to be able to meet the demand. In new producing areas the essential characters of the grounds include:

(1) Estuarine waters sufficiently enclosed—in a technical sense—to ensure the retention of the larvæ and spat in a maximum area under cultivation.

(2) A local seasonal temperature range giving frequent probabilities of a maximum temperature in the bulk of the sea-water of 64° F. or more, and a minimum rarely below 34° F.

(3) A large area of moderately clean ground, and moderately pure water which should not fluctuate greatly, nor fall much or often below 2·5 per cent, in saltness.

(4) A sufficient stock of large oysters to supply probabilities of an increasing spatfall year by year.

(5) A supply of cheap clean shell or other material for the annual sowing for spat.

(6) Reasonable shelter from gales, if much sandy or fine gravelly ground occurs in the locality.

(7) Immunity from gross sewage or industrial pollution now and in the fairly distant future.

(8) Absence of an abnormal amount of enemies or pests.

A review of these characters indicates that the southern regions of England and Ireland are most likely to yield new producing grounds, whilst a glance at Fig. 1 suggests that potentialities for production in Ireland are undeveloped to a greater degree than in England.

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Vibration in Bridge Structures.[1]

BRIDGE building may be reckoned amongst the earliest of the structural engineers' efforts, and locomotive construction as one of the first lines of development in mechanical engineering; but the adequate study of the actions of a locomotive on a bridge has required very modern resources in investigation, and all those refinements of experimental and analytical methods that mark the engineering technique of to-day. The problem in its various aspects and complexities has been very completely studied, with the aid of these resources, by the special Bridge Stress Committee appointed by the Department of Scientific and Industrial Research in 1923. The Committee comprised highly representative scientific and technical engineers, under the chairmanship of Sir J. A. Ewing, of the University of Edinburgh, and the full report of their deliberations and investigations has now been published. The remit of the Committee was "to conduct researches with reference to stresses in railway bridges, especially as regards the effects of moving loads." These comprehensive terms of reference have been very adequately interpreted, and the work of the Committee constitutes an invaluable study of the vibration of bridge structures under impact influences. Work with a somewhat similar motive had previously been attempted—notably by the American Railway Engineering Association in 1910, and by a special committee of the Indian Railway Board in 1917—but the present report goes much further and deeper into the subject.

The previous investigations had made fairly clear that the main cause of serious augmentation of bridge stresses arose from the unbalanced vertical forces developed by the locomotive. Certain effects could be traced to rough and flat wheels, irregularities of track, or to heavily loaded freight cars, but these were usually small in relation to the direct consequence of the pulsating force—or 'hammer blow'—due to the 'balance' weights on the locomotive wheels. While this was recognised, it has not been very effectively embodied in bridge stress rules; and, as in the well-known Pencoyd formula, the influence of impact is generally covered by a proportionate increase, varying with span length, of the live load stress. If impact is mainly due to locomotive actions, this process of making allowance on total live load is scarcely rational. It is the achievement of the Bridge Stress Committee that it has not only clearly elucidated the nature and cause of impact, but that the investigation is so complete as to permit of the standardisation and rationalisation of impact allowances in general.

An ordinary two-cylinder locomotive is balanced by the locomotive engineer by the addition of weights to the rims of the driving wheels. But this is merely a process of reducing the inertia force effects in the engine lines. What is eliminated in those lines is transferred by the so-called 'balance weights' to the vertical plane; and hence variation of horizontal force is changed to a vertical fluctuation giving rise to a pulsating force on the rails. The magnitude of this force is all-important. The report repeatedly refers to it; and it is recorded that the locomotive engineers of Great Britain are prepared to limit its value to a total per locomotive of 12½ tons at 5 revolutions per second of the wheels. It is, therefore, clear that the importance of the absolute value of this force as a factor in girder stresses is established and accepted. The context also explains that, while in some centres special care is taken to test the balance of locomotives after construction, in other cases more attention is required in this matter. It is also obvious that three- and four-cylinder, and electric locomotives, in which a much higher degree of balance is possible, have distinct advantages over the more common two-cylinder type.

The Committee's work consisted of the actual observation of bridge vibrations and the analysis

(*Continued on p.* 463.)

[1] Department of Scientific and Industrial Research. Report of the Bridge Stress Committee. Pp. vii+215. (London: H.M. Stationery Office, 1928.) 18*s*. net.

of the records therein obtained. The gross total of the work in the field and in the office is enormous; but the subsidiary work called for in the study of vibration instruments and their accuracy, special small-scale laboratory tests, the development of a bridge-oscillating machine, and the theoretical investigation of bridge vibrations, are all of considerable scope and important in themselves. Indeed, the analytical work of Prof. Inglis is already well known as a research of special distinction; but although it had been, in the main, separately and previously published in special papers, its function in guiding the investigation is only now clearly seen through its relation to the complete report.

The pulsating forces from the locomotive wheels create regular impulses on the structure during passage. If these are in agreement with the natural frequency of the bridge, large vibratory amplitudes may ensue as a result of resonance. The work of investigation, then, entailed the measurement of natural frequencies with the bridge loaded and unloaded; and the observation and recording of the deflections with the locomotive passing over, first at very low speeds, and then at speeds at and around resonance. Examinations were carried out on 52 bridges varying in span from 16 ft. to 345 ft. The locomotives were provided by the railway companies, who throughout co-operated with the Committee. All types were represented. In many cases the engines were specially chosen for the large hammer blow which they developed, so that the worst possible conditions could be fully observed. The total amount of information gathered, and the wide range of spans dealt with, full particulars of which are given, certainly permit of important conclusions which should prove thoroughly reliable in the guidance of bridge design.

The limitation of the amplitude of vibration in any case is partly an effect of damping; and in this connexion the interesting work on the influence of the locomotive springs should be noticed. There is apparently a pair of critical speeds depending on whether the suspension springs are in play or not, the probability depending on whether the oscillations of the bridge are sufficiently great to overcome the spring friction. Apart from damping, however, the span length is an all-important factor. With short spans the natural frequency is too high to be equalled by the locomotive speeds. With very long spans, on the other hand, the natural frequency agrees with low locomotive speeds, when the impulses are relatively small. To deal with these different effects the Committee develops a 'dynamic magnifier,' a multiplier akin to the usual amplification factor of vibration theory, which expresses the ratio of the vibration amplitude to the deflection that would be caused by a static load equal to the hammer blow. This factor is first developed for the synchronous condition for all spans and then corrected for the interrelations of span length and locomotive frequency. It would appear that spans around 100 ft. are subject to the largest dynamical magnification. The curve for this important factor should ultimately take an important place in bridge design rules.

The report briefly discusses other causes of impact, such as effects of irregularities of track, rail joints, and the 'lurching' of locomotives; and enters at large into the tabulation of loads and allowances for impact. Appendixes on impact formulæ, instruments, balancing of locomotives, etc., are given. The whole report constitutes an impressive compilation of the details and conclusions of a courageous and exhaustive full scale research that reflects great credit on the Committee and its staff.

Obituary.

THE issue of the *Physikalische Zeitschrift* for Jan. 1 contains a photograph and an obituary notice of Prof. A. H. Bucherer of Bonn, who died in May 1927, written by his former colleague, Dr. R. Tomaschek. He was born in Cologne on July 9, 1863, the eldest of six children of H. Bucherer, a chemical manufacturer, and his wife, a musical and highly educated English lady. He was educated at the Cologne High School, where he displayed a gift for languages. After serving his year in the army and spending a year at the Hanover technical school, he went in 1885 to the Johns Hopkins University, Baltimore, where he studied under Prof. Ira Remson, and for a time held a lectureship, then in 1893 to Cornell University, and in 1895 returned to Germany to complete his studies under Prof. Braun at Strasbourg, and took his doctor's degree in 1896. After a further three years at Leipzig under Ostwald, and at other universities, he became a lecturer on physical chemistry at Bonn in 1899. Later he became honorary professor, a post he resigned in 1923. From his youth he showed himself of independent thought, little disposed to conciliate those from whom he differed, and this attitude did not smooth his way in life. He is best known for his "deformable electron" and for his experimental determination of the influence of the speed of an electron on its apparent mass. He was not satisfied with Einstein's relativity theories, and was engaged towards the end of his life in an endeavour to deduce all the results of that theory and remove some of the difficulties it has raised, by a logical development of classical mechanics.

BY the recent death of Dr. Franz Oppenheim, announced in the *Chemiker-Zeitung*, Germany has lost one of its leading personalities in chemical industry. For nearly fifty years Dr. Oppenheim was associated with the Aktiengesellschaft für Anilinfabrikation in Berlin, of which concern he was president at the time of its inclusion in the I.G. Farbenindustrie Aktiengesellschaft in 1925. His ripe experience led to his appointment on the board of management of the latter amalgamation. He held several public offices connected with the German chemical industry; for example, he was treasurer of the Emil Fischer Society for the promotion of