

ON THE COMPOSITION AND DURABILITY OF LOCOMOTIVE BOILER TUBES IN REFERENCE TO COAL-BURNING.

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The question of Coal-burning in locomotive engines and its consequent action on the Copper Fireboxes and Brass Tubes has drawn attention to the importance of ascertaining the best alloy of brass for the tubes, and also to the necessity of overcoming the difficulties often experienced from the copper plates of the fireboxes being of hard or brittle quality; and the opinion has been extensively held that the duration of the brass tubes and copper plates has been lessened since the general adoption of coal-burning in locomotives.

Previous to the year 1852 three qualities of metal were recognised in copper smelting: namely, tile copper, tough cake, and best selected copper. Of these the tile copper was the lowest quality, and there was a difference in cost of £2 per ton between each quality. The best selected copper is produced by stripping or skimming off the upper surface of the melted metal in the smelting process, this portion being the purest quality of metal; the upper portion of the remaining metal formed the second quality or tough cake copper; while the tile copper was the residue at the bottom of the melting pot, containing the largest proportion of impurities. In 1852 the description called tile copper was discontinued, and the other two sorts only were made, namely tough cake, and best selected copper, with a difference in cost of £3 per ton. This change however did not prove beneficial in respect to the durability of copper plates and sheathing made from the new description of tough cake copper, which was not of such good quality as previously; for owing to the very great demand for best selected copper for the manufacture of Muntz's metal for sheathing and of brass tubes for locomotives &c.,

the stripping or skimming process in the smelting was now carried too far, the cake copper being seriously robbed by the greatly increased proportion of metal skimmed off to form the best selected copper, whereby the remainder was left inferior in quality to what it should be, and little if at all better than the tile copper of former years, while the best selected copper itself was also injured in quality by containing too great an admixture of impurities.

As early as 1858 it was found at Chatham dockyard that the copper sheathing of ships' bottoms, which is made from cake copper, did not last so long as before the above change; and copper sheathing which had been in use only two years was found to have lost as much as 14 per cent. of its weight; whereas only $\frac{1}{4}$ per cent. of the weight had been lost after eighteen years' wear of copper sheathing made in 1825, at which time but little best selected copper was made, the stripping or skimming process not having then been introduced to any considerable extent. At the present time the average duration of the copper sheathing on ships' bottoms is reduced to only three or four years, instead of from twenty to twenty-five years as formerly, owing solely it is believed to the extent to which the stripping process is now carried. The same explanation probably accounts also for the complaints which are frequently made that the copper firebox plates for locomotives are found inferior in quality to those obtained in former years.

The great and increasing demand for best selected copper undoubtedly caused a large quantity to be supplied under that designation which was not even so good as the tough cake of former years. Attention was again drawn to the subject at Chatham dockyard on the occasion of a ship which had lain some time in the harbour being suddenly ordered for sea; the brass tubes in the boilers, which were new, were then found to be leaky, and had to be taken out and the boilers re-tubed before the ship could proceed to sea. The cause of this and other similar failures was considered to be that the copper used in the manufacture of the tubes must have been of inferior quality, and not best selected as it ought to have been.

The following method of testing was consequently adopted by the Admiralty in 1865 for ensuring the use of the proper quality of copper in brass boiler tubes for marine purposes. Portions of several of the tubes are melted in a crucible, and zinc is added until the compound contains as nearly as possible 62 per cent. of copper and 38 per cent. of zinc, which is a composition that can be rolled hot and appears to give the maximum of tensile strength. The metal is then cast into an ingot, and after being brought to a low red heat in an annealing furnace is rolled out into a plate $\frac{1}{4}$ inch thick, from which strips are cut 1 inch wide. If the proper quality of copper has been used, these strips then stand a tensile strain of at least 6 tons each, equal to 24 tons per square inch; and the fracture when broken across presents a silky appearance in texture, which cannot be obtained if common tough cake copper has been used, or even ordinary selected copper, as none but the best selected copper gives this appearance to the fracture. As the quantity of copper contained in brass tubes is much in excess of the composition here fixed for the purpose of testing, it may appear strange to add zinc for reducing the proportion of copper; but the reason is that the richer alloys are so ductile that they elongate considerably under a tensile strain, and will not stand anything like the breaking strain of 24 tons per square inch, nor will the test composition containing the 38 per cent. of zinc stand the test, if annealed previous to testing. Another advantage in adopting the lower percentage of 62 per cent. of copper is that the appearance of the fracture of the low alloy gives a better test of the quality of the copper than a richer composition would afford.

From a number of experiments upon the tensile strength of alloys containing the above proportions of 62 per cent. of copper and 38 per cent. of zinc, it was found by the writer that only a few of the makes of best selected copper taken indiscriminately came up to the required strength; and a quality that would stand the test could only be ensured by an extra price for the copper. At the present time however some of the copper smelters have accepted this test, and produce a quality of best selected copper which is quite up to the mark. Great benefit has certainly been derived from

the government researches in this matter, which have undoubtedly caused an improvement in the quality of best selected copper; and the standard test above described is now invariably adopted by the writer for all best selected copper used in the manufacture of brass tubes for boilers.

The brass tubes in most general use at the present time for locomotive and marine boilers are known as solid-drawn tubes, consisting of two parts of copper to one part of zinc, which proportion becomes a little changed in the process of manufacture, owing to the volatility of the zinc when melted: and on analysis the writer has found the composition of the metal to be copper 69 or 68 per cent. and zinc 31 or 32 per cent. The question arises however whether this is the best alloy for the purpose, and whether the addition of more copper would not increase the durability of the tubes, especially in resisting the action of sulphur in coal-burning engines with bad coal; and the writer was first led to consider this question by finding some years ago that the practice on all the French railways was to adopt a standard composition containing at least 70 per cent. of copper, which was adhered to for all locomotive tubes. In this country the same conclusion has been arrived at on the North Eastern Railway, where it has been found by Mr. Fletcher after more than twenty years' experience with tubes of this composition that they are more durable than those containing a smaller proportion of copper; and consequently all the tubes for that railway are now required to contain 70 per cent. of best selected copper and 30 per cent. of best Silesian spelter. The actual results of working on that line, where the water is unusually bad, have been that 15 sets of tubes containing 70 per cent. of copper or upwards lasted an average of 87,808 miles each; while the average of 54 sets containing a lower proportion of copper was 81,665 miles. It is difficult however to arrive at any reliable statistical information respecting the duration of tubes, as it is materially affected by the quality of the water used in the boilers, and also by the quality of the coal as regards its freedom from sulphur; their average duration throughout the railways of this country may be taken at from 100,000 to 150,000 miles.

The proportion of 70 per cent. of copper is considered by the writer so great an improvement that it has been adopted as the composition of the locomotive tubes of his own manufacture; and this opinion is confirmed by the circumstance that the alloys of brass used for other purposes, such as to resist the action of sulphur and acids, are always made with this or even a higher percentage of copper. Hitherto the composition of locomotive tubes has been very various, the percentage of copper extending down to the proportion in the composition known as Muntz's metal, which is ductile when worked hot and contains 60 per cent. of copper and 40 per cent. of zinc; and one advantage which will attend the adoption of a standard percentage of copper in boiler tubes will be that old tubes when taken out of the boilers will have a certain definite value exactly in proportion to their weight.

The question of the best thickness of metal for the tubes is one of much importance, and one on which great diversity of practice at present exists upon the different railways; but with the increased percentage of copper in the composition it may safely be assumed that greater ductility will be obtained, and that some reduction in thickness of tubes may be made without diminishing their durability. The thicknesses of tubes range from as much as 9 and 13 wire-gauge ($\cdot 150$ and $\cdot 095$ inch) at the thick and thin ends respectively, down to as little as 13 and 15 wire-gauge ($\cdot 095$ and $\cdot 070$ inch); the most general practice of the leading English lines being about 10 and 13 wire-gauge ($\cdot 135$ and $\cdot 095$ inch). The thickest tubes, of 9 and 13 wire-gauge ($\cdot 150$ and $\cdot 095$ inch), have only been used regularly on one or two railways; and a serious difficulty having been experienced in keeping these thick tubes tight with very long fireboxes, a trial has been made at the writer's suggestion of the thin tubes of 13 and 15 wire-gauge for that purpose, whereby the previous difficulty of keeping the tubes tight has been obviated. The relative durability of the thinner tubes has not yet been proved; but an important saving in first cost is effected, the thick tubes having weighed 26 lbs. each for 11 feet length, while the thin tubes weigh only 21 lbs. each, effecting a saving on a set of 150 tubes of

750 lbs. weight, amounting to £29 in cost. Very good results have been obtained on one large railway with these thin tubes of 13 and 15 wire-gauge and $1\frac{9}{16}$ inch external diameter, in locomotives burning coal exclusively.

The greater rigidity of the thick tubes may have caused the difficulty previously mentioned of keeping them tight, the thick tubes not yielding so readily as the thinner ones to the inevitable difference in expansion of the brass tubes and iron boiler-shell. That this difference in expansion is a point of importance is seen from the circumstance that in a length of 11 feet the expansion of iron at 350° Fahr., the temperature of 120 lbs. steam, is $\frac{1}{4}$ inch, but that of brass is $\frac{3}{8}$ inch, giving a difference of 1-8th inch, which has unavoidably to be allowed for either by compression of the metal or by lateral springing of the tubes. On many railways the tubes are now annealed throughout, and the same practice has also been adopted to some extent by the Admiralty for marine boiler tubes; which tends to show that softness combined with great ductility is the desideratum needed.

On foreign railways it may be remarked that a different construction of tubes has been extensively tried, namely wrought-iron tubes with copper ends brazed on at the firebox end. The copper ends are bevilled to a feather edge on the inside and the tube ends in a similar manner on the outside, and the two are then brazed together. The object of this construction is to give the ductility of copper at the end where the tubes are flanged over the firebox tube-plate, and thus to overcome the difficulty of leakage, which has always been the great objection to iron tubes in locomotives. Although by this means an economy is effected in first cost by the use of iron tubes, in practice the saving is not so apparent; and on many foreign railways where such tubes have been tried, brass tubes are now being substituted for them. On one railway in Russia tubes of copper alone are used, but the fuel employed in that case is wood; and in the peat-burning locomotives on the Grand Trunk Railway of Canada brass tubes are now being substituted for the iron tubes previously tried.

Brass tubes are found to suffer serious damage from long exposure to damp, and to become hard or brittle, losing their ductility. This arises possibly from the circumstance that the injurious action known to be produced upon brass by the sulphurous acid gas present in the atmosphere of towns is greatly dependent upon the presence of moisture in the atmosphere: and at the writer's suggestion the stores for brass locomotive tubes have in some cases been heated and enclosed, with advantageous results in preserving the tubes from damage.

Mr. EVERITT exhibited a number of specimens of the testing of brass, and showed the hydraulic press in action by which the testing of the samples was effected. He explained that the practice at his own works in testing best selected copper was to mix 6 lbs. of the copper with 4 lbs. of best Silisian spelter, whereby the proportions in the resultant alloy became about 62 per cent. copper and 38 per cent. zinc. This was then rolled down into a plate 4 inches wide and of exactly $\frac{1}{4}$ inch thickness, which was cut into two portions, one being left hard for testing the tensile strength, and the other being annealed for bending. The latter was bent cold, and was required to stand being bent over completely double and hammered close, without any signs of cracking, as shown in the specimens exhibited, all of which had undergone this treatment without failing. The hard portion of the test plate was cut down in the centre of its length to a width of exactly $\frac{1}{2}$ inch, so as to present a section of $\frac{1}{4} \times \frac{1}{2}$ inch or 1-8th square inch to be ruptured by tension; this was then fixed in the hydraulic press, and the pressure was increased till the fracture was effected. With 62 per cent. of copper it was found that the specimens required a tensile strain of 13,000 lbs. to break them, equivalent to about 46 tons per square inch upon the initial section; but when the proportion of copper was increased to 70 per cent., the breaking strain became reduced by the greater ductility of the metal to 10,000 lbs., or about 36 tons per square inch on the

initial section. This confirmed the plan of testing prescribed by the Admiralty, in which zinc was required to be added to the alloy until the proportion of copper was reduced to 62 per cent. The specimens exhibited of the test pieces all showed the silky appearance of fracture, which indicated that the quality of the copper was of the required excellence. He showed also specimens of locomotive boiler tubes containing 70 per cent. of copper, of which the ends after being annealed had been flanged over when cold, for the purpose of testing the ductility of the metal; in one instance, the tube being $2\frac{1}{8}$ inches outside diameter, the flange had been spread out at right angles to the tube to $3\frac{5}{8}$ inches diameter; and in another tube of the same diameter the flange had been bent completely back upon the tube; in neither case were there any signs of cracking on the surface of the metal or at the edge of the flange.

Mr. E. A. COWPER considered they were much indebted for the description given in the paper of the actual proportions of copper and zinc employed in the manufacture of brass tubes; and the practical experiments that had been described and exhibited appeared conclusive as to the value of the increased percentage of copper in boiler tubes, and the importance of testing the quality of the copper. It was clear that some definite proportion of copper and zinc must be better than others for boiler tubes; and it was very desirable therefore that the best proportion should be adhered to in all cases, instead of tubes being made as hitherto of a variety of different compositions. In the case of gunmetal for bearings &c. it was usually the practice to specify beforehand the exact proportions of metal to be employed; and it would be desirable for the same plan to be carried out in respect to the composition of boiler tubes. In the investigation made by government respecting the quality of the copper employed for sheathing of ships and for marine boiler tubes, he understood it had been stated that the decline in the quality of best selected copper dated from the introduction of a great many sorts of foreign copper ore, particularly those from Australia and Peru, containing different sorts of impurities; and that it was no longer possible to get best selected copper made from Cornish ores alone, which were more free from impurities than Australian ores.

The presence however of a small percentage of phosphorus in copper proved an advantage he believed, by increasing the ductility of the metal, though damaging it for electrical purposes.

Mr. EVERITT thought it was not the quality of the best selected copper so much as the quality of the residue which had deteriorated in comparison with former years; and although by mixing with the Cornish ores the Australian and Chilian, containing a great variety of impurities, a less pure quality of metal was produced than had previously been obtained from the less rich but purer Cornish ores, there was no doubt that it was possible at the present time to make as good a quality of best selected copper as had ever been made, or even better. But the real difficulty was that so much best selected copper was wanted that the metal was stripped to such an extent in the melting process as to cause the quality to be very much deteriorated, both of the best selected copper itself, and especially of the inferior description left behind, or cake copper, which was the quality employed for the copper sheathing of ships.

Mr. S. CROSBY remarked that at the commencement of the manufacture of the late Mr. Green's solid-drawn tubes in 1841 the only copper used was that obtained from Messrs. Sims Wilyams and Co., which was the best that could be procured at the time and considerably more expensive than the other qualities. But of late years some very inferior material had been made as best selected copper, which had consequently produced a serious difference in the quality of the tubes manufactured from it, although no alteration had been made in the proportions originally adopted by Mr. Green of 2 parts copper to 1 part zinc. The extent to which this deterioration was carried led at length to the investigation of the subject by government, originating in the discovery of the circumstance mentioned in the paper, that the tubes in a steamer which had lain by for a long time had become rotten: this was a liability to which all brass tubes were exposed, when kept in a damp situation, and particularly when also made of an inferior quality or lower proportion of copper. Until that investigation the difference in the durability of boiler tubes had never been ascribed by the users of the tubes to the difference in the quality of the copper employed, but solely

to the proportionate composition of the brass. The result of the experiments then made at Woolwich had been the establishment of the system of testing described in the paper for ascertaining the quality of the best selected copper; and also the adoption of the same proportion of copper and zinc for marine boiler tubes, namely 2 to 1, that had been throughout used by Mr. Green. With this proportion, if the quality of the copper was sufficiently good to stand the prescribed test, and if it was also mixed with the best Silesian spelter, the tubes manufactured from the alloy would certainly prove thoroughly satisfactory as far as marine boilers were concerned. In regard to locomotive boilers, although the same proportion was as a rule satisfactory in this case also, there were unquestionably some railways upon which a considerably higher proportion than 67 per cent. of copper was necessary in the tubes, even with the very best copper that could be obtained; but he could not say whether this arose from any excess of sulphur in the coal burnt in those engines, or from some other cause not yet clearly ascertained.

With respect to the thickness of metal in locomotive boiler tubes, the original dimensions adopted by Mr. Green, by whom the plan was introduced of making the tubes taper in thickness, had been No. 12 wire-gauge ($\cdot 110$ inch) at one end, tapering to No. 14 ($\cdot 085$ inch) at the other. Previous to that time all locomotive tubes had been parallel in thickness throughout the entire length, the thickness being No. 14 ($\cdot 085$ inch) or thicker. Subsequently on the Liverpool and Manchester Railway a thickness tapering from Nos. 10 to 13 ($\cdot 135$ to $\cdot 095$ inch) had been adopted by Mr. Dewrance, after going carefully into the matter; and he believed this section had continued to the present time to be the one in general use upon most railways. On the Bristol and Exeter line Nos. 9 to 13 ($\cdot 150$ to $\cdot 095$ inch) were the dimensions used until recently; but in that district also the belief had lately been gaining ground that thinner tubes would answer the purpose equally well, particularly where the coal employed was of such an excellent description as that obtained from South Wales.

The PRESIDENT observed that, in reference to the case that had been mentioned of the failure of marine boiler tubes after standing idle for a length of time, he had also met with an instance of the

same sort, where the tubes had become very brittle after being left for a considerable time without getting up steam in the boiler ; and the reason appeared to be that, as the boiler was covered with felt, there was always a slight dampness remaining inside around the tubes, although they were not actually surrounded with water. He enquired whether it was anticipated that the use of a higher percentage of copper would obviate this liability to rusting in marine boiler tubes when standing idle. In locomotive boilers the tubes were worked so much more severely than in marine boilers that any means of increasing their durability was of great importance, even if it involved some increase in first cost of tubes.

Mr. EVERITT believed that the use of a larger proportion of copper in the tubes would render them less liable to rusting in marine boilers, when left standing in a damp atmosphere for a length of time.

Mr. J. FERNIE thought the paper that had been read was one of much value in supplying practical data respecting the composition of boiler tubes ; and the question of the quality of best selected copper was one of great importance also in the manufacture of gunmetal bearings for journals, consisting of an alloy of copper zinc and tin. In consequence of the frequent heating of railway carriage and wagon journals, he had himself made a number of experiments some years ago upon the composition of the gunmetal bearings ; and he had found great difficulty in obtaining a quality of copper good enough for making the required description of gunmetal, which was owing without doubt to the excessive stripping for the production of the best selected copper.

Mr. A. MUNTZ believed that the composition of the best alloy for brass boiler tubes depended a great deal upon the quality of the water and coal used for working the boiler. If the water were at all of an acid character, it would not do to have tubes containing a very low percentage of copper, because they would become brittle ; but any copper that was introduced beyond the percentage necessary to prevent the tubes from becoming brittle under the action of acid, which he considered to be about 62 per cent., would reduce the durability of the tubes, because the sulphur contained in the fuel

would act upon them more rapidly, and the metal being softer would wear away sooner from the mechanical action of the blast.

In reference to the case mentioned in the paper of copper sheathing made in 1825 which had lost only $\frac{1}{4}$ per cent. of its weight after eighteen years' wear, he was not able to understand how the loss of weight could have been so small during that length of time; because with the present metal sheathing composed of copper and zinc it was found that if the metal was too poor, containing too small a percentage of copper, the ship's bottom fouled, from not oxidising sufficiently; and if the metal was too rich in copper, it oxidised too rapidly, and would thereby become speedily worn away. If therefore any sheathing had remained many years on a vessel, he thought it would either have fouled to a great extent, or have lost a great portion of its weight by oxidation.

Mr. E. A. COWPER observed that the case mentioned in the paper was by no means a solitary one, in respect to the durability of copper sheathing on ships in former years, as there were many instances of old copper sheathing that had worn for fifteen years and upwards; whereas copper sheathing made at the present time had an average duration of only four or five years, and there were many cases in which bad copper sheathing had had to be stripped off after only a few months' wear.

The PRESIDENT moved a vote of thanks to Mr. Everitt for his paper, which was passed.

The Meeting then terminated; and in the evening a number of the Members dined together in celebration of the Twentieth Anniversary of the Institution.
