whether the contractions arise from the nerves, nerve ends, the muscle substance or a disturbance of the electrical equilibrium within the muscle mass. It must not be forgotten also that the relaxation of the muscle is possibly an active process, and, as experiments indicate on cilia, the relaxation may be stimulated by the positive ions, the contraction by the negative, somewhat as Howell suggested for potassium and calcium in the case of muscle. Lingle has already worked in this direction and will no doubt be able to clear up some of the discrepancies.

10. I believe the results so far obtained support strongly the truth of the hypothesis of the antagonistic action of the anions and cathions on protoplasm. They support Loeb's original suggestion of the importance of valence and of my conclusion that in motor nerves and some other tissues the anion stimulates, while the cathion inhibits. They also support the explanation of chemical and electrical stimulation and electrotonus given in my former paper.

11. The results obtained indicate also the truth of the general law, *i. e.*, *the physiological action of any salt is equal to the algebraic sum of the actions of its ions.*

A. P. MATHEWS.

CHICAGO,
March 3, 1903.

STREMMATOGRAPH TESTS. PRINCIPLES AND FACTS RELATING TO THE DISTRIBUTION OF THE STRAINS IN THE BASE OF RAILS UNDER MOVING TRAINS.

BEFORE it was possible to make any tests of precision showing the distribution of the stresses in rails under moving locomotives, it was necessary to improve the tracks, and introduce stiffer rails than were in use prior to 1884. The $4\frac{1}{2}$-inch 65-pound rails, with their splice bars, were too weak to distribute the loads of the locomotives and cars in an efficient manner. While the distribution theoretically follows the same general law in the lighter rails, yet the efficiency is so much less that it is impossible to obtain comparative tests in practice to confirm the theory of the distribution of stresses under locomotives.

On the $4\frac{1}{2}$-inch rails, the heaviest axle loads on passenger locomotives prior to 1889 were about 27,500 pounds. When many miles of the stiffer 5-inch 80-pound rails were in the track, the axle loads were increased to 40,000 pounds per pair of driving wheels.

The stiffer rails permitted better joints, capable of holding up the ends of the rails, which continued the functional action of a rail as a continuous girder to adjacent rails.

After the stiffer rails have been well surfaced in the track, the portion under the driving wheels becomes practically a restrained beam with numerous supports, the front end being held down by the forward truck wheels, and the other portion of the rail by the tender wheels.

The stiffer rails have been laid upon the same road-beds, without increase of width, to distribute laterally the heavier wheel loads to more breadth of road-bed.

The track for steam railroads is by construction flexible, but notwithstanding the high standards of smoothness which have been secured by reducing the looseness of the superstructure and its flexibility to small limits by stiffer rails, it is not a limited flexible structure like a bridge, in which the strains in the members may be analyzed and calculated.

The problem—or series of problems—in reference to the strains in rails and their distribution under moving locomotives and cars, is so complicated by the looseness of the superstructure and the imperfect elasticity of the road-bed, that it has not yielded to mathematical analysis, as for bridge members. While safety is the paramount question in either the bridge or rails, the conditions of service are so dissimilar that the same rules as to factors of safety do not apply. The bridge must support itself and the imposed load, while the rail is supported and distributes infrequent driving-wheel loads of large intensity of strain for a small fraction of a second. These can be repeated a few times daily and the rails not break, for years of service. In a bridge a strain lasts for several seconds, and must be limited to higher factors of safety.

The rails rest upon the cross-ties, and are spiked with ordinary hook spikes, which form a secure but not a rigid fastening. There is a slight looseness between the rail and the spike, between the rail and the cross-ties, and the latter in the ballast, which becomes decided under the rapid movements of the locomotives, increasing the strains in the rails.

The stremmatograph was designed to record autographically the strains in the base of the rails under moving trains. A series of stremmatograph tests have been made under moving trains in service, principally upon the 80- and 100-pound rails, having three-tie points, of the New York Central & Hudson River Railroad.

At first it was considered that the important problem would be to ascertain the maximum strains to determine the factors of safety in the rails. Numbers of such tests have been made, and it was found that under fast trains, at fifty miles per hour, it was not uncommon to record unit fiber strains in the base of the rails as high as 40,000 or even 45,000 pounds. The elastic limits in the steel of the rails under test run from 55,000 to 60,000 pounds, almost as high as the ultimate strength of bridge and structural steel.

In comparing the results of a number of tests it was noticed that the stresses under similar wheels were not alike, but when the total stresses for the entire locomotive were considered, close approximations were obtained, from two or more locomotives of the same class, when running at the same speed and doing the same work. Then a series of tests was undertaken of the highest precision, to trace the distribution of the stresses under the locomotives. It was found after a number of tests were reduced, that it was possible with two locomotives of the same weight and class, doing like work, the wheels being in perfect condition as to smoothness, to obtain results which would compare within one half of one per cent. when they were taken on the same rail, without any other locomotive passing over the rail in the meantime.

Numbers of stremmatograph tests have been tabulated and studied, from which some principles and facts have been deduced. These principles illustrate particularly the early American theory and practice of distributed wheel loads, and were applied in the inception of our railroads, and are still the basis of our unexcelled practice. They were understood qualitatively, and the railroads constructed in accordance therewith, but were not pointed out specifically, owing to the fact of the inability of making quantitative determinations of the forces transmitted to the rail and road-bed by the moving locomotives and cars. The state of the art rather than the science was the guide for practice.

Seven principles and three facts have been traced, which are true generally as applied to railroads, although high efficiency can not be obtained on tracks of light rails. This does not affect the principles, only the degree of efficiency attained.

One of the earliest efforts of the American engineers, after locomotion had been secured, was to adapt the construction of the wheel base of the locomotive and cars to the track, so that in their movements they would produce as little destructive action as possible. That became the guiding feature in the construction of the early railroads.

The track being a flexible construction, an effort was made to utilize a portion of the wheel base to stiffen a portion of the track for the heavier wheel loads.

Each type of locomotive would make a distinct general depression in the superstructure, as well as specific deflections under the individual wheel loads.

Mr. John B. Jervis, the chief engineer of the Mohawk & Hudson Railroad, in 1831, after the trials with the English locomotives, and also with the 'DeWitt Clinton,' observed that the motion, particularly of the English locomotives, of two pairs of wheels for the wheel base, was very unfavorable not only to the track, but severe for the engineer and fireman. Mr. Jervis was formerly the chief engineer of the Delaware & Hudson Canal Co., and had imported some English engines for use upon that road, when it was to be opened in 1829. The first locomotive made by R. Stephenson & Co., the 'America,' was landed in New York in May, but for some unexplained reason was never sent to the road. Later the 'Stourbridge Lion' arrived, which was constructed by Foster & Rastrick, of Stourbridge, England. This was sent to Honesdale, Pa., and a trial made with it on August 8, 1829. Mr. Horatio Allen, who had formerly been associated with Mr. John B. Jervis, and supervised its construction in England, acted as the engineer. No one else was upon the locomotive. The engine was started and run across the trestlework over the Laxawaxen Creek, and returned without accident. This completed its running, but not its service to American railroads. The engine was too heavy for the track, the weights upon the axles being greater than had been anticipated or prescribed by Mr. Jervis, and the structure was not capable of sustaining the locomotive.

Messrs. Jervis and Allen, after noticing the injury to the track by the 'Stourbridge Lion,' eventually devised entirely different mechanisms for application of the principle of subdividing and distributing the total load of the locomotive to the track. Mr. Horatio Allen designed an eight-wheel engine for the purpose. Each pair of driving wheels was driven by a separate cylinder, but they were not connected so as to keep the cranks at right angles to each other. Mr. Jervis designed, in place of one pair of driving wheels, a flexible four-wheel truck to support the front end of the engine, which served to subdivide the total load of the engine, and connected a pair of driving wheels to the main frame which supported the boiler and machinery of the engine.

While Mr. Allen and Mr. Jervis both had the idea of distributing the total load of the locomotive to a longer portion of the track, each used a different mechanism for applying the principle. The mechanical application of Jervis still survives and is in general use on most of the locomotives in the railroad world.

After three score and ten years of service and experience, the mechanical application of Jervis is the best. Mr. Allen's system was confined to three or four locomotives, and was succeeded on the same railroad by locomotives with the Jervis truck, the first one being named the 'E. L. Miller,' constructed by Mr. Mathias Baldwin, the founder of the Baldwin Locomotive Works.

Mr. Jervis's mechanical application made the state of the art so complete that his theory has been well-nigh forgotten.

The stremmatograph confirms the theory that on tracks of stiff rails and joints, locomotives when drawing their trains distribute their total load and effects of the expended tractive effort in accordance with a principle of mechanics. In the evolution of American locomotives this principle has received its greatest application, not only in more wheels in the wheel base of the engine, but in that of the tender.

The decided advantage of being able to distribute the total load of the locomotive through a number of wheel contacts, enables a heavy load to be carried without unwarranted injury to the track, by making the forward wheels check deflections under the following driving wheels. The drawbar-pull also becomes of assistance in the distribution of the loads on the driving wheels and effects of the expended tractive effort. In this way the combined stability between the locomotive and the superstructure of the permanent way is increased.

The rail is the most important member of the conservative system either of the superstructure of the track or of the permanent way. The bending of the rails is produced directly by the moving wheel loads, and the tension under one wheel contact can not take place without producing compression at some other point. Therefore, bending in either direction is resisted by the metal, which helps distribute the load to a longer portion of the track than is possible on lighter rails.

The combined stability, efficiency and capacity between the locomotive, rolling stock and the permanent way increase in a faster ratio than the direct stiffness between two sections of rails. This is shown by the great increase in the weight of the locomotives and cars in the last few years, running over the same road-beds which were formerly laid with light rails.

The stresses of the specific deflections of the different wheels of the locomotive running over a flexible track are of necessity quite irregular. The irregular application of steam also makes an irregular distribution of the stresses per revolution.

As the smoothness of the track has increased, the realized coefficient of adhesion of the system of the driving-wheel base of the locomotives has also increased.

P. H. Dudley.

SCIENTIFIC BOOKS.

Analytical Chemistry. By F. P. Treadwell. Translated from the second German edition by William T. Hall. Vol. I., 'Qualitative Analysis.' 8vo. Pp. xi + 466. New York, John Wiley & Sons. 1903.

There are so many books on qualitative analysis, and so many of them have little reason for existence, that it is a matter of satisfaction to examine one, like the work under consideration, which possesses many features of novelty and excellence.

The book begins with an introduction explaining general principles, including the law of mass action and the ion theory of Arrhenius. While the latter theory is apparently advocated, its influence is shown but little in the book as a whole. For instance, in the first part of the introduction it is stated that a precipitation always takes place when an insoluble substance is formed by means of a 'chemical decomposition,' and, although the part of the book which treats of acid radicals is headed 'Reactions of the Metalloids (Anions),' the substances dealt with are called 'acids.' This neglect of the modern theory will be approved by some, but it will be objected to by many.

The book seems to be particularly good in its clear and full descriptions of qualitative tests. Many new and improved methods are introduced, and the methods adopted are generally very satisfactory. However, the re-