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DELTA METAL:

ITS HISTORY, PROPERTIES AND USES.

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THE subject the author has the honour of bringing under your notice to-night is, he ventures to believe, of importance to all those engaged in engineering work, whether civil, marine, or mining. To the marine engineer whose attention is constantly directed to the all-powerful enemy—rust. To the mining engineer, who as often finds himself called on to cope with acids and foul air, both the sworn foes of iron or steel in any form. And to the civil engineer for both reasons. He thinks he is safe in saying the mean temperature of the sea over which our coasting steamers run is fully 5° above that on the English coast, and something like 13° above the mean in the North Atlantic and round the east coast of the United States, and if that be admitted it follows that the tendency to rust is very much greater, and the value of a material that will effectually resist rust proportionately higher. Presumably the water in mines is not affected by depths, but due to local causes, and the effect of copper and lead on iron with water as a medium is too well known to need comment from me.

A metal, then, that will not rust, is practically impervious to the action of acids, as strong as steel, amenable either to being cast, rolled, drawn, spun, or forged is found in Delta metal, of whose properties more anon.

The terms bronze and brass are frequently used in a very indefinite manner, so much so that many people consider them one and the same thing. True, it is very difficult to know where to draw the line; but, generally speaking, bronze is technically understood to be a mixture or alloy of copper and tin, while brass is an alloy of copper and zinc.

The word copper is derived from Cyprus, whence it was first obtained by the Greeks.

Tin has been known from the earliest ages, and is synonymous with Bedril in the Hebrew language. Tin was known 1,500 years antecedent to the commencement of our era.

Many writers of repute maintain that zinc was unknown before the Thirteenth Century, but Dr. Percy quotes authorities who agree that the Romans at least were well acquainted with this metal, and used it in the manufacture of an alloy, to which they gave the name of orichalcum, similar to that we now term brass.

Lead was known to the ancients alone with copper and tin. It is worthy of note, however, that the use of lead for water reservoirs was considered so objectionable that it was strictly forbidden by Hippocrates, Galen, Vitruvius, and others.

When we read so frequently, as we have done of late years, of lead poisoning, we cannot help coming to the conclusion that in many respects we are not so very far in advance of the old Romans, after all.

We have ample evidence that the Chinese were well up in the preparation and manufacture of bronze and other copper alloys at a very early date.

Delta Metal, which is now so well-known in the engineering world, is the outcome of the researches made by Mr. Alexander Dick, with a view to improve the ordinary brass—that is to say, the usual copper and zinc alloys.

Much has been done, and with good results, during the last decade to improve the bronze—that is, the copper and tin alloys, but no endeavours have, to the author's knowledge, been made to improve the qualities of the common brass, or copper and zinc alloys.

The author might mention, however, that about twenty years ago Aich and Baron Rosthorn, of Vienna, made a series of experiments, in the course of which they tried various proportions of iron in the copper-zinc alloys, and arrived at results which at first promised a higher degree of success than was ultimately attained.

These results, as tabulated by Dr. Percy, show that the alloys possessed the properties of tenacity and strength to a remarkable extent, but the great drawback seemed to be the want of uniformity in the composition of different castings produced from the same alloy, even when the greatest care was taken in the manufacture.

About twenty years ago, while engaged in the management of extensive brass works on the Clyde, Mr. R. Macintyre made numerous experiments with a view to making gun metal into which certain percentages of iron should be introduced. After giving the matter a fair trial, as he thought, he was unable to see where any decided advantage was gained, and so let it drop, but it was not till some years after, when comparing the experience of Aich and Rosthorn with his own, and looking at the success which Mr. Dick had achieved, was forced to the conclusion that he, at least, had been on a wrong track in trying to obtain the alloy by melting the iron in the copper.

Following up the researches of Aich and Rosthorn, Mr. Dick says his first object was to ascertain the cause of such uncertainty in the results. He produced various quantities of the alloy, in accordance with the Austrian method, but found the results varied in each lot, from the fact that the quantity of iron could not be accurately controlled. Such being the case, the next step was to find a method by which a known or definite quantity of iron could be introduced, and this he succeeded in doing, by dissolving the iron in the molten zinc to saturation, and then adding a known quantity of this compound, with or without pure zinc, to the molten copper. In consequence, however, of the partial oxidation of the metals during the process of re-smelting, by which the castings again varied, Mr. Dick found it necessary to introduce a small proportion of a deoxide, such as phosphorus, etc. Being thus enabled to introduce a definite proportion of iron in the alloy, it was only a question of patiently making and completing a long and costly series of experiments to ascertain the most suitable compositions of alloys possessing qualities to suit the widest range of applications, for it will be readily understood that in practical working, the manufacture of a great variety of alloys is a very great inconvenience. The Delta Metal Company, Limited, who work Mr. Dick's patents, now produce alloys differing widely in their qualities; but as it would occupy too much time were he to deal with them in detail, he will therefore confine his remarks more especially to that quality of Delta Metal which is known as No. 4 alloy. He might mention here, that the word "Delta" has been adopted by Mr. Dick for a trade mark, in order to somehow connect his products with his name, Δ (Delta), as you are aware, corresponding to the letter D in the Greek alphabet. In this connection it may be mentioned that, though the variety of alloys made or sold by the Delta Metal Company, Limited, seems considerable, it does not necessarily follow that all are under Mr. Dick's or any other patent, but simply that they are the Company's products.

The Delta No. IV. alloy, which, on account of its great strength and resistance to corrosion has by far the largest sale of the various alloys produced, can be forged hot for pump rods, valve spindles, propeller shafts, cranks, boiler stays, and a variety of other purposes. Objects made of Delta Metal instead of gun metal or brass, can be much reduced in weight while the strength is retained. A highly interesting series of experiments has lately been made by Professor Unwin, who tested the various alloys at high temperatures. If we consider that steam at the ordinary atmospheric pressure, has a temperature of 212° Fahr., we shall be led to see how boilers and fittings, working under higher pressures, will be affected by the correspondingly higher temperatures. Boilers being, as a rule, supplied with cast brass cocks and copper tubes, the question naturally arises, are these materials the best suited for the purposes for which they are employed? The tests referred to were made by Professor Unwin, to ascertain the tensile strength of metals at various temperatures, and the results are as follow:—

BREAKING STRAIN TONS PER SQUARE INCH.

	Rolled.			Cast in Sand.			
Temperature,	Copper.	Yellow Brass.	Delta.	Brass.	Delta.	Phosphor Bronze.	Gun Metal.
Atmospheric.	17·84	24·09	31·16	12·45	23·89	16·06	...
210°	17·41	...	...	...	...	...	11·66
258	...	22·44	...	...	...	...	...
260	...	...	28·30	...	...	...	...
270	...	...	...	...	...	14·16	...
300	16·43	...	...	...	...	...	...
310	...	...	...	...	23·36	...	...
350	...	...	...	11·83	...	12·26	...
380	...	...	...	...	...	...	12·26
400	...	21·23	26·58	...	...	...	...
406	...	...	...	...	...	...	11·06
410	15·95	...	...	...	22·48	...	...
430	...	...	...	...	...	12·41	...
440	...	...	...	...	...	...	12·30
450	...	...	...	10·40	...	...	...
500	15·09	18·33	23·83	7·69	...	11·10	7·84
506	...	...	...	...	19·68	...	...
550	...	...	...	7·68	...	...	...
570	...	...	19·32	...	...	...	...
590	...	...	...	...	16·00	...	...
600	14·30	15·86	...	...	...	8·17	5·22
615	...	...	...	...	...	...	4·82
635	...	...	...	...	12·70	...	...
340	13·70	14·49	...	...	...	..	...
645	...	...	...	3·23	...	...	...
650	...	...	16·04	...	...	...	...

The bars were turned down in the middle over a length of 2in. to a diameter of $\frac{1}{4}$in. or $\frac{5}{16}$in. and were fixed in an oil bath heated by a gas jet. Delta valves used for compressed gases were formerly cast in gun metal, but there was always the greatest difficulty in obtaining them sufficiently sound to avoid the gas passing the metal, so enormous is the pressure to which they are subjected. Now in Delta No. IV they are simply hot stamped. This stamping costs less than the casting of gun metal and not a single one of these stampings, of which many thousands have been supplied, has been found to leak or to be otherwise faulty, thus saving a great deal of expense, as any fault in such valves is generally found out after a great deal of labor has been expended upon the same. The sample of Bevil wheel stampings will illustrate the advantages of Delta stampings over gun metal castings. They require no cutting of the teeth; as you will see they come out perfectly, and besides this, they possess double the strength of cast gun metal. The sand castings of Delta No. IV. possess equal or even greater strength than best wrought iron, and amongst many uses of such castings the gearing for the Swiss Mountain Railway (Rigi and Pilatus), where the safety of the passengers completely depends upon the strength and soundness of these wheels may be mentioned.

"For testing the strength of each casting separately, a test bar was formed with the pattern, moulded, and cast along with it in one piece. The bars were then cut off, and tested by Professor Tetmayer, of Zurich, the results showing a tensile strength of from $21\frac{1}{2}$ to $23\frac{1}{2}$ tons per square inch, with an elongation of from 40 to 30 per cent. on a length of $7\frac{7}{8}$ inches. Besides these tests, the constructor of the Pilatus Railway, Captain Locher, had the following direct test made:—One of the Delta Metal pinions having been in use for a long time, the teeth had worn off about one millimetre, so that their thickness at the root was $\frac{5}{8}$ inch, and at the top $\frac{7}{16}$ inch, by a breadth of $4\frac{7}{8}$ inches. It was tested to show what power would be required to break such a tooth, the strain acting upon it under unfavourable conditions such as it in reality never experienced.

The pinion (Plate IX., Fig. 1) was put in the testing machine between two clamps, P, acting on the entire breadth of the top of the teeth. The test, made by Professor Tetmayer, gave the following results :—

P	5	9	10	12	14	15	16
L	0	0·015	0·019	0·059	0·098	0·133	0·169
P		17	18	19	20	21	21½
L		0·208	0·244	0·295	0·354	0·472	(broke)

P indicating the stress in tons, and L the shortening in decimals of an inch of the distance L originally measuring 2¾ in. Both as regards P and L the results were unexpectedly favourable."

The quality which Delta Metal No. IV. possesses of not corroding—a property which is due to part of the copper being substituted by iron—has introduced its use largely for sanitary purposes, as, for example, Kent's Water Meters, which are completely made of Delta; Maignen's Filters, in which the taps, air pipes, and other portions used to be made of brass, are now made of Delta Metal. Sir Frederick Abel selected Delta Metal for water bottles and other vessels used by the troops, on account of resistance to corrosion.

Delta Metal finds, so far as weight goes, its largest application in marine engineering for propellers, pump rods, and also for the building of the hulls of ships and torpedo boats. A number of the latter have been entirely built of this alloy, and a 60 ft. launch is on the stocks at Messrs. White and Sons, Cowes, Isle of Wight, while an electric launch is being built by Mr. Sargent, of Chiswick, for Baron Rothschild. A boat has been constructed by Messrs. A. F. Yarrow and Co., of Poplar, for the German Colony in Central Africa. The plates and angles are of Delta Metal, and the stern, keel, and propeller are forged of the same material; and in order to facilitate the transport, it is constructed in sections which can be easily put together. Another large launch is now being built, also in sections, it being specified that no piece should weigh more than 60 lb. The advantage gained by using Delta Metal instead of steel in the construction of these launches is that, whilst it possesses the same strength as the latter, and can thus be made of same thickness of material, it is practically incorrodible, which becomes of great importance in countries where skilled labour cannot be obtained, and where steel and iron hulls rust through in a very short time unless continually painted. The price of the finished launches is stated to be from 20 to 25 per cent. more than that of similar launches built of steel; but, taking into consideration that Delta always retains its value, it is maintained that the Delta launches are the cheaper.

Delta Metal is admirably adapted for use in gunpowder works and powder magazines, as it does not emit sparks when subjected to shocks. For torpedoes it affords the requisite strength with the minimum of weight. The interior parts of the Whitehead torpedoes, and Mr. Lege's patent torpedoes, the wire reel, spindles, and other parts of the Brennan, are made entirely of Delta Metal. At the Artillery workshops of one of the leading continental Governments, Delta Metal is being tried as a substitute for gun metal for wheel naves, and other parts of gun, ammunition, and ambulance carriages. The results of experiments made so far have been of a highly satisfactory character.

The four columns forming the legs of the Eiffel Tower are each composed of four standards resting upon cast iron shoes The upper part of these shoes is bolted to the standards, while the lower part enters a cast iron bed-plate to some little depth, thus forming a hydraulic press upon which a pressure of 800 tons can be exerted to adjust if necessary the level of the different parts. The hydraulic pressure is supplied by pumps, of which the cylinder, plunger, and valves are of Delta Metal. These pumps having to support a pressure of 3·5433 tons per square inch to ensure the working power of 800 tons on each standard, have all been tested to 700 atmospheres.

The ironclads "Marceau" and "Pelayo," the former of the French, the latter of the Spanish Navy, have been provided with hydraulic rammers—for the charging of the projectiles—made of Delta Metal, solid drawn tubes, working telescopically one into the other by means of hydraulic pressure. The construction of the apparatus was carried out under Special Survey, none of the tubes being accepted before having been submitted to a severe test. Some of these tests were as under:—

Diameter outside. Inches.	Inside. Inches.	Thick. Inches.	Bursting pressure. Tons square inch.
$2\frac{1}{32}$	$1\frac{13}{16}$	$\frac{7}{64}$	2·2225
$1\frac{19}{32}$	$1\frac{15}{32}$	$\frac{1}{16}$	2·8575
$4\frac{11}{16}$	$4\frac{5}{16}$	$\frac{3}{16}$	1·524
$4\frac{11}{16}$	$4\frac{5}{16}$	$\frac{3}{16}$	1·746

Among other hydraulic tests the following may be mentioned:—

A solid drawn tube 5·2in. outside diameter, and 0·098in. thick, having a circumference of 16·39in., was subjected to a pressure of one ton per square inch, at that pressure the measured deformation on the circumference was only 0·0492in. Another tube 4·7in. outside diameter, by 0·19in. thick, the deformation at the same pressure was 0·063in., but only temporary, and disappeared as soon as the pressure ceased.

Resistance to Shock.—Blocks of Delta Metal and of bronze (the latter of the composition used in the French Marine), both $1\frac{3}{16}$in. thick, and weighing forty-four lbs., were dropped from a height of one metre (3′ $3\frac{3}{8}$″) on a punch $\frac{9}{64}$″ section. The result was the following:—

	Delta Impression. Inches.	Bronze Depression. Inches.
1st blow	0.025	0.04
4th ,,	0.046	0.095
7th ,,	0.06	0.129
10th ,,	0.078	0.151

Compression Test, by Mr. W. H. Stanger.—Delta metal forged cylinder diameter outside 1.255in. inside 0.758in. area 0.786 square inch.

Limit of elasticity	...	34.85 tons square inch
Maximum Stress ...	...	52.99 ,, ,,

Percentage of compression: 21.4 per cent on 1.306in.

Other crushing tests were made at the Royal Testing Laboratory at Berlin with pieces of rolled bar, 1.189in. diameter area 1.11 square inch. One was tested to 61.404 tons per square inch ultimate, and another to 61.278 tons square inch.

A steel chain with one cast Delta link in the middle, diameter of links $\frac{5}{16}$in., was tested to over 35 cwt. when the last steel link broke. The other steel links were all considerably deformed, but the Delta link alone resisted without the slightest deformation.

RESULT OF TEST OF CAST DELTA METAL CHAIN.

Description.	Stress. Tons.	Under Stress. Inches.	Extension Permanent. Inches.	Remarks.
Delta Metal Chain cast in sand, diameter of link 0.733in.	2.176	.070	.01	Appearance of fracture. Yellowish grey close and uniform.
	2.544	.1	·03	
	2.946	.2	.1	
	3·381	·3	.25	
	3·616	·4	·34	
	3·870	·5	·43	
	4·040	.6	·53	
	4·285	·7	.62	
	4·464	.8	.72	
	4·665	·9	.81	Complete fracture at root of link (several links partly fractured.)
	8.147	2.8	.—	

Ultimate—19.3 tons.

The above chain was a portion of one of those supplied to the Brazilian armour-clad turret-ship "Riachuelo."

The length tested was ten feet.

Molesworth gives 4 tons as the working load of $\frac{3}{4}$-chain cable and test load as 10.1 tons; therefore Delta metal cast chain is practically as strong as wrought iron chains for ordinary ships' cables, as actually stronger than galvanized chain.

The most recent test was made by Mr. Stanger on the 24th October last, as follows :—

TENSION TEST OF CAST DELTA BAR.

	Inches.	Per cent.
Diameter	0.611	
Area	0.293	
Reduction in area		20.1
Extension on	4	20.5
Extension on	2	21.
Extension on	1	21.
Limit of elasticity		11.54 tons sqr. in.
Maximum stress		23.89 ,, ,,

Sound fine grained fracture.

Machron gives 16 tons for gun metal, and only 8 tons for cast brass, and for wrought iron only 22 tons.

The following is an extract from the *Engineer*, 15th July, 1887 :—

" CORROSION OF METALS IN MINE WATERS.

" The Bonafacious Coal Mining Company, in Westphalia, having much trouble from the acid waters quickly corroding the iron and steel of their underground machinery, made a series of experiments with a view to finding the relative corrosion of metals of suitable strength. Brass and gun metal are not strong enough, and trials were made of steel, iron and DELTA METAL. Rolled bars of each of these were immersed during a period of six and a-half months in the water issuing from the pits at Kray, and then carefully re-weighed and photographed. Plate IX, Fig. 2. The bars were of 7.5″ long, and had a sectional area of 0.62 inch. The following are the weights of the three kinds of bars before and after the trial. In consequence of the rapid corrosion of iron and steel, DELTA METAL is now being used instead for underground machinery in this and other mines.

	Wrought Iron.	Steel.	Delta Metal.
	lb.	lb.	lb.
Weight of bars when put in	1.1805	1.2125	1.2787
After $6\frac{1}{2}$ months ...	0.6393	0.6614	1.2633
Loss...	46.3%	45.45%	1.2%

Comparative Tests of Delta and Muntz Metal, by Professor Schoffel, of Vienna.

Round rolled and drawn bars of each of the two metals were tested in a solution of salt, results as under:—

	Rolled.		Drawn.	
	Muntz.	Delta.	Muntz.	Delta.
	millimetres.		millimetres.	
Diameter of bars...	$18\frac{1}{2}$	$20\frac{1}{2}$	$19\frac{1}{2}$	$20\frac{1}{2}$
Length of bars ...	50	50	50	50
	square millimetre.			
Surface exposed to corrosion ...	2960	3286	3223	3286
	kilo.	kilo.	kilo.	kilo.
Weight of bars ...	0·103	0·1385	0·1252	0·1385
	gram.	gram.	gram.	gram.
Loss in five consecutive trials ...	8·11	5·69	7·79	5.67
Loss per cent. ...	7·88	4·11	6·22	4·10
Appearance of surface	Wrinkled and undulated cracks.	Smooth and uniform.	Wrinkled flaws and cracks.	Smooth and uniform.

In August last (1889) the author ordered a sample lot of about 5 cwt. in ingots, billets, bars, plates and anglebars; and having a yacht building at the time, where the owner wanted everything as neat and natty as possible, he decided to use Delta fittings entirely about the decks.

In designing the fittings a reduction in the diameters of all eyebolts, chain plates, etc., of 20 per cent. was made, being the margin usually allowed for the deterioration of iron due to galvanizing.

The chain and runner plates on which of course all the heavy strain of the mast comes, together with many of the hooks and block-straps are of Delta, and have done their work right well, so far not even a sign of wear can be detected.