enough, and that no external source of heat acts through the metal of the cylinder. The reason is, not that heat is necessarily lost, but that a proportion of that which was known as heat to the thermometer is converted into work, which the thermometer of course cannot recognise; and this work, it must be understood, is not expended in giving motion to the engine, but in separating the ultimate atoms of the water of which the steam expanding is composed to a greater distance than they were before. This work is done on the steam itself, and is wholly distinct from the work also done in driving the piston against a given resistance. We may put this into more strictly scientific phraseology by saying that with decrease of density the latent heat of steam diminishes faster than the sensible increases, and therefore, when it is reduced by expansion from one density to another and lower, the latent heat, or work done internally on its molecules, increases, and to an extentannihilates an equivalent of sensible heat, and the amount of this equivalent can in all cases be determined by the consideration of the entire quantity of heat necessary to evaporate the given weight of water at the two pressures—initial and terminal.

As steam is employed in practice, however, we cannot neglect the influence which the temperature of the cylinder exerts on the changes in the condition of the steam. The cast iron absorbs heat when the steam first enters at its full temperature, and it subsequently restores this heat towards the end of the stroke when the pressure falls, and thus, to a certain extent, we may regard every unjacketed cylinder as acting the part both of a boiler and a condenser. Dry steam absorbs heat with extreme slowness—in this, as in other respects, obeying the laws which obtain with the true gases. Professor Tyndal states, for example, that moist air absorbs heat with not less than 6,000 times the power of perfectly dry air. On first entering the cylinder the steam, fresh from the boiler, comes in contact with the cool piston and cooler cylinder lid. A portion is at once condensed; and we shall show presently that, strange as it may seem, the entire loss with the best engines must take place while the cut-off is open, and not subsequently to its closing, as commonly believed. The result of this primary condensation, as we may term it, is that the steam is—unless previously super-heated—rendered damp, and it therefore imparts yet more of its heat to the metal with which it is in contact. As a consequence the cylinder lid and the piston are raised to the full temperature due to the pressure with the speed of lightning. This action is of course confined to one end of the cylinder. The other, from which the piston has just come, is in contact with moist steam or vapour from the condenser, at a temperature of little more than 100 degrees, and as this absorbs heat, its pressure rises sufficiently to cause it to flow into the condenser. Moisture is deposited on the interior of the cylinder and re-evaporated, and thus heat is carried to the condenser, not by radiation, as commonly stated, but by the direct convection of the most powerful cooling agent known—moist vapour. This vapour pervades the whole cylinder, and if time enough is allowed the surface of this last will be reduced to the temperature of the condenser. In practice, the piston commences its return immediately upon the completion of the forward stroke, and the vapour is thus swept into the condenser and the sides of the cylinder are perfectly dried. Even with the highest attainable speed, however, the cooling action of the vapour is so energetic that a very considerable loss must take place; and the amount of this loss increases as the speed of the piston becomes less, and thus we find that short strokes and high velocities are important direct elements of economy.

As the steam follows up the piston, successive portions of the now cool cylinder are uncovered, and, so long as the sensible heat of the steam is in excess of that of the metal, condensation and a deposit of moisture will take place. As the pressure falls, however, so does the temperature, and, once a certain point in the stroke is reached, condensation will cease. As the piston proceeds, and as the pressure and temperature of the steam continue to fall, the heat which the cylinder has received will be restored, and the deposited moisture will be re-evaporated. The cylinder then really becomes a boiler, and we find that, so far from an immediate loss ensuing on the first condensation, this re-evaporation actually tends to keep up the pressure to the end of the stroke. If no condensation or re-evaporation took place the curve of the indicator diagram would be a nearly true hyperbola, corresponding to the operation of Mariotte's law; but it is a fact that actual diagrams show a considerable departure from this law apparently favourable, the terminal pressures being higher than they ought to be. This gain is only apparent, however, and is due to the re-evaporation of the large quantity of water condensed at the commencement of the stroke, with a corresponding loss. Apart from the influence of external radiation, all the loss of useful effect is due to the presence within the cylinder during the exhaust, of vapour of only the same temperature as the condenser.

From the foregoing it will be evident that al true waste of steam must take place while the cylinder is in communication with the boiler. Practical diagrams show that, so far from any loss ensuing upon expansion, the pressures are really greater than those given by theory. It is true that the indicator in all cases shows, when properly fitted, a slight increase on the true pressure, but the error is so slight that it may be wholly disregarded. With the Richard's indicator it becomes all but evanescent. It is evident, therefore, that waste is not to be sought for during the expansion portion of the stroke. It is also evident that during this period, the boiler being completely isolated from the cylinder, nothing going on within the one can at all effect the other. Yet we know that the practical use of the engine proves that nearly three times as much fuel is used, even under the most perfect system, as that laid down by theory as necessary. In other words, three times too much steam enters the cylinder. But the steam can only enter the cylinder during the full pressure portion of the stroke; and it follows that it is during this portion of the stroke all the drain on the boiler must take place. Now during this period but a small portion of the cylinder is uncovered; and we find, therefore, that the surplus steam introduced is employed in re-heating the cylinder lid cooled