CIVIL ENGINEERING PROBLEMS IN THE CONSTRUCTION OF A GUGGENHEIM-PROCESS NITRATE PLANT ON THE PAMPA OF CHILE

THESIS FOR THE DEGREE OF C. E.

John Sterling Lane

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THESIS

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THESIS

INTRODUCTION

For any construction project there must be a background of study and work which leads to the adoption of that particular project at the site it is finally to be found. Each project has its own peculiar problems which must be studied and handled in the manner best suited to the conditions.

Locating a plant for the production of sodium nitrate by the Guggenheim-Process necessitates the proving of an area of sufficient extent of mineable ore to warrant the erection of a plant of such magnitude, picking the most advantageous site within this area for the erection of the structures, and a study of sources of power, water and materials, and the problem of transportation. Besides these main items, there are numerous other considerations which must be treated before the actual construction of the plant can be started.

All construction jobs are alike in being a series of problems of using the best available means to the required end, although each type of job differs from others of the same type as prevailing circumstances dictate. Each day's work is distinct from the preceding, and minor difficulties are always being encountered which call for solution based on previous experience, or which call for ingenuity.

This paper will deal with all the phases of this subject in which the Civil Engineer is interested and has an active part; and may prove a valuable reference not only as to methods but more especially as to procedure.

General Description of the Nitrate Pampa

The nitrate pampa of Chile is a plain, as the word denotes, but not the waving-grass type which seems to be the popular conception of a "pampa", being in reality a barren, desolate expanse of undulating desert. On its surface, there is absolutely no natural vegetation nor animal life, due mainly to the high salt content of the ground and the lack of water. The innumerable small hills and hogbacks are hardly appreciable in the monotony of grayish color given the sandy, rocky surface in the brilliant sunlight.

The narrow strip of land occupied by the nitrate-bearing ore lies between the Coastal Range on the west, and the foothills of the Cordillera on the east, extending roughly from Arica on the north to Chanaral on the south. The average width being approximately 15 miles and the length 500 miles, with an average elevation of 4000 feet above sea level.

The Coastal Range rises precipitously from the Ocean, access to the pampa being gained by making a zig-zag route along the face of the mountains, a steep ascent up a canyon, or by a combination of the two.

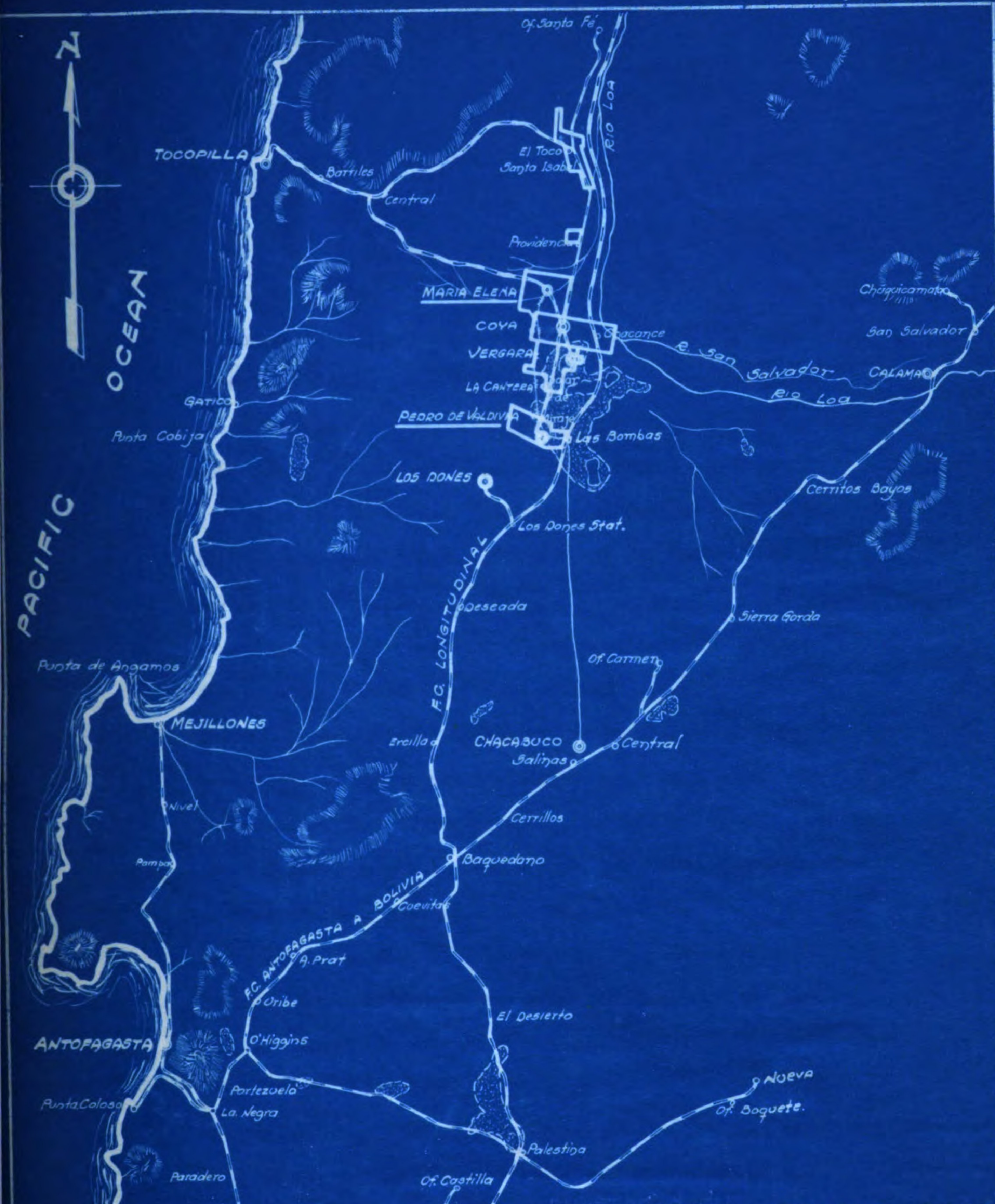
Rainfall as a factor against which precautions must be taken is non-existent. There are no recording stations because, practically speaking, there is nothing to record. Throughout the year, there are perhaps half a dozen showers which are very light and of only a few minutes' duration, and one which lasts several hours, and that is all. It is a factor not considered in design of buildings, roads, or connecting units. When enough rain falls to slightly dampen the ground, the surface color changes to a dark brown, which is a great relief to the eyes.

Fogs frequently find their way up the canyons at night, and at times last several hours of the morning, giving a cool freshness to the air, though lowering visibility. However, as the sun rises, the fog rapidly disperses, leaving the usual clear air with a few clouds at the horizon.

As the sun approaches the zenith, its brilliance and glare become more pronounced; the heat waves lengthen and burn as the strong west winds of the afternoon blow with increasing intensity. The evening and morning breezes are very gentle as

a rule and change direction late in the day, as they are always found blowing toward the Ocean in the morning. Combining the location of the pampa with the range of temperature between night and day may give the explanation of the shifting of wind direction. Occasionally on winter nights (winter being from June to September), the temperature falls to the freezing point, and at midday in summer, rises to 90 degrees Fahrenheit in the shade, with variations as the seasons change, although the nights are always cool, which seems to be a blessed trait of all deserts.

This, then, is the setting for the construction of the huge plants as now designed for the production of sodium nitrate by the process perfected under the direction of the Guggenheim Brothers.



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DWG. TITLE: GENERAL LOCATION PLAN OFICINA PEDRO DE VALDIVIA

OFICINA PEDRO DE VALDIVIA

DEPT. GENERAL PLANT LAYOUTS
DIV. GENERAL PROPERTY MAPS

MI-5007

SCALE: 1:1000 000

COMPAÑIA SALITRERA ANGLO-CHILENA
CONSTRUCCION LAUTARO

Government Triangulation

The Chilean Government has done very careful work in the establishment of a triangulation system which now almost completely covers every section of the country. The survey parties, consisting of highly trained and very competent men, equipped with the finest types of instruments and apparatus, have produced results which have been proved equal to that of the U. S. Coast and Geodetic Surveys in exactness.

The method consisted of starting from the ends of a Base Line, turning angles to desired points, going from these points to others ahead, and so on to another Base Line of known length and the angles balanced thereto. In the northern part of the country, the Base Lines have been located on the pampa because longer stretches of open level country are here available than along the coast to the west, or in the foothills to the east. Exact measurement is taken between the end points of the Line, and the latitude and Longitude of each determined by astronomical observations. Exact levels are run from mean sea-level, and the length of the Base corrected to sea-level. Each of these steps, as well as each angle turned, is repeated, checked, and rechecked.

The network of Primary Triangulation Stations was run from one Base to another with distances between Stations varying from 35 to 40 kilometers, as determined by the topography, and the whole system carefully balanced.

The number of hours which could be utilized every day for such field work is, of necessity, small. The afternoons are counted useless because of the force of the wind and the dazzling heat waves which make accurate work at this time of day impossible. Even a few hours after sunrise, visibility decreases with the increase in glare, and an object at any appreciable distance is carried from side to side as the breeze shifts the heat waves. Accurate work is done, therefore, only the first few hours immediately after sunrise. Foggy mornings eliminate the entire day since, by the time the fog disperses, the heat has risen, and with it the other elements which make accuracy impossible.

On the pampa the topography is quite ideal for triangulation work, with its absence of vegetation of any description, and the hills which make perfect stations for observation. Lack of rain and unstable footing eliminates other sources of discomfobt to most field parties.

At times, no more than an hour a day is available for the actual triangulation work, which means that everything must be placed in readiness before sunrise so that advantage may be taken of every minute of the brief period, starting as soon as visibility will permit.

Having the Primary Stations established, the Government has continued the work with a system of Secondary and also Tertiary Stations, in those sections where the possible need for more numerous points has warranted. Therefore, today, an extremely comprehensive system of land-survey references is to be encountered.

Ore-body Locations - Government

The story of the discovery and first uses of nitrate as an aid to agriculture and an element of explosives, dates back to the sixteenth century, and is involved with traditions and legends, and so will not be treated here. Let it, then, suffice to say that the discovery was made at the northern end of Chile as the map shows this country today, and that the first export of nitrate was made from the Port of Iquique, consigned to England in 1820.

Nitrate lands were sold outright at first, but as the value of the product became recognized through world demand, the lands, or rather the mining rights, were leased on a basis of square kilometers of area and with the only stipulation that the boundary must be continuous. As the nitrate-producing industry grew and the sales rose, it became evident to the Government that the choicest areas only were being leased and the greatest share of the land left in a miserable state, besides a large revenue being lost to the country. It was therefore decided that mining rights should be leased in accordance with the expected output as determined by the grade of the ore and the size of the ore-body in an area. The system of sampling the lands changed in manner a number of times until the present system was evolved.

The prospecting is now done by the Government. Sample pits are sunk at intervals of 400 meters over the entire territory and where the ore-body proves good, other pits are sunk at 200 meter intervals, and for a still more accurate estimate, at 100 meter intervals. These pits are tied-in to the triangulation system for recording and plotting on maps, and the assays of the rock give the thickness and grade of the ore body. From this data the estimate is made of the possible output.

With the foregoing information at hand, the Government sells mining rights to any section of land desired, after advertising for bids, and selling to the highest bidder.

Under the hand-mining methods of production, a cut-off of 13% nitrate in the ore is accepted as the limit of workable ore, and therefore the larger percentage of the nitrate ground is left untouched. With the mechanical mining methods employed under the Guggenheim-Process of production, a 7% cut-off is used, thereby mining out the larger percentage of the ground, in an almost continuous cut, which allows more efficient and larger scale operation.

Mineable Areas - Private Surveys

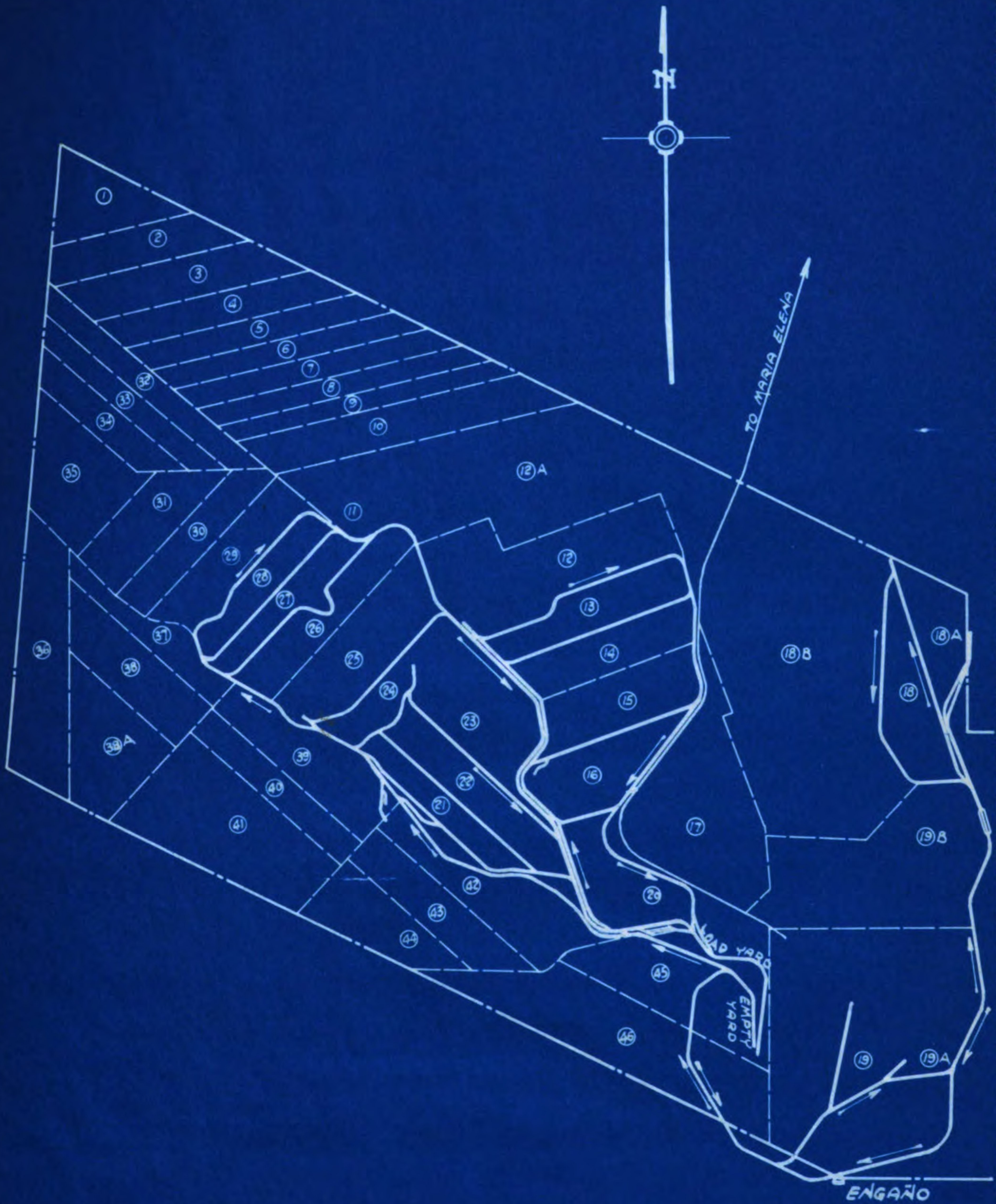
The present law by which only the Government may locate and sink sample pits, is of recent origin, and therefore does not embrace numerous lands held under previous rulings. These small holdings are of very irregular shape, since they consist only of the high grade ore which runs above 13%. These irregular scattered parcels do not conform to mechanical mining methods, and therefore all the area is united inside long straight boundary lines. In the instance of the latest plant built, "Oficina Pedro de Valdivia", special permission was obtained by the Anglo-Chilean Consolidated Nitrate Company, to sink all additional pits necessary for completely covering the squared-up area, the sampling to be check by the

Government.

The Company sent out field parties for the purpose of completing the system of pits, plotting all new and old pits on a topographical map of the whole area, and sampling all pits for a check on previous work and for estimating the possible output to determine the feasibility of the area for the construction of a fifty million dollar plant.

To this end, data must first be obtained from the Government Engineering Department which give descriptions of the triangulation stations in that section and of the sample pits tested. Topographical maps of parts of the area may be available, but it has been found more practical to ignore them and make an independent survey, using only the established government points and bench marks. A chain traverse is therefore run from one triangulation station to another, along a route best adapted for the location of instrument points for topographical surveying, and elevations are established on the instrument points by running circuits of closed levels. All the work is checked and balanced, and the topography taken from the established points for mapping on one-meter contour intervals. At the same time that the topographical notes are being taken, sights are also taken to each existing sample pit. Where an additional instrument point is needed, it may be located by a stadia "shot" for both distance and elevation. The one-meter contour interval is sufficiently small to give the desired information as to general surface topography, as is not so small but that a considerable area may be covered every day with a party of two or three rodmen.

The sinking and sampling of the test pits is purely the mining engineer's work and will not be detailed here. In outline, the work consists of stripping the loose layer of dirt off from the rock, which is drilled and blasted in successive steps of approximately three feet depth, down to such a depth that nitrate-bearing rock is no longer encountered. A completed pit is three feet in diameter more or less, and extends down to a depth of from three to ten or twelve meters. Drilling is necessarily done by hand, since the transportation of air compressors and hose and drills has not as yet proved economical. The drill holes are loaded with explosive, shot, cleaned out, and the operation continued. The presence of nitrate is tested by chipping particles of the rock onto a lighted wick and noting the burning or sparkling which takes place. The rock is classified as it appears along the face of the pit, and samples are tested in a laboratory to determine the exact percentage of the nitrate, since the wick tests gives only an estimate. An area of in-



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	TRCD 21-1-32 M.A.N.			MINE RAJO LAYOUT SHOWING PROPOSED RAJOS	OFICINA PEDRO DE VALDIVIA	GENERAL PLANT LAYOUT MINING DEPARTMENT MAPS	M3 - 5005
	CHKD 21-1-32 G.G.B.						SCALE: 1:50000
	IN CHGE:				COMPAÑIA SALITRERA ANGLO-CHILENA CONSTRUCCION LAUTARO		

locating the plant on ground which otherwise would be mined is out of the question. Although it would be possible to place the permanent town on such ground, it would be very undesirable as it would necessitate small units being completed, while mining and the essential blasting was being done, before other units could be completed. Hence the need for finding a suitable site on barren ground.

The ore is transported from the various sections of the mine to the plant at the primary crushers, in flat bottom gondola-type cars of 35 ton capacity, 6 to 9 cars in a convoy, moved by electric locomotives. The motive power is derived from a diesel engine power house and fed through trolleys on the main lines, the locomotives running from storage batteries on the branch lines along which the cars are loaded. The plant should be situated as near as possible to the center of gravity of the ore body, or perhaps slightly downgrade from the center of gravity, and at an elevation which will cause no excessive gradient to be overcome on the ore-train route to the crushers. This latter point of gradient is not of prime importance since the grade can be lowered by laying out a longer, more circuitous route, but the matter of distance is of great importance in economical operation, and therefore, the center of gravity is the goal aimed at, rather than giving preference to the topographical features.

The suitability of the foundation materials for bearing the structures to be placed upon them is of vital importance to any projected building program. That the material under the loose covering of sand and stone is rock, does not detract from the care with which it must be examined because of its seamy structure and high percentage of various soluble salts. Therefore, prospecting is done in the areas considered suitable from other viewpoints for a plant-site by sinking test pits in the same manner, but deeper than those sunk by the Mine Department for ore. In prospecting for good foundation material for the Oficina Pedro de Valdivia, pits were sunk in some instances to a depth of 15 meters and a salt content too great for the support of the buildings still encountered, and the work discontinued because the accumulation of gases became too strong. And so, one by one, the proposed areas were discarded in favor of the present site, which was finally accepted more through necessity than its being ideally situated, with reference to the ore body.

It stands well down from the center of gravity and on hard, almost granite-like rock, of low salt content. The matter of the soluble salt content is of utmost importance because of the amount of spill and leakage of water and solutions which is bound to occur, and the effect this would have on the crumbling and settlement of the foundations. Earthquakes, though quite frequent, are of only slight force, but must be considered in the design of structures and foundations.

The most important single factor in the operation of the plant is the disposal of the tailings, or waste material, known as "Ripio". It is taken from the leaching vats by clamshell buckets operated from movable cantilever bridges which span the vats from one side, and dumped into cars, run alongside and hauled out on the disposal track loop. This waste material, being wet, is of equal tonnage with the dry ore delivered at the crushers from the mine, and runs from 200 to 600 thousand tons per month, depending on the rate at which the plant is operating. A saving of only one cent per ton will aggregate a considerable amount over even a short period of time, and great stress is consequently given to economical disposal. It is desired that there be an area adjacent to a location for the vats, and sloping away from it, so that by keeping the upper surface level for economical haulage, the face of the dump will be high and long, and the need for track shifting will not be continuous, and the haulage distance will not increase in direct proportion to the amount dumped.

Wind direction is of no importance in the choice of the site itself, but is the main factor in determining the relation of one unit to another. It is desired to keep the crusher and vat-dust from blowing over the living quarters, power house, electrical units, and other plant buildings. To this end of locating the units, large scale accurate topographical maps are needed.

Preliminary Plantsite Surveys

The mine department, logically, does not spend time taking topography of the areas shown by the sample pits to be barren of ore, and so it falls to the Plant Construction department to extend the contours to cover the areas which appear from actual observation of the land to be possible plant sites. This work is done in the same manner as was that done by the mine engineering staff — running chain and stadia traverses from the established triangulation stations, and running systems of check levels to all the instrument points chosen. The traverse lines are plotted on a large map having a scale of 1:5000, the triangulation stations shown, as well as the instrument points with their designations and elevations. On this same map, the contour lines of the mine are traced for the purpose of tying in with the new lines, and as a check for discovering obvious errors.

The topography itself is taken from the points established along the balanced traverse line. Zero readings are first taken by sighting on another instrument point on the traverse line and making all reading on the horizontal verniers rather than using the magnetic readings, because they can be read more quickly and accurately, and the magnetic readings are taken only from time to time as checks on the bearings.

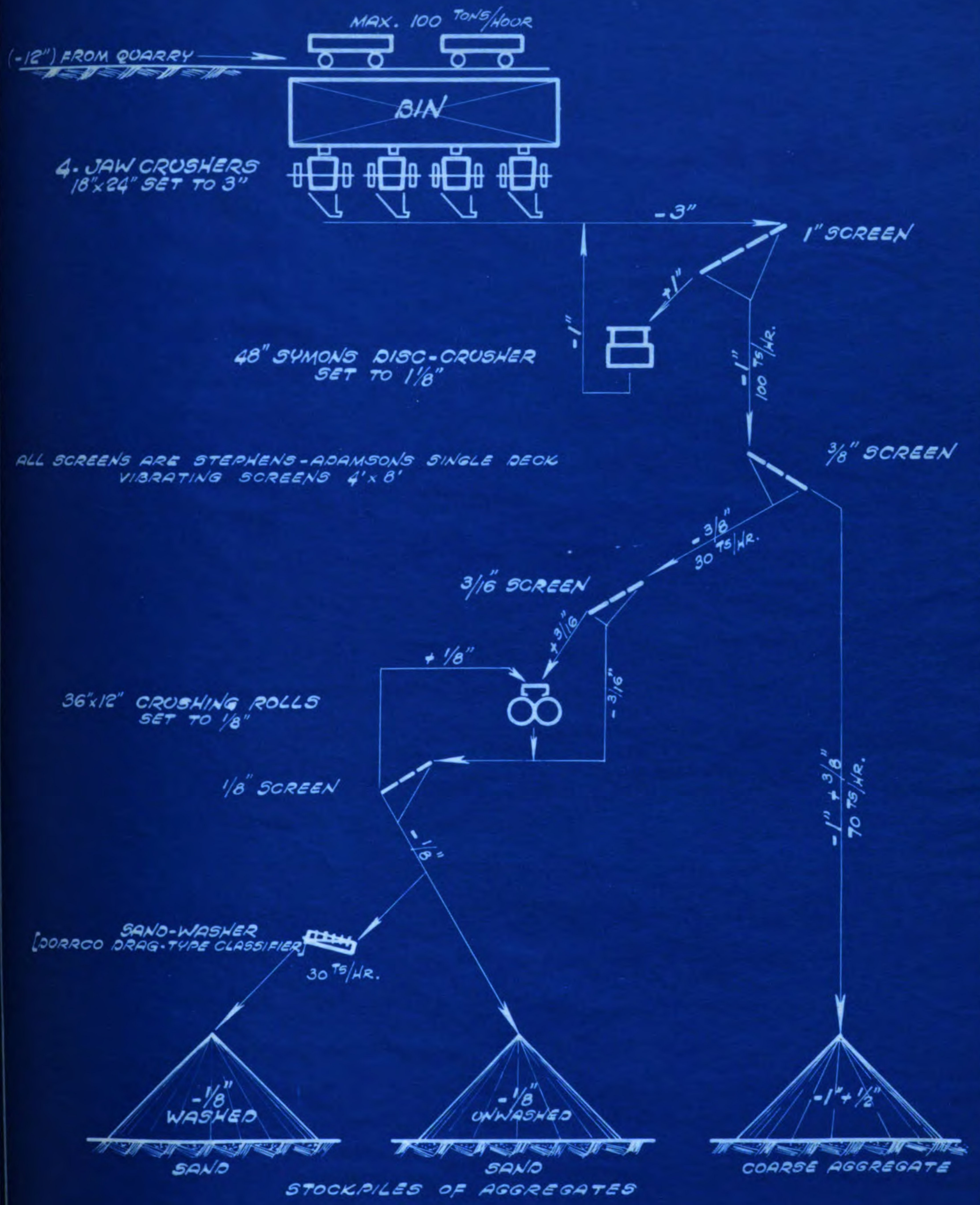
Excepting the instrument-man, the party was made up of Chilenos, the note-keeper being the one who could write the most legibly, and the three rodmen, among whom there was one with some experience in the work, and who was therefore commissioned to keep an eye on the others to see that they learn as rapidly as possible to pick the desired points at which to place the rod. It was found practical to designate a color to each of the rodmen, and the instrumentman to have a square of cloth of the same colors. As each flag was waved, the rodman knew he was to move to another point, place the rod and wait until his color was waved again. Because of the monotony of the ground color, the entire surface at a distance appears flattened out to a plain, and so stress had to be placed on the rodmen picking the tops of knolls and the lowest points between them, banks and beds of old dry rivers, and other irregularities in the surface. By correcting the positions chosen by the rodmen when they were close to the instrument, they soon learned which were the desired points, and so could be trusted at a distance. Of necessity, the longer readings were taken in the morning while the air was clearest, and drawing toward the instrument as the heat waves and wind disturbed the air. A number of scattered points were recorded as far as 800 meters from the instrument, but usually the outer edge of points was not more than 600 meters distant. Even with the inexperienced rodmen, and with instrumentmen who may have done very little topographical surveying, the parties averaged close to 400 points recorded daily, and with training a party has turned in 800 points. With the party organized, the routine of the instrumentman became one of calling out figures in Spanish to his notekeeper, as: horizontal angle, distance, (flag), vertical angle, and so on. The main difficulty encountered, besides the inexperience of the members of the party, was from the wind in its shifting the heat waves and thereby carrying an object with it, and its force in the later part of the day, against which the instrumentman must be braced while reading the verniers.

Studies for Communication and Sources of Materials

The preliminary topographical maps were completed as rapidly as possible with the field engineers aiding the office men in the evenings with the calculations of the recorded notes and plotting onto the map, so that the information might be available for use in conjunction with the factors aforementioned in the determination of the plantsite.

At the same time that these studies are being made, investigations are carried on to locate sources of sand and gravel for use in the construction work, water for building purposes and permanent use, and for transportation facilities to and from the plant.

Sand was found in the dry river beds and on flats, of good quality and properties, but only in quantity sufficient merely to do the preliminary work, and not enough to warrant the erection of a recovery plant. The same test pits sunk for locating supporting foundation material for the buildings, were also examined for concrete aggregate qualifications. A location was chosen at a hill, 8 kilo-



PEÑASCAL ROCK QUARRY.
FLOW SHEET

meters from the present plantsite, composed of rhyolite of good hardness and only very slightly decomposed. The quarry was here dug into the side of the hill by blasting out the rock in steps and advancing the track as was required to keep it against the face of the cut. The rock was hand loaded into cars which were run to the bins and discharged. Four jaw crushers capable of handling 100 tons of rock per hour, were installed and used throughout the construction work. The bulk of the sand was also produced at this same point by passing the finer gravel through a pair of horizontal rolls. The entire output was washed before sending it to the concrete mixing plants, and the resulting material was good hard, sharp sand and gravel, with a very low salt content. At the height of the construction work, river sand was brought in by trucks to keep the aggregate quantity sufficient to supply the demands of the numerous jobs requiring concrete at the same time.

Water first came to the property in a tank truck, from the Oficina José Francisco Vergara, which is now a subsidiary of the Lautaro Nitrate Company, Limited, at which there is a pumping station supplied from the Rio Loa at a distance of 22 kilometers. The first field office was at the "Las Bombas" station on the State Longitudinal Railway, which runs from Iquique to Santiago, and is only 5 kilometers from the present location of the Oficina Pedro de Valdivia. The fresh water came to Las Bombas by tank car from a junction point on the Railway at Baquedano, and the salt water by pipe line from the Rio Loa. The original source of all the water in this region is the Rio Loa, there being no ground water, although this River always contains salt water only. Its source is in the Andes Mountains and it cuts a deep gorge through the nitrate pampa, picking up salt as it flows, and has its outlet at the Pacific Ocean north of the port of Tocopilla, although it is rare that any of the water finds its way so far, due to the evaporation primarily, and now to the amount drawn from it to supply the oficinas in the pampa through which it flows. Although the water must be distilled for domestic use, it is suitable for concrete mixing, form and road sprinkling, blasting, and sanitary lines, having a salt content of only .3 to .6%. Arrangements were made, therefore, to pump the raw water from Las Bombas to the chosen site of the oficina, and to this end, a pipe line was laid connecting with the pumps at the railway station. Another, a four inch line, was laid from the Oficina Vergara distilling plant, to supply the necessary fresh water. Both of these water lines terminated in temporary tanks placed on a hill near the projected site, and served well, until the permanent system was installed.

The last big problem to consider was the transportation of goods and materials to and from the coast, either at Antofagasta or Tocopilla, and presented two distinct methods: first, transportation on the Company's lines, or second, transportation over the Government lines.

Apparently the most simple and logical solution to the transportation question was to take advantage of the proximity of the State Railway, only 5 kilometers distant from the plant, to which the Railway would build a branch line along the route laid out by the Nitrate Company, rather than go to the expense of building a line of its own to connect with its own railroad at the Oficina Marià Elena at a distance of 40 kilometers. However, balancing the chances of completing the connection by the date it would be needed for operation in bringing in materials, freight charges, and long time cost of operation, it was decided better to add the 40 kilometers to its own lines over which it has control of cargo movements, and can more economically handle shipments of the product from the two oficinas by dispatching it all from the same Port. Powerful electric locomotives haul trains from the Port of Tocopilla along the face of the canyon walls to the level of the nitrate pampa, and at a junction station, steam locomotives replace the electric on the remainder of the run to the oficinas further inland, the main one being the Oficina María Elena, from which a spur line goes on th the Oficina Vergara.

By matching up the topographical maps of the 40 kilometers between María Elena and Pedro de Valdivia, the route of extension of the railroad was laid out so as to miss as much as possible of the mineable ground, and still conform to the topography for grades, maintaining one percent as the maximum grade. The entire line from Tocopilla to Pedro.de Valdivia has a 42 inch gage, as do all the branches and spurs within the oficinas.

The road between the oficinas María Elena and Pedro de Valdivia is laid out to parallel the railroad, more from convenience than necessity, since the pampa can be travelled by automobile in any direction, and with very little scraping or grading, becomes a fair road after the passage of a number of cars. The usual practice in pampa road construction is to mix river gravel with the natural surface dirt after crude oil has been added to it, the result being a highway comparable to the macadam roads in the United States, and cared for occasionally scraping and adding oiled sand and gravel.

Final Plantsite Topography and Triangulation

More detailed, accurate information is desired regarding the chosen plant area than that given by the one-meter interval contour map with the scale of 1:5000, for purposes of making estimates of excavation, fill, and all the details of design and construction. It is also desired to establish a system of rectangular coördinates, having one base parallel with the axis of the plant in order that every point in the plant area will be designated as a positive "northing" and "easting", and that no other quantities need enter the plans which might cause confusion in design, field layout, or construction.

To this end, the existing topographical map and the ground itself is very carefully gone over to determine possible sites for the various main units and their relative locations to each other. With the main axis thus chosen, it is drawn as a direction line on the map, and its deflection from the true north, as given by the coördinates of the Government triangulation stations, is scaled from the map, and thenceforth this new direction is termed "Plant North". In this case it was N. 13° - 47' E. of true North. Next, the point of origin for the coördinate system was arbitrarily chosen by marking a point on the map far enough to the west and south of the plant site so as not to throw any of the units out of the northeast quadrant, and this point located with relation to the surrounding triangulation stations by taking angle measurements to them, and changing the Government Coördinates of all the stations to Plant Coördinates by systems of triangles -- a matter, merely, of computations.

The "working map" for layout, design, and construction purposes was to be put on cloth at a 1:500 scale, showing contour intervals of one foot. It being decided that the best manner of taking this final topography was to layout a network of points on 400 foot intervals, a line of stakes was run from a triangulation station, parallel with the plant meridian, so that a point was fixed every 400 feet on even hundred-foot plant Northings. From this line of points, cross lines were run to complete the network, the points established on these East-West lines being located on even hundred-foot "eastings", thus simplifying the work of placing them on the map and plotting the data derived from the succeeding stadia notes. The topography taken from each of these established points was recorded more rapidly than the former work, since the party had become more experienced and were never far from the instrument, the longest rod reading necessary being at only 280 feet from the instrument. The elevation of each point was established by running circuits of closed levels.

All plant work from this point to the end of construction is based on foot and yard measurements to conform with usual practice of estimates, design, and fabrication in the "States", from which most of the personnel and materials originate.

In preparation for the field layout of the actual construction work, a system of reference points and bench marks, advantageously placed, is essential to the progress of construction with delays. A 2000-foot Base Line was therefore staked out in the direction of the Plant North-South axis, on an almost level stretch of the ground. Wood stakes cut from "two-by-fours" were firmly set on line, and pieces of paper tacked on the tops to receive pencil markings of the line of sight and measurements. This work was, of course, done with the utmost care so that the exactness would be unquestionable, and angular measurements taken from the end points to all visible triangulation stations for a re-check, and so the length and location of the line established.

Although the position of the various units is not definitely known at this time, it can be approximated sufficiently to place reference points so they will not be disturbed at the beginning of excavation and construction operations. A point properly placed in this area was permanent until blasted out with the rock, which is an advantage seldom to be had on the average construction job in the United States. On this work the loose dirt was removed from the rock into which a hole was then drilled from two to three feet, and a bolt grouted into the hole, the head of the bolt being flush with the surface of the rock. When the grout is set and the bolt firmly held in place, a small punch-mark is made on the head.

The location of these reference points, later designated as Plant Triangulation Points, is determined by angular measurements with the end points of the Base Line, as well as with each other. This small system of triangulation stations serves as the foundation of all the field layout which is to follow when the actual construction is started.

Elevations are determined for each of the reference points by running circuits of closed levels to include all of them, and when the level notes and elevations are checked, these points are then designated as Bench Marks. Since all elevations used in the plant construction are well above 4600 feet, this amount was taken as the datum so that it would not be necessary to be using a set of large numbers. An actual elevation, then, of 4685.00 feet above sea level, would appear in field books and on drawings, merely as 85.00 feet. The same simplification followed the choice of the "origin" of

the rectangular system of coordinates.

With the completion of the one-foot contour map, and the establishment of the system of plant triangulation stations and bench marks, the field staff of the engineering department is ready for the actual construction work to be started.

Field Party Equipment

The equipment of the field parties for the work here, from preliminary topography and triangulation to the completion of the construction, was not much different from what might be encountered on equivalent projects in the United States.

The instruments used were the C. L. Berger and Sons Engineers' Wye levels and Engineers' transits, twelve of each being provided, and one transit for special work: a "Wild Universal Theodolite and Tachometer", made by S. A. Henri Wild, Heerbrugg, Switzerland. This latter instrument, reading direct to one second of angle, was used especially for the triangulation work and setting reference lines during construction, and always given respectful care.

One 50-foot and one 100-foot Keufel and Esser "City Engineers' Standard Tape", adjustable for temperature with spring balance, thermometer, and level, was used for Base Line work and also in setting reference lines during the construction period.

The remainder of the equipment for general use, besides the Berger instruments, consisted of 100-foot reeled, steel tapes, and six-foot folding rules from the Lufkin Rule Company; standard level rods and rods levels, some marked in feet and tenths and some in feet and inches, for different types of work; line rods of quarter-round wood, and hexagonal steel, marked alternately in black and white, or red and white bands; also the miscellaneous items as 8, 10, and 12-ounce plumb-bobs, hatchets, 4, and 6-pound hammers for setting stakes, colored lumber crayons, hand levels, stell squares, center punches, and a few sawa, files, etc. All field notebooks were of the Dietzgen Engineers' level, and transit, leather covered series.

Wood and steel stakes were supplied by the carpenter and machine shops and sent as required. Canvas covers were made up to protect the instruments from the dust of the job, and so lengthen the time between cleaning.

The Workmen

To gather together 8000 experienced men to one place, at one time, is a difficult task anywhere, and to organize that number, of whom 50% are inexperienced in construction work, and to complete that work satisfactorily with respect to quality and time schedule is a far greater task, but one that was accomplished in constructing the Oficina Pedro de Valdivia.

The Chilean workmen who came to build this Oficina were for the most part unskilled and inexperienced in any branch of the construction work, with the possible exception of excavation. Although some of the men had had previous experience, as they proved, or were known from other projects in the country, the majority had to be instructed in the work from the start, and as the construction progressed, proved their adeptness and capabilities in the various branches of the work. The larger percentage seemed to have a leaning toward things mechanical -- power tools, riveting hammer, air drills, and the like. Adeptness was shown in the shops, the carpenter work, crane and shovel operations, train crews, and the engineers' field parties. As is the case everywhere, the men worked willingly and well for leaders they respected, or where personal benefit could be gained. There are always the two extremes of "brilliant" and "dumb", which should not be taken to find the average. On this project, the average could well be taken by the improvement shown in the work of 8,000 as the construction progressed.

An example of inexperience might well be taken from the party of a field engineer where each member, as he started work, had to be taught his duties from the fundamentals: that it is better to hold the tape level in measuring; that a rod held for line or level readings must be plump; that a contrast of colors is advantageous in taking a sight on an object; that the stake should not be held with the tape to keep the measurement division on the point; that a rear chainman should be to one side of the line of sight; that the top of a stake should be moved by tamping the ground rather than knocking the stake, and all the other small and numerous details of the work. When these points are explained and the reasons illustrated so they are clearly understood, they rarely need to be repeated, an occasional reminder being sufficient, and each member of the party takes a certain pride in his knowledge, and in being able to do a thing better than some other member. Some of these men, through instruction and practice when time permitted became capable of doing simple level work, as well as setting-up, taking sight, and giving line with the transit. This is one extreme, of course, the other being these men who are exasperatingly slow to comprehend even after repeated explanations, but the average proved reliably accurate workers.

Design and Location of the Units

The work of designing the various units was done partly in the Company's New York office, and partly in the field office at the plantsite in Chile. This division of the work was based on the time necessary to send plans back and forth, the source of materials, experimentation being done at the María Elena plant, and the best means to expedite the progress.

The New York Office took charge of the main plant-production units for which the structural steel and equipment would be fabricated in the United States, or which might best be ordered through that office. These units included the primary and secondary crushing plants, screening plant, and rejects bin, the reinforced concrete leaching vats, crystallizing and centrifuge plants, Diesel power house, electric transformer banks, and all the connecting piping, cables, trenches, and belt conveyors and motors.

The Chile office had charge then of the entire water supply system, the warehouse and shop buildings, all living quarters, the graining and bagging plant and the grained nitrate storage yard, the sanitary system, and all connecting pipes, cables and conveyors. The structural steel for the warehouse and shops buildings was available from closed oficinas on the Pampa where similar buildings had previously been in service. Also available was a quantity of miscellaneous structural steel, to which was added new steel sent from New York, and this combined for the erection of the graining and bagging plants as fabricated in the machine shop of the Plant.

Road and track layouts were also made in the New York office to serve the units designed there, although most of this work was done in the Field office for the entire oficina. Fills were made with the rock from the excavation, except for the very slight fills for which the loose surface dirt proved satisfactory. Underpasses, and small bridges spanning trenches, were also designed in the Chile office.

The extension of the electric power line from the Oficina María Elena power house, and connecting with the Chile Exploration Company's line running from their power house at Tocopilla to the copper mine at Chuquicamata, were also laid out by the Field office.

The water supply system consisted of a dam and pumping station at the Rio Loa, some 45 kilometers distant from the Oficina, a pipe line to the booster station at the Oficina Vergara, at which point some of the water was sent through the distilling plant, and on to the storage tanks placed on a hill in the plant area of the Oficina Pedro de Valdivia. The storage tanks have a capacity for 9000 cubic meters of salt water, and 4000 cubic meters of fresh water, besides an elevated tank erected for additional pressure for flushing, and for fire protection. From the tanks, pipe lines were run through the plant and townsites as required for solutions, cooling, domestic, and sanitary purposes.

The dam at the Rio Loa was the most interesting unit of the water supply system, and although small, rather ingeniously designed. The water stream is neither large nor rapid, being only 150 feet wide, and of only 3-foot average depth, with soft sandy-clay bed. It was required to raise the surface of the river only a few feet in order to give a constant flow through the intake tubes to the settling basin and to the pumps. A churn-drill rig was used for driving 40-pound rails as piles, at two foot centers, across the face of the dam, leaving a projection of four feet. Against the upstream face of the piles, cement in sacks was stacked to form the main wall. The spillway was made by a rock fill, covered with fitted concrete slabs to prevent scouring, and was regulated by a pair of lift-gates operated from an overhead frame supported at each side on concrete walls. From the intake tubes, laid horixontally just below the surface of the river, the water was led through an open ditch to a concrete settling basin fitted with cleanout, flood gates, and screening grids. The water was pumped from the basin, over the river bank, and on to the distillation plant and booster station at the Oficina Vergara.

There were several features in the design of the building foundations and the superstructures, not encountered generally. The one particular feature was the protection against damage from earthquake shocks. Insomuch as there have been no recording instruments in service on the pampa, the actual force of the shocks could only be estimated, basing the conclusions on observed results of the shocks at the Oficina María Elena and old structures of other oficinas in the pampa. The foundation bearing material being rock of homogeneous structure with no significant faults or cracks, it was assumed that the force be uniform in the sub-soil, and design was based on theory that the force of the shocks would be dissipated through the structural steel of the super-structure of steel framework buildings.

In conforming with the assumptions, the free-standing column footings were specified to be firmly tied to the rock against sliding, either by setting the footings in solid pockets cut into the rock, or dowelling with reinforcing bars grouted into drill holes. Bearing walls were likewise tied and anchored to the rock, and the normal amount of reinforcing steel increased 1% against earthquake shock, this latter factor being held in all reinforced concrete design throughout the job. The structural steel of the taller, and the heavily loaded buildings, were designed with stronger members, gusset plates, and diagonal braces, than would otherwise have been employed, and the factors of safety increased in both concrete and steel.

In the case of the Leaching Vats, a novel design was used. These vats consist of a line of five double batteries of reinforced concrete tanks, set end to end; each battery being 326 feet long by 114 feet wise and 19 feet deep, with a partition wall across the center. The walls and floors are reinforced concrete, supported as a unit on a series of hour-glass and truncated pyramidal footings, which were tied to the rock as before described, and on which a thin steel plate of a size equal to each separate footing was placed when the concrete was poured. The upper surfaces of the plates were oiled and similar plates placed on the first so that the entire vat, when completed, rests on the steel plates with the film of oil between them, which would allow horizontal eqrthquake thrust to be dissipated in sliding the whole massive unit, rather than in destructively cracking it.

The crushing and screening plants, as a unit, were located at a slight angle with the plant axis, to conform most economically with the contours, with especial reference to the construction of the yards for the loaded and empty mine ore-cars as to the amount of excavation and fill necessary.

The "Workmen's Townsite" was likewise placed at an angle to conform with the topography for water supply and sewage disposal, and still maintain a uniform plan of layout. The living quarters were all designed in blocks having concrete walls reinforced with wire mesh, corrugated sheet iron roofs supported on two-by-four inch hips, rafters, and purlins, the floors of matched lumber, and small enclosed patios at the rear of each.

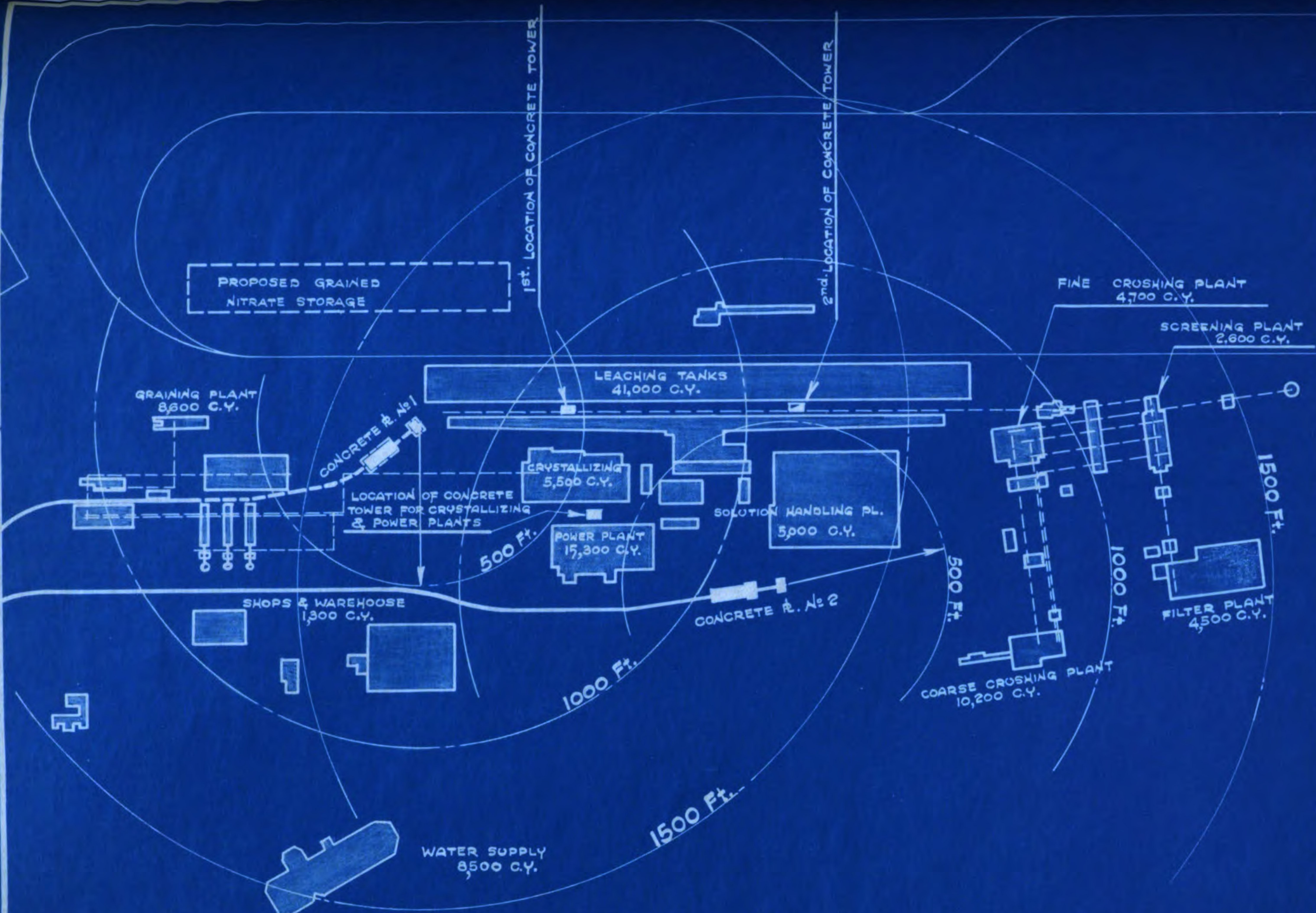
The "American Camp" was located on the north slope of a hill at the north of the plant, and just to the west of the Native Townsite. These houses were of similar construction to the blocks of native quarters, so designed with their arched porches, square windows, green trim and roofs against the white walls, to give a very attractive appearance, both individually and collectively.

Actual Construction - the Plan and Start

Correct planning and scheduling of the construction work is the most important factor in the coordination and continuous flow of the operations. Therefore, the quantities of excavation, fill, and concrete for each unit are studied, as well as the relative time each must be completed for steel erection and operation.

Until such time as permanent units could be completed, it was necessary at the start to provide for temporary field offices, living quarters, transportation, compressed air, and concrete mixing. Headquarters were first made at "Las Bombas", the station on the "State Longitudinal Railway", to which point lumber, piping, cement, and other materials were sent. Unoccupied bunk houses were made the living quarters, and the five kilometers to the oficina site were made by motor truck twice a day until temporary shacks could be built at the job. All temporary buildings throughout the period of construction were erected of corrugated sheet iron on wood framework.

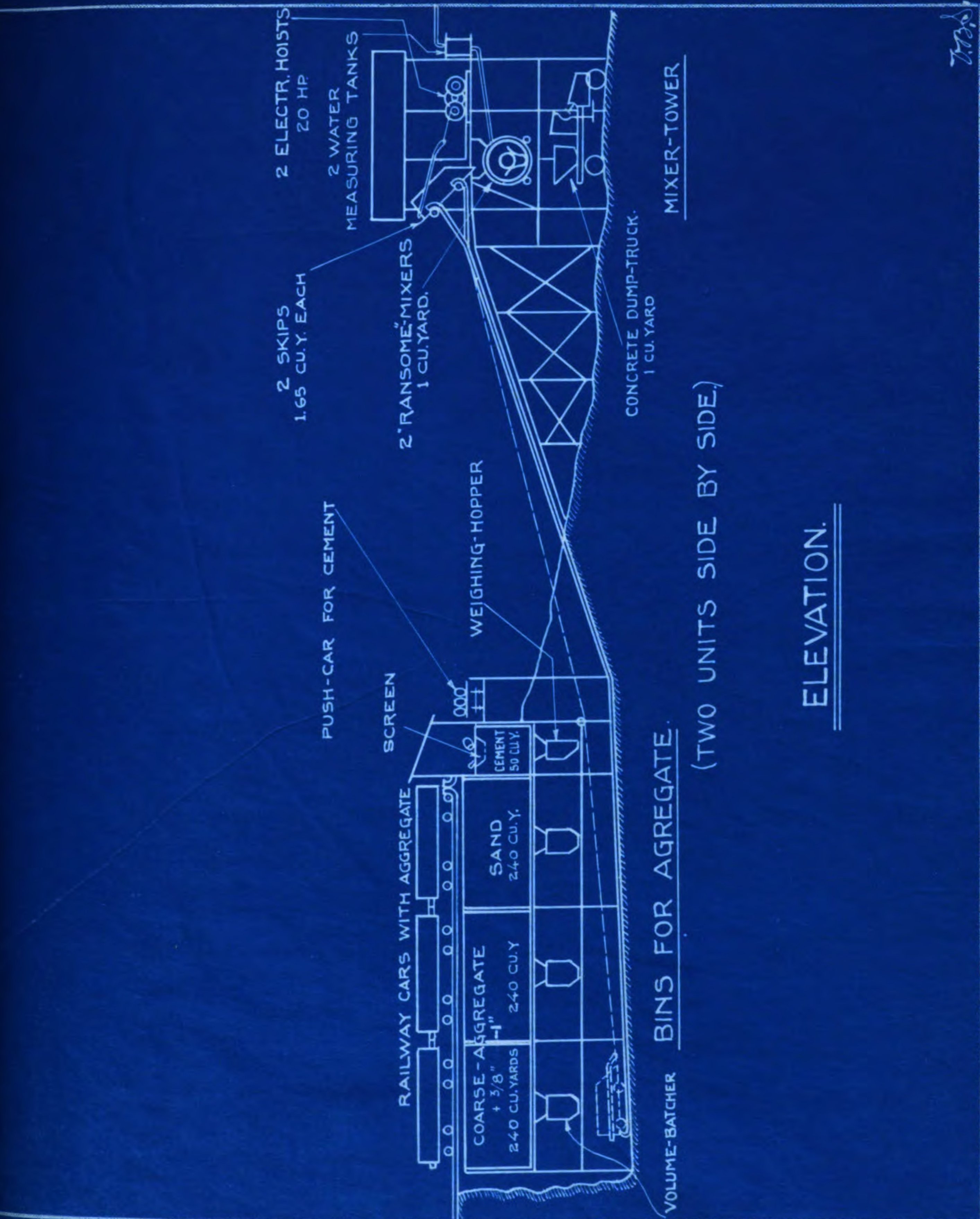
Excavation started with stripping, drilling, blasting, and mucking-out, of the townsite sewer trenches and the railroad cut necessary to bring the track from María Elena into the plant operations. All excavation was done by hand-drilling, and fuse-blasting, up to the time that the



LOCATION OF CONCRETE PLANTS AND DISTRIBUTION OF CONCRETE IN PLANT AREA.

MARCH 1932
V. N.

V. B. S.



REVISED

DWN: FINSTER 3/12/32

TRCD: G.P.R. 3/15/32

CHKD: FINSTER 3/15/32

IN CHGE:

ISSUED

APPROVED

DWG. TITLE:

CONCRETE-MIXING PLANT

GENERAL ARRANGEMENT

OFICINA

PEDRO DE VALDIVIA

CONSTRUCTION EQUIPMENT

CONCRETE & MASONRY EQUIPMENT

ZZ9-5000

SCALE: 1" = 20'-0"

THE LAUTARO NITRATE COMPANY LIMITED

electric power line was brought in and portable air-compressors provided. The workmen's townsite layout was begun at this point, as well as the permanent warehouse and plant tracks. Excavating gangs followed the layout parties as fast as facilities were provided for housing more men.

Layout of concrete mixing plants and material handling equipment is a major consideration at the beginning of all construction work anywhere. On this project the mixing plants were located near the centers of gravity of the quantity of concrete which each plant could provide, and as best situated to conform with the continuity of the work and the means of transportation.

Three concrete plants were erected; one principally for the townsites, located between the two and slightly uphill from them, thus making the loaded truck haulage on a level- or down-grade. The others were placed in the plant proper; one of them to take care, primarily, of the leaching vats, which was the largest single unit in concrete needs, requiring 41,000 cubic yards for its completion; the other plant to provide for the numerous smaller jobs, and so located that it might remain in service even after the plant was operating. Either mixing plant, however, could supply concrete to any part of the plant, and at times both were used to supply the same job simultaneously.

Each mixing plant was designed to be built of timbers and heavy planking and consisted of three bins, 240 cubic yard capacity — two for the coarse aggregate and one for sand, and a compartment for holding 50 cubic yards of cement. All fed through volume- or weighing-hoppers at the bottom, to a skip which was hauled by cable up an inclined track to be dumped into the drums of the two one-cubic-yard Ransome mixers which fed directly to the special tilt-bodies on the transporting trucks. The quarry cars supplied the aggregate bins from a deck track, and the cement was brought in from the stock yard at the side of the mixing plant on a push cart. Mixing time throughout the job was kept at from forty-five second to one minute.

In conjunction with the mixing plants a concrete testing laboratory was provided for regulating the mixes. Sieve analyses were made at the quarry and checks run from the aggregate bins at the plant. Water-cement ratio concrete was used throughout the construction work and necessitated continuous tests for salt content, slump, grading, and strength in compression and tension. The concrete salt content varied between 1.5% to 2.1% for the 121,000 cubic yards poured, and was so regulated that a very acceptable uniformity resulted in the concrete. The water-cement ratio held was 6.75 for 2500 pounds, and 7.50 for 2000 pounds of concrete, the tests showing that the average ran well above the required limits. Most of the cement was received from plants in Belgium and Norway, with some sent from the south of Chile during the final period.

A material-yard site was chosen to the northwest of the plant, on a flat section of the pampa. This yard was used for the purpose of uncrating and storing all materials as they arrived, and holding them until needed at the plant, and a customs officer was stationed here for making the necessary inspections. Structural steel trusses and columns and heavy equipment was here assembled and sorted for erection on the job.

Portable air compressors were available from nearby non-operating oficinas and used first for drilling at the warehouse hill until larger stationary electric-powered compressors were set up on a slope adjoining the drilling operations. The portable units were then used for working small, scattered jobs. Drill sharpening machines were temporarily placed near the warehouse site, and an old oil-burning steam shovel was sent from María Elena to aid in casting the blasted rock at the warehouse hill. This latter machine was soon replaced by a 3/4-yard Diesel shovel assembled at the station "Las Bombas".

Permanent houses for the workmen were concreted, roofed, and completed as rapidly as possible to accommodate the increasing number of men arriving for the construction. Portable mixers were used for all concrete work until the permanent plants could be erected. A more suitable headquarters than that first adopted was located near the site of the permanent office and a small staff colony consisting of office, mess hall, and living quarters was erected, the original shacks being used for time offices, first-aid rooms,etc.

For moving the excavated rock and bringing in materials, railroad tracks were immediately laid out, and as far as practical, conforming with the permanent positions. A temporary garage for servicing the numerous cars and trucks to be needed, a small machine shop, and tools for cutting and bending reinforcing steel, were built. As is true of any job, the start appeared hopelessly confused and tangled, but was soon straightened out to the "ordered confusion" of any rapidly progressing construction.

Supervision and Inspection

It was planned, of course, to place in responsible positions only those men whose qualifications best fitted them for successful organization, cooperation, judgment, and training of men. That the personnel was well chosen is best exemplified by the fact that this huge plant was in productive operation less than eighteen months after the start of excavation. That there were very few delays of any nature is a credit to the efficiency of the designing departments, material and equipment expediting, and the management of all the construction departments, separately and collectively.

The architect, the owner, the general contractor, the sub-contractors, and the superintendents and inspectors of each, could all be found on this project combined under the one Company. This condition automatically eliminated the possibility of monetary gain to any of the branches through dishonest, unsound, and often unsafe, methods of building, use of materials, or adjustment of figures. There are numerous "tricks" in construction work which may be termed "petty thievery", which leads to expenses for delays and repairs, and others which are very dangerous and may even be classed as criminal offences since they may lead to failures in a structure, costing the lives of many people, besides temporarily paralyzing operation. Among these "tricks" might be mentioned such as reducing the cement content in concrete mixing, placing concrete in uncleaned forms, bad seating of beams, improper placing of reinforcing steel, cutting down on the thickness of floor slabs, using inferior grades of bricks, omitting bolts and rivets, poor caulking and joining of pipe sections, and all the petty offenses of poor construction.

The superintendent of each department had to instruct his assistants in their duties and to see that the work was done correctly, but the final responsibility for all work as completed was placed with the field engineering department.

This placing of responsibility seemed soundly based because each member of that department for the proper execution of his duties, should have more general as well as detailed information about his section than any other one person on the job. Because he does the field layout for all departments and installations, as well as inspecting and checking them, the field engineer must be thoroughly familiar with the work and able to give the information always to be expected from him.

Field Layout

For purposes of field layout, the entire oficina was divided into sections, or division of the work, such that each could be handled by one engineer, and this turned over to him with the responsibility for the correct executions of the plans. On his work, then, the field engineer combined the duties of inspector, construction foreman, assistant superintendent, and the usual problems of general layout, working such hours as the job required, very often until midhight and some times all night.

As soon as approved plans were received for the layout of units, the location of the plant triangulation stations was examined, and where necessary were relocated at new positions where they would remain undisturbed. The areas were then staked out for excavation. The first crews hand-stripped the loose dirt covering the rock and cast, or moved it in wheelbarrows to the tracks along which it was carried to predetermined disposal points, most of it going into the fill for the Ripio tracks. The greater percentage of blasted rock also went to this samd fill for the Ripio Loop. With the rock surface cleaned off, crews came in for drilling to the depths designated by the engineer.

Electric power was available soon after excavating operations had started and permitted more compressors to be operated, large electric blasts shot off, and the operation of 3-yard electric shovels in casting or loading the broken rock. With this added equipment in service, the work rapidly spread to include the entire plant.

After experimentation, water-paint was used for marking boundaries and depths of cuts on rock surfaces, and proved very satisfactory. Green was the color used throughout by the engineers for all their markings, and other departments used other colors, so that there would be no confusion over the various markings, nor to whom they referred.

As the rock loading progressed in a cut, the tracks were thrown over to the face so that the shovel booms would reach the cars. With the advance, it was necessary for the engineer to check the excavation to see that too much was not being taken from the bottom nor sides of the cut. An excavation line is generally placed at eighteen inches from the outside formwork for a wall on any job where the bank will stand. However, in this rock, the face was figured closer, and the concrete poured against the rock face where the saving in concrete did not offset the cost of forming, stripping, and backfill. The rock usually broke so irregularly that formwork was seldom continuous along the face of any cut, unless the rock happened to break wide.

When the area was cleared sufficiently, reference points were accurately placed at locations which best suited the conditions, and were set in a manner similar to the triangulation points: bolts grouted into drill-holes, the exact point being punched on the head when the bolt was solid. Pencil markings on clean rock was servicible for a short time only, since the rock surface would flake and chip under the forces of expansion and contraction due to the wide range of temperature between night and day. These reference points were placed on lines which would prove of the most value to the job, as P.I.'s or P.C.'s for tracks and roads; column centers for buildings; center line for trenches; and street intersections for the townsites.

Following the main, rough cut, details such as column footings, motor foundations, etc. were staked out and all loose or cracked rock cleaned away. The outlines were then more carefully painted, and each checked for elevation and to see that the bearing surface was leveled up, and if not set in a pocket, that holes were drilled and anchor rods grouted in them.

The carpenters came close behind the excavators, for placing the batter-boards as located by the engineer to clear the formwork to follow. An inverted T was first set up and the ends of the cross bar weighted with rock to hold it firmly in place, the upright braced, and the ribbon nailed to the uprights at a level given by the engineer. Batter-boards are always a discouraging problem in the layout engineer's work, due to the numerous factors by which they may be shifted or destroyed, and make in themselves sufficient reason for the establishment of a number of reference points. There are opportunities for error by mistakes and misinterpretation at every step of the work, and so it rests with the engineer to be particularly accurate, and he has the training and mechanical instruments with which to do it. On this job, the probabilities that errors of one department would be checked by another were so very slight that more than usual dependence rested on the work of the engineer, besides increasing his normal duties on construction work. He was here obliged to check the location and dimensions of all formwork, the placing of reinforcing steel, the setting of templates, marked the center of each anchor bolt individually for boring the holes in the templates, the placing of the bolts for location and projection, setting of all sleeves, conduits, miscellaneous iron, and the bracing of all parts of the formwork to receive concrete. No concrete was poured without a written release from the engineer stating that all details of that particular form had been checked and was in readiness.

Special attention was given to the setting of anchor bolts for the structural steel buildings, so that delays might be avoided later in the steel erection. For all bolts, one template was placed with its under surface at the elevation of the rough concrete, thus maintaining the spacing of the bolts at the most important point, and also serving for an unmistakable guide in pouring the concrete. For bolts with projections of more than one foot, and some were as much as four feet, another template was placed just under the nut of the bolt and supported on two legs from the lower board, and the whole firmly tied from rocking by diagonal braces to the form. Slight differences in projection were taken up by turning the nut, thus raising or lowering the bolt as required. All bolts were later checked again, after placing the concrete and stripping the templates.

Base plates for the steel columns were received separately from the steel itself, and each was set on the bolts, brought to perfect level at the correct elevation, and grouted in place. The unit was then ready for the steel erection.

The value of accurate work on the foundations of any job cannot be over-estimated in the saving of time and labor on the job as a whole. The construction of anything is made unnecessarily difficult throughout by a few inaccuracies or careless mistakes at the start. It has been said that a layout engineer's work is two-thirds done by the time the foundations are complete. This statement seems well founded on fact when consideration is given to the trying period of excavation, especially of soft, mucky ground, in which everything seem to be shifting out of position, and the dependence of the rest of the structure on the foundations.

It is rarely possible to have too many reference points and line sights, and more often appears that there are too few, because of the many ways in which points may become lost, dug out, or otherwise destroyed or obliterated so as to become useless.

The pouring of the concrete for trenches, foundations, and all work below ground floor levels, was done principally by dumping from the trucks into floor hoppers, from which it was wheeled to the forms in concrete buggies on wide runways; although sometimes it was dumped into mortar boxes, shovelled into wheelbarrows, and so taken to the forms. However, this latter method was rare, and used only when the buggies were all in use on other parts of the work, or when the job was so isolated or small not to warrant building the heavier runways for accommodating buggies.

Floors above ground level, and walls and roofs, for the main units, were concreted by the use of buckets in steel towers, being hoisted up and discharging into chutes leading to floor hoppers and on to the buggies. Wood towers were erected for some units, and used for raising materials as well as concrete. For other units ramps were built, and the buggies or wheelbarrows pulled them up by hand to the forms, while for pours of small yardage high above the ground level, the containers were hoisted on a cable suspended from an outrigger.

the various types of placing-methods being adopted to best fit the needs of the individual job.

There was not much of the work of such similarity that form-panels could be designed for repeated use, except for concreting the leaching vats, trench walls, and the living quarters of both the American and Workmen's Townsite. Lumber was very rapidly used up in having to tear the sections apart after each pouring, in the unnecessary amount of cuts which the carpenters seemed determined to make in each piece, and the wasteful manner in which the stripping of the forms from the concrete was done.

The installations of all equipment, motor bases, tanks, drives, tile and finished concrete floors, and the innumerable miscellaneous items, were all required to be checked by the engineer. Steel columns were plumbed by instrument ahead of rivetting, and everything checked as erected. The magnitude of the steel erection was such that three locomotive cranes were in constant use, and the electric shovels pressed into service as they could be released from excavation and equipped with drag-booms for use as cranes.

Revisions and Alterations

There was, of course, frequent revisions to the plans, as is to be expected even on one small unit, following the checking of details. However, very few changes from the originally approved plans were received which were of more than minor importance to the smooth running of construction. Almost without exception, a revision was received by the field before that section of the work had advanced any appreciable degree, so close were the designing offices kept in touch with the field operations. A few delays in some units were suffered, but those cases were exceptional and unavoidable.

Future extension has been provided for in the present construction by building the units large enough to accommodate added equipment, the foundations for which have been installed. At such time as production may be increased, there remains only the placing of the equipment. The experience derived from the erection and operation of the Oficina María Elena has been the factor which has minimized alterations in the new Oficina. Experiments will be continued in the future, but the basic installations will doubtlessly remain as they stand at the present.

Job Progress Reports

The progress reports of the construction work are taken principally from the data included in the diaries and monthly cubication reports of each engineer. The compilation of this data, arranged with the separate charge numbers for each type of work for each unit, gives the main office a check on the status of the job with reference to unit costs, material dispatching, and general progress.

In making up his report, each engineer took cross section of his area and plotted the notes against the surface as given by the accurate topographical map, and computed the volume of excavation and fill done that month. Formwork was measured when placed, as was all work which might be buried at the time the report was to be made.

Formwork was given in square feet of actual contact surface, concrete, excavation, fill, backfill, masonry walls, and grout were in cubic yards, tracks, roads surfaced, and pipe were in lineal feet, while reinforcing steel was in tons, and guniting in square yards. Besides these items, an estimate of the percentage of each type or class of work was also given as completed to that date.

A daily entry was likewise made in a book, giving significant dates, such as the start of excavation, concrete, and steel erection; completion dates of each class of work;

and the movements of shovels, cranes, equipment, etc.

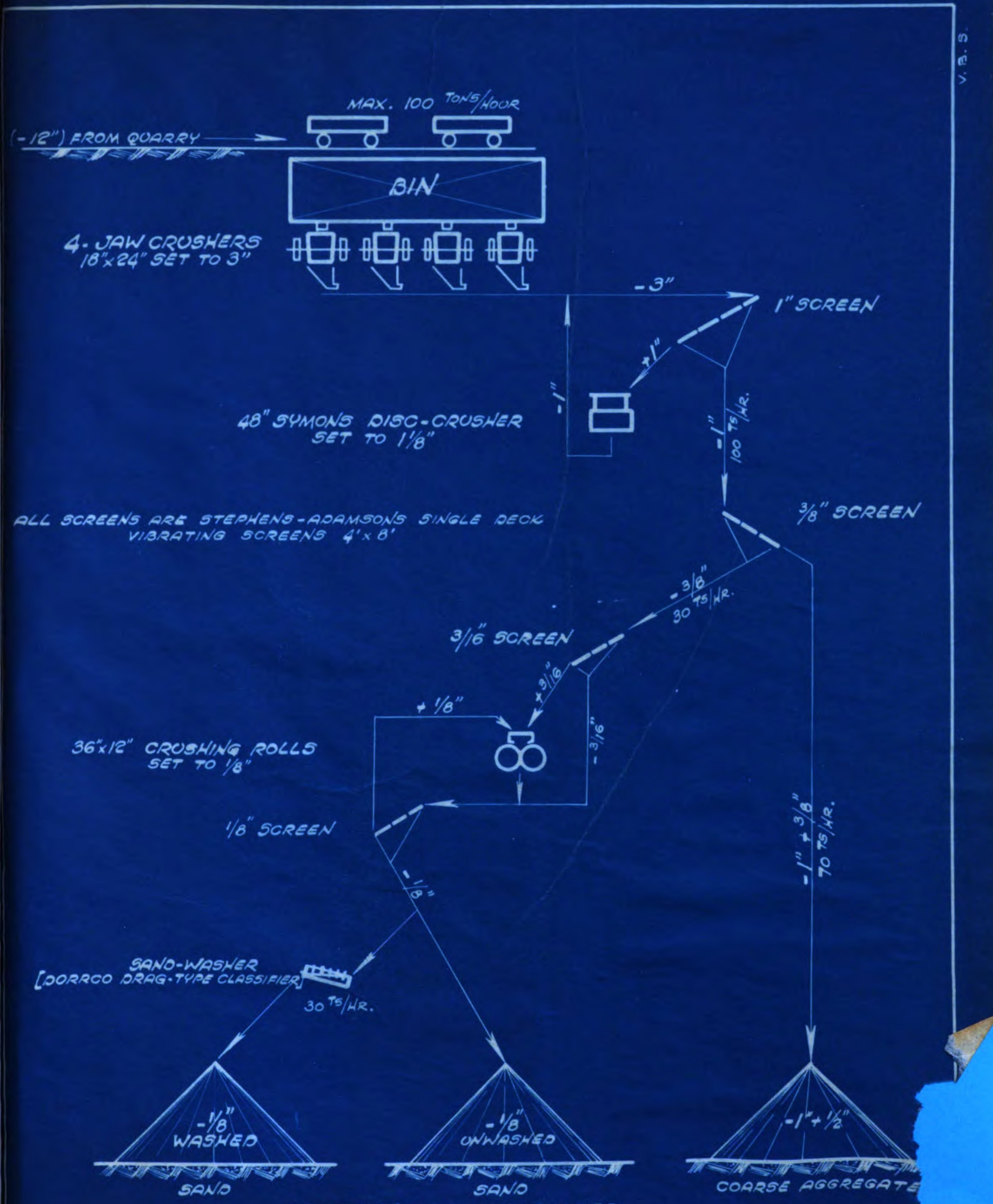
From a study of these data, the progress of the construction could be determined at any time, comprising as they did, all units of the actual erection work as set down by the men most familiar with the details of the advance.

Operation and Maintenance

As the construction was narrowing down, and the units of the Plant preparing for operation, and the Mine likewise organizing for production, the field engineers were transferred to one department or the other when they could be released. With the start of full operation of the plant, there remained only scattered odds and ends to be cleaned up, that part of the work often termed as the "Dust-pan jobs", which were finished under the direction of the single remaining field party. And so the Construction Field Engineering Department comes to a close, with its work well done.

Maintenance requires only occasional checking of the tracks in the plant lines, minor alterations made from time to time, and monthly measurements of the advance of the face of the Ripio Disposal dump. An independent staff is not needed for this work, but is merged with the production where operating duties are of more importance than field engineering as referred to construction.

The plant is operating satisfactorily -- the work of the civil engineer is complete.



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