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On the Expansive Working of Steam in Locomotives. By DANIEL KINNEAR
CLARK, C. E.—(With a Plate.)*

[Abstract of a Paper read at the Institution of Mechanical Engineers.]

Continued from page 11.

It is now proposed to consider the conditions on which the expansive working of steam in locomotives may be most beneficially carried out.

The condensation of steam in the cylinder by exposure, which takes place in certain arrangements of locomotives, is susceptible of proof in various ways: by the internal evidence of the indicator diagram, in respect of its general form, the form and course of the expansion line, and the back pressure; also by a comparison of the volume of sensible steam which is found to pass through the cylinder, with the volume of water found by measurement to be consumed from the tender and the boiler. The evidence of the expansion line of the indicator diagram will be first considered, both for well protected and partially protected cylinders.

Evidence of the Expansion line of the Indicator Diagram.—As the total heat of saturated steam is nearly constant for all pressures, being slightly greater the higher the pressure, there can be no condensation of steam during expansion, in a perfectly non-conducting vessel, but rather a slight surcharge. The surcharge is so slight, however, as not to require further

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notice in the present inquiry; we are only concerned in showing that perfectly protected steam under expansion, without any deduction from, or accession to its heat, continues substantially in a state of saturation, and unaltered in quantity or mass; and that if the indicator diagram show that at the end of expansion the final quantity of sensible steam is either greater or less than the initial quantity at the beginning, and surcharge by condensation or otherwise must have taken place in the condition of the expanding steam. The initial and final quantities, or their equivalents in water, are readily found by dividing the capacity of the cylinder and the clearance occupied by the steam, by the relative volumes due to the initial and final pressures. By the same law we may find the expansion curves, which would be described with a constant quantity of saturated steam under expansion; this has been done for the slow diagrams from No. 13, C. B., (Plate I. fig. 1.) and the curves of simple saturation thus found are shown in dotting. The deviations of these from the actual curves are all referable to one cause—the *condensation of the steam*.

In No. 1, the cylinder must have been at a lower temperature than the steam during the admission, and some condensation must have taken place, for no sooner is the steam cut off, than condensation is made visible by the sinking of the expansion curve below the standard throughout the whole of its length. In No. 2, also, this takes place to a small extent for the first half of the curve, when the temperatures of the steam and the material of the cylinder become equal; after this, as the pressure continues to fall, and the temperature of the steam with it, the curve rises and meets the standard curve at the end, in virtue of a partial re-evaporation of the steam previously precipitated, caused by the cylinder itself, which, colder than the steam, and heated by it in the first stage of the expansion, is now relatively hotter, and partially restores the heat of which it had previously robbed the steam.

In Nos. 3 and 4, the process of successive condensation and re-evaporation is still more distinctly brought out. In these cases, the greater portion of the heat engaged in the restoration of the steam during expansion must have been absorbed by the cylinder, by condensation of the steam during admission. Under the 3d and 4th notches, the observed final equivalents are shown to exceed the initial by 19 and 45 per cent. of the latter respectively; which proves that, in the two cases, at least 19 and 45 per cent. of the steam admitted *must have been condensed during admission*, as the additional steam can have been obtained from no other source. Although the actual expansion curves, Nos. 3 and 4, indicate much higher mean pressures *during expansion*, than the standard curves, and may so far be viewed as superior results, the favorable difference is only a partial amends for the much greater loss by initial condensation; and an expansion curve may be constructed backwards, in terms of the indicated mass of steam at the end of the expansion, to show from what initial pressure this mass of steam could have expanded, had there been no condensation. Take No. 4, for example. The final pressure at G is 13 lb., for which the relative volume is 939, and the ratio of the initial and final total volumes, or the degree of expansion, is 1 to 2.66; then $939 \div 2.66 = 353$, which is the relative volume for $66\frac{1}{2}$ lb. steam at the point of suppression. Tracing the expansion curve G H for this pressure, as in the drawing,

for which any number of intermediate points may be found in the same way, and drawing a horizontal admission line *III* to the beginning of the stroke, the extra shaded area so inclosed is a representation of the real loss incurred by initial condensation of the steam; and, without going into figures, it appears nearly as much again as the area or power actually obtained.

The diagrams just discussed are, of course, extreme cases, which might occur in any cylinder, outside or inside; and they have been selected simply for purposes of illustration. They have served to show in what way the expansion curves of indicator diagrams may be turned to account in developing the condition of the steam. Our business is now to find to what extent, in the ordinary working of locomotives, the condition of the steam is affected by the circumstances of the cylinder.

The first point is to show, by the expansion line, that in well protected cylinders the steam is not subject to condensation. Referring to the 26 diagrams obtained from the *Great Britain*, of which the cylinders are suspended in and freely surrounded by the hot gases in the smoke-box, it appears that for each notch the influence of speed on the relation of the initial and final water equivalents of the steam expanded is nearly inappreciable. Dealing therefore with the means, the mean differences by which the final are less than the initial equivalents are—

For the 1st notch 3 per cent. of the initial equivalent.

"	3d	"	5½	"	"	"
"	5th	"	2½	"	"	"

These per centages are practically nothing, and the virtual constancy of the mass of expanding steam during expansion, thereby proved, shows that for the greatest observed degrees of expansion in the cylinder of the *Great Britain*, no change in the condition of the steam is observable, and that there is, consequently, no condensation at all.

Experiments made by the writer on some of the engines of the Edinburgh and Glasgow Railway, with inside cylinders, lead to the same conclusion.

Numerous diagrams were obtained by the writer from the outside cylinder engines of the Caledonian Railway, of which the cylinders are placed beyond the direct influence of the heat in the smoke box, and considerably exposed to the atmosphere. Seventy-six were selected as average samples of diagrams obtained during the regular work of the engines. These have been analyzed in the way adopted for those of the *Great Britain*, and the mean results range from 9 per cent. deficiency, to as much as 67 per cent. excess at the greatest expansion. Specimens of the diagrams from No. 42, passenger engine, and from No. 125, goods engine, are given in fig. 2. These diagrams were taken by McNaught's Indicator, and the dotted lines show the actual curves which are affected by the oscillation, to which that indicator is subject at high velocities. The mean lines have been drawn on the diagrams on the principle which the writer has satisfied himself applies in the particular case of the indicator—that action and re-action are equal, and that therefore the mean line, or radical form, ought to inclose the same collective area of diagram as the fluctuations in the lines actually described, due partially to momentum, cutting off at one place as much as it incloses at another.

For the greater ratios of expansion, the final equivalent of the steam is much above the initial, and the greater the ratio the greater is the percentage of this excess, amounting to 67 per cent. with an expansion of $3\frac{1}{2}$ times. This relation is just what was found for the slow diagrams from No. 13, and there is no doubt the excess of steam, at the termination of the expansion, is due to the same cause, namely—the condensation of the steam in the cylinder during admission, and during the first part of the expansion, and the subsequent re-evaporation of a portion of the precipitated steam. During the experiment, there was at all times ocular demonstration of the existence of water in the cylinder, in the spray which escaped from it through the indicator, and *which was given off more abundantly the more expansively the steam was worked.*

To find the general rate at which the per centage of condensation increases in these engines with the degree of expansion, the results obtained may be referred, as ordinates, to a base line representing the ratios of expansion. Let A B, fig. 4, be a base line divided to represent the total volumes by expansion in terms of the initial volumes; and from B draw the vertical scale to measure the relative per centages of condensation. From A set off on the base line the ratios of expansion, and for each ratio set off perpendicular distances by the vertical scale, equal to the respective percentages of the differences of water equivalents, col. 13, and define their extremities by points, setting off *minus* per centages below the line, and *plus* per centages above. The mean line C D, drawn through these points, is straight, and represents the mean rate at which the indicated condensation increases with the degree of expansion. It is found to meet the vertical from division 1, at 20 per cent. below, crosses the base line at a volume of 1.53, and terminates at E, the point due to an expanded volume of 3.4, and to a per centage of 70, and would, if produced, meet the vertical from B, at $92\frac{1}{2}$ per cent. The straightness of the line implies that the indicated per centage of condensation increases uniformly with the relative volume by expansion. For an expansion of 1.53 times, the per centage of condensation, or indicated difference of equivalents, is nothing; and, generally, for expansions advancing by half volumes, the per centages are as follows:—

Expanded volumes, the initial volume being — 1.	Indicated per centages of condensation.
1.5	— $1\frac{1}{4}$
1.53	0
2	$17\frac{1}{2}$
2.5	$36\frac{1}{4}$
3	55
3.5	$73\frac{3}{4}$
4	$92\frac{1}{2}$

For every half volume of expansion there is an increase of $18\frac{3}{4}$ per cent. of indicated condensation, and this becomes so serious that for an expansion of four times, if this were practicable with ordinary valves and link motions, there would be $92\frac{1}{2}$ per cent. of loss by condensation, or a loss of nearly one-half of the total quantity of steam admitted.

For ready reference, it is expedient to find the relative expansion and indicated condensation for different periods of admission, yielded by ordinary link motions. The following table contains in col. 2 the total ex-

pendent volumes due by the nature of link motion to the several periods of admission in col. 1, and col. 3 contains the relative indicated per centages of condensation due to these expansions, measured from the diagram.

Of the Indicated Condensation of Steam in Outside Cylinders during the Admission of Steam.

Period of admission in parts of the stroke.	Total volume by expansion, the initial volume being = 1.	Indicated condensation, in parts of the indicated steam cut off.	Approximate proportion of steam condensed.	
			In parts of the INDICATED steam consumed.	In parts of the WHOLE steam consumed, (including the condensed steam.)
Per Cent.	Ratio.	Per Cent.	Per Cent.	Per Cent.
75	1.22	—12.0	12	11
60	1.40	— 5.2	12	11
50	1.54	0.0	12	11
40	1.78	9.4	21	17
30	2.07	19.9	32	24
20	2.45	34.1	46	32
12	3.17	66.1	73	42
1	2	3	4	5

Though the losses shown in the 3d column are great, the real losses must be still greater; because the restoration of condensed steam, by which the losses have been measured, cannot be entire. The indications, indeed, fail to show any loss at all, at 50 per cent., as the re-evaporation balances the condensation during expansion. For 75 per cent., the re-evaporation (if any) is so slight as to leave a deficit of 12 per cent., by condensation, during expansion, compared with what was indicated as cut off. Now, the whole tenor of the evidence shows plainly that the degree of condensation increases as the admission is shortened; and it may be safely inferred that as 12 per cent. is shown to be lost in full gear, there is at least 12 per cent. of loss for 50 per cent. of admission, cutting off at half stroke. An approximate loss of 12 per cent. will, on this ground, be adapted for all admissions greater than half stroke; and 12 per cent. will also be added to the indicated losses for shorter admissions, as an approximation to the real conditions.

Col. 4 contains the approximate losses as thus revised, in parts of the *indicated* steam admitted. Adding the *lost* steam admitted to that indicated, the sum expresses the *whole* steam admitted and expanded; and col. 5 contains the per centage of approximate loss, expressed in terms of the whole steam so used, which is a more convenient form for reference. From this column it appears that for 40 per cent. admission, 17 per cent., or one-sixth of the steam, is condensed; for 30 per cent., one-fourth; for 20 per cent., one-third; and for 12 per cent., or mid gear, two-fifths, or not far from one-half.

It must be added that the foregoing deductions are based on steam pressures under 60 lbs., generally about 50 lbs., during admission. For higher pressures, and admissions above half stroke, the condensation is proportionally less, as will afterwards be shown.

Proof of the Condensation of Steam in Outside Cylinders, by comparison of the indicated consumption of steam with the measured consumption of water.—Many experiments were made by the writer on this point; one was made with No. 42, passenger engine, on the Caledonian Railway, during a trip of 105 miles, from Glasgow to Carlisle, with an average train of $6\frac{1}{2}$ carriages, done in three hours 22 minutes, five stoppages included. Indicator diagrams were taken from the cylinder at intervals of one or two miles, and the notch of the expansion gear observed for each diagram, and the points of the line where each change of notch was made.

The several points of cutting off, expansion, and compression were accurately ascertained by means of the slow diagrams; from which were calculated the exact quantities and pressures of sensible steam actually consumed in each interval of the trip, and the water equivalents for the several quantities of steam present in the cylinder; which, multiplied by the number of strokes of the two cylinders in each interval, gives the total quantity of water efficiently used as steam. The following final results were thus obtained:

Distance traveled.	Water used as sensible steam.	Water consum'd as measured.	Excess.
1. Glasgow to Motherwell, . . .	30.76 ft.	35.82 ft.	5.06 ft., or 14 per cent.
2. Motherwell to Carstairs, . . .	43.91 ft.	48.85 ft.	4.94 ft., or 10 do.
3. Carstairs to Beattock, . . .	57.28 ft.	67.74 ft.	10.46 ft., or $15\frac{1}{2}$ do.
4. Beattock to Carlisle, . . .	62.42 ft.	79.50 ft.	17.06 ft., or $21\frac{1}{2}$ do.
Total, Carlisle to Glasgow,	194.37 ft.	231.91 ft.	37.54 ft., or $16\frac{1}{4}$ per cent.

The examination of the indicator diagrams in the manner employed before, by comparing the initial and final water equivalents of the steam during expansion, shows that at least 13 per cent. of this loss of $16\frac{1}{4}$ per cent. was due to condensation, and it is probable that no appreciable proportion was due to priming; indeed, the *least loss* was observed to take place with the least degree of expansion, and when the consumption of steam from the boiler is going on at the *greatest rate*, as we find on referring to the per centages of admission; which is the reverse of the effect that would be observed if priming were a material cause.

Experiments made by the writer with other outside cylinder engines, or *imperfectly protected* cylinders, corroborate the above deduction obtained from the performance of No. 42; and they are still further corroborated by his experiments on inside *well protected* cylinders, which show that in ordinary good condition there is no sensible excess of water of any importance, actually consumed from the boiler, above what is estimated from the indicated steam passed through the cylinder. These results are also confirmed by the results of the trials of Mr. D. Gooch, with the *Great Britain* and similar engines.

The increased *back pressure of exhaust* affords additional evidence of the presence of water in the cylinder. The back exhaust pressure is the consequence of the want of facilities for the timely discharge of the exhaust steam from the cylinder; and the impediments to its discharge are much

increased by the presence of water amongst the steam, whether due to condensation or to priming. The presence of water is immediately made apparent by the increase in the back exhaust pressure, shown by the indicator diagram, as the writer has on many occasions had an opportunity of observing. The *effects of priming* from foulness of the water in the boiler are shown in fig. 3: A and B are indicator diagrams taken from the well protected cylinders of the *Orion*, in which very little, if any, condensation could be detected. The diagram A was taken *before*, and the diagram B *after* the boiler was blown off and supplied with clear water, both being taken at the same speed, and showing 7 lbs. back pressure caused by priming in the former case.

The diagrams C and D, fig. 3, show that the *total quantity of water* from condensation is considerably greater, with the greater degrees of expansion, where a *smaller quantity of steam* is admitted, and consequently the loss is more seriously felt. These diagrams were taken from the outside cylinder goods engine No. 127, working at the same speed up and down an incline on the Caledonian Railway; the diagram C cutting off at two-thirds the stroke, and the diagram D at one-sixth of the stroke. The latter, D, though it had the advantage of a much earlier exhaust, and only one-fourth of the quantity of steam to discharge, was affected with 10 lbs. more back pressure than the former, C, when working in full gear. This great back pressure was maintained over a continued run of twenty miles, when of course the cylinders had got into their working heat for that degree of expansion; and the inference is, that the steam was loaded with water of condensation, (proved also by the expansion curve,) which was with difficulty expelled, and which only became proportionably less when the degree of expansion was diminished; and, consequently, the mass of steam increased that was to be cooled within the same superficies of cylinder.

That the *total mass of the steam* has much to do with the condensation is proved by the diagrams E and F, fig. 3, taken under the same degree of expansion, and at the same speed, but with 75 and 20 lbs. steam respectively admitted to the cylinder. In the latter diagram, F, the back exhaust pressure is 7 lbs. greater than in the former diagram, E, although the total quantity of steam to be discharged was so much less. In the latter case, indeed, there was found to be an excess of 18 per cent. of the whole water used over the indicated steam expended, which was most probably altogether by condensation, as the rate of consumption was so moderate as to preclude any likelihood of priming.

Now here is a case where, in the same class of engines, the back exhaust pressure *increases* as the quantity of steam to be discharged *becomes less*, notwithstanding that the facility for exhaust increases at the same time. This is clearly a case of water in the cylinder, the quantity of which increases with the degree of expansion; and the water is as clearly a precipitation of steam by condensation. Also, though a full admission of steam at higher pressures may reduce the proportion of condensation, yet whenever expansive working is attempted by cutting off earlier, the heavy back pressure and the course of the expansion line alike show that no pressure of steam, however high during the admission, can mitigate the evils of condensation in exposed cylinders.

Evidence from the Proportions of the Valve Gear.—The greater the lap of the valve, the greater also is the inside lead, for the exhaust exposed cylinder, we should expect, would therefore require longer laps than well protected ones, seeing that wet steam exhausts with difficulty. Accordingly, it has been found that in Sharp's inside cylinder engines, on the Edinburgh and Glasgow Railway, which have only a $\frac{5}{8}$ -inch lap—probably the shortest lap in present practice for a 15-inch cylinder—the exhaust is as perfect as in the Caledonian passenger engines with 1 $\frac{1}{2}$ -inch lap for the same cylinder. Further, in inside cylinders with clean boilers, it is practically a matter of indifference what amount of wear or slugging may have taken place in the valve gear, so far as concerns the exhaust: in outsides, on the contrary, it is a very important object to maintain the gearing in the highest order, so as to keep up the inside lead, as the wear of the gearing directly reduces the lead, and thereby increases the back pressure. The Caledonian is perhaps the first line in this country on which the special advantage of long lap for outside cylinders was experienced.

The formidable degree of condensation which accompanies high expansion in partially protected cylinders, accounts for the opinion held by men of experience of the inutility, for economical objects, of cutting off the steam earlier than at half stroke, for the proved advantage of expansive working in inside cylinders is neutralized in outsides by the condensation. Mr. Buddicom, of the Rouen Railway, led the way in the re-introduction of outside cylinders in this country: and to this day, he and some of his followers have adhered to the fixed gab motion.

Conditions on which the expansive working of steam in locomotives may be carried out with efficiency and success.—The first condition is to perfectly protect the cylinders, and to maintain them at a *temperature at least as high as that of the steam admitted to them*. Simple non-conducting envelopes are not sufficient; external supplies of heat must be employed, and the application of a steam jacket to the cylinder would be advantageous, when other sources of heat are not readily available. The writer tried an experiment with the *Orion*, Edinburgh and Glasgow Railway, which has its cylinders suspended in the smoke box, like the *Great Britain's*, in which, by the use of partitions, the hot air from the tubes was directed entirely round the cylinders, previously to its emerging by the chimney: but he could not detect the slightest change in the performance of the engine, probably because the hot air was really very little hotter than the steam, and the closer contact made no difference. For cylinders already well protected, more thorough modifications would be required to make a sensible improvement. The steam should also be surcharged, previously to entering the cylinder, by passing over an extensive heating surface, deriving its heat from the atmosphere of the smoke box, or, if necessary, from a hotter source.

Mr. W. C. Hare, of Stonehouse, Devon, to try the value of surcharging the steam, experimented on a small engine, with cylinder 3 $\frac{1}{2}$ × 8 inch stroke, and a boiler of 9 feet heating surface. He found that when the steam was passed over a surcharging surface of 5 $\frac{1}{4}$ feet in a coil of copper tube, and heated to 400° before entering the cylinder, the consumption of water from the boiler was three gallons per hour; and when the

communication with the surcharging pipe was cut off, and the steam led directly to the cylinder, the water used amounted to six gallons, or twice the other, while doing the same work, and involved a great increase of fuel consumed. To effect the reduction here noted, it appears that a surcharging surface equal to fully one-half of the heating surface has been necessary; and it is probable that for locomotives a considerable allowance must be made to produce a very decided change. The results of this experiment show that very much has yet to be done before the capabilities of the locomotive are fully developed.

As steam has been found so very sensitive to *exposure* on the one hand, and to *surcharging* on the other, it would probably be of advantage to *lead the hot smoke round the barrel of the boiler and the fire-box, or the barrel only, previously to its discharge by the chimney.*

The second condition of successful expansive working in locomotives is the combination of a sufficiently high boiler pressure of steam, with suitable proportions of cylinder and driving wheel, to admit of highly expansive working consistent with the required duty of the engine. It is probable that 150 lbs. per inch is about the highest pressure at which it is advisable to work a locomotive, consistent with the fair working and durability of its parts. The maximum pressure being settled, and it being assumed that the same pressure is to be maintained in the cylinder during admission, the degree of expansion to be adopted determines the capacity of the cylinder to develop the necessary average power. Long strokes are not advisable on the score of stability, at least for outside cylinders, and large diameters should rather be adopted; for the same reason, large wheels are preferable.

Thirdly, in the details of the mechanism, the cylinder should be arranged to have the shortest practicable steam-ways; as, for short admissions, a long steam-way deducts very much from the efficiency of the steam. Such an arrangement would be greatly promoted by the introduction of balanced valves, or such as have provision for preventing the steam pressure on the back of the valves; as, by being balanced, they could with facility be made large enough to embrace the whole length of the cylinder. The loads which ordinary valves are forced to carry on their backs are enormous; and though there is certainly no momentum in these loads to contend with, yet the friction of surfaces due to the loads is very great, even at the most moderate computation.

Discussion.—Mr. Stephenson (the Chairman) observed that he felt much obliged to the author of the paper for explaining in such a clear and practical manner the action of the slide valve and the link motion; and the paper was particularly valuable for the actual numerical results that were given so completely of the variations in practical working, showing the improvements effected and the defects avoided.

Mr. McConnell agreed that the link motion was the most advantageous and useful of any valve motions known for locomotive engines. He thought a hot air chamber should be contrived, passing round the cylinders, to be kept at a temperature sufficient to maintain the steam perfectly dry.

Mr. Clark said, that in the Great Western engines, Mr. Gooch had

carried the steam pipe straight down in front of the tubes, instead of curving it on one side as usual; and the pipe being of $\frac{3}{16}$ -inch copper, it absorbed the heat from the tubes rapidly, and surcharged or dried the steam.

Mr. Stephenson observed, that with regard to the question of surcharging steam, he remembered being told by Mr. Trevithick of an experiment which he made in Cornwall in 1830. He had to repair an old engine there, which had no steam jacket to the cylinder, as most of the other engines had, to keep up the pressure of the steam; and he built a brick casing round the cylinder, leaving an air space all round, and applied a small fire to keep this air heated. About one bushel of coals in twenty-four hours was consumed in heating the cylinder, and he found a great increase was effected in the duty performed by the engine, with the same consumption of fuel under the boiler as before. He then removed the fire from the cylinder, in order to find the relative efficiency of the coal when consumed under the boiler or under the cylinder, and he found that it took five bushels of coals applied to the boiler to produce the same effect as the one bushel of coals applied to the cylinder. Mr. Stephenson said, he had been so much impressed with the results of this experiment, that in the *Planet*, one of the early locomotives made in 1832, he had the cylinders carefully inclosed inside the smoke box, instead of being outside, and there was found to be a considerable increase of power effected by the plan. That was the first locomotive constructed with heated cylinders, and it appeared the principle ought never to have been deserted; but it was singular how temporary prejudices sometimes caused a good thing to be departed from. Those inside cylinders were abandoned because the crank axles were found liable to break; but then, after that objection was subsequently removed by improved manufacture, the prejudice against the inside cylinders still remained; however, they appeared now to be going back to them. The construction of locomotives was still perhaps much influenced by these local prejudices arising from individual circumstances; and he was confident that this Institution would conduce greatly to the removal of them, by the mutual interchange of ideas and experience that was promoted by it; and nothing could assist more in forwarding such a desirable object than the reading of such papers as the present one by Mr. Clark. He quite agreed with the opinion stated in the paper on the great drawback to the application of expansion in locomotive engines caused by the condensation, from the cylinders not being heated; he considered some additional heat was required to be supplied during expansion to prevent condensation taking place, as it appeared the quantity of heat in steam was not sufficient to maintain the whole in the form of steam during expansion, but a portion returned to the form of water, as shown in the able investigation of the expansion of steam given in Lardner's "Treatise on Heat."

Mr. Cowper described some experiments that had been made by Mr. Siemens and himself, which he thought showed that condensation did not take place during expansion. They took a cylindrical tin vessel closed at the top, about 12 inches high and 2 inches diameter, the metal of which was very thin, and coated thickly with felt outside to prevent any loss of heat. A small steam pipe was connected at the top, but the

bottom of the cylinder was open to the atmosphere; and a stream of 30 lb. steam was blown into the vessel from a very small orifice, and allowed to escape freely into the atmosphere at the open end of the cylinder. After a short time, when the cylinder had become hot, and was maintained just full with expanded steam at the atmospheric pressure, a thermometer inserted a short distance into the open end, showed a constant temperature of 214° to 215° instead of 212° , proving the total quantity of extra heat that is in high pressure steam; and no condensation could be perceived inside the cylinder, no vapor being visible until the steam had escaped from the cylinder into the atmosphere. This experiment was tried on several different occasions, and on one it happened that the boiler was priming slightly; and when a drop of water came over through the steam pipe and dropped upon the bulb of the thermometer, it was observed to fall suddenly to 212° , and remained at that point until the water was boiled off, when it again rose 2° to 3° above the boiling point as before.

Mr. Stephenson said he did not think that mode of trying the experiment would give a correct result as regarded the present question, as the steam was escaping into the atmosphere instead of being all confined within the cylinder, and the temperature in the cylinder being maintained above the boiling point would prevent any condensation taking place during the expansion of the steam.

Mr. Cowper did not think that in a cylinder thoroughly protected from loss of heat by radiation or conduction, any condensation of the steam would take place during expansion, and that if any condensation occurred, it would be found to be owing to the steam having lost some of its heat, which it could not recover. The result that he obtained by indicator diagrams from a pair of 35-horse power, high pressure, expansive, and condensing engines, which he had constructed some years since, fully bore out this view; the steam was expanded in the cylinder of each engine independently, and the practical expansion curve was obtained very accurately. The whole body of the cylinder was necessarily nearly at a mean temperature between the highest and lowest steam in the cylinder, (the cylinder not having a steam-jacket,) consequently the steam ought to be slightly cooled on entering the cylinder, and towards the end of the stroke, where it was at a lower temperature from expansion, it ought to be slightly warmed by the cylinder;—now the indicator figure showed both these circumstances to have taken place, for the actual curve during the first part of the stroke, after the steam had been cut off, was rather below the true expansion curve; and during the latter part of the stroke, it was rather above; this also showed that the expansion curve required a slight correction for the extra quantity of heat in the high pressure steam.

Mr. Clark remarked that he had found by the indicator diagrams that a great condensation of the steam took place in exposed outside cylinders during the first part of the stroke, from the coldness of the cylinders, and a considerable amount of condensation also was caused even in protected cylinders, where they were not artificially heated by exposure to the hot air in the smoke box, because the temperature of the mass of metal in the cylinder remained about the mean temperature of the steam

whilst expanding in the cylinder, which might be many degrees below the original temperature of the steam on entering from the boiler. This caused the actual pressure of the expanding steam to be below the theoretical pressure during the first half of the stroke, as shown in the indicator diagram, fig. 3; where the theoretical curve of expansion is shown by the dotted line BCD, allowing for the contents of the steam port and the clearance represented by the space AA. But about the middle of the stroke, the two curves coincide at C, as the steam was then at its mean temperature, and agreed with the temperature of the cylinder; and after that point, as the steam continued to expand and lower in temperature, the cylinder remaining nearly constant was hotter than the steam, and returned some of the heat it had robbed from the steam, re-evaporating more and more of the water that had been condensed, and raising the curve of actual pressure above the theoretical curve at the end D, where the exhaust commences. A portion of the lost steam is thus restored to the second half of the stroke, but a serious loss of power still remains; and the consideration of this action that is always going on to a greater or less extent in the cylinders of locomotives, however well they may be protected, except where they are artificially heated, shows what an important source of economy is to be found in carrying out that principle.

Mr. Crampton thought that enough attention had certainly not been paid to the condensation in the cylinders of locomotives at slow speed; he did not think it was of so much importance at high speeds. It was also particularly of importance in steamboat engines, where the question had not received so much attention as it deserved. He remembered an experiment which showed a remarkable effect of condensation; four condensing engines, of equal size, were working coupled together in a boat, with the steam cut off at one-quarter of the stroke and expanded; two of the engines were then disconnected, and the other two engines were worked, cutting off at half-stroke, using, consequently, the same quantity of steam as the four engines did, cutting off at one-quarter of the stroke; but a greater effect was found to be produced by the steam than when it was used in the four cylinders. This increase of effect appeared to be entirely due to the greater amount of condensation that took place in the four cylinders than in the two cylinders. There were no steam jackets, only ordinary clothing on the cylinders, and he thought much improvement was required in this respect in marine engines, and it was a matter well deserving the consideration of engineers. In reply to an inquiry, he said the boilers were working with salt water, but he did not think that would affect the result.

Mr. Peacock suggested, that part of the effect in the experiment mentioned by Mr. Crampton might have been due to the smaller amount of friction in the two cylinders than in the four cylinders, when giving out the same total amount of power.

Mr. Crampton replied, that a greater effect was found to be produced after allowance was made for the friction, by taking indicator diagrams, and the relative consumption of the water.

Mr. Whytehead thought the loss by back pressure would also be less in the case of the two cylinders than with the four.

HARRISON'S STEAM-ENGINES AND BOILERS.

Fig. 1—Sheet I.

Fig. 2—Sheet I.

Fig. 3—Sheet I.

Fig. 4—Sheet I.

Fig. 5—Sheet I.

Fig. 1-Sheet II.

Fig. 2-Sheet II.

Fig. 4-Sheet III.

Fig. 3-Sheet II.

Fig. 1-Sheet III.

Fig. 3-Sheet III.

Fig. 2-Sheet III.

Fig. 1—Sheet IV.

Fig. 1—Sheet IV.

Fig. 2—Sheet IV.

Fig. 4—Sheet IV.

Fig. 4—Sheet VII.

Fig. 7—Sheet IV.

Fig. 6—Sheet IV.

Fig. 3—Sheet VII.

Fig. 2—Sheet V.

Fig. 3—Sheet V.

Fig. 1—Sheet V.

Fig. 1—Sheet IX.

Fig. 3—Sheet IX.

Fig. 2—Sheet IX.

Fig. 1—Sheet VI.

Fig. 2—Sheet VI.

Fig. 5—Sheet VI.

Fig. 3—Sheet VI.

Fig. 4—Sheet VI.

Fig. 8—Sheet VI.

To the Committee on Publications.

GENTLEMEN :—In looking over the December number of the *Practical Mechanics' Journal* for the past year, I see published therein the specification of a new Express Locomotive, recently built for and put in operation on the London and North Western Railway. In some remarks appended to the specification, some stress is laid upon certain improvements in the mode of constructing the boilers, alleged to have been made by Mr. McConnell, the designer of the locomotive in question. By referring to the annexed specification of a patent for improvements in steam boilers, granted to me in England more than a year ago, and which I would request you to publish entire, with this letter, it will be seen that the extension of the fire box into the waist of the boiler, upon which the merit of Mr. McConnell's boiler mainly rests, is not new with him. Nor is the idea new with myself, as I am aware that this same thing has been done in this country nearly fifteen years ago. It was also the subject of a patent in England, granted to Stubbs & Grylls, in August, 1846. In both the above cases the plan was abandoned as not useful, and in my opinion failed, from not carrying out the principle far enough. Whilst I was engaged in preparing my specification in England, in the autumn of 1851, and winter of 1852, two locomotive engines were altered under my special direction, by Mr. McConnell, at the workshops of the London and North Western Railway at Wolverton. One of the above engines was put in operation early in 1852, and to my certain knowledge before the new express engines were commenced. Upon the eminent success of these altered engines, the boilers of the new engines were prepared, the latter being identical in principle with the former, although somewhat changed in form. I have for many years past been satisfied that the use of such long tubes as are now prevalent in the construction of locomotive boilers, has been, and is, an error in principle, and I think the results which are now being brought out in England, prove my opinion correct. I believe fully, that tubes of ten to fifteen feet in length, as now so extensively, and I might say exclusively, used, will be eventually abandoned for those of half the length, or even less.

I remain, gentlemen, yours, very respectfully,

JOSEPH HARRISON.

443 Arch Street, Philadelphia, Jan. 17, 1853.

Specification of Improvements in Steam Boilers. By J. HARRISON, Eng.

To all to whom these presents shall come. I, Joseph Harrison, engineer, of the City of Philadelphia, in the United States of North America, but now residing at No. 10 Oxford Square, Hyde Park Gardens, in the County of Middlesex, send greeting: Whereas, Her Most Excellent Majesty, Queen Victoria, by her letters patent, under the great seal of the United Kingdom of Great Britain and Ireland, bearing date at Westminster the eighth day of December, in the fifteenth year of her reign, did, for herself, her heirs and successors, give and grant unto me, the said Joseph Harrison, her especial license, &c., &c.

Marine Boiler.—Chapter the first. Figures No. 1, 2, 3, and 4, sheet