

will weigh no less than 80 tons, and the two boilers are expected to supply the steam required for indicating 3,000 horse power.—*Engineering.*

### THE QUALITY OF STEAM.\*

By JOHN W. HILL, M.E.

EXPERIENCE shows that steam always carries a certain percentage of water in suspension as it rises from the body of water of which it is formed. This percentage will vary as between different forms of boiler, and the same boiler operated under different conditions. The water so suspended in the steam is known as water entrained or as primage. The rising of the water in a boiler by induction, when a large steam pipe is suddenly opened, is entirely independent of the water entrained, and is not meant by any allusion to primage in this paper. I believe it is a fact observed in chemistry that anhydrous gases cannot be obtained by direct vaporization, and that a special drying process is necessary to saturate or remove the liquid always entrained in the gas upon its first formation. Saturated steam (that is, steam charged with such an amount of heat that any reduction thereof would produce condensation, and any increase thereof would produce superheat) is substantially a perfect gas, and is usually so considered in all formulæ upon its action in a steam engine.

Our best information upon the temperature (heat) of saturated steam at various pressures is from the experiments of Regnault, *Comptes Rendus*, 1847, with which all steam engineers are sufficiently familiar to avoid the description of his apparatus or the circumstances under which his experiments were made, at this time. It is proper to state, however, that the experiments of Regnault were to ascertain the relations of temperature, pressure, and density of steam; and as a corollary to determine the specific heat of steam and water at various boiling points. The determination of the relation of density and pressure was never made by Regnault, the only recorded experiments upon which were by Messrs. Fairbairn and Tate several years later.

It is now well known that the steam engine is a heat engine, that the water which is vaporized to form steam is simply a vehicle in which we store up the heat of the fuel, and which parts with a portion of this heat in transit through the engine, partly by conversion of heat into work, partly by conduction and radiation through the walls of the cylinder, and partly by the cooling effect of the atmosphere on the piston rod. No steam is expended in operating an engine; for the same weight of water as vapor which enters the cylinder by the steam pipe also leaves the cylinder by the exhaust pipe. If we deliver 1,000 pounds of steam at a given temperature to an engine through the steam ports, we shall draw off through the exhaust ports precisely the same weight of steam at a lower temperature. But during the passage of this steam through the engine a certain reduction of temperature has occurred, and the efficiency of the engine is a function of the limits of temperature between which the steam enters and leaves the cylinder, as enunciated by the junior Carnot more than fifty years ago.

To illustrate the efficiency upon the heat basis, let us suppose an engine condensing—consuming—16½ pounds of steam per hour, connected with a battery of boilers furnishing 10 pounds of steam per pound of coal from the temperature of the feed. Let the thermal value of the coal be taken at 15,000 units, and estimate 75 per cent. of this, or 11,250 units, as contained in the steam above the temperature of feed water. Then the efficiency of such an engine would be

$$100 \times \frac{11,250 \times 1.65 \times 772}{33,000 \times 60} = 13.82$$

per cent., or of every 100 horse-power resident in the heat expanded in working the engine less than 14 are utilized, the remaining 86 horse-power going out in the exhaust. It is well known that the best economy we have any record of has been obtained from pumping engines, and that a duty of 100,000,000 foot-pounds per 100 pounds of coal is seldom attained. Now, our condensing engine, working upon 16½ pounds of steam, or one and sixty-five hundredths pounds of coal per hour, represents a duty of

$$\frac{33,000 \times 60 \times 100}{1.65} = 119,988,000,$$

nearly 120,000,000 foot-pounds. From which it appears that about 14 per cent. is about a maximum efficiency with our present knowledge of construction. The object of this paper is, however, not to discuss the economy of steam machinery, but to show the necessity for an exact knowledge of the thermal value of steam, in estimating the economy of engine and boiler performance.

To illustrate the effect of a lack of knowledge of the quality of steam furnished by boilers, let us suppose a temperature of feed of 212° F., an expenditure of coal of 1,000 pounds, a consumption of feed-water of 12,000 pounds, and a boiler pressure by gauge of 125 pounds. The apparent evaporation from the temperature of feed in this instance is twelve pounds of steam to one of coal. Without information to the contrary, and in accordance with the usual practice, we would accept this as the evaporation and pronounce the result as extremely satisfactory. Suppose, however, the temperature of the steam, instead of being at saturation (1221.53 units), contained as a mean per pound only 1,135 units; then the actual evaporation, instead of being twelve to one, would be ten and eight-tenths to one, and this instance supposes an efficiency of furnace and boiler of nearly 75 per cent., and a thermal value of 15,000 units per pound of coal; in brief, supposes a quantity of coal and efficiency of furnace rarely obtained. None of the usual devices applied to steam boilers are capable of measuring the thermal value of steam, and recourse is had to special apparatus for this purpose. Two distinct forms of calorimeter have been used; one the continuous calorimeter, in which the condensation of a certain small percentage of the steam is maintained during the entire trial of a steam engine or boiler, and the other the intermittent calorimeter, with which at stated intervals known weights of steam are drawn from the boiler or steam pipe and condensed in known weights of water.

The continuous calorimeter consists usually of a coil of brass pipe or copper of ¼ to ½ in. diameter of bore, containing 30 to 50 lineal feet. This coil is placed within a tin can, through which the circulating water passes from below upward. The upper end of the worm is connected with the steam pipe or steam drum of the boiler, and the lower end terminates in a neck which delivers the condensed

steam into a receptacle mounted upon a carefully-balanced scale, with which the condensation is weighed from time to time, and dumped. The circulating or condensing water is measured by tanks of known capacity, or through a Worthington meter, the error of which is known by test. Standing thermometers are located as follows: One in the injection pipe, by which the circulating water enters the apparatus; one in the overflow nozzle, by which the circulating water leaves the apparatus, and one in the neck of the worm from which the water of condensation flows. Should there be an indication from the calorimeter data of superheat in the steam, an additional thermometer should be inserted in the head of the worm or in the steam pipe leading to it, to measure the superheat independently and check the record of the calorimeter. Steam flows through the worm and is condensed, the heat being transferred through the walls of the coil to the circulating water. The temperature of the circulating water is elevated through a range represented by the difference of temperature of the inflow and outflow. The temperature of the condensation as it leaves the calorimeter is read from the thermometer in the neck of the worm. The temperature of the steam is the unknown quantity which we seek. To illustrate the action of the continuous calorimeter assume a weight of steam condensed of 100 pounds, a weight of circulating water expended in condensing it of 2,000 pounds, a temperature of inflow of 50° F.; a temperature of outflow of 105° F., and a temperature of condensation of 60°; then temperature of steam, neglecting small effect of variation in the specific heat, is

$$60 + \frac{2,000 \times 55}{100} = 1,160^\circ \text{ F.}$$

Assume the steam as it entered the calorimeter, at a pressure of 135 pounds by gauge or 150 pounds absolute, at which pressure the temperature of saturation is, according to Regnault, 1,223.15 F. Then difference of temperature is 63.18 units, indicating that a portion of the water was entrained in the steam.

To estimate the percentage of primage we must bear in mind that the water in the boiler is first heated to a temperature of 362.56° F. (corresponding to a pressure by gauge of 135 pounds), before vaporization takes place; and that additional temperature of 860.2 units is necessary to vaporize the water so heated; and that the discrepancy in the thermal value of the steam applies to the temperature of vaporization, whence the water entrained as primage becomes

$$100 \times \frac{63.18}{860.2} = 7.35 \text{ per cent.}$$

The intermittent calorimeter consists of a water-tight vessel (preferably of wood to avoid transfer of heat to or from the contents thereof by conduction and radiation) mounted upon a sensitive scale, into which a known weight of water is drawn. A small steam pipe, usually three quarters of an inch in diameter, closely connected with the main steam pipe or steam drum of the boiler, dips into the vessel on the scale, and is provided with a cock or open-way valve to regulate the delivery of steam into the weighed quantity of water. The temperatures are taken with a hand thermometer. As suggested, a known weight of water is first weighed into the tank on the scale, usually some convenient quantity to estimate from, as 100 or 200 pounds, of which the probable condensation in the small steam pipe usually forms a part. The amount of condensation which will collect in the steam pipe between observations will vary with the quality of steam, and must be blown out to clear the pipe before the weighed quantity of steam to be condensed is blown in. The weight of water and condensation blown out of the pipe having been justified, the temperature of the contents of the tank is carefully taken with a reliable thermometer, and 5 or 10 pounds of steam blown in and condensed. (The weight of steam condensed should be as large as consistent with a limited temperature of the contents of the tank on the scale, to obtain a high range of temperature; since errors of weight are less liable to occur than errors of temperature, and the greater the range of the mercury the smaller the effect of errors of observation.) The desired weight of steam having been condensed, the flow through the pipe is promptly suppressed and a second temperature of the contents of the tank is taken. The first temperature from the second temperature represents the range of the contents of the tank. To illustrate the principle of the intermittent calorimeter, let the following data be assumed:

Weight of condensing water.....100 pounds.  
Weight of steam condensed..... 5 "  
Initial temperature condensing water... 60 F.  
Final temperature condensing water... 115 F.  
Range..... 55 F.

and the temperature of steam is

$$115 + \frac{100 \times 55}{5} = 1,228 \text{ F.}$$

Supposing steam, as before, at a pressure absolute of 150 pounds, the difference between the quality in the illustration and saturated steam is 4.82 units, corresponding to a superheat of

$$\frac{4.82}{0.475} = 10.15 \text{ F.}$$

I have not detailed the construction and action of the two well-known forms of calorimeter with the expectation of adding any to your knowledge thereof, but to bring the processes fairly before you previous to calling your attention to some of the results of my experience with the instruments. I shall not attempt, in the short time which, by courtesy, you allot me, to detail all my experiments with the calorimeter, as these are many and would frequently be simple repetition results, but shall refer only to a few experiments to show the value of investigations of this class. The first results we will examine are from a series of four experiments upon boilers set with smoke-preventing furnaces for the Cincinnati Industrial Exposition for 1879.

The first case was a return tubular containing 963.64 superficial feet of heating surface, and worked at a capacity equivalent to 2.77 pounds of steam per foot of heating surface per hour, which gave a temperature of steam of 963.46 units, indicating, with a pressure by gauge of 38.75 pounds, a primage of 26.26 per cent. The apparent evaporation from the temperature of feed (70.02° F.) per pound of coal was 7.59, but the actual evaporation from same temperature was only 5.6 to one.

The second case was a return flue boiler containing 519.45 superficial feet of heating surface, and worked at a capacity equivalent to 1.73 pounds of steam per foot of

heating surface per hour, which gave a temperature of steam of 864.73 units, indicating with a pressure by gauge of 80.29 pounds, a primage of 29.13 per cent. The apparent evaporation per pound of coal from the temperature of feed (166.01 F.) was 5.84, but the actual evaporation from same temperature was 4.14 to one.

The third case was a battery of 2 return tubular boilers containing 880.16 superficial feet of heating surface, and worked at a capacity equivalent to 3.20 pounds of steam per foot of heating surface per hour, which gave a temperature of steam of 1,005.93 units, indicating with a pressure by gauge of 76.18 pounds, a primage of 23.19 per cent. The apparent evaporation per pound of coal from the temperature of feed (169.11° F.) was 9.69, but the actual evaporation was 7.45 to one.

The fourth case was a direct tubular boiler containing 327.79 superficial feet of heating surface, and worked at a capacity equivalent to 2.96 pounds of steam per foot of heating surface per hour, which gave a temperature of steam of 1,441.35 units, indicating, with a pressure by gauge of 81.60 pounds, a superheat of 18.83 per cent. The apparent evaporation per pound of coal from the temperature of feed (74.55° F.) was 8.80, but the actual evaporation upon the basis of saturated steam was 10.66 to one. This boiler was set and worked simply for test purposes, and was furnished with superheating surface. The continuous calorimeter was used in these experiments. The next results to which I shall refer are the calorimeter tests for quality of steam during the trials of steam engines at the Millers' Exhibition, Cincinnati, 1880. In this instance the experiments were all made with the same boilers, operated under approximately the same conditions from day to day. The boilers, two return tubular, contained 137.24 superficial feet of heating surface, and were worked at the following capacities in pounds of steam per foot of heating surface per hour, for six different trials: 2.53, 2.42, 2.32, 2.41, 2.42, and 2.63—with corresponding temperature of steam of 1,243.84 units, 1,211.3 units, 1,315.86 units, 1,255.74 units, 1,301.65 units, and 1,313.11 units. Of these temperatures only one, the second, indicates primage; all others exhibit a slight superheat. The primage at 92.54 pounds pressure by gauge in the second experiment was 0.46 per cent. The percentage of superheat at 92.50 pounds pressure by gauge in the first experiment was 2.3; in the third experiment, with steam pressure at 91.65 pounds by gauge, 8.3 per cent.; in the fourth experiment, with steam pressure at 91.43 pounds by gauge, 3.34 per cent.; in the fifth experiment, with steam pressure at 91.44 pounds by gauge, 7.09 per cent., and in the sixth experiment, with steam pressure at 91.54 pounds by gauge, 8.06 per cent. The continuous calorimeter was used in these trials.

The former results were from four different boilers of different forms and dimensions, and operated at different steam pressures and rates of evaporation, with a range in the quality of steam from 19 per cent. of superheat to 29 per cent. of primage, while the last six results were all from the same boilers, operated at different times, under approximately the same steam pressure and rates of evaporation, with a range in the quality of steam from 8.3 per cent. of superheat to ½ per cent. of primage. From which it appears that with the same boiler or boilers, operating under similar conditions, an approximately uniform quality of steam should be had, and that the quality of steam in any one instance cannot be assured for another, unless the conditions are precisely alike.

The next results to which I shall refer are from three different trials upon the same boilers, operated with similar steam pressures, and at different rates of evaporation. The boilers, two in the battery, were of the return tubular variety, containing 932.02 superficial feet of heating surface. During the first trial, steam was made at the rate of 4.09 pounds per foot of heating surface per hour, with a resultant temperature of 1,153.09 units, indicating a primage at 92.59 pounds by gauge of 7.08 per cent.

During the second trial the boilers were worked at an evaporation equivalent to 2.86 pounds of steam per foot of heating surface per hour, with a temperature of steam of 1,199.04 units, indicating, with a pressure of 92.95 pounds by gauge, a primage of 1.92 per cent.

During the third trial the boilers were worked at a rate of evaporation equivalent to 2.90 pounds of steam per foot of heating surface per hour, with a temperature of steam of 1,174.17 units, indicating, at a gauge pressure of 92.28 pounds, a primage of 4.75 per cent. These experiments were made with an intermittent calorimeter. In all experiments exhibiting a small primage in the steam, as a superheat, the boilers were set to expose more or less of the steam room to contact with the hot gas.

The next results are from a series of three experiments with a small locomotive boiler, operated standing.

For the first trial the heating surface was 2.875 superficial feet, and ratio of heating to grate surface 25.90 to one. The boiler was worked at a capacity equivalent to 8.49 pounds of steam per foot of heating surface per hour, with a temperature of steam of 1,150.98 units, indicating at 105.5 pounds pressure, by gauge, a primage of 5 per cent. The apparent evaporation per pound of coal was 4.45, and the actual evaporation was 4.09 to 1.

For the second and third trials the heating surface, by the introduction of a water bridge into the fire box, was increased to 300.7 superficial feet, with a ratio of heating to grate surface of 41.67 to 1. During the second trial the boiler was worked at a rate of evaporation equivalent to 9.39 pounds of steam per foot of heating surface per hour, with a temperature of steam of 1,181.76 units, indicating at 98.25 pounds pressure, by gauge, a primage of 4.33 per cent. The apparent evaporation in this case was 7.58 pounds, and the actual evaporation 7.25 pounds of steam to 1 of coal.

During the third trial the boiler was worked at a rate of evaporation equivalent to 9.77 pounds of steam per foot of heating surface per hour, with a temperature of steam of 1,259.29 units, indicating a superheat of 8.67° F., at a pressure, by gauge, of 100.7 pounds. The apparent evaporation was 6.41 pounds of steam per pound of coal, and the actual evaporation upon the basis of saturated steam was 6.65 to 1. The rate of combustion and evaporation was higher for the third trial than for the second, with a better quality of steam and a reduced economy. In these trials the coal was burned within five or six per cent. of the total weights charged, and the calorimeter results can be fairly compared without correction.

The next result to which I will refer is from the boiler of a "Rogers" engine on the Ohio and Mississippi Railroad, in a running trial from Vincennes to Seymour, made last July. The heating surface was 984.33 superficial feet, and the rate of evaporation equivalent to 9.51 pounds of steam per foot of heating surface per hour, with a temperature of steam of 1,192.11 units, indicating a primage of 3.4 per cent., at a pressure, by gauge, of 125.56 pounds. The apparent evapo-

\* A paper read before the American Railway Master Mechanics' Association, at the Providence Convention, June, 1881.

ration in this instance was 3.97 pounds per pound of coal, and the actual evaporation was 3.83 to 1. The poor economy of this boiler was largely due to the high rate of coal consumption (146.25 lb. per superficial foot of grate per hour). With large grate areas and a reduced rate of combustion per superficial foot of grate per hour, the economy of locomotive boilers may be materially improved, as shown by the results obtained with the "Wooten" boiler on the Philadelphia and Reading Railroad.

I am aware that some of my professional friends are not seized of my faith in the reliability of calorimeter results, but I am unable to obtain from them any better objection than that some modifying data have been overlooked or neglected in those cases which do not meet their approbation. However, when they agree, as they invariably do, that condensed steam and condensing water may be accurately weighed, and that approximately accurate temperatures may be had with good makes of thermometers, then I can conceive no other objections to accepting the results of calorimeter experiments than the personal errors of observation which pervade all mechanical investigations.

If the power of steam engines is to be measured by the indicator or the less reliable dynamometer or friction brake; if the economy of boilers and engines is dependent upon the accuracy of weighing scales; if steam pressures are to be taken from spring gauges, and temperatures read from mercurial thermometers, and such results are held to be reliable for absolute and comparative effect, then the same reliability must, in simple justice, be accredited the calorimeter, for it depends solely upon correct weights and temperatures and involves no complex or uncertain quantities in the operation.

#### A NOVELTY IN RAILWAY CONSTRUCTION.

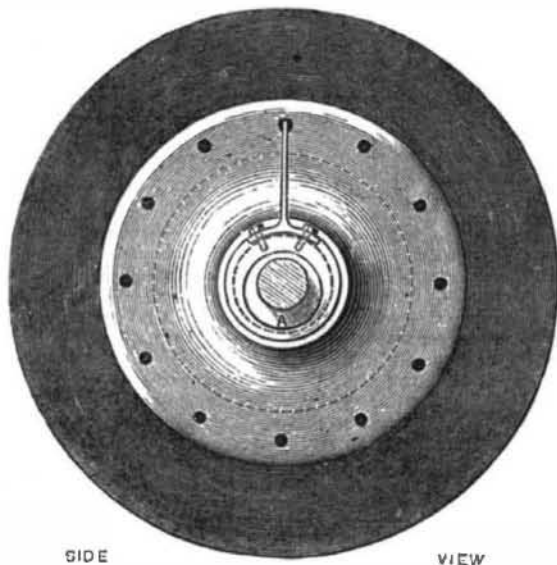
THE Darjeeling Tramway or Himalayan Railway is a novelty in railway construction, and will be justly regarded as one of the engineering sights of India. In his speech at the opening Sir Ashley Eden claimed for the enterprise the merit of having "solved problems never before solved in the history of railway undertakings. We know," he said, "of no other line which ascends 7,400 ft. in 50 miles, mounts gradients of 1 in 21, and comes round curves of 70 ft. radius." The line is described as presenting to the eye the appearance of "a snake winding up into the clouds." The tramway, which is 50 miles long, enables the journey from Calcutta—361 miles—to be performed in about 24 hours. Its terminus at Darjeeling is 7,690 ft. above the level of the sea. The capital of the Darjeeling Tramway Company is stated to have been raised entirely in India. The line was originally to have been completed within eighteen months, but this period has been exceeded.

The first rail was laid in May, 1879, and the contractors, Messrs. Mitchell Ramsay, succeeded in laying down the last between Jore Bungalow (7,800 ft. of elevation) and Darjeeling (about 7,400 ft.) in June last. The gauge is 2 ft. The rails are manufactured of toughened steel, and about 24,000 have been used in the construction of the entire line. Sleepers are laid at intervals of 2 ft. 8 in., extra sleepers being laid below the rail-joints; altogether above 100,000 sleepers have been used up. Bearing plates have been placed under the outer rails of all curves of 120 ft. radius and under, so as to preserve the rigidity of the outer rails. Taking the entire ascent, which commences at about the ninth mile from Silliguri beyond Lukua, at the edge of the Terai, the ruling gradient is 1 ft. in 25, but in isolated steep places, the gradient is 1 in 20. From the ninth mile the line curves and recrosses the road frequently, as a rule, however, keeping to the in or hill-side of the roadway. The first distinct deviation from the ascending road occurs at a place locally known as either the Horse Shoe, the Trestle Bridge, or as Agony Point, where the line simply beetles over the edge of the *khud*, and where the trains for safety's sake slacken speed. Above Tendoria, at the nineteenth mile, the train passes through a narrow bridge and slowly describes a loop of some 640 ft. in length and then recrosses the same bridge. From the loop onward the line gradually ascends, bearing away to the right, with the *khud* below to the right of the train; while on the left rises a crumbling steep hillside, looking very threatening, with enormous boulders of disintegrated rock, some of which have already given much trouble to the line watchers and authorities of the company. The line doubles to the leftward near Mahanuddy and its tea-garden, and then runs parallel, but in the reverse direction, above the road which the train has just traversed. The ascent continues gradually to Kurseong, some 5,200 ft. above the sea, and thence onward past some very troublesome and equally unsafe hill-sides toward Sonada. Thence on to Jore Bungalow. From Jore Bungalow the line descends from the saddle, circling round wide deviations toward Darjeeling proper, which is reached in about seven hours, run through from Silliguri, provided no landslips or other obstacles bar the way. The engines at present used are tiny tank ones, the carriages like open tramcars of the rudest and most uncomfortable description. As regards the engines,

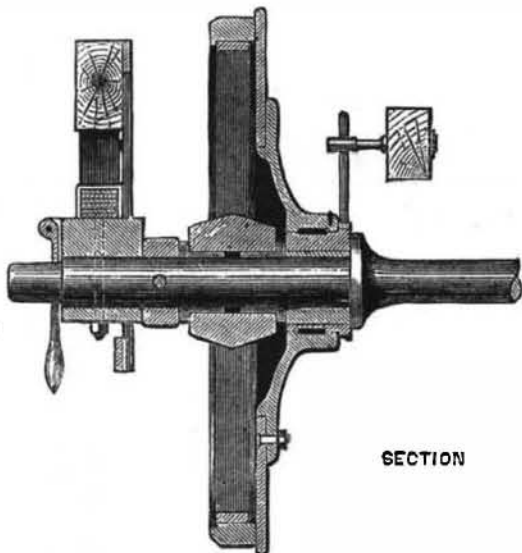
they are just like ordinary level-line locomotives trusting in the descent to very powerful brakes.

#### COMBINED ROAD AND RAIL TRUCK WHEELS.

In an article on Common Road Railways, we mentioned the desirability of wagons being so constructed as to be able to run on common roads as well as upon rails. We now illustrate the wheels fitted to wagons made by Messrs. Ransomes & Rapier, Ipswich, to enable this object to be effected. This wheel, which is shown in detail, is the invention of Mr. E. Perrett, of Westminster, and the wagons or



trucks to which they have been fitted are for use on the Dublin and Lucan steam tramway. As the line terminates some distance from the quays, the goods will be hauled by horses along the street to the terminus of the tramway, and then taken by steam to their destinations on the line, and *vice versa*. The special apparatus consists of a wheel loose on the shaft and provided with a flange, which, however, is quite separate from it and carried on its own boss; in the flange boss are two eccentrics, each of five-sixteenths of an inch throw; the inner one is fixed on to the shaft, and the outer one is prevented from turning



by a stop. When running on the rail the two eccentrics are placed so as to neutralize each other, and the wheel and flange rotate with equal angular motion, but by turning the shaft by means of a lever, and fixing it in that position, the flange is thrown up, and revolves at a higher level than the wheel, thus enabling the wheel to run on the road. The trucks are provided with a fore carriage and pole for use when running on the ordinary road.—*The Engineer*.

#### NEW STEAM LINE BETWEEN NEW YORK AND FRANCE.

A NEW screw steamer—Chateau Lafitte—366 feet 25x41.1 x30, of 3,462 tons gross, and 450 horse power, with cylinders 45-inch and 82-inch by 50-inch stroke, built by Messrs.

Oswald, Mordaunt & Co., shipbuilders and engineers, Southampton, for the Compagnie Bordelaise de Navigation à Vapeur, Bordeaux, lately went on her official trial of six hours' run round the Isle of Wight, when, with a displacement of 4,400 tons, she averaged a mean speed of 12½ knots, with a strong tide against her for the greater part of the way. On the second trial for speed on the measured mile with 1,600 tons on board, she averaged a speed of 13.6975 knots, one run being 14.062, and the other 13.333. Her engines indicated 2,687 horse power everything working cool and satisfactorily. She is the pioneer of the new company's fleet which is intended for service between Bordeaux and New York.

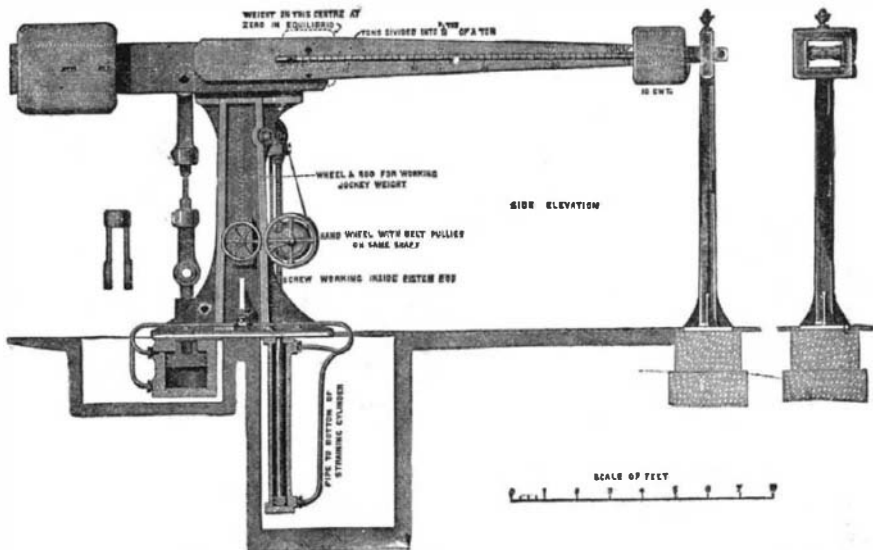
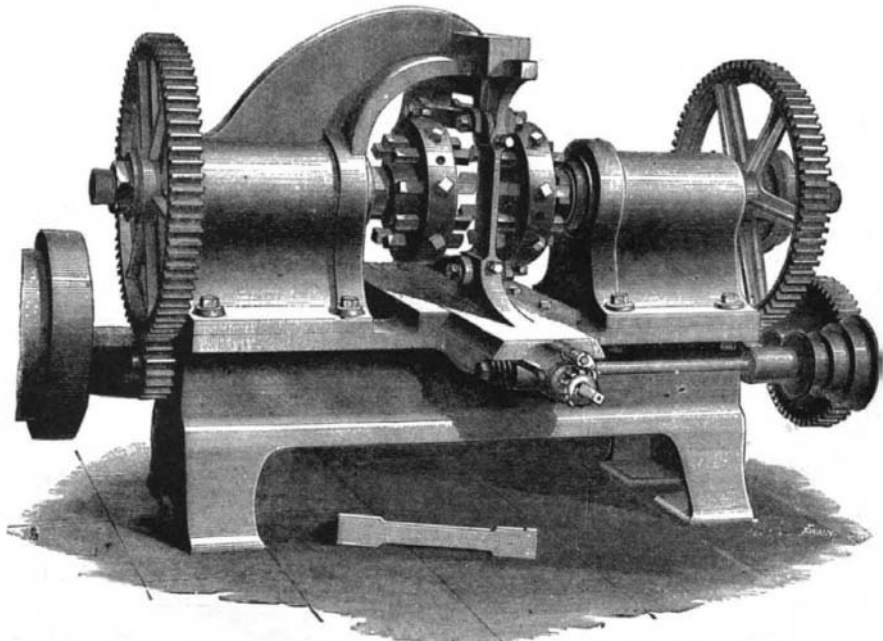
#### IMPROVED TESTING MACHINE.

In order to meet the increasing demand for mild steel ship and boiler plates, and also to carry out the requisite tests—tensile—specified by the Admiralty, Board of Trade, Lloyds' and Liverpool Registry, Bureau Veritas, etc., the Steel Company of Scotland found it necessary to have a machine capable of getting through a great number of tensile tests in a comparatively short time with precision and accuracy, and also to save the delay and inconvenience to which shipbuilders and boiler-makers were subjected when the materials had to be tested at their own yards.

Through the inefficiency of the hand-moved machine at the works, the machine we illustrate was designed by Mr. Thomas Williamson, works manager to the Steel Company of Scotland, and was made by Messrs. Westray, Copeland & Co., of Barrow-in-Furness. It has been in use for about two and a half years, and has been found to fulfill all the requirements in a satisfactory manner. The average number of tensile tests, for several months' actual work, was ninety per day of nine hours, or ten per hour, and the machine is capable of breaking one test piece every two minutes with perfectly accurate results, whence it becomes a question of measuring, checking, calculating, and reducing the strains per square inch, etc., in order to keep pace with the work of the machine. The labor has been reduced by one-half, while the work done has been increased about two-thirds per day, thus effecting a great saving in time and labor.

The machine is driven by two hydraulic rams, the small one for forcing and the large one straining. The small forcing ram—pump—is worked by a screw driven by worm gear and strap by power from line shafting, which arrangement gives a steady flow of pressure in the large cylinder, and does away with the objectionable intermittent reciprocating action of the ordinary plunger pumps, which may affect the real accuracy of a test when strain has gone beyond the limit of elasticity. The capacity of the forcing to the straining cylinder is such that the cubic contents of both are nearly equal, so that the displacement is nearly the same at either side of the piston, the one forcing and the other drawing, the water leaving the bottom side of the large ram while it is being forced down on the top side; therefore, when a piece is being tested and it breaks, the water under the ram acts as a stop and so prevents it from falling through any distance, and thus causing a sudden jar on the ram or steelyard levers, which jar is injurious to the knife edges of the machine.

The levers are compound and of the first and third orders, are graded 100 to 1 and balanced; the fulcrums have long knife bearing edges, viz., one inch equal to five tons, and are hardened to wear well. The traveling jockey weight, which is 10 cwt. standard imperial weight, runs on rollers guided by a groove, and can be worked automatically or by hand out and in on the main lever, which is just kept floating at the level of a finger pointer fixed to the column. The jockey weight is worked by a quick pitched screw through the center of the main lever, which is in turn worked by a pair of small toothed wheels, one of which is fixed to the machine column, and the other to the lever and on the dead center of the first lever. The pitch line of the toothed wheels being exactly in a line with the dead center knife edge, the motion at this point is virtually nothing. It is at the same time at right angles to the line of knife edge, consequently cannot disturb the sensitiveness of the steelyard when in operation. The machine is fitted with strong steel links, the top one being on knife edges on the lever, and the bottom one receiving the screw for adjusting the length for the test pieces; the screw is secured inside the trunk of a large ram. The ends of the links for receiving the test-pieces have round sockets with circular glands let into them, into which are fitted the tapered grips, so that the grips can be adjusted and turned in either direction, either to stand across or lengthways of the machine. The machine is specially adapted for tensile testing, but can be easily made to do either compression or bending testing if required. The machine is compact and easily got at for repairs, examining and readjusting knife edges; it takes up little space, and the gearing, being a worm and screw driven by belts, is noiseless. The levers, links, and ram are made of Hallside steel.



FIFTY-TON TESTING MACHINES, DESIGNED BY THOS. WILLIAMSON.