King and Mrs. Hallett discussed the paper, expressing dissatisfaction with the act, and saying women could take care of themselves. Mr. Robert C. Adams of Montreal read a paper on the phosphate industry of Canada. In 1883 it amounted to 17,500 tons. Phosphate lands have sold as high as $1,250 per acre. Mr. Hughes, Mr. Martin, and Sir Richard Temple discussed the paper. A valuable paper on the fisheries of Canada, by Mr. L. Z. Joncas, was read by Mr. Thomas White, M.P.[1] The paper was discussed by Mr. Cornelius Walford and Mr. C. W. Smiley of the U. S. fish-commission. Several forestry papers closed the sitting, — Professor Brown of Ontario, on the application of scientific and practical arboriculture to Canada; Mr. J. P. Hughes, on the necessity of forest preservation; Mr. A. T. Drummond of Montreal, on the distribution of Canadian trees; and Mr. F. B. Hough, on the future policy of the forest management of the United States. Mr. Walford remarked that forest culture in England pays four per cent profit, and in the United States seven per cent. Mr. Caruthers of the British museum also made remarks. The anthropometric committee presented a printed report, including observations on eyesight by Mr. C. Roberts. This report contained valuable tables. On Tuesday Mr. Cornelius Walford spoke upon land and water communication. Mr. E. Wragge and Alexander McDougall presented a joint paper upon the same topic. A paper by Emile de Laveleye, upon land laws, was read by the secretary. Miss Maria Rye, Mrs. Burt, and Mrs. Joyce each read a paper on female emigration. C. Le Neve Foster read a paper on the relative dangers of coal and metal mining. Many of the papers were presented by the authors in printed form, and printed abstracts of many others were circulated.

PROCEEDINGS OF THE SECTION OF MECHANICAL SCIENCE.

THE mechanical science section of the British Association appears to be in a prosperous condition, as was intimated, indeed, in the opening paragraph of the address of its president, Sir Frederick Bramwell: this is due, no doubt, to the fact that its scope is much wider than its name implies. The president's address was instructive as well as witty; it was in the form of an apology for the practical character of the section, and exhibited in detail the interdependence between it and the others, showing it to be complementary to them; but the distinguished author did not fail to scatter valuable suggestions throughout, and to indicate some lines of past and future progress. The address, however, contains no carefully digested summary of engineering progress for the past year or up to the present time; and though many valuable papers, prepared by request, summarize progress in particular directions, the general scientific reader must seriously regret the fact. The various criticisms upon the hampering action of the government toward engineering enterprises, such as electric lightning, the telephone, the Channel tunnel, brought out the strong feeling of the English members, that the government should confine itself to governing. The courtesy shown the president in the delivery and acceptance of his address was a pleasant feature: the presidents of the association and of the physical section, as well as the sectional vice-presidents and secretaries, were upon the platform, and the former moved a vote of thanks. In doing so Lord Rayleigh commented upon the Channel tunnel and other government interference; and was followed by Vice-president Thurston, who seconded the motion, expressing the American sympathy with the obituary notice of William Siemens, and cordially inviting the members to take part in Section D at Philadelphia.

The multiplication of section officers is to be noted; there being no less than eight vice-presidents, four secretaries, and a large sectional committee, among whom appear the following gentlemen from the United States: Messrs. Coon, Emery, Hoadley, Leavitt, and Woodbury, and Professors Barker, Bell, Rogers, and Webb.

Many of the papers read were 'progress papers,' containing masses of detail of little interest to the general reader. The importance and extent of some of them render it a matter of regret that they were not generally in print, and that they were presented in so hurried a manner. In many cases, an abstract setting forth the main features of the paper, and comparing and emphasizing the main facts, with illustrations and graphical representations of results, would be far more effective when time is limited; and though such abstracts involve labor, they are of great permanent value to the paper.

The papers were classified as follows: First session, civil engineering; second, mechanical engineering; third, electrical papers; fourth, miscellaneous. Some of them were prepared by request to describe American practice, and some attempt was made to have comparative English papers.

Mr. B. Baker described the Forth Bridge. The expected cost of this enormous structure is £1,600,000. Excluding the half-mile of approach viaducts, the bridge will be over a mile long, consisting of three cantilevers, each over 1,500 feet long, and two connecting trusses of 350 feet each. Cantilevers stand on the two (Queensferry and Fife) banks, and one rests on the only island (Inchgarvie) midway; they are to be 340 feet high by 130 wide at their centres, tapering to 40 feet by 35 at their ends, where they sustain the ends of the connecting trusses. The material is steel, to be put together (after the English fashion) by riveting as each plate is placed in position. Work is now being done on the piers, and some steel is ready for the superstructure; nearly 50,000 tons will be required. The bridge leaves two arched water-ways of 1,700 feet, with 150 feet clear central height at high water, and a half arch at each side. It was commenced about twenty months ago, and no difficulties are anticipated. Fourteen vessels, seventy-two steam and other cranes, and twenty-eight steam-engines, with numerous special machines,

[1] This paper will be published in the U. S. fish-commission bulletin.

are used in its construction. Each of the three main piers consists of four masonry columns, 70 feet in diameter, upon rock or hard clay bottom, centred at the corners of a rectangle 270′ × 120′. The deepest foundation will be 70′ below low water, which makes it 110′ high, allowing 20′ for the tide, and 20′ more above high water. Add to this 340′, and we have 450′ total height. There need only be added a central observing-tower or flagstaff to make it the highest structure in the world. Attention is called to the difference between English and other contractors: the former are "not much accustomed to pneumatic appliances, other than an ordinary diving-dress, and rarely resort to them." No use has been made of pneumatic apparatus already provided, but for the deepest piers compressed air will doubtless have to be used. The compression members of the bridge are tubes formed of bent steel plates riveted together. Compression joints are planed to fit, and forced together before riveting; and holes for rivets are drilled, not punched. The tension members are box-girders riveted up. A large number of experiments have been made to settle doubtful points, notably as to wind pressure, regarding which reliable data were wanting: in so large a bridge, the weight of trains is of little importance as compared with that of the structure and the pressure of the wind. As it must be a problem of some difficulty, to join the members of such a structure in a substantial and artistic manner, it is to be regretted that the details of the joints were not shown, and that no judgment can be formed of their merits. Altogether, though the proportions of the structure may not be pleasing, they cannot fail to be imposing; and the truss principle will hereby, as regards possible span, be placed for the first time abreast of the suspension cable.

The discussion participated in by Messrs. Hannaford, Leavitt, Emery, and Webb, brought out the relative costs per foot — £200, £160, and £75 — for this, the Victoria, and the International bridges; the latter two having only a single track. Steel was stated to be cheaper than iron; and many questions were asked as to the constitution, properties, etc., of the steel used, to which there was no time for suitable reply.

A paper on the Severn Tunnel Railway, by J. C. Hawkshaw, naturally followed. This tunnel, commenced in 1873, and nearly completed, is four and one-third miles long, and will save over two miles of ferriage. It is a twenty-five-feet hole, lined with vitrified bricks made from the excavated material, and laid in Portland cement. It passes principally through marl and coal, full of fissures. At the lowest point its roof is forty-five feet below the river-bottom, over which flows the water sixty feet plus a tide of thirty-six feet. To reach this depth we have slopes of over one per one hundred. Much trouble has been caused by water. In one instance the wells for miles round were dried, and a river nearly disappeared; at another, a sixteen-foot hole broke through the river-bottom; in fact, there has been a succession of floodings and cavings-in, and the work is a monument of perseverance. Pumps have been added until there are now eighteen, with a capacity of forty-six thousand gallons per minute. There have also been radical alterations of the original plan. When Sir John Hawkshaw was appointed engineer in 1879, he lowered the whole tunnel fifteen feet, necessitating a new driftway. The driftways were commenced from several shafts; and there are now twelve shafts about fifteen feet diameter and from seventy to two hundred and twenty feet deep. Electric lights are now used, and compressed air has been employed for drilling and ventilation, though now air is forced through the entire distance by an eighteen-feet-diameter fan. The cost of the work is not known, and it is difficult to believe that much time and money might not have been saved by employing, from the start, a properly planned pneumatic process; indeed, the extra fifteen feet depth of the tunnel below the river-bed would seem to be a permanent disadvantage which might thus have been avoided.

Three railway papers followed. The first, by W. K. Muir, on single-track railways, was a condensed statement of the construction and method of operating a railway in America, where but a single track can be afforded. General plans of stations and crossings were given, and an infinite number of details alluded to as necessary to safety, comfort, and economy. The numbering of the hours from one to twenty-four was advocated. Much was said upon modes of signalling, and an improved signal-lamp described. It was claimed that white and red signals were sufficient, it being safer to exclude green. In the discussion it appeared that an economy is effected by strengthening cars so that they can be loaded full: formerly grain was carried two and a half feet deep, now four is customary. The American method of making up a time-card was explained, where the trains are represented by threads stretched over a board ruled one way for time, and the other way for distance. Mr. Preece spoke of the safety on railways: the safest place in England is supposed to be a first-class carriage between London and Edinburgh. The president advocated running trains by telegraph from a central station, there being absolute safety with but one train on the track at a time. This caused reference to be made to a Paris incident, where an unusually long train, going round a loop, ran into its own tail. Sir James Douglass spoke of the excellency of American head-lights, and advocated a mechanical signal-lamp to save time; to which was replied that the American train-man was quick, and a wiggle or two of his lamp was enough.

Mr. J. H. Wilson's paper on American permanent way referred more to the construction of the line, forming therefore a complement to the last. The qualities of a perfect track are good surface and drainage, and straight or truly curved track, of accurate width, well fastened and with tight joints. American rails rest with broad flanges on wooden ties; while English rails are reversible, and rest in iron chairs, so that ties can be placed far apart. Wooden ties, being plenty here, should be laid only two feet apart. Engines weigh from forty to over sixty tons. Detailed specifications for rails, etc., according to the best practice, are given: ninety per cent of the rails must be thirty feet long, and a test piece must be furnished from each charge of steel. These specifications, and the rules by which rails are temporarily or permanently rejected, are elaborate and exact, and must result in a uniformity of quality and composition leaving little to be desired. In track-laying, the rails must meet within $\frac{1}{16}$ inch in summer, and $\frac{5}{16}$ inch in winter. Considerable space is devoted to ties, ballast, switches, frogs, crossings; and attention is called to the importance of the block-system, Westinghouse air-brake, interlocking switches, etc.

Mr. Vernon Smith's paper on the Canadian Pacific railway described the construction of the same, and pointed out its advantages. British Columbia joined the confederation in 1871 on a pledge that such a railway should be completed by 1881, afterward extended to 1891, seven hundred miles of it to be built by the government. The working season is about five months, and all supplies and men must be brought a great distance. Three gaps, of about four hundred miles each, now remaining, will be completed by next year. No existing railway has been built so quickly: every thing is completed at once, and in the most systematic manner; the longest delay has been one of three hours waiting for material. The road has been run at the rate of three or four miles per day, the maximum day's work being six miles and three-eighths. Different modes of excavating were compared; nine thousand Chinese work on the Pacific end; Italians and Swedes excavate twenty-five cubic yards per man per day, with shovels, etc.; Americans, with scrapers, move sixty to a hundred yards; and an eight to ten horse grading has been tried. The precaution has been taken of raising the embankment to the snow-level. Telegraphic service is established at the same time, which requires an additional corps of a hundred and fifty men. Coal-beds exist at both ends of the line. Crossing the Rocky Mountains requires some grades of a hundred and sixteen feet to the mile; but the pass is three thousand feet lower than those farther south, and the rest of the line has easy grades. A degree of longitude on this line is eight miles shorter than on the Union Pacific, so that the route from England to Japan can be shortened a thousand miles. Reference was made to the proposed railway from the Pacific to Hudson's Bay, which would be eighteen hundred miles shorter, but navigation is good only four months yearly, — a great difficulty also with the Canadian Pacific, unless it seeks a new outlet in Nova Scotia. This paper will appear in the transactions *in extenso*, and will be of great interest in England. Mr. Hannaford remarked that the six and three-eighths miles per day finished road would, however, be received with an incredulous smile.

On Friday eight papers were read on Mechanical engineering, and with true courtesy the visiting American engineers were placed at the head of the list: in marked contrast, however, was the want of tact displayed in the reception of Mr. Hoadley's valuable paper on steam-engineering practice in the United States, which was limited to so short a time as to amount to a virtual non-presentation. It is now in book form, and an abstract of the same may be expected at the Philadelphia meeting of the American association.

Professor Thurston's paper on the theory of the steam-engine was a historical sketch, tracing from the earliest period to the present the progress of the mechanical theory of heat, and the science of thermo-dynamics and its applications, and the completion of the theory by the addition of a theory of avoidable losses. The labors of Rankine and of Clausius were considered as to their influence on the theory of the subject. It was pointed out that Carnot established a number of fundamental principles, and first produced a consistent theory of heat-engines, which was further perfected by Rankine and Clausius. The limitations in applying the thermo-dynamic theory were described, and shown to have been familiar to Watt and to Smeaton, and to have been experimentally examined by Tredgold, Clark, Isherwood, and Hirn, and studied by Cotterill. It was concluded that the history may be divided, as by Hirn, into three periods: 1. Crude theory and incomplete experiment; 2. Perfected thermo-dynamics and systematic experiment; 3. Complete theory and exact experiment directed toward the determination of wastes. Professor Thurston calls the last two periods those of the theory of the ideal and of the real steam-engine, and believes that a working theory of heat-engines will soon be completely constructed. The complete paper will soon be published. In the discussion it was agreed on all sides, that the thing needed to still further accord theory and practice is an experimental engine specially adapted to scientific investigation; and it is to be hoped that some of our American schools will take hold of the matter before it is done elsewhere. Experiments were also referred to, where a copious supply of oil had reduced cylinder condensation in a marked degree.

Mr. E. D. Leavitt, jun., read a paper on pumping-machinery in America, largely statistical in its nature, in which he briefly sketched the most salient features in the development of the pumping-engine in the United States as applied to water-supply for cities and for mining purposes, giving particulars of the pumping-plant in all the principal water-works in North America. He called attention to the important work done in the development of pumping-machinery by the various hydraulic engineers of this country. Attention was called to those recent improvements in pumping-plant which have brought about the present great economy in certain places, most notably those designed by Mr. George H. Corliss, and others by himself. Prominent among these improvements have been compounding, higher steam pressures, and greater ratios of expansion. In conclusion, he drew attention to considerations from an economic standpoint, which decide whether to use a cheap plant with no great economy of fuel, or an expensive one from which great economy may be expected; the deciding point being, whether the extra cost of fuel for the cheaper plant will exceed the interest on the extra money invested in the more expensive one.

Mr. J. D. Barnett's paper, on the anthracite-burning locomotive of America, showed that the cleanliness of this fuel was forcing it into use, notwithstanding that it requires a much larger grate-surface, and has an evaporating efficiency but three-quarters that of bituminous coal at market prices: however, where the railroad-companies own the mines, the market price is no basis for comparison. The anthracite is also heavier to carry, and burns the fire-boxes out twenty to forty per cent sooner.

Messrs. A. McDonnell and J. A. F. Aspinwall, and W. Stroudley contributed representative papers on English locomotives. The weights of locomotives were given as from twenty-eight to thirty-nine tons,— much less than our own, but capable of great speed, which, however, is now equalled or excelled here. Improvements are rapidly forcing their way into English engines, which are now built in a limited number of classes, with interchangeable parts. Special tools are not used, however, to any extent in their construction, and but little attention is paid to elegance, or to the comfort of the engineer. Inside cylinders are mostly used; and on one road the driving-wheels are in front, on the supposition that they keep the track better.

Mr. D. Joy furnished a paper on his reversing and expansion valve gear. This is an arrangement of levers, etc., by which the valve motion is obtained from the connecting-rod instead of from the shaft. It is advantageously used on many locomotives, and has been applied also to marine engines. It makes the connections much shorter and lighter, and avoids the double eccentric. Many other advantages are also shown.

Mr. J. H. Bartlett's paper on heating buildings by steam from a central source is a most valuable *résumé* of the subject in pamphlet form. It shows, that, prior to 1876, large buildings and even blocks had been heated by steam from a central source; and in many cases steam had been successfully piped long distances. Mr. Holly then suggested the present district plan; and experiments were made which have led to a remarkable development of the system, which were described in detail. Drawings were given of Holly's reducing-valve and regulator, and of his steam-meter; also a plan of the large district in operation in New York city. Estimates for a district of four hundred (also a thousand) dwellings, and two miles of main, during two hundred and forty days, were given; and the relative cost given of the individual-furnace, individual-steam, and district systems, — the latter with four hundred, also a thousand consumers, — was $113, $197, $64, $58. The economy of elevating the burning of coal into a distinct business must be evident to all; and there is no better distributer of heat than steam. To form an idea of the magnitude of the New York company's operations, their plant should be inspected.

On Monday, papers were read by Mr. W. Smith, on the light-house system of Canada; and by Sir J. Douglass, on improvements in coast-signals. These were remarkably well illustrated by nearly one thousand square feet of colored drawings, covering the walls, and referring mainly to the new Eddystone light-house. Among these were Winstanley's (1696–1703, washed away), Rudyerd's (1706–1755, burned), Smeaton's (1755–1882, removed to another site), — all of about the same height; and the new light-house nearly twice the height (one hundred and thirty-three feet to lantern). Another drawing reproduced Smeaton's drawing of his light-house with a wave rising fifty feet above it, and added another immense wave which broke over the lantern in 1881, through which the moon was seen. Canada has nearly six thousand miles of coast, with about five hundred light-stations; and Mr. Smith referred to buoys to be placed below Quebec, with reservoirs of gas capable of maintaining a light for ninety hours. He remarked also, that Canada was doing her best to compete with New York for the carrying trade of the west, by improving her light-house system. Experiments are being made by the British government on coast-signals, some results of which were given. The electric light was found to have almost no fog-penetrating power, so that only by an immense multiplication of candle-power was it made equal to gas or oil in the worst weather. Its cheapness showed forcibly, however, in a statement that 22,000 times the light could now be had for the cost of the candles of Winstanley's house. A heavy wave was instanced as carrying away a three-hundred-pound bell, a hundred and ten feet above high water. There would seem, however, to be no reason why, with a properly shaped rock to deflect it upward, a wave might not rise to an immense height. A new system of lights and fog-signals was explained by Sir James Douglass, in which signals are repeated every thirty seconds (instead of three to four minutes); this is more consistent with the present speed of vessels, — though, as Sir William Thomson insisted, much too long a time: a signal should be capable of almost instant recognition. Only red and white lights are used in these 'flashing' signals, and red but sparingly; the signals themselves occupying about ten seconds, and being, in fact, the Morse alphabet with long and short flashes. The French and English governments are doing away with stationary and revolving lights, and introducing flashing ones. Fog-horns with reeds do not stay in order; and a steam siren is to be used, high and low notes being proposed instead of long and short blasts.

Mr. W. H. Preece read three electrical papers, — The 'watt' and the horse-power; Secondary batteries; Domestic electric lighting. Secondary batteries are now an accomplished commercial fact in England, the old Faure accumulator being as good a form as any. Domestic electric lighting can now almost compete with gas, which costs in London three shillings per thousand.

Attention was called to the fact that there is no incandescent lighting in Canada; and Sir W. Thomson called attention to the water-power running to waste in the Lachine rapids. A photographic gallery in Regent Street, London, was referred to, where the electric light is used for the negative and for printing, the pictures being delivered the same night. The dynamo is run by a gas-engine; and it was stated that more light could be thus had from gas, than by burning it directly. Sixteen feet of gas per hour will develop one horse-power.

Dr. W. A. Traill had a paper on the Portrush and Giant's Causeway electric tramway; and Mr. H. Smith, one on electric tramways. The former was accompanied by a working model. A review of previously constructed roads was given, and the points of difference emphasized; and the commercial success of the road was announced. Owing to the interest created by this paper, and the first two, Professor Thompson's paper on dynamo-electric machines was left over.

Mr. C. J. H. Woodbury described the 'automatic sprinkler' system in an American mill, and referred to a slow-burning construction of the latter, where heavy beams, widely separated, support a three-inch planking, on which is laid the flooring of hard wood. A large number of sprinklers have been critically compared in the interest of the insurance companies; and the result of this work showed a record favorable to the value of the apparatus, as it had operated in one hundred and forty-one mill fires, without any instance of total failure except in two instances, where the water supply had been shut off from the system. The sprinklers were tested for sensitiveness by exposing them to a jet of steam instead of a fire, because the former is more regular in its action. The resistance of the soldered joints to shearing-stress was exceedingly variable, ranging from twenty-five hundred to seven thousand pounds per square inch.

The first attempts to make sprinklers were devoted to endeavors to construct an arrangement for rigidly holding a valve to a seat; and, after these had proven failures, the method of soldering a cap over the sprinkler was next introduced. Later, Mr. F. Grinnell solved the problem, by placing the valve in the centre of a flexible diaphragm; and the arrangement of the parts was such that the water-pressure kept the valve shut until the soldered joint leaked, and then this same pressure forced the sprinkler open.

Professor Osborne Reynolds discussed the 'friction of journals.' The report of a committee on lubrication was referred to, and various methods of lubrication discussed. The method giving the best results is to let part of the shaft run in a bath of oil, which is then sucked in by the action of the shaft. With oil fed by a siphon or a plain hole, the friction is seven or eight times greater; and, in one experiment, the oil was forced out of the hole with over two hundred pounds pressure on a square inch. Professor Thurston was called upon, and gave his experience with lubricants, confirming the statements of the paper, and referring to a case in which he had used a pump to force oil to the journals. Evidently, if so much friction can be saved by copious and regular oiling, it might pay to supply journals systematically with oil under pressure.

AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

PROCEEDINGS OF THE SECTION OF MATHEMATICS AND ASTRONOMY.

THE first paper read in this section was by Prof. E. C. Pickering, upon the colors of the stars. The need of exact photometric measurement of different parts of their spectra was first pointed out, and the author then described a very ingenious method of accomplishing this. In the telescope tube, a little beyond the focal plane, is a direct vision prism, so set as to give a spectrum extended in declination; and on the preceding side of this prism is placed a piece of plane glass, whose edges are so ground, that, when a small portion of the following side of the cone of rays falls upon it, it gives a small white ghost, just preceding the spectrum and always opposite the same wave-length. In the focal plane is one of Professor Pritchard's neutral-tint wedge photometers, and behind it a thin metal diaphragm with four long narrow slits parallel to the equatorial motion; so that, when the spectrum transits behind them, four little stars — a red, yellow, blue, and a violet — shine through these slits, and the time of the disappearance of each, as they move towards the thicker edge of the wedge, measures its brightness. From these times may be deduced the magnitude and color curve of the star. To fix the same wave-lengths for each observation, the little white ghost is adjusted upon one of two parallel wires, which project out beyond the preceding side of the diaphragm. For a succeeding transit, the ghost is adjusted upon the other wire, half a slit-interval distant, and thus eight points of the spectrum are photometrically measured. Professor Young, of Princeton, spoke very highly of the ingenuity and effectiveness of the device, especially for the systematic measurement of a large number of stars. He pointed out, however, what might be a source of error; viz., the different sensitiveness of different observers' eyes to different colors, so that they would probably observe the times of disappearance of the four colored stars relatively slightly different.

The next paper, by Professor Daniel Kirkwood, discussed the question whether the so-called 'temporary stars' may be variables of long period, referring to the sometimes-claimed identity of the temporary stars of 945 and 1264 with the well-known Tycho Brahe's star, which blazed forth in Cassiopeia in 1572, and whose position is pretty closely known from his measures. The conclusion reached was, that on account of the sudden apparition of the temporary stars, the short duration of their brightness, and the extraordinary length of their supposed periods, they should be considered as distinct from variables.