It was farther preſumed in this inveſtigation, that the motions both up and down were uniformly accelerated ; but this cannot be the case when the reſiſtances increaſe with the velocity. This circumſtance makes very little change in the working-ſtroke, and therefore the theo­rem which determines the beſt relation oſ P to L may be confided in. The reſiſtances which vary with the velocity in this caſe are a mere trifle when compared with the moving power *y.* Theſe reſiſtances are, 1st, The ſtrangling of the water at the entry and at the standing valve of each pump. This is about 37 pounds for a pump 12 inches diameter, and the velocity one foot per second, increaſing in the duplicate ratio of the diameter and velocity ; and, 2d, The friction of the water along the whole lift. This for a pump of the ſame ſize and with the ſame velocity, lifting 20 fathoms, is only about 2 1/3 pounds, and varies in the simple pro­portion of the diameter and the depth, and in the du­plicate proportion of the velocity. The reſiſtance ariſing from inertia is greater than in the returning ſtroke; because the M in this caſe muſt contain the momentum of the water both of the pit-pumps and the jackhead­pump : but this part of the reſiſtance does not affect the uniform acceleration. We may therefore confide in the propriety of the formula *y —L/2.* And we may obtain the velocity of this ſtroke at the end of a second with great accuracy as follows. Let 2 *g* be the veloci­ty communicated by gravity in a ſecond, and the velo­city at the end of the firſt ſecond of the ſteam piſton’s *y*

deſcent will be ſomewhat leſs than y/M2g; where *M* expreſſes the inertia of all the parts which are in motion during the deſcent of the ſteam piſton, and therefore in­cludes L. Compute the two reſiſtances juſt mentioned

*y—1/2r* for this velocity. Call this r. Then y-1/2r/M 2 *g* will give another velocity infinitely near the truth.

But the caſe is very different in the returning ſtroke, and the proper ratio of p to L is not aſcertained with the ſame certainty : for the moving force *p* is not ſo great in proportion to the reſiſtance *m* ; and therefore the acceleration of the motion is considerably affected by it, and the motion itſelf is conſiderably retarded, and in a very moderate time it becomes ſenſibly uniform: for it is preciſely ſimilar to the motion of a heavy body falling through the air, and may be determined in the manner laid down in the article *Resistance of Fluids,* viz. by an exponential calculus. We ſhall content ourſelves here with ſaying, that the reſiſtances in the pre­ſent caſe are ſo great that the motion would be to all ſenſe uniform before the piſtons have deſcended 1/3d of their ſtroke, even although there were no other circum­ſtance to affect it.

But this motion is affected by a circumſtance quite unconnected with any thing yet considered, depending on conditions not mechanical, and ſo uncertain, that we are not yet able to aſcertain them with any preciſion ; yet they are of the utmoſt importance to the good per­formance and improvement of the engine, and therefore deserve a particular consideration.

The counter weight has not only to puſh down the pump rods, but alſo to *drag* up the great piſton. This it cannot do unless the ſteam be admitted into the cy­linder. If the ſteam be no ſtronger than common air, it cannot enter the cylinder except *in conſequence* of the piſton’s being dragged up. If common air were admit­ted into the cylinder, ſome force would be required to drag up the piſton, in the ſame manner as it is required to draw up the piſton of a common ſyringe ; for the air would ruſh through the ſmall entry of the cylinder in the ſame manner as through the ſmall nozzle of the ſyringe. Some part of the atmoſpheric preſſure is em­ployed in driving in the air with sufficient velocity to fill the ſyringe, and it is only with the remainder that the admitted air preſſes on the under ſurface of the ſy­ringe. Therefore ſome of the atmoſpheric preſſure on its upper ſurface is not balanced. This is felt by the hand which draws it up. The ſame thing muſt happen in the ſteam-engine, and ſome part of the counter weight is expended in drawing up the ſteam-piſton. We could tell how much is thus expended if we knew the denſity of the ſteam ; for this would tell us the velocity with which its elaſticity would cauſe it to fill the cylinder. If we ſuppoſe it 12 times rarer than air, which it cer­tainly is, and the piſton rises to the top of the cylinder in two seconds, we can demonſtrate that it will enter with a velocity not leſs than 1400 feet *per* ſecond, where­as 500 feet is enough to make it maintain a denſity 9/10ths of that of ſteam in equilibrio with the air. Hence it follows, that its elaſticity will not be leſs than 2/3 9ths of the elaſticity of the air, and therefore not more than 1/30th of counter weight will be expended in drawing up the ſteam-piſton.

But all this is on the ſuppoſition that there is an un­bounded ſupply of ſteam of undiminiſhed elaſticity. This is by no means the caſe. Immediately before opening the ſteam-cock, the ſteam was iſſuing through the ſafety-valve and all the crevices in the top of the boiler, and (in good engines) was about 1/10th ſtronger or more elaſtic than air. This had been gathering during ſomething more than the deſeent of the piſton, viz. in about three seconds. The piſton riſes to the top in about two seconds; therefore about twice and a half as much ſteam as fills the dome of the boiler is now ſhared between the boiler and cylinder. The dome is commonly about six times more capacious than the cylinder. If therefore no ſteam is condenſed in the cylinder, the denſity of the ſteam, when the piſton has reached the top, muſt be about 15/10ths of its former denſity, and ſtill more elaſtic than air. But as much ſteam is condenſed by the cold cylinder, its elaſticity muſt be leſs than this. We cannot tell how much leſs, both becauſe we do not know how much is thus condenſed, and becauſe by this diminution of its preſſure on the ſurface of the boiling water, it muſt be more copiously produced in the boiler; but an atten­tive obſervation of the engine will give us ſome infor­mation. The moment the ſteam-cock is opened we have a ſtrong puff of ſteam through the ſnifting valve. At this time, therefore, it is ſtill more elaſtic than air ; but after this, the ſniſting valve remains ſhut during the whole riſe of the piſton, and no ſteam any longer iſſues through the ſafety-valve or crevices ; nay, the whole dome of the boiler may be obſerved to sink.

Theſe facts give abundant proof that the elaſticity of the ſteam during the alcent of the piſton is greatly diminiſhed, and therefore much of the counter weight is expended in dragging up the ſteam-piſton in opposition to the unbalanced part of the atmoſpheric preſſure. The