formity in the heat of the billet, may cause the rupture to occur on one side of the centre, in which case the thickness of the walls of the tube will not be uniform. The irregularity once introduced cannot afterwards be rectified. Some weldless tube makers also consider that the severe stresses set up by these processes are liable to damage the material, and as the percentage wasted by the drill is so small, while the drilling ensures the removal of the most impure and unsound portion, they prefer to adhere to the original drilling process.

The Erhardt Process, used in Germany,* consists in forcing a mandril through a solid billet raised to a full red heat, in much the same way as the drilled billet is pierced in fig. 548. The blank is square in cross section, and is placed on end in a circular mould; the wall of the mould forming a circle circumscribed around the corners of the billet, centres and supports it against the thrust of the mandril, while the material displaced by it fills up the vacant spaces between the blank and the mould. The tubes are finished as in other processes, except that the very large ones are rolled like tyres, but between rolls having plain barrels, laid horizontally as in an ordinary mill. To avoid a continuous heavy pressure over the whole length of the barrels, the lower roll has its ends rocked backwards and forwards horizontally, so that, when looked at from above, the top roll, on which the blank is threaded, is constantly crossing the bottom one to and fro.

The Erhardt Company exhibited a weldless shell for a locomotive boiler made by this process at Dusseldorf Exhibition in 1902, and it is said are prepared to supply weldless rings for forming boiler shells up to 15 feet in diameter, made in this manner (see also p. 772).

Robertson's Process, used in this country, is another method of piercing a solid blank, which in this case fits the mould and is pierced horizontally, a pressure plate being kept in contact with the end of the billet to prevent the pressure of the mandril tearing its end open.†

Many other processes have been patented, and some worked, but not on such a scale as to give them much commercial importance.

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* English patents—3,116, 1891; 7,497, 1892; 854, 1896.
† English patents—1,627, 1890; 11,436, 1891.

CHAPTER XLIII.

WIRE-DRAWING.

The Process of Wire-drawing.—The rods intended to form wire are usually rolled down to No. 5 Gauge = 0·212 inch diameter, though some makers roll them as small as No. 8 Gauge = 0·160 inch. Any further reduction must be effected by drawing the rods cold through a series of round tapered holes in a die, each hole being smaller in diameter than the previous one.

The coils of rod as received from the rolling mills, are pickled in dilute Sulphuric or Hydrochloric Acid to remove any scale, and the acid removed by washing the pickled coils in lime-water, which neutralises any remaining acid, and the washed coil is sometimes dried in an oven. If the rod were drawn unpickled, the dies would be very rapidly cut by the scale; but care must be taken in the pickling, for, if carried too far, the rod becomes "rotten" and breaks in the drawing.

The prepared coil is taken to the drawing shop and dropped on to a drum running loose on a vertical spindle in convenient proximity to the drawing-bench, which consists of a series of revolving drums, technically known as "blocks," slightly tapered from the bottom upwards. Each block revolves on a vertical spindle which projects through the top of the bench, and all are driven by means of bevel wheels from one horizontal line shaft running beneath the bench. Each block can be started or stopped independently without stopping the line shaft.

Fig. 563, Plate xlvii., shows a wire-drawing block as made by Messrs. John Hands & Sons, of Birmingham, which is worked as follows:—One end of the coil of rod, if it has not been already pointed by heating and hammering at a smith's fire, or with small swaging hammers driven at a high speed, is pointed at the bench by means of a small pair of hand rollers having a pair of tapered grooves cut in them; or, for certain qualities of wire, by means of a file. The sharpened end is passed through the hole in the die placed to the left of the stops, A, and is gripped by the pair of pincers, B, attached to the chain, C; by placing the foot on pedal, D, the clutch, E, sliding on a feather on the shaft, F, is connected, by means of the teeth on their adjacent surfaces, to the small drum, G, loose on the line shaft, F. The chain is thus wound up and draws the end of the rod through the die placed at A, until the pincers, B, strike the eye on the end of the lever, H, and thus throw the clutch, E, out of gear with the drum, G. The pincers are then made to take a second grip of the wire as close as possible to the die at A, and a further length is drawn through, and the operation repeated until enough wire is drawn to go nearly twice round the circumference of the drum. That part of the wire squeezed in the pincers is spoiled, but most of this loss may be avoided by giving to the drawing-in gear enough travel to pull through the dies, with one grip, as much wire as will wrap far enough round the drum to prevent its slipping.

When this has been done the die is removed to the left of the stop, J, and the end of the wire secured in the grip, K, on the top of the block, L. During this operation the block remains stationary, having been raised for the purpose by means of the pedal, M, and rods, N, so that the driving pins, O O, are lifted clear of the plate, P, which revolves with the vertical shaft, Q. On removing the foot from the pedal, M, the block falls, the pins, O O, then enter corresponding holes in the revolving plate, P, which turns the block in the direction of the arrow. The wire is drawn through the dies and wound in a coil on the block until the whole length of the rod has passed through. The block is provided with a flange at its lower end, so that when the tension is relieved by the last end of the rod leaving the die, the coil shall not slide down the block, which is tapered slightly towards the top to facilitate the lifting of the coil of wire from it. The coil of wire is then ready for sale, or, if smaller sizes are required, it is passed on to other blocks, by which it is drawn down to a still smaller diameter.

The blocks on which the first few drawings are effected are known as "rippers," and are about 28 inches diameter, decreasing successively with the decrease in the diameter of the wire until they are only 6 inches or 8 inches diameter, for finishing very fine wire.

Continuous Drawing.—The most recent improvement in wire-drawing machinery is the employment of the continuous principle, by which the rod or wire is drawn through a succession of dies simultaneously, the number employed being limited by the amount of reduction possible before the wire requires annealing.

The amount of reduction in each die is determined by the strain which the reduced wire will stand without injury, and it is therefore impossible to put a series of dies in a line, one behind or ahead of the other, and attempt to draw the wire through the series by applying force to the finally reduced wire.

The difficulty is overcome by placing a power-driven barrel between each die and winding the wire two or three times around every barrel in succession. A pull is thus obtained from each revolving barrel sufficient to draw the wire through the die placed in front of it.

Fig. 564 shows a machine built for this purpose by Messrs. Rankin & Ludington, Limited, Waterbury, Conn., U.S.A. The wire is passed through the first die, on the left in the illustration, and given two turns round the first revolving barrel, which gives a sufficient grip to draw the wire through the first die. The end of the wire is then passed through the second die and given two turns around the next barrel, and so on, through as many dies and round as many barrels as the machine is designed for.

Each one of these revolving barrels, beginning with the second, is driven faster than the preceding one, the increase of speed being sufficient to take up all the elongation of the wire and allow a small amount of slip in addition. When the wire leaves the last revolving barrel, it is passed through a finishing die, and the power derived from the vertical drum on the right is sufficient to pull the wire through the last die and to coil it.

The illustration shows a machine fitted with 5 dies and 4 revolving barrels arranged tandem in one straight line. The machine can be lengthened or shortened as required, by adding or taking away one or more barrels and dies with their corresponding frames.

Another compact form of continuous wire machine, of very simple construction, by the same builders, is shown in fig. 565. This machine is more particularly intended for further reducing wire which has already been drawn on a larger drawing machine.

Nine drawing rolls or barrels of narrow width, with hardened steel rings on the outside, each larger in diameter than the preceding one, in proportion (with a marginal excess) to the elongation effected in the wire by the process of drawing, are keyed side by side on the same spindle,

g Bench. [To face p. 912.

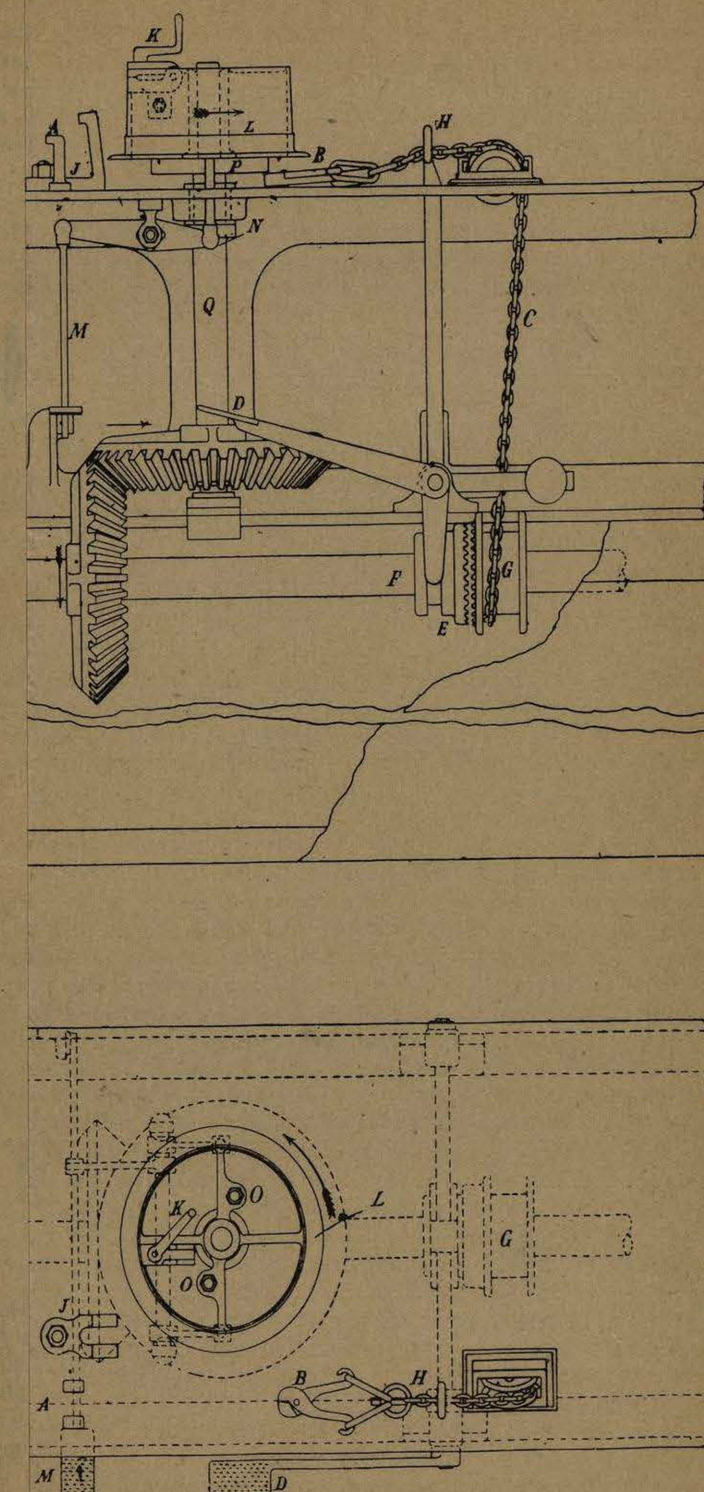

PLATE XLVII.—Wire Drawing Bench.

[To face p. 912.

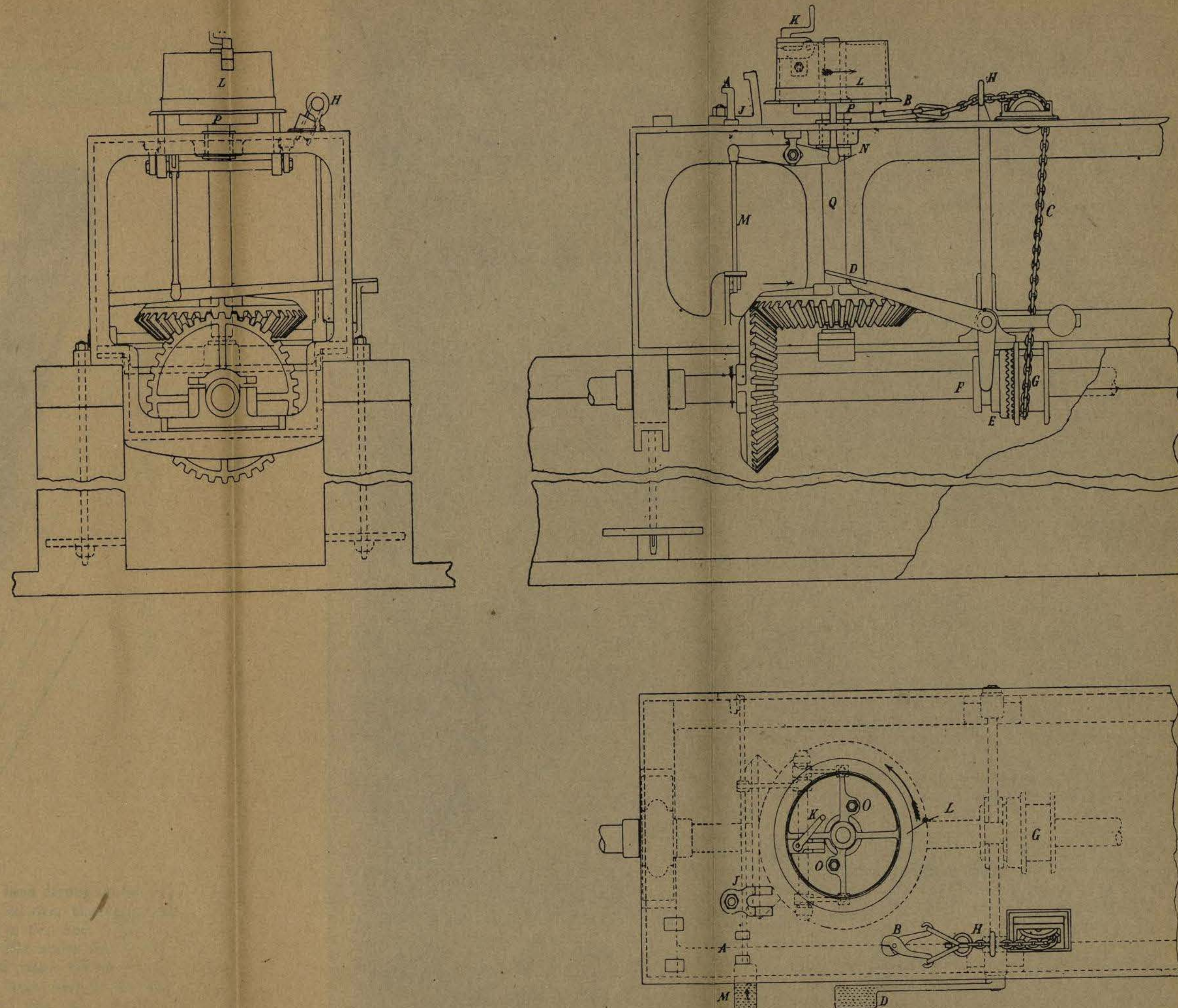

Fig. 563.

forming a cone which is driven by gearing. A second set of rolls of the same size as the first, placed parallel with them, run loose on a spindle.

The drawing in or "stringing up" is done in the following manner:— The end of the wire, having been pointed, is pulled through the largest die a sufficient distance to enable it to reach round the drawing roll or cone, and to enter the next die in the downward progression, and this operation is con-

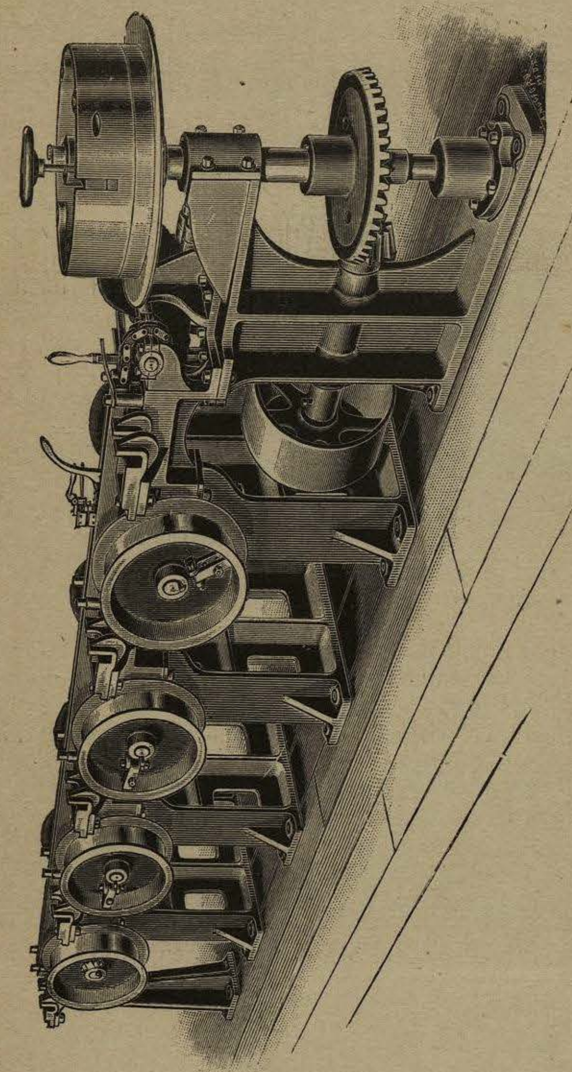

Fig. 564.—Continuous Wire-drawing Bench.

tinued until the whole series of dies have been strung on the wire. The wire, as it comes through the largest die, is led over the upper side of the smallest driven roll, round which it is given two and a half turns, and, leaving the under side of the roll, passes to the under side of the smallest idle roll; it makes a half turn round it, and passes thence from the upper side through the second die on to the next larger step of the driven roll, and so on till it reaches the largest step of this roll. Round this it is given two turns, passing off at the top side, whence it enters the finishing die, from which it is taken on to the drum on the vertical spindle to the right of the machine, which is driven by a belt.

With this machine, as designed, there are ten dies, and each die is carried in a separate cup and is flooded by a copious stream of lubricant poured over it by a small centrifugal pump (which is a part of the machine), and the under side of the conical rolls runs in a bath of similar lubricant, thus keeping the wire and dies cool. The bracket on the left carries the coil of wire which is to be drawn, the finished wire passing on to the drum on the right, from which it is removed when finished.

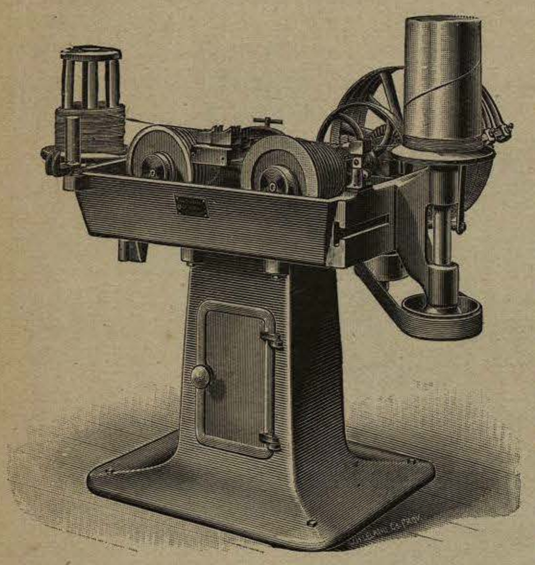

Fig. 565. -Continuous Wire-drawing Bench for Fine Wire.

Other forms of machines are used, working on the same principle, with a series of inclined rolls, but the two designs illustrated will serve to show the essential principles on which continuous machines are worked.

Continuous drawing has proved much more successful for copper and brass than for steel wire, which is so much hardened by the process as to greatly increase the wear on the dies. Some more suitable material must be discovered from which to make dies, before the process can be much further developed for drawing steel.

Speed of Drawing.—The speed at which the wire may be drawn varies with the nature of the material and the amount of reduction effected at each pass, and usually lies between 100 and 400 lineal feet per minute, but speeds of 500 to 700 feet may be sometimes employed. The small machine (fig. 565) is said by the makers to be capable of drawing certain classes of wire at speeds as high as 900 feet per minute.

Reduction Effected.—The reduction effected in any one pass likewise varies according to the material and its condition at the moment of drawing, the first pass after annealing may be arranged to give a greater reduction of section than can be effected after the wire has been hardened by previous drawings. Originally the number of the wire represented the number of passes it had gone through, but now a reduction of $1\frac{1}{2}$ or 2 "numbers" is more frequently made at each drawing, and for the first passes of the rod a reduction of 3 or 4 numbers at a time is not uncommon practice. A reduction of 6 numbers even has been accomplished on No. 5 rods. Heavy draughts, however, wear out the dies rapidly, and if long lengths are being drawn the two ends of the wire are not alike in size, and the limit of economy or expediency is reached before the limit of possibility. Generally it is found advisable for most purposes to reduce the section by about 20 or 25 per cent. of its area at each pass, though when it is desired to harden the wire a reduction of twice this amount is effected in one pass.

The wire is considerably hardened by passing through the die, even the softest being found to be considerably stiffer and more resilient after drawing. After a number of passes, varying from two to six, according to the quality of the steel being drawn and the amount of reduction at each pass, it becomes too hard and brittle to be drawn down any further, and must be annealed to soften it. This is effected by placing the coils in cast-iron pots made as airtight as possible, raising them to a blood-red heat, and then allowing the temperature to fall as slowly as possible. This process may have to be repeated several times before the rod is reduced to the smallest sizes, and as it needs pickling after every annealing to remove the scale, there is a considerable loss from scale and acid; moreover, the repeated annealing in the small sizes causes a slight loss of tensile strength due to the slight decarbonisation which occurs. Various devices have been proposed or tried to avoid scaling, such as filling the annealing pot with some inert gas which will not oxidise the wire, but so far with no great amount of success; the pickling has been dispensed with by bending the wire to and fro between a succession of rollers set out of line, thus cracking off the larger part of the scale. By employing the continuous process of drawing small reductions are effected at each pass and the speed of drawing might be increased, so that the wire could be finished almost as quickly as by the older method, and as light reductions do not harden the wire to the same extent as heavier ones, a considerable saving in cost might result in the case of the small sizes.

The Dies.—The dies through which the wire is drawn are, for the large sizes, frequently made of hard white cast-iron, and such dies when worn are rimered out for the next larger size; the smaller sizes of wire are drawn through self-hardened steel—that is to say, that the steel is not hardened by quenching, but is used in the state in which it is when it leaves the hammer; the holes in these dies are renewed when worn by hammering up the smaller end of the hole, and driving into it a tapered punch of the exact diameter needed. The steel in the dies employed for the best work is so high in Carbon that it might almost be considered white cast iron, were it not that it is malleable when hot. By the exercise of great care in the heating and the use of light hammers, the 4-inch square ingots, into which such metal is cast, are hammered down to about $1\frac{1}{2}$ by 2 inches to form the dies. It contains frequently more than 3 per cent. of Carbon, all in the combined form, is high in Manganese, and contains very little of any other metalloids whatever, particularly Phosphorus and Sulphur, the latter being present only as a mere trace. It would be impossible to harden such material by quenching it in water, as on any attempt to treat it in this manner it flies into small fragments. The finest grades of wire are drawn through gems, diamonds and rubies being chiefly used; they are fitted into a soft-metal socket much as a stone is secured by a jeweller, the metal being carefully bedded behind and hammered around them, the setting itself being held in a hole in a steel disc about $1\frac{1}{4}$ inch diameter.

To enable the wire to be drawn more easily, and to save the dies from undue wear, it is lubricated with oil or tallow for the larger sizes, down to about 18 or 20 G, after which soapy water or stale beer, or a fermented mixture of rye-flour in water, is more often employed; these processes are known as dry and wet drawing respectively.

For some purposes the wire is dipped in a solution of Sulphate of Copper, which deposits on it a very thin film of metallic copper, forming an excellent lubricant, persisting after several passes; it colours the wire more or less, and therefore, if a white colour is desired, it is not used for say three or four passes before the last. On the other hand, as it tends to prevent rust, it is usually employed before the last pass for wire which is used for upholstery springs and similar purposes.

Strength of Wire.—The increase in tensile strength conferred by drawing, even on dead soft steel, is very considerable. The following figures are taken from Mr. J. Bucknall Smith's excellent book,* where he states that the tensile strength may be raised as follows:—

Common Bessemer wire, . . .	to	40 tons per square inch.
Siemens wire, ...	„	60 „ „ „
High Carbon, ...	„	80 „ „ „
Crucible cast steel improved, . .	„	100 „ „ „
"Improved" cast "plough" steel, .	„	120 „ „ „
Special qualities of tempered and improved cast-steel wire may attain	„	150 to 170 tons.

A piano wire 0·0284 inch diameter tested at Watertown Arsenal showed the enormous strength of 462,870 lbs., or 211 tons, per square inch.

Quality of Steel Used.—The steel used for drawing into wire varies from dead soft basic steel, containing less than 0·1 per cent. C or under; telegraph wire, which must have as little electrical resistance as possible, contains usually 0·05 to 0·075 C; steel for wire ropes will have from 0·05 C if basic, to 0·50 C if acid Siemens or Bessemer; for springs steel is employed (usually acid Bessemer) containing 0·30 to 0·45 C, and for the best work crucible steel containing 0·6 to 0·9 C.

"Improved Steel," or "patented steel" wire is made by passing the wire through a heated muffle, into an oil bath placed as close to the muffle as possible, the oil being surrounded by a water jacket to keep down its temperature, whereby the steel is hardened; thence it passes through a bath of molten lead, in which it is tempered. All these appliances are placed as close together as possible, and the wire passed through tubes between one and the other to protect it as much as practicable, while heated, from the action of the air, the wire passing continuously right through the series of baths. A great variety of slight modifications are in use, the practice of each maker varying, but the object in view is the same in all—viz., to regulate the precise temperatures of heating, quenching, and tempering, and to exclude air as far as possible in the process, gas being in some cases used for this purpose. The process is usually applied before the last drawing.

A mild steel wire, having a tensile strength of about 50 tons per square inch when drawn, may have its resistance to rupture raised about 30 tons by such treatment.

"Plough Steel" Wire.—From experiments made by Dr. Percy, in 1886, on some plough steel wire (so-called because it was originally made for the purpose of dragging steam ploughs), the wire having been drawn from crucible steel made by Messrs. Thomas Firth & Sons, Limited, of Sheffield, and having the following composition—†

C, 0·828; Mn, 0·587; Si, 0·143; S, 0·009; P, nil; and Cu, 0·030
(no traces of Chromium, Titanium, or Tungsten),

it was found that the breaking weight of the wire was raised by successive drawings as follows:—

Diameter of Wire.	Breaking Weight in Tons per Square Inch.
0·191 inch.	90
0·159 „	100
0·132 „	115
0·093 „	154

* *Wire, its Manufacture and Uses*, by J. Bucknall Smith, p. 42. † *Ibid.*, p. 58.

"Bench Hardened" Wire is wire sold in an unannealed state, being still hard owing to the process of drawing.

Galvanised Wire.—Wire is "galvanised" to protect it from rust, most fencing wire, and the wire used for ships' cables, being treated in this manner. A slight alloying of the zinc with the steel of the wire takes place, and this reduces its strength, so that wire thus treated is never so strong as the black wire from which it is made. The process is conducted in much the same way as for sheets (see "Galvanising"), the wire being fed continuously through the pickling tank into the metal bath, and then passed through scrapers, and sometimes through sand in order to polish it; it is drawn through by winding the finished wire on to a drum. Smaller wires are frequently tinned for the same purpose, and are drawn after tinning to impart a bright surface.

Wire Gauge.—The diameter of wire is known by a number, which is measured by means of a wire gauge, consisting of a metal plate, in the edge of which are cut a series of slots gradually diminishing in size, each slot being marked with a special number.

For a long time the old Birmingham Wire Gauge, known as the "B.W.G.," was the standard. This originated about 50 years ago, and arbitrary as the divisions of this gauge seemed to be, there is little doubt that originally it was based on practical considerations, and that No. 0 represented the size of the wire rods as they came from the mill, and Nos. 1, 2, 3, &c., represented the size to which it was found in practice, that the rolled rod could be reduced by 1, 2, or 3 passes through a draw-plate. The variations in the percentage of reduction in size at different points is accounted for by the fact that the wire would stand much less reduction after several passes than it would do just after annealing: the sizes now have the appearance of having been selected arbitrarily and unreasonably, because circumstances have entirely changed owing to the use of different materials and appliances.

In addition to the B.W.G. a whole host of other gauges were used locally, while entirely distinct gauges were used for sheets. Sir Joseph Whitworth's proposal that the numbers should represent the thickness in $\frac{1}{1000}$ of an inch would probably have met with general acceptance on account of its extreme simplicity had it not reversed the common rule with which every one was familiar—namely, that in all gauges No. 1 represented the largest size, and that the size decreased as the "number" increased. With the object of avoiding the confusion, the Board of Trade prepared the Standard or Imperial wire gauge, known as the S.W.G., and by circular dated 4th September, 1883, gave notice that under the powers conferred upon the Board by the Weights and Measures Act of 1878, the new gauge would become the only legal standard on and after the 1st March, 1884.

The Brown & Sharpe wire gauge, prepared by the Brown & Sharpe Manufacturing Co., of Providence, U.S.A., at the request of the leading wire manufaturers of the States, is the recognised American standard.

The following table, compiled by Mr. R. B. Hodgson, of Birmingham,* gives particulars of the gauges which have been most generally employed.

In addition to sheet gauges, Mr. Thomas Hughes† gives a list of 52 different wire gauges which he found had been proposed or were in actual use—43 of them in this country. It is a matter for thankfulness that all these have been superseded by the Imperial Standard gauge.

* *The Practical Engineer*, Sept. 20, 1901.
† *The English Wire Gauge.* Pamphlet published 1879.

TABLE CXXII.—PARTICULARS OF VARIOUS WIRE GAUGES.

A	B	C	D	E	F	G	H	I	J	K	L
Descriptive Number.	Imperial Legal Standard Wire Gauge.	Stubbs' Wire Gauge.	Whitworth's Standard Wire Gauge.	Metric Equivalent.	Birmingham Wire Gauge, chiefly for Iron Sheets.	Fractions of an Inch for Gauge F.	Flat Iron Gauge. South Staffordshire Ironmasters' Association B.G.	Fractions of an Inch for Gauge H.	B.W.G. The old Birmingham Wire Gauge, traced back for 45 Years.	The old Birmingham Metal Gauge for Brass.	American, or Brown & Sharpe.
	inch.	inch.	inch.	m/m.	inch.	in	inch.	in.	inch.	inch.	inch.
0/7	·500	...	...	12·700	...	...	...	...	...	...	...
0/6	·464	...	...	11·785	...	...	...	...	...	...	...
0/5	·432	...	...	10·973	...	...	...	...	...	...	...
0/4	·400	·454	...	10·160	...	...	...	...	...	...	·46
0/3	·372	·425	...	9·449	...	...	·500	½	...	...	·40964
0/2	·348	·380	...	8·839	...	...	·4452	...	...	...	·3648
0	·324	·340	...	8·229	...	...	·3964	...	...	...	·32486
1	·300	·300	·001	7·620	·3125	5/16	·3532	...	·296	·0085	·2893
2	·276	·284	·002	7·010	·28125	...	·3147	...	·270	·0095	·25763
3	·252	·259	·003	6·401	·25	¼	·2804	...	·256	·0105	·22942
4	·232	·238	·004	5·893	·234375	...	·250	¼	·240	·012	·2043
5	·212	·220	·005	5·385	·21875	...	·2225	...	·213	·014	·18194
6	·192	·203	006	4·877	·203125	...	·1981	...	·200	·016	·16202
7	·176	·180	·007	4·470	·1875	3/16	·1764	...	·183	·019	·14428
8	·160	·165	·008	4·064	·171875	...	·1570	...	·167	·0215	·12849
9	·144	·148	·009	3·658	·15625	...	·1398	...	·150	·024	·11443
10	·128	·134	·010	3·251	·140625	...	·1250	⅛	·136	·028	·10189
11	·116	·120	·011	2·946	·12518	...	·1113	...	·121	·032	·090742
12	·104	·109	·012	2·642	·1125	...	·0991	...	·110	·035	·080808
13	·092	·095	·013	2·337	·10	1/10	·0882	...	·096	·038	071961
14	·080	·083	·014	2·032	·0875	...	·0785	...	·086	·043	·064084
15	·072	·072	·015	1·829	·075	...	·0699	...	·074	·048	·057068
16	·064	·065	·016	1·626	·0625	1/16	·0625	1/16	·067	·051	·05082
17	·056	·058	·017	1·422	·05625	...	·0556	...	·060	·055	·045257
18	·048	·049	·018	1·219	·05	1/20	·0495	...	·051	·059	·040303
19	·040	·042	·019	1·0116	·04375	...	·0440	...	·046	·062	·03589
20	·036	·035	·020	·914	·0375	...	·0392	...	·039	·065	·031961
21	·032	·032	...	·813	·034375	...	·0349	...	·033	·069	·028462
22	·028	·028	·022	·711	·03125	1/32	·03125	1/32	·030	073	·025347
23	·024	·025	...	·610	·028125	...	·02782	...	·027	·077	·022571
24	·022	·022	·024	·559	·025	1/40	·02476	...	·024	·082	·0201
25	·020	·020	...	·508	·02344	...	·02204	...	·022	..	·0179
26	·018	·018	·026	·457	021875	...	·01981	...	·020	...	·01594
27	0164	·016	...	·4166	·020312	...	·01745	...	·0185	...	·014195
28	·0149	·014	·028	·3759	·01875	...	·015625	1/64	·017	...	·012641
29	·0136	·013	...	·3454	·01719	...	·0139	...	·016	...	·011257
30	·0124	·012	·030	·3150	·015625	...	·0123	...	·015	...	010025
31	·0116	·01	...	·2946	·01406	...	·0110	...	·014	...	·008928
32	·0108	·009	·032	·2743	·0125	1/80	·0098	...	·013	...	·00795
33	·0100	·008	...	·2540	...	...	·0087	...	·012	...	·00708
34	·0092	·007	·034	·2337	...	...	·0077	...	·011	...	·006304
35	·0084	·005	...	·2134	...	...	·0069	...	·010	...	·005614
36	·0076	·004	·036	·1930	...	...	·0061	...	·009	...	·005
37	·0068	...	...	·1727	...	...	·0054	...	·008	...	·004453
38	·0060	...	·038	·1524	...	...	·0048	...	·007	...	·003965
39	·0052	...	...	·1321	...	...	·0043	...	·0065	...	·003531
40	·0048	...	·040	·1219	...	...	·00386	...	·006	...	·003144

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CHAPTER XLIV.

PROTECTING STEEL FROM CORROSION.

Galvanising.—The method most extensively employed for preventing the rusting of steel is that known as galvanising. The process was patented by Messrs. Morewood & Rogers in 1846,* and is largely applied for preserving, from the effects of the weather, the corrugated sheets used for roofing; and also for protecting buckets, tanks, ship's fittings, and various other small articles constantly exposed to water or damp. Galvanising consists of covering the surface of the steel with a thin coat of zinc, which adheres firmly, provided the article has been properly cleaned and freed from scale before dipping. The process was called "galvanising" because zinc and iron form together a galvanic couple, and zinc being electro-positive to iron is, therefore, attacked first, and thus preserves the iron from oxidation; nevertheless the word is a misnomer when applied to sheet iron and steel. Marine boilers are protected on a similar principle by hanging zinc plates inside them, the corrosive water dissolving them in preference to the steel boiler shell. Galvanised sheets exposed to fumes from burning Sulphur are, however, not so durable as ungalvanised sheets that have been painted or tarred.

The Modern Process.—Sheets to be galvanised are usually rolled somewhat thinner than the nominal gauge, so that they may be of the gauge specified when coated. After being annealed and straightened, they are dipped in a lead-lined bath, having an inner lining of timber inside the lead to protect it from damage by the sharp edges of the sheets. The bath is filled with a pickle consisting of five parts of water to one of acid, which is raised to a temperature of about 90° F. by a jet of steam passed into the tank through a lead pipe running down to within an inch of the bottom. The sheets remain in this strong pickle about twenty minutes, and are then removed to tanks filled with cold water, where they remain for twenty-four hours.

Where readily obtainable, Hydrochloric Acid, in the proportion of one of acid to one of water, is used in preference to Sulphuric Acid, because the pickle in that case does not need warming, and the sheets do not require to be soaked in water afterwards, but may be passed on at once to the bath of molten zinc, with only a momentary draining. The vats for Hydrochloric Acid are constructed of pitch-pine boards tongued and grooved together, the joints being made tight with india-rubber; or of York flags cemented together. The former last about twelve months, and the latter, which are more costly, for several years.

The cost of pickling by either acid is about the same, the difference in the quantity used being equalised by the difference in price, but the Hydrochloric Acid is quicker in its action, and the fumes generated by it are less annoying to the workmen.

The galvanising bath is formed of mild steel plate from 1 to 1¼ inches

* Patent No. 11,476, 1846.