In addition to driver McArthur's estimate, there is the statement of guard Hutchinson, to the effect that the speed on this occasion was not higher than customary, *i.e.*, 20 to 25 miles an hour. But in view of the above figures, and of the damage resultant to permanent way from the derailment, I have no doubt that the speed was really much higher. There is no speed restriction on the branch, and consequently there was no reason why drivers should not run as fast as may be necessary to keep time. It will be seen that the train was a minute or two late in starting from Roslin.

There is one other point to notice—the tank engine was running with the four coupled wheels leading and the bogie trailing. The oscillation is always greater with the coupled wheels in this position, and is further accentuated when descending gradients, or by any considerable speed.

After full consideration of all the available evidence, I am of opinion that the derailment was mainly due to the train running with coupled wheels leading at a speed higher than is desirable for safety, and possibly higher than the superelevation on the curve justified.

I have, &c.,
J. W. Pringle,
Major.

APPENDIX

Damage to Rolling Stock.

Engine No. 104.—Bogie frame and stay rod bent; bogie horn block broken; bogie centre broken; smoke box door and front plate damaged; left side of cab damaged; hand rails bent; left side tank cleading damaged; footplate and angle irons damaged; tallow cock broken; left piston head broken; brake shaft bent and brake gearing damaged; air brake tank damaged; footstep broken; rail guards broken; injector pipes bent and tank lid broken.

Brake third No. 1145.—One projection damaged; one coupling screw broken; one step board damaged; two step boards destroyed; three end panels destroyed; one buffer rod bent; one buffer casting broken; four step hangers destroyed and roof slightly damaged.

Third No. 1497.—One end badly damaged; one buffer rod bent; one end step destroyed; one body glass broken; one step board damaged.

First No. 12.—Top footboard damaged and two buffer rods bent.

Damage to Permanent Way.

113 sleepers broken; 8 rails broken; 79 keys broken; 80 spikes broken; 31 chairs broken.

Printed copies of the above Report were sent to the Company on the 13th August.

SOUTH-EASTERN AND CHATHAM RAILWAY.

Board of Trade, Railway Department,
8, Richmond Terrace, Whitehall, S.W.
12th October, 1912.

Sir,

I have the honour to report, for the information of the Board of Trade, in compliance with the Order of the 10th May, the result of the inquiry which I have held, in conjunction with Mr. Thomas Carlton, Assistant to the Engineer-Surveyor-in-Chief, Consultative Branch, Marine Department, Board of Trade, into the cause of the explosion, which occurred on the 29th April, about 6.3 a.m., on an engine near Tunbridge Wells, on the South-Eastern and Chatham Railway.

A train of empty carriages left Tonbridge Station at 5.53 a.m., and had travelled to a point about 1½ miles from Tunbridge Wells Station, when the firebox roof of the engine collapsed, under pressure of steam in the boiler. Both enginemen were driven or blown off the footplate by the irruption of steam and boiling water. In addition to suffering from scalds and burns, the men were seriously injured by their fall on to the ballast. The fireman was not sufficiently recovered to leave the hospital for over four months, and the driver, though otherwise now in good health, has completely lost his memory with regard to all the circumstances attending the accident.

The train consisted of engine and tender No. 216 (4–4–0 type and six-wheeled tender) running tender first, and four bogie coaches. The vacuum automatic brake was fitted throughout the train, with blocks upon the four coupled engine wheels, and upon all the wheels of the coaching stock and tender.

No damage resulted except to the engine. The train was brought to a standstill by the fracture of the vacuum pipe between engine and tender.

The distance from Tonbridge to Tunbridge Wells is about 5 miles. The gradients on the section of the down road (3½ miles long) traversed by the train prior to the explosion are all rising, with inclinations varying from 1 in 53 to 1 in 100. There is one tunnel with a length of 410 yards immediately outside Tonbridge; the remainder of the railway is mainly in cutting, and the curvature is considerable.

Evidence.

Frederick Charles Blunden, passenger guard, states: I have about 22 years service with the company, and have been guard about 15 years. I came on duty on the 29th April at 5.20 a.m., and ordinarily would book off at 3.45 p.m. I was guard of the 6.50 a.m. passenger train Tunbridge Wells to Tonbridge. I left Tonbridge with the empties for this train at 5.53 a.m. The train was made up as follows:—1 bogie first, bogie brake third, bogie tri-composite, and bogie composite, all 8-wheeled bogie stock. The coaches were fitted throughout with the vacuum automatic brake, blocks upon all wheels. I spoke to the driver, Daniel Kadwell, and also to the fireman, Henry Pilcher, at Tonbridge, before leaving. I have known both these men for a long time. I said nothing more to them than the usual "Good morning." They said nothing more to me than the usual morning remarks. The load, four bogies, is quite a light one. The engine was running tender in front. I cannot say whether the enginemen had been on duty for any length of time previous to this journey. There was no one else on the train except the two enginemen and myself. I was riding in the rear bogie brake third vehicle. As a rule, the train starts from the down main line at Tonbridge, but on this morning we were in the platform road. After putting my bag, lamp, and flags in the brake, I walked up to the engine, and spoke to the men as related. I just got through the footplate, and got off on to the offside, to see that everything was right on that side of the train. There was nothing unusual in the condition of either of the men. Both were perfectly sober. The train stood at the platform 8 or 10 minutes before starting. The train started, and nothing of any particular note occurred until a sudden stoppage took place owing to the brake being applied. This was midway between Tunbridge Wells Gas Siding and Tunbridge Wells stop-signal. The speed would be about as much as usual, 12 to 15 miles an hour, I should say. The time occupied from the time of starting from Tonbridge until we stopped, was 10 minutes. We left at 5.53 a.m., and stopped dead at 6.3 a.m. After stopping, I jumped from my seat and tried to open the window to look out, but it jammed. At last, when I managed to open the window, I looked out and saw the fireman lying on the up four-foot alongside the brake van. When I was standing raising the window, I heard the sound of an explosion and saw the steam rise. The noise did not sound very great to me at the end of the train, shut into the carriage. The brake had been applied presumably, and the train was actually coming to a stand, and was on the point of stopping, when the explosion took place. When the brake was first applied, I looked out over the top of the brake, thinking there was a signal at danger, but the signal I saw was clear. When I first saw the fireman lying in the up four-foot way I thought it was a platelayer. As soon as I got out, I found out who it was. He was not insensible when I came to him. He said "Look mate, my leg is broken." I told him to lie quite still, and I would see that he was taken care of. I then went back into the brake van and screwed down the hand brake, and chained it up. I then got down and went to the engine, and shouted for the driver. I got no reply, and when I looked round, I found him lying on his back on the down side of the road, between the hedge and the train, three bogies down. I went round the front of the engine and tender before I found him. I thought he was dead, from the man's appearance, and so I did not go to him, but went to Tunbridge Wells to get assistance. From the position of the men on the ballast, I think it was clear that they were either blown off the footplate, or jumped off the footplate, whichever happened, before the explosion took place which I heard in my van. I was looking out of the right-hand carriage window on the journey between Tonbridge and Tunbridge Wells, and after we had run about a mile in the open, between the tunnels, where the line is on a right-hand curve, I caught sight of the fireman's movements on the footplate. I could see enough of him to know that he was using his feeder. I could see the water drop out of the drain pipe outside the engine, presumably when the injector was applied, and afterwards steam issuing from the same pipe when the water had been sucked up. I saw the same thing as we were going over the viaduct about 2½ miles from Tonbridge Station. I am perfectly certain, therefore, that at least on two occasions the enginemen were feeding water into the boiler, through the injector, after leaving Tonbridge Station. There was 18 inches of vacuum in the gauge in my van. I noticed there was this amount passing Southborough Station, and there was no diminution in the amount of vacuum until we passed the Gas Siding, near Tunbridge Wells, when the brake was applied, presumably. The application did not appear to me to be of the same description as is made by a driver when he stops a train at a station or signal, or even for emergency purposes. The needle went gradually round from 18 inches until it reached the zero point, where it stopped dead. The movement of the needle in the vacuum gauge took place before the explosion that I have spoken of. When we came back from Tunbridge Wells, with assistance, and picked up the fireman, we went over to the driver, and found him just recovering consciousness, but he was in a stupid sort of condition, and was not able to give any account of himself. The fireman made no other statement when we picked him up. I work this empty train into Tunbridge Wells, one week in 13. The usual time for these empty trains to occupy between Tonbridge and Tunbridge Wells, is 12 to 13 minutes. This morning there was no difference in the time occupied. Ten minutes had elapsed when the explosion took place. The explosion occurred about a mile from Tunbridge Wells Station. I am well enough acquainted with locomotives to know the position and the necessary movements for applying the steam feed.

Henry Pilcher, fireman, states: I have about 10 years service with the Company, and have been fireman for 2¾ years. I came on duty on the 29th April at 4.30 a.m., and would ordinarily book off duty at 2.15 p.m. I was off duty on the day previous.

I went to the loco. depôt at 4.30 a.m. to get engine No. 216 ready. The first thing I do is to look at the water and the fire, and get the oil out. The boiler was then full right up. I could not get any more water in. She had 75 to 80 lbs. steam pressure at the time. The engine was blowing off at full pressure of 170 lbs. when we left Tonbridge Station. I was not on No. 216 the day previous, but I knew the engine, and had previously often fired on her. I started by blowing out the two water ganges. I remarked to my mate how full the boiler was. We do not like them as full as that. It was impossible to get a drop more water into her. I had the injector on twice during the journey. We came out of the loco. yard about 5.15, to fetch the carriages from the Jubilee Sidings. Whilst we were up at the Jubilee Sidings, I used the injector to feed more water into the boiler. We did two shunts up at the Jubileo Sidings, and it was probably 5.45 before we arrived at the down platform at Tonbridge Station. When we left Tonbridge Station, she was so full up with water, that I had to open the cocks. She was throwing water out when the regulator was opened. We were running tender first on this morning. After getting through the tunnel, about a mile distant, I used the injector to put more water into her. I used the injector a second time about 2¼ miles from Tonbridge. It was about a mile to 1½ miles beyond this point, that the explosion took place. The fire-hole door was open about two inches when the explosion occurred. A large volume of steam and water came out, and coal came out of the fire-box door, and I was blown, or pushed, I do not know exactly what happened, off the footplate. So far as I know, the brake was not applied by the driver. The failure of steam would automatically cause the vacuum brake to be applied. The train would stop of her own accord. I am quite satisfied, in my own mind, that the top of the fire-box was never exposed to the heat of the fire, without being covered with water on the journey. There was no leak in the tubes and no leak in the fire-box before we started, and with the amount of water in the boiler, it was impossible, in my opinion, that the top of the fire-box could have been exposed. The water was bobbing in the top of the glass on the second occasion that I used the injector. When I stopped injecting, about half a mile from the place where the explosion occurred, the water was out of sight. After closing the injector, the water was above the glass, and before the explosion occurred, the water came into sight again. There was about three-quarter glass, that is the water was about 1¼ inches from the top of the glass. We had no warning of anything being wrong, the first sign being the rush of steam. I was not firing when the explosion occurred, but had fired just previously. We had been going steadily all this time. I noticed no difference in the working of the engine on this date. I test the gauges by blowing them out. I blow the tail cock out first, empty the water out of the glass, shut the other two off, then shut the tail cock again, and afterwards empty the glass right out, gradually push the others up, and allow the water to come down into the glass again.

Daniel Kadwell, driver, states: I have about 21 years service with the Company, and have been a driver for three years. I do not recollect what time I came on duty on the 29th April. I was off duty on the Sunday (the day previous). I have no recollection of what occurred at any time before or after the accident on the 29th, and can make no statement, therefore, as to the circumstances attending the accident. I have driven engine No. 216 prior to this occasion. I experienced no difficulties on the previous occasions that I have driven her. I did not drive her on Saturday, the 27th. I can recollect going to bed on the Sunday night previous, and have no knowledge of what occurred between that time, and when I woke up and found myself in Tonbridge Hospital, about 10 days afterwards.

Aaron Chantler, driver, states: I have about 31 years service with the Company, and have been about 14 years driver. I drove engine No. 216, on the Saturday, 27th April. I drove her from Red Hill to London, and from London to Tonbridge *viâ* Red Hill. I was on the footplate about 8½ hours. The engine went into the shed after I had finished my turn of duty, about 10 p.m. so far as I can remember. I noticed nothing particular about the working of the engine, only that should I work her heavily, she has a tendency to lift the water through the cylinders. This only happened when working the engine heavily. On this occasion she began to lift the water, and I at once checked her. I reported that the water should be changed, so that the man would have no difficulty the next day. She was never short of water during the run, I saw it all the time. There was no leakage whatever in the firebox, everything being perfectly in order so far as I could see or hear. The boiler would not have held water, in the condition in which it was after the explosion. Before I left the engine on the Saturday night, the fire was drawn out, and I looked inside the firebox, and there was no sign of leakage whatever, and no water coming from anywhere.

Joseph Salman, fireman, states: I have about 15 years' service with the Company, and have been firing 10 years. I was with driver Chantler on the 27th April on engine No. 216. There was no sign whatever of any leakage, and nothing whatever in the firebox when the fire was drawn out. I attended to the water in the boiler during that run. She was all right from Red Hill to London, and running with about ¾ glass of water in the boiler she began to throw the water out, but not much to speak of. Steam was checked which stopped the throwing out of the water. I did not lose sight of the water at all. With the injector on I could get 3 to 4 inches of water into the boiler in about 2 minutes. It would take about 3 minutes to lose the 4 inches of water running up a bank. I should not use the injector between Tonbridge and Tunbridge Wells more than twice with a load equal to 10 vehicles on. I use the injector for about 4 minutes at a time then wait about 2 minutes before using it again. I should put the injector on before getting to the tunnel and keep it on until I got to the Viaduct. I should take the injector off about a minute before getting to Tunbridge Wells.

George Gregson, locomotive foreman at Tonbridge, states: Engine No. 216 has been in the Tonbridge depôt since July, 1911. She came from Ashford Works after being repaired. I did not examine the engine between Saturday, 27th, night and Monday morning. I saw the note in the Report Book that she was priming slightly, and gave instructions to firelighter Killick to change the water. Her last "shed-day" was 22nd April and the boilermaker then examined her boiler and firebox. There was no report of any leakage in the firebox of this engine for some months previous to the explosion. I made an examination of the engine when it arrived back from Tunbridge Wells. Nothing was done to the fittings before the engine was sent to Ashford.

I got inside the firebox and it appeared to have been burned, having been short of water, shewing a mark where the water had been. I have seen fireboxes overheated and bulged at the top before. In my opinion, if the boiler had been short of water before, or on the 27th April, and was in such a condition that it burst in the manner it did, it would have been leaking. I have found roof stays leaking with a slight bulge. We had a case about 3 months previously, the bulging was not very great but the leakage was considerable. I saw a distinct line round the firebox of the engine, giving me the opinion that the boiler had been short of water. I think the boiler was damaged after steam was got up on the last occasion—the stay-nuts had every appearance of having been very hot. I have never seen nuts stripped and pulled right through before. The fusible plugs are renewed about every 3 months. If they leak they are renewed at an earlier moment. Personally, I do not think they are of much value. When engines are running tender first I do not think the driver or fireman would hear the escape of steam through the fusible plug hole. The fusible plug in this case was last renewed on the 11th February, 1912. There was half a tank of water in the tender after the explosion.

William Killick, firelighter, stationed at Tonbridge, states: I have been in the service of the Company 24 years, 20 years in the Locomotive Department. I was on duty on Sunday, April 28th, from 6.0 p.m. until 6.0 a.m. on Monday. I changed the water in the boiler of engine No. 216, having instructions from the foreman to do so. After I had changed the water I gave my assistant instructions to light a fire. I went round twice after No. 216 was alight. From my experience she has always had a good tight boiler. At 1 a.m. I looked inside to see how the fire was going on, and saw nothing unusual and no leakage. She began to make steam about a quarter to 3. I had another look at the engine about 3.0 o'clock, she had about 20 lbs. of steam then and I saw no leakages. I then tried the test cocks. She was more than full glass, but when I opened the tail cock I saw the level come down. She never blew off, the most steam she had whilst standing in the shed being about 75 lbs., and this was about 4.30.

Laurence Mercer, cleaner, states: I have been over 3 years with the Company. I came on duty on the 28th April at 8.0 p.m. and booked off at 6.0 a.m. I lighted No. 216 that night. The first thing I did was to find out how the water was, try the test cocks, then open the damper. She had about an inch from the top of water in both gauges. I saw everything was shut off and then coaled her round. I did not look inside the firebox with a lamp. I got the fire put in her. I could see in the firebox and could see no leakage. I think I should have noticed a leakage if there had been one. I have previously noticed when fireboxes have been leaking inside. I did not go on her after steam was raised. I did not see any water running from the bottom of the firebox. I saw nothing unusual. I saw steam in the boiler and there was then no leakage.

Richard H. George, boilermaker, states: I have 22 years' service with the Company. I have been stationed at Tonbridge about 3 years. I have been boilermaker all the time. I examined the boiler of engine No. 216, on the 22nd April, in accordance with the general practice of examining them once per week. There were no bulges of any description, and no leaks of any sort. I saw the engine after the explosion, and examined it carefully. I saw the roof stays were blown right down, and she seems to have been short of water. There was discolouration just round the bottom of the crown—a line all round. I noticed some of the nuts were drawn off, being broken off right underneath the bottom of the firebox, and others drawn through the nuts and the top of the firebox as well. I have seen cases of shortness of water before, but have never seen one like this. In cases of shortness of water, the roof stays generally leak in the first place. I should think this explosion occurred when the top was red hot. I do not think it possible that the engine had been short of water and very badly damaged at the top, and that this was not observed when the engine was taken out on the Monday morning. If the damage had been done previously, all the roof stays would leak in the first place. I was in the engine on the shed day, a week before the accident, but not again until after the accident. On the 22nd April, everything was perfectly tight. I do not think it possible for the roof of the firebox to be slightly damaged from time to time without showing. I do not think it possible for a box to give way without being actually short of water and burned. The threads and everything in the copper was good, and it drew right through the nuts. When examining the boiler on the 22nd April, I noticed the lead plug and the roof stays were then in good condition. The damage could not possibly have taken place without some very great heat.

Horace Glover, foreman boilermaker at Ashford, states: I came to Tonbridge on the 29th April, and examined engine No. 216 at Tonbridge Shed, after the explosion. I went inside the firebox, and saw that the engine had been short of water. The annealing of the copper made me think this. It was discoloured, the discolouration being over the whole top of the box, down to the first row of firebox stays at top on the sides. It was a dull red colour. As soon as I examined the box I saw it had been short of water. I found the nuts all broken and torn off, some of the studs broken, and some of the nuts drawn through the thread. I think the nuts were torn off by pressure, and that the stays were red hot when this was done. I have never seen a nut come off like this when cold. I did not examine the water gauges, these being left until the engine came to Ashford. I did not examine the injector steam pipes. I have been about 32½ years as foreman at Ashford, in the boiler shop, and have seen a number of overheated tops, but none so bad as this one. I saw the fusible plug, the lead being all gone. There was a hole partly through, and a little grit left in at the bottom. The fusible plug was not in the firebox when I saw it—it was found amongst the ashes, having been thrown out. I should not think the boiler had been damaged previously, and given way as a result of this previous damage. It was a good firebox, no reduction in thickness anywhere, and all stays in splendid order, in fact 488 of them were renewed in July, 1911, these being larger ($1\frac{1}{16}$ in. instead of 1 in.), which should have strengthened it. It is an ordinary type of boiler. I have never known a boiler go like this when it has been cold. There was a line right round the firebox, with the exception of the tubeplate, showing it had been short of water. If the top of the box had been in any way damaged by heat previously, something would have had to be done before going out, as there would be a slight leakage. It takes very little on the top of the box to cause a leak. In my opinion, even if a boiler is slightly bulged at the top, and there is a

slight leak, provided the fireman keeps water on top, there is not likely to be an explosion. I have never known a fusible plug save a burned firebox.

James Smail, chargeman fitter, Ashford Works, states: I have been in the Company's service 32 years. I received instructions on the 30th April to take off the water gauges and injector cocks from engine No. 216. I found them free from dirt and scale, and in good working order. The water gauges were just in the usual positions, all complete, nothing broken whatever, and glasses quite clean.

William Campbell, chargeman fitter, Ashford Works, states: I have been 25 years with the Company. I received instructions on the 30th April to remove the injectors from engine No. 216, I found the water and steam ways clear, and the cones very clean. The injectors were in good working order.

Alan Cobb, locomotive inspector, states: I examined engine No. 216 on the 29th April, after the explosion. None of the engine fittings were interfered with at Tonbridge, except to take down the ashpan to examine the firebox, and the engine and tender were uncoupled.

John Woodgate, driver, states: I have about 22 years service with the Company, and have been driver about 6 years. I was instructed to take engine No. 216, and the train, from the main line after the explosion. I went on the footplate of engine No. 216. Both the feed cocks were closed on the tender. It was shut off with the exception of the right feed which was open to the warming cock. The tender had water in it on the next morning. The engine appeared to stand where we placed it with our engine.

Conclusion.

A detailed inspection of the boiler was made on the 21st May by Mr. Carlton, and again, after the firebox had been removed, on the 5th June. I was present on both occasions. I attach Mr. Carlton's report, under the following heads :—

I. Description and principal dimensions of the boiler.
II. Nature of the explosion.
III. Cause of the explosion.
IV. General remarks.

I also attach a sheet of drawings, explanatory of the condition of the boiler after the explosion.

Mr. Carlton's Report.

I. *Description and Principal Dimensions of the Boiler.*

The boiler was of the ordinary locomotive type, the outside plates were made of steel, the firebox of copper and the tubes of brass.

The total length from the inside of the front tube plate to the back plate was 16 feet $3\frac{1}{2}$ inches, the barrel was 4 feet $2\frac{7}{8}$ inches mean diameter, the height of the firebox casing 7 feet $7\frac{9}{16}$ inches, and the length of the casing 5 feet 11 inches.

The barrel was formed of two rings of plates $\frac{9}{16}$-inch thick. The longitudinal seams were double-strapped, and double-riveted, the circumferential seams being lapped, and double-riveted, the rivets being $\frac{15}{16}$-inch diameter. The firebox casing plate was $\frac{7}{16}$-inch thick, secured to the barrel by a double-riveted seam, and to the back plate by a single-riveted seam. The throat and back plates were each $\frac{7}{16}$-inch thick, and the front tube plate $\frac{7}{8}$-inch thick, the latter was secured to the barrel by an angle ring which was double-riveted to the barrel, and single riveted to the tube plate.

The firebox was 5 feet $4\frac{7}{8}$ inches in length at the bottom, and 5 feet $1\frac{5}{16}$ inches at the top, the height was 6 feet $3\frac{1}{2}$ inches, and the width varied from 3 feet $5\frac{7}{8}$ inches at the bottom, to 3 feet 7 inches at the top, all dimensions being over the plates. The tube plate was 1 inch thick at the upper part reduced to $\frac{9}{16}$-inch below the tubes. The wrapper and back plates were $\frac{1}{2}$-inch thick. The foundation ring was of square section $2\frac{1}{2}$ inches by $2\frac{1}{2}$ inches, and was single-riveted. The firebox box side stays were about 4-inch pitch, and were made of copper, with the exception of the five upper rows in the sides, and back end, which were made of Stone's bronze, and were flexible. They were 1-inch diameter, and screwed 11 threads per inch. The crown of the firebox was fitted with eight cast steel roof girders supported by sling stays from transverse angle bars riveted to the outer casing. The roof stays and nuts were made of best Lowmoor iron, the stays were screwed into the roof plate and girders, and nuts were fitted to the ends in the firebox. They were 1-inch diameter, and screwed eight threads per inch, the pitch of the stays being 4 inches in the longitudinal direction, and $4\frac{5}{8}$ inches in the transverse direction.

The upper parts of the front tube plate, and back plate were supported by 10 longitudinal stays, made of best Yorkshire iron, the ends were enlarged and screwed $1\frac{3}{8}$-inch diameter, and were nutted.

A steam dome 1 foot 9 inches diameter inside, and $\frac{5}{8}$-inch thick was fitted to the barrel. It was flanged at the bottom, and secured to the barrel by a double-riveted seam, a

substantial compensating ring being fitted inside the barrel. Sight holes and mud holes were provided in the boiler for inspection and cleaning purposes.

The tubes were 205 in number, and were $1\frac{3}{4}$ inches diameter outside, increased to $1\frac{3}{8}$ inches diameter at the end in the front tube plate.

The usual mountings were fitted and included one Ramsbottom safety valve (duplex) with valves each $3\frac{1}{2}$ inches diameter, adjusted to lift at 170 lbs. per square inch, two injectors and two water gauges. One fusible plug was fitted in the centre of the firebox crown.

II. *Nature of the Explosion.*

The firebox crown collapsed in one large bulge over nearly the full area of the top, 44 of the iron roof stays were broken flush with the under side of the crown plate, and the nuts were drawn completely off 23 of the other roof stays, the threads on the stay ends below the plates being entirely stripped.

The depth of the bulge at the centre was about 7 inches and the plate in bulging stretched considerably, causing the stay holes and the holes for the fusible plug to be enlarged. The steam escaped violently through these 68 holes, and the pressure was rapidly exhausted.

III. *Cause of the Explosion.*

The explosion was undoubtedly caused by the top of the firebox having become overheated, the stay ends and nuts being weakened to such a degree, by this overheating, that a large number of them failed to withstand the ordinary working load and an explosion resulted. The overheated part was plainly visible over the whole area of the crown, and extended down the sides of the firebox along an even line some 4 inches below the top, just above the upper rows of side stays. The line was clearly defined, and was typical of overheating through shortness of water, the water level having apparently fallen some 4 inches below the highest part of the crown. The upper rows of tubes were sagged, they also having been overheated.

IV. *Remarks.*

This locomotive of which the boiler formed part, is known as No. 216, and at the time of the explosion on the 29th April last was proceeding from Tonbridge to Tunbridge Wells, with four empty eight-wheeled bogie coaches. The train left Tonbridge at 5.53 a.m., and the explosion occurred 10 minutes afterwards at 6.3 a.m. The driver and fireman were both very seriously injured, and either jumped, or were blown off the footplate. The engine was ascending an incline at the time, and was running tender first.

The locomotive had been in the shed the previous day, Sunday, and on the preceding Saturday, April 27th, had been in use in passenger service, having taken a train from Redhill to London, and from London to Tonbridge *via* Redhill. The driver on that occasion was Aaron Chantler, and the fireman, Joseph Salman. Both these men stated in evidence that nothing whatever went wrong with the boiler on that occasion, and when the fire was drawn out at Tonbridge, at about 10 p.m., after work was finished, no leakage was observed from the boiler. Both men, however, stated that on one occasion during the day the boiler began to prime or "lift the water," but this action was at once checked. The driver reported the matter in the usual way when he arrived at Tonbridge, in order that the water in the boiler might be changed, and this was done before steam was got up on the following Monday morning by William Killick, the fire-lighter. The latter states that he was on duty from 6.0 p.m. on Sunday, the 28th April, until the following morning at 6.0 o'clock, and after changing the water in No. 216 boiler he gave his assistant instructions to light the fire. At 1.0 a.m. he looked inside the firebox to see how the fire was going on, and saw no appearance of leakage or of anything unusual. At about 3.0 a.m. there were 20 lbs. steam pressure in the boiler. Killick then tested the water gauges, and found the water to be up to the top of the glass. At that time also there was no appearance of leakage. Laurence Mercer, the engine cleaner who lit the fire, also saw no leakage from the boiler. The fireman, Henry Pilcher, who was on the locomotive when the explosion occurred, began duty at 4.30 on the morning of the explosion. He tested the water gauges and found the boiler full of water, and 70 to 80 lbs. pressure on the steam gauge. The locomotive left the yard at 5.15 a.m. to connect up to the carriages, and whilst engaged in this work one of the feed injectors on the boiler was used. Some little shunting was done, and it was about 5.45 a.m. when the train arrived at the down platform at Tonbridge Station.

The fireman states that when the train left Tonbridge Station for Tunbridge Wells

the safety valves were blowing off at 170 lbs. pressure, the boiler was full of water, and that when the regulator was opened it primed, water being thrown out and the cylinder cocks had to be opened in consequence.

The engine, as already stated, was running tender first on this occasion, and was ascending a gradient at a speed of from 12 to 15 miles per hour. When near the top of the gradient the explosion occurred. The fireman also states that he twice used the injector and put feed water into the boiler between Tonbridge and the place where the explosion took place. At the time of the explosion the fire-door was about 2 inches open and no leakage whatever was observed. The engine was doing easy work and the water gauge glasses are said to have been three-fourths full.

The guard of the train in his evidence states that whilst looking out of the carriage window after leaving Tonbridge he twice saw the injector put on by the fireman.

Daniel Kadwell, the driver of the engine, is unable to assist in the inquiry. The injuries he sustained appear to have caused loss of memory, and, although he has apparently recovered his physical health, he states that his memory is a blank from the time of going to bed on the night previous to the 29th April, when the explosion took place, until about 10 days afterwards when he returned to consciousness in Tonbridge Hospital.

After the explosion the tender was found to contain an ample supply of water. The water gauges and injector fittings were taken off, examined, and found to be clear and in good working order.

I inspected the boiler on the 21st May after the engine had been taken to the Ashford works, and again on the 5th June after the firebox had been removed for a better inspection to be made. The firebox crown was bulged, and a large number of the roof stays were broken and stripped as already described. The overheated appearance of the top of the firebox clearly indicated that the entire top, together with the upper portion of the side, tube, and end plates, had been red hot. The even line of overheating round the box showed that the water level in the boiler had been allowed to fall 4 inches below the highest part of the crown. There was an absence of soot on the overheated parts, a fact usually observed on boiler plates which have been red hot.

The manner also in which the nuts were forced off a number of the crown stays is only consistent with these parts having been red hot at the time of being forced off. The normal strength of the iron stays would probably range from 21 to 24 tons per square inch, but the actual working load at the time of failure was little over one-tenth of this amount, the reduction in strength being due to the softening effect of the overheating ; the stays must therefore have been at a very high temperature when they failed.

The fireman's statement is to the effect that the water gauge glasses were three-fourths full just previous to the explosion, but this statement entirely disagrees with the condition in which the firebox was afterwards found. With the gauge glasses three-fourths full the water level would be 5½ inches above the top of the firebox, and with the water level at the bottom of the gauge glasses there would be 2 inches of water on the top of the firebox. The question might be raised as to whether the water gauges were out of order and showing a false water-level. It would however be singular if both gauges were out of order at the same time, and the fireman's statement as to how they were working is descriptive of properly working gauges. It is also stated in evidence that they were afterwards examined and found to be clear. They were also tested by the fire-lighter William Killick, who appears to have observed nothing unusual in their working.

The suggestion was made that the boiler might have been short of water and seriously injured when the engine was in use on some occasion previous to entering the yard at Tonbridge, on Saturday the 27th April, and that in its weakened condition it failed after being put into use on the day of the explosion. Practical experience however teaches that if the damage to the crown had been so serious as to partly fracture some of the stays and partly force the nuts off others, excessive leakage must have taken place from the injured part, especially after the boiler had cooled down. There is evidence that no leakage whatever was observed—even from the fusible plug—up to the moment of the explosion. The suggestion referred to above is, in my opinion, improbable in the extreme, besides which there is clear indication on the firebox plates that the water-level had fallen 4 inches below the crown, which is such a bad case of shortness of water as to fully account for the explosion.

The fireman states that the water in the gauges was at the top or above the top of the glasses when leaving Tonbridge, and notwithstanding his statement that he saw the water-level three-fourths high in the gauge glasses just before the explosion occurred, I can only conclude that he is in error on this point, and that for some time before the explosion took place he had mistaken empty glasses for full ones.

It might here be stated that as the engine was ascending a gradient of 1 in 100 and was running tender first, the water would be lower at the firebox end of the boiler than at the smoke box end.

With regard to the statement that the fireman twice used the injector after leaving Tonbridge, which statement was corroborated by the guard; it is the custom to be continually using the injector, and he may have done this work mechanically, or he may have been confused as to the water in the boiler and thought it best to follow average practice in the use of the injector knowing that it must of necessity frequently be used.

In view of the time required to heat up the stays and plates in the firebox crown, steam being in contact with them, and in view also of the distance the water-level had evidently fallen below the top of the crown, as shown by the line of overheating round the upper part of the firebox it is, I think, probable that the firebox top had been bare of water for at least ten minutes before the explosion occurred. The statement of the fireman however cannot be reconciled with the above, nor to the condition in which the firebox was subsequently found, which indicated clearly :—

(1) That the explosion was due to the firebox crown and stays having been seriously overheated, and

(2) That the marks of overheating extended not only over the whole of the top, but 4 inches down the sides, and showed that the water-level in the boiler had fallen this amount below the top and was therefore 6 inches below the bottom of the water gauge glasses.

The fusible plug was afterwards found in the ashes, it having been blown out of the crown when the plate stretched and the hole was enlarged. The lead was melted out and the orifice was almost closed by scoria and hard scale. It had been renewed about 2½ months previously. The firebox except where injured by the overheating was in very good condition.

Engine No. 216 was built at Ashford Works in 1895, and rebuilt in January, 1909. A new boiler, firebox, and set of brass tubes was fitted when the engine was rebuilt.

The engine went through the shops at Ashford in July, 1911, when the boiler was examined inside and out, and the firebox caulked. A large number of new stays were fixed, and a new set of brass tubes fitted. The boiler was tested with water at a pressure of 220 lbs. per square inch, and with steam at 180 lbs. The safety valves were secured at 170 lbs.

The Company have furnished me with a return showing all the shed repairs executed to this engine at Tonbridge since July, 1911, and with the exception of an occasional leaky tube, there is nothing to show that the boiler has caused trouble.

I fully concur with the opinion expressed by Mr. Carlton, in his foregoing report, that this explosion was caused by overheating of the crown of the firebox, owing to serious shortness of water.

I have, &c.,
J. W. Pringle,
Major.

The Assistant Secretary,
Railway Department, Board of Trade.

Printed copies of the above Report were sent to the Company on the 8th November.
