was covered over in a rude way: a groove had been formed at the sides of the chasm, into which planks were placed to form a passage over it.

Mr. SIMPSON,—President,—said, that the tackle generally employed for gates and caissons, was not sufficiently strong to inspire confidence in the labourers, and the ordinary capstan was very troublesome to manage: all these mechanical difficulties might, however, be overcome. With reference to the plan of M. Singels, it should be observed, that there could be no difficulty in constructing a sliding gate in the Zuyder Zee, as the rise of tide was very small.

May 16, 1854.

JAMES SIMPSON, President,
in the Chair.

No. 915.—"On the Fatigue and consequent Fracture of Metals."[1] By FREDERICK BRAITHWAITE, M. Inst. C.E.

THERE are reasons for believing, that many of the appalling, and apparently unaccountable accidents on railways, and elsewhere, are to be ascribed to that progressive action which may be termed, the 'fatigue of metals.' This fatigue may arise from a variety of causes, such as repeated strain, blows, concussions, jerks, torsion, or tension, &c.

Metal, in a state of rest, although sustaining a heavy pressure, or strain, as in a girder, and exhibiting the deflection due to the superposed weight, will continue to bear that pressure, without fracture, so long as its rest is not disturbed, or the same strain is not too often repeated, but, if its rest is too frequently disturbed, the metal becomes deteriorated, and worn out, at the part subject to the reiterated strain, and fracture will, ultimately, ensue.

The history of some, apparently, unaccountable accidents which have happened, will furnish sufficient grounds for the consideration of the Members of the Institution, whether the

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[1] The discussion upon this Paper extended over portions of two evenings, but an abstract of the whole is given consecutively.

Author is justified, in arguing, that many accidents, at present involved in mystery, may be satisfactorily accounted for, and further, that by due examination, and inquiry, many casualties may be prevented.

Some years ago, at a large brewery in London, a vat was erected on cast-iron girders; they stood firmly for several years, but at length the girders broke, when one man was killed, and another was dangerously wounded.

The accident was, at the time of its occurrence, and is still, to the present moment, considered very mysterious. The probable solution is, that the iron girders were never strong enough to withstand the fatigue caused by the intermittent loading of the vessel; it being sometimes full, sometimes partly full, and sometimes empty. When it was full, the girders were too much deflected, and when empty, or partly so, the state of rest was disturbed, by the natural attempt of the metal to regain its original position; the repeated action of deflection and of rising towards its original position, imperceptibly slow, but not the less insidious, and dangerous, deteriorated the metal, and, ultimately, the girders broke.

For the purpose of cooling the wort at another brewery, a refrigerator was constructed of a long series of 'oval copper pipes;' this form being adopted, in order to present as large a surface as was possible, in the cistern, to the cooling effects of the water. The oval pipes were in lengths of 6 feet each, secured together by soldered joints, and, for the convenience of erection, at every three lengths of 6 feet, each, or at intervals of 18 feet, gun-metal flanges were introduced, and these were likewise secured to the oval copper pipes by soldered joints. After some years, attention was called to the chemical condition, or quality of the water, which, it was stated, had eaten away the solder of the joints, causing leaks, and waste of wort. The Author was long in doubt as to the real cause, but on narrowly examining several of the defective joints, the solder, which was composed of lead and tin, appeared, in several parts of the oval surface of the joints, to be in a state of powder. On a further examination of the joints attached to the gun-metal flanges, the solder was found to be perfect. The Author then reported to the proprietors, much to their gratification, that the cause of mischief was mechanical, not chemical.

The solution of the case was simply this: the position of the refrigerator was on the basement of the brewery, and the wort had to be pumped through the oval pipes to the top of the building. There was, consequently, a great internal pressure, which was materially increased by every pulsation of the pump. The tendency of the oval pipe to assume a circular form was only restrained by the gun-metal flanges, and the solder joints, but the latter were, of themselves, too weak to support the fatigue consequent upon the repeated action, and reaction. Wrought-iron collars were then introduced at every defective joint, and all the mischief ceased.

The Great Western Railway Company had adopted Ritterbandt's plan for preventing incrustation in boilers.

Mr. Daniel Gooch, the Locomotive Superintendent, directed the attention of the Author to a very serious, but as usual, 'unaccountable,' state of the back-plate of a locomotive boiler,—the thick wrought-iron plate to which the cylinders are attached,—along the inside of which, just above the row of rivets of the angle iron, there was a deep groove. At first, Mr. Gooch attributed the mischief to the chemical action of the muriate of ammonia on the iron; but the Author immediately declared the cause to be mechanical, and not chemical, stating, that the back plates were too weak to resist the constant buckling caused by the to-and-fro action of the piston, and suggesting, as a remedy, a stronger plate, or more stays.

In the year 1827, some three-throw pumps with 'cast-iron cranks' securely bolted together, were erected at a brewery. The pumps, when first erected, were placed in a well about 90 feet from the surface, and they had to throw the water into a reservoir, about 70 feet above the surface; this gave a pressure of 160 feet, or say, 80 lbs. per square inch on the piston. Some years after the pumps had been at work, one of the cast-iron cranks gave way at one of the throws, 'unaccountably' of course, owing to neglect, or inattention, &c. The crank was repaired, the same pattern being used; but a year afterwards, a second, and at the end of another six months, a third fracture occurred.

The Author was enabled to account for these accidents, from a consideration of the following circumstances. The water in the well falling off, the pumps were lowered 20 feet, thereby adding 10 lbs. per square inch on the pistons, and it was then

that the crank gave way for the first time; the reservoir was afterwards raised considerably, and again the crank broke; the pumps were again lowered, and the third accident happened. The remedy was a new, and stronger set of cranks, provision being made for any further lowering of the pumps. These stronger cranks have now been at work, night and day, during upwards of twelve years, and no further accident has happened.

There have been many instances of the sudden, and unexpected fracture of axles, cranks, crank-pins, levers, cranes, crane-chains, hooks, &c., and almost of all parts of various kinds of machinery, when subjected to continuous, and repeated strains, jerks, or concussions, and it is very remarkable, that in all cases, the destructive effect of this fatigue, was evident, in the metal at the fractures being altered in its structure.

For the purpose of more immediate illustration, let it be assumed, that a railway accident occurs by the 'unaccountable' detachment of the ash-pan of a locomotive, while the train is in full speed. Every one, at all conversant with the construction of a locomotive, knows the weight of an ash-pan, and further, that the pan is, in most cases, suspended below the furnace of the boiler, by iron rods of dimensions quite equal to sustain, so far as the suspension is concerned, not only the weight of the ash-pan, but of the whole locomotive. But this mere suspension is not the only strain to which these rods are exposed, for every concussion to the engine by suddenly stopping, or starting, backwards, or forwards, is immediately communicated to them, so that there are continual side-strains, and counter side-strains, which fatigue the metal in those directions, until fracture imperceptibly takes place; such an accident ought not, therefore, to be considered as unaccountable.

From a careful consideration of the above facts, the Author has arrived at the conclusion, that many of the railway accidents, to bridges, ash-pans, parts of a locomotive engine, carriages, or the chains connecting them, hitherto deemed unaccountable, are to be attributed to the fatigue of the metal, and he is of opinion, that a rigid examination, and subsequent strengthening, or changing of the parts, where necessary, of all bridges, machinery, and engines, will greatly tend to the prevention of such accidents, which, unhappily, must, on railways, always be of a very serious kind.

The object of this Paper is not to raise alarm, but to direct the serious attention of all engaged in using metals, (where they are either actively, or passively employed,) to the certain destructive effect of hitherto unobserved causes, which have, too often, been the lurking agents of many disastrous accidents.

It was the intention of the Author to have treated of the destruction of certain metals by other causes, such as oxidation, or the effects of acids; but as he cannot, at present, obtain from the Admiralty, the results of numerous experiments upon iron bolts and nails coated with and joined to copper, or brass, he proposes, with the consent of the Council, to present another Paper on that subject, probably during the next session.

Mr. F. BRAITHWAITE said, that the term 'fatigue,' as applied to this species of deterioration of metal, was suggested by Mr. Field; and most Engineers must, in the course of their practice, have met with many instances where accidents were referable to no other cause. The action in question was not confined to any particular metal, nor was it dependent on any peculiar form into which the metal was worked. Wire ropes, however strong, eventually gave way under this action, the reiterated strains to which it was exposed, during the process of manufacture, primarily inducing this species of deterioration.

Mr. RANKINE said, that in 1843, he had presented a Paper to the Institution, "On the causes of the unexpected Breakage of the Journals of Railway Axles;"[1] and the views which he had then taken upon the subject, were strongly confirmed by the Paper under discussion. The journals were rather slender, and they had been over-weighted: the result was a very minute fissure, which extended round the back of the journal, and gradually penetrated inwards, until, after running about three years, a complete fracture was effected. The surface of the fracture was convex, but in the centre, the metal still retained its fibrous texture. He attributed the accidents to the elasticity of the fibres being suddenly arrested at the shoulder, and in order to obviate this defect, he caused the axles to be hammered into a curve at the shoulder, so as to draw down the

[1] *Vide* Minutes of Proceedings Inst. C. E., vol. ii., 1843, p. 105.