ADDRESS TO THE CIVIL ENGINEERING SOCIETY OF JAPAN ON THE EVOLUTION OF RAILROAD BUILDING AND RAILROAD BRIDGEWORK IN AMERICA.

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Gentlemen,

It gives me exceedingly great pleasure to meet and address you, especially in view of the fact that there are present so many of my good friends of the long ago. It seems hardly necessary to mention that I take an intense interest in everything relating to the welfare and development of Japan, and that it is a profound satisfaction to me to note the wonderful progress that has been made during the last forty years in the Land of the Rising Sun. Tha tsatisfaction is greatly augmented by being told, as I have been many times of late, that my former pupils and numerous assistant engineers have been in the forefront of that progress. I finally believe that their work has aided materially in making Japan one of the leading nations of the world For these reasons words would fail me, were I to attempt to tell you how glad I am to meet you this afternoon.

My discourse is to be on "The Evolution of Railroad Building and Railway Bridgework in America." The reason for selecting these two specialties is that, besides technical teaching, to which all told I devoted six years, most of the engineering work I have done in my forty six years of practice has been in those lines.

In treating my subject, I shall not attempt to go back of my actual technical work, beginning in 1875; for I desire to speak only concerning things known from personal experience, and to deal solely with that portion of the development of American engineering practice in which I have played a part.

My first railroad work was on the surveying and building of the Canadian Pacific Railway between Port Arthur and Winnipeg in 1876 and 1877, where, as rodman in Government employ, I had a fine experience on preliminary, location, and construction. Resigning my Governmental position, I immediately became engineer to several of the subcontractors on the district, having charge of all their work.

Afterwards, for a long time I was Chief Engineer of the Omaha Bridge and Terminal Railway Company, then later Principal Engineer and Vice President of the projected Trans-Alaska Siberian Railway, a scheme which failed to materialize mainly because of the disapproval of the Japanese Government; and finally Chief Engineer of the Alberta and Great Waterways Railway Company. In addition to these engagements I have been retained from time to time to make reconnaissances of various railroad projects, some of which may yet materialize, besides acting for a quarter of a century as Consulting Engineer to the Kansas City Southern Railway Company and its predecessors. The reason for stating these facts is to show you that I have had actual practice on important railroad work; because many of you may regard me as solely a bridge specialist.

At the time of my graduation from Rensselaer, the fundamental principles of good railroad building were fairly well established; but since then some important improvements have been made, among them the following:

COMPENSATION FOR CURVATURE.

In the old days the limiting grade was used alike on tangent and curve. Where the curvature was slight this did not make much difference; but in difficult country, where often curves up to ten degrees were employed, the resistance to climbing was likely to be increased as much as fifty per cent for a combination of maximum grade and maximum curvature, as compared with the greatest resistance on tangent. Some years after I started in practice, this fault was recognized; and some experiments were made on the tractive efforts necessitated in climbing various combinations of grades and curves, the result being the establishing of the general principle that on any grade, the addition of each degree of curvature augments the resistance the same amount as would an increase of grade of about 0.04 per cent. For instance, on a combination of a one-per-cent grade and a six-degree curve, the resistance to traction would be the same as that on tangent with a 1.24 per-cent grade; hence, in order not to increase the resistance above that of a one-per-cent grade on tangent, the grade for the combination has to be reduced to 0.76 per cent. This coefficient of 0.04 is not exact, but represents an average for the various conditions of track and rolling stock. Today no American railway engineer who knows his business will ignore the effect of curvature on maximum grade.

Moreover, it is not only on grades approaching the maximum that this correction for curvature should be applied; for, in order to prevent irregularity in the tractive effort, it is advisable to compensate on comparatively low grades that extend over long distances. For instance, if there be a long stretch of 0.7-per-cent grade with a five-degree curve on a portion of it, on that portion the grade should be reduced to 0.5-per-cent. This refinement, which is too often ignored, results in easy riding of passenger trains and a steady draft for all locomotives. For flat grades, however, the compensation is unnecessary.

SPIRAL APPROACHES TO CURVES.

In the old days of railroading, the easement of sharp curves was unknown, the result being a rough jar or shock when a curve was reached and occasionally even a derailment. The practice of super-elevating the outer rail on curves was established before my time, as I remember studying about it at college. Were it not for the super-elevation, derailments would have been the rule rather than the exception when reaching very sharp curves at high speed.

The inventor of the easement curve is my good friend, Mr. Elliot Holbrook, a railway engineer of high standing and one of the first graduates of the Massachusetts Institute of Technology. He adopted a true spiral, but later practice has developed an approximate one. While acting as Chief Engineer of the Alberta and Great Waterways Railway Company some twelve years ago, I personally computed and established the easement curves for the road. The method adopted was to lengthen each circular curve one hundred feet at each end, and to make each easement two hundred feet long, irrespective of the degree of curvature, the limit of which was six degrees. For curves of less than two degrees I omitted the easement.

DOUBLE-TRACKING.

While there may have been some double-track railroad in America when I started engineering practice, there were very few miles of it; and today most of the great railroad systems have double tracks, and a few of them four tracks. Although the double-tracking has not doubled the cost of the road-bed, the costs of bridges and tunnels have been greatly augmented thereby, especially the latter, in which the cost per lineal foot varies about as the square of the diameter.

There is a great economy in the double-track road as compared with the single-track one, when large amounts of freight and many passengers are to be hauled; because, while the first cost of the line is not quite doubled, the carrying capacity is multiplied many fold.

DRAINAGE.

In the old days but little attention was paid to the fundamental and vitally-important matter of drainage. As long ago as 1878 I wrote a memoir on the subject, urging that more attention be paid thereto, the title of the paper being "Railroad Drainage." In it I showed how the drainage should be effected, and advocated that the side-ditches be graded just as carefully as the road-bed itself and that every depression or sag in the grade-line should have on off-take drain. For many years my words were unheeded by railroad engineers, especially on pioneer roads; but today more attention is being given to this requirement of first-class construction. If water is allowed to stand in the side-ditches, the base of the embankment is kept soaked; and in that condition its carrying capacity is diminished, with the results that embankments settle and that the material of their bases squeezes out into the side ditches. In order to remedy this defect, the elevation of the track is too often corrected by putting more ballast under the ties, instead of by drawing off the water from the right-of-way.

I feel that I cannot speak too forcibly concerning the ultra-importance of thorough, systematic drainage for railroads.

In Japan, where the railfall is great, more trouble is experienced from water than is the case in most parts of America; and in my travels over your railroads I have noticed that the drainage has been specially-well cared for in cuttings by building side-slope ditches, of either stones or concrete, discharging into the water-tables or side-drains, which are made wider and deeper than is customary in American practice. Again, catch-water drains back of the side-slopes are carefully built and maintained in this country. In view of all these precautions so excellently taken, it is probable that your road-beds do not suffer much from standing water, nor your side-slopes from gulleying.

PAPER LOCATION.

During my course at Rensselaer in the early seventies, the principle of locating wagon roads by the plotting of contour lines was known, because it was explained by our professor of geodesy; but probably there had not been, up to then, any railroad location worth mentioning done by means of paper location. At any rate, on the portion of the Canadian Pacific where I worked, the method was not adopted nor even discussed; hence it is fair to assume that this development has come in my time.

In my opinion, it is the only proper way to make a railway location; for there lives not a man who, by ordinary reconnaissance, preliminary, and location, can lay out as good a line as can be obtained by means of a thorough contour survey and the ensuing paper location. The old theory that a good railway locater is "born and not made" is a fallacy. It is true that some men can comprehend the characteristics of the ground much better than others and can locate fairly-good lines by the old-fashioned method; but they cannot arrive at the most-truly-economic-and-best line without an accurate contour map. Sketched topography is a delusion and a snare. It is essentially inaccurate, and, therefore, misleading; and perfunctorily-located contour lines give but little better results than sketched topography.

In my railway practice, I use two independent topography parties, one for each side of the line; and in flat country the cross-sections are carried out at least fifteen hundred feet in each direction and the contours are plotted one foot apart vertically. When the ground is rough, the distance out can be reduced, provided that the general layout of the line is satisfactory, or, in other words, that the right pass or passes have been chosen; and the contours can then be spaced two, three, four, or even five feet apart, according to the roughness of the locality. The elevations are determined by hand-level, and the alignment of the cross-section either by a simple-style cross-head or by the old-fashioned mothod of stretching the arms parallel to the tangent and suddenly bringing the hands together in front of the eyes.

By the use of an accurate contour map, a pair of dividers, a scale, a set of railroad curves, and a protractor, one can easily plot the best possible location of centre line, using judgment in compromising between excessive length and excessive cost of grading; and from the projected location there can be prepared a profile. On the Alberta and Great Waterways survey before mentioned, I had correct contour maps plotted in this manner; and with my own hands laid out every mile of two hundred or more miles of location. The result was that, although the country was quite rough in places, with fixed limits of one-per-cent grade in each direction and six-degree curvature, there was secured a line so straight that its excess length over that of a right line between termini was only fifteen per cent, and the volume of grading was only seven thousand cubic yards to the mile. It would have been absolutely impracticable to obtain such a favorable and economic line without a paper location from correctly-plotted contours.

I cannot too earnestly urge that you adopt this method exclusively for the location of all your railroad lines.

TIE PLATES.

As long as cheap, untreated sleepers were used, there was no necessity for tie-plates; but of late years treated ties have come into vogue. The treatment increases their cost, on the average, about one hundred per cent; but it lengthens their life three or four fold, as far as decay alone is concerned. But a treated tie in direct contact with the rails is generally destroyed by the pounding of the metal on the timber before the latter begins to decay; hence, in order to prolong its life, the said pounding has had to be minimized. This was accomplished by increasing the bearing area through the interposition of steel plates between the rail and the wood. On all first-class American railroads, tie-plates are used upon the main line, but not always for sidings or branch lines. They have come into being during the last three decades.

INCLINED RAIL.

The inclined rail has been employed for some time in Europe, and it is only within a decade that it has begun to come into use in America. It was tried in Japan, I am told, without tie-plates by notching the timber for a beveled bearing, but was abandoned because the said notching induced the retention of moisture and the decay of the wood beneath and adjacent to the rail. This result could readily have been anticipated, because water-pockets in timber always set up decay, unless unusual precautions be taken to prevent it, such as coating the wood with heavy paint or creosote oil.

The only way properly to obtain rail inclination is to use beveled tie-plates; and the best of them all is the Lundie Tie Plate, the invention of an eminent Scotch-American engineer, Dr. John Lundie, a graduate and post-graduate of the University of Edinburgh, which conferred on him the degree of Doctor of Science on account of some excellent scientific work that he did in America in the development of rapid transit by electricity.

Dr. Lundie's plate not only inclines the rails so as to make the top surfaces of their heads parallel to the coning of the wheels (at an angle of one in twenty), but also affords a slightly-cambered bearing on the wood, thus tending to give a uniformly distributed pressure thereon under maximum wheel loading. The inclination of the rail in this way adds fully thirty per cent to its life; and the cambering of the tie-plates materially increases the durability of the sleepers.

I take the liberty of suggesting to Japanese railway engineers that, at several places on tangent upon different lines of road where the traffic is greatest, the inclined rail with the Lundie tie-plate be given a trial in the following manner: Midway between stations seven or eight miles apart put in a stretch of three or four miles of new creosoted sleepers of the best quality, and on the middle third thereof place the Lundie tie-plate. On one of the outer thirds use ordinary tie-plates with the rails vertical, and on the other third no tie-plates at all. Then keep this stretch of track constantly under observation, so as systematically to record the wear and tear of both rails and ties on the three kinds of track, in order to determine the comparative economics thereof. By adopting this suggestion you will obtain some data of great value for the future building and maintenance of the Japanese railroads.

ROLLING STOCK AND OPERATION.

In character of rolling stock, methods of operation, systems of accounting, handling of heavy freight, etc., there have been great improvements in American practice during the last four or five decades; but my subject covers the evolution of "railroad building" and not that of operation; hence nothing will be said about these matters. For this exclusion there is sound reason; because, while well posted on the building of railroads, I have had no experience at all in their experience at all in their operation; and, as before stated, my address today concerns only things that I know at first-hand.

EVOLUTION OF RAILWAY BRIDGEWORK.

The various kinds of railroad bridges built in my time may be listed as follows:

Stone Masonry
Wooden
Combination
Wrought-Iron
Carbon-Steel
Alloy-Steel
Reinforced-Concrete.

STONE MASONRY BRIDGES.

Stone masonry bridges for railroads have never been common in the United States, because of their large first cost. They were confined almost exclusively to short-span arches in locations where stone was convenient and cheap and where the foundations were of solid rock, or other hard material, lying not far beneath the bed of the stream. They were employed in the early days of railroading by the better class of roads; and since then a few of them have been built from time to time up to the epoch of reinforced-concrete bridgework. At present very few of them are constructed in America in fact, their day has passed.

WOODEN BRIDGES.

Fifty years ago or more, nearly all truss-span bridges for railroads were built of timber, the Howe-truss type being by far the most common. They served a good purpose when metal was expensive and timber cheap; but since the reverse condition has existed they have gone out of fashion. The main objections to them were the use of wood in tension and the development of interior decay that caused failure without warning. On pioneer railroads built out into the wilderness where timber is plentiful, and where the transportation of metal is costly, it is still economic to employ wooden, Howe-truss bridges, and to renew them after eight or ten years with permanent structures.

COMBINATION BRIDGES.

It was to avoid the use of wood in tension that the "combination" bridge was evolved, the compression members thereof being of timber and the tension members of wrought-iron and later of steel. These, also, served a good purpose for a while, but they never were a really-satisfactory type of structure, on account of the shrinkage of the timber rendering them loose-jointed and vibratory. They usually lasted longer than the wooden, Howe-truss bridges, but did not afford as much rigidity under rapidly-passing loads. For a while their first cost was about one half of that for an all-metalic structure; but gradually, as steel became cheaper and timber scarce and expensive, the cost-ratio increased. When it reached seventy-five per cent, it generally was deemed economic to adopt steel bridges at the outset.

At first the detailing of the combination bridge was rather crude, but gradually it improved. This improvement, however, tended to augment the cost-ratio of the types. The last combination bridges designed and engineered by me were the temporary spans of the East Omaha Bridge over the Missiouri River at Council Bluffs, Iowa, built in the middle nineties. They cost about seventy-five or eighty per cent of what steel spans would have cost; and when their shorter life was duly considered, they were not truly economic, but the Company could not raise the money necessary to build the more expensive type. Moreover, they were supported on temporary timber piers; and it would have been illogical and incongruous to place permanent superstructure on temporary substructure, although on several occasions this has been done. These spans were so scientifically detailed and so carefully constructed that, when they were removed after ten years of service, not a single piece of timber showed any indication of decay, nor was there a sign of any kind of incipient failure. In my opinion, they would have given satisfactory service for another ten years, had not the live load been too greatly increased to warrant their retention.

The combination bridge held its own longer on the Pacific Coast than anywhere else in America, owing to the splendid timber obtainable there and to the high cost of transporting structural steel from the Eastern shops. It is possible that a few of them are still being constructed, but not to my knowledge.

WROUGHT-IRON BRIDGES.

The wrought iron bridge, especially for comparatively-short spans, was employed for two or three decades; but, when the steel bridge became cheaper per pound, the latter soon supplanted it, not withstanding the fact that wrought-iron resists the attacks of the elements better than does steel.

CARBON-STEEL BRIDGES.

The carbon-steel railroad bridge, which was first built at all extensively in America in the late eighties and early nineties, still holds its own for ordinary structures of moderate span-length. At first there was a tendency to employ high steel, but soon medium steel became the customary metal to adopt, on account of its greater reliability. Unfortunately, at least in my opinion, the American manufactures have combined to force upon railroad men the acceptance of a comparatively-soft steel for bridgework, the main object being the avoidance of rejections by the inspectors, although the excuse usually offered is that of uniformity of product. As the change has been made in the ultimate strength and the elastic limit of the steel without lowering the unit working stresses, it follows that bridges built of the softer metal are not as strong by five or six per cent as those in which the old-fashioned kind of medium steel was employed.

Quite lately, though, an attempt has been made to substitute a really-high carbon-steel for the bridge-steel of commerce and to stress it higher; but I do not approve of the innovation, because high-carbon steel is too brittle for the manufacture of bridges, unless all holes be drilled from the solid. The process of punching leaves incipient cracks in high-carbon steel; and these are likely to enlarge and cause trouble.

ALLOY-STEEL BRIDGES.

If greater strength than that of commercial carbon-steel be desired, it is better to obtain it by employing some alloy rather than to risk using a high-carbon steel, although, of course, the alloy is more expensive per pound. On account of its greater strength the permissible intensities of working stresses are higher, and, consequently, the total weight of metal required is smaller, thus often more than offsetting the larger pound price.

In 1903, I was retained by the International Nickel Company of New York, which then controlled three-quarters of the world's total output of nickel, to investigate the question of nickel steel for bridge building. The investigation required more than three years for its completion; and, after reporting the results to my principals, I prepared for the American Society of Civil Engineers a memoir thereon entitled "Nickel Steel for Bridges." This memoir with its numerous discussions was the means whereby nickel steel came into use for long-span bridges—notably the Manhattan Bridge over the East River at New York City, the Quebec Bridge over the St. Lawrence River, and the Municipal Bridge at St. Louis over the Mississippi River.

The advent of the Great War not only stopped the building of nearly all long-span bridges the world over, but also caused such a demand for nickel for military and naval purpose as to raise its pound price to an extent that prohibits, at least temporarily, its economic employment in bridge building. It may be used again therefor after the unit price drops to a normal condition; but there is a chance of some stronger and cheaper alloy being found for bridgework.

As shown at length in Chapter V of my lately-issued treatise on "Economics of Bridgework," it is probable that chromemolybdenum steel, termed therein "Chromol Steel," will prove to be the coming alloy for long-span bridge-building. Upon my return to the United States next spring, I shall probably be retained by the Climax Molybdenum Company of New York and Colorado to make an exhaustive series of experiments on "Molybdenum Steel for Bridges" similar to the before-mentioned one on "Nickel Steel for Bridges."

REINFORCED-CONCRETE BRIDGES.

It was only two decades ago that the building of reinforced-concrete bridges in America really began, and for a long time they were used for highway structures only, but now they are being adopted also for railway structures, both as arches and trestles. This type of bridge has come to stay. At first, everybody claimed that its life is unlimited, while that of the steel bridges is limited to two or three decades. Both of these claims are incorrect, because, first, unless the reinforced-concrete structure be built with the utmost care, and unless its mass be impervious to water, failure will ensue sooner or later; and, second, the life of a properly-designed, properly-manufactured, properly-built, and properly-maintained steel-bridge is indefinitely great. If reinforced concrete is permeated by water, rusting of the reinforcing bars will surely occur, and this will split the concrete and cause it to shell off, thus not only weakening the structure but also exposing the said bars to the unchecked attack of combined air and moisture.

For this reason it is claimed by some engineers that the reinforced-concrete bridge is still on trial; but it is me belief that, when proper precautions are taken in its deisgn and construction, it may properly be considered a reliably type of structure.

GENERAL DEVELOPMENT.

My connection with railway bridgework began in January, 1881, as Chief Engineer to a small bridge-building company in the Middle West, which position I held for a year and a half, resigning it to accept the Chair of Civil Engineering at the Imperial University of Tokyo, where I first became acquainted with a number of you, and where I contracted so many highly-valued friendships.

Looking back on the bridgework that I designed and supervised four decades ago, it seems strange that one could have done it without recognizing the enormity of its faults and the glaringly-unscientific character of its details. My excuse must be that I was then without any practical knowledge of bridge design, that the science of bridge construction had not begun to be evolved, and that all the other American engineers who worked on bridge building were about as ignorant as myself. At first it was necessary to adopt current practice in designing; and for those eighteen months I was so busy in the office and field, and so occupied in studying what had been done up to that date in bridgework, that there was no opportunity to do much towards the improvement of detailing. Luckily for me, all the railroad bridges that I engineered were of the combination type, i.e., having the compression members of wood and the tension members of wrought iron; consequently their life was limited to that of the timber. Fortunately for my reputation, all of my old structures lived out their allotted lives without failure, which was by no means the case with the work of certain other American bridge designers. There was one piece of construction, though, of a permanent character that was a nightmare to me for a full decade, viz., three wrought-iron braced-towers, supported on iron cylinders filled with concrete, and carrying two combination, Pratt-truss spans on the line of a narrow-gauge railroad. When the time came to remove these spans and replace them by metal ones, the contract was given to my old company; and I begged that it correct the glaringly-bad details of the towers. This was done; and thereafter my conscience was clear concerning the railroad structures of my early practice.

DETAILING.

Bridge detailing in America four decades ago was certainly atrocious; but that of the European engineers was even worse. This I learned in Japan by inspecting some of the railway structures built here by English engineers. They had faults of design inherently their own—faults that at first sight gave a shock to any American bridge designer; for it was a puzzle to him why such structures stood up under load. In those days the Americans were using pin-connected trusses and the Europeans riveted ones. The latter type ought to have been the more rigid; but the structures thereof then built were so crudely designed that the benefit of their stiffness was lost.

Some of you may remember the newspaper fight, extending over nine months, that I had here in 1885 and 1886 on the subject of "American *versus* English Methods of Bridge Designing." It was a spirited controversy, and did some good, in that it brought before engineers the world over the question of proper bridge designing. The expression "the world over" is used advisedly; for, although the Japan Mail, in which the controversy appeared, was not read much outside of this country, after the fight was finished I had it reproduced in full in pamphelt from, issuing eight hundred copies and distributing them broadcast throughout Europe, Asia, America, and Australasia. The subject was taken up in those countries by the technical press; and the pamphlet was given much prominence. As one looks back on it now, the most amusing feature of the entire controversy (and there were many amusing points brought up in the spirited discussion) is that both sides were wrong, because both of the types of bridge under discussion, as then built, were fundamentally and glaringly bad—but none of us knew it.

IMPROVEMENTS IN DESIGNING.

Soon after returning to the United States in 1886, I started private practice in Kansas City as a Consulting Engineer at the same time representing the Phoenix Bridge Company to the West of the Mississippi River. In my dual capacity I immediately began to do considerable work, at first mainly for the contracting company but are long for clients.

During my four years in Japan there had been a few improvements in American bridge designing, notably, in through structures, the riveting of the floor beams to the vertical posts, instead of suspending them by hangers from the bottom chord pins, and the riveting of stringers to the webs of floor beams, instead of resting them on the tops thereof. The general status of bridge designing in 1886, however, was about as crude and unscientific as ever.

At first, in making competitive plane for bridge jobs in the interest of my Company, it was necessary to adopt current practice in detailing; but soon I began to analyze the details, learning to follow the effects of a loading from its point of application on the span to the place of delivery on the substructure, and to endeavor to ensure that every connecting detail was made so strong that, were the bridge loaded to destruction, failure would occur in some main member rather than in a connection. This is the prime, fundamental principle in bridge designing; but up to that time it had not been established or even so recognized.

The more I studied to systemize bridge designing and raise it to the dignity of a science, the heavier grew my structures, and the greater the handicap under which I labored in competing for work, the result being that, while my private practice augmented, the number of contracts taken grew less, until after a few years my engineer's conscience forced me to make so many improvements in current practice that I could no longer compete at all. At the end of five years it became necessary to resign the agency of the bridge company and to devote myself entirely to consulting work.

At first my efforts were spent principally on the improvement of highway bridge designing, and I wrote several technical papers and published a long pamphlet on the subject; but the evils of the highway-bridge business were so chronic that my repeated efforts were almost in vain.

Turning to railway-bridge designing as a more promising field, I wrote for the American Society of Civil Engineers a paper on "Some Disputed Points in Railway Bridge Designing," calling attention in unequivocal diction to all the objectionable features of current practice and inviting discussion thereon. Between forty and fifty engineers responded to my appeal for an exhaustive discussion; and the subject was so well threshed out that the paper with its discussions marked a distinct epoch in American bridge building. After the memoir had been read and printed in the "Transactions," there was no valid excuse in subsequent designs for the adoption of the faulty detailing which hitherto had prevailed.

ELEVATED RAILROADS.

Soon after this, in connection with the building of two or three elevated railroads in Chicago, on which I was Consulting Engineer for both design and construction, I found, or rather made, an opportunity to do for elevated railroad designing what had just been done for railway bridgework; and in so doing it happened that I nearly lost my job, because of spending the Company's money in learning "how not to do it," and because the "powers" thought that I should have "known all about it" before accepting the position.

It was necessary first to make a special study of the various types of elevated railroads in New York City and Brooklyn, locating, their numerous and glaring faults, investigating their lack of economy, and recording all results in a report to the President of the Company. In that document were given tabulated quantities of all materials; and the costs per lineal foot for thirteen different possible types of layout were estimated, only three of them being recommended for construction, leaving the others to be thrown into the discard. Once more I nearly succeeded in getting myself discharged;

because it was deemed a waste of my time and the Company's money to make so many estimates. Why had I not recognized in advance that the rejected types were uneconomical? Any engineer who thoroughly understood his business would have known this! After much explanation, however, the disgruntled members of the Board were convinced that my investigations were really worth while; and for some time thereafter they permitted me to proceed unhampered with my work on the plans and specifications for submission to bidders.

SUB-PUNCHING AND REAMING.

The specifications for this elevated-railroad metalwork called for all rivet-holes to be sub-punched and reamed; and there was a general clause therein to the effect that no variations in the requirements of the said specifications would be permitted, and that all tenders based on any proposed variations would be rejected. One bidder submitted an alternative tender on the basis of punching rivet-holes full size, and offering, in consequence, a lower pound price that would have lessened the total cost of structure considerably. The President of our Company favored awarding the contract to this bidder on this reduced price; but I strenuously opposed his so doing, upon the bases of, first, its being actually uneconomic to accept inferior workmanship under any conditions, and second, its being unfair to the other competitors. I fought the matter to the bitter end, tendering my resignation in case the objectionable bid were accepted. Eventually, after a long, hard struggle, my contention prevailed, and the contract, amounting to more than one and a half millions of dollars, was awarded to the lowest legitimate bidder—a combination of the Union Bridge Company, of which Dr. Charles Macdonald was president, and the Elmira Bridge Company. The contract for the work, which had been drafted by myself, was signed in general conclave with much formality, and was handed by our president, Mr. Louderback, to Dr. Macdonald with the remark "Now, Dr. Macdonald, that you have your contract, signed, sealed and delivered, and no change in it possible without mutual agreement, I desire to ask you a question. Our Consulting Engineer, from start to finish, has insisted that all of the metalwork shall be sub-punched and reamed; and yesterday he was ready to resign his position, if his specifications were changed so as to omit this requirement. I now desire to ask your candid opinion about this matter. Is it necessary or even advisable to sub-punch and ream the metal?" To this Dr. Macdonald replied "Mr. Louderback, it is the only proper way to manufacture structural steelwork." This story soon became well known among engineers; and the incident tended greatly to establish sub-punching and reaming as a necessity for all bridgework of importance, thus marking another forward step in the growing science of bridge building.

After completing the detail plans for these Chicago elevated railroads and effecting thereon numerous improvements in both general layout and detail connections, I prepared for the American Society of Civil Engineers a lengthy paper on "Elevated Railroads," and solicited from its members, by numerous letters and oral requests, a thorough discussion. My solicitation was successful; and the result of the combined paper and discussions was to change the previous crude methods of designing elevated railroads into a science. Although, since the time these structures were built, more than a quarter of a century has passed, no improvement worth mentioning has been effected in the designing or manufacture of the metalwork of elevated railroads.

COMPETITIVE PLANS AND TENDERS.

The development of bridge building in America certainly owes something to the adoption of the method of calling for tenders on competitive plans furnished by the bidders, in that the said method encouraged ingenuity in design and keeness of vision in the competitors; nevertheless it had a most demoralizing effect upon the efficiency of the structures so evolved, rendering them light, loose-jointed, and vibratory. This method was employed very generally during two decades, until its evil effects became apparent by the wearing out of the structures built thereunder. Nor was it practicable to correct this uneconomic practice instanter, because public opinion had to be educated to comprehend that, for good designing, rigidity is just as important a requirement as mere theoretical strength, and that it takes extra metal and plenty of it to secure a structure that will properly resist vibration and impact. By degrees railroad engineers learned where this extra metal should be placed and how best to distribute it; then the pendulum began to swing too far the other way, because some railroad-bridge designers used steel extravagantly and in places where it would not do much good, regardless of expense.

Lately it has become necessary to study trus economy in bridge designing, so as to obtain truly-first-class structures at minimum legitimate cost, as you can see by reading my before-mentioned new book on "Economics of Bridgework."

That the pseudo-economic method of calling for tenders on competitive plans with all of its evil effects has not gone entirely out of existence is shown by the Yellow River Bridge competition, started about a year ago by the Chinese Government; for it failed absolutely to obtain a satisfactory result. In that competition nearly fifty plans and tenders were submitted. Three of these only could properly be deemed good, and even these three were decidedly uneconomic. The others, in general, were crude, expensive, unscientific, and even ridiculous. The outcome of the competition is still in doubt; and the Government has spent a lot of money, and has caused engineers and contractors throughout the world to spend even more—all to no effect. This fiasco has proved what was learned by sad experience in America many years ago, viz., that the only way to secure any benefit from competition in tendering on bridgework is for the owner to have proper plans and specifications drawn by an experienced bridge specialist, and have everybody bid strictly on these.

IMPACT.

Before the days of the Impact Formula, the careful bridge designer was forced to adopt various intensities of working stresses for different kinds of members and even for members of the same kind in spans of different lengths. No specifications then written cared properly for this variation, hence each designer was more or less a law unto himself, and the adjustment of intensities was both troublesome and unsatisfactory.

About a quarter of a century ago someone recognized that, if the dynamic effect of a moving load could be reduced to a static equivalent, much labor in bridge designing would be saved and many important improvements therein effected; and thereupon various endeavors were made to establish a satisfactory method of reduction. The first attempt, and one that persisted for a long time, in spite of its evident crudity and incorrectness, was to assume that for all members of all spans the live load is just twice as effective or destructive as the dead load. Personally I always opposed this solution, on the plea that, if it be correct for a beam-hanger, it is certainly extravagant for the bottom chord of a longs span bridge. It was more logical to vary the factor of reduction with the length of span covered by the moving load when the member under consideration receives its greatest stress; and on this basis C.C. Schneider established his welle known formula that was used for many years. In writing "De Pontibus" I adopted a similar one with the thought that it would more nearly meet actual average conditions. Both of these formulae have been widely used in American bridge designing.

A few engineers, myself included, from time to time as occasion offered, made desultory experiments upon the actual values of impact on railroad bridges; but not until the American Railway Engineering Association carried out its elaborate and systematic series of tests was the profession able to establish reliable impact formulae. These tests wer- made mainly on single-track, steam-railway bridges, but there were a few on double-track structures and a short serie- on electric-railway bridges.

In my opinion, the impact formulae given in "Bridge Engineering" for steam-railway bridges and for highway bridges are as good as any that have yet been evolved for structures having different numbers of tracks or different clear widths of roadway; but the formula thereof for electric-railway bridges gives results that are too great, judging by Prof. Turneaure's latest experiments, consequently I am now using my highway-bridge formula for electric-railway bridges.

The establishment of the impact formula, or in other words, the reduction of all dynamic stresses to their static equivalents, did as much to put bridge designing upon a scientific basis as any other step ever taken in bridgework; for it involves the only possible correct method of proportioning for live-load stresses.

SUBSTRUCTURE DEVELOPMENT.

PILE PIERS.

Half a century or more ago many bridge piers consisted merely of clusters of wooden piles capped and sway braced with timbers, their life being limited to about a decade, although careful selection of materials and good methods of construction often increased this limit considerably.

Stone-masonry shafts resting on bed-rock, hard clay, timber grillage, or piles were also widely used for railroad-bridge piers. When piles were employed, it was at first the custom to saw off their tops as nearly as possible at the same elevation, and to cover them with a timber platform more, or less ineffectively drift-bolted thereto, relying mainly on friction to prevent its sliding off under pressure from current, log-jam, or ice. I always seriously objected to this type, and substituted for it a mass of concrete encasing the piletops for at least twelve or fifteen feet, the mass itself being confined in a timber box. This made the shaft, the crib, and the piles act as a unit to distribute the load, and prevented unequal settlement of the foundation. I am using this method today; for, wherever it is feasible, it is the cheapest and most efficient type for founding piers one soft materials.

COFFER-DAMS.

Where a satisfactory foundation can be reached at a depth of about twenty feet below the probable elevation of highest water during sinking, the coffer-dam is generally the cheapest foundation method to employ; but, if there be many boulders overlying the base, or if springs of water be encountered, the trouble experienced will sometimes render the method a very expensive one.

The coffer-dams can be made of Wakefield sheet-piling, steel sheet-piling, or double timber walls with clay filling between. The latter method was used before my time, but both the Wakefield and the steel sheet-piling have come into use since, the latter being comparatively modern. It is wonderfully effective and economic under certain conditions, especially where no serious obstacles to pile driving are likely to be encountered.

PNEUMATIC CAISSONS.

The use of pneumatic caissons for bridge piers antedates my personal experience; but during the last forty or fifty years many importants improvements have been made in this method of pier construction, tending to economy of labor, savingf time, and oavoidance of danger. Where bed-rock can be reached by this method, it should be adopted, in spite of thefact that, comparatively speaking, it is generally somewhat expensive. In truth, if a caisson is to be landed on bed-rock at all, I deem it almost essential that the pneumatic process of sinking be adopted, in order to procure an even bearing all around for the cutting edge. If the bed rock is too deep for the pneumatic process, the caisson should land at an elevation a little above it, preferably in a mass of boulders.

OPEN-DREDGING CAISSONS.

The sinking of open caissons to great depths by dredging the interior through wells was used soon after I graduated, and possibly a little before. I employed it first in the late eighties, and was so successful with it that I have continued to use it ever since in the United States, Canada, and Mexico. It has always given me good results, and has often been the means of saving for my clients large amounts of money, besides enabling me to reach depths below water unattainable by the pneumatic process. I have probably used this method more extensively than any other engineer, hence my endorsement of it should carry weight.

STEEL-ARCH BRIDGES.

In Europe steel-arch bridges are much more common than they are in America, the reason probably being that European engineers have paid more attention to the matter of aesthetics than have their American brethren, who have considered principally economy in first cost—or, at least, have thought they were considering it. Truth to tell, none of us knew anything at all about the comparative costs of steel-arch bridges and simple-truss bridges until some three years ago when I gave to the American Society of Civil Engineers a paper entitled "Economics of Steel-Arch Bridges," in which I solved all the economic problems I could think of as likely to arise in the designing of such structures. As there is shown therein for the steel arch, in comparison with the corresponding simple-truss structure, a greater economy of metal and cost than bridge engineers in general had anticipated, I am hoping that in future many more arch bridges will be constructed in America than formerly, because the arch is a far more beautiful type of layout than the simple truss.

CANTILEVER BRIDGES.

The building of cantilever bridges in America and else-where was started about the time I graduated—at first to meet peculiar conditions of erection, but afterwards as a fad, for certain designers appeared to have an idea that there was some peculiar virtue in that type that it really did not possess. The cantilever is an economic expedient to be adopted for unusual conditions and not for economy of metal, unless the average span-length of the layout exceed six hundred feet or thereabouts. This question is treated at length in "Economics of Bridgework."

SEMI-CANTILEVER BRIDGES.

The method of erecting ordinary-truss spans by cantilevering during erection and afterwards disconnecting the adjacent spans was first suggested by myself over a quarter of a century ago, but there was no occasion in my practice to utilize it until several years later. My experience shows it to be both effective and economic. It was in connection with certain bridges designed by me for Japanese railroad that the use of this method of erection was evolved.

CONTINUOUS TRUSSES.

With the exception of swing spans, there are very few continuous-truss bridges in the United States; and this is as it should be, because there is no special virtue in them, excepting, under certain conditions, a saving in weight of metal for very long spans. On the contrary, there is a decided objection to their use, unless the foundations of the piers be solid rock, or other hard material; because a slight settlement of a pier will change materially the stress distributions in the trusses, which would not be the case were the spans non-continuous.

One of the ten major economic problems that had to be solved preparatory to writing "Economics of Bridgework" was the "Comparative Economics of Continuous and Non-Continuous Trusses." This I did by designing a series of long-span bridges, of corresponding lengths and loadings, for the two types, and figuring the weights of metal required therefor. The results of the investigation you can see in my book, hence there is no need today for me to repeat them—suffice it to say that you will seldom, if ever, find it really advantageous to make trusses of adjacent spans continuous over the supports.

SUSPENSION BRIDGES.

There has been but little advance made in the building of suspension bridges in America in my time, for the reason that very few of them have been built, and almost none for railroads. My late economic investigations have proved that, up to its practicable limit, the cantilever type is more economic than the suspension type for railway structures, besides being much more rigid. It is only for railway spans exceeding two thousand feet in length that the suspension type need be given any consideration; and even for still longer spans it will be found less economic than the cantilever, when alloy steel is employed.

MOVABLE SPANS.

Forty years ago the only movable span in general use was the swing. From time to time some freak type was tried, such as the pull-back draw or the jack-knife; but one or two trials sufficed to show its inefficiency. Some thirty years ago the bascule was tried and found satisfactory; and about the same time I designed and constructed the first vertical-lift bridge built on a large scale for high clearance, the previous vertical lifts having consisted of hand-operated, short spans over canals with a lift not exceeding ten or twelve feet.

My late economic investigations show that the swing span has no longer any *raison d'être*, and that in most cases the vertical lift bridge is superior to and less expensive then the bascule. It is only for the unusual combination of a short span and a great vertical clearance that the bascule is cheaper than the vertical lift. Certain diagrams in Chapter XXX of "Economics of Bridgework" will solve at a glance this question for any combination of conditions.

OPERATING MACHINERY FOR MOVABLE SPANS.

Many years ago all movable spans were operated slowly by hand-power; then, as the masses to be moved increased, steam power was employed. This was exceedingly uneconomic—because, generally, steam had to be maintained constantly, coal had to be shoveled into the furnace, ashes had to be withdrawn and carted away, and the operator had to be constantly at hand.

When electricity began to be available, it was quickly adopted for operating movable spans, although for a while the then-unavoidable uncertainly of the power supply militated against its employment. Soon, however, it almost entirely supplanted steam power for this purpose; and the advent of the gasoline engine did so completely. Today, when electricity is not available, a gasoline engine is used; and it is occastionally employed as a supplementary motor to provide for slow operation when the electric machinery, for any cause whatsoever, fails to function.

Hitherto a valid objection to the gasoline engine has been its great weight and clumsiness; but now it is practicable to use light automobile engines, hence gasoline power is likely to be adopted in the future for this purpose much more often than it has been in the past.

BRIDGE SPECIFICATION.

In the early days of bridge building, the specifications submitted to bidders for both designing and construction were short and crude, the idea being to tell the competitors in a general way what kind of structure was desired and leave it to their ingenuity and experience to evolve the layout and details. Engineers at that time seemed to take pride in the conciseness of their bridge specifications; but today the contrary policy holds good, for we have learned that the more information given and the more detailed the instructions the better it is for all persons concerned. I was one of the first engineers to insist on making specifications as full and complete as possible; and in so doing I sometimes laid myself open to censure by my principals.

There was a glaring case of this, about which it may interest you to hear. I was retained as consulting bridge engineer by an American Bridge Company in Mexico that had a concession for building a long line of railroad, and in that capacity prepared specifications for letting a contract at schedule rates for the substructures of all the bridges on the line. According to my established custom, I made a thorough investigation of all the existing conditions and recorded the results very fully in the specifications, so as to give the bidders all the help I could in preparing their tenders, making a plain statement of facts and not attempting to minimize any of the anticipated difficulties. The Chief Engineer of the road, in the presence of the President, criticized my specifications severely, stating that they furnished the bidders altogether too much information. My reply to the criticism was "That is impossible." He then claimed that each bidder should find out for himself the various things I had stated. My answer was that, if such a policy were adopted, each bidder would probably add considerably to each unit price quoted, in order to protect himself against contingencies; and that, if anyone were so unfortunate as not to figure on the adverse conditions likely to be encountered, and were to be awarded the contract at lower than legitimate prices, trouble would ensue, and the work would be delayed—all to the detriment of the Railway Company. The Chief Engineer then said, "Suppose that some of the information you have given proves to be incorrect and, in consequence, the work costs more than the estimate, who will stand the loss?" My reply was "Your Company will have to stand it, and very properly so, because the fault will have been yours in not choosing a better consulting Engineer." Eventually my way prevailed; but, in spite of all the information furnished, the prices tendered were exorbitantly high, owing to the unsettled conditions in Mexico; hence the contract had to be let on the "Cost Plus" basis.

The earliest bridge specifications in America were those prepared by the Railroad Companies; but sometimes the bidding companies offered specifications of their own, describing the kinds of structures they were prepared to furnish and the general rules and regulations relating to their manufacture and construction. Sometimes these were accepted; but the policy involved in so doing was bad, as, on the face of them, such specifications were drafted essentially in the interest of the bidder.

An important part of the work done by me personally in bridge building is the preparation and publishing of specifications. In the late eighties I wrote specifications for the designing and construction of railway bridges and others for highway bridges, delivering them as memoirs for publication and discussion by technical societies. They served a good purpose by effecting many minor improvements in both design and construction. During the late nineties, in writing "De Pontibus" I prepared two fairly-complete specifications for those days and incorporated them as separate chapters in the book, one being for design only, and the other for manufacture and erection.

About the years 1900 these specifications were excepted from "De Pontibus" and published as a small book, being sold at a nominal price for the benefit of any bridge designer desiring to employ them; and for nearly two decades they were widely used by the younger engineers throughout the United States and Canada, sometimes as a whole, but more often by either quoting verbatim in large blocks or recasting the diction whilst retaining the ideas.

About 1907 I wrote and published a little treatise, entitled "Specifications and Contracts," in which was discussed the underlying theory of specification and contract writing. Numerous examples were given and solved to illustrate the said theory, and others were set for solution by the student.

In 1916 my *magnum opus* "Bridge Engineering" was issued. It contains two long and very elaborate chapters on specifications, one, as before, being on design and the other on manufacture and erection. The latter contains a feature theretofore unattempted, or even thought of, viz., the furnishing in logical order of information concerning the writing of specifications to submit to bidders, with either special preliminary bidding plans or else a full set of detail drawings, the said specifications being so complete as to cover every point, not only in the building of the bridges themselves but also in that of all supplementary or allied constructions ever included in bridge contracts. The object of this chapter is to enable any young bridge engineer, who has not had much experience but who is gifted with a certain amount of judgment and common sense, to prepare, for any proposed bridge that has been designed, complete specifications in logical order, with no clause of any consequence omitted, to present to bidders in competition. There are three general types of clauses, viz., the variable, the incomplete, and the permanent; and each clause at the beginning is marked in heavy type, respectively, V, I, or P. For each variable item there is given a dissertation concerning how the clause should be written; and this is followed by an actual example taken from my practice. Each incomplete item is to be made complete by filling out one or more blank spaces. Finally, each permanent item when applicable to the case in hand, is to be copied verbatim. It almost goes without saying that, in the preparation of any particular specification, many of the items treated will be found unnecessary or inapplicable, consequently they should be omitted.

It is surprising to see how rapidly one can prepare a bridge specification by utilizing this chapter as just indicated. 1 know that such is the case, for I have often used it myself. When printing the various issues of the book, it is my custom to have the publisher strike off extra copies of this chapter for the use of my office. Two copies have to be sacrificed for each specification thus prepared with scissors and paste pot; but paper is cheap and time is expensive.

The latest bridge specifications are those of the American Railway Engineering Association. They are not complete, and perhaps never will be; because they are modified and extended from time to time, so as to bring them up to date. They represent the consensus of opinion of the best-posted railroad engineers of the United States and Canada on the subject of bridgework. I have had the honor for many years of serving on the committee by which they are compiled and drafted; and, therefore, can conscienciously recommend them to the railway engineers of Japan.

EVOLUTION OF CONTRACT-LETTING.

The oldest type of bridge contract is that of the "Lump-Sum." It is generally more favorable to the owner than to the contractor, because it throws upon the latter the onus of finishing the job in spite of any omissions of needed information in the specfications, and because it requires the contractor to do at his own expense any extra work that may prove to be necessary. Where the injustice involved is altogether too rank, either a compromise between the parties has to be effected or else a lawsuit has to be brought against the owner by the contractor.

The method of contract letting by schedule rates or unit prices, which followed that of the lump sum, is a great improvement upon the latter, in that the contractor is paid thereby only for the work he actually does—but for all of it. However, it does not protect him against the eventuality of paying more for materials and labor than he had figured on paying when making his estimate of cost.

The "Cost Plus" type of contract, which unavoidably came into vogue during war times, although it had occasionally been employed before then to meet exceptional conditions, is all in favor of the contractor and against the interests of the owner. The reason for this is that, under its operation, there is no incentive for either the contractor or his employees to exert themselves and push the work; and, while the contractor himself may be perfectly consciencious, his workmen certainly are not. They say to themselves and to each other "What's the use in hurrying? The more the work costs, the more the 'old man' makes"; and they govern themselves accordingly. It is true that the "Plus" of this method is sometimes not a percentage but a lump-sum profit. This, however, corrects only a portion of the evil. I am so opposed on principle to the "Cost Plus" type of contract that I shall never recommend any client of mine to adopt it, unless he is forced into so doing by circumstances absolutely beyond his control.

There is a method of contract letting, fair and just to all parties concerned and conducive to maximum effort on the part of everyone connected with the work, including the owner and his assistants as well as the contractor and his employees, evolved by me after profound consideration, extending over several months. It was presented to the American Society of Civil Engineers as my discussion of another paper and published in its Proceedings, then later was incorporated as a chapter of "Economics of Bridgework" under the title "Economics of Contract-Letting." Although the method is simple enough and applied only once, viz., at the final settlement of accounts, the explanation of its *modus operandi* is too long to expound in this address; hence concerning its details you are referred to the publications just mentioned.

EVOLUTION OF BRIDGE INSPECTION.

The inspection of the manufacture of structural metalwork at rolling mills and shops was inaugurated about the time of my graduation, consequently I have seen it evolve from its crude beginning to its present status, which, by the way, still falls considerably short of perfection. Too often in my experience there has been occasion to complain that "inspection does not inspect." The main reason for this is that clients seldom are willing to pay an adequate price for really good inspection; and in consequence, the inspectors and their assistants fall into slip-shod methods of doing their work. This habit soon becomes chronic; and then, no matter how large the compensation may be, the quality of the inspection will fall far short of the ideal.

Inspection of metalwork is sometimes paid for by days' work and sometimes by the ton of metal inspected, the price varying according to the size of the contract and the complexity or simplicity of the manufacture. Such inspection is performed sometimes by individuals, but generally by bureaus, each method having its advantages and its disadvantages.

If one has a very large bridge to inspect, it will be best to put a first-class man in charge of it at a good salary and let him select and determine the compensation of his own assistants. Generally it is wise in such a case to entrust the mill inspection to one of the inspecting bureaus, as there exists a combination of them for such inspection which results in a legitimate saving of salaries.

If inspection is paid for by the ton, it is truly economic to allow a good price for the work; because the value to the owner of the difference between good and bad (or even indifferent) inspection is far greater than any saving that could possibly be made on inspectors' fees.

DEVELOPMENT OF PAINT AND PAINTING.

Four decades ago but little attention was paid to the quality of bridge paint or to the method of its application, the chief object of the contractor being to get the painting finished and the job out of his hands as quickly and inexpensively as possible. The result was that the life of bridge paint was limited to about three years.

As painting in America has alway been more expensive than the paint itself, it soon became evident that an improvement in the quality of the pigment would be in the line of true economy; hence owners of bridges began to be somewhat particular in respect to the paint used by their erection contractors or applied to old structures by their own employees. This forced the paint manufactures into a competition on quality of product, and eventually some of them became willing to guarantee, under penalty, its lasting for a certain length of time. At first the guarantee was for five years—and that was then considered a good, long life—but as the paint was perfected the time was lengthened, until now it is possible to obtain a reliable guarantee for as long a term as ten years.

For thirty years I experimented on bridge paints, vainly searching for an ideal metal-protection; and it is only lately that I have found it. At the risk of laying myself open to unfair accusation, I am going to tell you what my find is, in the hope that the lives of your steel structures may be extended thereby. For a shop coat, Dutch Boy Red Lead Paint, ready-mixed for application (and not delivered at the shop in the form of either powder or paste), is by far the best paint ever manufactured. The pigment is ninety-eight-per-cent-pure red-lead; and, while its cost per gallon runs high, in respect to durability it is ideal. For the first field coat, my suggestion is an equal mixture of this paint and some first-class carbon paint, such as Goheen's Carbonizing Coating, Nobrac, or one of the best products of the Detroit Graphite Company. One of the highest authorities on paint, Dr. Sabin, recommends the Dutch Boy Red Lead for both field coats, but most authorities prefer that the elasticity of the three coats should increase from the metalic surface outward. This matter of bridge paint and painting is treated at length in "Economics of Bridgework" under the caption "Economics of Metal Protection," to which treatise you are referred for further information.

CONCLUSION.

This brings my already-too-long discourse to a close. In conclusion permit me to express the hope that, notwithstanding the fact of my subject being a historical one, I have been able to give you a few hints about railroading and bridgework that will prove of service in your practice.

Possibly this is the last time I shall visit Japan. However, I sincerely hope not, but that ere long I shall receive another professional call to the Orient, so that I may have the pleasure of again meeting my numerous good friends in both the Celestial Republic and the Land of the Rising Sun.

— THE END —