

Public Works (1898) Department.

G.O., No. 290-91 *Ly*

DATED 21st Feb 1898.

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*Approved
by M*

[Despatch Abstract.]

*Cracked tube plates of the heavy
Compound Engines of the E.C.R.*

*Ordered that the report of the Senior
Govt Inspector of Ryos on the — be for-
warded to the Govt of India.*

*Forwarding Copy of the Press embodying
the report of the Senior Govt Insps of Ryos on
the —*

Government (1898) of Madras.
PUBLIC WORKS.

Spare copies

FEBRUARY.

Forwarding copy of the Proceedings embodying the report of the Senior Government Inspector of Railways on the —.

GOVERNMENT OF MADRAS.

PUBLIC WORKS DEPARTMENT.

Railway.

Read the following paper:—

REPORT ON CRACKED TUBE PLATES OF HEAVY COMPOUND ENGINES ON THE EAST COAST RAILWAY.

In the Director-General of Railways' letter, No. 956 S., dated the 14th July 1897, I was instructed to direct special attention, on the occasion of the next half-yearly inspection, to the failure of copper tube plates on the heavy compound engines of the East Coast Railway. The engines in which failure occurred are amongst the thirty supplied under the advice of Sir. A. Rendell, and built by Neilson & Co., Glasgow—twenty of them under contract 4,190 of 1892, and ten more subsequently supplied. Up to June 1897 the plates of seventeen out of the thirty had failed; since then more failures have occurred. The longest distance run by a failed engine was 108,865 miles, and the shortest 50,535 miles. They weigh, with $\frac{3}{4}$ glass but empty grate, about 50 tons, with about 44 tons extra for a full tender. They are mounted on 6 five-foot wheels and a bissel truck.

2. The failures are very serious, sometimes extending across ten or twelve consecutive bridges between tube holes. The tube plate carries 214 tubes $1\frac{3}{4}$ " external diameter and $2\frac{1}{2}$ " pitch, so that the bridges are $\frac{3}{4}$ " only. The thickness of the tube part of the plate is one inch. The tubes which are 12 w.g. at the smoke-box end are 10 w.g. at the fire-box end where they are beaded over and ferruled. At the smoke-box end they are merely expanded without beading, and have a $\frac{1}{4}$ " projection. The distance between inner faces of tube plates is 11' 5".

3. The cracks occur for the most part in one or other of the two outer rows of bridges, at the sides and bottom, not at the top. Similar cracks would be produced if the edges of the plate were held rigidly and if its centre portion were violently buckled backwards and forwards. This indeed is exactly what I presume must happen when the side plates of the fire-box are prevented by their very short stays from expanding and contracting while the tubes being rigidly held at both ends are free to buckle the centre parts of the smoke-box and fire-box plates.

4. I labour under the great disadvantage of writing on a subject in regard to which I pretend to no special knowledge. But it seems to me that, under such conditions of to-and-fro wrenching, the plate *must* go unless made of the very best copper, and that anyhow sooner or later, after a large number of firings up and washings out any plate must go. I can imagine that failure under these conditions might not occur either if the forward ends of the tubes could slide in the smoke-box tube plate, or if the tubes were so bent that they could give a little.

5. The expansion between the fire-box and boiler shell is a relative one, consisting not only of that due to the relatively larger co-efficient of expansion of copper than that of steel (copper 1 in 104,400 per degree against steel 1 in 151,200 per degree), but also in the very much higher temperature of the copper fire-box than of the boiler shell. I have not a notion what the mean temperature of the copper is, but at one side of it there is a temperature of nearly the melting point of the lead safety plug, while at the other is the water of the boiler; whereas the steel shell has only the boiler water on one side and air under the lagging on the other. Supposing that the mean

temperature of the copper were 450° and of the steel 250° the 6 feet of copper side plate would desire to expand about $\frac{1}{8}$ of an inch, while the steel shell for a corresponding length would expand only about $\frac{1}{16}$ of an inch. The difference must be taking effect somewhere or other, in the very slight bending of the short thick stays, and to some small extent in the transverse flexure of the tube plate just in the very place where the cracks which we are dealing with are found to occur, but chiefly I take it in internal stresses in the side plates themselves. But the very small wrenching caused by the relative expansions and contractions of the fire-box and its shell does not represent the whole of the wrenching to which the tube plate is subject. There is also that due to the relative expansion and contraction of the 11 feet of the belly portion of the steel boiler and the brass tubes contained in it. The tubes are doubtless at a considerably higher temperature than the shell, though the difference is nothing like as great as in the case of the fire-box and its shell. It seems to be here that we must look for the source of the mischief.

6. I gathered from Mr. Hindmarsh, the Officiating Locomotive Superintendent of the East Coast Railway, that in his opinion the cracking of the bridges was due to excess of rigidity in the staying. The top of the fire-box is stayed not with girders but with, I think, 244 bar stays $\frac{1}{8}$ " diameter and about 18" long, except the two leading rows which are expansion stays, to permit of the upwards expansion of the tube plate when heated. Mr. Hindmarsh thought, and I agreed with him at the time but am now doubtful, that it would be sufficient if the next two rows of crown stays back of the two leading ones were also expansion stays, so as to relieve the rigidity. But though that might be of use if the injury were occurring in the crown plate, I cannot now see that it would help the tube plate very much, so long as the stays connecting the side plates, the door plate, and the lower part of the tube plate to the boiler shell are practically all of them only 2" or 3" long, and therefore incapable of bending to anything like the extent necessary to allow the side plates to expand as required by the conditions of their temperature. I take it that the side plates do not as a fact expand to any appreciable extent relatively to the boiler shell to which they are so rigidly connected by the multitude of short stays, and that the temperature takes effect in internal compressive stresses which these plates evidently stand well enough, because they are not, I believe, found to fail.

7. So far as it is possible for a non-expert to form an opinion on so special a subject, my opinion is that the cracking is due either to the copper of these particular tube plates not being good enough to stand the wrenching to which they are subjected as the result of the longitudinal expansion and contraction of the tubes every time the engines are fired up or washed out, or else that the design of the staying is faulty. It seems to me that what happens is as follows:—

(a) Owing to the shortness, 2" to 4", and the thickness, 1", and the close pitch, 3" to 4", of the stays connecting the sides and back of the copper fire-box and also the lower half of the copper tube plate, to the steel boiler shell, there is little relative expansion and contraction between them. The effect therefore of the difference in their temperature is chiefly to set up internal stresses in the metal, stresses which these particular plates are evidently capable of sustaining without injury.

(b) Except in so far as it is held rigid by the short thick stays near the top of the side plates, there is room for relative expansion to occur between the copper crown plate and the steel shell, because its long 18 inch stays can bend to a certain extent.

(c) The upward expansion of at least the middle part of the tube plate, from the belly stays upwards, is provided for by the adoption, for the front two rows of crown stays, of expansion or stirrup stays. These cannot, however, do much good near the sides of the tube plate, because here it is held rigidly by the side plates and their short side stays. Looking in through the wash-out hole I could see that, as a matter of fact, the incrustation at the expansion place of the end stays in the two expansion rows was not broken, showing that here at least they had not been acting.

(d) The wrenching and buckling which has caused the cracks is not apparently due so much to movements of the side plates of the fire-box as to the expansion and contraction of the 214 tubes, or rather to the relative expansion and contraction between them and the cylindrical steel shell of the boiler containing them. This relative

movement is due to the greater temperature, as well as the higher co-efficient of expansion, of the brass tubes as compared with the steel shell. The effect of this difference of temperature might exhibit itself (1) in protruding and withdrawing the forward ends of the tubes in the smoke-box tube plate if they were loose; (2) in the sagging of the tubes if they could bend; (3) in internal stresses throughout the tubes if both ends are rigidly fixed and if they cannot sag; (4) in bending and buckling the tube plates. All these effects may perhaps to a lesser or greater extent take place; but I judge that the tightening up of the forward ends of the tubes in the smoke-box tube plate by the use of the dudgeon-roller would make forward sliding impossible.

8. The greatest effect of the unequal expansions and contractions to which the parts of the boiler are subject *must*, apparently, be sought for in the bending and buckling of the fire-box tube plate just around the group of tubes. This effect can only be resisted by the highest quality of material; and if it is found that one set of plates fails and other sets do not fail, the deduction is that the thickness of plate or the breadth of the bridges or the quality of the copper, or all three, are unequal to the work required of them. This opinion I offer with diffidence, not being a locomotive expert.

9. I now come to the measures which are being adopted to patch up the cracks. The holes are being bored out and screwed, and taper screwed ferrules are being inserted in the screwed holes, and in these ferrules the tubes are being fixed as before. All that this treatment can do is to help to get the crack calked by shortening it up, and to enable the tube to be ferruled tight without enlarging the crack. But the damage has been done, and it in no way strengthens the plate to treat it like this. Mr. Hindmarsh said it is the usual practice. It may be good enough practice for a hole or two, but for ten or twelve cracked bridges all in a row it seems to me that the cure is worse than the disease, and that the only right thing is to take out the plate as soon as may be and put in a new one, selling the old one as old copper.

10. I recommend that the East Coast Railway get out a new lot of plates, and that as soon as this particular class of weakness exhibits itself in future a new plate be substituted. It seems to me that the patchwork process for this particular class of very extensive failure is only the merest makeshift, and a costly makeshift at that, and that at most it may be expected to keep the fire-box going for a comparatively short mileage.

11. In order to set at rest the question of the quality of the copper, I advise that long strips for testing be cut out, by sawing not by chipping, near the failed places, and other strips near places which have not failed; also similar strips from old tube plates which, though they may have gone in other ways, have not failed in this particular way. I advise that these test pieces be sent to be tested for strength and ductility, and also chemically, to the Madras Civil Engineering College, where Professor A. Chatterton's tests in the 100 ton machine of the College may be trusted to be thorough.

12. Since writing the above paragraphs, I have had an opportunity of searching for information in the Volumes of Proceedings of the Inst. C.E., and find the subject treated of in Vol. LX at page 463, where the author of a foreign article says: "Cracks in the corners between tube plates and side plates are assisted by the bellying outwards of the tube plates under the internal pressure, and by the expansive force of the tubes, which also tends to form cracks round the tube ends." At page 125 of Vol. LXXXI, Mr. J. A. F. Aspinall says that, "With regard to the amount of expansion of brass tubes when under steam pressure he had found, in trying a boiler over a length of 9' 3", that it expanded $\frac{3}{16}$ inch, and that the tubes in a length of 10' 4" expanded about $\frac{1}{4}$ inch, and one tube placed in a stuffing box at the smoke-box end expanded $\frac{1}{16}$ inch in addition; showing that the tubes would, if they were allowed, expand something like $\frac{1}{2}$ inch." At page 87 of the same volume Mr. W. S. Stroudley said that the practice on the L.B. and S.C. Ry. is that "when brass tubes are used they are bent upwards in the centre to about their own diameter, so that the expansion may not force the tubes through the plate and cause leakage; this has been found a very efficient remedy for the leakage of tubes. When iron or steel tubes are used, the differential

expansion is so small that this bending is not necessary; it is questionable however, if it would not be an advantage in those engines having very long fire-boxes." At page 162 of the same volume Mr. R. H. Lapage said that "at the smoke-box end he preferred merely to roll the tubes with a dudgeon-roller, letting the tubes stand out about $\frac{1}{4}$ inch, and to use no ferrules; by this means the tubes were allowed to expand a little, if necessary." This is apparently the way in which the smoke-box ends of the East Coast Railway tubes are fixed, but I doubt very much whether they can expand in the holes without leaking, under modern high pressures. Much useful information is to be found in the discussion on Mr. J. Fernie's paper on mild steel fire-boxes in Vol. LXXII. I gather from a perusal of the above papers that there used to be a general feeling that bar roof stays were not so good for very large fire-boxes as girder stays, though the former are well enough on small fire-boxes such as those of metre gauge engines.

13. I notice, through the papers, that it seems to be generally believed that stays should be kept well back from the flanged angles. But I see that, in the East Coast Railway fire-boxes, the forward vertical row of side stays is only $2\frac{3}{4}$ " back from the row of rivets which connect the side plates with the tube plate, and 5" back from the centre of the thickness of the tube plate. But at page 159 of Vol. LXXXI, Mr. R. H. Burnet speaks of a distance of $8\frac{1}{2}$ " to $12\frac{1}{2}$ " being appropriate for this place. The object, of course, of this increase of distance is flexibility, so as to allow of bending occurring between the rigid stays and the outer ring of tubes.

14. Were I responsible for the fire-boxes of the East Coast Railway compound engines, I would be disposed to try the effect, first, of using slightly bent tubes, the bend being upwards and to the extent of a semi-diameter, care being taken that the tubes did not touch; and, second, of removing at least one, and possibly two, of the front rows of vertical side stays; always, of course, assuming that it turns out that it is not the quality of the copper that is at fault.

FRANCIS J. E. SPRING, M.I.M.E.,
Senior Govt. Inspr. of Railways, Madras.

2nd Feb. 1898.

ORDER—No. 290 Ry., dated 21st February 1898.

Ordered that a copy of the above report be forwarded to the Government of India in continuation of G.O., No. 206 R., dated 4th February 1898.

[Here enter No. 291 Ry., dated 21st February 1898.]

(True Extract.)

FRANCIS J. E. SPRING,
Joint Secretary.

To the Consulting Engineer for Railways.
" Manager, East Coast Railway.

ENDORSEMENT—No. 291 Ry., dated 21st February 1898.

Forwarded.

(By order.)

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Exd. T. K. Narayana Aiyangar.

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Senior Govt. Insp. of Railways, Madras.

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