SV

INVESTIGATION

OF THE

CAUSES OF THE EXPLOSION

OF THE

LOCOMOTIVE ENGINE, "RICHMOND,"

NEAR READING, PA.

ON THE 2d SEPT. 1844,

MADE AT THE REQUEST OF

MESSRS. NORRIS, BROTHERS,

Locomotive Engine Builders, Philadelphia.

BY DIONYSIUS LARDNER,

Doctor of Civil Law—Fellow of the Royal Society of London—Consulting Civil Engineer, &c., &c.

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REPORT.

HAVING been applied to by Messrs. Norris, Brothers, locomotive engine builders, of Philadelphia, to investigate the circumstances attending the recent destruction of the engine "Richmond," which caused the loss of four lives and property amounting in value to nearly ten thousand dollars, and to ascertain, if possible, the causes of the catastrophe, I repaired to Philadelphia on the 20th, and Reading on the 21st Sept., visiting the spot on which the event occurred, and collecting the necessary information connected with it. The minutes of the information obtained, are given in full in the appendix to this report.

The engine "Richmond" was built for the Reading Railway Company by contract, and placed by Messrs. Norris on the road on the 14th August. A specification of this machine is given in appendix A. Its form, structure and material were of the usual kind, and similar, in all assential particulars, to other engines working on the same line. It was, however, supplied with two safety valves, each two inches in diamater, one being as usual placed on the dome of the fire box, immediately in front of the engine-man, and the other on the cylindrical part of the boiler, in front of the fire-box, and not within reach of the engine-man, while standing in his customary position.

It was agreed between Messrs. Norris and the company, that the engine should be run for sixty days on the railway, under the care of an engine-man appointed by Messrs. Norris, after which it was to be put in the hands of the company's engineer; but in order the better to prepare the latter for its efficient management, it was arranged that the company's engine-man, Joseph Ward, into whose charge the engine was finally to pass, should attend at Messrs. Norris' works, and assist in putting the engine together, and that he should accompany the engine-man of Messrs. Norris, in driving the engine during the above mentioned period of sixty days. When the engine was put on the road, on the 14th August, Jos. Ward accompanied Messrs. Norris' agent, but, after the second trip, the performance was found to be so satisfactory, that it was not considered necessary to continue the employment of the engineer of Messrs. Norris, and the engine was placed, without further trial, in the

charge of Joseph Ward, who continued to drive it from that time, until the epoch of the catastrophe by which it was destroyed.

Up to Saturday, the 31st August, inclusive, the engine had run between Pottsville and the depot at Richmond. A return of its performance has been supplied by the agents of the company, and will be found in appendix B.

On Monday, the 2d Sept., the engine started from the company's coal depot at Richmond, at eleven o'clock in the forenoon, taking a train of 88 wagons, the engine being driven by Joseph Ward, attended by Franklin Tye and Peter Mahon, as firemen, accompanied by James M'Cabe, as conductor, and Matthew Smith and Patrick Nugent, as brakesmen. At Norristown, about sixteen miles from Philadelphia, two additional brakesmen, Thomas Cowden and John Webster Powell, were taken up. The train arrived at Reading at a quarter past seven o'clock the same evening. It was detained there until ten minutes past eight o'clock, when it started for Pottsville, but before leaving the town, was again stopped and delayed about quarter of an hour, and finally left the crossing of the main street, Reading, at twenty-five minutes past eight precisely.

A storm of thunder, lightning and rain had commenced about sunset, and continued with unusual violence till a late hour at night. The lightning was frequent and vivid, and of the kind called zig-zag lightning. The peals of thunder were loud and hard, the sound being observed to follow the flash almost immediately. The danger was considered so great, that individuals who had been accustomed to the climate, feared to venture out, and it was said that such a thunder-burst had not been witnessed at Reading for twelve months past. It was in the midst of this storm that the train started from Reading. On arriving at a point of the road situated on a low embankment, two miles from Reading, a terrific explosion was heard from the head of the train; the cars were suddenly stopped; and the brakesmen on proceeding to the place of the engine, found the working part of the machine scattered in fragments about the road and on the slopes of the embankment; the tender was thrown over upon the wheels and broken carriage of the engine, and the boiler and its appendages had totally disappeared. The bodies of the firemen, Franklyn Tye and Peter Mahon, were found under the wagons killed by fractures of the head and body, and after further search, the body of the engineer was found in an adjacent field, about twenty yards on to the right of the place of the tender, with the head cut across the forehead and the leg crushed, being quite

dead. The body of Mr. M'Cabe, the conductor, was found, also dead, on the embankment at a point three hundred and thirty feet ahead of the tender, and the boiler, with the fire-box, smoke-box, chimney, and the two cylinders and pistons, was discovered lying in a field to the left of the road, at a distance of 250 feet from the place where the wheels and carriage of the engine lay. At a point in the field, about thirty feet nearer to the engine, a deep cavity was left, produced by the end of the boiler striking there, and rebounding from it to the place where it was found. The mass, which was thus projected to the distance of 250 feet from the spot where the explosion took place, weighed about ten tons.

The cylindrical part of the boiler and the smoke-box were uninjured. The funnel was lying near the boiler, and partly beneath it. The round end of the fire-box next the stand of the engine-man was flattened, so as to be crushed in and brought near the flue plate; the roof or crown piece of the fire-box was torn from the walls, the rent being generally above the angle, but in some places upon the angle at which it joins the walls or upright sides of the fire-box. The crown piece was found jammed in the fire-box between the part beaten in and the flue plate. The grate bars and ash pan were driven down upon the road with such force, that the latter took a very distinct print of the transverse wooden sleeper upon which it fell. The proper form of the crown piece is slightly concave at the lower surface, and it is secured by a series of strong cast iron stays, bolted to the upper surface, so as to aid in resisting the downward pressure of the steam. Its form, when found after the catastrophe, was at three of its four sides concave at the top, but at the fourth side concave at the bottom, the edge being curled downwards in a considerable degree. In the steam-casing surrounding the fire box were found three holes, about three inches diameter, the edges of which were turned inwards, *i. e.* towards the steam.

The working parts of the boiler, except the steam cylinders and pistons, which still remained attached to it, were broken into an extraordinary number of small fragments. The rods and other parts which had any considerable length, were twisted in the most irregular and capricious manner, and were scattered in every direction around the place where the event occurred.

The rails on which the engine was moving were forced from their support *outwards*. The adjacent line of rails, beside that on which the train moved, are represented to have been both cut through, as if

by the incision of a cold chisel. These rails, however, were none of them preserved by the agents of the company, and I could not obtain them for my own examination.

It appears that the engine started from the main street at twenty-five minutes past eight,* and the watch of James M'Cabe, the conductor, was stopped by the concussion at twenty minutes before nine. The interval, therefore, between the departure of the engine from Reading and the explosion of the boiler, was fifteen minutes.

Such being the general outline of the history of this catastrophe, it remains to consider what are the several modes in which it is possible to account for it; and it appears to me, that except some one of the following suppositions, there is no conceivable explanation of it.

FIRST SUPPOSITION.

That the fire generated steam faster than it was discharged through the cylinders or valves, and that an accumulation of elastic vapor was thereby collected in the boiler, having a pressure which augmented in the ratio of its accumulation, until at length this pressure became greater than the resisting power of the crown piece, which bursting downwards, caused the catastrophe.

SECOND SUPPOSITION.

That water was not supplied to the boiler as fast as it was consumed by the evaporation, and that thereby the crown piece and upper flues became uncovered; that, as a necessary consequence, these parts became overheated, and possibly even were rendered incandescent; that in this condition, water being thrown upon them, flashed suddenly into steam of enormous pressure and caused the catastrophe.

THIRD SUPPOSITION.

That the engine was stricken by lightning which broke it, tore the crown piece from the sides of the fire-box, and caused the catastrophe.

FOURTH SUPPOSITION.

That lightning passing on the boiler raised some part of it to a high temperature; that the water taking up the heat was rapidly evaporated, as it would have been by contact with highly heated or in-

* See evidence of Patrick Nugent, brakesman.

candescent metal; that steam of great volume and very extreme pressure being thus suddenly produced, the boiler yielded to the force, and the catastrophe took place.

THESE SUPPOSITIONS, including in my opinion every possible cause of the observed effects, I directed my inquiries to the discovery of such facts, as were likely to supply the means of either establishing them, or setting them aside. I shall examine them successively, and state distinctly the circumstances and reasoning which have led me to their rejection or adoption, as the case may be.

FIRST QUESTION.

Was the boiler exploded by the undue accumulation of steam within it by reason of the fire promoting the evaporation faster than the cylinders could carry off the steam?

It appears by the evidence of Thomas Yeager, engineer of the train immediately following the Richmond, that just before starting from Reading both safety valves were blowing off. It appears, also by the evidence of Thomas Cowden, brakesman, that the steam was blowing off at both valves just before the accident. It is evident, then, that both safety valves were free. According to the load carried by the engine, the steam which passed through the cylinder would have consumed water at the rate of about one cubic foot per minute. To admit the possibility of a large accumulation of steam in the boiler, it would then be necessary to suppose the evaporation to proceed at a much greater rate than would be sufficient to sustain this discharge through the cylinders and the two safety valves. Mr. Kirk, the foreman of the company, proved that while the engine stood for fifty minutes at Reading, the valves were not blowing off, which shows that no accumulation was then taking place.

That the material of the boiler would not yield to any ordinary pressure was proved by the most conclusive evidence. I caused pieces of the crown plate to be bent under the hammer, and doubled up, both hot and cold, and they showed all the signs of sound iron. I also caused pieces to be broken, which displayed at the fracture the usual appearance of the fibrous structure characterizing good iron. I also caused the crown piece to be examined by James J. Rush, Esq., engineer, of Philadelphia, and Mr. Simpson, master machinist to the railway company, whose opinions were in accordance with my own, and who declared that the explosion of the

boiler by the mere accumulation of steam within it by the ordinary action of the fire could not have happened.

If there were a tendency in the boiler to make steam faster than it was passing through the cylinder, it would be accompanied by an increased rate of speed in the train. It appears, on the contrary, by the evidence of two of the brakesmen, that the speed was not increasing at the time of the explosion, and that it did not exceed ten miles an hour.

My opinion is, that if the engineer had tried to produce this explosion by stimulating the fire to the utmost, the operation of the cylinder being free, and the two safety valves having play, he could not have done it.

The question must then be decided in the negative, and the first of the four suppositions must be rejected as involving consequences and requiring admissions which are physically impossible.

SECOND QUESTION.

Was the explosion caused by neglect or failure in feeding the boiler?

To judge rightly of this question, it will be necessary to attend to the routine of the duty of the engine man, and to consider the character of the driver of the engine which exploded, and the evidence as to the particular occasion on which this supposed neglect or failure occurred.

The boiler of a locomotive is fed with water by two force-pumps, which are wrought by the engine, and which drive the water from the tank or tender into the boiler. These pumps can be put in operation or suspended, at the discretion of the engine man. As the pumps are liable, from various causes, to get out of order, so that even when working they may not deliver water to the boiler, there is a cock provided in the feed pipe, called the "try cock," by which the engine man can ascertain whether the pumps, when in operation, are doing their duty. There are also several cocks placed at different heights on the boiler, called guage cocks, by opening which the engine man can at all times ascertain the depth of water in the boiler, and whether it may require feeding.

Proper attention to the feeding of the boiler is the first and most important duty of the engine man. It is a duty the neglect of which, he knows, must be invariably followed by an explosion, from the effects of which others engaged on the train may by possibility escape, but which must cost him his life. It is therefore a duty almost never neglected even by the worst engineers. The engine man exa-

mines, from time to time, the condition of the boiler by the guage cocks, and opens the feed pumps, so as to keep the level of the water to a proper height. There are particular occasions on which it is an invariable rule to fill the boiler. On approacing any chief station, where some delay is anticipated, the engine man ceases to supply fuel to the furnace, opens the fire door to check the combustion, and puts on the feed. By these means he arrives with a full boiler and low fire; the evaporation is suspended during the delay, and he starts again with a full boiler, the fire being restored to its activity before starting. But if the evaporation while he stands should boil down the water, he ascertains this by the guage cocks, detaches the engine and tender from the train, and runs for a short distance along the road, with the feed pumps on, so as to fill the boiler. Also, on approaching an ascending grade where, by reason of the increased resistance, a full power of steam becomes necessary, it is the custom to fill the boiler well just before coming to the foot of the grade, so that in ascending the pumps may be shut off, and the unimpeded evaporation used during the ascent. These are rules well understood by engine men, and which it may safely be assumed are never neglected by men of good character and tried habits.

By the evidence of all the witnesses connected with the Reading railway, Joseph Ward was one of the very best and most trustworthy engine men on the line. He was five years in the service of the company, and for the five preceding years was engaged by the Baltimore and Ohio and other companies, with all of whom he had the best character. Mr. Kirk, the foreman of the company at Reading, and Mr. Simpson, the master machinest at Richmond, both declare that they did not believe it possible that Ward could have neglected the feed pumps. It is also proved that his habits were sober in general, and that he was quite sober on the occasion in question.

But besides this general evidence, we have special proof. Powell, one of the brakesmen, saw Ward, before arriving at Reading, frequently try the guage cocks, and "saw that the boiler was well filled with water, and has no doubt that it was well filled with water, on arriving at Reading"—(see evidence) Cowden, the brakesman, "walked past the engine just before starting from Reading, and saw Ward try the guage cocks, and saw water coming from them." It is clear therefore, that on starting from Reading, the boiler was full. The explosion took place at the foot of the grade ascending at the rate of fifteen feet a mile. Ward would, therefore, as a matter of

course, keep his boiler filled until his arrival at that point, as it would be necessary, while ascending the grade, to cut off the feed. All these circumstances and proofs can leave no reasonable doubt that at the moment of the explosion the boiler was well filled with water.

But it may perhaps be said, that although the pumps were put on, they might have been obstructed so as not really to deliver the feed into the boiler. To this may be replied, that the engine man had at his hand the usual test, the try-cock, to which at all events he must have resorted. Mr. Simpson, the master machinest of the rail-road company, says that "on approaching Reading, Ward would have fed the boiler and ascertained the condition of the pumps by the try-cock, nor would he have proceeded from Reading if he did not find his pumps in working order." Mr. Kirk, the foreman at Reading, states, that "he has every reason for thinking that these precautions were taken on the present occasion."

With regard to the general efficiency of the feeding apparatus of the Richmond, the evidence of Mr. Simpson is most clear and conclusive. He says that Ward was his pupil—had been under him as fireman and was instructed by him in his business of engineman—that he was ten years acquainted with him—that as much from these long habits of intimacy as from the dictates of official duty, Ward must have communicated to him any defects which, from time to time, he might have found in the Richmond or any difficulties in working her—that during the whole time she was in his hands, he never made any such complaints—that he never mentioned an instance in which the pumps failed to deliver the feed, and that he, Simpson, does not believe that their action ever was imperfect. Simpson attended as usual on Sunday, the 1st September, at the depot to see the necessary repairs done to the engines intended to work on Monday—that the Richmond on that occasion required nothing to be supplied except a pin belonging to the half stroke which Ward himself replaced. That Ward said the engine drew Saturdays load (118 loaded wagons) easily, and had power to pull fifty wagons more without being strained.

If the water had been suffered to boil down so as to leave the crown piece and the upper flues uncovered, those parts must have been red hot or nearly so. The condition of copper tubes which have been red hot is easily recognized. Those in the boiler show none of the signs of having been overheated. The copper is neither reddened nor scaled nor rendered brittle. It has in short all the ap-

pearance of having been kept under water. None of the tubes have collapsed. The crown-piece of the fire place shows none of the indications of having been incandescent. Among other appearances against this, one seems to be absolutely conclusive—the soot still remains thick on the under side of the crown piece. Indeed I can positively pledge my judgment that neither the fire box nor the flues have been overheated.

I have caused these parts for the boiler to be examined by Mr. I. J. Rush and Mr. Simpson, each of whom concur generally in my views.

In reference to this point it is proper to observe here, that a rumor was prevalent that the explosion was produced by the imperfect action of the feed pumps. I traced this rumor to one of the brakesmen who was accordingly examined. It appeared that he was so unacquainted with the structure of a locomotive, that he was unable to point out the place of the feed pump on such a machine, and that when he saw the engineer, Joseph Ward, on Saturday, 30th September, repairing the pin of the half-stroke, he mistook that for the feed pump, and thereupon circulated the rumor that the pumps were imperfect, and hence the reported cause of the catastrophe.

I conceive then, that the above question must be decided in the negative, and that there is a body of evidence sufficiently clear and conclusive to warrant the rejection of the second supposition as untenable.

THIRD QUESTION.

Was the catastrophe of the 2nd September produced by the mere mechanical effects of lightning?

I think there are circumstances connected with the catastrophe which afford indications of the agency of steam or other elastic fluids so strong, that this question must be decided in the negative. The state of the crown piece of the fire place, the loud explosion, the direction in which the boiler was projected, and other circumstances needless to be particularised, form indications which can scarcely be mistaken.

FOURTH QUESTION.

Was the catastrophe produced by the combined agency of atmospheric electricity and steam?

The observation and researches of meteorologists have informed us in considerable detail of the various effects, mechanical, chemical and physical, produced on objects by atmospheric electricity. It is,

however, a matter of regret, that the result of their labors have been limited to the mere history of these effects. The mode in which they are brought about by electrical agency has not been conclusively established. Among the effects the most prominent are those produced upon the temperature of bodies ; that lightning fuses metals by raising their temperature, is proved by the fact, that metal fused by lightning has fallen in liquid drops upon a wooden floor, and upon the decks of vessels in which they have burnt holes. These effects have not been confined to masses of metal of limited dimension, nor have they been merely superficial, considerable masses have been on various occasions melted. When the lightning has not produced fusion, the iron has been rendered incandescent and soft, and reduced to the state necessary for welding it ; in a word, metals have been raised suddenly by atmospheric electricity to all conditions of temperature up to and including their points of fusion. Examples of these effects might be multiplied without end. In April, 1807, lightning passed along a large iron chain in Lancashire, in England, and so softened the links that by their own weight they were welded together, and the chain was converted into a rod of iron. The same effect was produced at different times in different places. In March, 1772, a bar of iron, four inches by half an inch thick, connected with a water pipe on the dome of St. Paul's Cathedral, was rendered red hot.

The mechanical effects of lightning consist in piercing solid bodies with holes, splitting them in pieces, bending and twisting them in various capricious forms, and in projecting their fragments, sometimes of enormous weight, to great distances. Buildings stricken by lightning, have produced a shock felt in their neighborhood like that of an earthquake ; the heaviest blocks composing their walls, being scattered in all directions, and projected to distances so great as two hundred feet. A church was stricken in Cornwall, from the roof of which, a stone weighing nearly 200 pounds was projected to a distance, 60 yards, another fragment being thrown to a distance of 400 yards. In another instance in Scotland a mass of rock, 28 feet long, 7 feet wide, and 5 feet thick, was raised in the air and projected over an eminence to a distance of fifty yards. Similar examples might easily be multiplied.

Large masses of iron are found to have a strong influence in attracting lightning, and this influence appears to be great in proporto its weight. Thus lightning passing outside the wall of a building, has been drawn through it by an iron boiler within. Some

years ago, a chain pier or bridge in England was destroyed during a violent storm, and although from its nature it was continued into the earth, it was broken to fragments, its heaviest parts were bent, doubled, twisted and knotted in most capricious forms, although no signs of fusion appeared upon it.

I have given these particulars in order to inform those not familiar with meteorological inquiries what are the actual effects which have been produced by the agency of atmospheric electricity; the question now is, whether this agency has been operative in the catastrophe before us.

It appears by the general evidence of the entire population around the vicinity of the catastrophe, as well as by the special evidence of the individuals who have been personally examined, that, at the time of this occurrence, a terrific storm of thunder and lightning raged; two of the men upon the train, who survived, prove that the flashes of lightning were incessant, both before and after the explosion, and that the lightning was of the species called "zig-gag lightning." It is proper here to observe that, of the different species of lightning, this is the kind by which terrestrial objects are generally stricken; this species never, (or if ever, very rarely) passes between cloud and cloud, but always between a cloud and the earth.

There seems to be then present all the conditions necessary for the production of such a phenomenon; the lightning is in continual play; it is of the kind necessary to produce the effect; 18 tons of iron, in the shape of a boiler and machinery, are present to attract it; there are abundance of disjunctions in this machinery, at least as decided as between the links of a heavy chain, by which conduction may be sufficiently broken to give full effect to the heating power of the electricity; finally this mass is broken to pieces, its parts being scattered about in all directions, broken, bent, and twisted, and projected in considerable masses to distances analogous to those recorded in similar cases. But granting the fact supposed, that lightning struck the boiler, how, it may be asked, can the explosion be explained?—for that an explosion did take place, seems extremely probable, if not morally certain. The character and loudness of the report, and the appearance of the remains of the fire-box, are sufficiently indicative of this. We answer that an explosion in the present case, with the cylinders in full operation, and the two safety valves free, could only be caused by an almost instantaneous evolution of a great volume of highly elastic fluid in the boiler—so great a volume that, compared with it, the steam escaping

through the cylinder, and valves would be as nothing. Such an effect would undoubtedly be produced by a sudden access of heat imparted to any part of the boiler in contact with water, or still more effectually if imparted immediately to the water itself. If, then, the electricity thus heated the boiler or any part of it, and that the water, as it might have done, took up the heat from the metal fast enough to prevent the latter from being fused, or rendered incandescent, the entire catastrophe, with all its concomitant circumstances, would be explained. The absence of marks of fusion or incandescence, the terrific violence of the explosion, the projection of a mass of ten tons to a distance of eighty yards, the fracture and scattering about of all the working parts, the bending and twisting of them in every conceivable variety of form, would all follow as the natural and usual effects of such agency. The freedom observed upon the bodies of the killed, from the effects of the lightning would be explained by the superior conducting power of the matter of the boiler, which according to its habit the lightning will seize by preference.

I pass over intentionally a supposition which might be made to the effect, that the water in the boiler might have been decomposed, and the catastrophe produced by its explosive constituents. The explanation we have given renders it unnecessary to resort to this extreme supposition, which certainly could not be supported by any reasoning which would entitle it to any degree of confident acceptatation, if indeed it be tenable at all.

Under all the circumstances of the case, I am therefore of the opinion, that the last supposition must be adopted as the only one which is adequate to the full explanation of this catastrophe. I do not forget that it may be urged that the boiler and its appendages were in metallic communication with the earth, and that during heavy rain, the soil itself was in a favorable condition for the escape of the electricity; but I know that in the structure of the boiler and its appendages, there were interruptions of the metallic continuity greater both in number and degree, than between the links of a chain, and other cases, in which it is proved that masses of iron have been rendered incandescent by lightning.

In fine, if my evidence were required on this point, in a casewhere the rights or liabilities of individuals rendered a positive decision of the question indispensable, I should not hesitate a moment to affirm that that decision must be made on the last of the above suppositions.

New York, Sept. 28, 1844. DION. LARDNER.

APPENDIX A.

SPECIFICATION OF THE LOCOMOTIVE ENGINE "RICHMOND."

Whole weight of engine, with wood and water, 36,925 lbs. Cylinders 14½ inches diameter, 20 inches stroke. The boiler contains 127 tubes 2 inches diameter, 4 tubes 1¾ inches diameter, in all 131 copper tubes 11 feet 8½ inches long. The waist of boiler is 40¾ inches diameter. The fire box 40½ inches wide, 40½ long, and 42½ inches in height, and presents a surface to the action of the fire of 48 square feet. Fire surface of the tubes 800 square feet.

The cylinders are attached to the outside of the boiler, and made fast to a frame extending the whole length of the boiler on each side, varying in thickness from 3 ⋈ 2½ inches to 4 ⋈ 2½. These frames are made fast to the boiler by lugs extending from the fire box end of boiler, and by braces extending from cylindrical part of boiler to the top of frame, secured by turned bolts of 1 inch in diameter.

The boiler, with its frames, cylinders, and all other machinery, rests upon an independent truck frame, constructed of the best faggotted iron 4 ⋈ 3 inches. In this independent frame are placed the 6 driving wheels, 46 inches diameter; the power is applied direct from the cylinders to the centre pair of wheels, and from them communicated to the forward and back wheels by means of coupling rods. On the dome of the boiler, immediately in front of the engineman, is placed a safety valve of 2 inches in diameter, with lever 25 inches long, fulcrum 2⅝ inches, with a spring balance attached of 48 lbs. graduation. A second safety valve, of the same dimensions, is placed on the cylindrical part of boiler, not within reach of the engineman while standing on the platform.

The fire box is constructed of the best quality iron, 5-16 thick, the crown of which is supported by 8 cast iron stay bars, arched in the centre, and extending to each side of fire box; these bars are 4 inches deep by 1¼ thick, and secured to the crown sheet by 1 inch bolts.

APPENDIX B.

Statement of the miles run, and work done by the "Richmond," to the day she blew up, inclusive.

No. of miles run	997
No. of tons hauled one mile, (cars and freight,)	368,631
Average weight of down trains do do through,	605
do do up do (empty cars alone) do	232

All tons of 2000 lbs.

G. A. NICOLLS, *Superintendent.*

APPENDIX C.

Patrick Nugent, Brakesman.—Informant was one of the brakesmen who attended the train drawn by the engine "Richmond" on Monday, 2d September. Started from the Richmond depot near Philadelphia at about eleven o'clock in the forenoon. The men with the train, besides informant, were James McCabe, conductor, Joseph Ward, engineer, Franklin Tye and Peter Mahon, firemen, and three other brakesmen. Arrived at Reading at about a quarter past seven o'clock. Informant looked at his watch at the moment the train passed the main street on leaving Reading, and observed that the time was twenty-five minutes past eight. The train had started from the depot at ten minutes past eight, but was stopped to shift some of the cars before arriving at the main street, which caused the delay of about fifteen minutes. From the time of passing the main street until the occurrence of the catastrophe the train did not stop. A storm of rain, with thunder and lightning, commenced at sunset and continued till after the accident. The flashes of lightning were constant, and accompanied by loud claps of thunder, both before and after the accident. The train consisted of 88 empty wagons, about 30 of which were iron and the remainder wood. The iron wagons were intermixed, without any particular order, with the wooden ones. The load was under rather than over the usual amount. The same engine usually took above one hundred wagons. The weight of the wooden wagons is about two tons, 3 cwt.; that of the iron two tons, 9 cwt. Informant was sitting in a wagon at some distance from the head of the train; the other brakesmen were at different distances between him and the end of the train. Informant was looking towards the side of the road, his head being level with the top of the side of the wagon, so that he could just look over it. He heard the loud report which attended the catastrophe, but did not look towards the engine. The wagon in which he sat sustained a slight shock from the sudden stop, by which he was thrown forwards, but not with violence, or so as to hurt him. The report was like that of a cannon, or the blast of a rock by gunpowder. The speed of the train at the time did not exceed thirteen and a half miles an hour. Being much frightened he leaped off the side of the wagon and ran down the slope of the embankment. On collecting himself he immediately returned to the wagons and called to the other brakesmen for a light. He sent one of them back to warn the following train against proceeding, and went forward to see the cause of the accident. He found the body of the fireman, Franklin Tye, lying under the wagons, between the rails, at a distance of about fifty feet behind the tender; his trowsers were drawn down about his feet; his flannel shirt was gathered round his head and neck, and his body stripped naked; his head was cut and his skull fractured. Informant drew out the body and laid it between the tracks, the railway being at this place a double line. Informant then went forward to the tender and there found the body of the other fireman, Peter Mahon, squeezed between the brake and the wheels, so that it could not be removed. When addressed by his name he moaned twice. Informant found the wheels, and some scattered fragments of the working machinery on the road, and on the slopes of the embankment in front of the tender. He descended the slope of the embankment on the right of the road, and found the body of Joseph Ward, the engineer, lying in the adjacent field beyond the wooden paling which forms the fence of the railway, and which is carried along the foot of the slope of the embankment parallel to the railway; this fence is about five feet high. The forehead of Ward was cut across, and one of his legs smashed. A farmer (Daniel Scheppe) now came up from ahead with a lantern, and told informant that the body of the conductor (James McCabe) was lying at a considerable distance ahead on the slope of the embankment; went forward and found it at a distance of three hundred feet ahead of the place where the explosion took place; it lay with the feet to the road, and the head downwards, quite dead, but with no external appearance of violence; informant raised the body and placed it on the road beside the rails. During all this time the rain continued falling. Informant was so overcome with fright and agitation that he returned to the tank and lifted up the water in the hollow of his hand to cool his lips. The distance from Reading at

which the accident occurred was two miles. Informant took the watch out of the pocket of McCabe, and found that it had stopped at twenty minutes before nine; one of the hands was bent.

APPENDIX D.

Mr. Kirk, Foreman of the Works of the Railway Company at Reading.—Informant states that Joseph Ward was one of the most efficient engineers, and one of the best conducted men on the road; that he had been five years in the Company's employ and enjoyed their full confidence; that his habits were sober and regular, and that on the present occasion he was perfectly sober. Informant says, that when an engine is approaching a chief station where some delay is expected, it is usual to open the fire door to check the furnace, and to open the feed pumps, so as to arrive with a full boiler, and not to put wood on the fire, that no unnecessary evaporation may be produced; that he has every reason for thinking that these precautions were taken on the present occasion. The engine stood for about fifty minutes at Reading, during the chief part of which time no steam was blowing off at the valves. Had not the boiler been just fed, or the fire let down, steam would have been blowing off. On receiving information of the accident informant collected a body of men, and prepared an engine and train of cars, and proceeded to the place of the accident, bringing with him two physicians, Drs. Marshall and Nagle; that he found matters there as described by Nugent; that the boiler, with the cylinders, fire box, and smoke box attached to it, were found lying in a field at the left of the road, and beyond the wooden paling; that the place of the boiler was two hundred and twenty feet ahead of the spot where the accident occurred; that at a point about thirty feet nearer the train, a deep cavity was made in the ground, such as might have been produced by the end of the boiler striking there and rebounding; that the fire box, which in its proper form is semicircular, was flattened, the crown piece being torn from the upright walls and from the flue plate; that these appearances suggested that the boiler first lighted on the ground upon the end or corner of the fire box; that the latter was bent in and flattened by the concussion, and that the boiler rebounded, and finally fell with the bottom nearly upwards, the smoke funnel being thrown partly under it; that the piston rods were bent like wax and broken off; that the fragments of the working machinery were scattered in all directions around the spot where the accident occurred, many heavy pieces being thrown to considerable distances in the adjacent fields; that the engine was supported on three pair of wheels, which supported a strong iron frame on which the boiler and machinery rested; that the wheels and frame remained on the road where the accident occurred, but not on the rails; that the ash pan was found resting on the wooden sleeper, on which it fell when the accident happened; that it seemed to have been drawn down with such force that it took a distinct form of the sleeper, which it still retains; that the fire door was found in the adjacent field near the body of Ward, the engineer; that the body of Ward appeared to have struck the ground with such force as to have imbedded itself to some depth in the earth, leaving a hollow print which still remains; that the rails on which the engine exploded were bent outwards and driven off their supports; that the rails of the adjacent line were broken; that these rails have not been preserved.

APPENDIX E.

John Webster Powell and Thomas Cowden.—On second September got on the train at Norristown about sixteen miles from Philadelphia, at request of McCabe the conductor; storm began about two miles from Reading; day was fair until then; train did not stop on the way to Reading for any purpose except for wood and water; did not hear, and do not believe that any thing was

the matter with the feed pumps; were acquainted with Ward for several weeks; Ward was, to the best of informants' knowledge and information, a sober, well-conducted man; arrived at Reading at a quarter past seven, left at ten minutes past eight; storm continued with thunder and lightning. Between Norristown and Reading, Powell saw the guage cocks frequently tried, and saw that the boiler was well filled with water; has no doubt that the boiler was well filled with water on arriving at Reading. Cowden walked past the engine just before starting from Reading, and saw Ward try the guage cocks, and saw water coming from them; is not certain which of the cocks he tried, but has no doubt that as usual he tried them all. Ward was at the time perfectly sober. After leaving the depot the lightning was frequent and vivid, the flashes succeeding each other rapidly, and the thunder hard and loud; the thunder followed the flash after a second. Both agree that the lightning was zig-zag lightning. Cowden was upon the fourth or fifth car from the last; Powell about twenty-five cars in advance of Cowden; Nugent and Smith were both ahead of Powell; Powell was astride on the edge of the wagon, with his face to the engine; Cowden was sitting on the back of a car, with his face towards the engine. There were some indications of the wheels slipping by the sound of the blast pipes; observed nothing in the sound of the blast pipe to suggest the idea of there being too much steam in the boiler. Both agree that the speed was not greater than ten miles an hour; the speed was not on the increase at the time of the accident. Cowden thinks that between the explosion and the nearest flash there was a short, but distinguishable interval; Powell thinks that the interval was so short as to be barely distinguishable. Powell was thrown down in the car by the explosion; Cowden did not feel it, and immediately acted on the brake. The sound of the explosion was louder than any cannon they ever heard; was like the heavy blast of a rock. Cowden went back to stop the approaching train; Powell went forward with a lamp and met Nugent, to whom he said, "What in God's name has happened?" Nugent answered, "that the engine was struck with lightning, and all hands were killed." The wheels of the engine were on the road, but aft the rails; the tank was pushed over the wheels; the working machinery of the engine was scattered in every direction round; some fragments were scattered on the slopes of the embankment; the rails of the adjacent track were broken as if they were cut by a chisel.

On the minutes of the evidence given before the coroner being read to Cowden, he says that there is a mistake in it; that he was not on the car next the engine. Cowden repeats that the engine was blowing off at both valves. Before arriving at Reading McCabe sat on the sand box, but witnesses do not know where he sat after he left Reading. Cowden says, that what he told the coroner was, that there was a *full* head of steam on, and not a *great* head, and that by this expression he did not intend to imply that there was any undue quantity.

APPENDIX F.

Simpson, Master Machinist to the Reading Railway Company.—Knew Joseph Ward for ten years; considers that he was an unexceptionable engineer; he was taught by informant his business as an engineer, having acted as fireman under informant on the Baltimore and Ohio railway. Was in the employment of the Company about five years; informant was also there during the same time. Is sure, from Ward's character, that he would not have pushed on without water. If the pumps were out of order Ward would have told informant, as it was his duty to do. On Saturday, the 31st August, Ward came down from Reading with one hundred and eighteen wagons, drawn by the Richmond; on arriving at the Richmond depot he made no report of defective pumps; never heard from Ward that he was obliged to stop on Saturday to clear his pumps; never heard him on any occasion complain of the pumps. Informant attends on Sunday at the depot to see necessary repairs done. On Sunday, 1st September, nothing was required to be done to the Richmond except a pin belonging to the half stroke, which Ward himself replaced. Ward said that the engine drew Saturday's load easily, and had power to pull fifty more wagons without

being strained. On approaching Reading, Ward would have fed the boiler, and ascertained the condition of the pumps by the try cock; nor would he have proceeded from Reading if he did not find his pumps in working order. On approaching the grade of fifteen feet he would have been careful to fill his boiler, it being usual to cut off the feed in ascending. Informant has examined the remains of the boiler, and particularly the crown sheet, flues and feed pumps; the iron appears to have been good, and the workmanship efficient. There is no appearance of being overheated either on the crown plate, the flue tubes, or any other part of the boiler or fire box; none of the tubes are collapsed. Thinks that the explosion could not be produced by the gradual accumulation of steam between Reading and the place of explosion. Never observed that the crown sheet of the fire-place of the Richmond had sunk before second September; if it had sunk it would have been Ward's duty to call informant's attention to it, and informant is sure, from Ward's character, and from their general intimacy and daily intercourse, that he would have done so. Does not believe that the crown sheet had sunk before the accident.

APPENDIX G.

James J. Rush, Engineer.—Has examined the remains of the boiler and machinery of the engine Richmond, which exploded on the Reading railway on the second September, and says that the iron in the boiler is sound and good, and the workmanship efficient; the feed pumps are constructed as usual in such machines, and seem to have been in working order at the time of the accident. The boiler was constructed in the form usual in these machines, and was subject to no objection on the score of its construction, which locomotives in general are not liable to.

APPENDIX H.

Dr. Marshall.—Was requested by the agents of the railway to go to the place of the accident. Gives the same account substantially of the condition of the bodies as Dr. Nagle. Informant questioned the brakesmen on the spot as to the circumstances of the explosion. One of them stated that he saw a flash of zig-zag lightning strike upon the boiler instantly before the explosion. Being again questioned on this after returning to Reading he distinctly repeated it, and was confirmed in it by another brakesman. Dr. M. says it was the worst burst of thunder and lightning which occurred for the last twelve months.

APPENDIX I.

Mr. Weber, Schoolmaster.—Resides in the basement of the church, less than half a mile from the place of the accident. Heard the noise of the cars approaching, and looked out from the porch and saw the engine by its sparks. Does not understand engineering, nor the construction or operation of a locomotive, but thought that the engine was laboring; cannot tell exactly what he means by its laboring. Said to his wife at the time that the engine would blow up, and almost immediately it exploded. Was looking towards it at the time, and although the flashes of lightning were frequent immediately before and after the explosion, he saw no flash at the moment of the explosion. The explosion was attended with a terrific noise; it shook the church so that the casements rattled; thinks the report might have been heard twenty miles off; accounts for its not being heard generally at Reading by the continual rolling of thunder at the time. His wife would not let him go out to see the effects of the accident until the storm abated, fearing that he would be struck with lightning.

APPENDIX K.

Thomas Yeager, Engineer in the service of the Reading Railway Company.—States that he drove the engine of the train which followed the Richmond on the night of the second September; that he started from Reading about ten minutes after the departure of the Richmond; that the storm was then at its height; that the flashes of lightning were constant and vivid; that soon after he started he felt an unusual shock, proceeding from a sudden jolt of the engine, as if the wheels had passed over some obstruction on the railway; that he imagined that the time of this shock corresponded with that of the explosion of the Richmond; that the rain was falling heavily, when soon after he saw a light waving ahead and immediately stopped; he learned from the brakesman who carried the light the accident; he then went on till he came up with the train drawn by the Richmond. Describes the state of the train, and the bodies, in the same manner as the other witnesses. Is positive that at the moment of starting from Reading the Richmond was blowing off steam at both valves; did not observe that she foamed or primed.

APPENDIX L.

Edward Caldwell, Boiler Maker.—Forged the crown sheet of the boiler of the Richmond. When he made the bends of the guage of the crown sheet found the iron sound. It is the custom, if found not sound, to put it aside; bent the angles hot. He was careful not to gall the corners by turning them too square. Is quite sure that there was no defect in the iron, or construction of the crown plate; iron was as usual 5-16 inch thick.

APPENDIX M.

Dr Nagle.—Is physician to the coroner. Was requested to go out to the place of the accident; did go, and saw the bodies. The conductor, James McCabe, was thrown to a distance of one hundred yards ahead; his skin was uninjured; his breast-bone and ribs of left side were broken by the fall, which was the cause of death. The engineer, Joseph Ward, lay in the adjacent field; had a deep cut across the forehead, and one of the legs crushed and broken; was dead. The fireman, Franklin Tye, had the skull fractured, and brain exposed and protruding. The fireman, Peter Mahon, had the spine broken. One of the brakesmen told him that he saw a flash of lightning at the time of the explosion, and all parties said that lightning was playing around the engine at the time.

APPENDIX N.

G. A. Nicolls, Esq., Superintendent of the Company's Works at Reading.—States that the rails at the place of the accident are the T rail, weighing fifty-two and a half pounds per yard, three and a half inch high, and three and a half inch wide at the base; are laid upon transverse wooden sleepers, eight inches wide, seven inches deep, and seven feet long; guage four feet eight and a half inches; rails spiked to the sleepers, except at the joints, where they are supported by cast iron chains, weighing twelve pounds each; the chains are spiked to the sleepers; the ends of the rails are bolted to the chain; a space of an eighth of an inch is allowed between the ends of the rails for expansion. The timber of the sleepers is white oak, and have been laid three years. The material of the embankment on which the accident took place is common earth mixed with loose limestone rock; height of embankment about ten feet.

APPENDIX O.

Mr. Huyster, a gentleman residing near the place of the accident.—States that the position of his house is about a quarter of a mile from the spot, and a little in advance of it, being distant in a direct line, at right angles, from the railway about a quarter of a mile. The storm began about sunset and continued till a late hour at night. The flashes of lightning and claps of thunder took place continually in rapid succession; the sound and the flash were almost simultaneous; the flashes were unusually vivid; the rain fell all the time. About half past eight, as informant and his wife were sitting at a table on which a lamp stood, a report was heard so violent as to shake the table; he thought that the house or barn had been struck. Just before this report the noise of the cars had been heard approaching, and his wife conjectured that the report proceeded from the railway, and that something had happened there. It afterwards appeared that this report was the explosion of the engine.

APPENDIX P.

Matthew Smith, Brakesman.—Informant is in the employment of the Reading Railway Company; was for eight days engaged with trains drawn by the "Richmond." On Saturday, 31st August, was with the train drawn by that engine from Reading to Philadelphia. Within eight miles of the Richmond depot (at Philadelphia) the train was stopped on that day, and Ward, the engineer, worked at the feed pumps. Informant, on being asked the part of the pumps at which Ward worked, could not name them, and was unable to show where, on an engine, the pumps were placed, or to point out the different parts of an engine. Informant accompanied the train as brakesman on Monday morning, second September. Ward did not work at the pumps on that trip; only stopped at the regular watering stations; left Reading with the train at a quarter past eight, P. M.; was stationed in a car about the 25th from the engine; stood with his face to the engine; saw no lightning after leaving Reading. The explosion was like the report of a cannon; jumped from the cars, and in so doing fell and rolled down the embankment; got up and saw Patrick Nugent, who said that he believed they were all killed; went up the road; found the two firemen lying dead under the cars.

APPENDIX Q.

PLAN OF GROUND ON THE PHILADELPHIA AND READING RAILROAD. WHERE " RICHMOND" ENGINE EXPLODED, SEPTEMBER 2, 1844.

X. Spot where Engine Exploded
a. Spot where Engine Lodged
c. Body of Engineer
d. Body of Fireman
Grade, 6 ft. per Mile ascending

b. Body of Fireman
e. Body of Conductor
Embankment at A. 11 ft. high
Do. at X, 5 do
Line. Straight