THE MADEIRA-MAMORE' RAILWAY

BY

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I recommend that the thesis prepared under my supervision by RALPH ANDERSON BENNITT entitled The Madeira-Mamore' Railway be approved as fulfilling this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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THE MADEIRA-MAMORE RAILWAY.

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      c. Difficulties.
      d. When completed.

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         a'. Organization.
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MAPPA
MOSTRANDO A
DIRECÇÃO GERAL E PROGRESSO DA CONSTRUCÇÃO
DA
E. DE F. MADEIRA E MAMORÉ
PORTO VELHO
SANTO ANTONIO
RIO MADEIRA
BRAZIL
INDIOS CARIPUNAS
VILLA MURTINHO
GUAJARA-MIRIM
BOLIVIA
RIO BENI
RIO MAMORÉ
RIO ABUNÃ
LEGENDA
VENEZUELA
GUIANAS
COLOMBIA
ECUADOR
PERU
AMERICA DO SUL
BRAZIL
BOLIVIA
PARAGUAY
CHILE
ARGENTINA

THE MADEIRA-MAMORE RAILWAY.

RESOURCES OF WESTERN BRAZIL AND BOLIVIA.

The enormous wealth of Bolivia can never be fully realized until means of opening up the country can be obtained. Bolivia was conquered by Hernando, and at one time was part of Peru. Bolivia's was the wealth which enabled Spain to fit out vessels and become the "Mistress of the Seas". Bolivia's rich deposits of silver, gold, copper, tin, lead, mercury, and coal are practically untouched, although from the silver deposits of the State of Potosi alone the vast sum of $3,000.000 had been extracted from 1546 to 1864. What work has been done has, to say the least, been very primitive, and only the surface has been touched.

In comparison with the other natural resources of Bolivia the mineral wealth seems small. As there is any climate between the snowcapped peaks of the Andes mountains and the tropical plains below, anything can be produced. Rubber, tobacco, cotton, cacao, the vanilla bean, cocoa, gums, and valuable woods grow in abundance.

The opening of the Madeira-Mamore Railway in Brazil on September 7, 1912, threw open one of the richest rubber districts in the world by making Bolivia more accessible. To place additional territories in South America at the command of the rubber gatherers is merely a question of building railroads. Peru has vast stretches of rubber forests, and when transportation facilities are improved the output from that country will be immensely increased. India rubber, as the product is known to the trade, grows wild in South America. Efforts at cultivation of the Brazilian rubber from seed have been successful in other lands, and to some extent cultivation has been practised in Brazil, but by far the greater portion of the rubber exported from there has been gathered from the forests of the northern interior. No systematic preparation of the ground is necessary, and the entire work of the rubber gatherers has been to obtain the milk from the rubber tree, and to get it to the market.

About one-half of the world's supply comes from Ceara, Manaos and Para. The product of these sections sets the price for the raw material in the markets. The Amazon territory, including the uplands of Brazil, Bolivia, and Peru, supply the bulk, although the cultivated rubber from the far East, as well as from Mexico, and Central America is beginning to enter into competition with that of South America. The vastness of Brazil's rubber trade may be realized from recent statistics. In one year this country exported $125,000,000 worth of crude rubber. The principal purchasers were Great Britain, The United States, France, and Germany.

There are several varieties of trees from which rubber may be obtained. The best grade of rubber is that obtained from the hevea tree, which is a native of the Amazon region. The hevea is a large tree of comparatively slow growth, and when full grown is about 12 ft. in circumference. It begins to yield its milk the fourth year of its growth, and may be tapped for twenty years or more. Next to the hevea comes the castillea, which grows in Southern Mexico, Central America, Ecuador, Colombia, and Peru. One of the principal sources of Peruvian rubber is the hancornia. In order to get the latex from this tree it is necessary to cut it down, which eliminates this variety as far as planting is concerned. Other rubber yielding varieties are the landoplihia, a vine growing in the Congo Basin in Africa: and the guayule, a shrub which is a native of Mexico.

To obtain the milk from the hevea rubber tree without harming the tree requires considerable skill on the part of the gatherers. With a small iron hatchet diagonal gashes about one foot apart in a horizontal row are made in the bark, care being taken not to penetrate the wood. Small tin cups are inserted below the cut to catch the milk as it slowly flows out. The following day another row of incisions is made below the first. This process is repeated until the ground is reached. A good tree will yield milk to a height of twenty feet. The milk in the cups is collected and taken to camp to be cured. A small cone shaped oven of clay in which a fire of pine nuts is built is used for curing the rubber. The milk has a small quantity of sulphur mixed in with it, which prevents the rubber from

Rubber Gathering.

sticking, and also gives it a yellow color. If black rubber is desired gunpowder is used. The rubber curer dips a stick in the milk and turns it slowly in the smoke, and as the milk solidifies pours on more until a ball about eighteen inches in diameter is obtained.

II OBSTACLES.

The revolutionary spirit of the Bolivian people together with their indolence and ignorance has stunted the development of the country. But these traits of the people could be overcome and their ambitions awakened could some means of transportation be found by which the products of the region might be brought to other nations On the West are the Andes mountains rising some fifteen thousand feet above the lowlands. Any goods brought to, or taken from, Bolivia must be taken up steep mountains on pack mules by paths along the face of precipices where even the sure-footed mule finds it difficult to go, and long exposure to the cold, and other terrible hardships, rendered these journeys, which lasted for weeks, very difficult and dangerous. A standard gauge railroad 325 miles long was built from Mollando, Peru, to Puno on Lake Titicaca. Freight was then carried across the lake and thence by road to La Paz, in Bolivia. In 1892 another road, a narrow gauge one, was built between Antofagasta, Chile, and Oruro, Bolivia, but trains could only run over it in daylight. But since these towns are at an elevation of 12,000 feet the construction of a railroad to the lowlands would be an enormous and costly undertaking. Hence a route over

the Andes Mountains is as yet impracticable.

Attempts were made to find an outlet to the Atlantic Ocean by means of the Paraguay and La Plata rivers. It was found that boats drawing nine feet of water could get up to Asuncion, the capital of Paraguay, and those drawing three feet could get up the Paraguay river to the mouth of the Sao Lourenco river. To carry cargo to this head of navigation from the Andes foot hills it is necessary to cross the great Mojos Basin, a vast region of 35,000 square miles extending both sides of the Paraguay river as far north as the Mamore river, a territory covered by water during four months of the year, from November to March. To quote from Colonel Church, who, from Captain Ballands' account of explorations on the upper Paraguay river, says: "All attempts to find a practicable route across the Bolivian Chaco from the Paraguay river south of latitude nineteen degrees south have been failures; and, according to the season, the traveler who attempts it may die of thirst or be drowned before he reaches the foot hils of the Andes four or five hundred miles distant."

Various voyages to the mines of Matto Grosso, Brazil, from Para were made, but to Lieutenant Lardner Gibbons, U. S. N., belongs the credit for making the first thorough exploration of the country. In 1851, two young lieutenants, Gibbons and Hernden, were ordered by the Secretary of the Navy to investigate the important waterways connecting Bolivia and Western Brazil with the Atlantic seaboard. Lieutenant Gibbons went to Vinchuta, Bolivia, thence by canoe via the Chapare, Mamore and Madeira rivers to Para. He took soundings in the rivers and made a

record of the condition of the country, climate, and the location of the rivers and rapids. He found that a series of nineteen falls and rapids was all that prevented continuous passage from Vinchuta to the Atlantic ocean, but he also found that this was the most unhealthy part of the country.

III. THE FIRST PROJECT.

In 1868 Bolivia invited Colonel George E. Church, an American engineer and explorer, to undertake the opening of the route to Bolivia via the Madeira and Mamore rivers. Accordingly, Colonel Church organized the National Bolivian Navigation Company with authority to negotiate a loan for carrying on the work. A concession was then obtained from the government of Brazil, which provided that "the enterprise shall be called the Madeira and Mamore Railway" and granted to Colonel Church "the exclusive right for a term of fifty years to construct, pay for, and possess said railway extending from Santo Antonio to Guajara Merim. It also gave a territory of some five hundred and forty square miles in addition to right of way, mining, and other privileges. After much vexatious delay the Public Works Construction Company of England took the contract to construct the railroad for the sum of $3,000,000. A powerful iron side-wheel steamer with ten iron barges was sent over with a corps of thirty engineers, and reached Santo Antonio on July 6, 1872. In one year only three and a half miles of survey had been made, and the Public Works Construction then repudiated its contract, claiming that the conditions had been misrepresented to them.

They at once filed suit for damages in the English courts, and thereby tied up the $3,500,000 deposited in the Bank of England. In order to save time Colonel Church was forced to compromise by giving the Public Works Construction Company $220,000.

IV. THE COLLINS BROTHERS' EXPEDITION.

Colonel Church, after his experience with English methods, turned to his own country, and on October 25, 1877 the contract to build the road was let to Messrs. P. & T. Collins of Philadelphia, at that time one of the most successful and reputable firms of contractors in the United States. The contract specified that work on the ground should be commenced four months from that date, and be completed in three years. The road was to be a meter gauge with minimum radius of curvature of 1320 feet, and maximum grade of one percent. The contractors were to be paid $29,000 per mile of main line.

On January 2, 1878 the Mercedita sailed from Philadelphia with fifty-four engineers under Mr. Chas. M. Bird, as Chief Engineer, and carpenters, mechanics, and laborers, in all a party of two hundred and twenty men. The Mercedita was loaded with instruments, railroad iron, merchandise, and provisions. After a perilous passage the party reached Santo Antonio, having been forty-eight days on the voyage.

They immediately began work constructing houses and clearing for the camp site. Soon two preliminary parties of engineers was started, followed up by a locating party. From time to time during the year and a half while work was in progress,

boats came in with laborers and supplies. As the parties got farther and farther away from Santo Antonio their food supply was cut off, and often for weeks at a time received nothing from their base of supplies. They would have starved to death had it not been for the kindness and hospitality of rubber gatherers. As it was, a great deal of the time they were in a half-starved condition, and the men became sick so much that it was often necessary to abandon work. Tortured by insects, insufficiently supplied with medicine, ~~not~~ even quinine, worried by occasional attacks of hostile Indians, and with the efficiency of the working forces cut down by sickness and death, these men stayed on for a year and a half, pushing their narrow lines through the dense jungle.

At Santo Antonio construction was going on handicapped by the same difficulties which beset the parties at the front. During all the time that the work was going on not one dollar of money was received to pay off the men. Consequently they became dissatisfied and mutinied frequently, and were only kept at work by sheer force of will of the men in charge. The money with which the work was to be carried on was tied up by litigation in England, brought on through the efforts of rascally speculators, who by wrecking the enterprise would bring much profit to themselves. In the face of all these difficulties the little band of determined men in Santo Antonio remained at work, and only left when ordered home by P. & T. Collins.

The results of the work done during the year and a half are surprising when the conditions under which the work was carried on are considered. With impaired credit and unpaid labor, P. & T. Collins had successfully inaugurated a most difficult undertaking, and spent their own capital, and yet were unable to obtain any portion of the amount confessedly due them, according to the terms of their contract.

A summary of the work accomplished is as follows:

Total length of line surveyed----------320 miles
Projected location from Santo Antonio---------- 67 "
Final accepted location---------- 36 "
Additional location---------- 4 "
100 foot right of way cleared---------- 25 "
Grading completed---------- 7 "
Construction train from Santo Antonio----------3.9 "
Permanent track laid----------2.2 "
Temporary track laid----------1.7 "
Telegraph poles----------2.8 "
Telegraph line completed----------1.6 "
Number of cross ties made----------30,000
Buildings constructed----------7
Nine trestles with total length----------1453 feet

Of the nine hundred and forty-one Americans who were sent down, it is positively known that two hundred and twenty-one died- a mortality of 23.6%. Of the laborers, no accurate account can be obtained, but the mortality was probably higher, owing to their ignorance and manner of living.

V. THE MADEIRA-MAMORE RAILWAY.

Very little was done in the way of constructing this road for a number of years. In 1903, by the Treaty of Petropolis, Bolivia ceded to Brazil a strip of valuable rubber land lying north of the Abuna river known as the Acre Territory, on condition that Brazil build a railroad around these falls in the Madeira and Mamore rivers.

In 1906 the contract was let to a Brazilian engineer, named Catambry. Then Chas. E. Faruquar, an American capitalist and promoter of other similar enterprises in South America, bought from Catambry the concession to build the road. He immediately organized the Madeira-Mamore Railway Company, capitalized at $11,000,000. The contract to construct the road was then let to Messrs. May & Jekyll, a firm of contractors organized under the laws of the State of Maine, who had had considerable experience in the tropics.

Mr. A. C. French was made Chief Engineer of the Railway Company, and in June, 1907, a party of sixteen engineers headed by Mr. H. C. Miller as Assistant Engineer, landed in Para, and again took up the great enterprise. The Javary, a river steamer, was chartered at Para from the Amazon Steam Navigation Company. The boat was loaded with a three months supply of provisions, and, carrying two hundred mixed laborers, started up the Amazon river. One stop was made at Santarem at the mouth of the Tapajos river, and then the trip up the river was continued without accident

until Manaos, at the mouth of the Rio Negro, was reached. Here trouble began, for the laborers rendered fearful by reports of unhealthy conditions on the Madeira river, mutinied and jumped overboard in their endeavor to escape to the shore. It was only by force of arms that they were compelled to get back on board the boat.

As soon as permission was obtained from the governor of the State of Amazonas to sail up the Madeira river the Javary got under way and arrived at Santo Antonio on the 24th of June, 1907. The problem then arose as to the location of a suitable camping site, and the party remained on board the Javary for three days until temporary quarters could be built. After exploring Santo Antonio and the vicinity for that time the camp was pitched on a little island opposite Santo Antonio, which became known as camp #1. Four engineers became dissatisfied and returned home, leaving but twelve engineers to carry on the work. The departure of these men crippled the little band and with the ravages of malaria and other tropical diseases made it difficult for much to be accomplished. A boat-load of provisions due to arrive in July was held up by the Customs in Para, in consequence of which the greater part of it spoiled and had to be thrown overboard. The scarcity of food supplies at Santo Antonio became alarming, and as no further information of any kind could be obtained for three months it was thought by the men that they were to experience a similar fate to what the Collins Brothers' Expedition had endured. Mr. Miller went down to Manaos to see what could be done, and

there he found that satisfactory arrangements had been made, and returned with Mr. R. H. May of May & Jekyll, five more engineers, and six construction men.

Two parties had been organized for construction work, one under the direction of Mr. E. H. Leibel, and the other under Mr. H. Craigo. One party started from Santo Antonio south in the direction of the Jaci-Parana river, while the other party began working north. This latter party abandoned their line for the time being, as all efforts were to be directed toward getting the first ten kilometers located, on account of a clause in the concession. After this had been done the work north of Santo Antonio was again taken up, as Mr. Miller was not satisfied with Santo Antonio as a terminus for the railroad. A point six kilometers north of Santo Antonio was decided upon and named Porto Velho or Old Port. Clearing for the site was begun the middle of August. In September the ground was looked over and Porto Velho accepted as the permanent terminal by the Brazilian Fiscal Engineer. Location from here was then immediately begun.

The preliminary line was first started southeast in a direct line to Guajara Merim over the old Collins line. After following this line for a few kilometers a great deal of porphyry rock was encountered, which necessitated heavy construction. This could be avoided by running the line closer to the Madeira river. Eight kilometers of the Collins roadbed was practically completed and the location carried their line up to this point. From here the line was turned toward the river where better grades

and lighter construction wereobtained.

A camp was located and a storehouse erected near the river at Sao Carlos, forty-seven kilometers from Porto Velho, by river, to serve as a base of supplies for the preliminary party. During the progress of the construction of the railroad one of the greatest difficulties was to keep,not only the forces at Porto Velho supplied with provisions and materials, but also all the camps on the river or deep in the forest. While ocean-going vessels can come up to Porto Velho without difficulty during December, January, and February of the year; yet,during extreme low water, in July, August and September, even light river steamers are obliged to proceed with great caution, and frequently get stuck on sand bars. It was found dangerous for boats drawing over five feet of water to attempt to come up in low water.

Two large hulks of old ocean boats were purchased and anchored in the Amazon river at Itacoatiara not far from the mouth of the Madeira river to be used to store materials in. Itacoatiara was the transfer point for men going up to Porto Velho. A number of river steamers, tugs, barges, launches, and large canoes, known as batalaos, were purchased and distributed along the river for various purposes. The river steamers were used to carry labor, mail and cattle, and the tugs towed barges loaded with construction material. Launches plyed between the falls,towing the loaded batalaos to camps or landings from which their cargoes were hauled by mule carts over roads cut through the jungles. These roads were little more than narrow clearings

On the Madeira River.

through the woods, and during the rainy season, when flooded, the stiff clay became a mire over which it was difficult to draw anything but very light loads. Then it was necessary to employ pack mule trains.

As the work progressed and camps were located further from Porto Velho, it became more and more difficult to keep them supplied, but so good was the organization, and so skillfully was the work done, that after the first year work was seldon delayed for lack of materials: nor did the men often lack the necessary food. Some of the transportation of freight was done by contract with Brazilians, who brought it up in large ten or twenty-ton batalaos paddled by domesticated Indians. These men sat on the edges of the boat and paddled almost ceaselessly all day. Upon reaching a portage the Indians carried the cargo around on their heads, dragged the boat over the rocks, and resumed their journey. Much could be said in praise of the patient and tireless energy of these humble workers. Occasionally, in trying to pass through rapids in the river the boat would strike a hidden rock, and, overturning, throw men and cargo overboard, frequently drowning some and losing all the cargo in the seething waters.

The preliminary and final locations were pushed ahead as rapidly as possible. The country over which the lines were run was fairly smooth, so little difficulty was experienced in maintaining a suitable grade. The maximum grade was one percent. The maximum degree of curve used was a six degree, metric system, or practically a nine degree curve, English system of measurement.

"To the Jaci-Parana" was the slogan, for more was known of this region from the notes and maps of the Collins Brothers' surveys than of any other part of the proposed line. What lay beyond was known only from what could be obtained from a very superficial reconoissance. Early in the year 1909 the Jaci-Parana river was reached and another party was sent out to locate a suitable crossing. The location stationing showed that the Jaci-Parana river was ninety kilometers or about fifty-five miles from Porto Velho. A few miles north of the Jaci-Parana river rough, choppy country was found and several preliminary lines were run in an endeavor to secure lighter construction. The soil here is a very stiff, hard clay, almost rock, called cascalho, in which it was very difficult to dig by hand and which could not be satisfactorily blasted.

From the Jaci-Parana river, Mr. Bolton took charge of the preliminary party with the object in view of reaching the Mutum Parana river as soon as possible. About all that was known was that the Mutum Parana river lay about fifty miles southwest. After a great deal of trouble the Mutum-Parana river was reached in April 1910. Many reports had been circulated about hostile Indians on this river, and when Bolton's party arrived they were pleasantly surprised to find that this tribe, the Caripuna Indians, was friendly. As they became more accustomed to seeing the white man around they became somewhat of a nuisance, as they were delighted with any shiny object they saw lying around, and were inclined to help themselves to the food. Several of them had

Caripuna Indians.

antiquated .44 Winchester rifles which they had probably obtained from rubber gatherers, and would gladly trade a bow and arrows for a few cartridges.

At the Mutum Parana river orders were received from the Chief Engineer, Mr. Ashmead, to proceed to Guajara Merim and to parallel, and keep as close to, the river as possible. From the Mutum Parana the Madeira river flows almost due east and then South, forming a large loop, across which it was thought well to run the line. After leaving the Mutum-Parana river a wide swamp forty kilometers long was discovered. A forty-four kilometer tangent across this swamp brought the line again to the Madeira river just above the mouth of the Abuna river. From here the line was run close and parallel to the Madeira and Mamore rivers. On April 3, 1911 the preliminary party reached Guajara Merim and tied in their line with the line of the party making a survey there for a crossing of the Mamore river.

The locating party successively under Mr. H. McLeod Miller and Mr. F. C. Kyte followed the preliminary party closely and reached Guajara Merim on August 1, 1911. The stationing of the last stake showed Guajara Merim to be 364 kilometers or 226 miles from Porto Velho.

In September, 1910, Mr. Karnopp was sent up to Guajara Merim to make surveys on the Mamore river for a suitable crossing to the Bolivian side. It took the party forty days to go from Porto Velho to Guajara Merim, while the return trip a year later required but three days. The party ran surveys on both banks of

A Thirty Mile Swamp

the river for a distance of ten miles, making notes of the topography of the country, borings for foundations, and soundings in the river. The work required just a year, they finishing in September, 1911. The total cost of the survey was $50,000. Various other river surveys were made, as Mr. H. F. Dose, Chief Engineer, was not entirely satisfied with what the results showed. One survey was made at Pau Grande, and another a little way below Bananeiro Falls: but the crossing at Guajara Merim was found to be the best. These other surveys were not so extensive as the one at Guajara Merim, and cost considerably less. The river at Guajara Merim is about a mile wide, with an island in midstream, and a good rock foundation was found. At the time of this writing no decision has been made as to when the bridge will be built. A rough estimate of the cost of such a bridge would be in the neighborhood of $2,000,000.

When the contract was let to May & Jekyll, later May, Jekyll & Randolph, it was on the terms of 12 1/2% of cost of construction, which included labor, cost of materials, and was exclusive of the commissary department and the salaries and maintenance of the engineering department. It was rightly judged that this form of contract would be most successful on account of the inability to fairly estimate the cost of construction for a railroad under such conditions. A higher grade of construction was the result.

The organization of the contractors' forces could be conveniently divided as follows: Construction, timekeeping, transportation and hospital departments. The construction

department included that part of the work which had to do with the actual construction of the roadbed, temporary wooden bridges, or all work done ahead of the track. The timekeeping department handled the wages of men, commissaries, and materials, and payment to subcontractors. The transportation department had charge of the handling of men and materials on river, by mule carts or pack trains. A large, sanitary hospital, modern in every respect, was built at Candelaria, three kilometers south of Porto Velho, and a large corps of doctors maintained there, and in camps.

The grading of the roadbéd was not begun until February, 1908. Clearing for the right of way began at about the same time, and a large force was kept at work continually until its completion in September, 1911. A great deal of this work was done by Bolivian Indian slaves, hired from seringueiros, or rubber gatherers. Part of the force at one time consisted of Bolivian Indian women, who were found to be very efficient, as they were large and muscular and well able to endure the arduous labor.

In general, in the construction of the roadbed, small contracts were sublet to a Spanish capataz, who divided his profits with his coworkers.

Various methods of handling material were tried in the construction of the roadbed. Plows and scrapers were used at first but this mode was soon abandoned as it became evident that the mules were unable to endure this kind of labor in that climate. A large number of Decauville cars and rails were then brought in, and proved to be such a success that they were used almost exclusively during the remainder of the construction of the road.

Methods of Excavation

The contracts were sublet for a few stations at the rate of about $1.00 per cubic meter for earth, $2.00 for loose rock and cascalhao, and about $2.50 for solid rock, the company furnishing the necessary equipment. The material for grading embankments was taken by hand from both sides of the road, and where this was insufficient or hauls from cuts were too long, borrow pits were excavated as near as possible to the embankment and material hauled in Decauville cars or carts. The subcontractors were paid for material actually excavated, from borrow pit or excavation measurements.

After track had been laid, and it was necessary to raise the grade, or if a fill was to be made across a ravine, a steam shovel was set to work nearby. Very little gravel or rock was found anywhere along the railroad, and the best material that could be obtained for ballast was the cascalhao, previously described. The material was loaded into Rodgers Ballast or Western Dump cars in trains of twenty cars, each car being loaded with about fifteen cubic meters. The unloading was done by means of a plow of the same width as the cars. A cable lying on the train was attached to the plow and to the locomotive, which then dragged the plow to the other end of the train, pushing the dirt over the sides or through the doors of the dump cars. One steam shovel was kept busy loading four trains.

Grubbing was done by the subcontractors where the fill was one meter or less, and the area grubbed was from toe of slope to toe of slope. No payment was made for grubbing in excavation. Fills were required to be made 4.0 meters wide, while cuts were

Filling a Small Stream.

made 4.2 meters wide with surface ditches 0.55 meters wide on each side. Slope for embankments was 1 1/2 : 1, while in excavation the slope was made 1 : 1. These slopes were satisfactory except at kilometers 239 and 240, where very deep cuts were made. Here it was found necessary to make the slope 2 : 1 and to widen the roadbed considerably on account of slides occurring in the rainy season.

Track laying was begun in July, 1908, and pushed ahead as rapidly as possible, and was finished in May, 1912. On the track gang were employed from four to six hundred laborers. Bunk cars were provided for the foreman and his assistants, while the laborers occupied palm huts left by the construction men. In laying the track an engine drawing cars loaded with rails, ties, etc., was kept at the head of track. From these cars the materials were loaded upon heavy hand-cars which distributed them as needed. A small party worked ahead smoothing the grade and laying limbs of trees at places where the roadbed was soft. The track gang was closely followed by a large gang surfacing and relining the track.

The railroad closely parallels the Madeira and Mamore rivers throughout its entire length, and hence crosses a great many small rivers and streams called igarapes. It was necessary to construct a trestle, either pile or frame, across most of these, as well as across ravines where high fills were necessary. In general, the pile driver was erected upon skids at the top of the grade and worked across. Where the ravines were very deep the grade was left unfinished a little way back from the first bent to permit of the erection of the driver on the bank. The piles

Effect of Heavy Rains.

were then driven as low as possible and cut off above the water line. Frame bents were constructed up to grade elevation on caps resting on these piles. All piles were driven until no appreciable penetration was apparent under the last five blows of the hammer. There were three pile drivers on the railroad, all being of the drop-hammer type.

Frame trestles were built across openings where but a small amount of water flowed. Mud blocks, usually eight in number, were firmly imbedded in the earth and the frame bent constructed upon these blocks. All of these trestles were firmly held by sway and longitudinal bracing. Across streams where the permanent structure was to have a span of any considerable length, the piles were sawed off just below the lowest elevation of the steel structure and pony bents were built up to the grade elevation. This was done only between the proposed abutments, and facilitated in the erection of the steel structure. The timber for all bridges was cut nearby, and drawn by oxen to the bridge site, where it was sized. It was specified that the minimum diameter for piles should be 1 ft., and caps and stringers 1ft.x 1ft. The timber ordinarily used for the wooden bridges resembled poplar wood, but was very much harder,and proved satisfactory. The life of a wooden bridge was very short, one and a half or two years being about the length of time that it was safe to use them. This was partly due to the wood itself, but probably the action of the weather and the attacks of ants and other insects had more to do with shortening their life.

The temporary bridge structures were replaced by permanent ones as soon as possible. These were either steel bridges or concrete and masonry culverts. One of the largest steel bridges built was that over the Jaci-Parana river. It consisted of one 272 ft. through span of the pin-connected, Baltimore-truss type, and two 79 ft. through spans of the lattice type. The foundations for this bridge were carried down to bed rock, which was found near the surface. In determining upon this site, as well as all other bridge sites, borings were made to ascertain the kind of foundation that could be obtained. The two abutments and the two piers were built in the river, and "United States" steel sheet piles were used to make a coffer dam for keeping out the water. Most of the concrete work was done during low water, which, of course, lessened the cost and difficulty of construction. The footings are about 12 ft. deep and the distance from the top of the foundation to the base of rail is approximately 45 ft. The erection of the bridge was done by American steel workers. An overhead traveller, constructed of timber, running on stringers placed on the wooden bridge, was used in the erection. A portable air compressor was used for riveting. Three months was required to erect the steel.

Over the Caracoles river a deck lattice-girder bridge of 125 ft. span was built. Unlike most of the rivers in that region, the Caracoles is very swift. When the abutments for the bridge were built the rainy season was close at hand, so the construction of the abutment proper was made up to the bridge seat, and the completion of the masonry left until the next dry season.

Excavating was done with a pick and shovel, and the material carried away a short distance by wheelbarrows and dumped. In excavating for the wing walls a grab bucket operated from a crane on the track was used. A foundation of coarse sand and clay was obtained, into which wrought iron cylinders two meters in diameter and one and a half meters high were sunk until their tops were flush with the ground surface. A 1:3:5 mixture of cement, sand and crushed rock was used, except for the bridge seat, where 1:2:4 concrete was used. Nine weeks were required to erect the steel structure, which is remarkably good time considering the facts that sickness crippled the gang so much that practically only five white men worked all the time, and that traffic was never delayed. A crane operating from the track was used in the erection. The two trusses were built up on greased rails resting upon the abutments each side of the outer rows of piles. The piles were then cut off eight inches below the bottom of the lower chord and the trusses pulled over to fourteen foot centers by means of "steamboat ratchets". The air for riveting was furnished by the portable air compressor.

A great many short span bridges were built of girders or "I" beams, most of them resting on box abutments. All steel bridges were designed for Cooper's E-40 loading, and the steel fabricated by the American Bridge Company.

Across small streams box culverts or "Acme" cylinder or arch culverts were constructed. For the 1.0 m. x 1.5 m. box culverts only, transverse reinforcing rods were placed in the

top slabs. The "Acme" cylinder culverts were built in sizes of 48" to 72" diameter by using the corrugated iron cylinder as a form around which the concrete was placed.

Along the track in the swamp south of the Mutum Parana river a ditch 10 ft. wide, 6 ft. deep and about five miles long was dug to drain the water to the river.

Where smaller drains were necessary vitrified pipes were used.

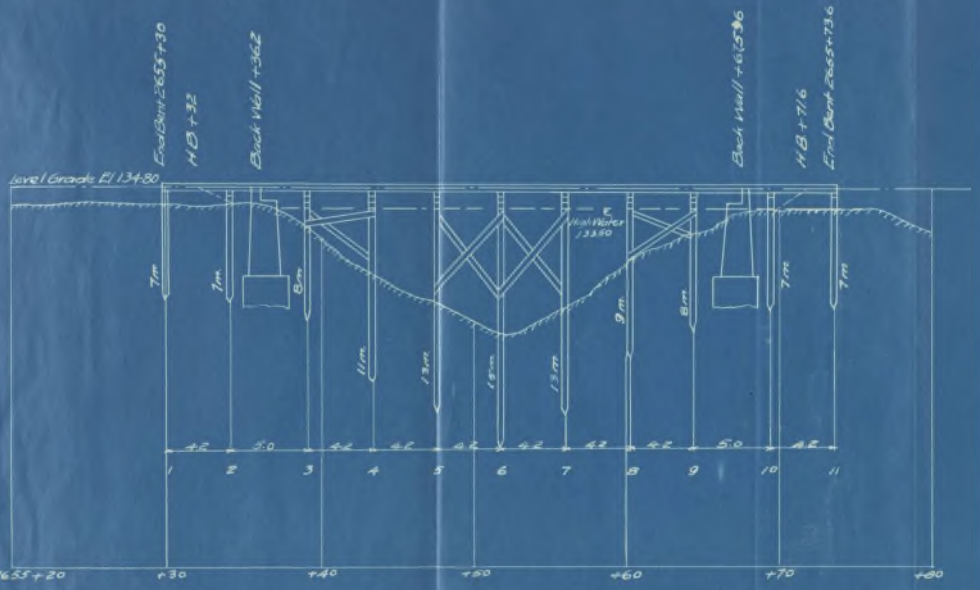
A ten thousand yard channel through which a small stream was diverted, was made at kilometer 300 to prevent the washing of the embankment.

The sand used for the concrete work was a clean, coarse, white sand obtained from a large bed about fifty-seven kilometers from Porto Velho. As before stated, no gravel beds were found along the line of the railroad. The rock was obtained by blasting from outcropping strata, and was crushed to pass a 2" ring. Most of the cement used was English and Belgium Portland cement, which came packed in wooden barrels. One-half yard batch concrete mixers run by steam were used.

The offices and employes quarters, and hospital buildings at Porto Velho, Candelaria, and Abuna were large frame structures, built upon concrete piers. The machine shops, depot, roundhouse, and power-house were steel frame structures. In camps the houses were built of palms. These baracaos, as they are called, were built by laying the palms on a framework of tree limbs. The baracaos possessed the virtues of being water-proof, well

The Caracoles River Bridge.

Porto Velho in 1912.



Bents 3 to 9 inclusive

BILL OF MATERIAL

TIMBER		IRON	
16	Piles 7m. long	44	Drift Bolts for Piles 0.018 x 0.61
8	" 8m "	44	Bolts for Stringers 0.018 x 0.65
4	" 9m "	88	" " Packing 0.018 x 0.88
4	" 11m "	70	" " Sway Braces 0.019 x 0.45
8	" 13m "	32	" " Lateral " 0.019 x 0.45
4	" 15m "	352	0.6 Washers } Packing 0.018 x 0.025
14	Caps 0.3 x 0.3 x 3.00	88	3 pool " } 0.018 x 0.102
4	" 0.3 x 0.3 x 4.25	98	0.6 - for Stringers 0.023
7	" 0.3 x 0.3 x 5.50		
4	Stringers 0.3 x 0.3 x 4.30		
10	" 0.3 x 0.3 x 8.40		
4	" 0.3 x 0.3 x 9.20		
4	" 0.3 x 0.3 x 9.30		
4	Sway Braces 0.075 x 0.25 x 5.5		
4	" " 0.08 x 0.25 x 7.0		
6	" " 0.08 x 0.25 x 9.0		
4	Lateral " 0.08 x 0.25 x 5.0		
4	" " 0.08 x 0.25 x 5.5		
8	" " 0.08 x 0.25 x 7.5		

MADEIRA-MAMORE' RY

PILE TRESTLE STA. 2655+50

To be Replaced by 30 M Thru Span

Div Engrs Office Camp 33 June 23, 1911

ventilated and cool, but were not vermin-proof.

The remoteness of the railroad and other physical conditions involved difficulties that were great, but the greatest difficulty that had to be met was the overcoming of tropical diseases. Every possible precaution to prevent disease was taken, but in spite of it, out of the thirty thousand laborers employed from June, 1907, to June, 1912, it is estimated by the chief surgeon that from five thousand to six thousand died. Eighty white men died at the hospital at Candelaria, and in all it is estimated that there are one hundred white men, mostly Americans, buried between Guajara Merim and Para. The mortality was about fifteen to eighteen percent for the laborers and about five or six percent for the white men. The high mortality of the laborers was due to their poorer living conditions, ignorance or carelessness, and on account of being obliged to do heavy manual labor under the burning sun.

It was recognized from the start that disease was the primary cause of the failure of the other attempts to build the railroad. Santo Antonio as a terminus was abandoned mainly on account of the unhealthy conditions prevailing there. Porto Velho is situated on high ground with a natural drainage toward the river. A sewerage system was built, the ground leveled, and every precaution taken to make the terminus sanitary and healthful. The hospital was built at Candelaria, three kilometers south of Porto Velho, and equipped according to the most up-to-date methods. All the buildings at Candelaria, as well as those at Porto Velho, were on raised foundations so as to avoid the miasma and insects

Candelaria Hospital.

of the ground. They had special ventilating arrangements, and broad verandas enclosed in wire mosquito netting.

Every employee was required to take ten grains of quinine daily and to drink only boiled water from hand filters. Mineral water was supplied for the sick, and every camp had a complete medicine chest. Mosquito-bar for cots and hammocks were furnished by the Company. The bed clothes were aired every day. In every large camp a good doctor was stationed. Visits were made by a physician four times a week to the small camps in advance of track and to those camps along the track.

The labor employed on the railroad was obtained from many different countries. The largest percentage were Brazilians, Spaniards, and West Indian negroes, but there were also a great many Greeks, Italians, Cubans, Russians, and Chinese. One of the most important problems in constructing the railroad was to keep a large force of men continually at work. It was found that better work could be obtained if those of one nationality were allowed to work together. Probably the most efficient workers were the Spaniards, as they were as a rule more energetic and intelligent than those of other nationalities.

The operating department had to do with the maintenance of structures, track, equipment of rolling stock, and the conducting transportation of freight. All machinery was American make, the locomotives were Baldwin make, and the cars and coaches were made by the American Car Mfg. Company.

Freight and passenger rates seem high as compared with rates in the United States. The charge per ton mile in car lots

for rubber is $0.84. Other classes of freight such as provisions, merchandise, etc., have a rate of about $0.50 per ton mile. First-class passenger fare is $0.18 per mile, and second-class fare is $0.10 per mile.

The cost of the Jaci-Parana River bridge is given in order that the reader may obtain an idea of the expense of building a steel bridge on the Madeira-Mamore Railway.

1-272 ft. span	575,000 lb.
2-79 ft. spans	168,000 "
Traveller	4,200 "
Total weight	747,200 "

Cost per Pound.	
Pay roll items	$0.035
Steel at bridge site	0.036
False work	0.054
Other charges	0.019
Total	$0.144

747,200 lb. @ $0.144 = $107,600.00

As fast as construction camps were opened up telephones were installed. Three relay stations were required to transmit a message from Guajara-Merim to Porto Velho. Great difficulty is experienced in keeping the line in repair during the rainy season on account of falling trees. The iron rails of the Collins Brothers' railroad were used as telephone poles, as wooden ones quickly rotted. At Porto Velho and Manaos the company installed

seventy kilowatt wireless telegraph stations, which at the time were the most powerful in the world. It is interesting to note that the Madeira-Mamore Railway has expended on an average of about $1,000,000 per year for wireless messages and cablegrams. Manaos is in cable communication with Para, and thus Guajara-Merim, the door of Bolivia, is in quick communication with the rest of the world.

A conservative estimate of the cost of the railroad is $35,000,000 for the 226 miles of main line, or about $155,000 per mile.

VI. CONCLUSION.

The formal opening of the entire road took place in July, 1912. An old Collins' locomotive, which had been rusting in the weeds for over thirty years, was rejuvenated and pulled the inauguration train from Porto Velho to Guajara-Merim.

The opening of this comparatively short railroad in the interior of an almost unknown country will exert an influence upon the development of this region that can scarcely be estimated. Bolivia, with her natural resources, which heretofore has been impoverished and isolated, is now in direct communication with the markets of the world. Incidentally, the territory of Acre and the State of Matto Grosso, both teeming with mineral and vegetable wealth, have also been opened up. The city of Para has enlarged its docking facilities in order to handle the increase in shipping. The civilizing effect on the regions along the railroad is most

Bolivian Officials.

marked, homes and towns springing up where five years ago there was nothing but primeval forest. American, English and Belgium capital is being poured into Brazilian and Bolivian enterprises.

The trade between Brazil, Bolivia and the other nations will be enormously increased; the effect upon the markets of the world will be great; the inhabitants will become enriched and civilized; and the Madeira-Mamore Railway will stand as a triumph of modern science and a monument to American Engineering skill.

Moonlight on the Madeira River.