tion during the descent of the piston. I proposed to remedy this defect by *employing wax, tallow, or other grease, to lubricate and keep the piston tight.* It next occurred to me that the mouth of the cylinder being open, the air which entered to act on the piston would cool the cylinder, and condense some steam on again filling it ; I therefore proposed *to put an airtight cover upon the cylinder, with a hole and stuffingbox for the piston-rod to slide through,* and to admit steam above the piston to act upon it instead of the atmosphere. There still remained another source of the destruction of steam, the cooling of the cylinder by the external air, which would produce an internal condensation whenever steam entered it, and which would be repeated every stroke ; this I proposed to remedy by an *external cylinder containing steam, surrounded by another of wood, Or of some Other substance which would conduct heat slowly.*

“ When once the idea of the *separate conden­sation* was start­ed, all those improvements followed as corullaries in quick suc­cession, so that in the course of one or two days, the invention was thus far complete in my mind, and I immediately set about an experiment to verify it practically. I took a large brass syringe A, one and three-fourth

inches diameter, and ten inches long, made a cover and bottom to it of tinplate, with a pipe S to convey steam to both ends of the cylinder from the boiler; another pipe E to convey steam from the upper end to the condenser (for, to save apparatus, I inverted the cylinder.) I drilled a hole longitudinally through the axis of the stem of P the piston, and fixed a valve at its lower end, to permit the water which was produced by the condensed steam, on first filling the cylinder, to issue. The condenser used upon this occasion consisted of two pipes *a b, c d* of thin tinplate, ten or twelve inches long, and about one-sixth inch diameter, standing perpendicular, and communicating at top with a short horizontal pipe *h* of large diameter, having an aperture on its upper side which was shut by a valve opening upwards. These pipes were joined at bottom to another perpendicular pipe *ρ* of about an inch dia meter, which served for the air and water pump ; and both the condensing pipes and the air-pump were placed in a small cistern C filled with cold water.

“ The steam-pipe was adjusted to a small boiler B. When steam was produced, it was admitted into the cylinder, and goon issued through the perforation of the rod, and at the valve of the condenser. When it was judged that the air was expelled, the steam-cock was shut, and the air-pump piston-rod was drawn up, which leaving the small pipes of the condenser in a state of vacuum, the steam entered them and was condensed. The piston of the cylinder immediately rose and lifted a weight of about eighteen pounds, which was hung to the lower end of the piston-rod. The exhaustion-cock was shut, the steam was re admitted into the cylinder, and the operation was repeated ; the quantity of steam consumed.

and the weights it could raise were observed ; and, excepting the non-application of the steam-case and external covering, the invention was complete, in so far as regarded the savings of steam and

fuel. A large model, with an

outer cylinder and wooden case,

was immediately constructed,

and the experiments made with

it served to verify the expecta

tions I had formed, and to place

the advantage of the invention

beyond the reach of doubt. It

was found convenient afterwards

to change the pipe-condenser for

an empty vessel, generally of

a cylindrical form, into which

an injection played, as in fig. 36,

and in consequence of there

being more water and air to extract, to enlarge the air pump.

"The change was made, because, in order to procure a surface sufficiently extensive to condense the steam of a large engine, the pipe-condenser would require to be very voluminous, and because the bad water with which engines me frequently supplied, would crust over the thin plates, and prevent their conveying the heat sufficiently quick. The cylinders were also placed with their mouths upwards, and furnished with a working-beam, and other apparatus, as was usual in the ancient engines; the inversion of the cylinder or rather of the piston-rod, in the model, being only an expedient to try more easily the new invention, and being subject to many objections in large engines.

“ In 1768 I applied for letters patent for my 'Methods of Lessening the consumption of Steam, and consequently of Fuel, in fire-engines,' which passed the Seals in Janu ary 1769; and my specification was enrolled in Chancery in April following, and was as follows :—

“ My method of lessening the consumption of steam, and consequently fuel, in fire-engines, consists of the fol lowing principles :—

“ First, That vessel in which the powers of steam are to be employed to work the engine, which is called the cylinder in common fire-engines, and which I call the steam-vessel, must, during the whole time the engine is at work, be kept as hot as the steam that enters it ; first, by enclosing it in a case of wood, or any other materials that transmit heat slowly ; secondly, by sur rounding it with steam or other heated bodies ; and, thirdly, by suffering neither water or any other substance colder than the steam, to enter or touch it during that time.

“ Secondly, In engines that are to be worked wholly or partially by condensation of steam, the steam is to be condensed in vessels distinct from the steam-vessels or cylinders, although occasionally communicating with them ; these vessels I call condensers ; and, whilst the engines are working, these condensers ought at least to be kept as cold as the air in the neighbourhood of the engines, by application of water, or other cold bodies.

“ Thirdly, Whatever air or other elastic vapour is not condensed by the cold of the condenser, and may impede the working of the engine, is to be drawn out of the steam-vessels or condensers by means of pumps, wrought by the engines themselves, or otherwise.

“ Fourthly, I intend, in many cases, to employ the expansive force of steam to press on the pistons, or what ever may be used instead of them, in the same manner as the pressure of the atmosphere is now employed in common fire-engines. In cases where cold water cannot be had in plenty, the engines may he wrought by this force of steam only, by discharging the steam into the open air after it has done its office.