THE

PRACTICAL
BRASS AND IRON FOUNDER'S
GUIDE:

A CONCISE TREATISE

ON

BRASS FOUNDING, MOULDING, THE METALS AND THEIR ALLOYS, ETC.

TO WHICH ARE ADDED

RECENT IMPROVEMENTS IN THE MANUFACTURE OF IRON, STEEL
BY THE BESSEMER PROCESS, ETC., ETC.

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CO.'S PENN WORKS, PHILADELPHIA.

FIFTH EDITION REVISED WITH EXTENSIVE ADDITIONS.

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PREFACE.

THE world at present groans under a load of new publications on every branch of *science* and *art;* with which no former period of our literary annals can for a moment be compared.

The most assiduous students, unable to peruse a thousandth part of the works which are daily soliciting their attention, are quite perplexed and distressed about what to choose and what to reject.

This I have frequently found to be the case with myself, and while debating the question in my own mind, have lost, in doubt and uneasiness, the time I meant to set apart for practical manipulation.

Impressed, therefore, with the unspeakable disadvantages that result from the circumstances just stated, and anxious to save others, in some degree, from that unpleasant dilemma in which I have myself been so often placed, I have resolved on the present publication, which I hope will to a very great extent accomplish the useful object I have in view.

With what judgment, however, the design has been formed, and with what skill it has been executed, it becomes not me to determine—that question, to the result of which I am deeply alive, remains now with a higher tribunal.

During the last fifteen years I have, from time to time, contributed papers to well known mechanical and philosophical publications, on subjects herein discussed. These I have carefully revised for the present work, and have added much information gleaned in the field of experience, and from the arcana of science.

I would add in conclusion, that I have been practically employed in the business for thirty-four years, having conducted the work, in all its branches, at Messieurs Sandford et Varreles, Rue de Rochechourt, one of the largest ateliers in Paris, as well as at the British government works, steam-engine and ship-building yard, Woolwich, London, for the last eleven years—so that the reader may relieve himself of all doubt and difficulty in the matter.

JAMES LARKIN.

PREFACE TO THE FIFTH EDITION.

With a view to its increased value and usefulness, the Publisher issues this greatly enlarged and improved edition of THE PRACTICAL BRASS AND IRON FOUNDER'S GUIDE, prepared from the manuscript of the author.

PHILADELPHIA, March 15, 1866.

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SUPPLEMENT.

BRASS AND IRON FOUNDER'S GUIDE.

ON THE PROPERTIES OF THE METALS.

THE metals constitute by far the most numerous class of undecompounded bodies in chemical arrangements. They are, in general, readily distinguished from other substances, by characters which every one recognises; but to an ordinary observer they do not appear to differ essentially from one another; they seem rather to owe their differences of colour, and other physical properties, to a tinge and character given to them by adventitious circumstances, and perhaps some trifling admixture of other substances. This opinion is natural, and was at one time the prevailing doctrine of the learned.

When chemistry began to be developed in the hands of the alchemists—upon whom it has been fashionable to heap ridicule for the extravagances of their notions—it was generally admitted that all metals were essentially the same; and as gold was reckoned the most precious, it was assumed to be the pure basis of all the other metals. Upon this assumption, the aim of alchemy was direct and rational; its object was to separate the substance, whatever it might be, the presence of which prevented lead and other *base* metals from being gold.

It is hardly necessary to observe that these efforts failed. Accordingly modern chemists, taught by experience to believe the required decomposition impossible, have come to the matter-of-fact conclusion that when metals are of different colours, degrees of hardness, lustre, ductility, fusibility, and so on, that they are of different natures.

Although the metallic character be readily and popularly recognised, it is difficult to define it with accuracy.

With the single exception of quicksilver, the metals are all solid at ordinary atmospheric temperatures; but their most striking property is their lustre, which is so remarkable as to be at once understood by the expression, *metallic lustre.* This property belongs, in a greater or less degree, to every metal: it is the property of strongly reflecting light, and seems connected with a certain state of aggregation of the metallic particles. The same property is however possessed, at least superficially, in a minor degree, by mica, animal charcoal, silenium, and polished indigo—bodies not at all metallic.

In consequence of the peculiar power of the metals to reflect light, they are no less remarkable for their opacity than their lustre. Thus, silver-leaf, only one hundred-thousandth of an inch in thickness, is perfectly opaque; and leaves of other metals, in general, allow no light to pass through their substance. Yet gold-leaf, of the two hundred-thousandth part of an inch in thickness, would seem, as observed by Sir Isaac Newton, to transmit green rays of light; and it is probable that, could we obtain films of other metals of equal thinness, they would be found to allow certain rays to pass through them. The fact, as observed with gold, has however been ascribed to the porosity of the metal, the rays transmitted passing through an infinite number of minute fissures in the thin leaf. This, it must be admitted, is quite compatible with perfect opacity of the substance of the metal; the leaf, like a piece of wire gauze, allowing the light to pass only through its interstices, and not through the solid metal itself, which may be perfectly impervious to all luminous rays.

The polished metals are imperfect radiators and receivers of heat, but they are excellent reflectors, both of light and heat: hence their peculiar fitness for the construction of mirrors. They are also, in general, excellent conductors of heat, and most of them also of electricity, though probably not all. The greater number of them are susceptible of assuming the crystalline form. With several of them this may be effected by fusion and slow cooling. Thus, by suffering the melted metal in a crucible slowly to concrete externally, and then perforating the solid crust, and pouring out the liquid interior, the cavity so formed will be found lined with crystals.

When a metal is precipitated by another, it is often deposited in a crystalline state. Thus, if a little mercury be thrown into a solution of nitrate of silver (lunar caustic), the silver is precipitated in beautiful crystals. The same phenomenon occurs, when a bit of zinc is suspended in a salt of lead. In like manner, if a stick of phosphorus be immersed in a silver solution, it becomes incrusted with beautiful metallic crystals, which after some time perfectly encase the phosphorus. Gold is also sometimes deposited in crystals from its ether solutions; and during the decomposition of several of the metallic solutions, by galvanic electricity, especially when low powers are employed, beautiful metallic crystals are often obtained. This is readily verified with solutions of copper and silver salts.

The metals possess, in different degrees, a peculiar tenacity, which, in its greatest perfection, renders them *malleable* and *ductile*—that is, capable of being extended under the hammer, and drawn into wire—properties which belong to no other species of matter. Thus, gold and silver may be beaten into leaves almost inconceivably thin; copper, tin, platinum, and lead, possess the same property, but less perfectly; others are entirely destitute of it, as arsenic, antimony, and cobalt. These last can indeed be readily reduced to fine powder, and hence they are distinguished as brittle metals.

Those metals which are malleable are also ductile; these properties are analogous, but do not appear to bear a uniform relation to each other, among the metals possessing them. Gold and silver are, however, the most ductile, as they are the most malleable. Thus, a grain of gold may be extended by hammering, so as to cover fifty-two square inches of surface, or it may be drawn into 500 feet of wire, and by enveloping it in silver, it may be extended to 700 feet. In like manner, platinum, which is inferior to copper and tin in malleability, has been drawn into wire not more than the $\frac{1}{30000}$th of an inch diameter—a degree of fineness, which, except under certain circumstances of illumination, is invisible. Iron may be drawn into wire as fine as the human hair; copper is less ductile, and zinc, tin, and lead, can be drawn into wire, but considerably less fine. The brittle metals, as might be supposed, do not draw.

The following table shows the order which the metals bear to one another, in respect to these properties:—

A TABLE SHOWING THE ORDER WHICH THE METALS BEAR TO ONE ANOTHER IN RESPECT TO THEIR PROPERTIES:—

Order of Malleability.	Order of Ductility.	Order of Tenacity.	Order of Brittleness.
Gold,	Gold,	Iron . . 1000	Antimony,
Silver,	Silver,	Copper 550	Arsenic,
Copper,	Platinum,	Platinum 494	Bismuth,
Tin,	Iron,	Silver . . 349	Cerium,
Cadmium,	Copper,	Gold . . 273	Chromium,
Platinum,	Zinc,	Zinc . . 199	Cobalt,
Lead,	Tin,	Tin . . . 63	Columbium,
Zinc,	Lead,	Lead . . 50	Manganese,
Iron,	Nickel,		Molybdenum,
Nickel,	Palladium,	Iron wire 1-tenth in. diameter is capable of sustaining 500lbs. avoirdupois.	Tellurium,
Palladium,	Cadmium,		Titanium,
Potassium,			Tungsten,
Sodium,			Uranium,
Solid mercury,			Rhodium.

Few of the metals when pure are very hard, and some are so soft as to yield to the nail. The following table of hardness is given from the experiments of M. Dumas:—

Titanium, Tungsten, Manganese,	are harder than steel.
Platinum, Palladium, Copper, Gold, Silver, Tellurium, Bismuth, Cadmium, Tin,	are scratched by calc-spar.
Chromium, Rhodium,	scratch glass.
Nickel, Cobalt, Iron, Antimony, Zinc,	are scratched by glass.

Lead yields to the nail.

Potassium, Sodium,	are soft as wax at 60°.

Mercury is liquid above minus 39°.

In respect to *fusibility*—that is, the capability of being melted by heat—the metals differ from each other as widely as in any other respect. Thus, mercury requires to be cooled down to minus 39° before it becomes solid, whereas the melting point of platinum is somewhere beyond 3280°. Potassium melts at 140°, and sodium at 190°. Tin becomes liquid at 444°, bismuth at 500°, lead at 600°, zinc at 770°, and antimony at 800°. Silver, gold, and copper, require a bright cherry-red heat to melt them (about 2000°); cast iron, nickel, and cobalt, a white heat (about 2800°); and manganese, and malleable iron, the highest heat of a smith's forge (about 3000°). The highest temperatures of our furnaces are only sufficient to agglutinate very imperfectly the metals molybdenum, uranium, tungsten, and chromium; and titanium, cerium, osmium, iridium, rhodium, platinum, and columbium, require the intense heat of the oxy-hydrogen blow-pipe, or that of voltaic electricity, to fuse them. Some of the metals, when exposed to heat, not only melt, but, obeying the general law of liquids, boil and evaporate when the heat is sufficiently high. Thus, mercury, zinc, cadmium, bismuth, tellurium, and antimony, boil and evaporate at a red heat; and, in a vacuum, mercury is known to evaporate at ordinary atmospheric temperatures (above 50°); silver and lead require a high heat to vaporize them; tin a still higher heat; and gold will only evaporate slowly under the most intense heat that can be applied. Several of the other metals, as iron and nickel, cannot be made to evaporate in the most intense heat with which we are acquainted. Arsenic, on the other hand, evaporates without melting.

There are several of the metals which emit a peculiar odour, especially when rubbed, or have their temperature slightly raised. This is particularly the case with copper, iron, and tin. The vapour of others is very remarkable. The arsenic vapour has the smell of garlic; that of tellurium smells like horseradish; and osmium takes its name from the smell of its vapour (osme, odour). Some of the metals have also a peculiar taste when applied to the tongue, which has been ascribed to their electrical condition; but it must be remarked that many of the most oxidable metals are entirely destitute both of *taste* and *odour*.

A high specific gravity was reckoned one of the most marked characteristics of the metals, till the discovery of the metallic basis of the alkalies by Sir Humphrey Davy. So intimately indeed was the metallic lustre associated in the mind with great weight, that when a piece of potassium was put, for the first time, into the hand of an eminent teacher of chemistry, in admiring its perfect metallic character, he poised it upon the finger, and exclaimed, "How heavy!" and the prejudice was only removed by seeing it float upon water. The list of metals, however, includes the densest forms of matter with which we are acquainted; and, although great weight cannot be regarded as a universal property, we have few examples in which the density is less than the density of water. These examples comprehend only potassium and sodium; all other metals are of greater specific gravity, up to platinum, which is twenty-one times the weight of an equal bulk of water.

The degrees of facility with which the metals combine with oxygen differ widely. Some, by mere exposure to the atmosphere, absorb its oxygen with great rapidity: such is the case with potassium and sodium: others absorb it more slowly, as manganese, iron, and arsenic; and lead and copper still more slowly. Others, again, do not oxidate by exposure to air, unless at a high temperature; this is the case with tin, zinc, mercury, antimony, bismuth, and cobalt, which absorb the oxygen readily when in a state of fusion. Others, again, do not oxidate by exposure to air and heat, or by immersion in water, as gold and platinum; the same is nearly true of nickel and silver. The tendency of the metals to combine with oxygen appears, however, to be greatly influenced by their mechanical condition; for some of them, which are only slowly oxidized by exposure to air and heat, are rapidly acted upon when in very fine mechanical division, even at common temperatures.

In combining with oxygen under heat, some of the metals burn with great splendour: this is exemplified in copper, zinc, tin, and bismuth. Iron filings, when thrown even into the flame of a candle, and very fine iron wire, when held in the external part of the flame, take fire and throw off beautiful scintillations. Antimony burns at a white heat, and tellurium burns before the flame of the blow-pipe. In short, at intense heats most of the metals may be burned, and, if placed in the flame of the oxy-hydrogen blow-pipe, they deflagrate with intense brilliancy and great facility.

On the other hand, *potassium* burns by contact with a piece of *ice*, with as much intensity as others do in the oxy-hydrogen flame.

The metals, by combination with oxygen, lose their metallic characters, and form an important series of definite compounds known as the *metallic oxides.* These have very different characters and properties; even the same metal not unfrequently affords oxides which differ from each other widely in properties and appearance. Thus fifty parts of mercury, combining with one part of oxygen, produces a black oxide, and with two parts of oxygen, the oxide is red and highly poisonous. Many of the metals thus afford more than one oxide; and it is to be observed, that when the same metal unites in more than one proportion with oxygen, the oxygen in the second and higher oxides bears a definite arithmetical relation to the first; and when two oxides are thus formed, that having the minimum of oxygen is termed the protoxide, and that with the maximum of oxygen the peroxide. This law of definite proportions will be explained hereafter.

Among the combinations of metals with oxygen, some are soluble in water and alkaline, such as the *fixed alkalies,* soda, potash, and lithia, and the *alkaline earths;* others are soluble and sour, forming the *metallic acids.* Some are insoluble in water, and have neither taste nor smell; and many when taken into the stomach act as poisons. Thus, oxide of arsenic is a notorious and virulent poison; oxide of copper is less virulent than arsenic; oxide of lead is a painful poison; oxide of nickel is also destructive of life; and the peroxide of mercury, unless in small quantities, is likewise poisonous.

ON METALLIC ALLOYS.

The metals, for the most part, may be combined with each other, forming a most important class of compounds, known as the *metallic alloys.* Many of these are more useful than the metals of which they are composed, and possess properties a good deal different from their elements. One of the best known and most serviceable of all the alloys is brass, a compound of zinc and copper: it is harder, more easily melted, more close in the texture, better coloured, and less liable to tarnish than copper; it is less brittle, and in every way more valuable than zinc. Pinchbeck is composed of the same ingredients as brass, but in different proportions, the zinc predominating. Copper and tin are two very soft and flexible metals, which, being fused together, form the alloy known as bell-metal, which is harder than iron, very brittle, and very sonorous. The same materials, in different proportions, form speculum metal, and the kind of ordnance improperly called brass cannon. Pewter is composed of tin and lead, sometimes with the addition of zinc, copper, or bismuth.

Plates upon which music is stamped are composed of tin and antimony; and printing types are formed of an alloy of lead and antimony, with a slight addition of bismuth. Tin-foil is an alloy of tin and lead; and plumbers' solder is composed of the same metals. Fusible metal is a compound of bismuth, lead, and tin, with sometimes a little mercury.

An *amalgam* of zinc and mercury is used for exciting electric machines, and that of mercury and tin is the compound employed for *silvering* looking-glasses. Gold coin is an alloy of gold and copper, in the proportion of 11 to 1; and jewellers' gold is an alloy of the same metals in the proportion of 3 of gold to 1 of copper. Green gold has silver instead of copper. Silver coin, in like manner, is an alloy of silver and copper in the proportion of 37 to 3. These *alloys* of gold and silver are harder, and consequently less liable to wear than the pure metals.

It is worthy of remark, that in the formation of alloys, the metals in the act of combination generally evolve heat. For instance, when platinum and tin-foil are fused together, there is the most vivid ignition; and when zinc and copper are suddenly mixed, in the proportion to form brass, the increase of heat is such as to vaporize part of the metal.

The alloys are formed by various processes, depending upon the nature of the metals employed. Most of them are prepared by simply fusing the two metals together; but if there be a considerable difference in their specific gravities, the heavier very generally subsides, and the lower part of the mass thus differs in composition from the upper. This may be in a great measure prevented by agitating the alloy till it solidifies, but this is not always convenient. Thus, in stereotype plates which are cast vertically, the upper side usually contains more antimony than the other. The same is observed when an alloy of gold and copper is cast into bars; the mould being placed perpendicularly, the upper part of the bar contains more copper than the lower. Copper and silver evince the same tendency to separate; although they appear readily to combine, it is found extremely difficult to form a bar of their alloy of perfectly uniform composition throughout. Many of the alloys, however, appear to be true chemical compounds; and in some cases the metals unite in definite proportions only.

It is indeed not improbable that wherever metals do form alloys, that the alloys so formed are definite compounds, and that any undue quantity of either metal present, simply mixes mechanically with the mass. Thus, among the artificial as well as natural alloys, there are many which crystallize; and in some cases, the true compound may be separated from the mere mixture of the superfluous metal by the process of crystallization.

The tendency of the metals to unite with other elements, and with each other, prevents their being often found disseminated in mineral nature, in their pure metallic state.

Some of them do occur so nearly pure as to be called *native metals.* Thus gold is found only slightly alloyed with silver and copper, and platinum occurs as an alloy of iron, palladium, iridium, rhodium, and osmium. Silver, copper, mercury, antimony, bismuth, arsenic, and tellurium, occur both in the native metallic state, although never absolutely pure, and mineralized with other bodies. Lead, tin, zinc, iron, antimony, and several others, are extensively disseminated as sulphurets, that is, combined or mineralized by sulphur.

The combination of a metal with its mineralizing substance, is what we denominate an *ore;* and it is in this state of ore that metals occur, when they are not found native. The ores are exceedingly diversified in appearance; sometimes they possess metallic lustre; sometimes they appear stony, at other times earthy. In some instances they are crystallized into regular forms, but more commonly they occur in shapeless masses. The ores are chiefly found in *veins*—that is, large fissures of rock, especially the granitic, schistous, and limestone rocks; but sometimes they are found in rounded and detached fragments, disseminated through certain alluvial and diluvial strata of the earth. The extraction of the metal from them is denominated their *reduction*, and implies a laborious series of operations, mechanical and chemical, comprehended under the term *metallurgy*.

The following table contains an enumeration of the metals, and may be useful for reference. The column headed "equivalents," shows the weight which unites with 8 oxygen to form the oxides, and the succeeding column contains the symbols by which the metals are denoted in systematic chemistry.

Names of Metals.	Authors, and Dates of their Discovery.		Specific Gravity.	Melting Points.	Equ. Hyd. = 1.	Abr. or Sym.
				Fahr.		
1. Gold (Aurum)	Known to the ancients.		19.25	2016?	200	Au.
2. Silver (Argentum)			10.47	1873	108	Ag.
3. Iron (Ferrum)			7.78	*2800?	28	Fe.
4. Copper (Cuprum)			8.89	1996	64	Cu.
5. Mercury (Hydrargyrum)			13.56	—39	200	Hg.
6. Lead (Plumbum)			11.35	612	104	Pb.
7. Tin (Stannum)			7.29	442	58	Sn.
8. Antimony (Stibium)	Basil Valentine	1490	6.70	. .	65	Sb.
9. Bismuth	Agricola	1530	9.80	497	72	Bi.
10. Zinc	Paracelsus?	1530	7.00	773	32	Z.
11. Arsenic	Brandt	1733	5.88	. .	38	Ar.
12. Cobalt			8.53	2810?	30	Co.
13. Platinum	Wood	1741	20.98	oh. bp.†	99	Pl.
14. Nickel	Cronstedt	1751	8.27	2810?	30	Ni.
15. Manganese	Gahn	1774	6.85	s. f. *	28	Mn.
16. Tungsten (Wolfram)	D'Elhuiart	1781	17.60	. .	100	W.
17. Tellurium	Muller	1782	6.11	620?	32	Te.
18. Molybdenum	Hielm	1782	7.40	oh bp	48	Mo.
19. Uranium	Klaproth	1789	9.00	oh bp	217	U.
20. Titanium	Gregor	1791	5.30	oh bp	24	Ti.
21. Chromium	Vauquelin	1797	. .	oh bp	28	Cr.
22. Columbium (Tantalum)	Hatchett	1802	. .	oh bp	185	T.
23. Palladium	Wollaston	1803	11.50	. .	54	Pd.
24. Rhodium			. .	oh bp	52	R.
25. Iridium	Tennant	1803	. .	oh bp	99	Ir.
26. Osmium			. .	oh bp	100	Os.
27. Cerium	Hisinger	1804	. .	. .	48	Ce.
28. Potassium (Kalium)	Davy	1807	0.86	136	40	K.
29. Sodium (Natronium)			0.97	190	24	Na.
30. Barium			. .	. .	70	Ba.
31. Strontium			. .	. .	44	Sr.
32. Calcium			. .	. .	20	Ca.
33. Cadmium	Stromeyer	1818	8.60	442	56	Cd.
34. Lithium	Arfswedson	1818	. .	. .	8	L.
35. Silicium	Berzelius	1824	. .	. .	8	S.
36. Zirconium			. .	. .	33	Zr.
37. Aluminum	Wohler ?	1828	. .	. .	14	Al.
38. Glucinum			. .	. .	18	Gl.
39. Yttrium			. .	. .	32	Y.
40. Thorium	Berzelius	1829	. .	. .	60	Th
41. Magnesium	Bussy	1829	. .	. .	13	Mg
42. Vanadium	Seftstrom	1830	. .	. .	69	V.
43. Lantanum	Mosander	1840	. .	. .	?	Ln

* Smith's forge.

† Oxy-hydrogen blowpipe.

ON THE CONDUCTING POWERS OF VARIOUS METALS FOR VOLTAIC ELECTRICITY.

THE researches of Pouillet have thrown much light upon our knowledge of the conducting powers of various bodies for voltaic electricity, and the results he has arrived at enable him to express the relative conducting powers of the different metals by the following numbers:—

Palladium	5791
Silver	5152
Gold	3975
Copper	3838
Platinum	855
Bismuth	384
Brass from	900 to 200
Cast steel from	800 to 500
Iron	600
Mercury	100

The resistance of metals to conduction of electricity has been accurately ascertained by means of the degrees of heat evolved by the passage of a current of equal intensity through different metals;

the heat developed in conducting wires is in proportion to the extent of surface of the positive plate, no matter whether the current emanate from a single cell or a series of cells. The following table shows the degrees of heat evolved by an equal current from different metals, measured by the pressure of expanded air upon a column of alcohol:

Metals.	Heat Evolved.	Resistance.
Silver	6	1
Copper	6	1
Gold	9	1½
Zinc	18	3
Platinum . . .	30	5
Iron	30	5
Tin	36	6
Lead	72	12
Brass	18	3

It is apparent that the conducting powers of the above metals are inversely as these numbers. Silver being a better conductor than lead, in the ratio of 12 to 1.

TABLE OF EXPERIMENTAL RESULTS AS TO SOME OF THE CHEMICAL AND PHYSICAL PROPERTIES OF THE ATOMIC ALLOYS OF COPPER AND ZINC, AND OF COPPER AND TIN. BY R. MALLET, M. R. I. A., ASS. INS. C. E., ETC.

TABLE I.—Showing the Chemical and Physical Properties of the Atomic Alloys of Copper and Zinc.

1	2	3	4	5	6	7	8	9	10	11	12	13	14
No. of Experiment.	Chemical Constitution.	Composition by weight per cent.	Atomic Weight, Hydro- [illegible]ing taken [illegible]s 1.	Specific Gravity.	Colour.	Fracture.	Ultimate Cohesion, per square Inch in Tons.	Order of Ductility.	Order of Malleability at 60° Fahrenheit.	Order of Hardness, &c.	Order of Fusibility.	Characteristic Properties, in Working, &c.	Relation to Cast-Iron, in presence of a solvent, i.e. Sea Water.
1	C. +	100.00 + 0	31.6	8.667	Tile Red.	E.	24.6	8	1	22	15	Well known.	All these Alloys increase the Corrosion of Cast Iron in Sea Water, when in their presence.
2	10 C. + Z.	90.70 + 9.30	348.3	8.605	Reddish yellow, 1	C. C.	12.1	6	13	21	14		
3	9 C. + Z.	89.80 + 10.20	316.7	8.607	Reddish yellow, 2	F. C.	11.5	4	11	20	13		
4	8 C. + Z.	88.70 + 11.30	285.1	8.633	Reddish yellow, 3	F. C.	12.8	2	10	19	12	Similor, &c. } Several of these are malleable at high temperatures.	
5	7 C. + Z.	87.70 + 12.30	253.4	8.587	Reddish yellow, 4	F. C.	13.2	9	9	18	11		
6	6 C. + Z.	85.08 + 14.92	221.9	8.591	Yellowish red, 3	F. F.	14.1	5	8	17	10		
7	5 C. + Z.	83.02 + 16.98	190.3	8.415	Yellowish red, 2	F. C.	13.7	11	2	16	9	Bath Metal.	
8	4 C. + Z.	79.65 + 20.35	158.7	8.448	Yellowish red, 1	F. C.	14.7	7	3	15	8	Dutch Brass.	
9	3 C. + Z.	74.58 + 25.42	127.1	8.397	Pale yellow.	F. C.	13.1	10	4	14	7	Rolled Sheet Brass.	
10	2 C. + Z.	66.18 + 33.82	95.5	8.299	Full yellow, 1	F. C.	12.5	3	6	13	6	British Brass.	
11	C. + Z.	49.47 + 50.53	63.9	8.230	Full yellow, 2	C. C.	9.2	12	5	12	6	German Brass.	
12	C. + 2 Z.	32.85 + 67.15	96.2	8.283	Deep yellow.	C. C.	19.3	1	7	10	6	Brass, Watchmakers.	
13	8 C. + 17 Z.	31.52 + 68.48	801.9	7.721	Silver white, 1	C.	2.1	0	22	5	5	Very Brittle, } Too hard to file or turn, lustre nearly equal to Speculum Metal.	All these Alloys decrease the Corrosion of Cast Iron in Sea Water, when in their presence.
14	8 C. + 18 Z.	30.30 + 69.70	834.2	7.836	Silver white, 2	V.C.	2.2	0	23	6	5	Very Brittle,	
15	8 C. + 19 Z.	29.17 + 70.83	866.5	8.019	Silver gray, 3	C.	0.7	0	21	7	5	Very Brittle,	
16	8 C. + 20 Z.	28.12 + 71.88	898.8	7.603	Ash gray, 3	V.	3.2	0	19	3	5	Brittle,	
17	8 C. + 21 Z.	27.04 + 72.96	931.1	8.058	Silver gray, 2	C.	0.9	0	18	9	5	Brittle,	
18	8 C. + 22 Z.	26.24 + 73.76	963.4	7.882	Silver gray, 1	C.	0.8	0	20	8	5	Very Brittle,	
19	8 C. + 23 Z.	25.39 + 74.61	995.7	7.443	Ash gray, 4	F. C.	5.9	0	15	1	5	Barely Malleable.	
20	C. + 3 Z.	24.50 + 75.50	128.5	7.449	Ash gray, 1	F. G.	3.1	0	16	2	4	Brittle.	
21	C. + 4 Z.	19.65 + 80.35	160.8	7.371	Ash gray, 2	F. C.	1.9	0	14	4	3	White Button Metal.	
22	C. + 5 Z.	16.31 + 83.69	193.1	6.605	Very dark gray.	F. C.	1.8	0	17	11	2	Brittle.	
23	+ Z.	0 +100.00	32.3	6.895	Bluish gray.	T. C.	15.2	13	12	23	1	Brittle, well known.	

TABLE II.—Showing the Chemical and Physical Properties of the Atomic Alloys of Copper and Tin.

1 No. of Experiment.	2 Chemical Constitution.	3 Composition by weight per cent.	4 Atomic Weight, Hydrogen being taken as 1.	5 Specific Gravity.	6 Colour.	7 Fracture.	8 Ultimate Cohesion, per square Inch in Tons.	9 Order of Ductility.	10 Order of Malleability at 60° Fahrenheit.	11 Order of Hardness, &c.	12 Order of Fusibility.	13 Characteristic Properties, in Working, &c.	14 Relation to Cast-Iron, in presence of a solvent, *i.e.* Sea Water.
1	C. +	100.00 + 0	31.6	8.667	Tile Red.	E.	24.6	1	2	10	16	Well known.	Every Alloy of C. + T. increases the Corrosive action of Sea Water on Cast Iron, in their presence; the maximum increase is due to Tin.
2	10 C. + T.	84.29 + 15.71	374.9	8.561	Reddish yellow, 1	F. C.	16.1	2	6	8	15	Gun Metal, &c.	
3	9 C. + T.	82.81 + 17.19	343.3	8.162	Reddish yellow, 2	F. C.	15.2	3	7	5	14	Gun Metal, &c.	
4	8 C. + T.	81.10 + 18.90	311.7	8.459	Yellowish red, 2	F. C.	17.7	4	10	4	13	Gun Metal and Bronze.	
5	7 C. + T.	78.97 + 21.03	280.1	8.728	Yellowish red, 1	V. C.	13.6	5	11	3	12	Hard Mill Brasses, &c.	
6	6 C. + T.	72.27 + 27.73	248.5	8.750	Bluish red, 1	V.	9.7	0	12	2	11	Brittle, } All these Alloys found occasionally in Bells, with mixtures of Zinc and Lead.	
7	5 C. + T.	72.80 + 27.20	216.9	8.575	Bluish red, 2	C.	4.9	0	13	1	10	Brittle,	
8	4 C. + T.	68.21 + 31.79	185.3	8.400	Ash gray.	C.	0.7	0	14	6	9	Crumbles,	
9	3 C. + T.	61.69 + 38.31	153.7	8.539	Dark gray.	T. C.	0.5	0	16	7	8	Crumbles,	
10	2 C. + T.	51.75 + 48.25	122.1	8.416	Grayish white, 1	V. C.	1.7	0	15	9	7	Brittle,	
11	C. + T.	34.92 + 65.08	90.5	8.056	Whiter still, 2	T. C.	1.4	0	9	11	6	Small Bells, Brittle.	
12	C. + 2 T.	21.15 + 78.85	149.4	7.387	Whiter still, 3	C. C.	3.9	0	8	12	5	" Brittle.	
13	C. + 3 T.	15.17 + 84.83	208.3	7.447	Whiter still, 4	C. C.	3.1	0	5	13	4	Speculum Metal of authors	
14	C. + 4 T.	11.82 + 88.18	267.2	7.472	Whiter still, 5	C. C.	3.1	8	4	14	3	" Files, Tough.	
15	C. + 5 T.	9.68 + 90.32	326.1	7.442	Whiter still, 6	E.	2.5	6	3	15	2	" Files, Soft & Tough.	
16	+ T.	0 + 100.00	58.9	7.291	White, 7	F.	2.7	7	1	16	1	Well known.	

Abbreviations used in column 7th to denote character of Fracture:—F.C. Fine Crystalline, C.C. Coarse Crystalline, T.C. Tabular Crystalline, F.F. Fine Fibrous, C. Conchoidal, V.C. Vitreo-Conchoidal, V. Vitreous, E. Earthy.

The maxima of ductility, malleability, hardness, and fusibility, are = 1.

The numbers in column 6th denote intensity of shade of the same colour.

The atomic weights are those of the hydrogen scale.

The specific gravities were determined by the method indicated in report "On Action of Air and Water on Iron," Trans. Brit. Ass. Vol. vii. p. 283.

The ultimate cohesion was determined on prisms of 0.25 of an inch square, without having been hammered or compressed after being cast. The weights given are those which each prism just sustained for a few seconds before disruption.

The copper used in these alloys was granulated, and of the finest "tough pitch;" the zinc was Mosselman's from Belgium; and the tin "grain tin," from Cornwall. They were alloyed in a peculiar apparatus, to avoid loss by oxidation, and the resulting alloy verified by analysis.

No simple binary alloy of copper and zinc, or of copper and tin, works as pleasantly in turning, planing, or filing, as if combined with a very small proportion of a third fusible metal—generally lead is added to C. + Z., and Zinc to C. + T., as is known to workers in metals.

ON FOUNDING.

The general object of *founding* is, to mould iron, copper, tin, zinc, lead, &c., &c., in a melted state into the various forms required for the parts of machines and other constructions.

Wrought iron and steel cannot be properly melted by heat. At high temperatures they drop away and spark off, while the main body of the metal maintains its consistency, and it undergoes rapid oxidation, as is shown by the scales which are perpetually formed on its surface.

These metals are, however, in this condition rendered extremely ductile, and the wrought iron especially may be fashioned with facility into any required form, by the application of the hammer. On the contrary, pig iron, of which wrought iron and steel are preparations, has peculiarly the property of liquefaction by heat, and is therefore well adapted as a material for castings, in which strength and hardness are required.

The business of the founder is therefore to take advantage of the common law, according to which fluids always find their level. If, for example, a quantity of water be poured into a vessel, however curiously shaped, it first finds the bottom, and then spreads on all sides as it rises, filling every corner it can reach. The body of water must then be a perfect model in form of the interior of the vessel, and this may be seen by solidifying it in its place by the application of cold, and extracting the body of ice.

To mould a quantity of melted metal into a desired form, two things are therefore necessary: first, a model, or pattern of the required form. Secondly, a substance of sufficient susceptibility and adhesiveness to receive accurately, and to retain impressions of that pattern made upon it, against the violence of the liquid metal, when run into the mould which is thereby formed.

ON BRASS FOUNDING.

Brass founding, considered as a branch of engineering, is beset with a host of empirical rules and fancies, to an extent which naturally surprises the scientific practician, when he considers it with regard to the present calculating and philosophizing age.

Every founder thinks he possesses the only true and orthodox system of producing first-rate castings, and, as a matter of course, every one differs from his neighbour in his routine of practice, without reflecting that the process admits as fully of a reduction to scientific rules as any of its sister branches of the manipulatory art.

It is scarcely necessary to observe, that excellence can never be attained in any art in the prosecution of which so loose a system is tolerated: *guess-work* will ever give chance results, productive only of inconveniences and objections, which a more systematic code of regulations would entirely obviate. The number of alloys of copper which come under the generic name of brass, as has been shown, amount to a numerous family, and are of the greatest importance, not only to the engineer, but to artists generally, involving the use of the following different metals, all of which are required in a greater or less degree to suit the variety of operations where brass is indispensable: namely, copper, tin, lead, zinc, antimony, and, in some cases, nickel.

The first four of these metals are those in the greatest request for engineering purposes. The leading metal of this series, copper, was known to the ancients previous to the discovery of *malleable* *iron*, and was applied to all the purposes for which the latter metal alone is now used.

Although we find brass frequently spoken of in the Scriptures, as well as in many portions of profane history, yet it is a well ascertained fact that this refers to copper; the brass of the present day being a discovery of much later date.

COPPER.

THE word copper is derived from the Island of Cyprus, where it was first wrought by the Greeks. The best method of obtaining it pure, where extreme purity is an object of importance, is to dissolve it in nitric acid: the solution is then diluted, and a piece of iron introduced, upon which the pure metal is precipitated, any adherent particles of iron being readily removed by washing with dilute sulphuric acid. Another method has lately been discovered of purifying copper, namely, by melting 100 parts of it, with 10 parts of copper scales (black oxide), along with 10 parts of ground bottle-glass, or other flux. Mr. Lewis Thompson, who received a gold medal from the Society of Arts, for this invention, says that, after the copper has been kept in fusion for half an hour, it will be found at the bottom of the crucible, perfectly pure, while the iron, lead, arsenic, &c., &c., with which this metal is usually contaminated, will be oxidized by the scales, and will dissolve in the flux, or be volatilized. Thus he has obtained perfectly pure copper from brass, bell-metal, gun-metal, and several other alloys, containing from 4 up to 50 per cent. of iron, lead, bismuth, antimony, arsenic, &c. The scales of copper are cheap, being the product of every large manufactory. Copper melts at a white heat, and by slow cooling may be crystallized. Its specific gravity is 9, nearly. It melts at a temperature of 1996° Fahr.

On the Reduction of Copper.

The reduction of copper ore is made by several consecutive processes. The *first* is by calcining it, and, when the *ore* is sufficiently "roasted" to oxidate the iron which it contains, it is melted. The melted metal is, after a time, suffered to flow into a pit filled with water, by which it becomes granulated.

It then undergoes further heating, and what is called technically its slag (or scoria) is taken off, and it is allowed again to run off into water.

After these processes it is cast in sand, when it becomes solid, and in this state is called "blistered copper."

It is now fit for what is called the refinery, and undergoes an operation called *refining*, or *toughening*. This is considered to be an operation of delicacy, and requires great skill and care in the workmen. It is conducted to a furnace similar to the melting furnace, and the object is to thoroughly purify the metal from any portions of oxygen, which is performed by adding charcoal to the copper, while it is in fusion, and stirring it occasionally, till it is judged to be pure.

TIN, OR BEDIL IN THE HEBREW.

THE next metal on our list has also been known from the remotest ages. It is mentioned by Eleazar the priest in the book of Numbers, chapter 31st, verse 22d. All the other metals supposed to have been then known are enumerated in the same passage. Thus, lexicographers form *bedil*, "to separate," tin being a separating metal. This carries the knowledge and use of *tin* back 1500 years antecedent to the commencement of our era. The Phœnicians used tin, of course, in the erection and decoration of the Temple of Solomon. Their brass was bronze; zinc had not then been discovered. We read of tin, also, having been got by the Carthaginian navigator, Himiles, from the Scilly Islands; they certainly present appearances of ancient excavations. Tin occurs, native, in two forms—as peroxide, and as sulphuret of tin and copper. The last is rare; the former constitutes the great source of tin, and, in its native mixed state with arsenic, copper, zinc, and tungsten, is called "tin-stone;" but, when occurring in rounded masses, grains, or sand in alluvial soil, is called stream tin. The metal reduced from the tin-stone forms *block tin*—that from the stream tin forms *grain tin.*

The greater part of the East Indian tin comes from Siam, Malacca, and Banca. The last place is an island near the south-east coast of Sumatra. The mines were discovered in 1711; in 1776 there were ten pits which were worked by the Chinese on account of the King of Palimbang. One hundred and twenty-five pounds cost him only five rix dollars. The greater part went to Alinia, or was used in India.

On the Reduction of Tin, Grain, and Block Tin.

THE best ore of tin is found in Cornwall; it is commonly blasted by gunpowder, and is procured in pieces of considerable size, which are stamped, by beams shod with iron, to powder. It is then well washed, till the earthy particles are carried off, and the tin is fit for the smelting-house.

After being roasted in a reverberatory furnace, and again washed, it is a second time subjected to the furnace, being now mixed with small coal and, in some cases, with a small quantity of lime. The melted tin thus produced is at last placed in a small furnace, and exposed to a very gentle heat, when the purest portion melts first, and is drawn off. This is called "common grain tin." And the inferior, which still contains a small proportion of copper and arsenic, is then cast into pigs, called "block tin."

The purest tin is procured from the stream works of Cornwall, and affords from 65 to 75 per cent. of the best grain tin; its specific gravity is about 7.5;

it melts at a temperature of 442°. Like copper, it is the nucleus of an immense number of subsidiary metals, which it is our intention shortly to enter upon.

ZINC.

Zinc is a metal whose extensive range of application is only now beginning to be understood. It is found in the state of oxide and sulphuret; its specific gravity is about 7.7; its fusing point is 773°, but at a temperature of 300°, it becomes extremely malleable, and may be rolled into thin leaves, or drawn into fine wire. One of its most valuable modern applications, is as a protective covering for iron, being the best known substance for this purpose. The purifying of zinc may be effected by melting the impure metal with *lead*, in equal parts, in a deep iron pot, stirring them well together, skimming off the impurities as they rise, covering the surface with charcoal to prevent oxidation, and keeping them in a fused state for three hours. The lead descends to the bottom by its greater density, and leaves the zinc above, to be drawn off by a pipe in the side of the melting-pot. This contrivance is the subject of a patent, granted to Mr. William Godfrey Kneller, in 1844.

LEAD.

LEAD was also known to the ancients. Its specific gravity is 11.4; melts at a temperature of 612°. This metal is highly poisonous, and the greatest amount of caution ought to be observed in its application to domestic purposes, as, when in contact with water in open vessels, it quickly tarnishes, and small crystalline scales of oxide of lead are formed, a portion of which dissolves in the water, and is again precipitated in the form of a carbonate. If, however, the water contains a very slight amount of sulphuric acid, or a soluble sulphate, the corrosion is prevented.

ANTIMONY.

Antimony was discovered by Basil Valentine (a monk), in the fifteenth century. It is of a grayish-white, having a slight bluish shade, and very brilliant. Its texture is lamellated, and exhibits plates crossing each other in every direction. Its surface is covered with herbarizations and foliage. Its specific gravity is 6.702. It is sufficiently hard to scratch all the soft metals; it is very brittle, easily broken, and pulverizable. It fuses at 810° Fahr.; it can be volatilized, and burns by a strong heat. When perfectly fused and suffered to cool gradually, it crystallizes in octahedra. It unites with sulphur and phosphorus. It decomposes water strongly. It is soluble in alkaline sulphates; sulphuric acid boiled upon antimony, is feebly decomposed. Nitric acid dissolves it in the cold; muriatic acid scarcely acts upon it. The oxygenated muriatic gas inflames it, and the liquid acid dissolves it with facility. Arsenic acid dissolves it by heat with difficulty. It unites by fusion with gold, and renders it pale and brittle. Platina, silver, lead, bismuth, nickel, copper, arsenic, iron, cobalt, tin, and zinc unite with antimony by fusion, and form with it compounds more or less brittle. Mercury does not alloy with it easily. We are little acquainted with the action of alkalies upon it. Nitrate of potash is decomposed by it. It fulminates by percussion with oxygenated muriate of potash.

THE order and facility of working these metals vary considerably with the purpose to which they are applied. Thus, regarding their wire-drawing ductibility, gold is the most ductile metal, being 1. The four first metals are as follows: copper 5, zinc 6, tin 7, lead 8. Their relative values as laminable substances are considerably different: thus, under the same circumstances, copper is 3, tin 4, lead 6, zinc 7.

The following tabulated statements exhibit the most approved properties of the most useful class of alloys, as laid down by the best authorities, together with the specific purposes to which they are adapted. The first we shall treat upon are the alloys of copper and tin. In this table the quantity of tin is that which is added to one pound of copper.

COPPER AND TIN.

1	ounce,	Soft gun metal.
1¼	“	A slightly harder alloy, fit for mathematical instruments.
1½	“	Still harder, fit for wheels.
1½ to 2	“	Brass guns.
2 to 2½	“	Hard bearings for machinery.
3	“	Musical bells.
3½	“	Chinese gongs, cymbals, &c.
4	“	Small house bells for domestic purposes.
4½	“	Large do.
5	“	Largest bells, for churches, &c.
7 to 8	“	Speculum metal for the reflectors of telescopes, light-houses, &c.

Temper, is a mixture of 2 pounds of tin to 1 pound of copper, and is used for adding to tin in the manufacture of pewter; the object being to introduce an extremely small quantity of copper.

BRONZE FOR CANNON, STATUES, ETC.

BRONZE is an alloy of copper, with from 8 to 10 per cent. of tin, together with small quantities of other metals, which are not essential to the compound. Cannons are cast with an alloy of a similar kind, and the ancient bronze statues were of the same composition.

ON BELL METAL.

BELL METAL is a compound of 80 parts copper to 20 parts tin. The Indian gong, so much celebrated for the richness of its tones, contains copper and tin, in the above proportions. The proportion of tin in bell metal varies, however, from one-third to one-fifth of the weight of copper, according to the sound required, the size of the bell, and the impulse to be given. M. de Arcet has discovered that bell metals formed in the proportion of 78 parts copper, united with 22 of tin, is indeed nearly as brittle as glass, when cast in a thin plate or gong. Yet if it be heated to a cherry-red, and plunged into cold water, being held between two plates of iron, that the plate may not bend, it becomes malleable. Thus he manufactures gongs, cymbals, and tantums out of this compound.

ON COPPER AND TIN MIXTURES.

The above are the best proportions in use at the present day; for some other peculiar objects a slightly different mixture is adopted, as a small amount of zinc or silver, and even arsenic. The best mode of mixing the component metals of this alloy, appears to be to melt each separately, and then to add the tin to the copper at the lowest stirring temperature. To complete the combination the alloy is again melted very gradually by placing the metal in the crucible almost as soon as the fire is lighted. The hardness of this alloy, compared with the extreme softness of the metals, gives us an example of the chemical changes effected by their combination. Thus, the speculum metal, as used by Lord Rosse, is totally devoid of malleability, and from its hardness cannot be acted on by the file.

His speculum consisted of four atoms of chemical combining proportions of copper to one of tin: or, by weight, 126.4 copper to 58.9 tin. This alloy, which is a true chemical compound, is of a brilliant white lustre; its specific gravity 8.811; nearly as hard as steel, and almost as brittle as sealing-wax. The speculum is six feet in diameter, five and a half inches thick. It was cast open, ground with emery, placed on a table in a cistern filled with water at a temperature of 55° Fahr., polished with red oxide of iron, procured by precipitation from green vitriol, or sulphate of iron, by water of ammonia.

ALLOYS OF COPPER AND ZINC.

We now come to the consideration of another branch of the copper alloy family of great value in the arts. This is copper and zinc.

The following table contains the best proportions of the principal mixtures. In this table the quantity of zinc is that which is added to one pound of copper.

⅛ to ½	ounce.	This addition is used principally for the purpose of producing sound copper castings.
1 to 1¼	"	Gilding metal for jewellers.
2	"	Tombac, or red brass.
3 to 4	"	Red sheet brass, pinchbeck, and bath metal.
5	"	Purbeck metal.
6	"	Bristol brass. This and the five preceding mixtures solder well.
7 to 7½	"	Good dipping metal.
8	"	The general proportion for all ordinary brass articles.
10⅔	"	Muntz's metal, for ships' fastenings, sheathing, &c.
14	"	Strong brazing solder, for heavy copper work, &c.
16	"	Soft spelter solder.

From the volatile nature of zinc the above proportions can seldom be strictly adhered to; but a slight variation does not much affect the filing and working of the metal.

An alloy of copper and lead is often used in place of gun metal for inferior work, on account of its cheapness and facility of manipulation. It is very brittle, particularly where much lead is used.

The whole of the different metals just discussed, when mixed together, constitute gun metal, or brass, *par excellence.* This alloy is applied to a very great variety of purposes, and is the one most in demand for engineering works. The principal ones are compounded as below.

ALLOYS OF COPPER, ZINC, TIN, AND LEAD.

1½ ounces tin, ½ ounce zinc, and 16 ounces copper, constitute an extremely tenacious metal, used where great strength is required.

1½ ounces tin, 2 ounces brass, 16 ounces copper, for wheels, &c.

2 ounces tin, 1½ ounces brass, 16 ounces copper, for articles requiring turning.

2¼ ounces tin, 1½ ounces brass, 16 ounces copper, for bearings, nuts, &c.

1⅞ ounces tin, 1⅞ ounces zinc, 16 ounces copper a composition for general purposes, used by an eminent engineer.

2½ ounces tin, ½ ounce zinc, 16 ounces copper, for bearings to resist great strains.

2½ ounces tin, 2½ ounces zinc, 16 ounces copper, an extremely hard metal, almost too hard for the file.

1 ounce tin, 2 ounces zinc, 16 ounces copper, good button metal.

5 pounds of zinc to 8 pounds of brass (called platina), an extremely pale, nearly white metal, used by Birmingham button-makers.

9 pounds of zinc to 32 pounds of brass, another alloy, called Bath metal.

10 pounds of tin, 6 pounds of copper, 4 pounds of brass, constitute white solder.

14.75 tin, 144 copper, and 12 brass, is the alloy of the English standard measure.

◆

Manheim Gold.—3 parts copper, 1 part zinc, and a small quantity of tin. If these metals are pure, and melted in a covered crucible, containing charcoal, the alloy bears so close a resemblance to gold as to deceive very skilful persons.

Best *Pinchbeck*, 5 ounces pure copper, and 1 of zinc.

Princess Metal.—3 parts copper, 1 part common brass, and ½ ounce zinc.

5½ pounds copper, ½ pound zinc, best *Tombac*, beautifully red, and is more durable than copper.

Artificial Gold.—16 parts virgin platina, 7 parts copper, 1 part zinc, put in a crucible, covered with powdered charcoal, and melted till the whole forms one mass.

Fine Brazing Solder.—12 pounds of copper, 11 pounds of zinc, flux with powdered brimstone.

We might multiply these examples of the different mixtures, but as we have already extended this portion of our article to a considerable length, and have given what appear to be the best for general purposes, we shall defer any further remarks on the subject, until we come to white metals, receipts, &c., at the latter part of the work.

HAVING discussed the *rationale* of the mixture and proportion of the metals used in alloys of copper, the matter leads us to the further consideration of casting them. Brass moulding is carried on by means of earthen, or sand moulds. The formation of sand moulds is by no means so simple an affair as it would at first sight appear to be, as it requires long practical experience to overcome the disadvantages attendant upon the material used. The moulds must be sufficiently strong to withstand the action of the fluid metal perfectly, and, at the same time, must be so far pervious to the air as to permit of the egress of the gases formed by the action of the metal on the sand. If the material were perfectly air-tight, then damage would ensue from the pressure arising from the rapidity of the generation of the gases, which would spoil the effect of the casting, and probably do serious injury to the operator.

If the gases are locked up within the mould, the general result is what moulders term a *blown* casting; that is, its surface becomes filled with bubbles of air, rendering its texture porous and weak, besides injuring its appearance.

Plaster of Paris is often used for a number of the more fusible metals. This material, however, will not answer for the more refractory ones, as the heat causes it to crumble away and lose its shape.

Sand, mixed with clay or loam, possesses advantages not to be found in gypsum, and is consequently used in place of it, for brass and other alloys. In the formation of brass moulds, old damp sand is principally used in preference to the fresh material, being much less adhesive, and allowing the patterns to leave the moulds easier and cleaner.

Meal dust or flour is used for facing the moulds of small articles; but for larger works, powdered chalk, wood-ashes, &c., are used, as being more economical.

If particularly fine work is required, a *facing* of *charcoal* or *rottenstone* is applied. Another plan for giving a fine surface is to dry the moulds over a slow fire of *cork shavings*, or other carbonaceous substance, which deposits a fine thin coating of carbon. *This*, when good fine facing-sand is not to be obtained.

As regards the proportions of sand and loam used in the formation of the moulds, it is to be remarked, that the greater the quantity of the former material, the more easily will the gases escape, and the less likelihood is there of a failure of the casting; on the other hand, if the latter substance predominates, the impression of the pattern will be better, but a far greater liability of injury to the casting will be incurred from the impermeable nature of the moulding material. This however may be got over without the slightest risk, by well drying the mould prior to casting, as you would have to do were the mould entirely of loam.

For some works, where easily fusible metal is used, metallic moulds are adopted. Thus, where great quantities of one particular species of casting is required, the metallic mould is cheaper, easier of management, and possesses the advantage of producing any number of exactly similar copies. The simplest example which we can adduce is the casting of bullets. These are cast in moulds constructed like scissors, or pliers, the jaws or nipping portions being each hollowed out hemispherically, so that when closed a complete hollow sphere is formed, having a small aperture leading into the centre of the division line, by which the molten lead is poured in.

Pewter pots, inkstands, printing types, and various other articles, composed of the easily fusible metals, or their compounds, are moulded on the same principle. The pewterer generally uses brass moulds: they are heated previous to pouring in the metal. In order to cause the casting to leave the mould easier, as well as to give a finer face to the article, the mould is brushed thinly over with red ochre and white of an egg; in some cases, a thin film of oil is used instead.

Many of the moulds for this purpose are extremely complex, and, being made in several pieces, they require great care in fitting.

With these peculiar cases we have, at present, little to do, and shall conclude with a few observations on the method of filling the moulds. The experienced find that the proper time for pouring the metal is indicated by the wasting of the zinc, which gives off a lambent flame from the surface of the melted metal. The moment this is observed, the crucible is to be removed from the fire, in order to avoid incurring a great waste of this volatile substance. The metal is then to be immediately poured. The best temperature for pouring, is that at which it will take the sharpest impression and yet cool quickly. If the metal is very hot, and remains long in contact with the mould, what is called *sand-burning* takes place, and the face of the casting is injured.

The founder, then, must rely on his own judgment, as to what is the lowest heat at which good, sharp impressions will be produced. As a rule, the smallest and thinnest castings must be cast the first in a pouring, as the metal cools quickest in such cases, while the reverse holds good with regard to larger ones.

Complex objects, when inflammable, are occasionally moulded in brass, and some other of the fusible metals, by an extremely ingenious process; rendering what otherwise would be a difficult problem a comparatively easy matter.

The mould, which it must be understood is to be composed of some inflammable material, is to be placed in the sand-flask, and the moulding sand filled in gradually until the box is filled up. When dry, the whole is placed in an oven sufficiently hot to reduce the mould to ashes, which are easily removed from their hollow, when the metal may be poured in. In this way (as will be afterwards shown) small animals, birds, or vegetables may be cast with the greatest facility.

The animal is to be placed in the empty moulding-box, being held in the exact position required, by suitable wires or strings, which may be burnt or removed, previous to pouring in the metal.

Another mode which appears to be founded on the same principle, answers perfectly well when the original model is moulded in wax. The model is placed in the moulding-box in the manner detailed in the last process, having an additional piece of wax to represent the runner for the metal. The composition here used for moulding is similar to that employed by statue founders in forming the cores for *statues*, *busts*, &c., namely, two parts brick-dust to one of plaster of Paris. This is mixed with water and poured in so as to surround the model well. The whole is then slowly dried, and when the mould is sufficiently hardened to withstand the effects of the molten wax, it is warmed, in order to liquify and pour it out. When clear of the wax, the mould is dried and buried in sand, in order to sustain it against the action of the fluid metal.

If our limits permitted, we might mention the details of numerous other works in the founding of brass. We must for the present content ourselves with a brief examination of one or two cases which come more or less within the province of the engineer. One of these is the founding of bells, a subject of considerable interest, as works of this kind are often of very considerable magnitude, and demand the skilful attention of the engineer. Large bells are usually cast in loam moulds, being *swept* up, according to the founder's phraseology, by means of wooden or metal patterns, whose contour is an exact representation of the inner and outer surfaces of the intended bell. Sometimes, indeed, the whole exterior of the bell is moulded in wax, which serves as a model to form the impression in the sand, the wax being melted out previous to pouring in the metal. This plan is rarely pursued, and is only feasible when the casting is small.

The inscriptions, ornaments, scrolls, &c., usually found on bells, are put on the clay mould separately, being moulded in wax or clay, and stuck on while soft. The same plan is pursued with regard to the ears, or supporting lugs, by which the bell is hung.

BRASS GUNS

ARE another important branch of this manufacture. They are moulded in a manner quite distinct from any other work of this nature. The exterior surface of the gun is produced by wrapping gaskin or soft rope round a tapered rod, of a length slightly greater than that of the gun. Upon this foundation of rope the moulding loam is then applied; the surface being turned to the exact shape and proportions of the gun.

A long fire is used by the founder in this process, in order to dry the mould as he proceeds in its manufacture. When perfectly dry, the surface of the mould is black-washed over, and again covered with loam to a depth of two or three inches. This exterior coat of loam is secured and strengthened by a number of iron bands, and the whole is well dried. The primary mould is now completely withdrawn from the outer shell, the formation of which renders it an easy matter, as the timber rod leaves the rope with great facility, when the latter may be withdrawn, and the clay covering picked out afterwards.

The trunnions of the gun are formed separately, and attached to the shell in the ordinary way. When finished, the moulds are sunk perpendicularly in a sand pit, near a reverberatory furnace, a vertical runner being made, leading to each mould, which it enters near the bottom. A suitable channel communicates with the furnace containing the brass intended for the guns. The metal being introduced at the bottom of the mould, no air can possibly be detained by its entrance, as each mould is full open to the atmosphere at the top.

FIGURE CASTING

Is another branch of our subject, and one which, from its general complexity, ranks as the greatest effort of the founder. As an example of this process we shall take the moulding of thin ornaments in relief.

The ornament, whatever it may be, a monumental bas-relief for instance, is first modelled in relief, in clay or wax, upon a flat surface. A sand flask is then placed upon the board, over the model, and well rammed with sand, which thus takes the impress of the model on its lower surface. A second flask is now laid on the sunken impression, and also filled with sand, in order to take the relief impression from it. This is generally termed the *cope*, or *back mould.* The thickness of the intended cast is then determined by placing an edging of clay round the lower flask, upon which edging the upper one rests, thus keeping the two surfaces at the precise distance from each other, that it is intended the thickness of the casting shall be.

In this process, the metal is economised to the greatest possible extent, as the interior surface, or back of the casting, is an exact representation of the relief of the subject; and the whole is thus made as thin in every part as the strength of the metal permits.

Several modifications of the process just described are also made use of, to suit the particular circumstances of the case. What we have said, however, is a detail of the principle pursued in all matters of a similar nature. In conclusion we will give a composition for cores that may be required for difficult jobs, where it would be extremely expensive to make a core-box for the same:—

Make a pattern (of any material that will stand moulding from) like unto the core required. Take a mould from the same in the sand, in the ordinary way; place strengthening wires from point to point, centrally; gate and close your flask. Then make a composition of two parts brick-dust and one part plaster of Paris; mix with water and cast. Take it out when set, dry it, and place it in your mould warm, so that there may be no cold air in it.

BRASS MIRRORS.[*]

An Etruscan mirror, placed in the hands of "Gerharht of Berlin," was found to consist, in 100 parts, of 67.12 copper, 24.93 tin, 8.13 lead; approximating closely to an alloy of 8 parts copper, 3 of tin, and 1 of lead. The oxide of tin obtained in the course of analysis was carefully examined before the blow-pipe for antimony, but he saw no trace of that metal.

A similar mirror has been analysed by "Klaproth." He found 62 per cent. copper, 32 tin, and 6 per cent. lead.

Copper.—Copper is thick and pasty, and without some alloy will not run into the cavities and sinuosities of the mould.

Metals.—A quarter of a grain of lead will render an ounce of gold perfectly brittle, although neither gold or lead are brittle metals.

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[*] See Job, xxxvii. 18; Exodus, xxxviii. 8.

Surface of Metals.—The surface of metals should be carefully defended, while in the fluid state, from the action of the atmosphere, by a stratum of wax, pitch, or resin, if the fusing point be low; or by a layer of salt, powdered glass, borax, charcoal, &c., if it is high.

Blanched Copper.—8 ounces of copper, and ½ an ounce of neutral arsenical salt, fused together under a flux of calcined borax and pounded glass, to which charcoal powder is added, makes blanched copper.

British Weapons and Tools in Bronze, anciently called Corinthian and Syracuse Brass.—The metal of which the British weapons and tools were made, has been chemically analysed in modern times, and the proportions appear to be—

In a spear head,	1	part of tin to	6	parts of copper.
In an axe head,	1	do.	10	do.
In a knife,	1	do.	7½	do.

ON BRASS.

In Germany brass appears to have been made for centuries before the manufacture was introduced into England. This is stated to have been done by a German, who worked at Esher, in Surrey, in the year 1649. The analysis of a few pieces of bronze, of undoubted antiquity, namely, a helmet with an inscription (found at Delphi, and now in the British Museum), some nails from the treasury of Atreus, at Mycenæ, an ancient Corinthian coin, and a portion of a breast-plate, or cuirass, of exquisite workmanship (also in the British Museum), affords about 87 to 88 parts copper to about 12 to 13 tin, per cent.

The experiments of Klaproth and others give nearly the same results as to ingredients; the quantities sometimes slightly differ. Lead is contained in some specimens, as has been shown. Zinc, and the nature of it, as heretofore observed, was not known to the ancients.

In an antique sword, found many years ago, in

France, the proportions in 100 parts were, 87.47 copper, 12.53 tin, with a small portion of lead, not worth noticing.

METHOD OF CASTING IN PLASTER—MEDALLIONS, ETC.

Obtain some fine plaster, of good colour, and pass it through a muslin sieve, to remove any coarser particles which may be present. By mixing *gum arabic* with the water intended to be used in the plaster, not only will the plaster be rendered very hard when it sets, but a beautiful gloss will be given to the surface. Care must be taken to drop the plaster powder gradually into the water, and to permit the bubbles to rise before the mixture is stirred; otherwise it will become lumpy. The plaster should be of the consistence of the yolk of an egg, and, of course, used immediately. If the medal intended to be copied is a valuable one, with a smooth surface, it will be advisable not to oil it, as, in cleaning the oil off, the polish may be injured; but if the surface be rough there will be no remedy, and the oil must afterwards be removed, by dabbing the surface of the medal gently with a soft cloth.

A rim of thin lead, brass, copper, or even oiled paper, is then tied round the medal, and some liquid plaster, in the first place, stippled over its surface with a soft brush, to prevent the formation of air bubbles, as well as to insure its insertion into the most minute crevices; after which the plaster is poured upon the surface to the thickness of half an inch, or an inch if a large medal.

To separate the mould from the medal, all we have to do is to immerse it in water, when it is readily removed; otherwise the mould is sure to be broken.

To obtain a plaster cast from this mould, we must oil it with warm boiled *linseed oil*, and allow it several days to dry. Whenever the mould is used it must be well oiled; otherwise the surface of the casting will be destroyed. The best olive oil must be used, or the colour of the plaster will be injured.

TO TRANSFER ENGRAVINGS TO PLASTER CASTS.

COVER the plate with ink, and polish its surface in the usual way; then put your rim round it, as before stated, and pour in your plaster, mixed as before. Jerk the plate repeatedly, to allow the air bubbles to fly upwards, and let it stand one hour; then take the cast off the plate, and a very perfect impression will be the result.

TO VARNISH PLASTER CASTS.

PLASTER CASTS are varnished by a mixture of soap and white wax in boiling water. A quarter of an ounce of soap is dissolved in a pint of water, and an equal quantity of wax afterwards incorporated. The cast is dipped in this liquid, and, after drying a week, is polished, by rubbing with soft linen, producing a polish like marble. If to be exposed to the weather, saturate them with linseed oil mixed with wax, or rosin may be combined. In casting the plaster, always use *spring water* and *gum arabic.*

TO CAST CONCAVE OR CONVEX MOULDS OF MEDALS, ON "TIN-FOIL," WITH PLASTER.

Take a medal, &c., and cover it with very thin "tin-foil," which press as close to the medal as you can; go over every part with a brush, laying on tolerably hard, in order to press the tin-foil into every cavity of the medal. After which, you may pour plaster upon it, and, when it is hard, take the medal out, leaving the tin-foil in the plaster; then, with a little fine olive oil, anoint the tin-foil, and the plaster where it must part, and pour more plaster upon the tin-foil, which also let harden. You may then separate them, and take out the tin-foil, and you will have both a concave and a convex mould.

TO CAST VEGETABLES, INSECTS, SMALL BIRDS, FROGS, FISH, ETC., IN PLASTER MOULDS.

PROVIDE a trough of boards, nailed together so as not to let the water run through the joints. Suspend in the trough, by thread or Holland twine, in several places, the vegetable, plant, insect, &c., which you would cast, which being performed, mix four parts of plaster of Paris, and two parts of fine brick-dust, with common water, to the consistence of cream, and with this cover the thing intended to be cast, observing not to distort it, by any means, from its natural position. When you have filled your trough, let it harden by placing it near the fire by degrees till you can make it red hot. Then let it cool, and, with a pair of bellows, blow and shake as much of the ashes out of the mould as you can. You must now put a small quantity of quicksilver into the mould, and shake it, in order to loosen every part of the ashes therein; also to make a passage through where the strings were tied, in order to let the air out when you pour in your metal.

TO PREPARE A METAL FOR THE ABOVE WORK.

Take of grain tin 6 ounces, bismuth 2 ounces, and lead 3 ounces. Melt them together in an iron ladle, and you may cast in the above mould to your satisfaction.

You may combine the above ingredients in such proportions as to compose a metal that will melt in boiling water. Thus,

Sir Isaac Newton's Fusible Metal is composed of 8 parts bismuth, 5 parts lead, and 3 parts tin. This alloy melts at 212°.

Rose's Alloy is still more fusible: it is 2 parts bismuth, 1 lead, and 1 tin, and melts at 201°.

The late *Dr. Dalton's Fusible Alloy.*—3 parts tin, 5 parts lead, and 10½ parts bismuth; melts at 197°. The addition of a little mercury makes it more fusible, and fits it to be used as a coating to the insides of glass globes.

An alloy of equal parts of tin and bismuth melts at 280°. A less proportion of bismuth adds to the hardness of tin, and hence its use in the formation of pewter, or pewter solder.

TO CAST IN WAX.

THE mould is first made in plaster, but before being used it is placed in warm water, of which it is allowed to absorb as much as it will take—oil not being used in this process. The surface must then be allowed to dry, or the wax would not adhere closely. Pure wax is too greasy for the purpose, and *bladder flake-white* is therefore mixed with it; the quantity cannot be stated; but the addition of too much gives wax the appearance of plaster, by taking away its richness. The oftener the wax is remelted, the more its colour is injured.

In order to obtain a gray marble colour, a marble powder, procurable at any statuary, is mixed with the wax, which not only gives a beautiful appearance to it, but renders it more durable.

The wax is poured into the mould and allowed to flow over its surface, and by moistening the plaster mould in water when the wax has become hard, the cast is easily removed. Wax models may be fastened by means of linseed oil and flake-white, and also by a combination of bees' wax and resin.

TO CAST IN SULPHUR.

THIS is a very permanent mode, but as a mould it can only be used for plaster; for hot wax or sulphur would injure its surface. When sulphur is heated to the temperature suitable for forming casts, it becomes nearly black, and has, therefore, to be coloured in the proportion of one ounce of vermillion to three ounces of sulphur. The surface of the mould, however, need only be coated with this expensive mixture, and common sulphur in any quantity.

You must use wood to stir the sulphur, as iron will take away its colour. The sulphur will take fire in melting, unless it is properly stirred, and at first will become thick and viscid, but by continuing the application of heat, it will again assume a perfectly liquid form.

TO CAST IN GLUE.

If a medal is so much sunk and engraved that you cannot get a plaster cast off, a mould may be obtained by pouring glue upon it. In this manner a bunch of grapes can be taken in the natural state, and by cutting the glue down the centre, the grapes can be extracted, and the mould used to produce a representation of the original in plaster. Isinglass may be similarly used, but it is first mixed with flake-white, in the state of powder. When the plaster is hard, place the whole in boiling water, when the glue will melt away, leaving a perfect cast of plaster grapes.

TO MAKE A FINE GLUE, WHEREWITH YOU MAY CAST CURIOUS MEDALS.

Steep isinglass in brandy, and when it is dissolved boil it together with water, and pour it over any medal, and when dry it will appear perfect. It must be of a tolerably thick consistence, much like common glue.

TO CAST IN BREAD PASTE.

TAKE the inside of fresh bread, and work it up well with vermillion—the longer the better, until it becomes viscid and tough. It is then to be worked well into the mould. After having obtained the mould, it must be fastened down upon a piece of wood, by wetting it so as to prevent it from warping as it dries. After it has been thoroughly dried you may oil it, and then obtain as many casts as you please from it, in plaster, wax, or sulphur.

By means of bread-paste a traveller may always take a model of any small object of interest he meets with on his journey; and thus a proper knowledge of its mode of use becomes invaluable. Scrolls, ruins of tombs and temples, &c., have often thus been copied and brought home at a trifling cost.

TO CAST FIGURES IN IMITATION OF IVORY.

Make isinglass and strong brandy into a paste with powder of egg-shells, well ground. You may make it whatever colour you please, but cast warm water into your mould, which should be previously well oiled over. Leave the figure in the mould to dry; and on taking it out it will be found to bear a strong resemblance to ivory.

RICE GLUE STATUARY.

Mix rice flour intimately with cold water, and gently simmer it over the fire, when it readily forms a delicate and durable cement, not only answering the purpose of common paste, but admirably adapted to join together paper, card, &c. When made of the consistence of plastic clay, models, busts, basso-relievos, &c., may be formed; and the articles when dry are very like white marble, and will take a high polish, being very durable. In this manner the

Chinese and Japanese make many of their domestic idols. Any colouring matter may be used at pleasure.

A COMPOSITION FOR ORNAMENTS.

Take pounded chalk, what quantity you please, add thereto as much thin glue as will make it into paste, which mix well together. Then put it into moulds, being a little oiled, and press it well in; after which take it out, and it will grow as hard as stone.

You must make no more of it than you want for present use; if left it grows hard, and cannot be used again.

ALLOYS, AMALGAMS, ETC.

THE formation of alloys appears to depend upon the chemical affinity of the metals for each other, and in some instances it seems to be wanting, for no combination occurs. Thus, according to Gellert, bismuth and zinc do not combine.

The change of properties which metals undergo by combining, furnishes strong evidence of its arising from *chemical affinity* and *action*. Thus, with respect to colour, copper, a reddish-coloured metal, by union with zinc, which is a white one, gives the well known "yellow alloy brass."

The fusing point of a mixed metal, is never the mean of the temperature at which its constituents melt, and it is generally lower than that of the most fusible metal of the alloy.

Alloy is a word used to designate either a natural or artificial compound of two or more metals; except when mercury is one of them; the mixture is then termed an *amalgam*.

The natural alloys are far less important substances than those which are artificially procured. Thus arsenic occurs combined with the following metals, namely, antimony, bismuth, cobalt, iron, nickel, and silver.

There is also found a native alloy of antimony and nickel, and of antimony, cobalt, and nickel; others might be mentioned; but there is no instance of a native alloy, strictly speaking, being applied to any useful purpose. Whereas, the artificial alloys, as has been fully shown, are of the highest importance, both for the uses of common life, and for manufacturing purposes. By uniting different metals, compounds are formed, which possess a combination of qualities not occurring in any one metal.

Platina is always used in a pure state, and copper, iron, lead, and zinc, are also very commonly so used. But gold, silver, tin, antimony, and bismuth, are, as we have shown, generally alloyed; the first three on account of their softness, and the two latter because they are extremely brittle. Gold and silver are hardened by alloying with copper; copper is hardened by zinc, tin, &c., &c.

All alloys formed of brittle metals are brittle; those made of ductile metals are in some cases ductile and in others brittle. When the proportions are nearly equal, there are as many alloys which are brittle as ductile—but when any of the metals is in excess they are most commonly ductile. In combining ductile and brittle metals, the compounds are brittle if the brittle metal exceed, or nearly equal the proportion of the ductile one; but when the ductile metal greatly exceeds the brittle one, the alloys are usually ductile.

The *density of alloys* sometimes *exceeds*, and in other cases is *less* than that which would result from calculation. The following alloys afford examples of "*increased* and *diminished* density:"—

Increased Density.	Diminished Density.
Gold and Zinc.	Gold and Silver.
Gold and Tin.	Gold and Iron.
Gold and Bismuth.	Gold and Lead.
Gold and Antimony.	Gold and Copper.
Gold and Cobalt.	Gold and Iridium.
Silver and Tin.	Gold and Nickel.
Silver and Bismuth.	Silver and Copper.
Silver and Antimony.	Iron and Bismuth.
Silver and Zinc.	Iron and Antimony.
Silver and Lead.	Iron and Lead.
Copper and Zinc.	Tin and Lead.
Copper and Tin.	Tin and Palladium.
Copper and Palladium.	Tin and Antimony.

Increased Density.	Diminished Density.
Copper and Bismuth.	Nickel and Arsenic.
Copper and Antimony.	Zinc and Antimony.
Lead and Bismuth.	
Lead and Antimony.	
Platina and Molybdenum.	
Palladium and Bismuth.	

Not only are the properties of metals altered by combination, but different proportions of the same metals produce very different alloys. Thus, by combining 90 parts of copper with 10 parts of tin, an alloy is obtained of greater density than the mean of the metals; and it is also harder and more fusible than the copper; it is slightly malleable when slowly cooled; but, on the contrary, when heated to redness and plunged into cold water, it is very malleable. This compound is known by the name of *bronze*.

Again, as has been previously laid down, if 80 parts of copper be combined with 20 parts of tin, the compound is the extremely sonorous one, called *bell metal*.

An alloy consisting of two-thirds copper, and one-third tin, is susceptible of a very fine polish, and is used as *speculum metal*.

It is curious to observe in these alloys, that in bronze, the density and hardness of the denser and harder metal are increased, by combining with a lighter and softer one; while, as might be expected, the fusibility of the more refractory metal is increased by uniting with a more fusible metal. In bell metal, the copper becomes more sonorous by combination with a metal which is less so. These changes are clear indications of *chemical action.*

It has been already observed that the natural alloys, considered as such, are not important bodies. The only one, if indeed that may be reckoned so, is the alloy of iron and nickel, constituting *meteoric iron,* and of which the knives of the Esquimaux appear to be made.

The artificial metallic alloys are of the highest degree of utility. Thus, gold is too soft a metal to be used either for the purposes of coin or ornament; it is therefore alloyed with copper. Silver, though harder than gold, would also wear too quickly unless mixed with copper; and copper is improved both in hardness and colour by combination with zinc and tin, forming brass and bronze.

YELLOW BRASS.

THE following table exhibits the composition of several varieties of this species of brass. No. 1 is a cast brass, of uncertain origin. No. 2 is the brass of Jemappes. No. 3 is the sheet-brass of Stolberg, near Aix-la-Chapelle. No. 4 and 5, the brass for gilding, according to De Arcet. No. 6, the sheet-brass of Romilly. No. 7, English brass-wire. No. 8, Augsburg brass-wire. No. 9, the brass-wire of Neustadt, Eberswald, in the neighbourhood of Berlin.

Metal.	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.
Copper .	61.6	64.6	64.8	63.70	64.45	70.1	70.29	71.89	70.16
Zinc. . .	85.3	33.7	32.8	35.55	32.44	29.9	29.26	27.63	27.45
Lead . .	2.9	1.4	2.0	0.25	2.86	— –	0.28	— —	0.20
Tin . . .	0.2	0.2	0.4	0.50	0.25	— –	0.17	0.85	0.79
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0 nearly

TO MAKE COPPER MEDALS AND MEDALLIONS.

Let black oxide of copper, in a fine powder, be reduced to the metallic state, by exposing it to a stream of hydrogen in a gun-barrel heated barely to redness. The metallic powder thus obtained is to be sifted through crape upon the surface of the mould, to the thickness of a quarter or half an inch, and is then to be strongly pressed upon it, first by the hand, and lastly by percussion with a hammer. The impression thus formed is beautiful, but it acquires much more solidity by exposure to a red heat, out of contact with the air. Such medals are said to have more tenacity than melted copper, and to be sharply defined. This plan was discovered by M. Boettger, for which he was awarded the gold medal of the Society of Arts.

An improvement on the above plan, whereby you may prepare the powder of copper more easily and of better quality, by precipitating a boiling hot solution of sulphate of copper, with pieces of zinc; boiling the metallic powder, thus obtained, with dilute sulphuric acid, for a little, to remove all traces of the zinc or oxide; washing it next with water, and drying it in tubulated retort by the heat of a water-bath, while a stream of hydrogen is passed over it. This cupreus precipitate possesses so energetic an affinity for oxygen, that it is difficult to prevent it passing into the state of orange oxide.

AMALGAM.

AMALGAM, a compound of two or more metals, of which one is always mercury; and this circumstance distinguishes an amalgam from an alloy. Nature presents us with only one amalgam, which is silver, and is termed by mineralogists "native amalgam." It occurs in Hungary, Sweden, &c., and is met with either semi-fluid, massive, or crystallized in rhombic dodecahedrons. Klaproth found it to consist of 64 parts of mercury, and 36 of silver, out of 100 parts. Most metals may be amalgamated with mercury, and the combination appears to depend on *chemical affinity*.

When the cohesion of a metal is slight, as in the cases of potassium and sodium; or when its affinity for mercury is considerable, as in the instances of gold and silver, amalgamation takes place readily, by mere contact. When, on the other hand, the cohesion of a metal is strong or its affinity for mercury is weak, heat or intermediate action, or both, are requisite to effect amalgamation.

If forty-four parts of mercury be mixed with one part of potassium, combination occurs with the evolution of much heat; and when the resulting amalgam is cold, it is hard and has the appearance of silver. When the quantity of mercury exceeds one hundred parts to one of potassium, the compound is liquid, and an amalgamation containing only 1.5 per cent. of potassium is susceptible of crystallization. The density of an amalgam exceeds that of the mean of the metals; this and the tendency of one or both metals to oxidize, are additional indications of chemical combination.

There are some metals, it has been observed, requiring heat to amalgamate them. Antimony offers an example of this: to effect combination it must be melted, and while liquid mixed with hot mercury. Mere heat, however, causes scarcely any action between iron and mercury; they may be amalgamated by mixing the filings of the metal with powdered alum, and rubbing them together in a mortar with a little water. After trituration, the alum may be washed out. By the intervention of tin or zinc, iron may be combined with mercury, and a double amalgam is formed. Platina also unites with mercury, by the intervention of the amalgam of potassium, but not by direct action. The double amalgam of iron and zinc does not rapidly undergo any change, and is not attracted by the magnet. All amalgams are decomposed by a red heat; the mercury being distilled, and the more fixed metal remaining. The process of amalgamation and decomposition is employed to separate gold and silver from their ores. The mercury obtained by decomposing the amalgams is distilled and repeatedly used for the same purpose, with comparatively little loss.

The amalgams of gold and silver are used or employed in the process of gilding and plating. We have also shown the amalgam of tin is largely used in what is called silvering mirrors, and that various amalgams of tin and zinc are employed for exciting electricity in the machine.

BISMUTH.

At a high temperature this metal is volatilized; may be distilled in close vessels, and solidifies in foliated crystals. If it be merely melted in a crucible, and cautiously cooled, it crystallizes in well-defined cubes. Bismuth, as met with in commerce, is not pure, for it generally contains iron and arsenic. In order to purify it, it is to be dissolved in nitric acid; the solution is to be decomposed by water, and the precipitate, after being boiled in a solution of soda, is to be mixed with black flux, and moderately heated in a crucible.

Bismuth combines with copper to form a pale-red brittle alloy. It forms a brittle compound with silver; and it has been proposed.as a substitute for lead, in refining silver. It is said to form a more fluid oxide, which penetrates the cupel more readily than that of lead; and may also be used in smaller quantity.

With mercury it forms a very fluid alloy, and makes the following metals brittle by combination: tungsten, palladium, rhodium, gold, and platina.

It is principally employed in making fusible alloys, and as an ingredient in solders. It is often called in the arts "tin glass."

ON FRICTION.

Friction is independent of the velocity; at least when the velocity is neither very great nor very small. With hard substances, such as wood, metal, and stone, the amount of friction is simply as the pressure, without regard to surface, time, or velocity. Friction is greatest with *soft*, and least with *hard* substances. The diminution of friction by *unguents* depends on the nature of the *unguents*, without reference to the substances moving over them.

The following table shows the comparative amount of friction of different metals, under an average pressure of 54.25 pounds to 69.55 pounds.

Names of Metals, Tried.	Average Weight.	Proportions.	Weight per Square Inch.
	lbs.		lbs. oz.
Brass on Wrought Iron . . .	69.55	7.312	11 12.4
Steel upon Steel.	69.55	6.860	11 12.5
Brass upon Cast Iron . . .	54.25	6.745	8 0.5
Brass upon Steel	69.55	6.592	11 12.5
Hard Brass upon Cast Iron	54.25	6.581	6 15.9
Wro't Iron upon Wro't Iron	69.55	6.561	11 12.5
Cast Iron upon Cast Iron .	54.25	6.475	8 0.5
Do. do. Steel . . .	69.55	6.393	11 12.5
Do. do. Wro't Iron	69.55	6.023	11 12.5
Brass upon Brass	69.55	5.764	11 12.5
Tin upon Tin	69.55	3.305	11 12.5

From hence it would appear that *hard metals* have less friction than *soft ones;* and that the friction of *hard* against *hard* may be generally estimated at about one-sixth of the *pressure.*

Relative to unguents, Sir John Rennie's experiments show that for gun metal or cast iron, with oil intervening, and a weight of 1120 pounds, the friction amounted to $\frac{1}{6}$.63 of the pressure; but on diminishing the insistent weights the friction was diminished to $\frac{1}{37}$.33.

BELLS.

The large bells now used in churches, are said to have been invented by Paulinus, Bishop of Nola in Campania, about the year 400: whence th "Nola" and "Campania" of the lower Latinity. They were probably introduced into England very soon after their invention. They are first mentioned by Bede, about the close of the seventh century. Ingulphus records that Turketul, Abbot of Croyland, who died about the year 890, gave a bell of a very large size to that abbey, which he named Guthlac. His successor, Egelric, cast a ring of six others, to which he gave the names of Bartholomew, Bettelin, Turketul, Tatwine, Pega, and Bega. Baronius informs us that Pope John XIII., A. D. 968, consecrated a very large new cast bell, in the Lateran Church, and gave it the name of John. The ritual for the baptizing of bells may be found in the Roman Pontificale.

The city of Nankin, in China, was anciently famous for the largeness of its bells, as we learn from Father le Compte; but they were afterwards far exceeded in size by those of the churches of Moscow.

A bell in the tower of St. Ivan's Church, in Moscow, weighed 127,836 English pounds, or 57 tons 1 cwt. 1 qr. 16 pounds. A bell given by the Czar Boris Godunof to the Cathedral of Moscow, weighed 288,000 pounds, or 128 tons 11 cwt. 1 qr. 20 lbs. And another, given by the Empress Anne, probably the largest in the known world, weighed 432,000 pounds, or 192 tons 17 cwt. 0 qrs. 26 pounds. According to Coxe (Travels in Russia, vol. 1, page 322), the height of this last bell was 19 feet, the circumference at the bottom 63 feet 11 inches, and its greatest thickness 23 inches. The great bell of St. Paul's, London, weighs 12,000 pounds, and is 9 feet in diameter.

The largest bell in England, is "Great Tom,"of Christ Church, Oxford, which is 17,000 pounds weight.

ON FLUXES.

Black flux is made by mixing one part of powdered nitre with two parts of powdered *argol*, which is the commercial name for impure cream of tartar, or bitartrate of potash.

This mixture is to be gradually thrown into a red-hot earthen crucible, so as to deflagrate it, taking care not to make the heat so high as to fuse the mixture.

In this case, the nitric acid of the nitre is decomposed, its oxygen acts upon the carbon of the tartaric acid, carbonic acid is formed, and this uniting with the potash, both of the nitre and bitartrate, is converted into carbonate of potash. The whole of the carbon of the tartaric acid is not, however, so acted upon; and the excess remains mixed with the carbonate of potash, in the state of finely divided charcoal.

This flux should be immediately reduced to powder, and kept in a well stopped bottle; otherwise it will become damp by the absorption of moisture, to which the carbonate of potash is subject. This flux is doubly useful; the carbonate of potash combines with the earthy parts of the *ore*, such as *silica* and *alumina*, while the charcoal unites with the oxygen of the metallic oxides, and, carbonic acid being formed and expelled, the metal is reduced and melts. This flux is especially useful in the process of detecting arsenious acid, and reducing it to the metallic state.

Argol, already described, is an impure bitartrate of potash, powdered and mixed with the pulverized substance to be reduced, and is sometimes advantageously used as a flux. Owing to the intimate mixture of the charcoal and potash in this flux, a good deal of potassium is evolved; and upon the reducing property of this metal, the reduction of the oxides of other metals frequently depends to a considerable extent.

Charcoal alone is, in the case of pure oxides, sometimes employed as a flux: thus, a crucible lined with charcoal is useful for the reduction of oxide of iron; or the oxide may be mixed with charcoal.

Sal-enixum, or the refuse from aquafortis, is an excellent flux for copper, &c.

FUSING AND MELTING POINTS, ASCERTAINED BY MEANS OF PROFESSOR DANIEL'S REGISTERED PYROMETER.

Mercury, ...	—39°	Fahrenheit.
Tin, ...	442°	Crichton.
Bismuth, ...	497°	do.
Lead, ...	612°	do.
Zinc, ...	773°	Daniel.

Antimony	809°	Daniel.
Silver,	1873°	do.
Copper,	1996°	do.
Gold,	2016°	do.
Cast iron,	2787°	do.

Bismuth is mentioned by Agricola, about the year 1529, A. D. It is of a reddish-white colour; its lustre is considerable, and its structure lamellated. It is so brittle as to be easily reducible to powder. When cold, its density is 9.83. It melts at 462°, according to Crighton, jr.; Irving, 476°; Daniel, 497°. Thus even doctors disagree. Probably, however, the specimens experimented upon might have slightly varied as to quality—the reader is furnished with all the facts.

FLUIDITY.

According to Dr. Irving, the undermentioned bodies contain the annexed quantities of heat when rendered fluid:—

Lead,	162°	Fahrenheit.
Zinc,	493°	do.
Tin,	500°	do.
Bismuth,	550°	do.

ANTI-FRICTION METALS.

Many use 9 and 10 parts tin to 1 part copper.

A superior composition to either of the above is, 1 part copper, 1 part regulus of antimony, to 10 parts of tin. Melt the copper first, then add the antimony, with a small portion of tin; cover up the whole with charcoal for a short time prior to casting; add the remainder of the tin. These compositions are solely used for lining brass bearings.

The following is an excellent anti-friction metal, not used for linings, but used in castings instead of brass: namely, 85 parts zinc, 10 parts tin, to which is added 5 parts of antimony.

TABLE FOR CONVERTING DECIMAL PROPORTIONS INTO DIVISIONS OF THE POUND AVOIRDUPOIS.

Decimal.	oz.	dr.	Decimal.	oz.	dr.	Decimal.	oz.	dr.	Decimal.	oz.	dr.
.39		1	12.89	2	1	25.39	4	1	37.85	6	1
.78		2	13.28	2	2	35.78	4	2	38.28	6	2
1.17		3	13.67	2	3	26.17	4	3	38.67	6	3
1.56		4	14.06	2	4	26.56	4	4	39.06	6	4
1.95		5	14.45	2	5	26.95	4	5	39.45	6	5
2.34		6	14.84	2	6	27.34	4	6	39.84	6	6
2.73		7	15.23	2	7	27.73	4	7	40.23	6	7
3.13		8	15.62	2	8	28.13	4	8	40.62	6	8
3.52		9	16.01	2	9	28.52	4	9	41.02	6	9
3.91		10	16.41	2	10	28.91	4	10	41.41	6	10
4.30		11	16.80	2	11	29.30	4	11	41.79	6	11
4.69		12	17.19	2	12	29.69	4	12	42.19	6	12
5.08		13	17.58	2	13	30.08	4	13	42.54	6	13
5.47		14	17.97	2	14	30.47	4	14	42.97	6	14
5.86		15	18.36	2	15	30.86	4	15	43.36	6	15
6.25	1	0	18.75	3	0	31.25	5	0	43.75	7	0
6.64	1	1	19.14	3	1	31.64	5	1	44.14	7	1
7.03	1	2	19.53	3	2	32.03	5	2	44.53	7	2
7.42	1	3	19.92	3	3	32.42	5	3	44.92	7	3
7.81	1	4	20.31	3	4	32.81	5	4	45.31	7	4
8.20	1	5	20.70	3	5	33.20	5	5	45.70	7	5
8.59	1	6	21.09	3	6	33.59	5	6	46.09	7	6
8.98	1	7	21.48	3	7	33.98	5	7	46.48	7	7
9.38	1	8	21.88	3	8	34.37	5	8	46.87	7	8
9.77	1	9	22.27	3	9	34.69	5	9	47.27	7	9
10.16	1	10	22.66	3	10	35.16	5	10	47.66	7	10
10.55	1	11	23.05	3	11	35.55	5	11	48.05	7	11
10.94	1	12	23.44	3	12	35.94	5	12	48.44	7	12
11.33	1	13	23.83	3	13	36.33	5	13	48.83	7	13
11.72	1	14	24.22	3	14	36.71	5	14	49.22	7	14
12.10	1	15	24.61	3	15	37.11	5	15	49.61	7	15
12.50	2	0	25.00	4	0	37.50	6	0	50.00	8	0

Application of the Table.

The Chinese Packfong, similar to our German silver, according to Dr. Fyfe's analysis, page 108, is said to consist of—

40.4	parts of Copper	equivalent to	6 oz. 7 drams,	full.
25.4	— Zinc		4 — 1 —	full.
31.6	— Nickel		5 — 1 —	nearly.
2.6	— Iron		7 —	nearly.
100.0 Parts.			16 oz. 0 —	Avd.

KELLER'S STATUE COMPOSITION.

THE brothers Keller, who were very celebrated statue founders, used an alloy, 10,000 parts of which contained 9140 parts of copper, 714 parts tin, 118 parts zinc, and 28 parts lead. This is the composition of the statue of Louis XIV., which was cast at a single jet, by Balthazar Keller, in 1669. It is twenty-one feet high, and weighs 53,263 French pounds. These statues are usually miscalled bronze.

The best brass consists of four parts of copper to one part of zinc.

Bronze was well known to the Romans under the name of "*orichalcum,*" who took advantage of its resemblance to gold, in robbing the temples and other public places of that precious metal. Thus Julius Cæsar robbed the Capitol of 3000 pounds weight of gold; and Vitellius despoiled the temples of their gifts and ornaments, and replaced them with this inferior metal.

THE CHINESE PACKFONG,*

According to Dr. Fyfe's analysis, is said to consist of

40.4	parts of copper	equivalent to	6 oz. 7 dr. full.
25.4	" zinc		4 oz. 1 dr. full.
31.6	" nickel		5 oz. 1 dr. nearly.
2.6	" iron		7 dr. nearly.
100.0	parts.		16 oz. 0 dr.

COPPER.

Copper, when mixed with as much zinc as possible, that is 89 pounds copper to 100 pounds zinc, becomes white. The best "Goslar zinc" is from the Hartz, Germany.

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* Similar to our German silver.

SILVER STEEL.

1 part silver, 500 parts steel, according to Faraday and Stodan. This alloy would be superior to the best steel. Steel also combines with other metals, such as nickel, platinum, manganese, &c.

COPPER AND ANTIMONY.

75 parts copper, and 25 parts antimony. This alloy is brittle, lamellated, of a violet colour, susceptible of a fine polish, and is more fusible than copper.

ANTIMONY AND TIN, COPPER AND BISMUTH.

100 parts of tin, 8 parts of antimony, 4 parts of copper, and 1 part of bismuth, constitute the compound commonly called *pewter*.

BISMUTH AND LEAD.

1 part of bismuth, and 1 part of lead, a very tenacious alloy, melting at 165° Centigrade, equivalent to 370° Fahrenheit.

2 parts of lead to 1 part of bismuth, gives an alloy which dilates powerfully at the time of cooling. (This property makes it extremely suitable to all castings in which the greatest sharpness and finish are desirable.—H. MEIGS.)

FULL MEASURE OF CAPACITY OF TIN AND LEAD

82 parts tin, and 18 parts lead.

BRILLIANTS OF FAHLUN,

THUS called, are made from 29 parts of tin, and 19 parts of lead. A very fusible and brilliant alloy.

QUEEN'S METAL,

IMITATING silver, has great metallic lustre: 9 parts tin, 1 part lead, 1 part antimony, and 1 part bismuth.

TIN AND ZINC.

1 part tin, and 1 part zinc, is almost as tenacious as brass, and melts at 460° to 500° Centigrade, 900° Fahrenheit.

TIN AND IRON.

THESE two metals may be alloyed in all proportions. 35 parts of tin to 65 parts of iron, form an alloy of a clear crystalline gray, and so brittle that it may be reduced to an impalpable powder.

TO SILVER COPPER.

PRECIPITATE silver from its nitric solution by the immersion of polished plates of copper. Take of this silver 20 grains, supertartrate of potass, 2 drachms, common salt, 2 drachms, and of alum, half a drachm. Mix the whole well together.

Then take the article to be silvered, clean it well, and rub some of the mixture, previously a little moistened, upon its surface. The silver surface may be polished with a piece of soft leather.

The dial-plates of clocks, scales of barometers, &c., are plated thus.

MOSAIC GOLD (*or molu*),

MAY be thus made: take copper and zinc, equal parts; mix them together at the lowest possible temperature at which copper will fuse, and stir until a perfect mixture of the metals is effected. Then add gradually small portions of zinc at a time, until the alloy acquires a proper colour, which is perfectly white while in the melted state. It should then at once be cast into figured moulds. This alloy should contain from 52 to 55 per cent. of zinc.

TO BRONZE BRASS, ETC.

To 6 pounds of muriatic acid, add 2 pounds of oxide of iron, and 1 pound of yellow arsenic. Mix all well together, and let it stand for two days, frequently shaking it in the mean time, when it is fit for use.

Whatever may be the article which requires bronzing, let it be perfectly cleaned, and free from grease; immerse it in the above solution, and let it stand for three hours, or rather till it will turn entirely black. Then wash the spirits off, and dry it in sawdust, which has been found the best.

After the article is perfectly dry, apply to it some wet black, the same as used for stones, and then polish it with some dry black-lead and a brush, and it is ready for lacquering.

LACQUERS.

Lacquers are used upon polished metals and wood, to impart the appearance of gold. As they are wanted of different depths and shades of colours, it is best to keep a concentrated solution of each colouring ingredient ready, so that it may at any time be added to produce any desired tint.

1. *Deep Gold-coloured Lacquer.*—Seed lac, three ounces; turmeric, one ounce; dragon's blood, a quarter of an ounce; alcohol, one pint. Digest for a week, frequently shaking. Decant and filter.

2. *Gold-coloured Lacquer.*—Ground turmeric, one pound; gamboge, an ounce and a half; gum-sandarach, three pounds and a half; shell lac, three-quarters of a pound (all in powder); rectified spirits of wine, two gallons. Dissolve, strain, and add one pint of turpentine varnish.

3. *Red-coloured Lacquer.*—Spanish anatto, three pounds; dragon's blood, one pound; gum-sandarach, three pounds and a quarter; rectified spirits, two

gallons; turpentine varnish, one quart. Dissolve and mix as the last.

4. *Pale Brass-coloured Lacquer.*—Gamboge, cut small, one ounce; cape aloes, ditto, three ounces; pale shell lac, one pound; rectified spirits, two gallons. Dissolve and mix as No. 2.

5. Seed lac, dragon's blood, anatto, and gamboge, of each a quarter of a pound; saffron, one ounce; rectified spirits of wine, ten pints. Dissolve and mix as No. 2.

* The following receipts make most excellent lacquers.

1. *Gold Lacquer.*—Put into a clean four-gallon tin 1 pound of ground turmeric, 1½ ounces of powdered gamboge, 3½ ounces of powdered gum-sandarach, ¾ of a pound of shell lac, and 2 gallons of spirits of wine. After being agitated, dissolved, and strained, add one pint of turpentine varnish, well mixed.

2. *Red Lacquer.*—2 gallons of spirits of wine, 1 pound of dragon's blood, 3 pounds of Spanish

anatto, 3½ pounds of gum-sandarach, 2 pints of turpentine. Made as No. 1 lacquer.

3. *Pale Brass Lacquer.*—2 gallons of spirits of wine, 3 ounces of cape aloes cut small, 1 pound of fine pale shell lac, 1 ounce of gamboge cut small, no turpentine varnish. Made exactly as before.

But observe, that those who make lacquers, frequently want some paler, and some darker, and sometimes inclining more to the particular tint of certain of the component ingredients. Therefore, if a four-ounce phial of a strong solution of each ingredient be prepared, a lacquer of any tint can be procured at any time.

4. *Pale Tin Lacquer.*—Strongest alcohol, 4 ounces; powdered turmeric, 2 drachms; hay saffron, 1 scruple; dragon's blood in powder, 2 scruples; red saunders, ½ scruple. Infuse this mixture in the cold for 48 hours, pour off the clear, and strain the rest; then add powdered shell lac, ½ ounce; sandarach, 1 drachm; mastic, 1 drachm; Canada balsam, 1 drachm. Dissolve this in the cold by frequent agitation, laying the bottle on its side, to present a greater surface to the alcohol. When dissolved, add 40 drops of spirits of turpentine.

5. *Another Deep Gold Lacquer.*—Strongest alcohol, 4 ounces; Spanish anatto, 8 grains; powdered turmeric, 2 drachms; red saunders, 12 grains. Infuse and add shell lac, &c., as to the pale tin lacquer; and when dissolved add 30 drops of spirits of turpentine.

N. B. Lacquer should always stand till it is quite fine, before it is used.

GREEN BRONZE LIQUID.

Take one quart of strong vinegar, half an ounce of mineral green, half an ounce of raw umber, half an ounce of sal-ammoniac, half an ounce of gum arabic, two ounces of French berries, half an ounce of copperas, and about three ounces of green oats, if these can be procured, although, if they cannot, the preparation will succeed perfectly well without them. Dissolve the whole in a strong earthen vessel, adding the berries and the oats, over a gentle fire; bring the compound to boil, then allow it to cool, and run it through a flannel bag, when the bronze will be ready for use.

TO SILVER IVORY.

IMMERSE a slip of ivory in a weak solution of nitrate of silver, and let it remain until the solution has imparted to it a deep yellow colour. Then take it out, and immerse it in a tumbler of clear water, and expose it in the water to the rays of the sun. After it has been exposed thus for about three hours, the ivory acquires a black colour, which on being burnished soon becomes a brilliant silver one.

ZINCING.

COPPER and brass vessels may be covered with a firmly adherent layer of pure zinc, by boiling them in contact with a solution of chloride of zinc, pure zinc turnings being at the same time present in considerable excess. The same object may be attained by means of zinc, and a solution of sal-ammoniac, or caustic potassa.

TABLE I.—METAL PLATES.

This table shows the weight of a square foot of different metal plates, of thicknesses of one sixteenth of an inch to one inch, advancing by a sixteenth :—

Sixteenths.	Wrought Iron.	Cast Iron.	Cast Copper.	Cast Brass.	Cast Lead.	Cast Zinc.	Cast Tin.	Cast Silver.
	lbs.	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*
1	2.5	2.3	2.9	2.7	3.7	2.3	2.4	3.4
2	5.1	4.7	5.7	5.5	7.4	4.7	4.7	6.8
3	7.6	7.0	8.6	8.2	11.1	7.0	7.1	10.2
4	10.1	9.4	11.4	11.0	14.8	9.4	9.5	13.6
5	12.7	11.7	14.3	13.7	18.5	11.7	11.9	17.0
6	15.2	14.0	17.2	16.4	22.2	14.0	14.2	20.5
7	17.9	16.4	20.0	19.2	25.9	16.4	16.6	23.9
8	20.3	18.8	22.9	21.9	29.5	18.7	19.0	27.3
9	22.8	21.1	25.7	24.6	33.2	21.1	21.4	30.7
10	25.4	23.5	28.6	27.4	36.9	23.4	23.7	34.1
11	27.9	25.8	31.4	30.1	40.6	25.7	26.1	37.5
12	30.4	28.1	34.3	32.9	44.3	28.1	28.5	40.9
13	32.9	30.5	37.2	35.6	48.0	30.4	30.9	44.3
14	35.5	32.9	40.0	38.3	51.7	32.8	33.2	47.7
15	38.0	35.2	42.9	41.2	55.4	35.1	35.6	51.1
16	40.6	37.6	45.8	43.9	59.1	37.5	38.0	54.6

TABLE II.—CAST METAL BALLS.

Diam.—*Ins.*	Iron.—*lbs.*	Copper.—*lbs.*	Brass.—*lbs.*	Lead.—*lbs.*
1	$\frac{3}{22}$	$\frac{1}{8}$	$\frac{3}{19}$	$\frac{3}{14}$
2	1.1	1.3	1.3	1.7
3	3.7	4.5	4.3	5.8
4	8.7	10.7	10.2	13.8
5	17.0	20.8	19.9	26.9
6	29.5	35.9	34.3	46.4
7	46.8	57.1	54.5	73.7
8	69.8	85.2	81.4	110.1
9	99.4	121.3	115.9	156.7
10	136.4	166.4	159.0	215.0

TABLE III.—CAST IRON PIPES.

THIS table shows the weight of cast iron pipes 1 foot long, of bores from 1 inch to 12 inches diameter, advancing by ¼ of an inch; and of thicknesses from ¼ inch to 1¼ inch, advancing by ⅛ of an inch.

Bore.	¼	⅜	½	⅝	¾	⅞	1	1⅛	1¼
In.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
1	3.1	5.1	7.4	10.0	12.9	16.1	19.6	23.5	27.6
1¼	3.7	6.0	8.6	11.5	14.7	18.3	22.1	26.2	30.7
1½	4.3	6.9	9.8	13.0	16.6	20.4	24.5	29.0	33.7
1¾	4.9	7.8	11.1	14.6	18.4	22.6	27.0	31.8	36.8
2	5.5	8.8	12.3	16.1	20.3	24.7	29.5	34.5	39.9
2¼	6.1	9.7	13.5	17.6	22.1	26.8	31.9	37.3	43.0
2½	6.7	10.6	14.7	19.2	23.9	28.9	34.4	40.0	46.0
2¾	7.4	11.5	16.0	20.7	25.7	31.1	36.8	42.8	49.1
3	8.0	12.4	17.2	22.2	27.6	33.3	39.3	45.6	52.2
3¼	8.6	13.3	18.4	23.8	29.5	35.4	41.7	48.3	55.2
3½	9.2	14.2	19.6	25.3	31.3	37.6	44.2	51.1	58.3
3¾	9.8	15.2	20.9	26.9	33.1	39.7	46.6	53.8	61.4
4	10.4	16.1	22.1	28.4	35.0	41.9	49.1	56.6	64.4
4¼	11.1	17.1	23.4	30.0	36.9	44.1	51.6	59.4	67.6
4½	11.7	18.0	24.5	31.4	38.7	46.2	54.0	62.1	70.6
4¾	12.3	18.9	25.8	33.0	40.5	48.3	56.5	64.9	73.6
5	12.9	19.8	27.0	34.5	42.3	50.5	58.9	67.6	76.7
5¼	13.5	20.7	28.2	36.1	44.2	52.6	61.4	70.4	79.8
5½	14.1	21.6	29.5	37.6	46.0	54.8	63.8	73.2	82.8
5¾	14.7	22.6	30.7	39.1	47.9	56.9	66.3	76.0	85.9
6	15.3	23.5	31.9	40.7	49.7	59.1	68.7	78.7	88.8
6¼	16.0	24.4	33.1	42.2	51.5	61.2	71.2	81.2	92.0
6½	16.6	25.3	34.4	43.7	53.4	63.4	73.4	84.2	95.1
6¾	17.2	26.2	35.6	45.3	55.2	65.3	76.1	87.0	98.2
7	17.8	27.2	36.8	46.8	56.8	67.7	78.5	89.7	101.2
7¼	18.4	28.1	38.1	48.1	58.9	69.8	81.0	92.5	104.3
7½	19.0	29.0	39.1	49.9	60.7	72.0	83.5	95.3	107.4
7¾	19.6	29.7	40.5	51.4	62.6	74.1	85.9	98.0	110.5
8	20.0	30.8	41.7	52.9	64.4	76.2	88.4	100.8	113.5
8¼	20.9	31.7	43.0	54.5	66.3	78.4	90.8	103.5	116.6
8½	21.7	32.9	44.4	56.2	68.3	80.8	93.5	106.5	119.9
8¾	22.1	33.6	45.4	57.5	70.0	82.7	95.7	109.1	122.7
9	22.7	34.5	46.6	59.1	71.8	84.8	98.2	111.8	125.8
9¼	23.3	35.4	47.9	60.6	73.6	87.0	100.6	114.6	128.9
9½	23.9	36.4	49.1	62.1	75.5	89.1	103.1	117.4	131.9
9¾	24.6	37.3	50.3	63.7	77.3	91.3	105.5	120.1	135.0
10	25.2	38.2	51.5	65.2	79.2	93.4	108.0	122.8	138.1
10¼	25.8	39.1	52.8	66.7	81.0	95.6	110.4	125.6	141.1
10½	26.4	40.0	54.0	68.3	82.8	97.7	112.9	128.4	144.2
10¾	27.0	41.0	55.2	69.8	84.7	99.9	115.4	131.2	147.3
11	27.6	41.9	56.5	71.3	86.5	102.0	117.8	133.9	150.3
11¼	28.2	42.8	57.7	72.9	88.4	104.2	120.3	136.7	153.4
11½	28.8	43.7	58.9	74.4	90.2	106.3	122.7	139.4	156.4
11¾	29.5	44.6	60.1	75.9	92.0	108.5	125.2	142.2	159.5
12	30.1	45.6	61.4	77.5	93.6	110.6	127.6	145.0	162.6

TABLE IV.—CAST METAL CYLINDERS.*

Diam.—*Ins.*	Iron.—*lbs.*	Copper.—*lbs.*	Brass.—*lbs.*	Lead.—*lbs.*
1	2.5	3.0	2.9	3.9
2	9.8	12.0	11.4	15.5
3	22.1	27.0	25.8	34.8
4	39.3	47.9	45.8	61.9
5	61.4	74.9	71.6	96.7
6	88.4	107.8	103.0	139.3
7	120.3	146.8	140.2	189.6
8	157.1	191.7	183.2	247.7
9	198.8	242.7	231.8	313.4
10	245.4	299.5	286.2	387.0

TABLE V.—SPECIFIC GRAVITY AND WEIGHT OF MATERIALS.

METALS.	Specific Gravity.	Wt. of 1 cubic foot.	Wt. of 1 cubic inch.
	oz.	*lbs.*	*oz.*
Antimony, cast	6702	418.9	3.878
Arsenic	5763	360.2	3.335
Bismuth, cast	9822	613.9	5.684
Brass, cast	8396	524.8	4.859
Brass, wire	8544	534.0	4.944
Bronze	8222	513.4	4.753
Cobalt, cast	7811	488.2	4.520
Copper, cast	8788	549.3	5.086
Copper, sheet	8915	557.2	5.159
Copper, wire	8878	554.9	5.136
Gold, pure	19258	1203.6	11.161
Gold, hammered	19362	1210.1	11.205
Gold, standard	17647	1102.9	10.230
Gun metal	8784	549.0	5.083
Iron, bars wrought	7786	486.6	4.506
Iron, cast	7207	450.4	4.171
Lead, cast	11352	709.5	6.569
Mercury, solid	15632	977.0	9.046
Mercury, fluid	13568	848.0	7.852
Nickel, cast	7807	487.9	4.518
Platinum, pure	19500	1218.8	11.285
Platinum, hammered	20336	1271.0	11.767
Silver, pure	10474	654.6	6.061
Silver, hammered	10511	656.9	6.083
Silver, standard	10534	658.4	6.096
Steel, tempered	7818	488.6	4.524
Steel, soft	7833	489.6	4.533
Tin, cast	7291	455.7	4.244
Type metal	10450	653.1	6.047
Zinc, cast	7190	449.4	4.161

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* The cylinders are solid, each one foot in length.

TABLE VI.—SPECIFIC COHESION AND STRENGTH OF METALS.

In the following table of *specific cohesion*, the cohesion of *plate glass* is assumed as unity. If any of the numbers in this table be multiplied by 9240, the product will express the force in pounds, which would tear asunder a bar of the corresponding material, of one inch square of transverse section. Thus, the specific cohesion of steel, razor temper, is 15.927; whence the extreme cohesion of a bar one inch square is 15.927 × 9240 = 147,165.48 pounds.

	Specific cohesion.
Antimony, cast	0.113
Bismuth, cast	0.345 to 0.319
Copper, wire	6.606
" cast, Barbary	2.396
" " Japan	2.152
Gold, wire	3.279
" cast	2.171
Iron, wire	12.004 to 9.108
" bar	8.964 to 5.839
" " best quality	7.006
" " German, B R	9.880 to 6.514

	Specific cohesion.
Iron, bar, Swedish, L	9.445 to 7.296
“ “ Liege	8.794 to 6.621
“ “ German, L	9.119 to 7.382
“ “ Spanish	8.685
“ “ Oosement	8.142 to 7.296
“ “ fine grained	5.306
“ “ medium fineness	3.618
“ “ coarse grained	2.172
“ cast, French	7.470 to 4.000
“ “ German	7.250
“ “ English	5.520 to 4.334
Lead, milled	0.354
“ wire	0.334 to 0.270
“ cast, English	0.094
Platinum, wire	5.995 to 5.625
Silver, wire	4.090
“ cast	4.342
Steel, razor temper	15.927
“ soft	12.739
Tin, wire	0.757
“ cast, English block	0.706 to 0.565
“ “ Banca	0.391
“ “ Malacca	0.342
Zinc, wire	2.394
“ patent sheet	1.762
“ cast, Goslar	0.312 to 0.286

TABLE VII.—DIRECT COHESION OF METALS.

THE numbers in this table of experiments express the direct cohesion of bars one inch square in tons, of 2240 pounds.

		Tons.	lbs.
Iron bar, cast horizontally . .		8	32
" " vertically . .		8	69
Cast steel, previously tilted . .		59	93
Blistered steel, reduced by hammer		59	43
Shear " " "		56	97
Swedish iron " "		32	15
English " " "		24	93
Hard gun metal		16	23
Wrought copper, reduced by hammer		15	8
Cast " " "		8	51
Fine yellow brass		8	01
Cast tin		2	11
Cast lead		0	81
Wrought iron, mean of 26 experiments,	*Brunel*	31	20
" " 9	*Brown*	29	25
" " 8	*Telford*	25	00
Iron cable, " 13	*Brown*	21	25

TABLE VIII.—RESISTANCE OF METALS TO PRESSURE.

In this table of experiments the number of pounds are the weights required to crush cubes of one-quarter inch in the edge.

	lbs.
Iron, cast vertically . . .	11136
" " horizontally . . .	10114
Copper, cast	7318
" wrought	6440
Brass	10304
Tin, cast	966
Lead, cast	483

TABLE IX.—RESISTANCE OF METALS TO TORSION.

This table of experiments by *Brandreth*, exhibits only the relative resistance to *torsion*, that of lead being assumed as unity.

	lbs.
Cast steel	19.56
Shear steel	17.06
Blister steel	16.69
English iron	10.13
Swedish iron	9.50
Hard gun metal	5.00
Fine yellow brass	4.69
Copper	4.31
Tin	1.44
Lead	1.00

GOLD AND SILVER SOLDERS.

Hard Solder for Gold is prepared from gold and silver, or from gold and copper, or from gold, silver, and copper.

Gold Solder.—66.6 parts of gold, 16.7 parts of silver, and 16.7 parts of copper.

Hard Solder for Silver.—Equal parts of silver and brass; but made easier of fusion by the admixture of one-sixteenth of zinc.

Another Silver Solder.—19 parts fine silver, 1 part copper, 10 parts brass.

Another Silver Solder.—66.6 parts silver, 30.4 parts copper, 3.4 parts brass.

BRASS SOLDER.

Brass mixed with a sixth, an eighth, or even one-half of zinc.

Another Brass Solder.—12 pounds copper, and 11 pounds of zinc.

METHOD OF SOLDERING GOLD AND SILVER.

After the solder is cast into an ingot, it would be more ready for use if you were to draw it into small wire, or flat it between two rollers. After that cut it into little bits, then join your work together with fine soft iron wire, and with a camel's-hair pencil dipped in borax, finely powdered and well moistened with water, touch the joint intended to be soldered, placing a little solder on the joint. Apply it on a large piece of charcoal, and with a blow-pipe and lamp blow upon it through the flame until it melts the solder, and it is done.

TO CLEANSE SILVER AFTER IT IS SOLDERED.

MAKE it just red hot, and let it cool; then boil it in alum water, in an earthen vessel, and it will be as clean as when new.

TO CLEANSE GOLD AFTER IT IS SOLDERED.

PUT it through the same process as silver, but, instead of alum-water, boil it in wine and sal-ammoniac.

SILVER-SOLDER FOR JEWELLERS.

19 dwts. of fine silver, 1 dwt. of copper, and 10 dwts. of brass.

TRINKET COMPOSITION.

75 parts gold, 25 parts copper, and a little silver.

SILVER-PLATE AND MEDAL ALLOY.

95 parts silver, and 5 parts of copper.

GOLD COIN OF AMERICA ALLOY.

90 parts gold, 2.5 silver, and 7.5 copper.

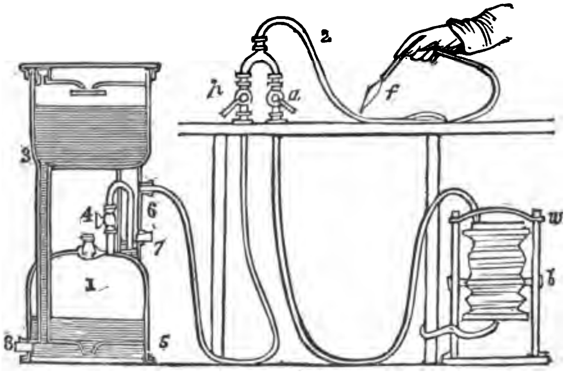
SOLDER FOR IRON.

NOTHING here is necessary but good tough brass, with borax, applied, mixed with water to the consistence of cream.

SOLDERING AND BURNING METALS.

BESIDES the more common processes of soldering, properly so called, the process of *burning* together must frequently be employed, as in making small additions to old castings, and repairing small defects in new ones.

In operations of this kind, very high degrees of heat are often required. This caused the introduction of the blow-pipe into the workshop. Perhaps the most powerful and convenient form of this instrument is that invented in France, by Count de Richemont, and patented in England by Mr. Delbruch. A figured description of the same, with its use explained, we now present to our readers.



The elastic tube *h* supplies hydrogen from the generator, and the pipe *a* supplies atmospheric air from a small pair of double bellows *b*, worked by the foot of the operator, and compressed by a constant weight *w;* the two pipes meet at the arch, and proceed through the third pipe *e* to the small jet *f*, from whence proceeds the flame. All the connexions are by elastic tubes, which allow perfect freedom of motion, so that the portable blow-pipe is carried to the work.

In soldering by the autogenous process, the works are first prepared and scraped clean as usual; the hydrogen is ignited, and the size of the flame is proportioned by the stop-cock *h;* the air is then admitted through *a*, until the flame assumes a fine pointed character, with which the work is united.

The gas generator bears some resemblance to Pepys' gasometer. When it is first charged, the stopper 1 is unscrewed, and the lower chamber is nearly filled with curly shreds of sheet zinc, and the stopper is replaced. The cover is now removed, and a plug with a long wire is inserted from the top into the hole near 3; the upper chamber is next filled with dilute sulphuric acid (1 acid and 6 water), until it is just seen through the central hole to rise above the plate immediately beneath it. This measures the quantity of liquid required to charge the vessel without the risk of overflow. The plug is now withdrawn from 3, and the cocks 4, and *h*, being opened, the air escapes from the lower vessel by the pressure of the column of water which enters beneath the perforated bottom 5, upon which the zinc rests. The cocks 4 and *h* are now closed, and by the decomposition of the water hydrogen is generated, which occupies the upper part of the lower chamber, and drives the dilute acid upwards, through the aperture 3, so as to place matters in the position of the engraving, which represents the generator about two-thirds filled with gas.

The gas issues through the pipe *h* when both cocks are opened, but it has to proceed through a safety-box, 6, in which the syphon-tube dips two or three inches into a little plain water, introduced at the lateral aperture 7: by this precaution the contents of the gasometer cannot be ignited, as should the flame return through the pipe *h*, it would be intercepted by the water in the safety-box. After three or four days' constant work, the liquid becomes converted into the sulphate of zinc, and is withdrawn through the plug 8; the vessel is then refilled with fresh dilute acid, as already explained, but the zinc lasts a considerable time.

The generators are made of lead, or, where portability and lightness are required, of copper washed with lead, and all the exposed parts of the brass work are washed and united with lead to defend them from the acid. Occasionally the air is likewise supplied by *aerometers*, or vessels somewhat resembling the gas generator, but which are only filled with common air, and therefore do not require the zinc or acid.

The difference between the aero-hydrogen blowpipe described above, and the oxy-hydrogen blowpipe of Dr. Hare, is this:—in the latter the pure gases (oxygen and hydrogen) are mixed in the exact proportions of two volumes of hydrogen to one of oxygen—which quantities, when combined, constitute water, and during combination evolve the greatest amount of heat. The aero-hydrogen blowpipe is supplied with common air and pure hydrogen.

SOFT SOLDERS.

TIN and lead in equal parts. Easier of fusion still is tin, lead, and bismuth, in equal parts; or one or two bismuth, one lead, and one tin, easier still.

For soft soldering brass, tin-foil makes a fine juncture, applied between the joints, care being taken to avoid too much heat. This is most excellent for fine brass work. The tin-foil must be moistened in a strong solution of sal-ammoniac.

A SOLDER FOR LEAD.

2 parts lead and 1 part tin. Its goodness is tried by melting it and pouring the bigness of a dollar piece upon the table; for if it be good there will arise little bright spots in it. Apply rosin when you use the solder.

PLUMBER'S SOLDER.

1 part bismuth, 5 parts lead, and 3 parts tin, forms a compound of great importance in the arts.

COMPOSITIONS OF PEWTER.

1. 100 parts tin, 17 parts of antimony; *the French add a little copper.*

2. 12 pounds of tin, 1 pound of antimony, 4 ounces of copper.

3. 7 pounds of tin, 1 pound of lead, 6 ounces copper, 2 ounces zinc. *Melt the copper first.*

WHITE METAL.

10 ounces lead, 6 ounces bismuth, and 4 drachms of antimony; or, 2 pounds of antimony, 8 ounces of brass, and 10 ounces of tin.

MOSAIC MIXTURE.

EQUAL parts of tin, bismuth, and mercury, forms a metal used for various ornamental purposes.

SILVERY-LOOKING METAL.

A VERY fine silvery-looking metal is made from 100 parts tin, 8 parts antimony, 1 part bismuth, and 4 parts copper.

METAL FOR FLUTE VALVE KEYS.

4 ounces of lead and 2 ounces of antimony.

GERMAN TITANIUM.

2 drachms of copper, 1 ounce of antimony, and 12 ounces of tin.

SPANISH TITANIUM.

8 ounces of scrap iron [illegible] steel, 1 pound of antimony, and 3 ounces of nitre.

The iron or steel must be heated to whiteness, and the antimony and nitre added in small portions. Two ounces of this compound are sufficient to harden one pound of tin.

BRITANNIA METAL.

4 ounces of plate brass, 4 ounces of tin; when fused add 4 ounces of bismuth, and 4 ounces of antimony. This composition is added at discretion to melted tin.

COLUMBIA METAL.

4½ pounds of tin, ½ pound of bismuth, ½ pound of antimony, and ½ pound of lead; or, 100 pounds of tin, 8 pounds of antimony, 1 pound of bismuth, and

4 pounds of copper. This alloy is used for making tea-pots, and other vessels which imitate silver.

TYPE METAL.

10 pounds of lead, and 2 ounces of antimony. The antimony is added when the lead is in a state of fusion. The antimony gives hardness to the lead, and prevents its contraction when cooling.

For Small Types.—9 pounds of lead, 2 pounds of antimony, and 1 pound of bismuth. The antimony and bismuth are added when the lead is melted. This alloy expands in cooling; the mould is therefore entirely filled when the metal is cold, and no blemish is found in the letters. Stereotype plates are formed of this alloy. Some employ tin instead of bismuth.

Type Metal of the French Letter Founders.—Four-fifths of lead, and one-fifth of regulus of antimony.

The letter founders of *Berlin* use 11 pounds of antimony, 25 pounds of lead, and 5 pounds of iron. Many add tin, copper, and brass; while some make their types from 3 parts lead, to 1 of antimony.

GERMAN SILVER.

1. 25 parts nickel, 20 parts zinc, and 60 parts copper. If for casting add 3 parts of lead.

2. 16 parts copper, 8 parts zinc, and 3½ parts nickel.

3. 8 parts of copper, 3½ parts of zinc, and 2 parts of nickel.

4. 28 parts copper, 13 parts zinc, and 7½ parts nickel.

5. Copper, 8 parts; zinc, 3½ parts; nickel 3 parts.

This last is a very beautiful compound. It has the appearance of silver a little below standard. By some persons it is even preferred to the more expensive compound. Manufacturers are strongly recommended not to use a metal inferior to this.

SPECULUM METAL.

1. Copper, 64 parts; grain tin, 29 parts. Melt the metals separately, under a little black flux. Incorporate thoroughly by stirring with a wooden spatula; then run the metal in the mould, so that the face of the intended *mirror* may be downwards.

2. Copper, 32 parts; tin, 14 parts; arsenic, 2 parts. A very good metal.

3. Copper, 32 parts; tin, 13½ parts; arsenic, 1½ parts.

4. Copper, 32 parts; tin, 15 parts; arsenic, 2 parts. Better than 2 and 3.

5. Copper, 32 parts; tin, 15 parts; brass, 1 part; silver, 1 part; arsenic, 1 part. A most excellent metal, and by far the whitest, hardest, and most reflective metal I have ever yet met with.

6. Copper, 6 parts; tin, 2 parts; arsenic, 1 part. Sir Isaac Newton's mixture. It is a compact metal enough, but very yellow when polished.

7. Copper, 3 parts; tin, 1¼ parts. Compact, and whiter than the last.

8. Brass, 6 parts; tin, 1 part. Compact, but too yellow.

9. 2 parts of 7th composition, and 1 part of 8th. Compact, but much too yellow when polished. 7, 8, and 9, are experiments by Professor Molyneux, F. R. S.

10. Copper, 32 parts; tin, 2 parts; arsenic, 1 part. A pretty good metal, but polishes too yellow. Professor Mudge's composition.

REMARKS.

In melting arsenic, nitre is a good flux for fixing it with other metals.

In using iron filings in your compositions, use corrosive sublimate (viz. chloride of mercury) for fixing it.

Powdered flint glass also makes a most excellent flux for copper, tin, and arsenic.

No. 5. This metal, when broken, should appear of a bright, glassy, and quicksilver complexion. If it appears hard and of a dead white, more tin must be added. The copper will sometimes take sixteen ounces of tin, if it is very pure. If it appears bluish and rough, more copper or brass must be added.

It is somewhat singular that arsenic, though particularly recommended by Sir Isaac Newton, Dr. Olynthus Gregory, and others, for giving homogeneity to metallic compositions, should be so hastily thrown aside by the founders. This imprudent disuse of it, I can only attribute to the disagreeable fumes or vapours, which arise when it is introduced into the crucible, to the melted mixture, which may produce disagreeable effects upon the operators, if proper care be not taken to prevent them from being received into the lungs. All the precaution necessary, is to bruise the *arsenic* coarsely, and introduce it into the crucible with a pair of tongs, having tied it up in a piece of paper, giving it then a stir with a wooden spatula made of birch, during which time retaining your breath—avoid it till you can see no more vapours arise from the crucible, when the metal will be ready to pour.

The common black flux is made of two parts of tartar, and one of nitre.

I have always found from adding a small quantity of arsenic, viz., from one-half ounce to one ounce to the pound of metal, that it would considerably improve even porous metal, and make it harder, likewise, as well as whiter.

In making speculums, the casting should be taken from the mould red-hot, and put into a quantity of hot ashes to anneal it, or else it will break in the sand. Let it remain in the ashes till the whole becomes cold.

Professor Nevil Masculyne, speaking of arsenic, says—I have been assured by two ingenious experimental philosophers that the fumes of arsenic, even when the garlic smell is very strong, are not in the least prejudicial to the lungs.

A careful study of the above remarks will be of inestimable advantage to the practical brass founder, saving him both loss of work, as well as loss of time.

PLATINA.

Mirrors for telescopes, &c., are made of platina, of exquisite beauty. The Spaniards are in the habit of mixing it with iron, in order to form gun-barrels, which are said never to rust, and which are much stronger than iron barrels alone, as it gives to the iron a remarkable toughness. It forms a valuable coating for copper and iron, and may hereafter become precious for the formation of *coins* and *medals*.

Platina, in its malleable state, may be cut with a knife; but with steel it forms an alloy not to be touched with a file.

The nitro-muriatic acid is the proper solvent for platina.

ON THE PROPERTIES OF ARSENIC.

ARSENIC is a brittle metal, and, in the recent fracture, of a lively bright colour, between tin-white and lead-gray; but on exposure to the air it soon loses its metallic lustre, and turns prismatic, dull, and at last black. Its specific gravity is, according to Professor Mudge, between 8.310 and 5.763, according to its texture.

Its hardness surpasses that of copper, but its ductility is so little, and it brittleness so great, that it is readily converted into a powder by the hammer. It is entirely volatilized when heated to 356° Fahr. It sublimes in close vessels, and then crystallizes in tetrahedra, or octahedra. When heated with the excess of air, it emits a strong smell of garlic, and burns with a bluish white flame. It combines with sulphur by fusion. It unites to phosphorus, and combines with most of the metals.

Besides giving a white colour to copper, it renders many of the ductile metals brittle. When mixed with hyper-oxygenated muriate of potash, it detonates strongly by the stroke of a hammer. It is soluble in hydrogen gas by heat. It does not decompose water alone; it decomposes sulphuric acid by heat. The nitric and nitrous acid oxidate it rapidly. The muriatic acid attacks it with heat. The oxygenated muriatic acid (now termed chlorine), when in a gaseous state, inflames it instantly. It is nearly unalterable by the fluoric, boracic, phosphoric, and carbonic acids. It unites with alkaline sulphurets and hydro-sulphurets. It is a deadly poison.

If you insert a little arsenic, reduced to fine powder, between two polished plates of copper, and bind closely together with *iron wire*, and heat them, the inner surfaces of the copper plates will be rendered white by the arsenic.

Experiment No. 1. *Experimental proofs of the properties of arsenic. Arsenic burns and is volatilized by heat.*—Introduce into a crucible, made red-hot in a coal fire, a small quantity of arsenic, and it will begin to burn and become volatilized. If this crucible be covered with another, and the joinings luted with clay, the arsenic will be found in the upper one in brilliant crystals.

Experiment No. 2.—The union of arsenic with copper may likewise be effected by fusing 1 part of arsenic with 4 of copper, in a common crucible.

The alloy produced is a white metal. It is necessary in this experiment to cover the substances in the crucible with common salt, to prevent the action of the air.

FONTAINEMOREAU'S NEW ALLOYS OF ZINC, A SUBSTITUTE FOR BRONZE, COPPER, AND BRASS.

An invention of a new alloy of zinc, with small proportions of other metals, found to possess very peculiar advantages, has lately been introduced into England, where it has been patented in the name of M. Fontainemoreau. It is likely to prove of great utility in the manufacture of machinery, and in castings relating to the fine arts. As a substitute for copper and bronze it already bids fair to be extensively adopted.

The proportions of metals which have been found most advantageous in forming varieties of the alloy, after very numerous and extensive experiments, are as follows:—

No. 1. Zinc, 90 parts; copper, 8 parts; cast iron, 1 part; lead, 1 part; 100 parts.

No. 2. Zinc, 91 parts; copper, 8 parts; lead, 1 part; 100 parts.

No. 3. Zinc, 92 parts; copper, 8 parts; 100 parts.

No. 4. Zinc, 99 parts; copper, 1 part; 100 parts.

No. 5. Zinc, 97 parts; copper, 2½ parts; cast iron, ½ part; 100 parts.

No. 6. Zinc, 97 parts; copper, 3 parts; 100 parts.

No. 7. Zinc, 99½ parts; cast iron, ½ part; 100 parts.

No. 8. Zinc, 91½ parts; copper, 8 parts; cast iron, ½ part; 100 parts.

The proportions stated of any of these metals may be slightly varied, so long as by such variation the alloy is not made too brittle, or too soft. For instance, the proportion of copper may be varied from about 1 part to about 12 parts, in every hundred; but any greater proportion of copper than this, and less than that used in forming common brass, would make the alloy brittle. The proportion of cast iron may be varied from about one-quarter of a part, to about two parts in every hundred. The proportion of lead may be varied from about one, to about twenty-four parts in every hundred parts; but the presence of some third metal is necessary to produce a proper combination of the zinc and lead. Instead of pure copper, or any other of the simple metals before to be used, brass, or the other alloys formed of these metals, may be used. But where this is done, the quantity of copper and the simple metals contained in such alloys must be taken into account in calculating the relative proportions of simple metals which the new alloy is to contain in reference to the tables of component parts.

The principal object of the addition of the small quantities of copper, cast iron, and lead to the larger proportions of zinc, is to change the manner of the crystallization of the zinc after it has been fused and set to cool.

The new alloys are of a closer texture, more homogeneous, and malleable, than simple zinc, and some kinds of iron; are less liable to oxidation, and of a much finer grain than zinc—somewhat resembling that of steel, especially when the alloys are rolled. They are also easier filed than either zinc, copper, or brass, and the filings do not stick in and clog the file.

N. B. By casting the new alloys in metallic moulds, their *hardness* and homogeneity is increased, and a sort of *temper* is imparted to them, resembling or approaching to steel.

For the purpose of rendering the alloys which are of a silvery-gray colour, perfectly suitable as substitutes for copper, bronze, brass, and other metals, the colour proper to the metals of which they are intended to be substitutes, is imparted to them by means of any solution of copper. The hydrochlorate of copper is found to answer best—

Firstly.—For giving the alloys a blackish-bronze colour, they are treated with a solution of the salt of copper, diluted with a considerable quantity of water, and a small quantity of nitric acid may be added.

Secondly.—To impart a red or copper colour, add to the solution of salt of copper, liquid ammonia, and a little acetic acid. The salt of copper may be dissolved in the liquid ammonia.

Thirdly.—To impart a brass, or antique bronze colour, either of the three following means may be adopted: 1. A solution of copper, with some acetic acid. 2. The means before described for copper colour, with a large proportion of liquid ammonia. 3. Water acidulated with nitric acid, by which beautiful bluish shades may be produced. It must be observed, however, that this last process can only be properly employed on the alloys which contain a portion of copper.

In either of these methods of colouring, a solution of sal-ammoniac may be substituted for the liquid ammonia. The quantities of each ingredient have not been stated, as these depend upon the nature of the alloy, the shade or hue desired, and the durability required.

The blackish-bronze colour may be superadded to the red or copper colour, whereby a beautiful light colour is produced on the prominent parts of the article bronzed, or on the parts from which the blackish-bronze colour may have been rubbed off.

These new alloys may be used as substitutes for various metals now in general use, such as iron, in various parts of machinery; iron, lead, tin, or copper, in pipes and tubes, and bronze, brass, and copper, in machinery and manufactories, as well as for most of the other purposes for which more expensive metals are employed.

ON ZINC AS A PROTECTIVE COVERING FOR IRON; AND THE ADAPTATION OF THE PROCESS OF ELECTRO-DEPOSITION FOR THAT PURPOSE. BY F. PELLATT, ESQ.

Read at the Institution of Civil Engineers, London.

THE object of this paper is to direct attention to the properties of zinc as a protecting coating to iron; to describe the processes already employed for this purpose; the reason of their failure; and the peculiar adaptation of the electro-deposition of the metal for the end desired.

It would be a needless waste of time to say anything regarding the superior value of iron as a material; but a few remarks respecting its chemical influences may not be misplaced.

The cause of iron becoming corroded is its superior affinity for oxygen. If the iron and water are both pure, this is not, indeed, found to be the case; but under ordinary circumstances, *neither* of these exist in a state of purity. The iron, therefore, owing to its own impurity, and that of the water, is subject to a powerful destructive influence, which is best known to those most experienced in its use; and there is no circumstance in which we can place iron to be free from the action of water, it being present in the air and earth. So powerfully is this metal affected in the earth, or in contact with some salts, that it loses all its essential properties, and is converted into a substance so soft that it may be scratched by a finger nail. These facts render it of the utmost importance that some means be obtained for its protection, which, at the same time, will not interfere with the natural properties of the iron. The substances hitherto used for protecting iron are tin and paint. These, as lasting coatings, are not effective. The tin being electrically negative to the iron, renders it a means of destruction, instead of protection, when any part of the iron is exposed. By the laws of electricity, when metals are in contact, the *negative* metal is protected at the expense of the *positive*.

Circumstances, such as different chemical menstrua, may alter the relative electrical states of metals. But under all ordinary circumstances this rule holds good; and zinc being the positive metal, it becomes, in consequence, a protector to the negative metal, iron. This electrical property of zinc in connexion with iron and other metals, has induced those to whom it was known, to recommend it as a coating. The difficulty hitherto has been the obtaining of zinc pure, and the application of it without injuring the texture of the iron.

From the known qualities of zinc, it has been lately much employed for various purposes, but has entirely disappointed the expectations formed from its properties. The reason of this is, that no zinc of commerce is pure, and that the impurities existing are destructive to it, from the electrical law we have alluded to. The impurities existing, more or less, in all zinc, are lead, iron, arsenic, and one or two other metals, all of which are electrically negative to zinc; the consequence being that every atom of impurity, in connexion with the zinc, forms a galvanic battery of many thousands, or rather millions, of pairs of plates, the impurities being protected, and the zinc destroyed.

It has no doubt surprised many who have made use of zinc, to find it in a few weeks or months, according to circumstances, perforated with small holes, and completely destroyed. We say according to circumstances, because the ordinary *time* zinc lasts depends not only on the amount of impurities contained in it, but also on the exciting fluid to which it is subjected. Exposed to the action of water from the atmosphere, the destructive influence operates comparatively slowly; but with more exciting fluids very rapidly.

Thus, a roof erected in the neighbourhood of a vinegar distillery, was completely destroyed in six weeks; and vessels used for dairy purposes have lasted but a very short time, owing to the presence of acids—these causing a rapid galvanic action between the zinc and its impurities. It is then quite evident that impure zinc, being itself valueless, cannot afford protection to any other metal. Now, the only process yet in use for the purpose of coating iron with zinc, is that of immersing the iron in melted zinc. This we conceive open to many objections. The iron by this process being raised to a temperature of at least 800°, causes it to combine with the zinc, forming an alloy on the surface, which changes its state, and becomes brittle. But upon this subject, we shall refer to the report made by M. Dumas to the French Academy. He says—

"The zincing of iron, made by steeping iron in a bath of melted zinc, has many inconveniences; besides, the iron combining with the zinc, constitutes a very brittle, superficial alloy. The iron loses its tenacity—a circumstance which is not perceived.

however, except in trying to zinc fine iron wire, or very thin plate. Besides, the surface, being covered with a layer of not very fusible metal, is always ill-formed. Thus, fine iron wire cannot be zinced by this process, as it becomes fragile and deformed; bullets cannot be zinced, as they become misshapen, and no longer of the same calibre."

We have reason to believe that very nice manipulations, and annealing the iron after zincing, may remove some of M. Dumas' objections to this process. Still, two fatal objections, in our opinion, would exist to its use: first, the impossibility of obtaining *pure* zinc, except at an enormous expense, the only process being sublimation or distillation; and secondly, the impossibility of retaining its purity, during the process of applying it to iron.

Setting aside the fact of an alloy of iron and zinc being produced by the action of heated iron immersed in melted zinc, the presence of foreign matter necessary to retain the zinc in fusion, renders it impure; these matters forming less fusible compounds, and zinc being very volatile, a great amount of waste is created.

But it is well known to all those acquainted with the deposition of metals from soluble salts by the electro process, that pure metal only is deposited;

so that this process is not open to the objection upon this head, which may be made to every other, more especially in treating a metal of so intractable a character as zinc. It is also applicable to all sizes and shapes of work, requires no expensive erections, and, what is important in large operations, may be performed anywhere, and by any person.

Although the protecting influence of zinc (we of course speak of pure zinc) upon other metals is practically unknown, it has been well known to men of science; and we shall take the liberty of quoting the opinions of some of the best chemists upon the subject; bearing in mind that zinc is electrically positive to other metals, and as such protects them from oxidation at a very trifling loss to itself—and that, by a well known law of electrical science, one body being electrically excited, that body induces its opposite state in other bodies with which it is in contact. Keeping these three points in view, we would call attention to the following opinions:—Dr. Kane says, "Zinc preserves the other metals, even if it be iron, from oxidation;" and, again, "Zinc, when exposed to the air even in presence of water, becomes covered with a varnish of a gray substance, probably a definite sub-oxide, which is not further altered by exposure." Professor Graham, alluding to iron in water, says, "Articles of iron may be completely defended from the injury occasioned in this way, by the more positive metal zinc, while the protecting metal itself washes away slowly;" and further, when speaking of zinc, "When exposed to air, or placed in water, its surface becomes covered with a gray film of sub-oxide, which does not increase; and this film is better calculated to resist both the mechanical and chemical effects of other bodies than the metal itself, and preserves it." And Professor Daniel, in his new work, says, "That a plate of pure zinc, when immersed in water, speedily becomes dulled by the formation of a thin coat of oxide; but the oxidation proceeds no further, because the adhesion of the metal prevents a renewed contact of the metal and the water."

From these authorities we notice that pure zinc has a double protecting influence, the iron being protected by the zinc, and the zinc by its own oxide, besides that peculiar galvanic influence induced by the positive state of the zinc with respect to the iron. With regard to the peculiar adaptation of the electro processes to the zincing of iron, we shall again quote from M. Dumas' Report. He says, "Manufacturers, and those concerned in military affairs and the fine arts, will learn with interest that these processes enable us to zinc, in an economical manner, iron, steel, and cast iron, by means of the pile or battery, with the solution of zinc, by operating without heat, and consequently not interfering with the tenacity of the metal; by applying it in thin layers, and by thus preserving the general forms of the pieces, and even the appearance of their minutest details. The thinnest plate may receive this preparation without becoming brittle, and may be turned to account in roofing buildings."

We hope these authorities fully support what we have asserted, that pure zinc affords a perfect protection to iron, is not itself susceptible of rapid decay, and is easily applicable to the electro process. We are aware that other opinions upon this subject have been given; some have almost denied its galvanic influence, and have reduced it to what they term a *mere* "*tendency*," whilst others have much overstated it. Effects which may be witnessed every day, prove that there is a secret galvanic agency at work when metals are in contact. Take, for instance, the decay of iron when in contact with lead. Every one has observed that iron railings let into stone work with lead, are much decayed within a short space of the contact of these two metals, while the remaining portion is comparatively sound. This effect is from the iron being positive to the lead, which is therefore protected at the expense of the iron.

It is matter of regret that zinc cannot be used with the same protecting property to articles in use at sea. This arises from its strong affinity for muriatic acid, thereby forming muriate of zinc, which being readily soluble is taken off by the water, leaving a new surface of zinc to be acted on, thus rapidly destroying the zinc.

In situations where the articles are not exposed to the run of salt water, the zinc will be found a protection.

The zinced iron solders readily. All other metals may be treated by this process for ornamental purposes. Copper will be found very useful. The depositions by alkaline solutions are perfectly firm, and not subject to the objection to which those made by acid solutions are; these being always insecure from the formation of an oxide upon the iron, induced by the acid of the solution. The deposited copper may be bronzed or gilt, and will be found most useful for ornamental work.

Many specimens of zinced iron, some of which had been exposed to the action of the weather for months, were exhibited to the meeting, as well as specimens of iron coated with copper by the same process.

WATER IN PIPES.

THIS table shows the quantity and weight of water contained in one fathom of length of pipes of different bores from 1 inch to 12 inches in diameter, advancing by ½ inch. The weight of a cubic foot of water is taken at 1000 ounces avoirdupois, and the imperial gallon at 10 lbs.

Diameter in inches.	Quantity in Cubic inches.	Quantity in Imperial gallons.	Weight in lbs. Avoird.
½	14.14	0.051	0.51
1	56.55	0.205	2.05
1½	127.23	0.460	4.60
2	226.19	0.818	8.18
2½	353.43	1.278	12.78
3	508.94	1.841	18.41
3½	692.72	2.506	25.06
4	904.78	3.272	32.72
4½	1145.11	4.142	41.42
5	1413.72	5.113	51.13
5½	1710.60	6.187	61.87
6	2035.75	7.363	73.63
6½	2389.18	8.641	86.41
7	2770.88	10.022	100.22
7½	3180.86	11.505	115.05
8	3619.11	13.090	130.90
8½	4085.64	14.777	147.77
9	4580.44	16.567	165.67
9½	5103.52	18.459	184.59
10	5654.87	20.453	204.53
10½	6234.49	22.550	225.50
11	6842.39	24.748	247.48
11½	7478.56	27.049	270.49
12	8143.01	29.452	294.52

ON CRUCIBLES.

THE manufacture of crucibles is a branch of the potter's art, requiring great care to insure success; and until lately, was at the best a very uncertain process. The chief requisites in a good crucible are, refractoriness in the strongest heats, capability of withstanding the corrosive effects of any substances that may be ignited in them, and the effects of sudden alterations of temperature. They must also be composed of a material sufficiently solid in its texture to prevent the passage of the solid metal through its pores.

The composition producing pots of the best quality is formed by pure fire clay mixed with finely ground *cement* of old crucibles, to which is added a portion of black lead or plumbago. The clay is prepared in the same manner as observed in pottery generally. The vessels, after being worked to the proper conical shape, are slowly dried, and then baked in a kiln.

The composition used in the Royal Foundry of Berlin is formed of eight parts in bulk of Stourbridge clay and cement, five of coke, and four of graphite or plumbago. Crucibles manufactured from this mixture are capable of withstanding the greatest possible heat in which wrought iron melts, being equal to from 150° to 155° Wedgewood. They also bear sudden cooling without cracking. In the Berlin foundry they have been employed for twenty-three consecutive meltings of seventy-six pounds of iron each, which perhaps is the most complete and trying test that could be adopted.

Another composition is as follows:—8 pounds Stourbridge clay, 4 pounds burned clay cement, 2 pounds coke powder, and 2 pounds pipe clay; the whole being compressed in moulds while in a pasty state.

The Hessian crucibles from Great Almerode and Epterode, resist the action of fluxes, and are tolerably lasting. They are made from a fire clay containing a small amount of iron, but no lime. This is incorporated with silicious sand. These crucibles are rather porous, but they resist the effect of saline and leaden fluxes, and are not liable to crack, but they melt below the fusing point of bar iron.

The black lead crucibles bear a much higher heat. Their composition is two parts of graphite and one of fire clay; this is mixed into a pasty mass by means of water. The crucibles are baked slightly in the kiln, but are not completely hardened until put in the furnace for use. They are of a smooth surface, and are consequently suitable for gold and the precious metals generally. These crucibles are perhaps the very best yet manufactured, and many of the brass founders throughout Europe, and, for aught I have yet seen to the contrary, all the brass founders of America, are adopting them in preference to ordinary clay ones.

Mr. Anstey's patent process for the manufacture of crucibles is as follows:—2 parts of finely ground raw Stourbridge clay, and 1 part of the hardest gas coke, previously pulverized, and sifted through a sieve of one-eighth of an inch mesh, are mixed well together with water. This mixture is moulded on a revolving wooden block, somewhat similar to the process pursued in pot throwing, a gauge being used to regulate the thickness of the pot, and a cap of linen placed upon the core previous to the application of the clay, in order to prevent its adhering when removed. The pot is then dried in a gentle heat, and is not thoroughly completed until required for use. It is then warmed before a fire, and laid in the furnace, with the mouth downwards—the heat of the fire having been previously lowered by the application of fresh coke. It is gradually brought up to a red heat, reversed, and fixed in its proper position in the furnace, and is then ready to receive the charge of metal.

PLUMBAGO.

PLUMBAGO, or black lead, of which pencils are made, is a compound of iron and carbon, in the proportion of 9 parts carbon to 1 of iron. It has nothing similar to lead about it, unless its inquinating property, by which paper is so readily marked. In this combination we have a metallic alloy less cohesive than almost any other substance, mercurial amalgam excepted; whilst the very same ingredients, in different proportions, produce another alloy, *steel*, which has properties diametrically opposite, as it is capable of cutting the hardest substances, with very few exceptions. The softest steel is harder than the hardest iron.

HARDENING STEEL.

The process of hardening steel is called *tempering* or *attempering*, and consists in that novel arrangement of the particles which is produced when steel, while hot, is plunged into cold liquids, as water. The colder the liquid, or the more sudden the operation of cooling, the harder will the steel be.

Case-hardening is the superficial conversion of the surface of iron into steel, by heating it in contact with animal carbon, in close vessels. Bar iron is converted into steel in the same way, only that powdered charcoal is the substance in which it is imbedded.

ON BORON.

This is the basis of a substance which has been long and extensively used in the arts and in medicine, under the name of *borax*. It is found abundantly in Thibet and in *South America*, but in a state too impure to be used without refining. This was long a secret process practised by the Venetians and Dutch, who imported the crude salt into Europe, under the name of *tincal.*

Borax has a sweetish taste, and is "soluble in twelve parts of cold, and two parts of boiling water." Its crystals are transparent, but effloresce and become opaque in a dry atmosphere; and they appear luminous by friction in the dark.

It melts at a heat a little above that of boiling water, and gives out its water of crystallization, after which it forms a spongy mass, well known as calcined borax. When further heated to ignition, it passes into a glassy-looking substance, known as glacial borax.

Boracic acid is obtained in unlimited quantity from the lakes of Tuscany. The water requires simply to be evaporated until the acid solution has been sufficiently concentrated to afford crystals. The acid thus obtained is chiefly taken to M. Payen's works, at Marseilles, where it is manufactured into borax.

Dry borax, at a high temperature, has the remarkable property of melting and vitrifying the metallic oxides into glasses of different colours. On this account it is a most useful reagent for the blow pipe. With oxide of chrome it forms an emerald green glass, and with oxide of cobalt an intensely blue glass.

Oxide of copper tinges it pale-blue; oxides of iron, bottle-green; oxide of tin, opal; oxide of manganese, violet; oxide of nickel, pale yellowish-green. With the oxides of silver and zinc, and with several of the earths, it forms white enamels.

Borax, in consequence of this property of vitrifying the metallic oxides, is used to clean the surface of metals, in processes of soldering with hard solder, and of welding *cast steel.*

It is also valuable in the fusion of metals to protect their surface from oxidizement. And it is worthy of remark, that, when mixed with shell-lac, in the proportion of one part to five, borax renders that resinous substance soluble in water, and forms with it a species of varnish.

ON SULPHUR.

THIS element, popularly known as *brimstone*, stands sufficiently well characterized by its brittleness, non-metallic appearance, and peculiar yellow colour. As a combustible it is universally known. Exposed to a temperature of 218° it melts almost into a liquid. When heated a few degrees higher, it becomes tenacious; and when heated to the temperature of 300°, it takes fire, burns away with a lambent blue flame, and leaves no residuum. As the temperature rises the flame becomes more white; and in pure oxygen gas the combustion goes on with great brilliancy.

If, while melted and viscid, sulphur be poured into cold water, it acquires somewhat the consistency of soft sealing-wax, and in this state it is very commonly used for taking impressions from seals and medals.

Native sulphur is brought into this country chiefly from Sicily, where it occurs in beds of a blue clay formation, occupying the central half of the south coast of the island, and extending inwards as far as the district of Etna. Sulphur is also an abundant ingredient in various minerals: iron pyrites and galena, sulphurets of iron and lead, are particularly abundant in some localities; and at one time a large portion of the sulphur used in England was obtained from the copper pyrites of the mines of Anglesey. It was, however, less pure than the fine sulphur of Sicily, and other volcanic districts, being commonly mixed with arsenic and other metallic impregnations, which are difficult to separate.

Sulphur is sometimes employed for cementing iron bars into stone; and at present it is in repute for taking impressions of seals and cameos. When used for this purpose, it is commonly kept previously melted for some time, to give the casts the appearance of bronze. The principal consumption of it, however, is in the manufacture of sulphuric acid, gunpowder, and vermillion.

When the end of a sulphur match is lighted, the flame emits copious fumes, which are a compound of oxygen and sulphur. These fumes are intensely acid to the taste; they constitute what is called sulphurous acid, the first of the combinations of sulphur and oxygen. The gas has a strong affinity for the water, and the solution which it forms with it is known as liquid sulphurous acid. This, if left exposed to the air, absorbs more oxygen, and passes into sulphuric acid.

Sulphur also combines with hydrogen, forming the highly poisonous and offensive gas known as sulphuretted hydrogen, and which not unfrequently contaminates the coal gas supplied to us for illumination. Sulphur and carbon also combine, and form a beautifully transparent and colourless liquid, exceedingly volatile, and giving off an odour the most fœtid and nauseous which it is possible to conceive. Sulphur likewise enters into combination with metals, forming sulphurets, and is a most excellent flux in the making of brazing solder.

SELENIUM.

This is a rare elementary substance, nearly allied to sulphur in its properties, although it in some respects partakes of the nature of a metal. It was discovered by Berzelius, in 1817, in the refuse of an oil of vitriol manufactory, where it was derived from the iron pyrites employed in the works, and which contain a mixture in very minute proportions of a similar compound of selenium and iron. It has also been found sparingly in combination with several other metals, as lead, cobalt, copper, and bismuth; and with sulphur, in the volcanic products of the Lipari Islands.

It is separated from its combinations with difficulty, and hitherto only in minute quantities. When obtained free of admixture, selenium, at common temperatures, is brittle, solid, of a reddish-brown colour, and metallic lustre, without taste or smell. But when finely powdered the powder assumes a deep-red, inclined to purple. It softens at the temperature of 180°; is pasty at 200°, and melts at a few degrees above the boiling point of water. When warm it exhales a strong odour of decayed horseradish, and is so ductile that it may be drawn into threads, which are red by transmitted, but gray by reflected light. It boils at 600°, and in close vessels throws off deep-yellow vapours, which condense into black, metallic-looking drops.

ON CHLORINE.

Chlorine enters into numerous highly important and interesting combinations. Various bodies, when immersed in it when in a liquid state (that is, when, submitted to a pressure of four atmospheres, it becomes a yellow transparent liquid), take fire spontaneously. A candle burns in it with a red flame, and a piece of phosphorus introduced into it, burns with a pale-white light. Copper, tin, zinc, antimony, and arsenic, when introduced into it in their leaves, or reduced to filings, take fire, and, combining with the gas, form compounds analogous to the oxides, and which are therefore called *chlorides*. Mercury also enters rapidly into combination with it, forming chloride of mercury, a substance better known as *corrosive sublimate*.

The grand source of chlorine is the water of the ocean. This is an enormous solution of *salt*—a universally known and indispensable article of consumption with the human race; an article, indeed, which seems to be essentially necessary to maintain the body in a healthy condition. Now this *salt* is a compound of chlorine and a metal. It is, in fact, a chloride, consisting, when pure, of 60 of chlorine, and 40 of sodium, in 100 parts; and whether it be obtained by evaporation of sea water, or be dug out of the salt mines of Wieliczka or Northwich, it has the same composition.

SOME of the minerals contain but one earth; but minerals are found in which the earths are combined in different proportions, by processes which produce that apparently endless variety of objects which mineral nature presents for our contemplation.

Science has of late years demonstrated that none of the earths are simple substances, that is, chemical elements. Sir Humphrey Davy has proved that none of them are entitled to that character, that they are in fact compounds of certain metals with oxygen—that is, metallic oxides. This has been shown by the very direct method of abstracting oxygen from them, and thereby separating the metallic base. Thus, alumina (being the basis of alum) is the oxide of a gray and hard metal like platinum, and which burns with great brilliancy when heated with access of air, and reproduces the earth by absorption of oxygen from the atmosphere.

It is very singular that soda, as distinguished from potash, has been known with us only of late years; whereas it was familiar to the Greeks and Hebrews. It was also known in Egypt, where it is found native, and is known by the name of *natron*—which occurs in the Bible. Thus Jeremiah speaks of washing in natron.*

From the preceding summary we may reckon ourselves justified in concluding that the solid strata of our globe—that is, the superficial shell with which we are acquainted, if not the vast mass of the globe itself—are nothing more than masses of metals of different kinds, disguised by oxygen: that they are in fact oxides, and bear evidence, in many cases, of being the products of combustion.

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* Jeremiah, ii. 22.

APPENDIX.

AN APPENDIX

OF

USEFUL AND VALUABLE RECEIPTS.

TO BROWN GUN BARRELS.

TAKE of nitric acid, half an ounce; sweet spirit of nitre half an ounce; blue vitriol, two ounces; tincture of steel, one ounce. Mix all together in eight gills of water. Apply this mixture with a sponge, then heat the barrel a little, and move the *oxide* with a hard brush. This operation may be repeated a third and fourth time, till you have the brown required.

It is then to be carefully wiped, and sponged with boiling water, in which there has been put a small quantity of potass. The barrel being taken from the water, must be made perfectly dry, and then rubbed smooth with a burnisher of hard wood; afterwards heated to the height of boiling water and varnished with the following varnish:—

Varnish for gun barrels that have undergone the process of browning.

TAKE of spirits of wine two parts, dragon's blood, powdered, three drachms; shell-lac bruised, one ounce; dissolve all together. This varnish being laid on the barrel, and become perfectly dry, must be rubbed with a burnisher to render it smooth and glossy.

ETHEREAL SOLUTION OF GOLD.

SATURATE nitro-hydrochloric acid with pure gold. Crystallize, and with the crystals saturate water. Shake this aqueous solution in a phial with an equal volume of pure ether; then two fluids will result, the lighter of which is the ethereal solution of gold, and may easily be separated. This must be kept in a darkened bottle, as by exposure to light it quickly decomposes, flakes of gold being deposited.

Any substance moistened with this will receive a coating of metallic gold, and hence metals may be rendered not liable to corrosion.

Even in the dark it cannot be preserved long, but undergoes slow decomposition

TO COAT SMALL NAILS, ETC., WITH TIN.

PUT half an ounce of powdered tin (which may be procured of any operative chemist), into a common Florence flask, pour on about two ounces of concentrated muriatic acid, and boil over a spirit lamp until the tin is dissolved. When cool, pour into any convenient vessel and dilute with about an equal bulk of pure water. Drop in the nails required to be coated, holding the vessel so that they may all fall to one side. Immerse a piece of sheet-copper into the solution, as far apart from the nails as possible, and connect it with the latter by means of a piece of copper wire. The effect of this arrangement is the developement of a current of voltaic electricity, which causes a rapid decomposition of the fluid, and the deposition of tin on the surface of the nails. After being subjected to this treatment for about an hour, the nails will be found to have received a thick coating of metal, and may then be removed from the liquid, dried, and polished.

Recourse is frequently had to the above process for the purpose of coating the nibs of steel pens with tin, in order to prevent them from rusting. It succeeds better than any other method ever tried.

BRONZING ELECTROTYPE CASTS.

Chemical Bronze.

THERE are many modes of bronzing employed in the arts; the intent of each is to bring out the workmanship of the object. The selection is entirely a matter of taste. To prevent too great a sameness of appearance in a cabinet, it is, perhaps, better not to confine oneself to a solitary method.

A chemical bronze may be made by boiling two ounces of carbonate of ammonia with one ounce of acetate of copper, in half a pint of vinegar, till the vinegar is nearly evaporated. Into this, pour a solution consisting of sixty-two grains of muriate of ammonia, and fifteen grains and a half of oxalic acid, in half a pint of vinegar. Replace the vessel on the fire till the contents boil; when cold, strain through filtering paper; preserve the liquor for use. The remaining sediment may be again treated with another half pint of the solution. This preparation must only be applied to medals bright and clean.

Dirty specimens may be polished by an article used in domestic economy, consisting of rottenstone, soft soap, and water. The medal is to be well rubbed with a hard brush dipped in this. Care must be taken not to scratch the medal. It must afterwards be washed in water and placed to dry; when dry, the application of the leather and plate-brush will produce the required polish. Medals may also be cleansed by dipping them in *nitric acid*, either concentrated or diluted. Wax and grease may be removed by boiling in *pearl-ash* and water, or by pouring the boiling ley on the medals.

In applying the bronze, first warm the medal, then dip a camel-hair pencil into the liquor and brush the surface for half a minute; immediately after, pour boiling water over it. Directly the medal is dry, rub its surface lightly with soft cotton very slightly moistened in linseed oil. Gentle friction with a piece of dry cotton will finish the operation. The colour produced by this means is *red;* its tints vary according to circumstances. Medals bronzed thus must be examined occasionally before they are consigned to the *cabinet;* for if perchance the vinegar has not been perfectly washed away, they will be disfigured by the formation of a green powder,—the acetate of copper. Should this occur, it may be removed by means of the moist and dry cotton.

BLACK LEAD BRONZE.

A VERY beautiful bronze is obtained by the simple application of plumbago. It is obtained in a few minutes, and with very little trouble. The tint obtained seems much to depend on the state of the surface of the original medal. Copies of some medals "take" the black lead better than those of others. To produce the tint in the greatest perfection, the operation should be performed immediately after the medal is separated from the mould. Bright specimens from fusible moulds are best, but all others may be thus treated; those taken from wax should be cleansed with pearlash or soda.

The bronze is obtained by brushing the surface of the medal with plumbago, then placing it on a clear fire till it is made too hot to be touched, and applying a plate brush so soon as it ceases to be hot enough to burn the brush. A few strokes of the brush will produce a dark brown polish, approaching black, but entirely distinct from the well known appearance of black lead. If the same operation is performed on a medal that has been kept some days, or upon one that has been polished, a different, but very brilliant tint is produced. The colour is between red and brown. The richness of colour thus produced is by many preferred to the true dark brown.

CARBONATE OF IRON BRONZE.

Beautiful tints are produced by using plate-powder or rouge. After moistening with water, it is applied and treated in precisely the same manner as the plumbago.

TO TIN IRON.

Metal to be tinned must be cleansed, if new work, by putting it in a pickle—a mixture of sulphuric acid and water—then scoured with sand, and cleansed in water: but if old, the pickle should be a mixture of muriatic acid and water. It is then ready for tinning.

The article should be placed on the fire, and sufficient heat applied to melt the tin. Care should be taken that too great a heat should not be applied, or the article will be burned. It must be rubbed well with a piece of sal-ammoniac placed between two wires, likewise some powder sprinkled upon it, to keep the metal from oxidating. Apply the tin, wipe it over with a piece of tow, then the work is finished.

LIQUID GLUE.

SHELL-LAC dissolved in wood naptha (the pyroxilic spirit of the chemists, and the naptha of the oil and colour shops) makes good liquid glue, water-proof, and not requiring the application of heat. A quarter of a pound avoirdupois of shell-lac to be dissolved in three ounces of naptha, apothecaries' measure. Put the former into a wide-mouthed bottle; pour the latter upon it, and stir the mixture two or three times during the first thirty-six hours.

ARTIFICIAL FIRE-CLAY.

THE fusibility of common clay arises from the presence of impurities, such as lime, iron, and magnesia. These substances may be easily removed by steeping in hot muriatic acid, then washing with water, and drying. Excellent crucibles may be made from common clay prepared in this manner.

A CEMENT WHICH RESISTS THE ACTION OF FIRE AND WATER.

TAKE half a pint of milk, mix with it an equal quantity of vinegar, so as to coagulate the milk; separate the curds from the whey, and mix the latter with the whites of four or five eggs, well beaten up. The mixture of these two substances being complete, add to them quick-lime, which has been passed through a sieve; make the whole into a thick paste, to be of the consistence of *putty* when used.

This cement has been applied to close the fissure of an iron cauldron for the boiling of pitch, and which has been in use for five years without requiring further repairs.

CEMENT FOR THE JOINTS OF CAST IRON.

TAKE of cast iron borings, 20 pounds; flour of sulphur, 2 ounces; muriate of ammonia, 1 ounce; mix intimately in the dry state, and then add a sufficient quantity of warm water to render the whole quite wet. Press the mass together in a lump, and allow it to remain until such time as the combined action of the materials renders it quite hot, in which state it must be hammered, with proper tools, into the joints.

NIELLO-METALLIC ORNAMENTS.

COVER the object to be ornamented with an etching ground similar to that employed by copper-plate engravers; draw the ornament with a needle, and etch it by means of a corrosive acid; then carefully remove the etching ground with the proper dissolving fluids (such as oil of turpentine, ether, &c.), and afterwards wash the object quite clean, and set for a moment with a weak acid. Place it now in a galvano-plastic apparatus, and leave it until it becomes galvano-plastically covered, that is, all the etched lines filled up. When all the lines and cavities are completely filled up in this way, and the deposit in them is equally high as, or yet higher than, the plain surface, the object must be taken out of the galvano-plastic apparatus, and the metallic layer, which has been raised by the operation, ground or planed off until brought to the same level with the metal of the object, leaving the etched lines or cavities full.

Of course, the metal of the object to be ornamented and the metallic deposit must be different. The effect produced is extremely pretty, and the means cheap and simple.

TRACING PAPER.

Mix six parts (by weight) of spirits of turpentine, one of resin, one of boiled nut oil, and lay on with either a brush or sponge.

TO FIX DRAWINGS.

A METHOD which is equally simple and ingenious, of giving to drawings in pencils and crayons the fixidity of painting, and without injury, is obtained by spreading over the back of the paper an alcoholic solution of white gum-lac. This solution quickly penetrates the paper, and enters even into the marks of the crayon on the other side.

The alcohol rapidly evaporates, so that in an instant all the light dust from the crayons and chalk, which resembles that on the wings of a butterfly, adheres so firmly to the paper, that the drawing may be rubbed and carried about without the least particle being effaced.

The following are the accurate proportions of the solution: 10 parts of common gum-lac are dissolved in 120 parts of alcohol; the liquid is afterwards bleached with animal charcoal.

For the same purpose may be used even the ready-made paint that can be purchased at the colour stores, containing a sixth of white-lac, and adding two-thirds of rectified spirits of wine. After it has been filtered, there is nothing further to be done than to spread a layer of either of these solutions at the back of the drawing, in order to give them the solidity required.

ANTIDOTE TO ARSENIC.

MAGNESIA is an antidote to arsenic, equally efficacious with peroxide of iron, and preferable to it, inasmuch as it is completely innocuous in almost any quantity, and can be procured in any form.

TO SOFTEN IVORY.

SLICE half a pound of mandrake and put it into a quart of the best vinegar, into which immerse your ivory. Let it stand in a warm place for 48 hours, and you will then be enabled to bend the ivory into any required form.

TO SEPARATE THE METALLIC PORTION FROM GOLD AND SILVER LACE.

IMMERSE the lace for a short time in nitric acid.

BLUEING AND GILDING STEEL.

THE mode employed in blueing steel is merely to subject it to heat. The dark blue is produced at a temperature of 600°, the full blue at 500°, and the blue at 550°.

Steel may be gilded by the following process: to a solution of the muriale of gold, add nearly as much sulphuric ether. The ether reduces the gold to a metallic state and keeps it in solution, while the muriatic acid separates, deprived of its gold, and forms a distinct fluid. Put the steel to be gilded into the ether, which speedily evaporates, depositing a coat of gold on the metal by dint of the attraction between them. After the steel has been immersed it should be dipped into cold water, and the burnisher should be applied, which strengthens its adhesion. Figures, flowers, and all descriptions of ornaments and devices, may be drawn on the steel by using the ether with a fine camel-hair pencil, or writing pen.

TO HARDEN STEEL DIES.

A VESSEL holding 200 gallons of water, is to be placed at the height of 40 feet above the room in which the dies are to be hardened. From this vessel the water is conducted through a pipe of one inch and a quarter in diameter, with a cock at the bottom, and nozzles of different sizes to regulate the diameter of the jet of water. Under one of these place the heated dies, the water being directed on to the centre of the upper surface. By this process the die is hardened in a way as best to sustain the pressure to which it is to be subjected; and the middle of the face, which by the old process was apt to remain soft, now becomes the hardest part. The hardened part of the dies so managed, were it to be separated, would be found to be in the segment of a sphere, resting in the lower softer part, as in a dish, the hardness, of course, gradually decreasing as you descend towards the foot. Dies thus hardened, preserve their form till fairly worn out.

PORTABLE GLUE.

Boil one pound of the best Russian glue, and strain. Then add half a pound of brown sugar, and boil thick. When cold, the compound may be poured into small moulds, and afterwards cut into pieces.

This glue is very soluble in warm water, and is particularly useful to artists for fixing their drawing-paper to the board.

PREVENTION OF CORROSION.

The best means of preventing corrosion of metals is to dip the articles first into a very dilute *nitric acid*, to immerse them afterwards in linseed oil, and to allow the excess of oil to drain off. By this process metals are effectually prevented from rust or oxidation.

CEMENT.

MIX ground white lead with as much finely-powdered red lead as will make it of the consistence of soft putty.

SOLUBLE GLASS.

WHAT is called soluble glass is now beginning to come into use as a covering for wood and other practical purposes. It is composed of 15 parts of powdered quartz, 10 parts of potash, and 1 part of charcoal.

These are melted together, worked in cold water, and then boiled with 5 parts of water, in which it entirely dissolves. It is then applied to wood-work, or any other required substance. As it cools it gelatinises, and dries up into a transparent, colourless glass, on any surface to which it has been applied. It renders wood nearly incombustible.

JAPANNING.

First. Provide yourself with a small muller and stone, to grind any colour that you may require.

Secondly. Prepare yourself with white hard varnish, brown varnish, turpentine varnish, Japan gold size, and spirit of turpentine, which you may keep in separate bottles until required.

Thirdly. Provide yourself with flake white, red lead, vermillion, lake, Prussian blue, king's and patent yellow, orpiment, spruce and brown ochre, mineral green, verditer, burnt umber, and lampblack.

Observe that all wood-work must be prepared with size, and some coarser material mixed with it, in order to fill up and harden the grain of the wood —such, indeed, as may best suit the colour intended to be laid on—which must be rubbed smooth with glass-paper when dry; but in case of accident it is seldom necessary to resize the damaged places unless they are considerable.

With the foregoing colours you may match always any one in use for japanning, always observing to grind your colours smooth in spirit of turpentine;

add a small quantity of turpentine and spirit varnish, and lay it carefully on with a camel's-hair brush, then varnish with brown or white spirit varnish, according to colour.

For a black, mix up a little size and lamp-black, and it will bear a good gloss without varnishing over. To imitate black rosewood, a black ground must be given to the wood, after which take some finely levigated red lead, mixed up as before directed, and lay on with a flat, stiff brush, in imitation of the streaks in the wood; after which take a small quantity of lake, ground fine, and mix it with brown spirit varnish, carefully observing not to have more colour in it than will just tinge the varnish; but should it happen on trial to be still too red, you may easily assist it with a little umber, ground very fine, with which pass over the whole of the work intended to imitate black rosewood, and it will have the desired effect. If the work be done by a good japanner, according to the foregoing rules, it will, when varnished and polished, scarcely be distinguished from the real wood.

TO PRESERVE POLISHED STEEL FROM RUST.

Mix some oil with caoutchouc; melt in a close vessel, stirring to prevent burning. A high temperature will be required. This will form a perfect air-proof skin over the surface, which may very easily be removed by brushing with warm oil of turpentine.

CEMENT FOR ATTACHING METAL TO GLASS.

Take two ounces of a thick solution of glue, and mix with one ounce of linseed oil varnish, or three-quarters of an ounce of Venice turpentine. Boil together, agitating until the mixture becomes as intimate as possible. The pieces cemented should be fastened together for the space of forty-eight or sixty hours.

VARNISH FOR COLOURED DRAWINGS.

Canada balsam, one ounce; oil of turpentine, two ounces. Dissolve. Size the drawings first with a jelly of isinglass, and when dry apply the varnish, which will make them look like oil paintings.

JAPANNERS' COPAL VARNISH.

Take of the best pale African copal, seven pounds; fuse; add two quarts of clarified linseed oil. Boil for a quarter of an hour, remove it into the open air, and add three gallons of boiling oil of turpentine. Mix well, then strain into the cistern, and cover up immediately.

SOFT VARNISH.

Callot's soft varnish for etching:—linseed oil, four ounces; and half an ounce each of gum benzoin and white wax. Boil to two-thirds.

HARD VARNISH.

Callot's hard varnish for etching:—Take four ounces each of linseed oil and mastic, and melt together.

FLEXIBLE VARNISH.

Flexible varnish for balloons, &c.:—India-rubber in shavings, one ounce; mineral naptha, two pounds. Digest at a gentle heat in a close vessel until dissolved, then strain.

FRENCH POLISH.

Dissolve one part of gum-mastic, and one part of gum-sandarach, in forty parts of spirits of wine, and then add three parts of shell-lac. This process may be performed by putting the ingredients into a loosely corked bottle, and then placing it in a vessel of water a little below 173° Fahrenheit, or the boiling point of spirits of wine, until the solution be effected.

BRUNSWICK BLACK.

Foreign asphaltum, forty-five pounds; drying oil, six gallons; and litharge, six pounds. Boil for two hours, then add dark gum amber (fused), eight pounds; hot linseed oil, two gallons. Boil for two hours longer, or until a little of the mass, when cooled, may be rolled into pills. Then withdraw the heat, and afterwards thin down with twenty-five gallons of oil of turpentine. Used for iron-work, &c.

MORDANT VARNISH.

Take one ounce of mastic, one ounce of sandarach, half an ounce of gum-gamboge, and a quarter of an ounce of turpentine. Dissolve in six ounces of spirits of turpentine.

ANOTHER.

PLACE a quantity of boiled oil in a pan, and subject it to a strong heat. When a disengagement of black smoke takes place, set it on fire, and in a few moments extinguish it, by covering over the pan. Then pour the matter while heated into a bottle, previously warmed, adding to it a little oil of turpentine.

ANOTHER.

MIX asphalte and drying oil, diluted with oil of turpentine. For bronzing, or very pale gilding.

ANOTHER.

TAKE a quantity of camphorated copal varnish, and add a little red lead.

ANOTHER.

DISSOLVE a little honey in thick glue. For gilding, &c.

SUPERIOR GREEN TRANSPARENT VARNISH.

THE beautiful, transparent green varnish employed to give a fine glittering colour to gilt or other decorated work, may be prepared as follows: Grind a small quantity of Chinese blue with about double the quantity of finely powdered chromate of potash, and a sufficient quantity of copal varnish thinned with turpentine. The mixture requires the most elaborate grinding or incorporating, otherwise it will not be transparent, and therefore useless for the purpose to which it is intended. The "tone" of the colour may be varied by an alteration in the proportion of the ingredients. A preponderance of chromate of potash causes a yellowish shade in the green, as might have been expected; and *vice versa* with the blue, under the same circumstances. This coloured varnish will produce a very striking effect in japanned goods, paper-hangings, &c., and can be made at a very cheap rate.

ETCHING VARNISH.

TAKE of white wax, two ounces; and of black and Burgundy pitch, each half an ounce. Melt together, adding by degrees two ounces of powdered asphaltum. Then boil until a drop taken out on a plate will break when cold, by being bent double two or three times between the fingers, when it must be poured into warm water, and made into small balls for use.

SUPPLEMENT.

ON PATTERN-MAKING—CONTRACTION OF METALS, ETC.

IT is necessary to make patterns in some degree larger than the intended castings, to allow for their contraction in cooling, which equals from about the ninety-fifth to the ninety-eighth part of the length, or nearly one per cent. This allowance is very easily and correctly managed by the employment of a contraction-rule, which is made like a surveyor's rod, but one-eighth of an inch longer in every foot than ordinary standard measures. By the employment of such contraction-rules every measurement of the pattern is made proportionally larger without any trouble of calculation.

When a wood pattern is made, from which an iron pattern is to be made, the cast being intended to serve as the permanent foundry pattern, as there are two shrinkages to allow for, a *double* contraction-rule is employed, or one the length of which is one-quarter of an inch in excess in every foot. These rules are particularly important in setting out alterations in, or additions to, existing machinery. The latter is measured with the common rule, and the new patterns are set out to the same nominal measures, with a single or double contraction-rule, as the case may be—the three being made in some respects dissimilar, to avoid confusion in their use. The entire neglect of contraction-rules incurs additional trouble and uncertainty. The contraction of brass is nearly three-sixteenths of an inch in every foot, but from the small size of brass castings the contraction-rule is less required for them, as the differences may be easily allowed for without it. Iron castings weigh about fourteen times as much as the ordinary deal and fir patterns from which they are made—that being nearly the ratio of the specific gravities of those materials.

In reference to the *qualities* of *Iron*, it may be worthy of remark, that the same mixture of iron will be found to differ very much according to the size of the objects in which it is cast. Iron which in a plate one-fourth of an inch thick may be quite brittle and hard, will mostly be of good, soft, and useful quality in a stout bar, or plate of two or three inches thick. Thick castings are necessarily slow in cooling, and are seldom very hard unless intentionally made so.

Between the extremes (say three parts of pig-iron to one of old, or three parts of old iron to one of pig-iron), various qualities may be selected. In castings for machinery, the general aim is to obtain a strong, sound, and tough iron. Mixtures of this nature which are used for iron ordnance, are called gun-metal amongst the gun-founders.

CONDUCTING HEAT OF BRASS AND IRON.

THE power of conducting heat is considerably less, in red-hot iron, than in copper and brass; and therefore the moulds for the latter require to be in a drier condition than those which may be used for iron. But in either case, the presence of superfluous moisture is always attended with some danger to the individual, as well as to the work. Iron founders may use their moulds with safety when sensibly more moist than is admissible for brass and copper castings. It is confirmatory of the fact, that the more dense the *mould*, the drier it must be—as the sand used by iron-founders is also coarser, and therefore more porous than that employed by brass-founders.

VARIETIES OF TOMBAC.

	1	2	3	4	5	6	7	8	9	10
Copper...	82–0	82	82–3	80	85	85–3	86	90–0	92	97–8
Zinc......	18–0	18	17–5	17	15	14–7	14	7–9	8	2–2
Lead	1–5	3	......	.....	.....	....	.....	1–6	.....	....
Tin	3–0	1	0–2	3	t'ce	....	.....	......	.....	....
	104–5	104	100–0	100	100	100–0	100	99–5	100	100–0

Nos. 1, 2, and 3, are for making gilt articles; 4, French mixture for sword-handles, &c.; 5, Okar metal near Goslar, in the Hartz; 6, Yellow tombac for Parisian gilt ornaments; 7, Hanoverian; 8, Chryso chalk; 9, Paris tombac; and 10, the red tombac of Vienna.

ON SAND-CORE MOULDING, BLACKENING, ETC.

AMONGST the great variety of work denominated green-sand moulding, much and varied contrivance is displayed in the structure of the moulds. In particular, the management of cores is a matter of very considerable importance, and the malformation of them is a prolific source of failure in the production of sound castings.

Cores are especially useful for forming vacancies in castings. Their forms may be long, and proportionably small in diameter, or winding, and otherwise intricate; and seeing that they are necessarily surrounded by the metal when cast, they ought to have, as much as may be, the qualities of firmness of substance and openness of pores. Cores are commonly composed of rock-sand and sea-sand. The former having a proportion of clay in its composition, to which it owes its powerful cohesiveness when dried, serves very well for short cores that rest on the green sand at both ends, as open communication with it is thus afforded for the free escape of the air in the interstices of the cores.

But when rock-sand is used for cores of a considerable length (which, of course, are surrounded on all sides by the metal, except the small imbedded portions at the extremities, by which alone the air can escape), it requires to be moderated by the admixture of free-sand, as a counteractant to the clay. The clay communicates the necessary cohesiveness to the material of the core; the sand, on the contrary, loose and open, renders it less binding and more porous. Free-sand alone is also employed in the construction of confined cores, that they may afterward be easily extracted, as the sand has naturally no power of cohesion.

Wanting cohesiveness, it must be tempered to a proper consistency by the addition of clay and water, yeast, flour, or the refuse of pease-meal, used for light flat moulding purposes. In the use of the latter materials, it must be accurately proportioned to the sand with which it is mixed. The clay-water is, in ordinary cases, made use of as a cement, and the yeast only in very particular circumstances. For large compact masses of core, the common green sand may be used.

The longer cores are stiffened by iron wires and small rods, which are bent, if necessary, to the form of the cores. These rods are dipped in clay-wash, and enveloped in the core in the progress of its formation, and are afterward extracted from the casting. The cores of considerable length are pierced longitudinally by wires for the "escape of the air;" or in cases where this is impracticable, on account of bends or angles in the core, a piece of string is laid in the sand alongside the stiffening wires, which is afterward drawn out, when the core is dry, leaving its perforation behind it. With all these precautions, securing the strength of the cores and letting off the air, your castings have every chance of being good, and free from blow-holes. When the bearings of cores at the extremities are considered unfit for steadying them, they are further sustained by staples struck into the sand at several places in their length, and projecting above it just as much as the thickness of metal, the core is placed upon them, and sustained steadily in its place. The staples are, of course, buried in the casting, and the projecting points outside cut off in the course of dressing it. Chaplets are used to bear up cores having plain surfaces. Another set of chaplets, or staples, are placed in the cope, and well secured at the back, when the flask is closed, firmly fixed, and in contact with the upper half of the core. It is thus prevented from floating off its seat when immersed in the fluid metal, and prevented from springing. This is a matter of greater moment than the mere sustaining of the core from below, as will be apparent on considering the great difference of specific gravities of sand, dry loam, and iron or brass.

In this case, the upward effective pressure of the fluid metal upon the core is proportional to the difference of their specific gravities, which, being so much in favor of metal, the pressure upward, sustained by the chaplets, cannot be much less than the weight of a body of metal of the same bulk as the core, for the support of which they are destined; in brass-founding particularly, great care should be taken that the staples and chaplets are sufficiently strong. Should they be too slightly made, they will bend or melt before the hot metal, and prove entirely useless. *This is too often neglected.*

Ordinary black-wash for cores consists of oak charcoal, powdered, and a little clay, diluted with horse-dung water. Blackening for moulds is often composed of finely ground plumbago, mixed with a little charcoal, the whole diluted with a solution of the soluble parts of horse-dung. This is frequently mixed with pease-meal, or other meal, glue, and extracts from the refuse of tanneries. But all these compositions are more or less too close, and cause a dull surface to the cast. The first is the best, if applied not too much diluted. Blackening, or a coating of carbon, will prevent the burning of the sand, and consequent roughness of the casting, as it fills the pores of the sand. A little plumbago mixed with it makes it more refractory still, and is very desirable where a great body of metal surrounds a small core.

One part of clay mixed with nine parts of free-sand, or any other pure sand, is considered sufficiently strong for core sands. Still, these properties depend very much on the nature of the sand and the adhesiveness of the clay, and also what kind of cores are to be made from it—large and complicated cores being made stronger than small ones.

The various kinds of good moulding-sand employed in foundries for casting iron or brass, have been found to be of an almost uniform chemical composition, varying in grain or the aggregate form only. It contains between 93 and 96 parts silex, or grains of sand, and from 3 to 6 parts of clay, and a little oxide of iron in each 100 parts. Moulding-sand which contains lime, magnesia, and other oxides of metal, is not applicable, particularly for the casting of iron or brass. Such sand is generally either too weak or too close—will not stand or retain its form, or it will cause the metal to boil through its closeness.

In practice, different kinds of castings require different kinds of sand for the purpose of moulding, which will furnish the subject for another article.

ON WASHING SWEEPINGS, ASHES, ETC., FROM BRASS FOUNDRY FURNACES—GILDERS' AND JEWELLERS' WORKSHOPS—AND PLACES WHERE METALLURGIC OPERATIONS ARE CARRIED ON.

THE clinkers, ashes, or cinders, which remain in furnaces after metallurgic operations have been completed, may appear to be among the most useless things. Not so, however. If they contain any metal, there are men who will ferret it out, by some means or other. Not many years since, the ashes of the coal or coke used in brass and bronze furnaces, were carried away, after picking, as rubbish. But shrewd people have detected a good deal of volatilized copper, &c., mixed up therewith, and the brass founder can now find a market for his ashes as an inferior kind of *ore;* or which is still more preferable, in case of slackness of work, can cleanse and smelt them himself; which every brass founder can (or at least, ought to know how to) do. It needs hardly to be stated, that all sorts of filings and raspings, cuttings and clippings, borings and turnings, and odds and ends in the metallic form, are all available for re-melting, whatsoever the metal may be; all is grist that comes to this mill.

If the metal be a cheap one, it will not pay to extricate a stray per centage from ashes and clinkers; but if it be one of the most costly metals, not only are all scraps and ashes and skimmings preserved, but particles are sought for in a way that may well astonish those to whom the subject is new.

Take gold as an example. There are dealers who sedulously wait upon gilders and jewellers, at intervals, to buy up every thing (be it what it may) which has gold in or upon it. Old and useless gilt frames are bought; they are burnt, and the ashes so treated as to yield up all their gold. The fragments and dust of gold, which arise during gilding, are bought and refined. The leather cushion which the gilder uses, is bought, when too old for use, for the sake of the gold particles which insinuate themselves into odd nooks and corners. The old leather apron of the jeweller is bought. It is a rich prize; for in spite of its dirty look, it possesses very auriferous attractions. The sweepings of the floor of a jeweller's workshop are bought, and there is probably no broom, the use of which is stipulated for with more strictness, than that with which such a floor is swept. In short, there are in this world, (and at no time so much as at present) a set of very useful people, who may be designated as manufacturing scavengers. They clear away refuse, which would else encumber the ground, and they put money into the pockets both of buyers and sellers; they do effectually create a something, out of a commercial nothing. It is essentially necessary, however, for the brass founder (should he employ a smelter of metals to wash his foundry ashes, his own man being too busily engaged in the moulding shop) to have them cleansed and smelted on his own premises, as he will effect a considerable saving thereby, beside have a very superior metal, than if washed off the premises and returned after smelting. The reason is obvious: crucibles generally break before the tin, zinc, or lead is added to the copper, which is always melted first; this being the case, the smelter has an opportunity (and rarely fails to advantage by it) of reducing the alloy with the inferior metals, at the cost of the employer. There is great room for trickery here, and I have known brass founders themselves (and clever ones at that), who could not detect the imposition. Every brass founder ought to be capable of washing and smelting his own refuse and shop dirt. This may be done (as before stated) at any period of the year, and find him employment when he might otherwise have nothing to do in the moulding shop, as well as save his employer from laying out cash for that which he has at home, if only gathered together.

CORNISH REFINING FLUX.

Deflagrate, and afterward pulverize, two parts of *nitre*, and one part of *tartar*. The following fluxes answer the purpose very well, provided the *ores* be deprived of all their sulphur, or if they contain much earthy matter; because in the latter case, they unite with them, and convert them into a thin glass, but if any quantity of sulphur remain, these fluxes unite with it, and form a *liver* of sulphur, which has the power of destroying a portion of all the metals; consequently, the assay must be, under such circumstances, very inaccurate. Limestone, feldspar, fluor-spar, quartz, sand-slate, and slugs, are all used as fluxes. Iron ores, on account of the argillaceous earth they contain, require calcareous additions; and the copper ores, rather slugs, or vitrescent stones, than calcareous earth.

CRUDE, OR WHITE FLUX.

One part nitre, to two parts tartar, mixed well together.

BLACK FLUX.

THE above flux detonates by means of kindled charcoal, and if the detonation be effected in a mortar slightly covered, the smoke that arises unites with the alkalized *nitre* and the tartar, and renders it *black*.

CORNISH REDUCING FLUX.

MIX well together, 10 ounces of tartar, 3 ounces and 6 drachms of nitre, and 3 ounces and 1 drachm of borax.

IMITATION SILVER METAL.

4½ pounds tin, ½ pound bismuth, ½ pound antimony, ½ pound lead. This metal retains its silvery brilliancy to the last.

ON CASE-HARDENING IRON.

CASE-HARDENING iron is done by reducing the prussiate of potash to a paste, in a little water, smearing over your article, and heating it in the fire to a dull red heat, and then dip in cold water.

VARNISH FOR IRON.

THE best varnish for iron is red lead, laid on first with a very thin coat, left to dry, then give one or two more coats.

VARNISH FOR POLISHED IRON.

USE common gum copal varnish. You may mix a little oil in it.

TO PRESERVE GUM ARABIC SOLUTIONS.

A FEW drops of alcohol, or any essential oil, will preserve a quart of the mucilage of "*gum Arabic*" or "*gum Tragacanth*" from spoiling. A small quantity of dissolved *alum* will preserve flour paste.

BEST COMPOSITION OF BRASS FOR ROLLING AND FORGING.

ANY proportion between the extremes of 50 parts copper and 50 parts zinc, or 62 copper and

38 zinc, will roll and work at the red heat. The very best composition, however, is 60 parts copper, to 40 parts zinc.

REMARKS ON THE FLUXING OF METALS.

METALS are contained in the ores, in most cases, as compounds, and if it is the object to separate them, we are to put such matter in contact with them, as will deprive the metal of its compound. If a silicate of iron is melted, we do not precipitate iron by adding carbonate of soda, or caustic lime, to the fluid mass; this addition merely increases the fluidity of the *slag*, without producing any metal. But if we add sodium, the oxide of iron will be deprived of its oxygen, and form metal. Carbon has more affinity for *oxygen* than *metal*, in the high heat of a melted silicate. If, therefore, we add carbon to the melted silicate of iron, some iron is produced. In all cases, the metal requires a *slimy, glassy* substance coating, to protect it against the influence of oxygen, when exposed in small particles to that influence.

Almost all metals burn more readily than *carbon* —gold, the platina metals, and silver, in some measure, excepted. If, therefore, we desire to obtain a metal, we must produce a *slag*, which protects it, and at the same time admits of its coagulation. I would strongly recommend the founder to use as general flux (for copper foundings, particularly, where large masses of copper have to be melted, prior to adding his tin and zinc), sal. enixum (the refuse from aqua-fortis), to be obtained at most of the chemical works, at a trifling cost. I know of nothing to equal it. This, with charcoal, surpasses every thing else.

TINNING CAST COPPER, OR BRASS.

CAST-IRON may be tinned by a solution of tin, as muriate of tin, mixed with an equal part of sal-ammoniac, if brushed over the metal, will highly further the operation of tinning; i. e., make a solution tin, by dissolving oxide of tin (tin putty) in potash ley—adding to the saturated solution some tin-shavings or filings. Make this hot as possible; place in your brass or copper, and they will be *tinned* in a few seconds.

The following table of experiments on the tenacities of metals, is given with the results, and the experimenters' names.

	In tons, 2240 lbs.	Experimenters.
Cast copper,	8–½	Sir J. Rennie.
Hammered copper,	15–0	"
Sheet copper,	21–0	Kingston.
Wire copper,	27–0	"
Wire platina,	17–0	Guyton.
Cast silver,	18–0	"
Wire "	17–0	"
Cast gold,	9–0	"
Wire "	14–0	"
Hard gun metal,	16–0	Sir J. Rennie.
Fine yellow brass,	8–0	"
Cast tin,	2–0	"
Wire tin,	3–0	"
Cast-iron, No. 1,	6 to 7¾	Hodgkinson.
Cast-iron, No. 2,	6 to 8	Hodgkinson.
Cast-iron, No. 3,*	6 to 9¾	Hodgkinson.

The above tests are on bars one inch square.

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* The strongest quality of cast-iron, is a Scotch iron known as the "Devon Hot Blast," No. 3. Its tenacity is 9¾ tons per square inch. Its resistance to compression is 65 do. The experiments of Major Wade,† on the gun-iron at West Point foundry, and at Boston, give to us results as high as 10 to 16 tons, throughout, and on small cast bars as high as 17 tons.

† Strength and other Properties of Metals for Cannon. 4to. Philadelphia: H. C. Baird. 1856.

ON REDUCING COPPER WITH WHITE ARSENIC.

In reducing copper scraps with white arsenic, for buttons, ornaments, candlesticks, clock dials, figures, &c., &c., to give them the color of silver, the whole should be brought down under a flux of common salt. The metal is very highly poisonous, and should not in any case be used for cooking utensils. Arsenic being more fusible and brittle, is much used in shot factories, in the proportion of 1½ lbs. arsenic to 500 lbs. of lead for small shot, and 3 lbs. of arsenic to 500 lead for large shot.

TIN AND ZINC.

Tin and zinc will waste more than copper in re-melting metals. To prevent this as much as possible, a flux of potash and soda, freely mixed with charcoal, in the proportion of two ounces to the hundred pounds of metal, should be added immediately after the mass is melted, to prevent oxidation, and loss of strength and beauty. The quicker the metals are reduced under a good flux, and cast into work, the more perfect will be the crystallization and homogenity. If zinc is to be added after the crucible is taken from the fire (in casting brass work), it is best to introduce it in the form of yellow brass.

TIN AND IRON.

Eight ounces of iron to six ounces of tin, make a beautiful composition, resembling steel both in lustre and hardness. A less proportion of tin still adds to the hardness and brilliancy of iron.

COPPER, TIN, AND IRON ALLOY.

Let tin-plate scraps be melted with block-tin, under a flux of *nitre*, and poured out, when melted, together. The metals would not readily combine otherwise. Thus the Spaniards and Chinese cast excellent bells, of the following composition:

Copper	74	pounds.
Tin	25	"
Iron	1	"
	100–0	

CORINTHIAN BRONZE.

90–0	Copper.
7–0	Tin.
3–0	Zinc.
100–0	

SYRACUSE BRONZE.

82–25	Copper.
17–50	Zinc.
25	Tin.
100–00	

SHIP-NAILS COMPOSITION, STRONG AND DURABLE.

10 Pounds copper, 8 lbs. zinc, and 1 lb. iron.

CHINESE WHITE METALS.

	No. 1.	No. 2.	No. 3.	
Copper,	55–0	50–0	62–0	Copper.
Zinc,	17–0	25–0	19–0	Zinc.
Nickel,	23–0	25–0	14–0	Nickel.
Iron,	3–0	No iron.	2–½	Cobalt.
			2–½	Iron.
	98–0	100–0	100–0	

No. 4.

78–0 Copper, 4–0 nickel, 3+5 zinc.

Add one-fourth part of zinc to No. 4 metal for soldering the four compositions.

FENTON'S ANTI-FRICTION METAL.

7½ parts grain tin,
7½ parts purified zinc,
1 part antimony,

TO MAKE WHITE LACQUER.

TAKE spirits of wine (highly rectified) one pint, which divide into 4 parts. Then mix one part with half an ounce of "gum mastic," in a phial by itself; one part spirits and half an ounce of "gum sandarach" in another phial; one part spirits and half an ounce of the whitest parts of "gum Benjamin." Then mix and temper to your mind. No rule can further instruct you, unless the quality of the gums and spirits could be ascertained. It would not be amiss to add a very small piece of "white rosin," or clear "Venice turpentine," in the mastic bottle; it will assist in giving a gloss. If your varnish should prove strong and thick, add clear spirits; if too hard, pour from the mastic bottle; if too soft, a little from the sandarach or Benjamin. When you have brought it to a proper temper and ready for use, warm the plate on a hot heater, and with a camel's hair brush dipped in the varnish, stroke it quickly over until no shades appear.

The following paper was read by Mr. Sterling, before the London Institute of C. E., January 29th, 1853:

ON IRON, AND SOME IMPROVEMENTS IN ITS MANUFACTURE.

THERE is no doubt that many most valuable improvements have been introduced (more especially of late years) by ironmasters and others connected with the iron trade. But these have chiefly had reference to the later stages and finishing processes in iron-making, and to the machinery connected with these processes. Of the chemistry of the blast-furnace—of the changes produced by the process of refining, and in puddling—we are still ignorant. Having devoted a good deal of time to this subject, the writer may be allowed to say, that the more he has studied it, and the more he has seen of iron-making, the more convinced he is of our ignorance. And it is to be hoped that some steps will be taken to improve our knowledge, and render the various processes certain and economical.

The improvements in iron manufacture which are touched on in the following remarks, are not of the nature of those alluded to above; they are of an inferior class, and should properly be called improvements in iron, or in the manufacture of certain kinds of iron, for certain purposes. It will be unnecessary to enter minutely into the various processes for converting the iron ore into cast and malleable iron, or to describe at length the various materials used.

The chief varieties of iron ore which are used in this country are the clay-band, the black-band, and the hematite. From the hematite, the purest pig-iron and strongest bar-iron are said to be made; and from clay-band a stronger malleable iron is generally supposed to be obtained than from the black-band; but the various qualities can be altered by the judicious ironmaster, and malleable iron of as good quality can be produced from black-band as from the hematite or clay-band. The writer does not here allude to improvement of quality by mixing different ores (by which it is well known the bad qualities of some descriptions are entirely removed), but to the skilful treatment of one or more ores of a somewhat similar character.

The first stage in the manufacture of iron, is the conversion of the ore into cast-iron, which is accomplished in various ways. In Great Britain, the ore, after being calcined, if necessary, is introduced, with layers of coal or coke and a flux (usually a carbonate of lime), into a large furnace, and a strong blast (either hot or cold) is urged through the previously kindled mass, to accelerate the combustion of the fuel, and the conversion and fusion of the metal, which is usually tapped from the furnace once in the twelve hours, and run into pigs or ingots, which go by the name of "hot or cold blast iron," according to the nature of the blast employed. The subdivisions of both these sorts of iron are the same, viz: Nos. 1, 2, and 3, when for foundry purposes; and forge, or white iron, when intended for being converted into malleable iron. These numbers and qualities of iron are supposed to differ from each other in the quantity of carbon contained in each, although this is doubted by many eminent chemists. No. 1 is certainly darker, softer, and more carbonaceous-looking than the other numbers, and forge or white iron appears to contain much less carbon than any iron intended for foundry purposes; but, as we see a similar effect produced on foundry iron, by rapid chilling, to that produced in forge iron by the supposed abstraction of carbon, it will, perhaps, be more readily admitted that color is not a test (or at least not a certain one) of the quantity of carbon which iron contains.

It may be here remarked, that the Nos. 1, 2, and 3, give *no real idea* of the nature of the iron—they are relatively comparative, and only indicate the *differences between cast-iron of the same district and make.* Thus, what is called No. 1 in Wales, resembles hard No. 2 in Scotland, and corresponds to Staffordshire No. 2 (average); Welsh No. 2 is fully as hard as Staffordshire No. 3, or Scotch No. 4 (a brand), intermediate between No. 3 and forge iron. As a general rule, Nos. 1 and 2 are adapted for small castings, Nos. 2 and 3 *mixed* for medium castings, and No. 3, or 3 and 4 in Scotland, or 3 in England, for heavy castings; but the mixtures of Welsh and Scotch, or of Staffordshire, Welsh, and Scotch, are found to make stronger and better castings than those made from one sort of iron.

This mode of producing strong castings has been long practiced, and is in many places convenient; and the increase of strength is no doubt satisfactory; but there is still a want of uniformity in result, and an occasional difficulty in keeping to the proportions, and even in obtaining the brands specified by the engineer or architect, or chosen by the founder on his own experience.

It seemed to the writer very desirable, therefore, to obtain if possible a kind of iron which should be either uniform and constant in its strength, or at least, *not under a certain standard*—and, after numerous experiments and trials, he attained this object by making certain mixtures of cast and wrought-iron, which have been called "toughened cast-iron."

Allusion has already been made to the different numbers of cast-iron, and to their qualities; and it ought further to be stated, that No. 1 is considered the weakest, and No. 3 the strongest. To render these uniform in strength, and at the same time to equalize *that of cast-iron from different districts,* it is only necessary to vary the quantity of wrought-iron introduced, by which means all other mixture is avoided, and so much greater strength insured, as to allow a margin for considerable variation in strength, from any accidental defect, as well as for a diminution in weight, taking the averages of the toughened cast-iron and of the best mixtures:

Trans[illegible]rse strength of bars 1 *inch square,* 4 *feet* 6 *inches between supports.*[*]

Cast-iron, average breaking weight,	436 lbs.
Toughened cast-iron, ditto,	733 "

Tensile strength.[*]

Cast-iron, average breaking weight,	7·036 tons.
Toughened cast-iron, ditto,	11·790 "

Crushing strength.

Cast-iron, average crushing weight,	38·582 tons.
Toughened cast-iron, ditto,	59·522 "

To render the above more intelligible, the proportions are given below, which have been found to bring very soft Scotch (No. 1 hot-blast) and very

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[*] The averages of the transverse and tensile strength are from the experiments of Mr. Hodgkinson, in the government report and elsewhere, and other experimenters; Mr. Hodgkinson is the sole authority for the resistance of crushing force.

hard Welch (No 2 cold-blast) to nearly the same strength.

Scotch, No. 1 hot-blast, breaking, when unmixed, at 430 lbs.
With a mixture of 33 per cent. of wrought-iron scrap, broke at.................................... 713 "
The same Scotch iron as the first, with only 20 per cent. of malleable scrap, broke at about....... 620 "
Showing a deficiency in the quantity of the scrap.
Welch, No. 2 cold-blast, breaking, when unmixed, at 440 lbs.
With a mixture of 10 per cent. of wrought-iron scrap, broke at.................................... 689 "

The results obtained by Mr. Hodgkinson are very favorable, as shown in the following table, where the breaking weights of common cast-iron and toughened cast-iron are given, from the report of the commissioners appointed to inquire into the strength of iron.

Table of Comparative Strength of Cast-Iron.

Description of Iron Bars, all two inches square.	Transverse Breaking Load in Centre.	Tensile Breaking Strength.	Crushing Strength.
	lbs.	Tons per inch.	Tons per inch.
Toughened cast-iron, with 20 per cent. wrought scrap,....	2,174	11·50	54·64
Low Moor, No. 1	1,207	5·67	27·00
Blaenavon, No. 2, ...	1,220	7·46	49·11 30·50
Warrington best gun mixture,	1,375	—	—

Comparative trials, on a larger scale, made by Mr. Owen (by command of the Admiralty), gave equally satisfactory results. Tensile strength, according to Mr. Owen, 12·50 tons.

Since these experiments and trials were made, the toughened cast-iron has been successfully used in the construction of several public works, Windsor bridges, Chelsea bridge, Yarmouth bridge, &c., &c.; and it may be mentioned that, by being allowed to reduce the scantling in proportion to the increased strength gained by employing the toughened cast-iron, the contractors for the heavy castings of the Manchester viaduct were enabled *profitably to fulfil* their contract; whereas, had they used common iron, and been confined to the specification, they would have been heavy losers.

For shafting, rolls, pinions, cog-wheels, cast-iron railway-carriage wheels, cylinders, and other castings where strength and closeness of texture are desirable, the toughened cast-iron will be found most useful; also, cast-iron which will not chill in its unmixed state, readily chills, with less loss of strength than usual, when mixed in proper proportions with malleable iron.

To insure that the proper proportion of malleable iron is contained in each pig, and also to render the mixture more easily conveyed from place to place, the writer prefers making the mixture at the blast-furnace; and this is done by distributing the proper weight of malleable scrap in the moulds into which the melted iron is to be run. It is thus firmly fixed, and melts more easily and regularly with the cast-iron in the cupola or other furnace, the cast and wrought iron heating gradually to the melting point of the former, when the wrought iron is easily acted upon, and fluxed by the cast-iron.

The process of converting cast into malleable iron is much more varied than that of converting the ore into cast-iron. In some districts a great proportion of the cast-iron is refined previous to its conversion; in others little refined iron is used, and in some works cast-iron is at once converted into malleable iron; and this latter process seems to be gaining ground.

Refining is, perhaps, the least understood, and the least capable of being explained, of any process connected with iron manufacture. The iron is kept in a fluid state in contact with carbonaceous matter exposed to a blast, and, although it would seem that by such means more carbon *ought to be combined* with the iron, experience shows that a great change is produced in the nature of the metal, and that, as far as we know, the *quantity* of carbon is *diminished*, and the iron rendered more nearly akin to malleable iron, or at least so altered as to be more quickly converted into it.

Refining is an expensive process, great waste of material being unavoidable, but it is still necessary for certain descriptions of iron, and the expense is partly compensated by the greater quickness with which the conversion takes place in the puddling-furnace.

Puddling is the last and most important process in the conversion of cast into malleable iron. It is still an extremely rude one, and its theory is not understood; it consists in melting, in a peculiarly-constructed air-furnace, refined or cast-iron, or a mixture of them, and, as soon as the fusion is complete, in continually stirring the melted metal till spicular or granular particles show themselves. Previous to this, the melted metal swells up, and what is technically called boils; gas is evolved, and this appears to be the period at which conversion commences; the solid particles increase in quantity, and the whole mass acquires a semi-solidity; the workman keeps collecting the more solid portions and forming them into balls, which become larger and larger, until the whole of the malleable iron is collected, and nothing remains but what is called cinder, in a perfectly fluid state, which is afterward removed from the furnace by tapping, and again used in certain proportions, along with ore, in reproducing cast-iron. On the removal of this cinder from the iron, by puddling, squeezing, and rolling, the quality of the resulting wrought-iron very much depends.

To avoid the process of refining, to shorten the process of puddling, and to improve the quality of the resulting wrought-iron, are, undoubtedly, most desirable. The writer has endeavored to accomplish this, and has reason to believe that partial success has attended his efforts. Instead of using refined iron, a mixture of wrought and cast-iron (as already described) is taken, and, after being melted and run into pigs or slabs of the requisite size, it is puddled in the usual way, and the process of puddling is found to be thus so shortened as to allow of from one to two heats more being brought out in the course of the twelve hours; the yield is greater, and the quality of the iron is much improved, as regards fibrousness and tensile strength, rendering such iron particularly well adapted for cable iron, tension bars, shaftings, axles, &c., but not for the wearing surfaces of rails, nor for the tires of wheels.

Before proceeding to touch on certain other processes, which the writer believes to improve iron for special purposes, it may be well to point to some alloys of cast-iron, as the making these led him to make the addition of the same and other metals to wrought-iron.

The first is an alloy of iron and tin, which is extremely hard, sonorous, and capable of receiving a very high polish; the addition of manganese, and a very small per centage of zinc, gives somewhat greater tenacity. Bells made of these alloys have a pure and clear tone. Cast-iron will take up from 20 to 25 per cent. of tin.

Cast-iron alloyed with zinc becomes closer in its texture, and, as far as the writer's experiments have yet gone, stronger, and not less malleable. Alloys of bismuth, antimony, copper, and silver, possess some scientific interest, but it would be out of place to touch on them now.

Having observed the hardening effect which tin produces upon cast-iron, the writer tried a similar mixture in the puddling-furnace, and found a corresponding result, with this essential difference—that whereas cast-iron will take up about a fifth of its weight, wrought-iron is rendered too hard for subsequent working by any quantity exceeding one per cent.; and taking the various descriptions of iron (Staffordshire, Scotch, and Welsh), one half per cent. of tin produces a description of iron crystalline, close in texture, and harder than common wrought-iron.

This quality of iron appeared to be suitable for the wearing-surfaces of rails and tires of wheels, and subsequent trials which have been made have fully confirmed this opinion. Lamination is prevented, and the rail, when properly made, wears smoothly and evenly. As in all iron, and particularly in rails, much depends on manufacture; but points and crossings made of this hardened iron, and rails upon sharp inclines, where the wear previously had been very rapid, have been found to last more than double the time of any rails previously tried, and, as they are yet not worn out, it is at present impossible to say how much longer they will last. The writer does not believe their increased duration to arise solely from the *greater hardness*, but more from the peculiar crystalline texture and fine grain of the iron resisting the lamination, which great speed and heavy engines so rapidly produce. The sections of the rails show the proportion which it is considered best that the crystalline should bear to the fibrous iron, or to whatever other iron the rail may be composed of.

The addition of zinc, its oxides and other ores, produces the very opposite effect to tin and the other metals above named. Iron of what is called cold-short quality is rendered, by this means, fibrous, tough, and strong; red-short iron is also improved in quality by the same means, but it is found that a larger addition of zinc, or its ores or oxides is required to effect an improvement in red-short than in cold-short iron. The quantity necessary to improve cold-short iron varies much in different districts, and each peculiar iron requires to be separately considered; it is also necessary to know the per centage of zinc in the ore, if ore be employed, and to ascertain that such ore does not contain foreign matters, which might counteract the effect of the zinc. The addition of these metals to the iron is best made when the iron in the puddling-furnace is beginning to boil.

The writer was much gratified to observe in the American department of the Great Exhibition, a confirmation of his experiments on this subject; iron, naturally cold-short and red-short, being rendered free from each of these qualities by the addition of an ore of zinc. Samples in all stages of progress were exhibited.

Table of Comparative Strength of Wrought-Iron.

Description of Iron.	Tensile breaking strain.	Deflection with strain of 9½ cwt.	Permanent set, in lengths of 2¼ feet.	Final stretch, in length of 2 feet.
	Tons p'r in.	Inches.	Inches.	Inches.
Hardened wrought-iron, with ⅔ per cent. tin...	22·92	1·42	1·02	¼
Toughened wrought-iron..	27·81	......	......	......
Dundyvan's best bar........	24·33	2·02	1·60	3½
S. C. Crown average result	24·47	......	......	......
Hartley's general average of bar-iron...........	23.33	......	......	......

Had the limits of a mere sketch like this permitted, the writer would have entered on the consideration of the relative qualities of cold and hot-blast iron, and of the effects produced by the use of cinder; also, on some combinations of iron with the earthy bases, and on the effects of various salts and fluxes in the blast and other furnaces. Several other alloys of iron possess considerable interest, and, in conclusion, allusion may be made to a remarkable property which iron possesses of closing the grain of other metals and alloys to which it is added in minute quantity.

Mr. Stirling exhibited a number of specimens of the toughened wrought-iron in bars, and the hardened wrought-iron, as applied to the surface of rails, showing their fractures, and specimens of the toughened cast-iron, showing the mode of mixing the wrought-iron scrap with the pig metal; also specimens of an alloy of zinc, copper, and tin, and another of the same composition, with an addition of 1⅛ per cent. of iron, showing the great closeness and fineness of grain that were produced by this small admixture of iron. It was explained that it was advisable to alloy the iron with the zinc before mixing with the copper, otherwise, there would be imperfection and unsoundness in the metal, the iron appearing in the form of what are technically called "tears."

The Chairman said he considered it a very important subject, and thought the paper showed valuable results of extensive practical trials combined with scientific inquiry. He asked at what period the tin or zinc was added to the wrought-iron.

Mr. Sterling replied, that it was put into the puddling-furnace when the extreme of the boiling was just pased, or passing, and conversion just commencing, and the formation of spicula beginning. A more fluid iron required the metal to be put in at a later period, and iron that came to mature sooner required the metal put in earlier. It was difficult to give a definite rule; it could only be judged of by particular experience.

Mr. Duclos thought the presence of zinc in the iron was doubtful; from its volatility, the greater proportion would probably be dissipated in the furnace. He considered it more probable that the change in the iron was caused by the physical quality of the iron undergoing some alteration in consequence of the presence of zinc.

Mr. Stirling said h[illegible]id not consider the mixture of zinc with the iron to be in all cases an alloy, as the proportion was occasionally only ¼ per cent., and he felt uncertain about its mode of action; the quantity of zinc required varied very much; it had to be determined by experiment with the different ores and furnaces.

Mr. Duclos observed that in some iron works he had been acquainted with in Belgium, he had never found any trace of zinc in the iron made from ore containing zinc, but metallic zinc was found to accumulate in the top of the furnace. Many years since a series of experiments had been made by M. Carsen on various mixtures of iron with zinc and other metals, but they had not led to any practical application. There was no question that sufficient attention had not been paid to the properties of the alloys that can be made with iron, and he was glad to see the steps taken by Mr. Sterling; he did not quite agree as to the want of knowledge of the iron manufacture; he thought there was a great deal of knowledge on the subject, but he would wish the principles carried out further.

Mr. Sterling remarked that, in the case mentioned, in Belgium, two processes—smelting and refining—intervened, by which most, if not all the zinc might be volatilized. There was no doubt that the practical making of iron was well understood, but not the theory and principles, otherwise the process might be further simplified, and, as the result, iron would most probably be produced complete at one process, instead of two or more. He thought that further improvements would be more studied and accomplished when iron and coal were dearer.

Mr. M'Connell said there was great room for improvement in railway tires and rails. If the tire now lasted 70,000 miles on the driving-wheel of the engine, it was considered very good work. The expense of replacing tires, and the failure, was a very serious item; and if, by Mr. Stirling's process, the iron could be made to last longer, it would be a great source of economy and convenience.

Mr. Beasley inquired why the wrought-iron scrap was put into the pig mould, in making the toughened cast-iron?

Mr. Stirling replied, that one object was to insure a definite proportion for each charge; also, the wrought-iron melted more easily in the furnace, when mixed in that manner with the cast-iron, which seemed to act as a flux, the whole getting heated together; the cast-iron dropping, eats away the wrought-iron. If thrown separately into the cupola, part of the cast-iron would melt down first, and the two would not get uniformly mixed; the wrought-iron was liable to get oxidized, and wasted.

Mr. Beasley observed, that he was aware if the wrought-iron was thrown into the puddling-furnace with the pig, it would burn away, and not improve the quality; but if it was thrown into the fire a little time before the puddler commenced balling his iron, it would very much improve the quality.

Mr. Sterling said that it was an old practice to add wrought-iron in the puddling-furnace, in order to get a quicker yield; but it would not melt thoroughly in that case and make a uniform mixture. It should be first remelted in the cupola from the mixed pig, to make a uniform mixture, and then remelted, and worked in the puddling-furnace.

Mr. Beasley remarked, that he had melted wrought-iron in the cupola, and then worked it in the puddling-furnace, and had found the result to be better than from the ordinary pig-iron alone; but it was not a sufficient advantage to make it worth the extra expense; he had obtained a greater yield.

Mr. Stirling observed, there was a process for melting wrought-iron, which was then converted back, by decarbonizing, to a state approaching to steel. It was intended to be used for small articles, such as snuffers, scissors, &c., instead of forging them.

Mr. Adams inquired about the application of the hardened iron to tires. The best scrap tires were found the worst to wear; they laminated more, and consequently he did not use them. Those he used, were made, he believed, of two blooms, the lower one of scrap or other tough iron, and the upper one from a puddled ball not piled. The wearing surface was consequently crystalline iron, hard, not laminated, and was more suitable to resist the rolling and crushing action that the wearing surface of the tire was subject to.

Mr. Stirling replied that he had seen a similar process extensively carried on. The lower part of the tire was made of No. 3 iron, and the wearing surface of No. 2 iron, consisting of two puddled balls hammered thoroughly, then reheated and passed through rolls, and lastly welded to the No. 3 iron for the lower part. For such purposes as the wearing surfaces of wheel-tires and rails, scrap-iron was certainly the worst, from the inequality of the pieces united by welding, necessarily numerous and irregular. When the wearing and rolling action came into effect, unequal wear and lamination of the surface must be the result.

Mr. T. Fairbairn said the results of the trials he had made of the toughened cast-iron, were a near approximation to Mr. Hodgkinson's experiments. But he did not think it would be prudent, or altogether safe, for an architect or engineer to reduce the section of a girder to the extent which the relative transverse strength given in the tables would appear to warrant. He would rather retain the large section, and avail himself of the additional security which the use of the toughened iron undoubtedly gave.

Mr. Stirling observed, that to obtain the full increase of strength, would require different trials with different iron, in order to ascertain the best proportion of scrap. But, in the right proportions, from the general results of observations, he believed it might be confidently stated that one fifth of the weight might be taken from ordinary sections of girders by using the toughened cast-iron, leaving a greater strength of girder. However, he would much prefer seeing all the strength of the ordinary section left, for extra safety. The strengths given in the tables in the paper, were chiefly taken from Mr. Hodgkinson; and were the average results of his experiments, showing an increase of transverse strength of 78 per cent.

Mr. R. Williams asked whether, in practice, any difficulty was found to arise in uniting the two qualities of hard and soft wrought-iron?

Mr. Stirling replied, that no difficulty was found in the manufacture, and they were found to be soundly welded together.

Mr. R. Williams observed, that as the hard iron, which melted at a lower temperature than the soft iron, was necessarily the topmost in the pile, when placed in the furnace to be welded, either that would be over-heated, at the expense of its quality, or the inner piles would be under-heated, and endanger the soundness of the bloom. With regard to the lamination of tires, this was not so much owing to the fact of their being made of piled iron, as to the mode of piling; and by piling the bars edgewise, instead of flatwise, there was little, if any, liability to laminate. Puddled iron could be made hard or soft, at pleasure, according to the management of the process, without the introduction of any alloy into the puddling-furnace.

Mr. Stirling replied, that the hard iron came quite as soon to a welding heat as the other iron, and a most perfect weld resulted.

Mr. M'Connell remarked, that in the manufacture of steel tires, the steel did not lengthen so much as the iron in rolling, and it made a difficulty in rolling the tires to make them sound throughout; and he inquired whether any difficulty of that kind was found with the hardened iron for the wearing surface of tires and wheels.

Mr. Stirling replied, that in rails no separation between the materials had been found. He had not yet had experience in tires. On the Edinburgh and Glasgow railway, on the steep incline at Cowlairs, Mr. Adie had had rails hardened on this plan laid down for some years, and had found them to last better than steel-covered rails, which had been also tried, and usually wore out in a considerably shorter time. The hardened rails were still going on well, and an additional portion of that line was now being laid with them. In consequence of the first rails manufactured being made too hard, they showed distinctly a tendency to separate—and the failure was valuable as experience. Also, they were made more liable to separate by the hardened piece laid on being round-topped in the pile. Fifty or sixty rails, made at the very first works where the plan had been tried, had been broken at different times for examination, and were found quite sound.

Mr. E. A. Cowper said he had used wrought-iron scrap, mixed with cast-iron in the ladle, the melt being rather hotter than usual. It closed the grain of the iron very much, and was found advantageous in casting hydraulic presses, or other castings where a very close grain was required. He had put in as much as 15 per cent. of scrap.

Mr. Stirling observed that he had never found that more than about 5 per cent. could be combined in that manner, and then the mixture must be more or less imperfect, and the metal would be partially chilled.

Mr. Cowper said he had not found any objection from the metal being cooled. It was taken pretty hot, and clean iron-turnings were put into the ladle and well stirred up, which secured complete mixture and fusion.

Mr. Slaughter inquired what was the relative cost of toughened cast-iron.

Mr. Stirling replied, that in a girder, if the section were reduced one fifth, the cost would be cheaper; if the price of cast-iron were very low, the toughened iron would then be proportionately dearer.

Mr. Slaughter said he had tried the toughened iron for a number of locomotive-cylinders, at the recommendation of Mr. Gooch, on the Great Western railway, and found it made very fine, perfect, and sound castings, better than he had ever made before. He intended to continue the use of it, and considered it an excellent material for cylinder castings, and preferable for any purpose for which the strongest and best iron was required. He did not find the iron dearer, but, on the contrary, less expensive than the iron he had previously used for the purpose.

Mr. Stirling explained that the toughened iron might be made from a cheaper iron, such as the Scotch hot-blast, which, at £3 per ton, would be about £3 10*s*. for the cost of the toughened iron, which would then surpass in strength a dearer iron, such as Blaenavon, at £5 or £5 10*s*. per ton. So that, although the increased expense of the process was 10*s*. or 12*s*. per ton, the final cost was less, because a cheaper description of iron could be used, and a greater strength was at the same time obtained, as shown in the table of experiments.

Mr. Slaughter said he had found that the toughened iron was less expensive. That which he used was made from Dundyvan or Calder iron, at £3 or £3 10*s*. per ton, and he found it better, when toughened, than the cold-blast iron which he had previously used at £5 or £5 10*s*. per ton.

The chairman proposed a vote of thanks to Mr. Stirling for his valuable and interesting paper, which was passed. He thought that important practical results were likely to follow from such an able investigation, and they were much indebted to Mr. Stirling for bringing it before them; and he trusted that he would continue the course, and favor the institution with the further results.

ON THE STRENGTH OF MATERIALS.

BY C. A. LEE, C. E.

ALL solid bodies are proved to be possessed of certain general properties, among the most important of which is the capability of offering resistance to forces tending to change the relative position of their particles. It is this that it is proposed to discuss.

There are different hypotheses as to the ultimate arrangement of the particles of bodies, but for estimating their strength it is customary to suppose them to be made up of fibres running parallel to the length of the body—which fibres are more or less elastic, and capable of being extended or compressed within a certain limit, which is called the "limit of elasticity." The amount of compression or extension is directly proportional to the force applied, and to the length of the piece, and inversely proportional to the transverse section. It must be understood, however, that these changes of form are very minute, depending on the nature of the material in question. Moreover, the same force will produce equal extensions and compressions in the same piece. Suppose we take a bar of iron and bend it—it is evident that the fibres on the convex side are lengthened, while those on the concave side are shortened. It is the natural elasticity of these fibres that causes the bar to spring back when the pressure is removed. If the bar is bent so much, and consequently the fibres extended and compressed so much as to exceed the limit of elasticity, the bar will not return fully to its original form, but will take what is called a permanent "set." When a piece is submitted to a strain sufficient to give it a permanent set, it will from that time, if the force is continued, undergo a gradual yielding, until finally it gives way. This gradual yielding sometimes takes months and years to be sensible; but experiments have proved that it does take place. After the natural elasticity is once destroyed, the piece, if the charge is continued, keeps growing weaker. It is thus seen that in practice it is absolutely out of the question to submit materials to a greater strain than that corresponding to the limit of elasticity, and it should never ordinarily exceed from one half to three quarters of this limit. There will be given, farther on, practical rules for guidance in this respect.

There are several species of strains to which materials may be subjected—compression, extension, torsion, transversal strain, and detrusion, or where the force acts at right-angles to the fibres.

When a solid is subjected to a strain sufficient to cause rupture, either by crushing or extension, it is proved by experiment that the force necessary to produce this effect is directly proportional to the transverse section of the body—that is, to the area of the section. There will be found, in the Table, the ultimate resistance of different kinds of materials to extension and compression; but it must be remembered that these experiments were made on fair, sound specimens, and under favorable circumstances, and that the pieces subjected to compression were but once and a half their base in height. When the specimens exceeded six times their base, they gave way by bending.

Explanation of the Table, No. 1.—The first column gives the different materials. The second gives the weight of a cubic inch or foot of each, in pounds. The third gives the weight necessary to rupture, by extension, a piece one inch square. The fourth gives the same with regard to compression. The fifth and sixth give the limits which should not be exceeded, in practical applications, in pounds, per square inch of section.

MATERIAL.	Weight of a cubic foot, in pounds.	Ultimate resistance to extension per square inch of section.	Ultimate resistance to compression per square inch of section.	Limit which should not be exceeded in practice.—Extension.	Limit which should not be exceeded in practice.—Compression.
Ash (English)	47.5	17000	9000	1000	1000
Beech (do.)	43.8	11000	12000	"	"
Box	62.5	20000	12000	"	"
Elm	33.8	5800	10000	"	"
Fir (New England)	34.4	12000		"	"
Fir (Riga)	47.0	12600		"	"
Larch	33.8	7000	4000	"	"
Locust	59.5	20500		"	"
Oak (English)	50.0	12000	8000	"	"
Oak (Canadian)	54.5	12000	5000	"	"
Oak (Dantzic)	47.5	14500	7000	"	"
Pine (pitch)	41.2	10500	6700	"	"
Pine (red)	41.3	10000	7500	"	"
Teak	47.0	15000	12000	"	"
IRON,	Weight of a cubic inch, in lbs.				
Bar 1 inch square (Welch)	0.281	58000	70000	10000	15000
Two inch round bar	"	59000	"	"	"
Russian 1 inch round bar	"	53000	"	"	"
Swedish 1 inch square bar	"	58000	"	"	"
American bar iron	"	48000	"	"	"
English cable iron	"	53000	"	"	"
" hammer hardened	"	63000	"	"	"
Iron Wire.					
⅓d inch diam. Philipsburg	"	75000		12500	
0.19 " " "	"	66000		11000	
0.156 " " "	"	80000		13300	
0.1 " " English	"	72000		12000	
Boiler Iron (American).					
Piled iron	"	56000	70000	9300	11700
Hammered plate	"	55000	"	9100	"
Puddled iron	"	51000	"	8500	"
Cast iron	0.26	18000	80000 to 150000	3000	13000 to 25000
Wrought Copper, in sheets	0.32	30000	100000	5000	16000
Cast Copper	0.317	17000	117000	3000	19500
Copper wire	0.32	60000		10000	
Cast Tin	0.263	4200	1000	700	170
Cast Zinc	0.248	8400		1400	

[TABLE CONTINUED.]

MATERIAL.	Weight of a cubic inch, in pounds.	Ultimate resistance to extension per square inch of section.	Ultimate resistance to compression per square inch of section.	Limit which should not be exceeded in practice.—Extension.	Limit which should not be exceeded in practice.—Compression.
Rolled Zinc	0.25	7000		1170	
Cast Lead	0.41	1700	483	300	80
Rolled Lead		1800		300	
Yellow Brass	0.282	16000	103000	2700	17000
Gun metal		32000		5300	
Granite	0.097		10000		1000
Sandstone	0.088	800	5000	80	500
Limestone (Magnesian)	0.115		5000		500
Oolites			2000		200
Limestone (Silicious)	0.114		5000		500
Hydraulic lime mortar	0.055	140	500	15	50
Hydraulic cement	0.056	234	700	25	70
Ordinary lime mortar (old)	0.058	70	500	6	50
Best quality Brick	0.069	280	2000	30	200
Inferior Brick	0.062	100	800	10	80

The preceding table has been prepared from the highest authorities—Morin, Poncelet, Claudel, Barlow, Hodgkinson, Franklin Institute, and others, and the utmost reliance may be placed upon it. It has been prepared especially for the *practical use* of American mechanics. The numbers in the fifth and sixth columns are those recommended by the most eminent engineers and practical men both in this country and Europe.

With regard to the absolute ultimate strength of materials, it is proper to state that they vary very much for different specimens of the same material. This applies more especially to wood, but also in some degree to all substances. It depends much on the state of the specimen. For instance, in the following table will be found the result of experiments made on short cylinders of timber, with flat ends, subjected to a compressive force. The cylinders were one inch in diameter and two inches in height. The results in the first column were obtained from timber moderately dry; those in the second column were obtained in like manner from similar specimens which were turned and kept in a warm place two months longer. A comparison of the two columns will show the great importance of having timber thoroughly seasoned in order to obtain its full strength.

DESCRIPTION OF WOOD.	Strength per square inch, in pounds.	
	Green.	Dry.
Ash	8683	9363
Beech	7700	19300
Birch	3200	11600
Oak (Quebec)	4230	6000
Oak (English)	6480	10000
Larch	3200	5560
Willow	2898	6128

With regard to the safe amount of strain it is proper to charge materials with in constructions, the engineer will be guided in each particular case by his judgment. It is impossible to give rules for every case. If, for instance, a piece of timber is to occupy a position where the strain upon it is steady, and it is exposed to no abrasion or decay, supposing it to be a fair sound specimen, it might be submitted safely to a strain as high as one sixth or one fifth of its ultimate strength. But, ordinarily, this would be too high. The French *mecaniciens,* Poncelet, Morin, Claudel, and others of the highest authority, have agreed upon certain limits to be used in practice for all kinds of materials and which will be given below. This limit for wood is one tenth the ultimate strength. This is the same ratio recommended by Haupt in his work on Bridges, and which he found to be perfectly successful in practice, as combining a judicious degree of strength with the least quantity of material.

As the mean ultimate strength of wood may be rated at ten thousand pounds per square inch of section, both for compression and extension, we have for our practical limit, not to be exceeded in ordinary cases of construction, one thousand pounds per square inch. Where timber is exposed to other than the legitimate strains due to its position in the structure to which it belongs, and which we will show how to calculate farther on, the engineer must of course use his judgment, unless these outside forces are such as to be calculated. The limits spoken of above, are, for wood, stone, and mortars, one tenth their ultimate resistance both for extension and compression, and one sixth for metals. As M. Poncelet has remarked, it would be more proper to determine these limits from the limits of elasticity of the several bodies, but experiments on this point have been made in but few instances.

ON THE STRENGTH OF IRON.—CAST-IRON.

THIS material, which has come to be used so extensively in the arts and in constructions, and whose uses are daily extending, has been made the subject of a great number of experiments. The most recent and reliable are those of Mr. E. Hodgkinson, the English experimenter. Those especially made by him on the strength of columns, both solid and hollow, and the most suitable forms for cast-iron beams to sustain a transverse strain, have supplied the engineer and architect with the most valuable guide in using and adapting this metal to the various purposes of construction.

Resistance to Extension.—Experiments have been made on this point by Mr. Rennie and Captain Brown, of England, and under the direction of the Franklin Institute in this country, and also by Mr. Hodgkinson of England. The first named gentleman obtained for the ultimate tensile strength of cast-iron, from 14,000 to 18,000 pounds per square inch of cross section. The results obtained by Mr. Hodgkinson, also on English iron, both hot and cold-blast, was from 12,000 to 19,000 per square inch.

The experiments by the Franklin Institute on American cast-iron give for the mean tensile strength, 20,834 pounds per square inch. This material, however, on account of its brittleness, and comparatively low power of resistance to a strain of extension, is seldom ever submitted to it. It is much used in the shape of cast-iron beams, to resist a transverse strain, but this has been shown to be nothing more than a strain of compression on one part, and of extension on another part of the same piece. In large works, it would be much better to use a combination of cast and wrought-iron for resisting a transverse strain, the cast for compression and the wrought for extension.

Care must be taken, however, that the different degrees of expansion of these two materials by heat produce no injurious effects. The limit of elasticity as assigned by Claudel, is $\frac{1}{1200}$th, and the force necessary to produce it 16,100 pounds per square inch. Some few remarks on the characteristics of cast-iron may not be out of place here. (They are mostly from the pen of Professor Mahan.) Cast-iron is divided into two distinct varieties, the white cast-iron and gray cast-iron. There are of course intermediate varieties, which partake more or less of the properties of these two, as they approach in appearance nearer the one or the other.

Gray cast-iron when of good quality is slightly malleable in a cold state, and will yield readily to the action of the file, when the hard outside scale caused by the chill in casting is removed. It is also sometimes termed soft gray cast-iron; it is softer and tougher than the white iron. On striking a sharp corner with the point of a hammer, an indentation will be produced, when in the other variety a piece would fly out. When broken, the surface of the fracture presents a granular structure, the color is gray, and the lustre is what is termed metallic, resembling small brilliant particles of lead strewed over the surface.

White cast-iron is very hard and brittle; when recently broken, the surface of the fracture presents a distinctly marked crystalline structure. The color is white, and lustre vitreous or glassy.

The following description, from Mr. Mallet's Report to the British Association for the Advancement of Science, comprises the different varieties:

"*Silvery.*—Least fusible, thickens rapidly, when fluid, by a spontaneous puddling; crystals vesicular, often crystalline; incapable of being cut by chisel or file; ultimate cohesion a maximum; elastic range a minimum.

"*Micaceous.*—Very soft; a greasy feel; peculiar micaceous appearance, generally owing to excess of manganese; soils the fingers strongly; crystals large; runs very fluid; contraction large.

"*Mottled.*—Tough and hard; filed or cut with difficulty; crystals large and small mixed; sometimes runs thick; contraction in cooling a maximum.

"*Bright Gray.*—Toughness and hardness most suitable for working; ultimate cohesion and elastic range generally are balanced most advantageously; crystals uniform, very minute.

"*Dull Gray.*—Less tough than the preceding; other characters alike; contraction in cooling a minimum.

"*Dark Gray.*—Most fusible; remains long fluid; exudes graphite in cooling; soils the fingers; crystals large and lamellar; ultimate cohesion a minimum; and elastic range a maximum.

"The gray iron is most suitable where strength is required; and the white where hardness is the principal requisite."

The color and lustre presented by the surface of a recent fracture are the best indications of the quality of iron.

A uniform middling dark gray color and high metallic lustre are indications of the best and strongest. With the same color, but less lustre, the iron will be found to be softer and weaker, and to crumble more readily. Iron without lustre, of a dark and mottled color, is the softest and weakest of the gray varieties.

"Iron of a light gray color, and high metallic lustre, is usually very hard and tenacious. As the color approaches to white, and the metallic lustre changes to vitreous, hardness and brittleness become more marked, until the extremes of a dull or grayish white color, and a very high vitreous lustre, are attained, which are the indications of the hardest and most brittle of the white variety.

"The strength of cast-iron varies with its density, and this element depends upon the temperature of the metal when drawn from the furnace, the rate of cooling, the head of metal under which the casting is made, and the bulk of the casting.

"The density of iron cast in vertical moulds increases according to Mallet's experiments, very rapidly from the top downward, to a depth of about four feet below the top; from this point to the bottom, the rate of increase is very nearly uniform.

"All other circumstances the same, the density decreases with the bulk of the casting; hence large, are proportionally weaker than small castings. From all these causes by which the strength of iron may be influenced, it is very difficult to judge of the quality of a casting by its external characters; in general, however, if the exterior presents a uniform appearance devoid of marked inequalities of surface, it will be an indication of uniform strength."

There has been considerable discussion with regard to the relative merits of hot-blast and cold-blast iron. Messrs. Fairbairn and Hodgkinson have investigated the matter, and their conclusions are expressed in the following paragraph: "The ultimatum of our inquiries made in this way stands in the ratio of strength, 1000 for the cold-blast to 1024.8 for the hot-blast. The relative powers to sustain impact are likewise in favor of the hot-blast, being in the ratio of 1000 to 1126.3."

The durability of cast-iron under exposure depends on different circumstances, the bulk of the casting, its homogeneity and density, &c. Mr. Mallet has made researches on this subject, and the following are the conclusions he arrived at:

"That the decay of iron when exposed to the action of water, is principally due to Voltaic agency, especially in tidal rivers, where there are strata of different densities, a Voltaic pile being thus formed of one solid body, and two fluid ones, making the corrosion much more rapid than where the water is homogeneous. Pure sea-water has much less action on iron than the water of harbors and docks, owing to the hydrosulphuric acid contained in the latter, and which comes from the mud at the bottom. In sea-water (pure) the rate of corrosion of pieces one inch thick, is four tenths of an inch for cast-iron, and six tenths for wrought-iron per century. In fresh water the corrosive action is much less than under any other circumstances of immersion, the coat of oxide formed on the outside not being dissolved and washed away as in sea-water, but remaining as a kind of protection. In hot sea-water, the corrosion is most rapid of any other circumstances. Iron, chill-cast, corrodes more rapidly than when cast in green sand, by reason of the want of homogeneity of the metal, thus forming Voltaic couples of different densities. When soft and hard cast-iron are brought together under water, the soft is corroded much more rapidly than when by itself, while the hard suffers much less; castings made in dry sand are more durable in water than those made in green sand. From one eighth to one fourth of an inch on the outside of castings, is termed the hard crust. When this is removed, the iron corrodes much more rapidly. The chief point in making castings to be exposed to this agent, is to have them as homogeneous as possible, and of as great density."

Mr. Mallet concludes with the following very judicious remarks: "The engineer of observant habit will soon have perceived, that in exposed works of iron, equality of section or scantling, in all parts sustaining equal strain, is far from insuring equal passive power of permanent resistance, unless, in addition to a general allowance for loss of substance by corrosion, this latter element be so provided for, that it shall be equally balanced over the whole structure; or, if not, shall be compelled to confine itself to portions of the general structure, which may lose substance without impairing its stability."

COMPOSITION FOR SILVERING BRASS.

TAKE silver, or gold lace, half an ounce; add thereto one ounce of double refined aqua fortis; put them in an earthen pot, and place them over a gentle fire till all be dissolved, which will happen in about five minutes; then take it off and mix it in a pint of clear water, after which, pour it into another clean vessel to free it from grit or sediment, and then add a spoonful of salt, and the green water will immediately let go the silver particles, which will form themselves into a white curd. Then pour off the water and throw it away, for it is of no further use. The white curd must then be mixed with two ounces of salt of tartar, half an ounce of whiting, and a large spoonful of salt, more or less, according as you find it for strength. Mix it well up together, and it is ready for use.

STEEL BY THE BESSEMER PROCESS.

A Paper read by Mr. A. L. Holley, before the Polytechnic Association of the American Institute, New York, October 12th, 1865.

ALTHOUGH the general composition and nature of steel are well understood by the members of the Polytechnic Association, it may not be inappropriate to refer briefly to these subjects, as preliminary to a consideration of the Bessemer process and its results.

It is well known that cast-iron is, substantially, iron with five per cent. of carbon, and one or two per cent. of silex, and some other impurities. Steel is iron with one to one tenth per cent. of carbon and a trace of silicium, and traces of some other substances. Wrought-iron is substantially pure iron—iron from which all but a trace of carbon has been eliminated. These are the three commercial forms of iron. Steel is subdivided, first, according to its quality—that is to say, substantially according to the high or low degree of its carbonization; second, according to the method of its manufacture.

First, as to carbonization. High steel, or hard steel, is that which contains a large amount of carbon, and a low specific gravity. Its distinguishing properties are extreme ultimate tenacity, hardness, and capability of extension without permanent change of figure; but its extensibility beyond the elastic limit is small, and it is therefore brittle under concussion. It will harden when heated and immersed in water; it is with difficulty welded, because it deteriorates under high heat, and because its welding heat is very near its melting point, and it is melted at a low temperature, as compared with wrought-iron, on account of its excess of carbon.

Low steel—also called mild steel, soft steel, homogeneous metal, and homogeneous iron—contains less carbon, and has a higher specific gravity. It can be welded without difficulty, although it deteriorates by overheating, and it more nearly resembles wrought-iron in all its properties, although it has much greater hardness and ultimate tenacity, and a somewhat lower range of ductility, depending on its proportion of carbon. It has less extensibility within the elastic limit than high steel, but greater extensibility beyond it—that is to say, greater ductility.

The grand advantage of low steel over wrought-iron, for nearly all purposes, is that it can be made liquid at a practicable heat, and run into solid homogeneous masses, however large—thus avoiding the great defect of wrought-iron, want of soundness, due chiefly to welds. It is also harder, more elastic, and more tenacious.

Second, steel is named according to the processes by which it is manufactured.

What is called "puddled steel," or, by some of its makers, "semi-steel," ought not to be called steel at all. The idea of steel involves the idea of casting from a liquid state, and of consequent homogenity. Puddled steel, so called, is high wrought-iron. It is wrought-iron puddled in the ordinary way, except that the process is stopped before the product is quite decarbonized. And the product possesses not only the ordinary defects of wrought-iron in the usual degree, but the defect of a want of uniformity in a much higher degree. It is not easy to guess at a minute chemical quantity through the flame of a puddling furnace. Puddled steel, however, is stronger than wrought-iron.

Crucible steel or pot steel is made from cast-iron by making cast-iron into wrought-iron, *i. e.*, entirely decarbonizing it by the puddling or charcoal refining process, and then melting the wrought-iron with carbon in crucibles, to recarbonize it to the proper degree. Or, wrought-iron bars are covered with charcoal and baked for some days in a converting oven. By this process the bars are somewhat carbonized, but still possess the structural defects of wrought-iron. The product called blister steel, is used in this state for the cheaper kind of springs, etc.; but its chief value is for re-melting in the crucible, with additional carbon, to form cast-steel. Crucible steel is also made from scrap Bessemer steel—the spillings from ladles, etc., and ingot and bar ends; also from cast-iron decarbonized to the required degree in the Bessemer converting vessel—and then poured into water. The product is fine shot of perfectly uniform steel, which are re-melted with or without additional carbon. The Bessemer process, in addition to making ingots, thus furnishes, directly and indirectly, the material for a large quantity of the best tool steel as well as low crucible steel now produced in Sheffield.

A little manganese, or some substitute for that metal, is always put into the crucible with the carbon. Chemists do not agree as to the precise chemical office of the manganese or its substitutes; but the result is to increase the ductility of the steel, in both the heated and the cold state.

Bessemer steel is just as much cast-steel, both structurally and chemically, as steel made in crucibles; because it is poured from a melted state into masses of any size, and because it is definitely and uniformly carbonized.

By the Bessemer process steel is made in two ways from cast-iron. 1st, as in Sweden, by blowing air through melted cast-iron, the oxygen of the air uniting with the carbon in the cast-iron, and so removing all but the amount required in steel, say one half to one tenth of one per cent. The oxygen also removes all but a trace of the silex; and the other impurities are burned out. By this process a certain definite number of cubic feet of air are blown through a certain weight of iron, and the blowing is stopped before the iron is quite decarbonized. 2d, by the Bessemer process it is more usual and more convenient to blow the air through the melted cast-iron until all the carbon and silex are removed, after which a small amount of melted crude cast-iron is mixed with the decarbonized metal, thus giving it the proper quantity of carbon, silex, and manganese; or, instead of cast-iron, artificial mixtures, containing carbon, silex, and manganese, or some substitute for manganese, are poured into the decarbonized iron.

The steel thus produced is cast into ingots, which are then ready for the hammer or the rolls. The apparatus employed is, first, a large melting furnace to melt the cast-iron to be converted; second, a converting vessel, into which the melted iron is run, and where the air is blown into it to decarbonize it; third, a small melting furnace, where the small quantity of cast-iron or other material for recarbonizing is melted; fourth, a ladle, ladle crane, etc., into which the steel is poured from the converting vessel, and from which it is let out into the ingot moulds.

The melting furnaces used in England and on the continent are reverberatory furnaces; that is, furnaces in which the flame of the fuel is thrown down upon the iron, instead of the iron being mixed up with the coal. Thus the impurities of the coal do not mix with the iron. The furnaces are similar to common puddling furnaces. They were at first used in this country, but the cupola has now been substituted.

The converting vessel is a cylindrical vessel of plate-iron with rounded or dome ends. It is (for making two tons of steel at a charge) about five feet in diameter and ten feet high. It is mounted on trunnions, so that it may be turned either end upward. On one end is an inclined mouth or spout, and on the other a tuyere box, to which air is admitted from the blowing engine by means of a hollow trunnion and pipes connected with it. The converter is lined with a refractory material about a foot thick—any silicious stone ground fine and rammed in; and the air is carried through this lining, from the tuyere box, by means of six fire-clay tuyeres, each tuyere having a dozen holes about a quarter of an inch in diameter. To the other trunnion is attached gearing and a crank to revolve the converting vessel.

The ladle is a plate-iron vessel some three feet high and three feet in diameter, lined say two inches thick with refractory material, chiefly moulding-sand. In the bottom of it is a hole in which is set a fire-clay nozzle. A fire-clay stopper, lifted and lowered by a hand-lever fastened to the outside of the ladle, fits into this nozzle, and thus forms a valve by which the hole in the bottom of the ladle is opened and closed.

The ladle is mounted on a crane, which allows it to move up and down, and to swing round in a fixed circle—that is, to swing under the converter, to catch the steel, and then to be hoisted and moved over the ingot moulds in succession. The process is as follows: Two tons of pig-iron are melted in the large furnace—time, one hour and a half. Meanwhile the converter has a fire made in it, and two or three pounds per square inch pressure of blast let in, to heat the lining red hot, and the ladle is turned bottom upwards over a little furnace to heat. By means of another crane the ingot moulds are also ranged in the pit in a half-circle, so that the ladle can swing over them. When the iron in the large furnace is nearly melted, a small quantity of pig-iron or other recarbonizer is set to melting in the small furnace. When the iron in the large furnace is melted, the converting vessel is turned on its axis, spout downwards, and the coal emptied out. It is then turned into a horizontal position, and an iron trough, lined with loam, suspended on rollers, is swung one end into the mouth of the vessel, and the other under a spout leading to the tap-hole of the furnace. The furnace is then tapped, and the iron runs through the channel thus formed into the converting vessel. The air-blast is then let on, and the vessel turned spout upwards, the tuyères or air passages thus being underneath the melted cast-iron. The air is blown up through the cast-iron at about fifteen pounds pressure per square inch. Combustion, first of oxygen and silex, and then of oxygen and carbon, and a violent boiling, at once ensue. In from six to ten minutes, the flame blowing out of the mouth of the converter into the chimney changes from a dull red, full of sparks, to an intense white, with splashes of cinder. After five to ten minutes more the flame gets thinner, shows purple streaks, and finally drops away, not entirely, but very obviously to the practiced eye. At this instant the metal is entirely decarbonized. More air blown in would begin to burn the iron itself. At this instant, then, which is so clearly defined that a dozen men tolerably familiar with the process would cry "stop" at the same second, the converter is turned down into a horizontal position, and the air-blast shut off. The recarbonizer from the little furnace is then run into the converter by the same means, thus restoring to the metal the exact quantity of carbon, silicium and manganese, or its substitute, required, the liquid cast-iron being only the vehicle for conveying these ingredients. The chemical mixture of the recarbonizer with the decarbonized iron is complete and almost instantaneous. It causes a momentary boiling of the mass in the converter.

The ladle is then swung under the mouth of the converter, and the latter being lowered, the steel pours out into the ladle. While the ladle is being raised over the ingot moulds the mouth of the converter is still further lowered to let the slag run out. Some of the slag runs out with the steel and forms a coating over it in the ladle, thus keeping it hot. The slag consists of such impurities of the iron as have not passed off in a gaseous form.

The ladle is then moved over the tops of the moulds successively, and the steel let into them by the stopper and lever above mentioned. When a mould is full, a plate of thin sheet-iron is laid on top of the steel, then a shovelful of sand, then a thick plate, which is wedged down. In ten to sixty minutes, depending upon their weight, the ingots, still red hot, are removed from the moulds, and may be hammered or rolled into rails, plate, shafting, or other forms, without reheating, except to warm the exterior, chilled by the moulds. Usually, the ingots are allowed to cool before hammering. This cooling changes their crystalization and improves their ductility. The ingot moulds are usually of cast-iron, from two to three inches thick. Some of them are solid, and widest at the bottom, so that the ingot will slip out there. Others are made in two halves, held together by hoops, and are taken apart to let the ingot out.

Ingots are cast in the form most convenient for hammering and rolling into the desired shapes, and of all weights, from one hundred to five thousand pounds. The loss of iron in the whole process is from twelve to eighteen per cent. * * * * *

The Bessemer process is, to the casual observer, almost ridiculously simple. It is, in fact, very simple; and it is conducted without any risk or difficulty, always providing that the irons used are of good quality; as most American irons are. In fact, it is almost impossible to make bad steel, or steel that is not uniform, out of good uniform irons, if ordinary attention is paid to the manufacture and the machinery, because the quality of the steel is not in a great degree dependent on the skill or judgment of the operator. The ingredients are mixed by weight. Bessemer steel cannot be economically made, however, without first-rate blowing machinery, good and convenient apparatus, and constant vigilance on the part of the two or three skilled operatives who have charge of the tuyeres and linings.

The great commercial advantage of the Bessemer process over all other steel processes, and, considering the quality of the product, over puddling, is its cheapness. The only fuel used is that for melting the pigs in a cupola, for heating the converter at the commencement of a series of charges, and the small amount for heating ladles, etc. The fire materials cost something more than in iron making. the pig-iron required is more expensive than the average irons used in puddling. Very little skilled labor is required. Some steel products are produced at about the cost of wrought-iron products of the same shape and weight.

The grand advantage of Bessemer steel over wrought-iron, especially in large masses, is its perfect homogeneity—the absence of welds, and consequent imperfections, such as the laminations of rails, blisters in boiler-plates, and cold shuts in heavy forgings. Its tenacity is double that of wrought-iron, considering the above mentioned and unavoidable defects of wrought-iron in welded masses. In the bar, it is one half greater than that of wrought-iron, or from ninety thousand to one hundred and twenty thousand pounds per square inch, according to the degree of carbonization required for different purposes. The nature of the Bessemer process renders the product more uniform than wrought-iron can be, in all its qualities. The stiffness of this steel, proportionate to its tenacity, adapts it to girder and ship building, and peculiarly fits it to resist compressive as well as tensile strains, as in piston-rods. While the elasticity, and hence the safe working load, of the lowest steel is much greater than that of wrought-iron, its ductility is equal to that of the best wrought-iron. Two-inch bars may be bent double, when cold, under the steam-hammer. This property insures its safety in the form of axles and tires. The hardness of the material, as well as its homogeneity, increases its durability in the form of rails, guns, and parts subjected to abrasion. It is peculiarly adapted to plates requiring intricate flanging, and subjected to the immediate contact of fire. For a given strength it may be thinner than wrought-iron. It does not blister, and the carbon in it protects it against corrosion.

This process of making steel was brought out by Mr. Bessemer in 1856. English and European manufacturers began to adopt in 1859 and 1860, and at the present writing not less than one hundred thousand tons of Bessemer steel are produced per year.

The idea of blowing air into melted cast-iron is at least three hundred years old. The fusing furnace for partially decarbonizing cast-iron, preparatory to puddling, has been worked on this principle for more than one hundred years. Since Mr. Bessemer's patents were issued, and since his practice began, claims have been made by two or three other persons for making steel by the Bessemer process; but not a pound of steel or malleable iron was ever made by either of these processes; and it is physically impossible to make steel or malleable iron by either of them.

Mr. Bessemer spent a large fortune in his effort to carry the process away beyond the highest stage of decarbonization that could be reached by the fusing or any of its modifications; and I can say, from personal experience, that in his process the use of air as a mechanical agent is quite as indispensable as the use of air as a chemical decarbonizer. The attempt to completely decarbonize cast-iron without the use of the apparatus for which Mr. Bessemer has not only one but many distinct patents in England and in the United States, will result in the production of nothing but scrap, unequally decarbonized, and incapable of being either cast, balled, or utilized in any way.

Mr. Bessemer was also the first to suggest and to patent the process of recarbonization, both by running cast-iron into a decarbonized iron, and by other means, and the process of alloying manganese in connection with the pneumatic process. There are now seventeen extensive Bessemer steel works in Great Britain. At the works of the Barrow Steel Company, one thousand two hundred tons per week of finished steel can be turned out, and when their new converting house, containing twelve more five-ton converters, is completed, these magnificent works will be capable of producing weekly from two thousand to two thousand four hundred tons of cast-steel. There are at present erected and in course of erection, in England, no less than sixty converting vessels, each capable of producing from three to ten tons at a single charge. When in regular operation, these vessels are capable of producing fully six thousand tons of steel weekly, or equal to fifteen times the entire production of cast-steel in Great Britain before the introduction of the Bessemer process. The average selling price of this steel is at least £20 per ton below the average price at which cast-steel was sold at the period mentioned. With the present means of production, therefore, a saving of no less than £6,240,000 per annum may be effected in Great Britain alone, even in this infant state of the Bessemer steel manufacture.

TO SILVER BRASS.

HAVING well cleared the brass from all scratches (otherwise it will spoil its appearance), rub it over with a piece of an old beaver hat and rotten-stone to clear it from all greasiness; then rub it with salt and water with your hand; then take a little of the before-mentioned composition on your finger, and rub it over where the salt has touched, and it will adhere to the brass, and appear as well as silver. After which, wash and steep it in plenty of clear cold water, to kill the aqua fortis which remained in the composition; and when dried with a clean hot rag, it is then ready to be varnished with the white lacquer.

RESISTANCE TO COMPRESSION.

THE best authority on this point is Mr. Hodgkinson, whose experiments were very full and varied. The trials were mostly on small columns with circular bases. The resistance was found constant for a height less than once and a half the diameter of the base, from this to a height equal to three times the base; the resistance was less than before, but still remained constant; and for any height greater than this, the resistance decreased with the height. When the piece was higher than three times the base, the rupture generally took place by bending. The pieces submitted to experiment generally yielded by an oblique fracture, the upper part sliding off on the lower. The angle made by the plane of the fracture, with the axis of the solid, was constant, and equal to about 55°.

The strength was found to be in direct proportion to the area of the cross section. The measure, therefore, of the resistance offered by a solid to rupture, either by compression or extension, is that force which will rupture a sectional area of the solid represented by unity. The following are the results obtained by Mr. Hodgkinson. The mean of the experiments on hot-blast iron gave, for crushing weight, 121,685 lbs. per square inch; cold-blast iron gave a mean of 125,400 lbs. per square inch. These were on short prisms, whose cross section was a circle. When the section was a square, or other regular figure, the resistance was decreased to 100,600 lbs. per square inch.

Table from Mr. Hodgkinson's Experiments.

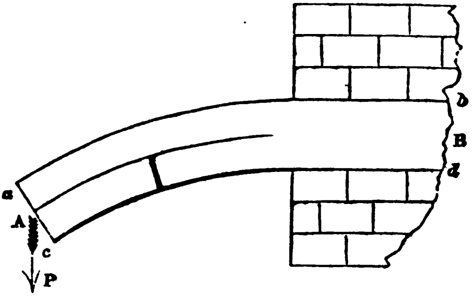
DESCRIPTION OF METAL.	Compressive Force per square inch, in pounds.	Tensile Force per square inch, in pounds.
Devon iron, No. 3, hot-blast.......	145,435	21,907
Buffery iron, No. 1, hot-blast.......	86,397	13,434
Do. " No. 1, cold-blast......	93,385	17,466
Do. " No. 2, hot-blast.......	82,734	16,676
Do. " " cold-blast......	81,770	18,855
Carron iron, " hot-blast.......	108,540	13,505
Do. " " cold-blast......	106,375	16,683
Do. " No. 3, hot-blast.......	133,440	17,755
Do. " " cold-blast......	115,442	14,200

Resistance to a Transverse strain.—The resistance of cast-iron to a transverse strain, is a subject of the highest importance to the engineer and architect. Indeed, to prove this, it is only necessary to point to the daily extending uses of this material in almost every possible shape, and it is well known that cast-iron is seldom, if ever, submitted to any other than a transverse strain, as in cast-iron beams, girders, &c., and a strain of compression, as in columns, which will be investigated farther on.

The theory of the transverse strain has been fully investigated; and great numbers of experiments have also been made on this point, so that among mechanics the matter is considered as sufficiently settled.

The remarks below apply to other materials, as well as to cast-iron.

Let A B be a body to which a force, P, is applied, in a direction perpendicular to the direction of the fibres. Supposing the force to be sufficient to bend the body, as in the figure, the fibres *a b*, on the upper side, will be extended, while those, *c d*, on the lower side, will suffer a strain of compression. This can be made evident; for, by increasing the weight P, until a fracture takes place, the rupture will be found to commence on the convex side, thereby proving that the fibres on that side have been most extended; and if some of the fibres on the convex side be separated by cutting them through transversely, it will be found that a smaller force than P will suffice to produce the rupture.



If, on the contrary, the fibres on the concave side, *c d*, be cut through transversely to a depth, *m n*, corresponding to about half the depth of the piece, and a slip of hard material like a sheet of iron be interposed, so as to just fill the place cut out, it will be found, on subjecting it again to the force P that the thin plate will be strongly retained by a pressure tending to compress it, while the strength of the solid will not be altered—the rupture commencing under the same strain, and in the same place as before. As we proceed from the convex toward the concave side of the solid, the extension of the fibres will gradually become less, until at a point at or near the centre of the piece, the length of the fibres will be found to undergo no variation. Beyond this distance, the fibres will be found to be more and more compressed, until we arrive at the concave side, where the compression will be at its maximum. The position of the fibres, whose form is not altered by the flexure, and represented by the line *e f*, is called the neutral axis. Its position varies for different substances, but for practical purposes may be considered to coincide with the centre of gravity of a transverse section of the solid.

The fibres, whose lengths are not altered, are contained before the flexture in a plane perpendicular to the direction of the pressure, and which, of course, contains the neutral axis, as one of its elements. After the flexure, these fibres form a cylindrical surface, whose elements are parallel to the same plane.

Moreover, the fibres, at equal distances above and below this plane, undergo equal extensions and compressions.

In order to investigate the circumstances of a body submitted to a transverse strain, it is necessary to obtain the moment of the acting force, with reference to the points of support, and establish an equation between this and what is called the "moment of elasticity," when the deflection of the body is in question, and the moment of rupture, when rupture is the point. The investigation is conducted by the aid of the higher analysis, and would be of no use to the practical engineer. It is therefore omitted—all the results, however, being given in a form to be easily understood. These remarks apply to other materials, wood, &c., as well as to cast-iron.

The experiments of Mr. Hodgkinson on cast-iron beams, the strength of best form for, &c., are the latest and most reliable authority on this point.

The following are the results of one of his experiments on bars of cold-blast iron five feet long; distance between supports, four feet six inches; the weight being applied at the middle of the bar:

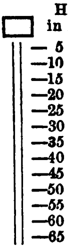
Rectangular Bar 1 inch deep, 1 inch broad.			Rectangular Bar 3 inches deep, 1 inch broad.			Rectangular Bar 5 inches deep, 1 inch broad.		
Weight in pounds.	Defl'ct'n in inches.	Set in inches.	Weight in pounds.	Defl'ct'n in inches.	Set in inches.	Weight in pounds.	Defl'ct'n in inches.	Set in inches.
16	.033		1082	.091	.003	4936	.110	.013
30	.062		1343	.111	.006	5867	.130	.017
56	.120	.002	1605	.138	.008	6798	.153	.020
112	.240	.007	1836	.164	.010	7730	.179	.025
168	.370	.014	2126	.190	.012	8662	.195	.030
224	.510	.028	2388	.220	.015	9593	.219	.034
280	.649	.041	2649	.250	.019	10525	.250	.042
336	.798	.061	2910	.281	.026	10588	Broke.	
392	.953	.084	3172	.310	.031			
448	1.120	.120	3433	.345	.037			
504	1.310	.170	3694	.378	.046			
514			3825	Broke.				
518	Broke.							
Ultimate deflection, 1.36.			Ultimate deflection, .395.			Ultimate deflection, 0.252.		

STATIC PRESSURE OF WATER UNDER DIFFERENT HEADS.

A CONVENIENT and easily remembered method for approximating to the pressure of water, is to allow one half pound pressure per square inch for each foot of head. The pressure at any point being directly as the perpendicular depth below the level of the surface, this simple rule affords a ready method of ascertaining its amount with an accuracy sufficiently close for ordinary purposes. That it is not strictly correct, however, may be readily perceived; and having occasion, recently, to calculate with tolerable exactness the pressure corresponding to several heads between ten and one hundred feet, I present the following Table for the convenience of others, having enlarged it by the addition of several numbers outside of the limits named above. The temperature of the water is assumed at 59° Fahrenheit; the density, from the presence of salts and other foreign matters, is assumed at 1.000,149, distilled water being 1.000,000. This density, corresponding with the investigations of Briagarand on the water of the Garronne, and with that of Brisson on the Seine, I have assumed as the density of ordinary fresh water. An allowance should perhaps be made for the increase of density due to the compression under great heads, but too slight to be of any practical importance.

Recent experiments on this point indicate a compression about $\frac{46}{1000000}$ of its bulk, under a pressure of one, atmosphere, or 33.90 feet head.

A pipe of cast-iron 15 inches diameter and $\frac{3}{4}$ of an inch thick, will sustain a head of water of six hundred feet. One of oak, two inches thick, and of the same diameter, will sustain a head of one hundred and eighty feet.



Head in feet.	Pressure, in pounds, per square inch.
1	.43
2	.88
3	1.30
4	1.73
5	2.16
10	4.33
15	6.50
20	8.66
25	10.83
30	12.
35	15.16
40	17.33
45	19.50
50	21.66
55	23.83
60	25.90
65	28.06
70	30.55
75	32.72
80	34.66
85	36.83
90	38.90
95	41.07
100	43.33
125	54 17
150	65.
175	76.05
200	86.67
300	130.01
400	173.34
500	216.68
600	259.02
700	305.55
800	346.69
900	389.03
1000	433.37
1500	650.05
2000	866.74
3000	1300.11
4000	1733.48
5000	2166.88
6000	2600.22
7000	3033.59
8000	3466.96
9000	3900.33
10000	4333.70

By paying strict attention to the above Table, much loss and inconvenience will be saved, particularly to plumbers, &c., in laying down pipes of the required strength according to the pressure, saving bursting, taking up, and laying down others, to say nothing of the annoyance of tearing up pavements, highways, &c., through the want of a proper knowledge of the static pressure in all cases per square inch.

DIRECTIONS FOR PREPARING AND FITTING BABBITT'S ANTI-ATTRITION METAL.

MELT 4 pounds of copper, add by degrees 12 pounds best quality of Banca tin, 8 pounds regulus of antimony, and 12 pounds more of tin while the composition is in a melted state.

After the copper is melted and 4 or 5 pounds of tin have been added, the heat should be reduced to a dull red, to prevent oxidation; then add the remainder of the metal as above. In melting the composition, it is better to keep a small quantity of powdered charcoal on the surface of the metal. The above composition is called *Hardening*. For lining the boxes, take one pound of this *Hardening* and melt it with two pounds of Banca tin, which produces the lining metal for use. Thus, the proportions for *Lining Metal* are 4 pounds of copper, 8 pounds of regulus of antimony, and 96 pounds of Banca tin.

The article to be *lined*, having been cast with a recess for the *lining*, is to be nicely fitted to a *former*, which is made the same shape as the bearing: Drill a hole in the article for the reception of the metal, say one half or three fourths of an inch, according to the size of it. Coat over the part not to be tinned with a clay wash; wet the part to be tinned with alcohol, and sprinkle on it powdered *sal ammoniac;* heat it till a fume arises from the sal ammoniac, and then immerse it in melted Banca tin, care being taken not to heat it so that it will oxidize.

After the article is tinned, should it have a dark color, sprinkle a little sal ammoniac on it, which will make it of a bright silver color, and cool it gradually in water. Then take the *former*, to which the article has been fitted, and coat it over with a thin clay wash, and warm it so that it will be perfectly dry; heat the article until the tin begins to melt, lay it on the *former*, and pour in the metal, which should not be so hot as to oxidize through—the drilled hole giving it a head, so that as it shrinks it will fill up. After it is sufficiently cool remove the *former.*

P. S.—A shorter method may be adopted when the work is light enough to handle quickly, viz.:—When the article is prepared for tinning, it may be immersed in the lining metal instead of the tin, brushed lightly in order to remove the sal ammoniac from the surface, placed immediately on the *former,* and lined at the same heating.

SOLDERING FLUID FOR SOFT SOLDER.

To two fluid ounces of muriatic acid add small pieces of zinc until bubbles cease to rise; add half a teaspoonful of sal ammoniac, and two fluid ounces of water.

P. S.—By the application of this, iron or steel may be soldered *without being previously tinned.*

ALLOY OF THE STANDARD MEASURE USED BY GOVERNMENT.

576	Parts of	copper,
59	"	tin,
48	"	brass (yellow, 22 cop. to 1 of zinc).

TUTENAG.

8 Parts of copper, 5 parts of zinc, and 3 parts of nickel.

EXPANSION METAL.

9 Parts of lead, 2 parts of antimony, and 1 part bismuth.

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THE END.

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