudinally with the dam but with uniform 20 foot spaces between them. The problems was how to fill these 20 foot spaces after the middle section was solid and the water was running through them.

It was first intended to drop shutters over the openings on the upper side and build up concrete in 5 foot lifts in five or six of the openings, then remove the shutters to other openings and bring the concrete up level with those already lifted the first 5 feet. By repeating this process the openings would be filled by a succession of 5 foot lifts and the water allowed to flow over the concrete as soon as it had set up enough to permit it. This, at the best, is a slow method and, with the main object of saving time, the method actually put into practise was devised.

This method was to build a screen of concrete in the upper part of these 20 foot openings leaving a passageway for the water, measuring 13'x20' underneath. This suspended concrete was built on a hanging platform of 15" "I" beams shown in Drawing No. 52-B-193, and the block of concrete marked "A" in Drawing No. 52-B-232 was first put in place after a heavy notched recess had been cut out of the concrete in the block on either side. This recess was intended, after the concrete had set up, to give a foot hold or abutment support to a concealed arch in block "A". After this block was in place, blocks "B" and "C" followed in due course, all of these three blocks being built above the water which, in the meanwhile, flowed through the 13'x20' opening below.

After the crest lift was in place a wide gauge track was laid on top of the dam, together with a third rail to form a narrow gauge track for "Dinkey" and cars to deliver concrete, the wide gauge track being used by the travelling cranes as well as travelling "A" frames which handled the steel shutters.

To close the 13'x20' openings a steel shutter was designed which consisted of 15" "I" beams laid horizontally and covered on the upstream side by 1/4" steel plates. On the inside and around the outer edge of this shutter, which measured 23'x15' was fastened a 12"x12" timber in which a half-round recess was cut to hold a 3" linen fire hose which was used as a gasket. Inside the gate, and protruding 3/4" were five heavy cast iron rollers on each side, on which the gate rolled while being lowered into place. After the gate had reached its location over the opeing, water at a pressure of 65 lbs. to the square inch was turned into the fire hose thereby effecting a very efficient seal at the upper side. This can be seen in drawing No. 52-B-231. Previously to the placing and caulking of the shutters, they were lowered as nearly into place as might be with a view of discovering if any log or other obstruction was in the opeing, and the diver was then sent down, reported on the obstructions, and fastened a line on anything that could be removed by that method. If the obstruction was rock or gravel which drifted rather freely in this river, then a derrick boat with an orange peel bucket removed the obstruction, that method being rendered necessary by the very swift current of water running through the opening. A number of the first opeings, where the water did not come above the top of the steel shutter, were caulked by means of the diver placing a 1/2" cotton rope between the concrete and the 12" x 12" timber on shutter for occasionally it would be found that the lowering of the gate had dislodged the fire hose from its place. Of these methods, neither was distinctly better than the other and they were used whereever it was judged the most time would be saved, about half being caulked by one method and half by the other.

CLOSURE OF DAM.

After this upper steel gate was ready, a wooden shutter, as shown on the same drawing, was placed on the lower side of the opeing where there was seldom more than 2 ft. or 3 ft. of water and kept caulked on the inside with oakum and empty bags. An Emerson pump was then lowered into the opening thus protected and a suction pipe brought the water from the inside of the upper gate to the pump, a row of bags having been previously laid across the upper edge of the opening, their purpose being to raise what leak water there was under the steel gate up to a height sufficient to cover the pump suction. A similar bag dam of cement was also laid around the pump and on that a form was built which enclosed the pump in a species of pump well, thereby enabling the concreting of lift "D" to be gone on with without hindrance from water. In the lower gate a couple of small steam syphons were placed so that their suctions were inside the gate but below the edge of the concrete and they took care of the leakage from that source. Concrete for lift "D" was then brought by means of the tracks on the crest and lowered partly by buckets and partly through a jointed steel pipe. This concrete "D" was a monolith and placed, as shown, to completely close the upper opening. As soon as this concrete had set up both the steel and wooden gates were removed and used elsewhere; Then the concreting of blocks "E", "F" and "G" was effected in one operation. The suction pipe bringing the water to the Emerson pump was left in place a grout pipe being brought up to the surface to enable it to be grouted when the diver had blocked its upstream opening after the steel gate was removed.

This method of closure was found to be very rapid and economical, as many as four of these openings being closed in a week after the steel shutters were in place, great economy being effected by having large masses of concrete to put in at once and also from the fact that the shutters had only to be set and caulked once for each opening. There is no doubt but that there was at least two months' time saved by closing in this way rather than by the old fashioned method, not the least of the economy being that blocks "A", "B" and "C" were put in place before the dam was otherwise ready to be closed.

Description of Hales Bar Dam.

Selection by Commanding Position

JAMES FORGIE
CONSULTING ENGINEER
84 William Street
NEW YORK

CONTRACT.

UNITED STATES GOVERNMENT AND CHATTANOOGA & TENNESSEE RIVER POWER CO.

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THIS AGREEMENT entered into this 12th day of September, Nineteen Hundred and Five, between Major H. C. Newcomer, Corps of Engineers, U. S. Army, party of the first part, and the Chattanooga & Tennessee River Power Company, corporation organized under the laws of the State of Tennessee, with its principal office in Chattanooga, Tennessee, party of the second part, WITNESSETH:

That, in conformity with an act of Congress approved April 26th, 1904, entitled "An act to enable the Secretary of War to permit the erection of a lock and dam in aid of navigation in the Tennessee River, near Chattanooga, Tennessee, and for other purposes" (33 Stat. L., 309) as amended by an act of Congress approved January 7th, 1905, (33 Stat. L., 603) and with the specifications hereunto attached and the drawings relating thereto, all of which form a part of this contract, the said Major H. C. Newcomer, Corps of Engineers, U. S. Army, for and in behalf of the United States of America, and the said Chattanooga & Tennessee River Power Company do covenant and agree to and with each other as follows:---

WHEREAS, under the said acts of April 26th, 1904, and January 7th, 1905, the Secretary of War is authorized and empowered to grant permission to the City of Chattanooga, Tennessee, or to C. E. James and J. C. Guild, residents of Chattanooga, their heirs and assigns, upon failure of said city, within four months of the passage of said act of April 26th, 1904, to formally notify the Secretary of War of its intention to avail itself of the benefits of said act, to build and construct a lock and dam across the Tennessee River at Scott Point, near Chattanooga, or at such other point or place in the mountain section of said river below Scott Point as the Secretary of War may approve, upon the terms, provisos, conditions and stipulations provided in said acts of Congress;

AND WHEREAS, the City of Chattanooga, Tennesssee, having failed within said period of four months to notify the Secretary of War of its intention to avail itself of the benefits of said act of April 26th, 1904, the said C. E. James and J. C. Guild, did, pursuant to the requirements of said act of April 26th, 1904, within the period prescribed therefor, formally notify the Secretary of War of their intention to proceed with the construction of the lock and dam as authorized, and did submit to the Secretary of War, for his examination and approval, maps showing the location of the lock and dam at Hales Bar, which is in the mountain section of said river, about fifteen and one-half miles below Scott Point and about thirty-three miles below Chattanooga, Tennessee:

AND WHEREAS, on May 24th, 1905, the Secretary of War did grant unto the said C. E. James and J. C. Guild, theirs heris and assigns, permission for the construction of the said lock and dam at Hales Bar, upon the following conditions:

1. That this permission and approval are preliminary only, and shall be subject to all the provisions and conditions of said act of Congress, including the authority of the Secretary of War to hereafter require such bond as he may consider necessary, not exceeding $100,000.00, to insure the commencement, prosecution and completion of the work herein authorized, and compliance with the terms, conditions and requirements of said acts of Congress.

2. That the said C. E. James and J. C. Guild shall purchase and convey to the United States the land, etc., required by said act of April 26th,

1904, to be procured and donated to the United States within the period of six months from the date of this instrument".

AND WHEREAS, the said C.E. James and J.C. Guild have transferred and assigned unto the party of the second part all the rights, privileges and franchises conferred on or belonging to them under the aforesaid acts of Congress, and the aforesaid grant of May 24th, 1905, from the Secretary of War, and have formally notified the Secretary of War of said transfer and assignment:

AND WHEREAS, the party of the second part has assumed all the obligations and duties devolving upon the said C. E. James and J. C. Guild under and by virtue of the provisions of the aforesaid acts of Congress and grant from the Secretary of War:

NOW, THEREFORE, for and in consideration of the grant by the United States of such rights as it possesses to use the water power produced by said dam and to convert the same into electric power or otherwise utilize the same for a period of ninety-nine years, as provided in the act of Congress of April 26th, 1904, aforesaid, the said party of the second part do hereby agree as follows:

1. To build the lock and dam at Hales Bar in accordance with the plans and specifications approved by the Secretary of War and as otherwise provided in the aforesaid permit of the Secretary of War dated May 24th, 1905, and the aforesaid act of Congress approved April 26th, 1904, as amended by the aforesaid act of Congress approved January 7th, 1905, and to conform to all other provisions of the said act.

2. To build the works and structures necessary to utilize the water power produced by the said dam in accordance with the plans approved by the Secretary of War, and to use, maintain or strengthen these works and structures without cost to the United States, in such manner as the Secretary of War may deem necessary in the interests of navigation.

3. To hold and save the United States harmless from and against all and every demand or demands, of any nature or kind, for or account of the use of any patented invention, article or process included in the materials hereby agreed to be furnished and the work to be done under this contract, or on account of any damage to person or property resulting from the construction of said lock and dam.

IT IS FURTHER AGREED, by and between the parties hereto, as follows:

4. All materials furnished and work done under this contract shall, before being accepted, be subject to a rigid inspection by an inspector appointed on the part of the party of the first part and such as do not conform to the specifications set forth in this contract shall be rejected. The decision of the engineer officer in charge as to quanitty and quality shall be final.

5. No claim whatever shall, at any time, be made upon the United States by the party of the second part for or account of any work or material performed or furnished, or alleged to have been performed or furnished, under or by virtue of this contract.

6. The party of the second part shall be responsible for and pay all liabilities occurred in the prosecution of the work for labor and material.

7. Until final inspection and acceptance of all the material and work herein provided for, no prior inspection or act is to be construed as a waver of the right of the party of the first part to reject any defective work or material or to require the fulfillment of any of the terms of the contract.

8. No work shall be done on Sundays or legal national holidays, except in cases of emergency, upon the written consent of the party of the first part.

9. In the prosecution of the work herein specified, the employment of persons undergoing sentences of imprisonment at hard labor which have been imposed by courts of the several States, Territories or Municipalities having criminal jurisdiction, is prohibited.

10. The party of the second part will be required to discharge any employee who, in the opinion of the party of the first part, is objectionable or incompetent. Such discharge will not be made the basis of any claim for compensation or damages against the United States or any of its officers or agents.

11. The party of the second part must at all times be represented on the work by a competent agent, with full authority to act for him in all cases.

12. This contract shall be subject to approval by the Chief of Engineers, U.S. Army, and the Secretary of War.

IN WITNESS WHEREOF, the parties have hereunto set their hands and seals the day and year first above written.

IN PRESENCE OF

JOHN M. G. WATT as to H. C. NEWCOMER,
Major, Corps of Engineers,
U. S. Army.

JAMES Mc FARLAND as to CHATTANOOGA & TENNESSEE RIVER POWER CO.,
By R. H. WILLIAMS,
President.

SPECIFICATIONS.

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1. WORK TO BE DONE.

The work to be done under these specifications is the construction of a lock and dam, exclusive of lock gates, iron work and machinery to operate the lock; also the construction of the foundation and substructure of a power house; the foundation and substructure of a transformer house; the construction of an extension of the dam including core walls and embankments; the excavation and shaping of a head bay and of a tail race and various slopes, paving, riprap and other details.

2. LOCATION.

The location of the work is at Hales Bar in and at the sides of the Tennessee River, about 33 miles by river below Chattanooga.

3. GENERAL CONDITIONS.

The works and constructions included in the agreement and in these specifications are:

A. A lock and dam to be constructed in accordance with an act of Congress approved April 26th, 1904, and an ammendment to that act approved January 7th, 1905.

B. Constructions to utilize water power, including the foundations and substructure of a power house; the foundations and substructure of a transformer house; an extension of the dam, excavation and shaping of head bay, ant tail race and various slopes, paving, riprap, metal work and other details.

For the works included under Caption A plans and specifications have been prepared and approved by the officers of the Corps of Engineers and by the Chief of Engineers, U. S. A., and duly approved by the Secretary of War. These plans become part of the agreement and the specifications are included in the following specifications.

For the works included under Caption B the plans have been prepared by the Engineer of the Chattanooga & Tennessee River Power Company and approved by the Secretary of War and become part of the agreement and of these specifications. The specifications for these works are also included in the following specifications.

4. SUPERVISION.

The works included under Caption A will be conducted under the direction of the United States Engineer Officer in charge of the improvement of the Tennessee River. The works included under Caption B will be conducted under the direction of the Engineer of the party of the first part in this agreement, the methods and details of construction being subject to the approval of the said United States Engineer in all matters affecting the stability and permanence of those works and structures that form a continuation of the dam and are essential to the maintenance of the pool above the dam.

The party pf the second part in this agreement will be duly advised from time to time as to the methods and details of supervision and inspection. He will be under the immediate direction and inspection of the Engineer of the party of the first part and of his duly authorized agents, through whom, when necessary, the directions of the United States Engineer Officer will be transmitted.

5. DRAWINGS.

The work must conform in general to the drawings accompanying these specifications and to such others in explanation of detail or minor modifications of plans as may be furnished later; all such drawings shall be considered as forming a part of these specifications.

6. MATERIAL.

The lock, dam, substructure of power house, core walls and other masonry shall be built of concrete either with or without the use of large stones imbedded therein as specified hereafter.

7. FREEDOM FROM WATER.

All excavations and embankments shall be made and finished in the air and not under water. No conrete or masonry shall be laid under water, except to stop leaks or springs, no exposed to running water until set.

The Constractor shall furnish all materials requisite for this purpose and shall erect, place, connect, extend, maintain in good and tight condition and reconstruct or renew when requisite such coffer dams, sheet pilings, crib work, fillings and all other constructions, enclosures and other connections as may at any time be necessary to secure and maintain this condition of freedom from water. He shall also furnish, place in proper positions, maintain in good order and operate whenever required such pumps and other means as may at any time be requisite to clear and keep free from water all spaces and places where masonry or concrete or other constructions are in progress or are to be laid, or where excavations or embankments are in progress or are to be made or worked. The location, materials, methods of construction and maintenance and of operation of these provisions for freedom from water shall be such as the Engineer approves.

The payment of the amount agreed upon for the item of "Construction and Maintenance of Coffer Dams and other provisions to keep spaces and places free from water" will cover in full, all materials, constructions, labor, the provision and operation of pumps and all other requisities, also the maintenance, renewals, new constructions and removals requisitie for compliance with these specifications from the beginning of the work until the final completion and acceptance.

The total amount payable for this item will be paid in three equal installments.

One equal installment will be paid when the excavations have been completed at all points where concrete is to be laid on rock.

One equall installment will be paid when all masonry is completed to Elevation 605.

The final equall installment will be paid when the whole work is completed and the materials composing the coffer dams removed as far as directed by the Engineer.

The furnishing of the requisite materials and the construction of the provisions to insure freedom from water shall begin immediately after the execution of the contract and shall progress with a speed and in a manner approved by the Engineer.

8. EXCAVATIONS.

The earth, gravel and any other materials over-lying the rock where the foundations of the lock, the dam, the power house substructure and the connections of this substructure with the core wall are to be laid, shall be excavated as soon as possible.

The excavation of all material above the elevation of the water in the river shall be begun immediately after the execution of this contract and shall progress with speed satisfactory to the engineer. The excavation of all material below the elevation of the water in the river shall be made with speed and as soon as practicable.

The clearing and preparation of all surfaces upon which any foundations are to be laid and the actual construction of the foundations are essential features for immediate progress and shall be pushed forward to the satisfaction of the Engineer.

All excavations shall be made to surfaces, lines and slopes in each case directed.

The rock is to be excavated to the depth directed at each point. Any fissured, loose, disintegrated or shell rock must be removed. In excavating rock near the foundation lines, explosives shall be used only when absolutely necessary and then only in small quantities and as approved by the Engineer. The concrete is to be stepped into the rock in such form as the Engineer shall direct at each point so as to secure thorough contact and to provide against any possibility of movement or sliding. The details for such stepping and for the exact form of rock foundation will be directed after the rock surface is exposed and its stratification and character observed. All seams encountered must be cleared out and filled with concrete; and all leaks or springs found in the area to be covered by the lock and dam and other constructions must be closed or otherwise treated as directed by the Engineer.

In the lower approach to the lock the rock excavation must be carried down to elevation 591. In the lock chamber between the lower miter wall and the upper end of the lower gate recess, rock excavation must be carried down to elevation 590, and from this latter point to the upstream edge of the upper miter wall at least down to elevation 591. Any excavation required in the upper approach above the coffer wall need not go below excavation 620. The rock at the base of both lock walls for a distance of four feet back from the chamber face must be excavated to the same elevation as that in the chamber. The rock in the tail race and in its extension in the river and the rock at all other points where directed shall be excavated to the lines, slopes and surfaces as in each case directed. Where earth is to be excavated, the excavations shall be made to the depths, lines, slopes and surfaces in each case directed.

9. EXCAVATION OF SOLID ROCK.

There shall be included in the classification of excavation of solid rock the excavation of solid rock and of all rock in ledges or detached masses exceeding one cubic yard each.

10 EXCAVATION OF EARTH.

Clay, indurated clay, marl, gravel, material commonly known as hard pan and all materials excavated of any character not clearly included in the above classification of solid rock will be classified and paid for only as earth excavation.

11. DISPOSITION OF MATERIAL.

The material excavated shall be depositied where directed by the Engineer. Top soil, is so directed, shall be piled at locations not to interfere with other work and after slopes are finished shall be spread over them to depths and shapes directed. The price formexcavation of earth will be paid for this second movement and placing of top soil.

All other materials which, in the opinion of the Engineer, are suitable for embankment shall be placed in the embankments at such locations as shall be directed for each separate grade of such material. The method of deposit and treatment shall be specified under head of embankment.

Any materials which, in the opinion of the Engineer, are not suitable for use in any part of the embankments shall be deposited where and shaped in the manner directed.

12. EMBANKMENT.

The embankments both above and below the core wall shall be made from materials from excavations suitable in the opinion of the Engineer. These materials shall be selected as in each case directed and deposited at the various parts of embankments in each case indicated. They shall be deposited in layers of a thickness directed at each point. After being deposited each layer shall be wetted by means of a jet from a hose to the extent in each case directed and then rolled with rollers of a weight and construction approved by the Engineer. The rolling shall be continued to the satisfaction of the Engineer.

Where directed, the material underlying the location of embankment shall be excavated to the depths and forms in each case directed and this material shall be deposited where directed.

The slopes, lines, forms, dimensions and methods of construction of embankments shall be at each point as directed; connections between embankments and other points of the work or of the natural ground shall be made as in each case directed.

The price paid for excavation of earth shall be in full payment for such excavation and for the placing of the material in the emabnkment and for shaping, watering, rolling and all other requirements of these specifications, including haul up to one thousand feet.

Should the Engineer direct that material excavated be deposited at a distance from the point of excavation exceeding one thousand feet, there shall be paid in addition to the price for excavation, the price of one and one-half cents per cubic yard for each one hundred feet haul beyond one thousand feet, the line over which haul is to be made and the location of excavation and deposit to be determined by the Engineer.

These provisions will apply to any material, if such should occur, directed to be excavated especially for the purpose of obtaining material for a special purpose.

13. SLOPES.

All slopes of excavation and embankment shall be brought to true lines and s surfaces as directed, whether to receive paving, riprap, top soil or otherwise.

14. BACK FILL AND PAVING.

The space behind the land wall of the lock must be backfilled with earth, gravel and broken stone, thoroughly compacted by method of deposit or by ramming, and the top must be paved with concrete or stone blocks not less than five inches thick. The bank on the right side of the river for a distance of about 400 feet from the lower end of the land wall must be graded and riprapped with hand placed stone of approved sizes to a depth of twenty-four inches, with good substantial toe of heavy stone at the foot of the slope. All other surfaces indicated upon plans or directed by the Engineer shall be riprapped in the same manner or paved with concrete or stone blocks not less than five inches thick, in each case as directed.

15. FOUNDATIONS.

All foundations for concrete work must be on or in solid rock, and shall be prepared and thoroughly explored in the open after the water is excluded from the site. A sufficient number of borings must be made to ascertain the character of the underlying material. The base of the lock walls is shown on the drawings at elevation 592; this must be understood to be approximate only, as the character of the rock encountered may, on the one hand, necessitate deeper foundations or, on the other hand, permit portions of the natural rock to be included in the wall sections as shown. The base of the masonry of the dam; of the substructure of the power house; of the core wall and of all other constructions extending to rock shall be thoroughly excavated or left in natural condition and at such elevations and in such forms and manner as at each point directed.

16. CEMENT.

All concrete must be made with Portalnd Cement to the specifications and tests recommended by the Board of Engineer Officers, June 6th, 1901, and published in the Professional Paper No. 28, Corps of Engineers, U. S. Army. The brand shall be subject to approval by the Engineer. The contractor must protect the cement from injury whilst in the shed and in handling and he will not be allowed to use any cement wetted or otherwise damaged. He must permit access to it at all times by the Engineer or Inspector, and must afford facilities for taking out samples for testing.

17. PROPORTION.

The proportions of the concrete shall be one barrel of cement to ten cubic feet of sand or crucher dust and twenty cubic feet of broken stone or gravel.

18. SAND.

The sand must be sharp and hard and so graded in size that at least 50 per cent will be retained on a No. 50 sieve. If so required by the Engineer, it must be screened, but it need not be washed unless containing a mixture of over 5 per cent of earthly matter. Rock dust from the crusher passing a quarter inch screen will be accepted wholly or partly in place of sand, at the discretion of the Engineer.

19. BROKEN STONE.

The broken stone or gravel must be hard and sound and must run from pieces passing a two and one-half inch screen to pieces retained on a quarter inch screen.

20. MORTAR.

All mortar, except that in the concrete, must be composed of one barrel of cement to eight cubic feet of sand.

21. CULVERT LINING.

All culverts and other water passages as hereinafter specified must be lined throughout with mortar facing, as specified, the thickness of the layer being one and one-half inches.

22. LARGE STONES.

Large stones of suitable form may be imbedded in the mass of concrete. They must be hard and sound and must be placed not nearer than one foot to the exterior of any wall. They shall not be nearer to each other than about twelve inches measured horizontally, and about nine inches measured vertically. They shall be set in such manner as not to interfere with the placing of any iron work. All these stones must be cleaned before being set and thoroughly moist at the time of laying. They must be thoroughly bedded upon concrete placed immediately before laying the stone with a bed free from voids. They must be covered with a layer of concrete and care must be exercised to compact the concrete around the stone thoroughly. A ll stones must be set with their widest bed on the bottom.

23. FORMS.

The forms in which the concrete is to be placed must be held at all times firmly in position so as to secure acurately the required outlines of the masonry and be strongly tied and braced to prevent deformation in ramming; and any objectionable deviation from line before completion must at once be corrected. No concrete shall be laid in any section until all posts, braces, ties and lagging are lined up to the satisfaction of the Engineer. All form lumber must be of good quality, sound and well seasoned and free from defects which would disfigure the concrete. The use of warped and crooked lumber will,not be permitted. All lagging for surfaces that will be exposed to view in the completed work and that against which any facing mortar is to be placed must be dressed on one side and be of even thickness; it must not be less than two inches thick before dressing. Especial care must be taken to secure smooth and even surfaces in the concrete formed against dressed lagging, which must be neatly fitted, with close joints and must be laid and kept level. All butt joints must rest on posts. If tie rods are used they must be provided with sleeves at least three inches inside the face of the wall so that the ends can be withdrawn when the concrete is finished; or the tie rods may be left bedded in the concrete. Templates shall be used for the mortar facing and may be of steel or of thin boards, held one and one-half inches from the inside face of the lagging, to separate concrete and the facing while they are being deposited . They must be in good working condition all the time. Forms shall remain in position after the concrete has been completed in them until permissi on is given by the Engineer for their removalDuring this time suitable precautions must be observed to prevent the concrete from drying out too rapidly. Such material in the forms as may be satisfactory to the Engineer may be used in the construction of other forms, after proper cleaning and trimming.

24. VOIDS AND OPENINGS.

All necessary voids and openings for culverts, wells and for other purposes as may be required by the Engineer must be left in the concrete. Recesses for ladders, coffer beams, line hooks, etc., must be formed so as to leave a smooth surface on the finished work. All exposed edges, such as top edges of lock walls, next to chamber, gate recesses, ladder recesses, culvert openings, etc., must be rounded to a radius of two inches, unless otherwise directed.

25. MIXING CONCRETE.

Concrete must generally be mixed by machinery, but hand mixing may be allowed for small quantities. The machinery may be of any type, approved by the Engineer, which is capable of turning out good concrete, thoroughly and evenly mixed. If required by the Engineer, the gravel or broken stone must be thoroughly drenched shortly before being put in the mixer; the sand may be moist, but the use of wet sand will not be permitted. Of the four materials, stone, cement, sand and water, the cement must always be placed in the mixer second and the water last. The amount of water used shall be subject to variations at the orders of the Engineer, but must be such that it will produce a concrete that will quake after being rammed. All mixing must be thoroughly done to the satisfaction of the Engineer. All mortar, whether by itself or in the concrete, must be in place before it has perceptibly hardened; otherwise it must be wasted by the Contractor. No retempering will be allowed under any circumstances.

26. PLACING CONCRETE.

The method of placing the concrete in blocks or otherwise, shall be subject to the approval of the Engineer. The concreting must be carried on in daylight only, except by special written permission of the Engineer for each occasion. Before beginning work on the foundation, the bed rock must be thoroughly cleaned, the rock being roughened if so directed by the Engineer and a bed of mortar about one-half inch in thickness must be spread thereon to provide a tight joint between the foundation and the wall.

The Contractor will not be allowed to drop the concrete nor to use slides or chutes for depositing it. As soon as the co ncrete is depositied in the forms it must be spread in layers from six to eight inches thick, and be compacted at once by ramming. The number of men to be employed in ramming shall be as directed by the Engineer, as the ramming must be thorough. The rammers must have metal faces, and be of such forms, size and weight as the Engineer may direct. If the Contractor so desires, he may use pneumatic rammers, subject to the approval of the Engineer.

Suitable provision must be made to secure a good bond between adjacent blocks or portions of the concrete mass that are to be laid at different times. Whenever concrete is to be placed on or against other concrete that has set, the surface must be thoroughly brushed off and roughened, as may be directed by the Engineer, and wetted and must be covered with a half inch layer of mortar applied immediately in advance of fresh concrete. No concrete will be allowed to come into contact with dry, dirty or dusty surface.

No concrete shall be laid in water, except to stop leaks or springs, nor exposed to the action of running water until set. The planks against which concrete or mortar is to be placed must be made damp just before such placing.

27. FACING.

A mortar facing one and one-half inches thick must be used for the slope of the dam, for the interior surfaces of culverts and all water passages. All other concrete surfaces exposed to view in the finished work, including the upstream faces, the downstream faces and the river face of the power house substructure, must consist of mortar without any gravel or stone showing on the surface. If this result cannot be obtained by methods of depositing and ramming the concrete with the use of facing templates with mortar facing less than one and one-half inches thick; then a mortar facing of one and one-half inches thick must be used for all such surfaces. The composition of this facing is to be as noted in paragraph 20.

When the concrete and facing have been deposited, the facing template must be withdrawn and the whole mass thoroughly rammed so that the facing and backing may go on simultaneously in the same horizontal layers. The Contractor must provide competent laborers who shall be retained on the facing work whenever it is being carried on, since the appearance of the structure depends upon the perfection of this work. No careless or unskilled labor will be allowed to work on it.

Whenever concreting is to be suspended for the day, care must be exercised that the facing is left fairly horizontal.

28. FACING FINISH.

As soon as the form is removed from any surface, all cavities or openings left by the withdrawal of bolts, or from any other cause, must at once be carefully filled with facing mortar as directed.

29. COPING.

The coping or top finish of all walls and piers shall be of mortar one inch thick, and must be placed on the top layer of concrete immediately after this layer has been tamped. The entire coping layer must be divided by joints about one-eighth inch wide into rectangles of approved size and must have all edges rounded to a radius of two inches, and have its surface slightly roughened with a special tool making indentations or small pits. The coping on the crest and toe of dam shall be one and one-half inches thick, laid as above specified, but without joints. All this work must be done in the best style of sidewalk finish and any that is not satisfactory to the Engineer must be removed and replaced by the Contractor.

30. PROTECTION OF CONCRETE.

When freshly laid concrete or mortar is exposed to unfavorable weather conditions before it has set, the Contractor must supply suitable means of protection and any injured by lack of protection shall be at once removed and replaced by him. No concrete shall be placed when the temperature is lower than 34 degrees Fahrenheit, except by permission of the Engineer and under such conditions as may be required by him.

31. PLACING OF LOCK GATES, ETC.

The United States will furnish the lock gates, operating machinery and all other metal work of the lock necessary for its operation. The Contractor must place in position all metal work that must be embedded in the concrete when it is laid.

Bolts may be set with a template as the work progresses but if not found in true position when the concrete has hardened they must be taken out and reset correctly. If not set in this manner, holes for them must be provided either by drilling after the concrete has set or by using, during the progress of the work, a removable form of sufficient size to allow the bolt to be set later on with mortar filling in its exact location.

32. GAUGES.

Two gauges must be formed in the river wall of the lock at such location as may be directed. These gauges will be made by form as shown on detail drawing to be furnished by the Engineer and when the forms are removed the figures and tenth marks must at once be filled with mortar colored red.

33. FOUNDATION AND SUBSTRUCTURE OF POWER HOUSE.

These shall be of concrete in all respects as herein before specified except that in the piers between arched passageways no large stones shall be used which will be nearer than one foot to any face nor nearer each other than one foot measured horizontally and nine inches vertically and such stones shall not be placed so as to interfere with any metal construction. In the arches, roofs and floors between piers, including those of the main floor and sub-floor of the power house, concrete only shall be used without the admission of stone larger than the broken stonce specified for concrete.

Pipes and appurtenances, steel, beams, rods, or other forms shall be accurately placed where and as directed and the concrete tamped in such manner as to form complete contact with every part of the surface of the steel. The concrete shall be quite wet and tamped so as to be dense and without voids. The metal shall be cleaned before use and protected by a coating of neat Portlandt Cement applied with a brush as directed.

The price agreed upon and paid for steel and pipe used in the work shall include payment for the delivery and protection of the steel and for placing it in the work and this price and the price for concrete in power house foundations and substructure shall include payment for all cost of steel and concrete as finally laid and finished.

The price for concrete in foundati on and substructure of power house will

will apply to all concrete in that foundation and substructure and to the extension of concrete from the power house to the junction with core wall of dam, such junction being at the point where the top of the core wall becomes concealed by earth covering.

Great exactness will be required in the passages, openings and details of this power house foundation and substructure.

The foundation and substructure of power house must progress with all possible speed so that the water wheel appurtenances may be placed at an early date.

The coffer dams and means for keeping water from the power house substructure must be maintained in good condition until their removal is permitted.

34. EXTENSION OF DAM.

The dam between the power house and the high ground eastward will be formed by a core wall and an embankment.

35. CORE WALL.

The core wall shall be founded upon or stepped into the natural rock which shall, for this purpose be excavated to depths and forms directed. The core wall shall be of concrete made and laid in conformity to clauses 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29 and 30 of these specifications. If an extension or any portion of the core wall is directed to be founded at an elevation higher than the natural rock, the foundation is to be made in such manner and with such materials as directed.

36. TRANSFORMER HOUSE.

This shall be founded upon concrete piers or in such other way as the Engineer determines after examination and excavation at the site. Metal shall be placed in the concrete of the substructre of this house as and where directed and the specifications for power house substructure will apply to this substructure.

37. SLUICEWAY IN DAM.

A sluiceway shall be formed in the dam at the points and in the manner to be shown by detailed drawings and directions.

38. PASSAGEWAY IN DAM.

The passageway shown in the cross section of dam shall be accurately formed and treated as specified for culverts. Pipes of the size and at the points directed shall be set in the concrete of the dam, leading to the downstream face.

39. PROVISION OF FORMS.

The price agreed upon for any concrete shall include the cost and provision of all forms, centers, templates and appurtenances and also the facings and finish as specified.

40. COFFER DAMS; MAINTENANCE AND REMOVAL.

For the convenience of the United States or its agents in erecting the lock gates and placing any other metal work, the lock must be kept unwatered for such time as may be necessary, without extra expense to the United States.

When the necessity for any coffer dam shall have ended, the material composing it must be removed at least down to the general level of the bed of the river; but if permitted by the Engineer, some designated portions above the dam may be left in position.

41. REMOVAL OF RUBBISH.

Within sixty (60) days of the completion of the work all the grounds must be cleaned up and put in as good shape as they were before commencement of work, without extra expense to the United States or to the party of the first part.

Nickajack closure - Initial filling started . . . - Dec. 14, 1967
- Reservoir filled to El. 634 . . . Dec. 16, 1967

Hales Bar Units - Time of last generation . . . 3:32 AM Dec 15, 1967

Hales Bar Units 1-14 retired from service . . . Dec. 15, 1967

FOR PHOTOS (Numerous)
OF THIS
SEE
PHOTO & STEREO
FILE BOX
AT HOME

Permanganate of Potash
Pages 12 & 15
of MAIN Report