carrying out these tests, this also is comparatively small. All we can say is that after the various known factors have been taken into account, that a portion of the loss due to unburnt coal is from an undetermined cause, and that the explanation offered by Mr. Fry is possibly correct, namely, that it is due to unconsumed hydro-carbons passing away into the front end. He considered that this may be produced by the partial distillation of the particles of coal which are carried off the grate by the draught, or that there may be unconsumed free hydrogen in the flue gases. Evidence supporting this view is furnished by the fact that the gas analysis shows more nitrogen than can be accounted for by the other products of combustion, and that if this excess of nitrogen is assumed to be a hydro-carbon gas, the heat contained in it, together with the expected loss by sparks and a reasonable ashpan loss, make up very closely the total loss through unburnt coal. There is here possibly a chance for better economy, that we have hitherto not suspected, but it may be stated that so far as can be learned from the tests, it will not be obtained from the use of a brick arch as it was found that its value consisted in the reduction of the loss by imperfect combustion, due to the formation of carbon monoxide. The engine from which this diagram of heat balances was obtained was fitted with an arch and, as it shows, the loss from carbon monoxide was exceedingly small. On the engines not having a brick arch there was a considerable loss from this cause, amounting to as much as 16% at higher rates of combustion, and although it so happened that these same engines were subject in each case to unfavorable conditions, there is still good evidence to support the claim made that a properly proportioned brick arch will effect a saving in coal of 5 to 10%.

These points however, while interesting, do not affect the main information given by this diagram, which it may be stated, is from the most efficient boiler tested at St. Louis. It shows that, under the most perfect conditions of testing, uniform work, economical firing and a boiler in as good condition as possible, the heat accounted for in the steam is from 50 to 70% of the heat in the coal, as the rate at which the coal is burnt decreases from 110 to 40 lbs. per square foot of grate per hour. If this efficiency is combined with that of the engine, which as previously stated varied from 8½ to 10%, we find that the total efficiency of the locomotive, under testing plant conditions varies from 4½ to 7%, so that we see that the general statement of a loss of 95% of the heat present in the coal, is confirmed by the best results that have so far been obtained from locomotives.

We also see to what a large extent this loss is unavoidable as long as we are forced to transform heat into work by means of any form of steam engine, and the high degree of perfection that has already been reached by our present locomotives when the limiting efficiency which they could possibly attain is properly considered.

The figures so far discussed have entirely referred to efficiency on the basis of indicated horse power. Before this power reaches the rail, it is reduced by the friction losses in the cylinders, motion and axles, and the resultant power is what is termed the dynamometer horse power. Figs. 2, 3 and 4, which are reproduced from the report of the St. Louis tests, show the coal per dynamometer horse power hour for three freight locomotives tested at St. Louis, at 40, 80 and 160 revolutions per minute respectively. It will be seen that the most economical results were obtained from no. 585, a Michigan Central Rd. cross compound, which at low speeds showed a fuel consumption of only 2¼ lbs. per h.p. hour. This corresponds to a total efficiency of 7.5%, and is an exceedingly economical result for any type of non-condensing steam engine. As shown on the diagrams the fuel consumption increased at higher speeds, and at 160 revolutions per minute, which corresponds to 30 miles an hour for a 63 inch wheel, it amounted to 3½ lbs. Fig. 5 shows roughly the coal consumption of these different engines as the speed increased, and is interesting when their varying types are considered. No. 1499 is a Pennsylvania Rd. simple consolidation, 22 by 28 inch cylinders, 56 inch drivers, 205 lbs. boiler pressure. Heating surface 2844 sq. feet, grate area 49.2 sq. ft. No. 734 is a Lake Shore & Michigan Southern Rd., simple consolidation, 21 by 30 inch cylinders, 63 inch drivers, 200 lbs. boiler pressure. Heating surface 2858 sq. feet. Grate area 33.7 sq. feet. No. 585 is a Michigan Central Rd. compound consolidation, 23 and 35 by 32 inch cylinders, 63 inch drivers, 210 lbs. boiler pressure. Heating surface, 31681 square feet. Grate area 49.4 square feet.

The compound engine is evidently far more economical than the simples, but it should be remembered that the conditions on a testing plant are more favorable to this type of engine than are those in regular road service. On the testing plant, they are working absolutely uniformly, everything is maintained as constant as possible during the time the test is conducted, and it is under these conditions, as we know, that the best results from a compound engine can be obtained. The boiler efficiency of no. 585 was also exceedingly good, and in fact a large proportion of the economy is due to this, as no. 734 showed only from 70% to 82% of the boiler efficiency of 585, and that of no. 1499 showed very poor results at the higher rates of evaporation, due to the insufficient air supply. Still while there may be reasons why the simple engines showed so much greater fuel consumption than the compound, there are no reasons why the compound should show more, and the fact remains that a steam locomotive under the best conditions, has developed a dynamometer horse power hour at a coal consumption of 2¼ to 3½ lbs., corresponding to a total efficiency of 4.9 to 7.5%.

We have found therefore that in order to realize what are avoidable and what are unavoidable losses in the conversion of heat into work by a steam engine or locomotive, it is necessary to consider first what degree of economy could be obtained by an ideal steam egine working under certain limiting conditions, and then consider with what perfection our existing locomotives approach that ideal. Locomotives do not however, operate upon testing plants, but in hauling trains, and the real point we are interested in is the extent to which our locomotives in actual service approach the best results which it is possible to obtain. We know that on the testing plant the machinery was in the best possible condition, the boiler was not leaking, the valves and pistons were as tight as they could be made, and the firing was as good as it could possibly be. To what extent do we approximate the testing plant results and how does our actual efficiency compare with that obtained upon them?

Unfortunately when we are dealing with road conditions there are a number of factors to be considered that cannot be accurately allowed for. In place of constant conditions there are exceedingly variable ones, part of the time the engine is running and part of the time standing, and any comparison that can be made must necessarily be more or less approximate. No estimate can be made that is a reasonable one for determining the exact consumption of the engines in pounds of coal per dynamometer horse power hour, but one figure can be obtained with reasonable accuracy, namely, the efficiency of the equipment and organization as a whole. If in place of the ideal steam engine we consider the best results obtained upon the testing plant as the ideal of locomotive efficiency, we can determine fairly closely the degree to which such an ideal is approached by our locomotive and operating departments. To do this some particular section or division must be selected and for this purpose I will refer to the results obtained on district 1 of the Central Division on the C.P.R. during the last few months. On that district the fuel consumption has for several months been below 80 lbs. per thousand equivalent gross ton miles. In one month it was 75 and in another 76, and these figures are not taken from any particular test but represent the total consumption on the division, averaging over 7000 tons of coal a month. When it is considered that, although the difference in level of the two ends of this division of 420 miles is small, only 150 ft., the heavier tonnage is uphill, it is doubtful whether this result has ever been equaled in this or any other country, especially where the large amount of traffic which it includes is taken into account. It is therefore a good example to consider for comparison with an ideal engine, but on account of the hill condition on the east end, the section from Ignace to Winnipeg is preferable in place of the entire district.

The coal records available on the road show the total coal consumed per 1000 equivalent gross ton miles, and cannot therefore be directly compared with the coal per dynamometer h.p. hour. Supposing, however, a train had an average resistance over a division of 5 lbs. a ton, so that 1000 tons gave a resistance of 5000 lbs. This 5000 lbs. pulled one mile or 5280 ft. would equal 26,400,000 foot pounds. A horse power hour is 1,980,000 foot pounds, so that 1000 ton miles with a train having a resistance of 5 lbs. per ton is the equivalent of 12.8 h.p. hours. This is evidently proportional to the resistance, so that if the average resistance of the train were 10 lbs. per ton, 1000 ton miles would equal 25.6 horse power hours and so on. I cannot give the exact figure for the resistance of a train from Ignace to Winnipeg, but the figure obtained for a very similar district, Outremont to Smith's Falls, was 4.50 lbs. eastbound and 7.00 lbs. westbound. The difference in level is 2.6 ft. per mile which accounts for 1 lb. per ton from an average of 5½. From other figures we have, I believe the figure of 7 lbs. per ton is slightly high and that figure for a level undulating road with short grades not exceeding 0.5 or 0.6% would be about 5½ lbs. The difference in level would increase this to 6½ tons up hill and reduce it to 4½ lbs. down. Now from Ignace to Kenora the grade averages 2.7 ft. per mile down west bound, and from Kenora to Winnipeg 2.53 ft. per mile down west bound, so that with very little danger of inaccuracy we may say that the average resistance is 4½ lbs. per ton west and 6½ lbs. per ton east bound on these two sections. 1000 ton miles is therefore the equivalent of 11.5 and 16.6 h.p. hours respectively, and if we assume that when working, the ideal engine has a speed of 20 miles per hour corresponding to a coal consumption of 2.7 lbs. per dynamometer h.p. hour, the coal required per 1000 e.g. ton miles would be 31 and 44½ respectively. Taking the month of July this corresponds with actual results of 61 and 86½ lbs., or an efficiency of 51% in both cases, and this in a sense may be said to be the efficiency of the operation as a whole. This