The engine raises a weight, and it is the descent of this weight that forces or raises the water, thus permitting great rapidity of motion of piston when steam is applied. 76-3

From this mode of operation, the balanced (commonly called "cornish") valves and the general simplicity of its construction, there is little or no friction attending its working—so little, indeed, that in calculations nothing is allowed for it, and in an engine of 75 horse power, not more than a pint and a half of oil is used per week of 168 hours, the piston getting tallow. 76-4

In the crank engine, although the steam may be cut off at the same point as in the Cornish engine, yet from its construction (its motion being regulated by a fly wheel,) the same degree of rapidity during a part of its stroke is not practicable nor even desirable. The fly wheel shaft would break off before such a motion were attained.

Again, in the Cornish engine the power is applied at the extremity of the weight to be moved, while, in the crank engine, it is applied near the center, being subjection to a friction caused not only by the heavy fly wheel, but also by the whole power of the engine pressing on the journals of the shaft. And, further, I am of the opinion that there is a vast deal of the power of the engine absorbed by the fly wheel.

The superior economy is, third, because there is not so much leakage of steam in the operation of the Cornish engine as in that of the double engine.

Theoretically, pistons are steam tight, but practically there always is more or less leakage, and that engine to whose piston, steam direct from the boiler is applied for the longest period in a given time, is of course liable to the greatest amount of leakage. Now let us compare the two engines under consideration: let them each have ten feet stroke and ten strokes per minute. In the Cornish engine the piston will descend, steam being applied in, . 1 1-4 seconds
the piston will turn at bottom in 1 do.
the piston will ascend in . 2 do.
and will turn at top of stroke
and condense the steam in . 1 3-4 do.

In the double-acting engine the piston will descend, steam being applied in . 2 seconds.
and turn at bottom of stroke in . 1 second.
ascend, steam applied, in . . 2 seconds.
and turn at top of stroke in . . 1 second.

These tables I do not pretend are mathematically correct to the most minute fraction of a second, yet they are near enough correct for all practical purposes.

By examining them it will be found (there being in the case of each engine ten strokes per minute) that, in the Cornish engine, steam direct from the boiler, is on the piston 1 1-4 seconds per stroke, and consequently 12 1-2 seconds per minute; while in the double-acting engine steam is on the piston 4 seconds each stroke and 40 seconds per minute. Hence, in the matter of leakage, the ratio between the two is as 12 1-2 is to 40. But this is not quite a fair comparison, the cylinder of the Cornish engine being larger in bore than that of the other, the ratio between the two in this respect being as 1 1-2 is to 1. Now, by working out these proportions we find that the double-acting engine is liable to more than one hundred per cent. more leakage than is the Cornish engine.

Let it be further understood, as it were, as a corollary to the foregoing proposition, that the Cornish engine may be made to perform her up-and-down strokes at any required speed, or, in other words, is perfectly adjustable, thus admitting of the use of just the quantity of steam required by the amount of work to be done, or other circumstances attendant upon any particular case.

And in the fourth place, this superior economy arises because, in the Cornish engine, the condensation of the steam is more effectually performed than in the double-acting engine—a more perfect vacuum being formed.

The Cornish Steam Engine.

Circumstances have put it out of my power sooner to finish and forward to you this communication. It was commenced immediately on reading your remarks appended to my article on page 123, in which my endeavor was to compress what I had to say into the smallest possible space; and I was satisfied to state merely such facts as would lead to further investigation on the part of those interested in the economical use of steam power.

In your remarks at the close of my former article, you propound to me the following queries; which, with pleasure, I will endeavor to answer: 76-2

First, "Should not the double-acting condensing engine of 35 3-8 inches cylinder, be considered of equal area with the Cornish engine of 50 inches?"

I answer, Certainly. In my communication of the 29th ult. I was comparing engines of the same power, giving to the double engine every possible advantage, and yet claiming a decided superiority for the Cornish engine.

Your other query is, "*Why* is this superior economy?"

It is, first, because a portion of the steam used at any time is made effective in the next stroke of the engine.

But this will be better understood by giving an outline account of the working of the Cornish engine.

Sufficient steam is introduced at the top of the cylinder to force the piston down; the equalizing valve then opening allows the steam to pass from the top of the cylinder, through the equalizing pipe, to the bottom of the cylinder; this being but a small space when compared with the whole content of the stroke of steam, reduces it but little. The piston then ascends at the required speed (this is regulated by ballast,) and before it reaches the top of stroke, the equalizing valve closes, preventing any further escape of steam from the top of the cylinder, the piston compressing the remaining steam until the engine is brought to a stand. This is intended to overcome momentum, and to prevent the piston from touching the cylinder head, serving as an elastic cushion between the two. But it also is an item in the economy of the engine; for this compressed steam, filling the ports and the space between the piston and cylinder head generally ranged from 1 to 3 lbs. per square inch above the pressure of the expanded steam—reduced as above—in the descent of the piston and the operation of equalizing, thus requiring so much less steam for the next stroke.

For example, take a fifty inch cylinder loaded to an average pressure of fifteen pounds per square inch on the whole stroke, but being introduced at a sufficient pressure (say 27 lbs.) to expand three-quarters of the stroke, and reducing the steam at the end of the stroke to about 7 lbs., and when equalized, to about 6 1-2 lbs. This steam, when compressed as above, at the upper end of the stroke, will be of say 8 1-2 lbs., pressure per square inch on the piston, left behind, as it were, from the first stroke, again to become effective in assisting in the second stroke.

This superior economy is, in the second place, because steam is used expansively, with more effect, in the Cornish engine, than is possible in the crank engine.

Steam being introduced at a high pressure into the cylinder, the piston commences descending rapidly, and acquiring a momentum which carries it (the steam valve having been closed) beyond the point where the reduced steam ceases to be effective, the engine will then turn her stroke, and the piston will ascend some considerable distance without the intervention of valves; and so complete is the turn that a stranger to this motion would think the engine attached in some way to a crank. This expansion is in a great degree rendered effective by the mode of attachment, (I speak of pumping water in the usual manner with the Cornish engine.)

Direct Acting Pumping and Cornish Engines. 76-1

As considerable has appeared in our columns relating to the Cornish Pumping Engine, the same question has lately excited no small amount of discussion on the other side of the Atlantic. A paper has been read on the subject before the Royal Scottish Society of Arts, by D. Landale, in which he described a direct-acting pumping engine, which, since 1852, has been slowly making headway against the Cornish Engine, on account of its simplicity and cheapness. There are two kinds of this engine, both condensing, high-pressure, and expansive; one with a 40-inch cylinder and 12 feet stroke, which is simply a Cornish engine turned upside down, the cylinder resting on a strong sole plate over the mouth of the shaft, and the piston-rod attached direct to the forcing set-pump rods. The air pump is small in diameter, with the same length of stroke as the engine, thus doing away with the ponderous beam, parallel motion, and heavy masonry of the cylinder pedestal, lever wall, and engine house, and obtaining any desirable length of stroke by merely adding to the length of the cylinder and piston-rod, thereby increasing the efficiency of the pumps, and making smaller ones do the same work. The second kind of engine is also inverted over the shaft, and secured and attached to its work in precisely the same way. It also uses high pressure steam expansively; but its peculiarity consists in there being a constant vacuum above the piston, both during the descent and ascent of the load. During a portion of the descent the piston is nearly *in equilibrio*, having a vacuum on both sides; that under being a partial, and the one above being about 12 1-2 lb. per square inch, or the common condenser vacuum. As the piston and load continue to descend against this vacuum, a self-acting valve shuts toward the piston, and a full vacuum is acquired by the time the piston has got to the lower end of the cylinder, thus giving a tension or extra pressure equal to 4 tuns on the 70-inch cylinder at the moment when it was most required to overcome the *vis inertia*. The steam valve is then opened, and high steam admitted for the up-stroke. There are only two double beat valves worked by the engine. The vacuum valve is self-acting, oblong, and hinged, working on the upper port of the cylinder.

To understand the action of the Cornish engine in this particular, I will proceed with the description of its working where I left off above, in the consideration of the first reason.

A 76-5

After the engine has been brought to a stand, the piston being again at the upper end of the stroke, the exhaust valve opens, and the engine rests an instant, the first jet of the exhaust forcing all the water, air, and vapor, from the condenser, then the injection valve opens, and the fresh stream of cold water effects instantaneously a more perfect vacuum than could otherwise be obtained—then the steam valve opens for the next stroke, &c.

The escape of the exhaust, the injection of water for condensation, and the admission of fresh steam in the Cornish engine, are each separately under the control of the engineer; and allowing the engine more or less time for condensation, is called by them giving her more or less "hark."

A 76-6

I have given a few reasons which I trust will be sufficient to lead to further research in this surprisingly much neglected subject—the economical use of the steam power. These are some of the points in which the Cornish engine has a decided advantage over the double-acting condensing engine. It seems almost impossible to give reliable mathematical demonstrations to prove all of its advantages,—the best tests I know of, after all, being the indicator and the coal heap.

In closing I would wish to notice Mr. Haine's remarks on page 147.

In his attempt to point out the absurdity of the principle, that "the economy of the engine is as the diameter of its cylinder," he overlooks the other long recognized and universally established principle, that "the piston should move through a space of from two hundred to two hundred and twenty feet per minute to perform economically.

It would be "absurd" in the extreme, to add to the economy of an engine by an increased size of cylinder, and at the same time subtract from it by the neglect of some other well known principle.

There are double-acting condensing engines built by the same mechanics, under the care of the same superintending engineers, clothed and attended to in the same manner, cutting off their steam at the same point, and in the performance of which the same reputation is at stake, as is the case with the so-called Cornish engines. And yet the result is as stated in my former communication.

I would be glad could arrangements be made in such a way that the expenses should not fall upon single persons—to accept a challenge from Mr. H., to the effect that the two engines of equal power be tried next to one another, with a forfeiture if our engines will not perform as we say. I to be subject to the forfeiture if my engine will not do its work with twenty-five per cent. less fuel than his; he to be subject in like manner if it does.

JOHN WEST.

Norristown, Pa.

[We received the foregoing communication from Mr. West some time since, and have delayed its publication for one particular reason. A short time previous to the appearance of Mr. West's article on page 123, this volume SCIENTIFIC AMERICAN, and since that period, this subject of the Cornish *versus* the common Double Engine, has been under discussion, week after week, in the *London Mining Journal*, and we waited to obtain a satisfactory conclusion of the whole matter, from that discussion. We must confess to a disappointment: none of the contributors to the above journal have explained the peculiarities of the Cornish Engine, nor pointed out its advantages in pumping as Mr. West has done in this communication.]