This method of testing is hardly out of the experimental stage, but is of considerable interest, as it is the first machine designed to record, not only the number of bends, but the bending effort of each bend.

Test for Welding and Hot Working.—A very useful test is to take two pieces of the material about 1 inch square and weld them together, as shown at *a, b* in the sketch (fig. 231). A $\frac{1}{2}$-inch to $\frac{3}{4}$-inch hole is then punched at *c*, and while still at a full red heat this hole is expanded by means of taper drifts until it is about $2\frac{1}{2}$ inches in diameter, or nearly three times the cross-section of the specimen. The sample should show no sign of opening in the weld, and the edges of the expanded portion should be free from cracks and perfectly smooth. Another test for welding is to weld two pieces as shown in fig. 231 at *e, f*, and while still hot bend the sample backwards and forwards five or six times across the weld, noticing if the weld show any signs of opening.

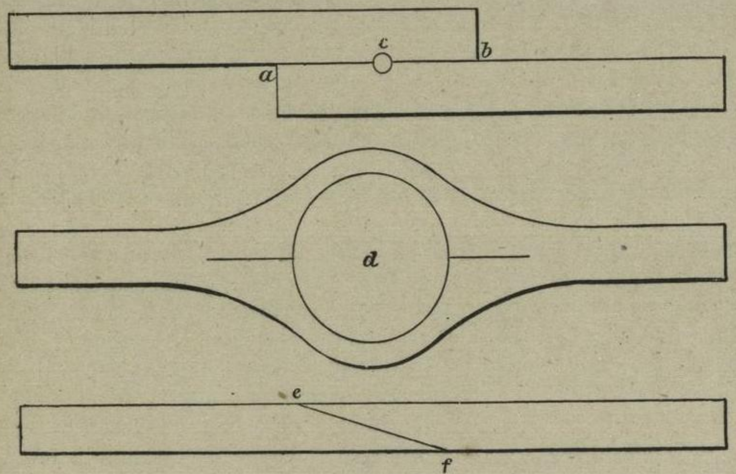

Fig. 231 —Welding and Drifting Tests.

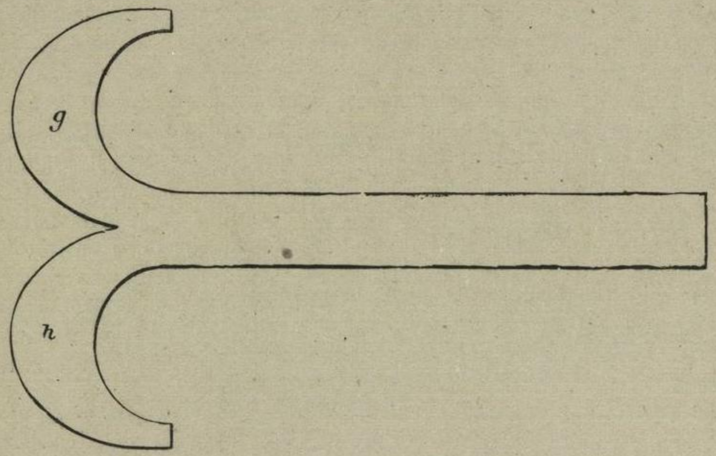

Fig. 232.—Plating-out or Rams-horn Test for Red Shortness.

Samples should also be hammered or plated out very thin, at different temperatures, to see if there are any signs of cracking at the edges, and what is known as the rams-horn test is sometimes used. It consists in hammering on an anvil one end of a bar from a welding temperature to dull redness until it is about $\frac{1}{8}$ of an inch thick, and then cutting down the centre of the plated-out portion, reheating and bending the two pieces, *g* and *h*, backwards, as shown (fig. 232). The edges should be smooth and free from cracks. When the material is required for boiler plate the above tests are excellent for testing its working qualities.

A cold bending test, either in a bending machine or by means of a hand or steam hammer, is also often made, and it is usually specified that the sample shall be bent over a round bar $2\frac{1}{2}$ times the thickness of the sample, and shall bend over parallel without fracture. In the case of dead soft material it should not only bend over parallel but stand hammering over close without fracture, and sometimes it is specified that, previous to bending, the sample must be quenched in water from a red heat, to make sure that the steel is not appreciably hardened by quenching. The above tests are applicable to all structural materials, such as plates, channels, angles, &c.

Testing Rails, Axles, &c.—A test very largely used for rails, tires, &c., is the falling weight or drop test, and it is one of the most useful of practical tests employed. It consists in allowing a weight to fall from a specified height a certain number of times on to the sample. In the case of axles and rails these are placed on bearings a certain distance apart, and the weight is allowed to fall on to the centre of the specimen, the deflection being noted after each blow. For axles the falling weight test varies according to the views of the engineer. For engine axles it varies from a 1 ton weight falling 30 feet, five times, to a 1 ton falling 25 feet, sixteen times, the axles resting on bearings usually 3 feet 6 inches apart, and being reversed after each, or each alternate, blow. They must after this treatment show no signs of failure, but the deflection will, of course, vary with the diameter of the axle. Figs. 233 and 234 are sketches of a machine used for testing axles by the falling weight. If equal deflection is desired the weight can be kept constant and the drop varied according to the following rule:—*

Drop varies as (diameter at centre)^3.

Thus, starting with an axle $4\frac{3}{4}$ inches diameter at centre, and 1 ton falling 20 feet six times as a standard, the drop for 1 ton on to $4\frac{1}{4}$ inches diameter axle will be—

$$\frac{h}{H} = \frac{d^3}{D^3} : h = \frac{(4\frac{1}{4})^3 \times 20}{(4\frac{3}{4})^3} = 14{\cdot}33 \text{ feet.}$$

This rule is said to give excellent results, and the following table is a record of a few typical drop tests showing the amount of deflection with each blow: the axle was reversed after each alternate blow:—

Diameter.	Weight.	Fall.	1st Blow.	2nd Blow.	3rd Blow.	4th Blow.	5th Blow.
Ins.		Ft. Ins.					
$4\frac{3}{4}$	1	20 0	3 -$3\frac{1}{4}$	Straight.	$2\frac{1}{8}$-$2\frac{3}{8}$	Straight.	$2\frac{7}{8}$-3
$4\frac{1}{2}$	1	17 6	$3\frac{1}{4}$-$3\frac{5}{8}$	Do.	$2\frac{3}{8}$-$2\frac{5}{8}$	Do.	$2\frac{3}{4}$-$3\frac{1}{8}$
4	1	12 0	$3\frac{1}{4}$-$3\frac{3}{4}$	Do.	$2\frac{1}{2}$-$2\frac{3}{4}$	Do.	$2\frac{7}{8}$-$3\frac{1}{16}$

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* *Engineer*, July 22, 1898, p. 75.

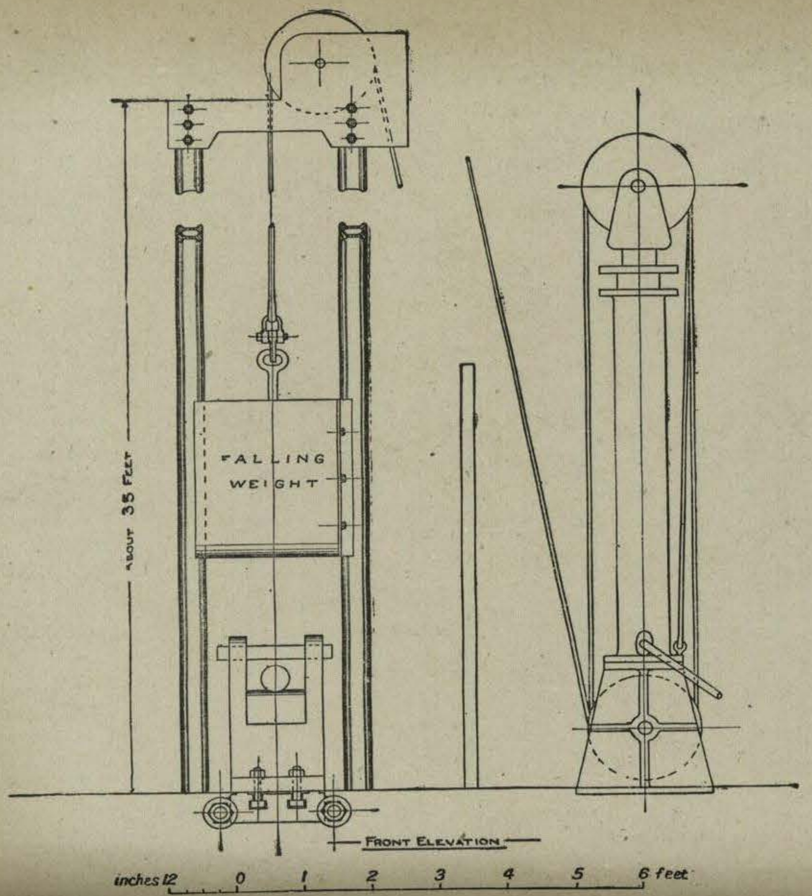

Fig. 233.—Drop-Testing Apparatus for Axles.

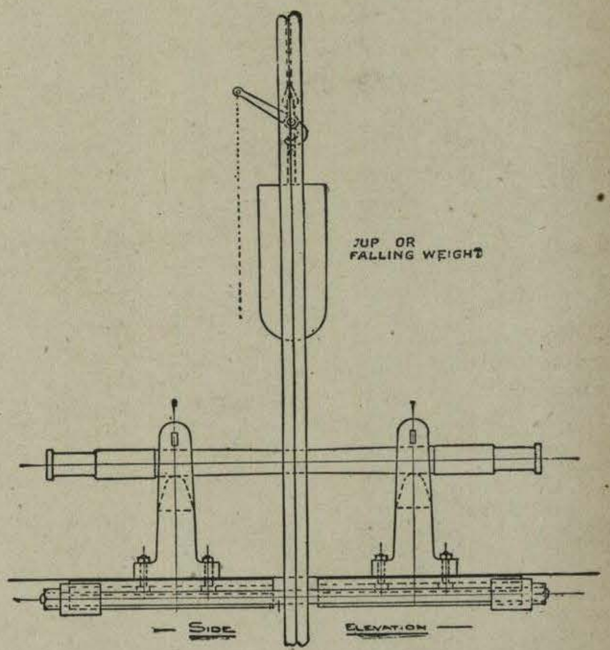

Fig. 234.

TABLE LIX.—Falling Weight of One Ton.

Description.	Material.	Dia.	Drop.		1st.	2nd.	3rd.	4th.	5th.	6th.	7th.	8th.	C.	P.	S.	Si.	Mn.	Elong. 4 In.	Red. of Area.	Ultimate Stress.
		In.	Ft.	In.	In.	In.	In.	In.	In.	In.	In.	In.								Tons per Sq. Inch.
Engine, . .	Siemens, . .	5	30	0	3½	Str.	3	Str.	2⅞	Str.	2¾	Str.	·27	·03	·02	·19	·50	23	42	32·84*
,, . .	,, . .	6¾	30	0	½	Str.	¾	⅛	¾	Str.	⅝	Str.	·41	·04	·02	·26	1·05	26	50	35·70*
Carriage, . .	,, . .	4¾	30	0	3¼	⅛	2⅞	¼	2½	½	...	...	·32	·05	·09	·07	1·1	22	42	32·66†
,, . .	,, . .	4¾	30	0	3¾	¼	2⅞	½	3¼	¼	3	⅝	·33	·04	·05	·03	1·01	22	36	30·70*
Waggon, . .	Bessemer, . .	4¾	20	0	3¼	¼	2⅜	¼	2¾	¼	...	...	·29	·04	·05	·09	1·08	25	50	35·0*
,, . .	,, . .	4½	17	6	3½	¼	2¼	¼	3¼	¼	...	...	·27	·04	·05	·05	·88	23	42	32·5*

* Close good. † Close broke.

TABLE LX.—Axles Failing under Test. Also Faulty Composition.

Description.	Material.	1 Ton Falling.	1st.	2nd.	3rd.	4th.	5th.	6th.	C.	P.	S.	Si.	Mn.	Elong. 4 In.	Red. of Area.	Ultimate Stress.
		Feet.	In.	In.	In.	In.	In.									Tons per Sq. Inch.
Waggon, . .	Bessemer, . .	20	3¼	¼	2¼	Str.	3	Broke	·25	·04	·11	·07	·95	26	50	32·84
,, . .	,, . .	20	3¼	¼	2⅜	¼	Broke	...	·24	·04	·09	·05	·99	23	50	30·0
,, . .	,, . .	18	3⅜	Broke	...	...	...	...	·28	·04	·10	·06	1·07	21	54	33·7
,, . .	,, . .	18	3	¼	2⅛*	¼	2¾	Broke	·27	·03	·10	·03	1·03	24	38	30·0
Foreign makers,	,, . .	20	3¼	Str.	3	Str.	3¼	Str.	·34	·06	·07	·23	·63	25	43	39·6
	,, . .	20	2¾	Str.	2⅜	Str.	2½	Str.	·32	·04	·16	·16	·74	3 In. 29	...	34·0

* Journal flew off at third blow.

The figures in columns marked 1st, 2nd, 3rd, &c., give the deflection under each blow of the falling weight, the axle being reversed after the first and then every alternate blow.

The axle after standing the drop test is nicked and broken, and tensile and bending samples are taken from it, such samples being cut out as far as possible away from the fracture.

Tensile tests are nearly always specified for axles, and these will vary with the kind of axle—*e.g.*, a straight or a crank axle and with the composition of the steel. Specifications of various engineers are given in the Appendix. In the case of rails tensile tests are rarely asked for, the drop test, with chemical analysis, being generally considered sufficient.

Sometimes axles are deflected to 90° under the falling weight and afterwards bent under the hammer until the ends touch, as shown in fig. 235. Crank axles cannot be tested under the falling weight and bending tests, tensile and sometimes bar tests have to be relied upon. The latter consist in taking a bar 9 inches long, 1¼ square, cut from the crank, placing it on bearings 6 inches apart, and giving it twelve blows with a 10-cwt. tup falling 7 inches, the bar being reversed after each blow. The test pieces in crank axles are either cut from A, as shown in the sketch (fig. 236), or from a piece, B, forged for this purpose on the end of the crank journal.

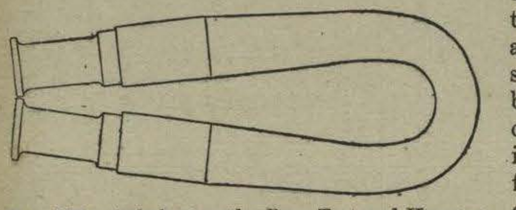

Fig. 235.—Axle bent under Drop Test and Hammer until the Ends touch.

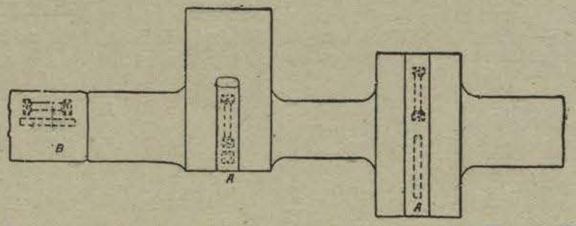

Fig. 236.—Crank Axle, showing Position from which Tensile Test Pieces are usually Slotted.

Tables lix. and lx., from Mr. Glover's article in the *Engineer*,* give the results of some good and bad axles under drop test, with the chemical composition and tensile tests.

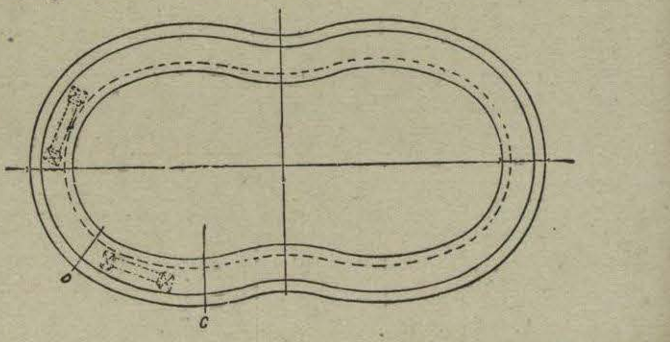

Fig. 237.—Tire after Drop Testing.—Samples for Tensile Tests are usually slotted from the portion of the Tire which is least distorted; positions as shown in sketch.

* *Engineer*, July 22, 1898, p. 76.

Tire Testing.—It is usual to have pieces cut from the tires selected by the inspector and tested for tensile strength, elongation, &c., and in some cases bending and drift tests are made. The falling-weight test, however, is the one which is almost universally applied, whether the others are or not, and consists in placing a tire in the *running position* and compressing it, as shown in Fig. 237, either by means of a falling weight or in a hydraulic press. Figs. 238 to 239 are sketches of a tire drop-testing machine, which is used at the Blochairn Works of the Steel Company of Scotland, for which I am indebted to the General Manager, Mr. Clark; this type of machine is used in most works, the press being comparatively little employed.

The tire is generally subjected to repeated blows of a weight of 20 cwts. falling through 10 feet, 15 feet, 20 feet, 25 feet, and 30 feet, until it is deflected ⅙ of its external diameter, and any tire which cracks before the required deflection is reached is rejected. The amount of deflection required varies with the class of tire, whether carriage, engine, or waggon, and some engineers stipulate for a deflection equal to ⅛ of the external diameter. The American Standard Specification specifies that the tire shall be subjected to successive blows from a 1 ton weight, falling from increasing heights until it shows a minimum deflection equal to $D^2 \div (40 T^2 + 2 D)$, the letter "D" being internal diameter, and the letter "T" thickness of the tire at the centre of the tread. If the tire stands the falling-weight test satisfactorily, it is nicked and broken, and the fracture examined; samples are then cut out for tensile tests, and, when required, cold bending and drift tests.

The following table gives the results of the drop testing of a number of tires of different diameters, and it will be noticed what an important influence the diameter has upon the stiffness of the tire, as indicated especially by the two engine tires, which are of identical sections, the larger tire giving nearly double the deflection of the other:—

TABLE LXI.—Average Tests. Various Classes of Tires.*

Description.	Material.	Dia.	Analysis.					Tensile.			Falling-Weight Test.									
			C.	P.	S.	Si.	Mn.	Elong. p.c. in 4 In.	Red.	Ultimate Stress.	10 Ft.	15 Ft.	20 Ft.	25 Ft.	30 Ft.	30 Ft.	30 Ft.	30 Ft.	30 Ft.	30 Ft.
		Ft. In.									In.	In.	In.	In.	In.	In.	In.	In.	In.	In.
Engine,	Siemens,	5 1	·62	·04	·02	·28	·55	16	25	50·1	¾	2¼	3⅜	5⅛	6½	8	9⅜	10⅝	11¾	13
,,	,,	3 0	·50	·06	·02	·10	·91	16	24	43·2	⅛	½	1¼	2⅛	$3\frac{3}{16}$	$4\frac{9}{16}$	5¼	6⅞	7⅞	...
Carriage,	,,	3 0	·46	·04	·05	·16	·76	19	20	40·7	½	1⅜	2¾	4¼	5⅝	7	...	...	...	...
Waggon,	,,	2 8	·38	·04	·05	·19	1·20	19	36	39·6	1¼	3⅛	4⅝	5¾	7	...	...	...	...	...
,,	,,	2 8	·37	...	...	...	...	21	38	42·8	Compressed; 8-inch deflection.									
,,	Bessemer,	2 8	·34	...	...	...	...	17	24	39·5	1½	3¼	5¼	7½	...	...	...	...	...	...
,,	,,	2 8	·33	·04	·07	·08	1·31	22	45	40·4	Compressed; 8-inch deflection.									
											Bending.					Drift.				
Engine,	Siemens,	...	·52	·05	·03	·18	·81	15	23	46·6	53° broke.					1¼ in. cracked.				
Waggon,	Bessemer,	...	·31	·03	·04	·09	1·23	21	32	41·8	180° ,,					1½ in. good.				

Generally one tire from each cast of steel is selected for drop testing, and, in the event of failure, another tire is frequently tested by the engineer before condemning the entire charge. Sometimes tires fail owing to local

* *Engineer*, July 1, 1898, vol. lxxxvi., p. 1.

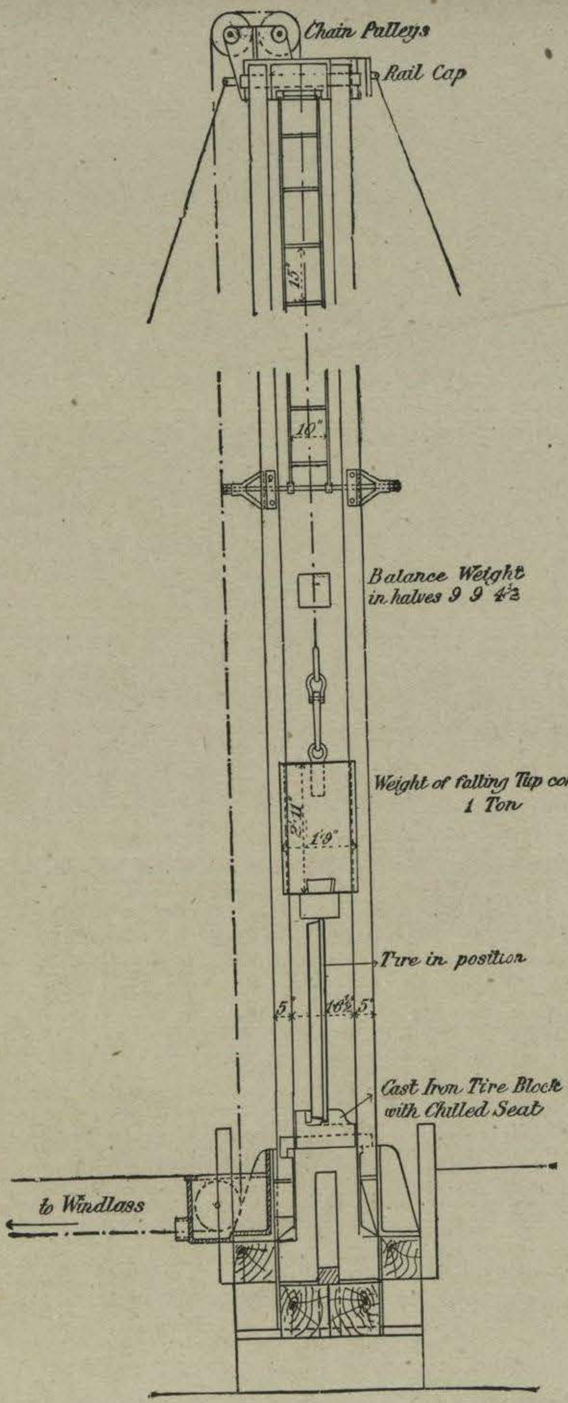

Fig. 238.—Drop Testing Machine for Tires.

Fig. 239.

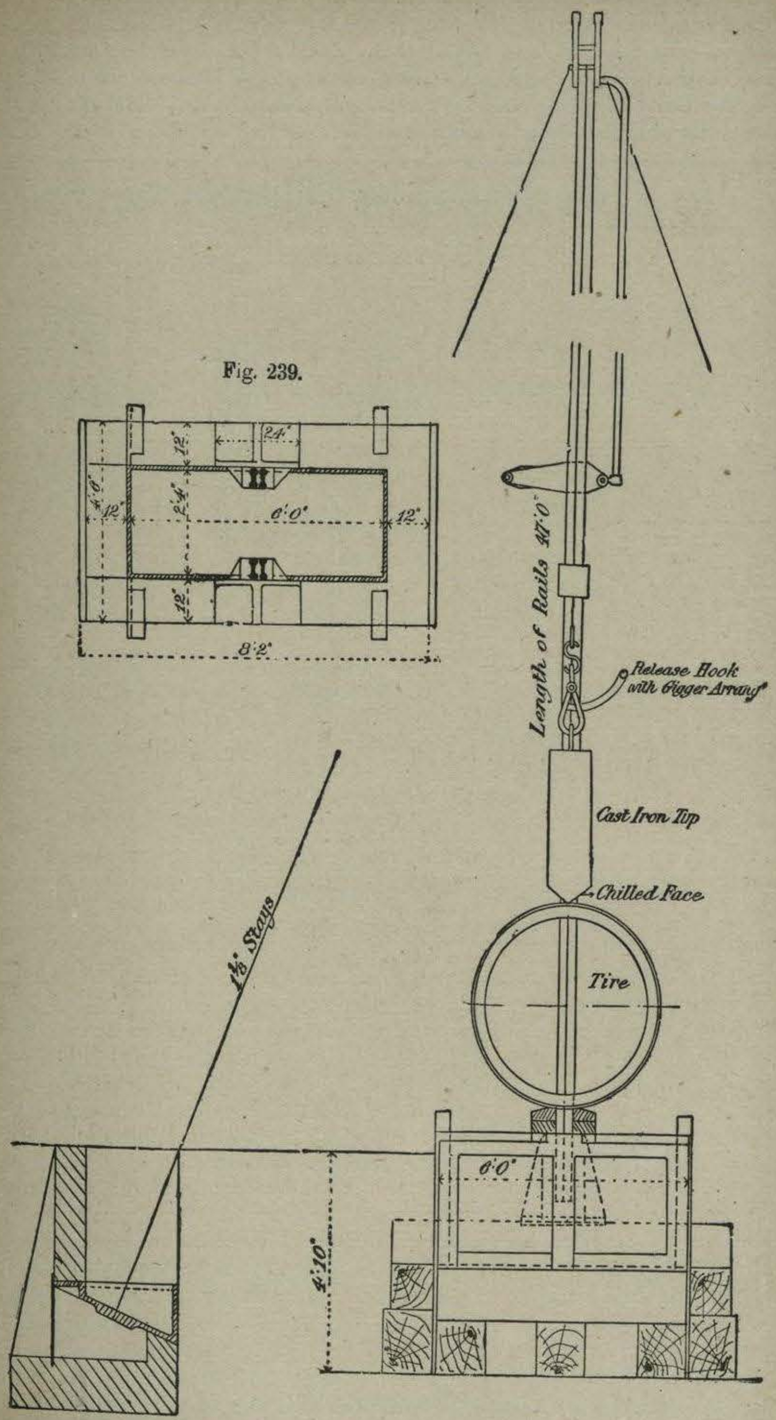

Fig. 240.—Drop Testing Machine for Tires.

chilling during manufacture, and these usually show a finer crystalline structure near the edge of the fractured surface. In such cases annealing will restore the ductility and enable them to stand the tests. This will, of course, have a general softening effect, reducing the tensile strength and increasing the elongation and reduction of area. In the following table, some results obtained by annealing are given :—

EFFECT OF ANNEALING ON WAGGON TIRES.*

Material.	Carbon.	Unannealed.			Annealed.		
		Elong. per cent. in 4 Inches.	Reduction of Area.	Ultimate Stress.	Elong. per cent. in 4 Inches.	Reduction of Area.	Ultimate Stress.
Bessemer, . .	...	13	18	48·7	25	50	41·9
,, . .	...	12	14	43·9	23	56	40·3
Siemens, . .	·38	18	34	38·6	28	42	35·7
,, . .	...	8	11	42·3	21	47	31·6

EFFECT OF CHILLING (TEST PIECE CHILLED AFTER CUTTING).

		Normal.			Chilled.		
Siemens, . .	...	25	47	38·6	...	nil	65·7

EFFECT OF OIL HARDENING (WHOLE TIRE TREATED).

		As Rolled.			Oil Hardened.		
Siemens, . .	...	19	29	36·4	23	35	38·9

The tensile tests have always to be made on short pieces on account of the curvature of the tire, usually parallel lengths of 2, 3, or 4 inches, being taken for the elongation.

Different engineers specify different limits for these tests, some preferring a harder material than others, as will be seen from the specifications given in the Appendix.

Springs.—Although springs may be used for numerous purposes the great bulk are required for railway work, and are either laminated, spiral, or volute. Generally no tensile tests are required, although some engineers specify these; most are content with some form of compression test coupled with a chemical analysis. In case of laminated springs, one or two bars are chosen out of every 100 before the spring is manufactured. These should be 30 inches long, and are cambered to a radius equal to eighty times the thickness of the bar, and then tempered to suit the particular class of spring. They are then scragged straight once, when the loss in camber should vary from $\frac{1}{8}$ to $\frac{5}{16}$, and on scragging straight again six times there should be no further loss. After the springs are fitted they are usually tested in a steam scragging machine similar to that shown in the sketch (fig. 241). In this machine, by means of an eccentric valve motion, the length of stroke can be varied to any required extent. The following tests, according to Mr. Glover,* are those more generally specified for laminated, volute, and spiral springs, the particular test selected depending upon the engineer :—(1) They may be scragged either straight or until half the camber is removed; or (2) until the spring is deflected 1 inch per foot of span. Thus a carriage spring 7 feet long must deflect 7 inches, and a short stiff engine spring 3 feet 6 inches long must deflect $3\frac{1}{2}$ inches; or (3) a load 40 to 50 per cent. in excess of working load may be applied. In

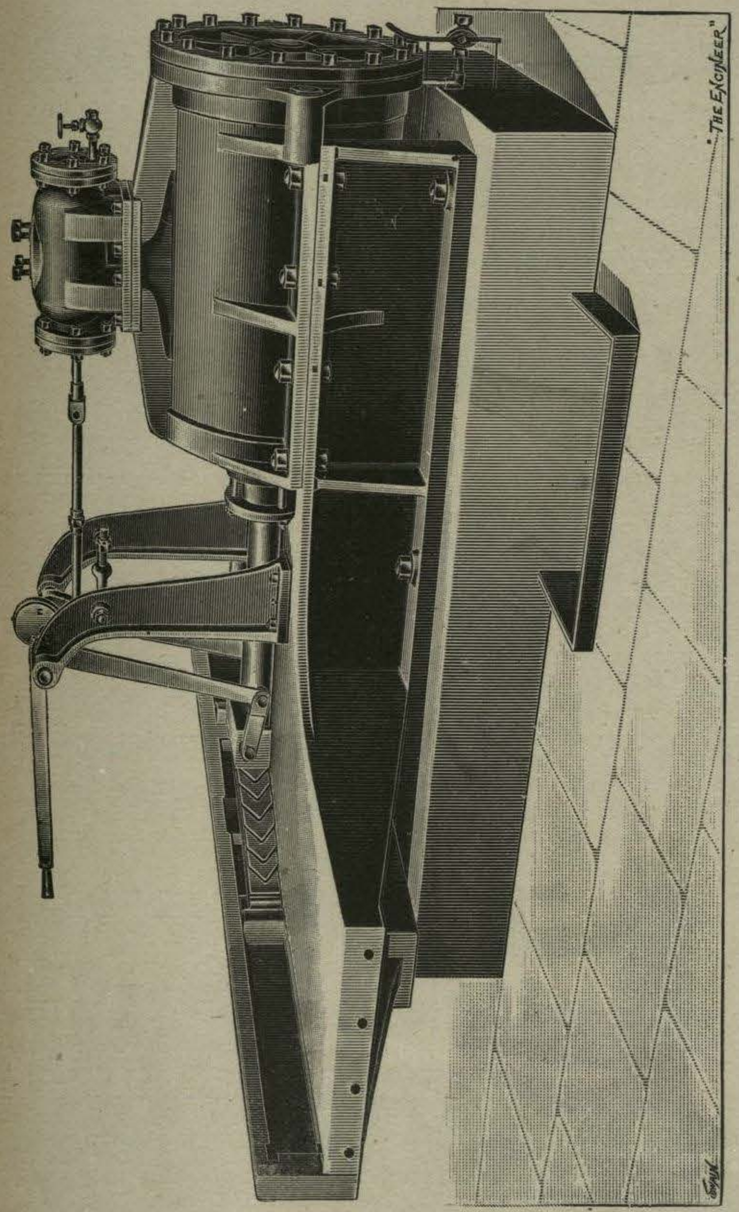

Fig. 241.—Spring Scragging Machine. From the *Engineer*, Aug. 5, 1898.

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* *Engineer*, July 1, 1898.

* *Engineer*, August 5, 1898, p. 130.
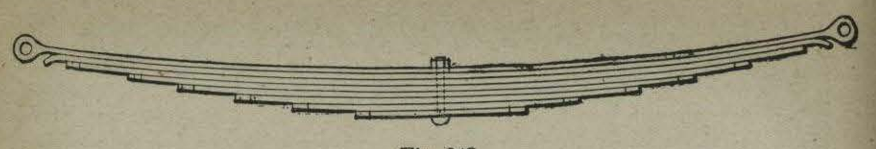
Fig. 242.

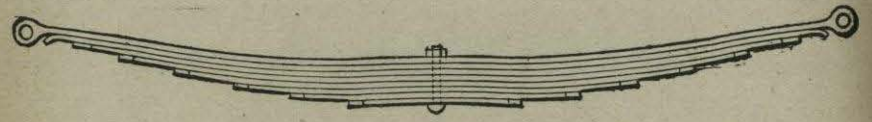

Fig. 243.

Fig. 244.

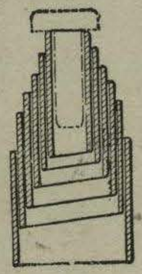

Fig. 245.

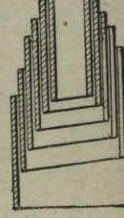

Fig. 246.

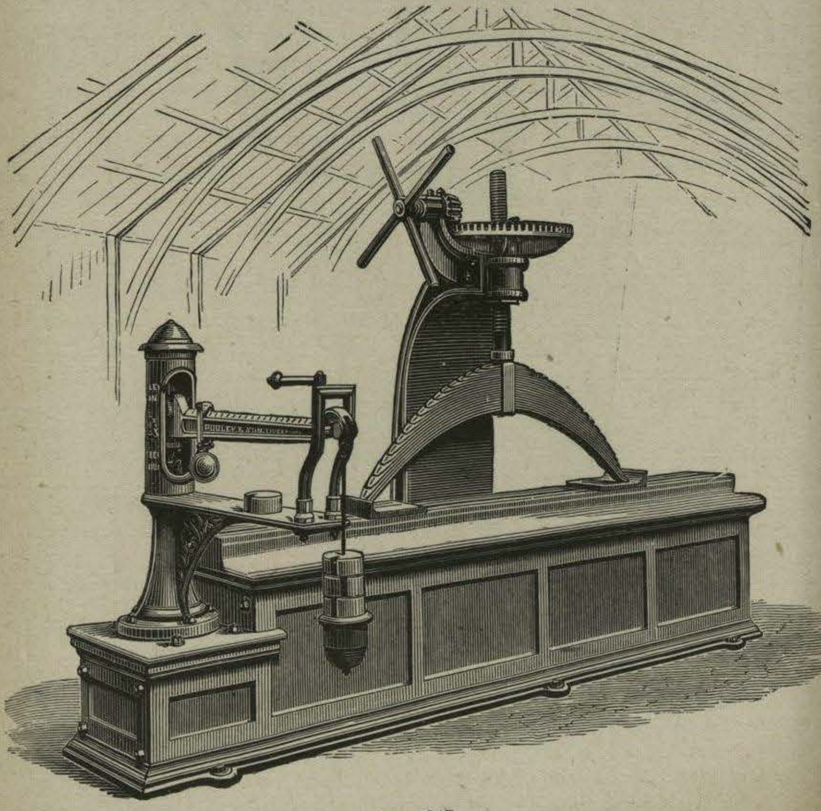

Fig. 247.

all these cases the spring must resume its former camber when the load is removed, which camber should not be more than $\frac{1}{4}$ inch above that specified for engine and carriage-bearing springs, and $\frac{1}{2}$ inch above for carriage and waggon buffer springs; nothing is allowed below specified camber in any case. Long springs when scragged should come up in one regular curve, fig. 242, and not as fig. 243, which shows want of evenness in tempering.

After scragging, springs are inspected for workmanship; the plates should bear on each other at the points. A good plan is to undo one spring in every twenty-five or so, in order that this may be clearly shown (fig. 244), also the plates when bolted up should fit closely together along their whole length, any open spaces meaning bad setting. All plates split at the ends should be rejected.

In testing volute or spiral springs, they are usually compressed solid several times, and should then not lose more than $\frac{1}{16}$ inch camber, and when released should not be more than $\frac{1}{8}$ inch above—nothing below—the specified camber. In compressing volute springs it is sometimes advisable to put a pin with turned head (fig. 245) into the top scroll in order to prevent buckling or distortion (fig. 246).

A good test for uniformity of temper in a batch of springs is to specify a minimum load when the springs are scragged straight or to the maximum deflection. A weighting test is taken occasionally from each sort of spring; increasing loads are applied and the deflection noticed after each increase of weight. Fig. 247 shows a compact machine copied from *Engineering*, in which such tests are carried out; it is made by Messrs. Pooley, of Liverpool, and is suitable for any class of spring—spiral, volute, or ordinary laminated. The pressure is applied by screw gear, in this case shown as worked by hand, but in most cases driven by belting. Table lxii., from Mr. Glover's paper, gives the results of tests as carried out in such a machine.

Spring case buffers contain volute, spiral, or india-rubber springs, and may be tested at 1, 2, and 3 inches compression with certain specified weights; the spindles should be fair and the plungers a good fit, otherwise sticking and non-return of the buffer head occurs.

TABLE LXII.—SHOWING DEFLECTION OF SPRINGS COMPRESSED UNDER VARYING LOAD.

Type.		Length between Centres.	Number and Thickness of Plates.	Camber Unloaded.	Deflection, per ton.											
					1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	.	
		Ft. Ins.	Ft. Ins. In.	Ins.	In.	In.	In.	In.	In.	In.	In.	In.	In.	In.		
Engine, . .	Bearing, . .	2 10	10 5 × $\frac{1}{2}$	$2\frac{7}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$		
,, bogie,	,, . .	3 6	4 5 × $\frac{5}{8}$ 8 5 × $\frac{1}{2}$	$4\frac{7}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$		
,, . .	,, . .	Timmis' spiral	6 ins. dia., 2 ins. hole	$12\frac{5}{8}$ long	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{1}{4}$	...	...	...	...		
,, . .	,, . .	Spiral	$6\frac{1}{2}$ ins., $2\frac{1}{8}$ ins.	$12\frac{7}{8}$,,	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{3}{16}$	$\frac{3}{16}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{3}$	$\frac{1}{8}$	$\frac{1}{8}$	$\frac{1}{8}$		
					Deflection, per $\frac{1}{2}$ ton.											
					5.	1.	1·5.	2.	2·5.	3.	3·5.	4.	4·5.	5.	5·5.	6.
		Ft. Ins.	Ft. Ins. In.	Ins.												
Carriage, . .	Bogie bearing,	5 0	9 $3\frac{1}{2}$ × $\frac{1}{2}$	6	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{5}{8}$	...	...	...	...
,, . .	Buffing, . .	5 8	2 3 × $\frac{7}{16}$ 18 3 × $\frac{3}{8}$	15	$\frac{11}{16}$	$\frac{15}{16}$	$\frac{15}{16}$	$\frac{7}{8}$	$1\frac{5}{16}$	$1\frac{1}{8}$	1	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{8}$	$1\frac{1}{16}$
10-ton waggon,	Bearing, . .	3 9	9 4 × $\frac{1}{2}$	6	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{4}$	$\frac{3}{16}$
7-ton ,,	,, . .	3 9	7 4 × $\frac{1}{2}$	7	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{5}{16}$	$\frac{5}{16}$
Waggon, . .	Buffing, . .	5 $11\frac{3}{4}$	1 3 × $\frac{7}{16}$ 18 3 × $\frac{3}{8}$	$14\frac{1}{2}$	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{4}$	...	...
Horse-box, .	Bearing, . .	4 0	7 4 × $\frac{1}{2}$	$3\frac{1}{2}$	$\frac{11}{16}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{11}{16}$	$\frac{11}{16}$	...	...	...	...	...	...	...

CHAPTER XV.

CARBON AND IRON.

THE mutual relations of Carbon and Iron is a subject which, until comparatively recent years, had not been systematically investigated. While the peculiar characteristics possessed by steel have been recognised from the very earliest times, yet the explanation of the phenomena of hardening, tempering, and annealing, constituted problems the solution of which became possible only by the higher development of more exact processes of chemical analysis, and investigation involving the application of technical skill of a high order. It was not until 1781 that the chief cause of the phenomena referred to was shown by the Swedish chemist Bergman to be the presence in steel of varying, though small, amounts of Carbon.

Many and varied were the recipes of early writers for the treatment of steel, but all knowledge of the subject was empirical, the nature of the fluid employed for quenching being regarded as the secret to successful treatment. The constitution and behaviour of steel formed a wide field for the speculations of supporters of the doctrine of Phlogiston, and the eminent chemist Stahl, while recognising the essential identity of iron and steel, held the belief that the difference lay solely in the relative richness of the latter in Phlogiston. The developments of physical chemistry have led us to regard changes occurring in solid matter, such as steel, as due to molecular disturbances.

These modern views were foreshadowed in a remarkable manner by Reaumur, who regarded steel as containing in its molecules Sulphurs and Salts which by heating were driven out from the molecules into the interstitial spaces, and that by sudden cooling the particular conditions existing at any temperature were preserved. Bergman, to whom reference has already been made as having established the fact that steel differs from iron in containing small amounts of Carbon, also conceived the possibility of the iron itself being allotropic at different temperatures. Although anticipating in a remarkable manner the views of modern workers, as will be shown later, Bergman seems to have been influenced, in common with other writers of this period, by the necessity of adhering to the conception of Phlogiston.

The Direct Combination of Iron and Carbon.—The verification of Bergman's statement with respect to iron and Carbon quickly followed when Clouet, as pointed out by Sir W. Roberts-Austen, melted a small iron crucible containing a diamond and obtained as the result a fused mass of steel. The question of the possible effect of furnace gases was eliminated by Pepys, who, in 1815, heated iron wire with diamond dust *in vacuo*, while later Clouet's experiment has been repeated by Sir W. Roberts-Austen, who used electrolytic iron and performed the operation *in vacuo*. As to the possibility of direct carburisation of the iron there can be no doubt, but it would seem, as the result of this experiment, that combination does not take place until a full red heat is reached. This disposes of the assumption made by Le Play and early writers that the cementation of iron necessarily involves the action of Carbonic Oxide, and shows that Carbon may diffuse into and combine directly with iron.