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	$\frac{1}{2}$	...	...	·40964
0/2	·348	·380	...	8·839	...	...	·4452	...	...	...	·3648
0	·324	·340	...	8·229	...	...	·3964	...	...	...	·32486
1	·300	·300	·001	7·620	·3125	$\frac{5}{16}$	·3532	...	·296	·0085	·2893
2	·276	·284	·002	7·010	·28125	...	·3147	...	·270	·0095	·25763
3	·252	·259	·003	6·401	·25	$\frac{1}{4}$	·2804	...	·256	·0105	·22942
4	·232	·238	·004	5·893	·234375	...	·250	$\frac{1}{4}$	·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	$\frac{3}{16}$	·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	$\frac{1}{8}$	·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	$\frac{1}{10}$	·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	$\frac{1}{16}$	·0625	$\frac{1}{16}$	·067	·051	·05082
17	·056	·058	·017	1·422	·05625	...	·0556	...	·060	·055	·045257
18	·048	·049	·018	1·219	·05	$\frac{1}{20}$	·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	$\frac{1}{32}$	·03125	$\frac{1}{32}$	·030	073	·025347
23	·024	·025	...	·610	·028125	...	·02782	...	·027	·077	·022571
24	·022	·022	·024	·559	·025	$\frac{1}{40}$	·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	$\frac{1}{64}$	·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	$\frac{1}{80}$	·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 $1\frac{1}{4}$ inches

* Patent No. 11,476, 1846.

thick, rivetted, or better still, welded into one piece. It is set upon a foundation of brickwork, which covers the whole of the bottom and rises for a height of 6 to 8 inches all round the sides, so as to prevent the bottom of the bath from being burnt when the dross, which collects at the bottom, attains a dangerous thickness. The sides are supported at intervals on the exterior, to prevent outward bulging under the pressure of the fluid metal within, and the whole bath is surrounded by a coke fire placed between it and the brickwork surrounding it; holes are left at intervals to admit air, and plates are placed on the top of the coke, by manipulating which the temperature of the metal can be regulated. In some works coal fires are employed with flues passing to and fro along the sides of the bath, and thence away to a chimney. By the former method more even heating can be obtained, while any leak is more readily seen, and can be more easily stopped.

The crude zinc, known commercially as "spelter," melts just below 425° C., and the metal is maintained at a temperature of 16° to 28° above the melting point. Care must be exercised to keep the bath at the correct temperature; if too cold the process is delayed, and if too hot much zinc is wasted by oxidation. The bath, which should last from nine to eighteen months, may be destroyed in a few weeks by overheating. The life of a bath is indeed always uncertain, some, for no apparent reason, lasting much longer than others, but an average life of twelve months may be considered satisfactory.

At a short distance from each end of the bath is a division of wrought-iron plate, projecting downwards below the surface of the metal, and in the partitions so formed Ammonium Chloride, known commercially as "Sal Ammoniac," is placed on the surface of the metal; this acts as a flux to remove the oxide, and makes the zinc more fluid, thus enabling a thinner and more even coating to be obtained.

Inside the galvanising bath are two pairs of rolls, 7 to 10 inches diameter, and 3 feet 6 inches long, situated about 10 to 15 inches below the surface of the fluid metal, one pair at each end of the bath. The sheet to be coated is directed by guides, which lead it downwards through the first flux box on to the first pair of rolls, by which it is slowly fed into the molten zinc; it is then directed in a curved path by means of other guides to the second pair of rolls at the exit end, by which it is slowly raised out of the bath, the sheet entering and leaving through the flux boxes. The flux, as it becomes discoloured and loses its efficiency, is removed from the exit box and put into the entrance box, new clean flux being placed in the former to replace the spent flux removed.

The rolls in each pair are geared together by means of pinions cut out of wrought iron, cast iron being inadmissible, owing to the rapidity with which that metal is destroyed by the melted zinc. They are driven by means of similar wheels, which gear with others on a shaft above the bath; this is actuated by a belt on a cone-pulley having three or four different speeds, by which means the speed at which the sheet travels through the melted zinc may be regulated. The thickness of the sheet determines the time needed to heat it sufficiently to enable it to take up the coating of zinc, which will not adhere until the sheet attains the same temperature as the zinc in the bath.

In Heathfield's patented process, several pairs of rolls are employed, the last pair being placed just above the surface of the metal, with the object of squeezing off any superfluous zinc; the patentee claimed that better and cleaner results were obtained with less expenditure of labour; and that, a thinner coating of zinc could be put on the plates by this process than by any other method.

As the sheet emerges it is seized by a pair of tongs and dropped, while still hot, into a tank of water, from which it is removed to a second similar tank; two tanks are employed because the water in the first soon gets so hot, and becomes so heavily charged with dissolved flux that, if the sheet were taken from it direct, it would dry white on the surface; the first immersion in hot water is useful, as it dissolves any particles of flux which may adhere to the sheet, while the last trace is removed in the cold tank.

By regulating the length of time between the removal of the sheet from the zinc bath and its dipping into the water, its appearance can be modified; if dipped instantly, the sheet drys with an even and comparatively dull surface, whereas, if sufficient time is allowed for the complete formation of the crystals before the sheet is dipped in the water-bath, it has a spangled crystallised appearance; when it is desired to give such a finish, a small proportion of tin is often added to the bath.

The dipped sheets are passed on to girls, who rub them over with saw-dust to remove the water, and they are finally dried over open coke fires, or in ovens, before packing. If packed wet, "sweating" is apt to occur, which spoils their appearance, and often damages the protective coating. In some modern plants the sheets are allowed to cool in the air without dipping in water at all, and are handled entirely by machinery, being fed regularly through the pickle, and carried on rollers or bands to the corrugating machines.

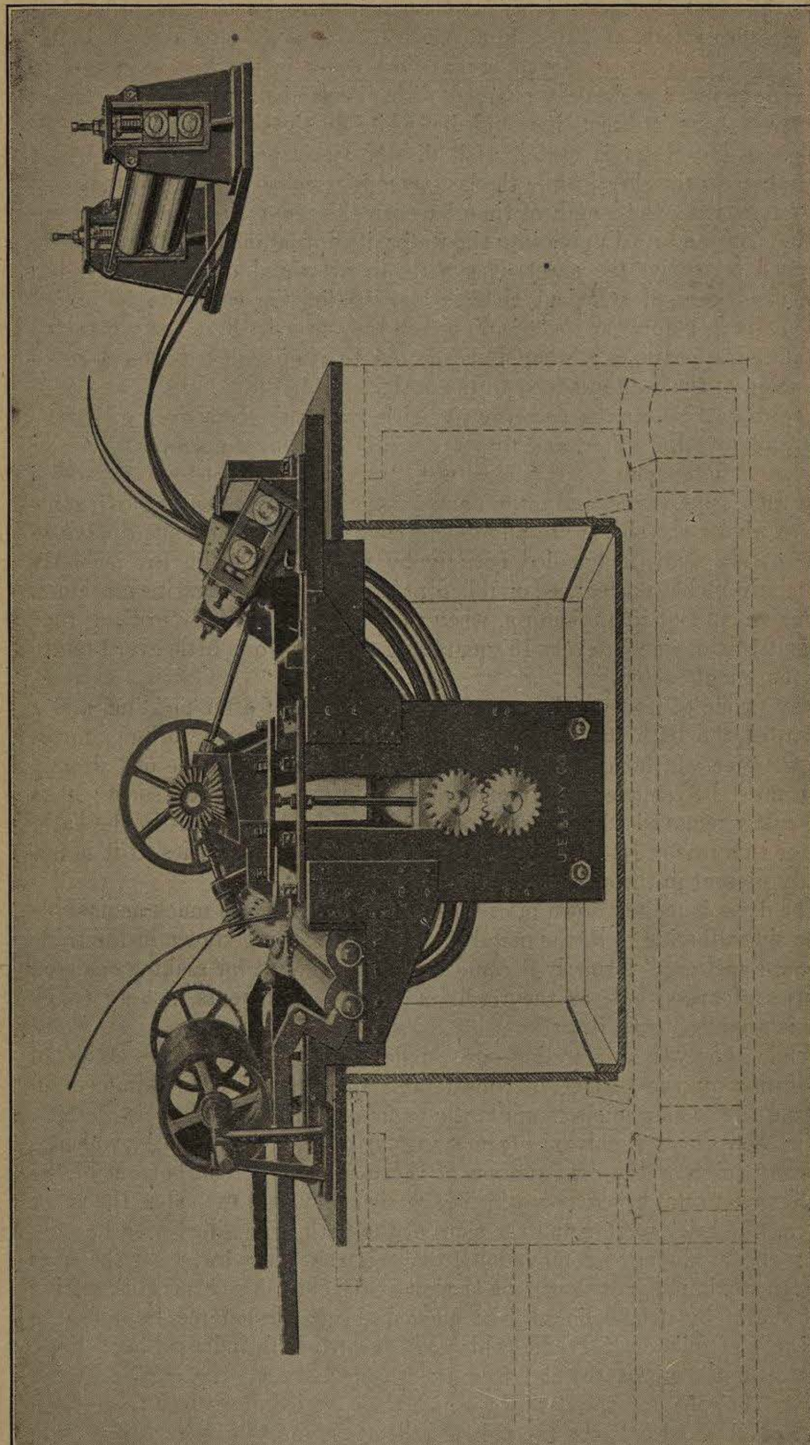
The amount of zinc taken up, when the process is carefully worked, runs to about 1 lb. of zinc for every 15 square feet of surface, or a little over 1 ounce per square foot coated.

Any Oxide of iron which may remain on the sheet after pickling, and a portion of the bath itself which becomes oxidised during working, mixes with the zinc and falls to the bottom of the bath in the shape of "dross," which must be removed about once a week by means of iron slices; it is more easily removed when a small proportion of lead is present in the bath, and for this reason lead is sometimes added in small quantities, if it is not already present in the spelter when purchased.

The dross is melted down in cast-iron pots to remove as much as possible of the zinc adhering to it, the metal thus recovered being known in the trade as "hard spelter;" formerly it could only be employed for making common qualities of brass, but, as the result of recent experiments, a very tough brass is produced from it.

While the bath is standing—on Sundays or other holidays—Oxide of Zinc forms on the surface in considerable quantities; it is skimmed off and sold to the zinc smelters under the name of "zinc ashes."

Fig. 566 shows a galvanising machine in position in its bath, which is cut away to show the construction of the machinery. The bottom of the bath rests on solid brickwork, which is carried up round the sides, the space between the brick setting and the sides of the bath being filled with burning coke; the products of combustion from this coke pass away by the flues below to a chimney, not shown, on the left of the cut. The brickwork setting is all shown by dotted lines. The pickled sheets are entered between the small pair of rolls on the right, which are covered with india-rubber; these squeeze off the moisture, and feed the sheets between the curved guides between the rolls and the bath, by which they are led down into the molten zinc, and diverted between the pair of rolls at the bottom, which pass them up between the last pair on the left, which, being pressed together by weighted levers, squeeze off the superfluous zinc. Fig. 567 shows a view of the machinery taken from the opposite side.



[illegible] Machine in Position in the Bath : Brick Setting shown in dotted lines.

This machine is made by the United Engineering and Foundry Company of Pittsburg, U.S.A.

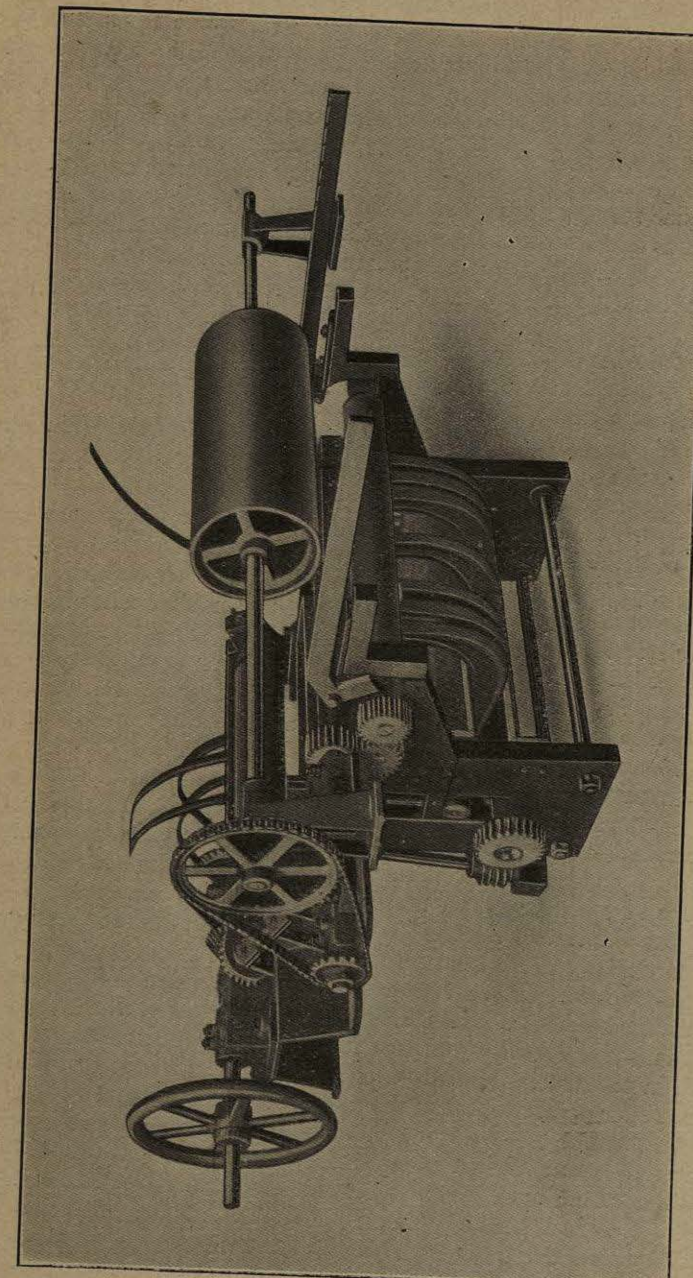


Fig. 567.—View of Galvanising Mechanism as seen from the other side.

The Old Dipping Process.—Before the introduction of power-driven rolls for leading the sheets into and out of the bath, they were dipped into the bath with tongs, and removed when supposed to be sufficiently coated; the sheets were frequently bent by this method of handling, and as they rested on the dross at the bottom of the bath, particles of dross adhered to them and spoiled their appearance. The amount of zinc taken up by this method depended largely upon the time the sheets were allowed to remain in the bath, and this period was subject to the care exercised by the workmen; this difficulty was removed when they were fed in and out at a regular speed by mechanical means, which were independent of the judgment of the individual workman. The zinc also drained off the sheets in an irregular manner, leaving the surfaces rough, and two or three times as much zinc was used as is now needed; this difficulty has been removed by the use of the flux, which causes the zinc to flow much more evenly. The quantity of zinc requiring to be kept hot in the modern process is only about half as much as in the older one, because the sheet, instead of being dropped on edge below the metal, is passed approximately horizontally a little below the surface; reducing the amount of hot metal reduces the inevitable loss by oxidation.

Galvanising Articles of Irregular Shape.—Tubes, forgings, and castings varying in shape cannot be fed into the bath by rolls, but must be dipped one at a time; pieces weighing more than ½ cwt. or so each are lowered in and removed again by a crane, smaller pieces by means of tongs, and the very small ones several at a time in wire baskets. Wire netting, buckets, sheet-iron, water cisterns, and spouting are dipped after they have been put together, the coating of zinc, by protecting the heads of the rivets, assisting to hold the parts together, and closing any joints which may not be quite tight. Those surfaces which have been machined take the metal best, and present the cleanest surface when coated; small forged or stamped and malleable cast articles, which can be "rumbled" bright in a shaking barrel, take the metal fairly well, but ordinary cast-iron requires great care and much time in pickling, and is never very clean; while steel castings, which necessarily have the roughest surface of all, inevitably present a very rough appearance when galvanised.

Disadvantages of the Process.—The objection to the ordinary method of galvanising is that the material to be coated must be subjected to a temperature above that of molten zinc. This impairs the delicate temper of high grade wire, and at the same time reduces the strength and stiffness of cold rolled or drawn material. The heating also destroys the flatness of thin sheets, and changes the form of plates which have been bent to shape, particularly if the bending has been done cold. Moreover, a thin stratum of alloy is formed between the iron and zinc, where the two metals are in contact, and this alloy, having considerably less tensile resistance and very much less ductility than the steel itself, always causes some loss of strength in the articles treated—a loss which may amount to a serious proportion of their total strength in the case of small wire or thin sheet.

Cold Galvanising.—With the view of avoiding the loss of strength in the material caused by hot galvanising, attempts were made, but with little success for many years, to deposit zinc electrically from an aqueous solution of a Zinc Salt, generally Zinc Sulphate or Chloride. The zinc was deposited very irregularly, some parts of the articles to be coated being left entirely uncovered, while the metal was deposited in irregular or spongy masses on other parts. The more acid set free during the process, the more irregular became the deposit, which was discoloured when Hydrogen was liberated.* If an even coating was obtained it was apt to crack and shell off the surface of the steel immediately the slightest bending occurred. The time taken was excessive, and the zinc anodes were unable to maintain

* *The Engineer*, 7th June, 1895, p. 494.

the strength of the solution, even though used in the form of plates having surfaces greatly in excess of the cathodes.

Cowper-Coles Process.—These difficulties have been overcome in the process recently perfected by Mr. Cowper Coles,* in which the solution of Zinc Sulphate is pumped continuously through regenerating tanks, whence it returns by gravity to the galvanising vats. The regenerating tanks are filled with zinc dust, which exposes an enormous surface in a very small space. The dust employed is that found in the flues of zinc smelting furnaces, where the volatilised metal is deposited when the fumes cool. The solution is maintained at a temperature of about 21° C., and the coating thus deposited adheres more firmly than that obtained by the ordinary hot process, and admits of the material being bent to a greater angle without fear of fracturing the surface, while the steel is not injured by the operation of coating.

In any process for depositing zinc from a solution of its salts, the electric current will not travel through the fluid electrolyte for more than a short distance, so that articles can only be coated on these surfaces which face, and are not far distant from, the zinc plates used as anodes, which must, therefore, surround the article closely on all sides; hence it is not easy to get the metal deposited in sharp internal corners, or on irregularly shaped articles, while tubes, unless of 4 inches or more in diameter, can only be coated on the outside.

The process of electro-deposition is necessarily slower and more costly than coating the articles by immersing them in molten zinc, but it is nevertheless extensively employed at the present time for protecting the thin frames and plating of torpedo boats, and other small vessels, made for the British Admiralty. The plates, having been pickled in a solution of two parts of Hydrochloric Acid and one of water, or in very weak pickle (as low sometimes as 5 per cent. of acid), are well scrubbed to remove any remaining scale, and are then dipped in a strong solution of soda to neutralise any remaining acid. They are hung in the plating vats surrounded with zinc plates in close proximity, and an electric current of from 3,000 to 4,000 amperes, at a pressure of 5 volts, is passed through the plates. About half an hour is generally needed to deposit the thickness of zinc (·86 oz. per square foot of surface), required by the Admiralty specifications.

Sherrardising or "dry galvanising" is a new process invented by Mr. Sherrard Cowper-Coles. It is effected by placing the tubes or small articles to be treated in air-tight revolving drums, partially filled with Zinc dust, which is the fumes condensed in the flues of zinc smelting furnaces, and containing about 80 per cent. of metallic zinc in a very fine state of division, intimately mixed with about 20 per cent. of Zinc Oxide in the form of an impalpable powder. The drum is placed in an oven raised to a temperature above 400° and below 750° F., usually between 500° and 600° F., which is well below the point of actual fusion of zinc. In a few hours there forms on the surface of the articles a very thin coating of an alloy of iron and zinc, above which is an outer skin of pure zinc. Even if this outer skin shells off, the coat below is an efficient protection against corrosion.

The temperature to which the articles are exposed is raised and lowered so gradually that the quality of the iron or steel is not deteriorated, and the temperature is so much lower than that of a bath of molten zinc that the temper quenched steel is not "drawn" by the operation.

The threads of screwed tubes or of nuts and bolts treated by the hot dipping process are clogged with metallic zinc, and have to be re-screwed

* *The Engineer*, 4th October, 1895, p. 343.

before they will fit each other, but the coat produced by Sherrardising is so thin and so uniformly deposited that this is unnecessary, and the coating will take an excellent polish.

Various processes have been patented for electro-depositing zinc, but none of them can be said to afford the same protection as the hot process, because no actual alloy is formed between the surface of the iron and that of the zinc, which easily shells off when the articles are bent over, the adhesion between the two being insufficient to withstand rough usage. It is also very difficult to get an even coating, heavy irregular deposits forming at some points, while others remain entirely uncovered. Even when the coating appears to be uniform there are usually minute holes in the protective covering, which cannot be detected until corrosion begins, and once begun it proceeds with remarkable rapidity.

The appearance of the surfaces of articles treated by the three processes is usually quite distinct and readily distinguishable. The surface of articles dipped in molten zinc, if large, are often spangled, and in any case show where the molten metal has run, often being covered with spots and lumps of molten zinc. Those of Sherrardised articles are bright, evenly coated, and have a flat lustrous surface, while those treated by electro-deposit usually show a matt or frosted surface, much paler in colour than the others, though at least one electro-depositing process produces a bright metallic lustre, which is not so easy to distinguish from hot galvanising.

Spent Acid.—The disposal of the acid which has been employed to pickle articles intended to be galvanised, or otherwise coated, presents serious difficulties. Though insufficiently active for further use, the spent acid is highly destructive to animal and vegetable life, and, therefore, unsuitable for discharge into streams or rivers; its corrosive action renders its presence equally objectionable in the sewers, and if allowed to soak into the ground it may pollute the wells in the neighbourhood. Sulphuric Acid can be neutralised with lime, the cost of the lime being the larger part of the expense of treatment, but where Hydrochloric Acid is used no neutralising agent can be employed which is not too costly for use on a large scale, and the only method of treatment which has so far proved at all practicable commercially, is one invented by Professor Turner, of Birmingham University, in which the acid is evaporated on the hearth of a reverberatory furnace, and the fumes given off are condensed for further use. The process is successful, but the plant required is so extensive that manufacturers will only use it under severe pressure from the local authorities.

Tin Plates.—Another and much older process for protecting sheets of iron or steel from rust—namely, by coating them with molten tin—was in regular operation in Saxony at a very early date, and was thence introduced into South Wales about 1665. The process is more costly than coating with zinc, not only because tin is more expensive (having varied in price during the past few years between £90 and £130 per ton, while the price of zinc in the same period has fluctuated between £19 and £29 per ton),* but because tinning needs more care, and the sheets have to undergo more numerous operations, both before and during the process of coating. The surface of ordinary rolled sheets is too rough to take the thin even coat of tin, as thin sometimes as ·01 oz. per square foot, which is required to give the brilliancy expected. "Tin plates," which should correctly be called "tinned sheets," though the former name is universally employed, are chiefly made for working

* The prices of spelter and tin have lately varied within very wide limits, and it is impossible to say at the present time, while the European war is in progress, what are normal prices for either of these metals. Recently tin has varied from £175 to £148 per ton, and spelter from £115 to £60 per ton, and in exceptional circumstances, within comparatively recent years, spelter has been purchased below £15 per ton.

up into small articles for domestic use, or into those intended to contain food, for which a coating of zinc would be unsatisfactory, owing to the much greater ease with which that metal is dissolved by most acids present in foods, giving rise to the formation of salts injurious to health.

The sheets to be tinned are pickled in the same way as those to be galvanised, but more carefully. The first pickling is called by the workmen black pickling, on account of the quantity of scale removed, and is now usually performed by means of machinery. This pickling is done in acid made from pyrites, either the common brown oil of vitriol (known in the trade as B.O.V.), and having a specific gravity of 1·6 to 1·74, or the paler acid of 1·83 specific gravity. It is doubtful if the lower price of the former compensates for its reduced strength. The bath at first has a strength of about half acid and half water, more acid being added from time to time, as the experience of the workman tells him is necessary. The spent acid, which should have a specific gravity of 1·25, is pumped out, and the Sulphate of Iron is occasionally recovered by evaporation at the chemical works, and sold as "copperas" or "green vitriol." The pickling machines consist essentially of open frames or crates known as "cradles," in which the sheets are placed on edge, and the crate rocked mechanically up and down or to and fro in the acid, so as to ensure an even passage of the liquid over the whole of their surfaces, by which means more even results are obtained, with a saving in time and considerable saving in acid. They are then washed in a similar manner in clean water and stacked on the flat in cast-iron pans, to a height of about 2 feet, and covered with a cast- or wrought-iron box cover, with sand laid in the pan for 3 or 4 inches deep round the sides, to exclude air as much as possible. The pots are rolled into annealing furnaces on cannon balls in the same way as for ordinary annealed sheets, or in some American works they are lifted by a travelling crane into square annealing pits, which are sunk below the floor, and closed with removable covers, constructed much in the same way as the soaking pit furnaces for steel ingots. The plates are raised to a bright cherry-red heat, which is maintained for eight or ten hours; they are then allowed to cool slowly, and are known as "close annealed sheets."

Fig. 568 shows the mill of the McKeesport Tin Plate Company at McKeesport, Pa., constructed by the Mesta Machine Company of Pittsburg. The mills have rolls 26 inches diameter, and are changed by tilting or sliding one housing along the bed. They are driven through ropes from a pair of Corliss engines having cylinders 30 inches diameter by 5 feet stroke.

When annealed, the plates are passed, one at a time, while cold, three or four times between a pair of short chilled rolls, from 18 to 22 inches in diameter. Each housing for carrying those rolls is now commonly provided with two pins and boxes (see fig. 500). To get a fine surface on the rolls, they are frequently screwed down hard against each other, and the mill run empty with water only on the rolls. These rolls flatten the plates, and impart to them a fine smooth dense surface, but as cold-rolling hardens them it is necessary to give them a second annealing, in the same way as the first, except that the pickle used to remove the scale is somewhat weaker; they are then washed to remove the acid, and are kept in water until required for coating with tin. This pickling is generally done in "brimstone acid" made from the fumes of burning Sulphur, or in "gas waste acid" made from the spent Oxide removed from the purifiers at gas works, because both these acids are free from Arsenic; this is always present in acids made from Pyrites, and leaves black streaks on the plates. The total quantity of acid used, since the introduction of pickling machines, may vary from 9 to 10 lbs. per box of thick plates, down to 5 lbs. for the thinner and commoner qualities.

Thirty years or so ago the method of tinning consisted in dropping the plates, one at a time, into a pot containing warm grease, and then removing

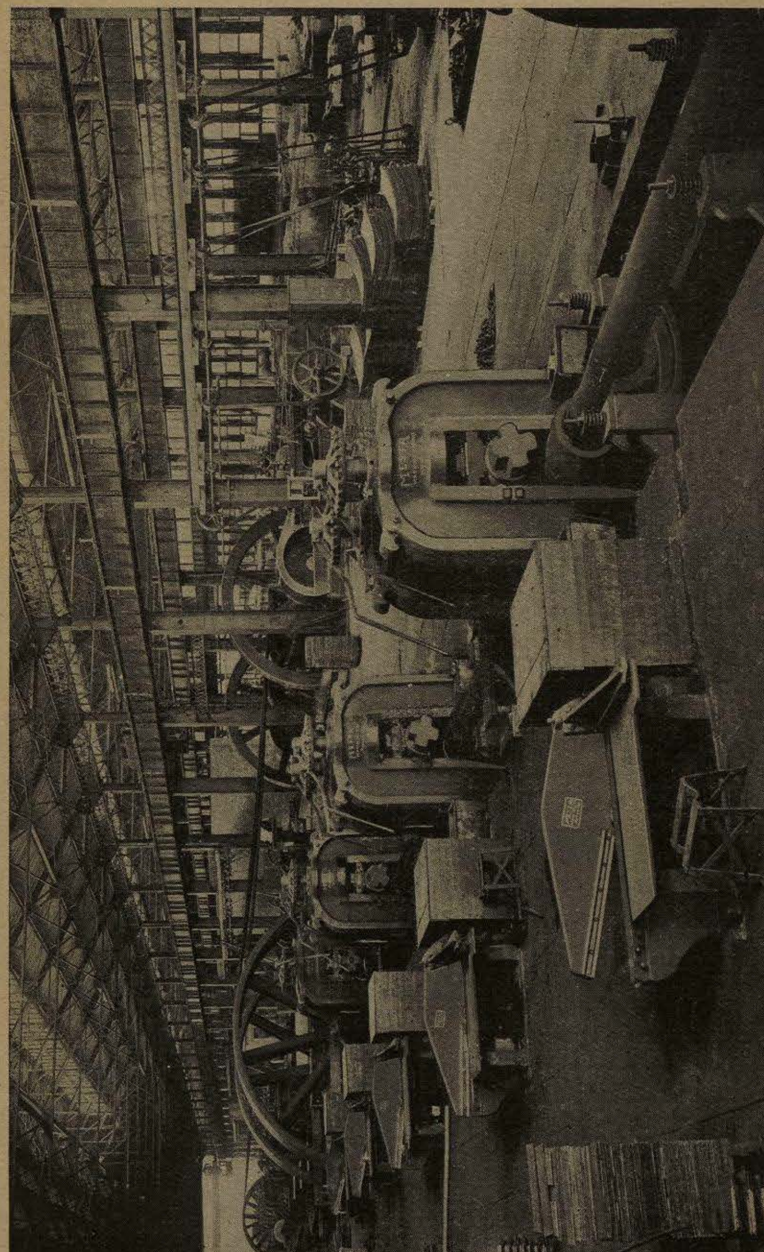


Fig. 568.—Set of Tin Plate Mills.

them to a pot containing molten tin covered with palm oil. After remaining in this for a short time they were removed, rapidly brushed on each side by a hand brush, and passed into a second pot containing tin at a somewhat higher temperature; thence they were removed to a pot containing

melted palm oil to permit the superfluous tin to drain off, and then placed in a rack to cool. The thickness of the coating of tin thus obtained was irregular, and an unnecessary amount of tin was consumed, so that a great improvement was effected about 1860 when the plates were passed through

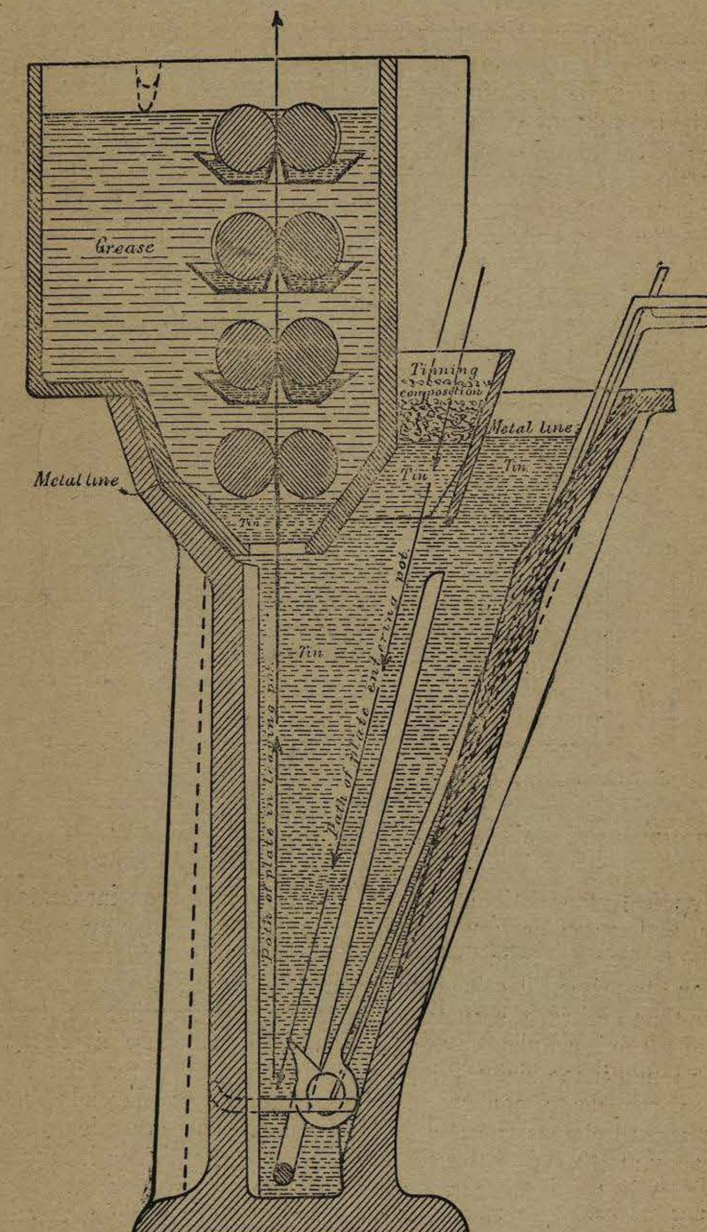


Fig. 569.—Tinning Pot and Rolls for the Manufacture of Tin Plates.

rollers revolving in the grease on the surface of the tin, through which they emerged from the last pot, these rollers squeezing off any superfluous tin which might adhere to the plate.

In modern works the process is performed in mechanically-actuated tinning pots (fig. 569), acting on much the same principle as the galvanising plant previously described, the whole process being effected in one pot, by the use of a flux of Chloride of Zinc, to which is added a little Ammonium Chloride, through which the plate enters the tin. This flux considerably hastens and cheapens the process, while the plates have a cleaner and brighter surface when tinned in this manner, and now that the initial difficulties have been overcome the plates are equal in quality to those made in the older way.

Fig. 570 shows the plant in operation.

The tinning rolls are made of wrought iron, and are not polished as an inspection of the finished plate would lead one to suppose, but the marks made by the tool, when turning them in the lathe, are purposely left on them. The rolls are driven at a definite speed which determines the amount of tin taken up by the plate, the quantity running usually to 2 or 3 per cent. of the weight of the steel plates, the object kept in view being to give what is known as a "coke finish" to a cwt. of plates with 2 lbs. 4 ozs. to 2 lbs. 6 ozs. of tin. Special qualities will have from 3 to as much as 6 lbs. of tin per cwt. of plates in exceptional cases.

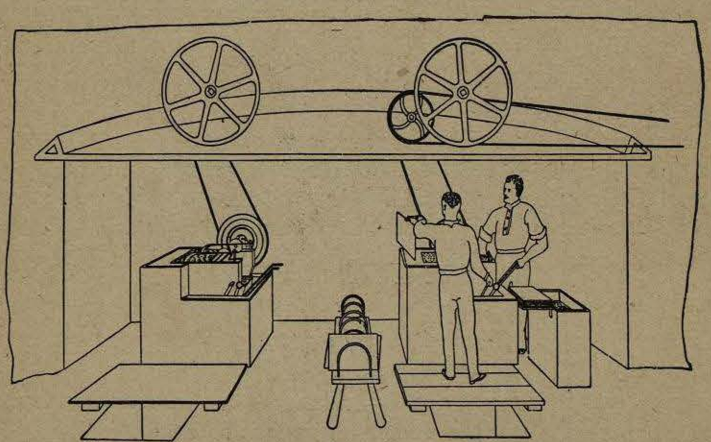


Fig. 570.—Tinning Pots in Operation.

The vertical type of tinning pot is suitable for plates of moderate size or thickness, but long or very thin plates are liable to double up when it is attempted to lift them from their bottom edges. The cold plates cool down the tin, and to prevent it being chilled and adhering to the plates in greater thickness than desired, the molten tin must be kept very hot, so that the surface of the finished plate loses brilliance. The grease also gives off very annoying fumes if too highly heated, and may even take fire. These difficulties are overcome by employing tinning pots of the form shown in fig. 571. which is taken from the paper by Mr. Beaumont Thomas mentioned in the Bibliography at the end of this chapter, the block from which it is printed having been lent for this purpose by the Council of the Institution of Mechanical Engineers. The plate enters the pot on the right, the tin in which is maintained at a high temperature, through the flux contained in division, *a*, upon the surface of the tin. When pushed forward it is diverted by the guides which guide it upwards between the rolls, *c*, and on issuing from these it is diverted downwards by other guides into the second pot, the tin in which is at a lower temperature, and then passes upwards through the grease contained in the pot, *d*. The two pots being entirely separate, and

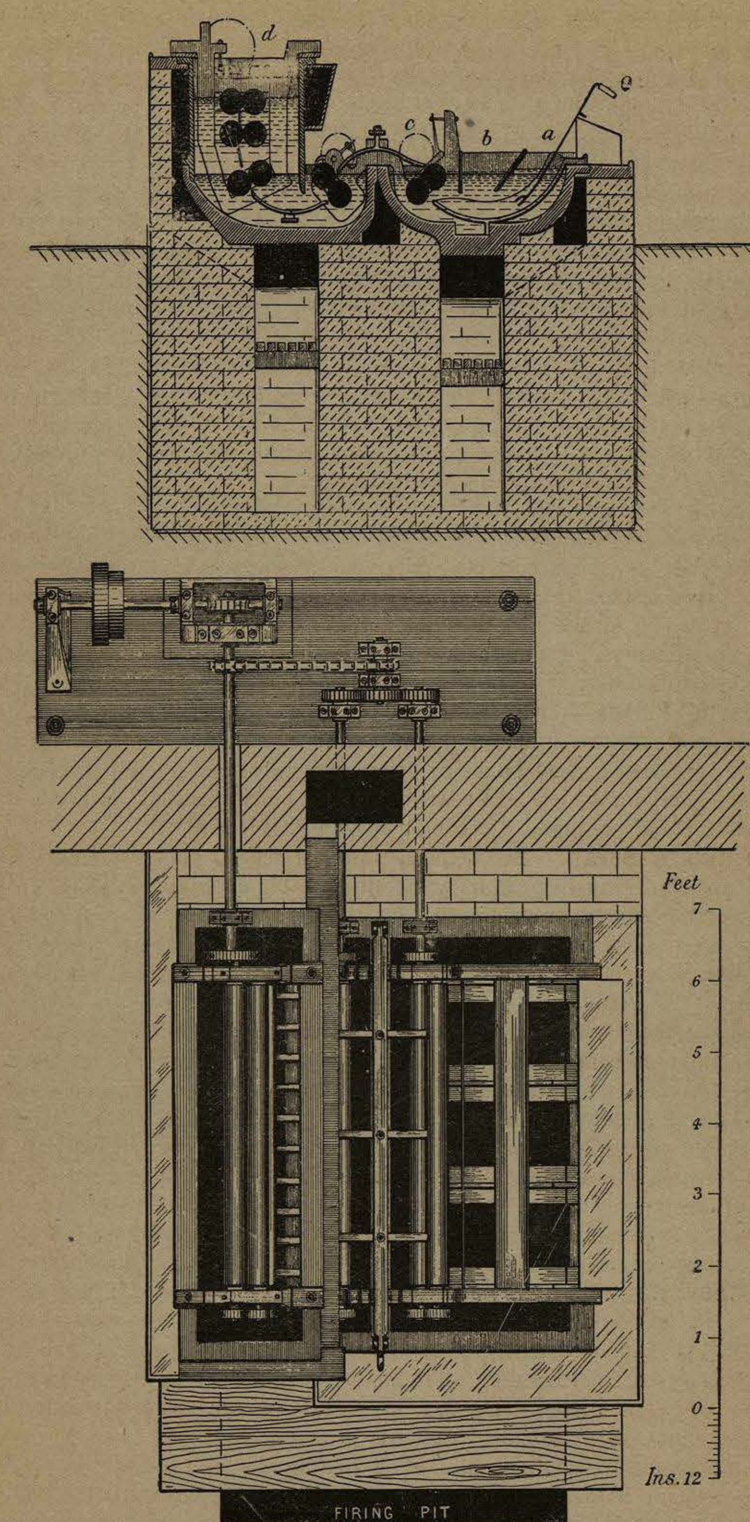


Fig. 571.—Tinning Pot (*Lydney*).

separately fired, there is no difficulty in maintaining each at its most suitable temperature. There are three sets of guides in the width of the pot, and a plate is fed along each successively. One man feeds the plates in, and a second removes them to the cleaning machine.

The cooled plates are passed on to girls who polish them by means of hand-rubbers of sheep-skin, rubbing them with bran or sharps to remove the grease. In some of the larger and more recent works this process is performed by machinery, which consists of different arrangements of rollers covered with sheep-skin, these rollers revolving at varying speeds, and the sheets being passed through between them.

The polished sheets are put up into wooden boxes for sale, the ordinary box containing 112 plates of 30 S.W.G. thickness, measuring 14 by 20 inches, and weighing 1 lb. each plate. Plates are made having a great variety of sizes and qualities of finish, which are known in the trade by various marks and names which have been given to them by the workmen, a list of which would serve no useful purpose in the present work. From these are made the cans used for tinned meats and fruits, now so extensively used, as also the smaller domestic articles.

Plates larger than 21 inches by 30 inches, curiously enough, are known in the trade as "tinned sheets," in contra-distinction to the smaller sizes, which have always been known as "tin plates." They are obtainable in sizes up to 36 inches wide by 72 or more inches long, and 20 S.W.G. or more in thickness. From them are made the baths, milk cans, milk pails, &c., in common use.

Terne Plates.—Terne plates are an inferior quality which have been dipped in a mixture of lead and tin, instead of into pure tin, and are used chiefly for making deed boxes or other articles which are not intended to contain food, for which lead-coated plates are inadmissible, on account of the risk of lead poisoning which may occur by their use.

Tinplate Scrap.—Tin being a valuable metal, many attempts have been made to remove it from waste tinplate clippings, or to work up the innumerable empty provision tins which are a positive nuisance to local authorities. The methods employed may be classified under four heads:—(1) Dissolving the scrap in acids and separating the iron and tin salts so formed. (2) Dissolving the tin only, and leaving the steel as it is. (3) Dissolving the tin from the surface of the steel sheet scrap by contact with mercury; then heating the amalgam thus obtained to drive off the mercury in the form of volatile fumes of metallic mercury, which are condensed by cold, and the metallic tin is left behind. (4) Dissolving the tin scrap in molten pig-iron. None of the processes, however, so far appear to have been commercially successful, the material recovered not paying the expense of working any of them, unless we except a very recent solution process now being worked here and in Germany, by which the stripping of the tin from the steel is hastened by a weak electric current.

Other Methods of Protection.—Wherever bilge-water can lie, the interiors of iron and steel ships are washed or coated to a considerable thickness with Portland cement, which adheres firmly to the metal and has considerable protective powers. Material intended for export is often dipped while still warm in boiled linseed oil, which forms a species of protective varnish upon which ordinary paint may afterwards be laid.

The coating of small articles, such as the various parts of bicycles by electro-plating with nickel, is a method of protection familiar to everyone; brass is similarly deposited from a solution containing salts of both zinc and copper on to small articles forming portions of harness, &c.; but, as most metals are electro-negative to iron, such coatings, like ordinary paint or varnish, are effectual only so long as the protecting skin remains intact, and when this is removed by wear, the coat of different metal actually hastens the destruction of the parts so exposed. The same objection applies to coating with molten lead, which will adhere if the plates are first tinned, or are dipped in a solution of Hydrochloric Acid, in which tin and zinc have been dissolved.

Gun barrels are "browned" by rubbing them with a mixture of Chloride of Zinc and olive oil. Various processes have been tried for forming a coat of oxide on the surface of the metal, sufficient to protect the parts below from oxidation. Barff's process, which at one time was used considerably, consisted in passing superheated steam amongst the articles while raised to a red heat in a muffle. The defect of all such processes is that, wherever the skin of protective oxide formed is broken, the part exposed is attacked with increased vigour.

None of these processes are worked on such a scale as to entitle them to be considered as branches of steel manufacture requiring more than a passing notice.

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