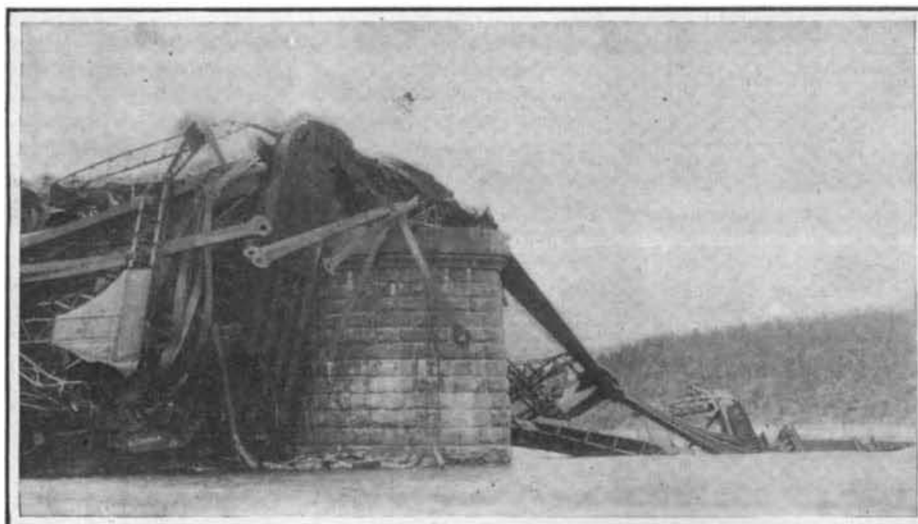
THE QUEBEC BRIDGE DISASTER.

The fall of the magnificent cantilever bridge across the St. Lawrence River at Quebec, which occurred on the afternoon of August 29, 1907, is without question the greatest of all bridge disasters. As a tragedy, it will always be memorable for the fact that it happened at the close of a day's work, when eighty-five men were scattered from end to end of the structure, and that of these only eleven were rescued, the other seventy four being carried down to death in the enormous tangle of twisted and broken steelwork. Sad as is this disaster when viewed in relation to the great loss of life, it takes on equal importance, as we have shown editorially, from the fact that the fallen bridge embodied the highest technical knowledge and skill of the leading bridge engineers of this country, and the workmanship of one of our largest bridge works. Nor is our shaken confidence to be restored by any suggestion that there was carelessness in erection, or any untoward accident involving suddenly applied stresses in the bridge, to which circumstances its failure may be attributed. All the evidence at hand points to the fact that the bridge failed under stresses which, if the theories upon which such bridges are built are correct, were far below the breaking stress of the steel of which the bridge was built.

The fallen structure, which was designed to cross the St. Lawrence River a few miles above Quebec, consisted of two deck spans, each 210 feet long, reaching from the abutment to the anchor piers, and a huge cantilever construction, with a total length of 2,800 feet between the anchor piers. Each cantilever consisted of an anchor or shore arm 500 feet long and a cantilever arm 562½ feet long. Suspended between the ends of the cantilever arms was a 675-foot truss span, the longest simple truss span ever built. It will be seen from the above dimensions that the central in the compression members, were probably insufficient. Thus, the main vertical posts at the towers measured 5 feet by 10 feet, and the bottom chord sections 4½ feet by 5½ feet. Some of the sections as built up at the works and lifted into place at the bridge weighed 100 tons each. The eye-bars were from 1 3/8 to 2¼ inches thick, 15 inches in width, and in some cases were 76 feet in length; and the tensional stresses which had to be provided for were so large, that in one case there was a maximum number of fifty-six of these bars assembled on one eye-bar pin. These pins, moreover, were of enormous size, varying in diameter from 12 inches to 24 inches, while some of them were 10 feet in length.

The building of the steelwork of the bridge commenced in 1902, when the 210-foot deck trusses were erected. Work on the main cantilever construction commenced July, 1905, when steel falsework of a special design was erected beneath the south cantilever arm, to carry the weight of that arm during its erection. This falsework alone weighed 1,000 tons, and upon this were erected during that season six panels of the south anchor arm, weighing altogether 5,346 tons. During the season of 1906 (because of the severe winter season, work is restricted to about six months of the year), the south anchor arm was completed, and the south cantilever arm erected. During the present season, up to the time of the disaster, about one-third of the central suspended truss had been built out by overhang beyond the south cantilever arm, until on the afternoon of August 29 the steelwork projected about 800 feet out over the river from the main pier. At the extreme end of the arm was a small 250-ton traveler, which was used in the erection, while near the end of the cantilever arm was a huge gantry traveler, 300 feet in height and weighing about 750 tons, which had been used in erecting the cantilever. The completed work, from

At the present writing, any analysis of the cause of failure must necessarily be speculative; but the accompanying photographs, which were taken by the representative of the Scientific American two or three days after the disaster, coupled with our own investigation of the wreck, and the evidence which has already been given before the coroner, render it possible to determine, with some certainty, not merely where the break in the cantilever first occurred, but the sequence of events as this mighty 18,000-ton mass of steel settled down into its present position. In the first place, because of the lamentable death of the skilled workmen, there is no eyewitness of the disaster who can give any intelligent description of how it went down; but such testimony as there is agrees that the bridge did not fall over sidewise, but that it settled vertically upon itself, slowly at first and then with a rush. A careful study of our photographs supports this supposition; for it will be noticed that, in the view looking parallel with the axis of the bridge, the mass of wreckage lies practically in the same vertical plane in which the two trusses stood when the bridge was in position. It is well understood among bridge engineers that if failure is to be looked for in the main members of a bridge, it will come in the compression rather than in the tension members, and the condition of the wreck proves the truth of this supposition; for the tension members, and particularly those of the top chord, may be traced practically intact from the top of the anchor pier, where they are exposed under the overturned anchor pier towers, through these towers, clear across the top of the mass of wreckage, over the main cantilever pier, and down into the water of the main channel of the St. Lawrence. Probably they continue intact out to the end of the cantilever arm, 150 feet below the surface of the water. Moreover, that the bridge did not fail by lateral distortion is rendered



Showing Tower Post Broken Across Main Pier; Also the Top-Chord Eyebars.

Anchor Pier With Anchor Posts Dragged Forward by the Fall of the Bridge.

THE QUEBEC BRIDGE DISASTER.

span had a clear width of 1,800 feet and was, therefore, the longest in the world, the next longest spans being those of that other great cantilever construction, the Forth Bridge near Edinburgh, which contains two clear spans each 1,710 feet long, or 90 feet less than the main span in the Quebec Bridge.

The bridge was intended to form a connection in the system of Canadian steam railways, and provision was also made for trolley lines, roadways, and footpaths. The Canadian government and the city of Quebec were largely interested in the enterprise. Indeed, the bridge will mean so much to the Dominion that, although its completion may be delayed, it will not be indefinitely postponed by the late disaster. The contract price for the steelwork alone was about $3,000,000, and the probable ultimate cost, had it not been for the present disaster, would have been between $6,000,000 and $7,000,000.

Not only was the bridge of unprecedented proportions in the length of its span, but its capacity for traffic was also large, provision being made for two steam railroad tracks to carry the heaviest modern freight locomotives and trains; for two electric railway tracks; two roadways, and two footwalks. All of this was to be carried on the same level, the width center to center of the trusses being 67 feet. Necessarily, all the dimensions for the bridge are on a large scale. Thus, the least depth of the trusses, which occurs at the portals or ends of the cantilevers, is 97 feet, and the greatest depth, over the main piers, is 315 feet. The clear headway from the under side of the bridge to the water at high tide was to have been 150 feet for a width of 1,200 feet. The height of the peaks of the main posts above the river is 400 feet. In the whole bridge, as completed, there would have been 38,500 tons of steel. Naturally, the individual members reached large proportions, although, as events have proved, these sizes, at least the anchor pier to the end of the completed work over the river, measured about 1,300 feet in length, and its greatest depth, as already stated, was 315 feet. The weight of the steel work, that is, of everything above the piers, was, as estimated by the Phœnix Bridge Company, the builders of the bridge, 18,000 tons. Adding the weight of the two travelers, or say 1,000 tons, we reach a total weight of the structure of say 19,000 tons. Although some of the flooring of the bridge had not yet been built into place, it is probable that the weight of the travelers, and the particular conditions of loading at the time of the accident, produced maximum stresses in the various members of the bridge which were as large, if not greater than those which would occur when the bridge was completed, and subjected to the combined stress of full live load and heavy wind pressure. We are informed by the Phœnix Bridge Company that the engineers kept very careful records of the deflections and movements of the bridge under the changing loads as the work advanced; and that not only were these observations carefully made, but the varying stresses under these changing conditions were also carefully calculated. These calculations showed, that at the time of the failure of the bridge, the maximum compressive stresses under the conditions which existed on the afternoon of the disaster were about 16,000 pounds per square inch in the lower chord of the anchor arm near the tower pier, or only 45 per cent of the maximum safe stress to which these chords might be theoretically subjected without risk of failure.

Nevertheless, there is at this hour an ever-accumulating mass of evidence to show that the bridge fell because of the buckling of the lower chord of the south anchor arm, at the point marked by a white cross in our engraving showing the appearance of the bridge when completed.

probable by the fact that the lateral bracing between these top chords lies symmetrically, though of course twisted and broken in places by the impact of its fall, between the top chord members. Furthermore, had the bridge failed through the rupture of the tension members, that is, of the top chords or of the diagonal ties, the parting of the metal would have been instantaneous, and accompanied by a report louder than that of the most powerful piece of ordnance in the world to-day. Witnesses seem to agree, however, that although there were subsequent thunderous crashes while the bridge was falling, the commencement of its settlement was not marked by any loud report. Since, then, it seems evident that there was no failure of the tension members, that is of the eye-bars, it follows that we must look to the compression members, either in the tower, in the vertical posts, or in the bottom chords, for the point of failure. The evidence already given before the coroner points to the failure as having occurred in the lower chord of the anchor arm, in the second panel out from the foot of the tower, at the point marked with a cross in the accompanying engraving. It is also generally admitted by those who were responsible for the design and erection of the bridge, that it was the anchor arm which gave way. This is further verified by the fact that, although the other sections of the bottom chords have suffered only such distortion and fracture as might result from the impact and wrenching of the fall, this particular section had been bent into the form of a letter S, being literally bent back upon itself. Such a distortion is exactly of the kind which one would expect to occur when a compression member fails through excessive loading.

Now, the theory that the fall of the bridge was due to the crumpling up of the bottom chord at the point indicated, is strongly borne out by the present condition of the wreckage, which is lying in just the very positions which the various parts of the bridge would take consequent upon the buckling of the lower chord at the point indicated. As the buckling took place, the now unbalanced lateral thrust in the lower chord of the cantilever arm would bring an enormous lateral shearing force to bear upon the foot of the tower, pushing the foot of the towers inwardly toward the anchor arm, until they slipped off to the ground on the shore side of the tower pier. Meanwhile the whole of the cantilever would be pivoting forward and settling swiftly into the river, the shore arm falling to the ground between the main pier and the anchor pier. The enormous impact as the bottom chords struck the ground would cause the heavy vertical posts to crumple in upon themselves, until the whole mass had sunk down into the position shown in our engravings, the top chord eye-bars being drawn forward above the mass of wreckage, a condition of things which is shown very clearly. That the foot of the towers were thrust shoreward, and that the towers were bent across the piers with the heads far out in midstream, is shown by one of the photographs, in which the lower part of the tower with its four webs will be seen against the shore side of the tower, while the crest of it is showing about 100 feet out in midstream.

As to the future of the Quebec bridge, while it is probable that it will eventually be built, we doubt whether it will be built upon the present plans, unless indeed they are subject to modification, at least as regards the posts and chords. We are informed that practically the whole of the steelwork for the northern half of the bridge, some 20,000 tons in all, has been constructed and is ready for erection. It may be possible that, in the revised plan, the compression members may be strengthened, among other means, by the substitution of cover plates for the present open latticing, and the bridge completed, except for this modification, on the original lines. This change, however, would mean a great increase of dead load, and necessitate the employment of higher unit stresses in the eye-bars.

The Current Supplement.

The American Museum of Natural History in New York recently added an exact model of a large whale to its mammalian collection. This technical achievement is explained with the aid of very excellent illustrations in the opening article of the current SUPPLEMENT, No. 1654. Dr. Rabes writes on the heart weights of various animals, and shows that the relative size of the heart is a measure of metabolic activity. The connection between physical and psychical conditions is set forth by Dr. O. Mueller. What was perhaps the most exhaustive study ever made of a single problem of ventilation was recently concluded for the Rapid Transit Subway of New York by Dr. G. A. Soper. His report is published in full. Prof. Ernst von Halle, the distinguished German authority of shipbuilding, reviews the rise and tendencies of German transatlantic enterprise. The progress of the submarine boat is critically analyzed in the light of the recent experiments conducted by the United States government. The aeroplane experiments of M. Louis Bleriot are described by Capt. Ferber, himself a well-known aeronaut. His article is a *résumé* of what has been accomplished to date in France with aeroplanes of various types, including the type invented by the late Prof. Langley. Mr. J. H. Morrison's excellent history of armored war vessels passes to a third installment, in which armor plating in the United States is discussed. Dr. Richard Wiesner contributes an instructive article on the germicidal effect of sunlight. At various times we hear the question asked: How did the ancient masons raise the enormous blocks of stone which they used in their temples and pyramids to the heights and positions in which they are now found? Mr. Clement E. Stretton endeavors to answer this question by describing some mechanical contrivances with which the ancients were probably familiar, and which answered all requirements. It is difficult in this year of grace to realize that it is only one hundred years since navigation by steam actually reached the position of a recognized commercial means of transport. For that reason an article is published in the current SUPPLEMENT commemorating Robert Fulton and the centenary of steam navigation. The recent announcement by Sir William Ramsay that he has discovered a means of degrading copper to lithium, renders of peculiar timeliness and interest a paper on the disintegration of atoms, in which the entire subject of radio-activity is authoritatively reviewed in the light of the most recent investigations. The usual notes and formulas appear in their accustomed places.

An apparatus for life saving at sea has been invented by Mr. R. Lavachery, a Belgian engineer residing at Chapultepec, Mexico. It consists of a rifled cannon from which a projectile is fired; to the projectile are attached a cable, an anchor, and a rocket. The mechanism is said to be very simple, and for humanitarian reasons the inventor has not patented it.

Correspondence.

The Evils of Train Telephone Orders.

To the Editor of the SCIENTIFIC AMERICAN:

The recent accident that occurred at Mattoon, Ill., in which fifteen people lost their lives, owing to a misunderstanding of "meeting orders," given over the telephone, proves that as yet the telephone has not reached the stage of perfection where it can with safety to the traveling public supersede the telegraph for the handling of trains. It would be a very simple matter to have a set of telegraph instruments in the telephone boxes, at sidings, and either the conductor or motorman on each car be required to know telegraphy, and on regular train order blanks the superintendent or dispatcher could arrange for meeting points, the conductor or motorman signing for the same, thus avoiding in a great measure the possibility of collisions.

F. H. SIDNEY,
Signal Dept., B. & M. Terminal Div.
Boston, Mass., September 3, 1907.

Drying Kilns.

To the Editor of the SCIENTIFIC AMERICAN:

As the rapid drying of timber has rendered drying rooms or kilns a necessity to many, the following suggestions will no doubt be of value. A very useful kiln may be constructed as follows: Walls of brick, roofing of rubberoid, ceiling of galvanized iron, and floor of battens laid on joists and kept apart. Under the floor are laid steam pipes, to heat the air which enters the room below them. The ceiling is perforated with holes equally distributed over its entire area, Through these holes the air from the room is drawn by either exhaust fan, ventilators, or chimney.

For those who prefer to have the steam pipes outside the kiln, the usual arrangement of motor, fan, and pipes in a separate room is satisfactory. The heated air is delivered to the kiln preferably at the top and escapes through small holes distributed equally over the floor space. As the sides and top of the kiln are made practically air tight, the coolest air escapes first; and by making the outlets of less area than the inlet, a slight pressure may be maintained in the room, and thus create an even temperature throughout.

As the result of considerable experience with drying kilns, the writer considers them only suitable for timber that has been partially seasoned.

Carlton, near Sydney, Australia. T. HUMPHREY.

Panama Canal Problems.

To the Editor of the SCIENTIFIC AMERICAN:

I have found your editorial on "Safeguards for the Panama Canal Locks" quite interesting. For ten years or more I have given careful thought to every engineering phase of the Isthmian problem, and I am glad the commission realizes the immense loss that might follow a collision with lock gates of the ordinary type.

Perhaps any of the devices which you state have been considered by the commission may be made to give full protection against such a disaster, but would it not be best to make the gates of such enormous structural strength that they would resist any collision that might happen? In that event the ship would get the worst of it. Still it would be wise to make the head gates so that they could easily be closed even if the lower gates were carried away. That can be done, and I think it ought to be. I would rather depend upon gates that are used in everyday service, than any device designed for use only in emergencies.

There are many reasons why the work at Panama should be completed as soon as possible, and no good citizen should even think of putting the slightest obstacle in the way to that end. Now, or never, seems to be the time for helpful suggestions or to show how the general scheme of the commission could be improved, for if any defects can be discovered now, it will be wise in Congress to have them removed before the contracts are let, and it will exhibit the courage of true greatness in the President to call a halt until a right start can be made. Better a slight delay now, than to complete the task in record-breaking time only to be confronted with troubles that cannot be evaded without great delay and expense.

It seems to me that as the site at Gatun is almost as large as could be wished for three locks in flight, a single lock with a usable length of 1,200 feet could be substituted for the three, with a saving in cost of building and operation. The time to pass through a single lock with 85-foot lift would be less than to pass two or three locks having in the aggregate the same lift. I know it may be said it is not possible to build gates for such a lock, and in reply I would say that at the proper time I shall show how it can be done.

In preference to any canal plan I have seen, I would suggest that it be built with a single lock at Gatun with a lift of 70 to 75 feet, and with a second lock between Gamboa and Obispo with a 70-foot lift to reach the 140-foot summit level. Three locks on the Pacific side would be required to complete the scheme. By this plan the work on the Culebra Cut might possibly be completed in another year. The Gatun Lake at any level from 68 feet, as proposed by the French, up to 85 feet, will submerge much swampy area, but it should not be forgotten that, unless the topography is very peculiar, there will be a new area of swamps created.

I would have a concrete dam built at Gamboa as near to the line of the canal as may be and carried from the bedrock (about sea level) to an elevation of 75 feet at the crest. Sloping from the crest I would continue the dam up the Chagres Valley with rock-fill construction and at intervals of 500 feet or more have a concrete curtain cross the valley extending from the surface of the rock-fill down to bedrock. This would make it water-tight, and if the strata of rock-fill were thick enough it would be safe against any possible erosion. Hydraulic giants and the Chagres would furnish the means—the water and the power—to wash almost any loose material from the slopes of the banks of Gamboa Lake to fill in back of the dam up to the level where rock-fill should begin. As soon as the 150-foot level was reached by this process the water supply for the 140-foot summit level would be assured. As a higher level was attained with a corresponding increase of lake area, increased power would be available to extend the fill back of the crest of the rock-fill dam even for a mile or more (with shallow depth). Such a dam would be safe from the start and could be made more and more safe each year. It might be that a variation of 20 feet in the lake level would, with the possible flow through the flumes to the turbines, prevent any flow over the dam except at rare intervals. It seems reasonable to believe an effective control of the Chagres would thus be gotten, but not until the lake area for the different levels was known could its nature be determined with exactness.

The available power of the Chagres might in future years wash out enough of the Culebra Cut so that the summit level could be brought down to 70 feet.

The canal will be subject to shoaling by sediment and debris carried into it by the various streams which must flow into it. How to remedy this condition is a serious matter. I have not learned that an adequate solution of the problem has been found by the commission. I have a plan, partly developed, that may be successful, but I am not ready yet to make it public. I want, however, to suggest in closing that the power of the Chagres can be made to help in the removal of such deposits. HENRY FITCH.

Washington, D. C.

Official Meteorological Summary, New York, N. Y., August, 1907.

Atmospheric pressure: Highest, 30.33; lowest, 29,71; mean, 30.00. Temperature: Highest, 91; date, 8th; lowest, 59; date, 29th; mean of warmest day, 80; date, 8th; coolest day, 65; date, 24th; mean of maximum for the month, 79; mean of minimum, 65.1; absolute mean, 72; normal, 72.7; deficiency compared with mean of 37 years, —0.7. Warmest mean temperature of August, 77, in 1900. Coldest mean, 69, in 1903. Absolute maximum and minimum for this month for 37 years, 96 and 51. Average daily deficiency since January 1, —1.4. Precipitation: 2.48; greatest in 24 hours, 1.66; date, 23d and 24th; average of this month for 37 years, 4.53. Deficiency, —2.05. Accumulated deficiency since January 1, —5.79. Greatest August precipitation, 10.42, in 1875; least, 1.18, in 1886. Wind: Prevailing direction, south; total movement, 6,766 miles; average hourly velocity, 9.1 miles; maximum velocity, 28 miles per hour. Weather: Clear days, 10; partly cloudy, 16; cloudy, 5; on which 0.01 inch, or more, of precipitation occurred, 10. Thunderstorms, 13th, 24th. Mean temperature of the past summer, 71; normal, 71.83. Precipitation of the past summer, 6.95; normal, 12.16.

Micro-Photography in Colors.

Micro-photography in colors by the new Lumière process was the subject of a paper read before the Académie des Sciences by C. F. Franck. He used the Lumière color photography plate which we recently described. The experiments with micro-photography on the new plates were commenced last March in the laboratory of the Lumière firm at Lyons, and are the first of the kind which have been made. The author is now continuing his researches at Paris, at the College de France, where he has a well-equipped microphotographic laboratory at his disposal. He has succeeded in making enlargements of microscopic specimens from 30 to 1,000 diameters. These enlargements are photographed in their natural colors, and some interesting specimens of such photographs were shown to the Académie. Among these were gneiss crystals, and a longitudinal section of the vertebral column of an embryo, showing the ossification. Different organs of the frog and insects were also shown. Preparations which require the use of polarized light are taken upon the plates as easily as the others. As an instance we find the gneiss of Mont Blanc, with all the different colors and tints, well shown upon the color plate. The great advantage of colored micro-photographs will at once be appreciated and the method will no doubt be used to a large extent in the future.