Wherever the importance of two great trading towns, or commercial countries, can bear the expence of a lock canal, it may be conſtructed; but it is impoſſible to branch off into the leſs important or poor diſtricts with large boats, which carry with them all their conſequent expences: which is not only unmechanical, but impolitic, in two reſpects; it excludes the benefit of water conveyance to ſuch diſtricts, towns, and hamlets, and bars out a trade which ought to be drawn into the canal to the benefit of the proprietors.

But a ſmall canal, forming a communication between two important counties, is ſo eaſy of acceſs, in conſequence of the ſmall boats, that lateral cuts are eaſily conſtructed; they conſequently will extend into the country, and others from them into every nook and corner where forty or fifty tons per day can be collected: thus the country will be nouriſhed, as veins feed the conſtitution; and the canal become important, like a river receiving numerous ſtreams: while another advantage of the ſmall boats, that of moving ſlow and taking quantity, or conveying a leſs quantity and paſſing with the rapidity of a coach, *which will moſt materially accommodate merchandize and valuable articles*, will take in almoſt the whole ponderous carriage of the kingdom; which circumſtance will draw immenſe quantities of trade on canals that muſt for ever be excluded on the lock principle. The canal being alſo cheap, and ſuited to a ſmall trade, yet adequate to a trade of the firſt importance, conſequently the boats of one may navigate the other wherever canals extend, perſevering regularly throughout; while their cheap formation is the greateſt poſſible inducement to their conſtruction: I ſhall therefore bring this ſubject to a few queſtions, which I wiſh every ſpeculator to apply to his own deliberations.

Firſt,

Firſt, As a ſmall canal, *averaging the ſituations*, may be conſtructed for one half the ſum which a canal for twenty-five ton boats would coſt, or about one third the expence of one for forty-ton boats; Is it not better for a ſubſcriber to have as good a proſpect of receiving ten or fifteen *per cent.* by the ſmall, as five by the greater work; yet, guarded againſt any material loſs, have every advantage which the large canal could give?

Secondly, In conſtructing a navigation, is it not better to expend 33,000l. in a ſmall canal, and have the proſpect of drawing in numerous connections by the cheapneſs of the ſyſtem, than to ſpend 66,000l. for twenty-five ton boats, or 100,000l. for forty-ton boats, in forming large canals, to accommodate a few unuſual articles which the ſmall boats cannot convey, and thereby prevent the poſſibility of lateral cuts; which would return infinitely more trade into the canal than the ſmall boats exclude *?

Thirdly, Which will command the moſt trade, the ſmall boats, by the cheapneſs with which they may be extended into every diſtrict where there is any thing to carry; or the large boats, by their capacity to contain unuſual and bulky articles?

Fourthly, Or will the conſequence of thoſe unuſually bulky commodities be put in competition with goods of medium dimenſions: which are certainly ninety parts out of a hundred of the whole carriage of the kingdom?

Fifthly, In a national view, is it not better to have three hundred miles of canal for the ſame money which it now coſts to make *one*

* I beg Gentlemen to conſider what are the things which cannot be conveyed in boats twenty feet long, four feet wide, remembering my proviſion for timber.

or two hundred; and extend the conveniencies of water-carriage in a two or three-fold proportion?

Sixthly, If a company are about to expend 300,000l. in a canal for forty-ton boats, the canal only thirty miles long*, when ninety miles might be extended into populous diſtricts for the ſame money; which, in common ſenſe, would make the beſt return to the ſubſcribers?

Seventhly, It is not a fair criterion to judge of the application of a ſmall canal by theſe circumſtances?

Eighthly, Is it not alſo fair, to compare the intereſt of the principal ſaved, *by adopting the ſmall, inſtead of the large boats*, with the expence of transferring the cargoes from large to ſmall boats; conſidering, that the transfer of cargo will fall on the freighter?

Ninthly, To view this ſubject to its extent, as of individual and national importance, will not the ſmall boats draw infinitely more trade into the channels of canal conveyance, in conſequence of their cheapneſs and expedition, than can ever poſſibly be done by the large and expenſive mode of locks?

Tenthly, Will not this ſyſtem draw almoſt the whole carriage of the kingdom on canals; the greater part of which muſt for ever be conveyed in wheel carriages, if the lock principle is purſued?

Let each ſpeculator, or member of a committee, contemplate theſe queſtions, and conſider the proceſs; let them propoſe theſe queſtions to their engineers, and requeſt an anſwer; and I have no doubt of diſcuſſion drawing the large boats out of the ſtreams of

* This is the caſe in many canals, or nearly this ſum.

preju-

prejudice, and launching them into the rivers, their natural and proper ſituation.

Having put the queſtion to engineers, I conceive it neceſſary to be properly underſtood by them: for I really have as a great a deſire to be in harmony with all men, as to harmoniſe the canal ſyſtem.]

I do not therefore mean to call their abilities to account, by this queſtion, or to find the leaſt fault with the works they have conſtructed; the lock-canals, though limited in their extenſion, and imperfect in their principle, were not invented by them; they have but proſecuted the principle, as the beſt method hitherto known for general utility.

When a company of gentlemen wiſh a canal, they apply to and give credit to the reputation of an engineer; he conſequently acts to the beſt of his judgment, which judgment is uſually formed on eſtabliſhed cuſtoms; and which, in many inſtances, has been judiciouſly exerted. But if ſuch a ſyſtem of operation was invariably to be continued, there would be no more ſcientific improvement among men, than in a bed of oyſters.

I therefore look upon it as a duty in every man, who has the leaſt pretenſion to ſcience, to inveſtigate every plan, which has even the reſemblance of improvement; and he is reſponſible to his employers, if he perſiſts without paſſing his candid judgment; his judgment ſhould alſo be put to the teſt, by oppoſing it to one well verſed in the ſubject; and thus light would appear, as friction brings forth the ſparks of latent fire.

I am

I am aware, this challenge to a fair diſcuſſion may be conſtrued into ſelf-importance in me, by oppoſing my opinion to all others: but be that as it may, I deem it indiſpenſably neceſſary in all improvements of a public nature.

A man, unthinking, may turn up a tuft of earth, and find a vein of gold, which intereſt will urge him to purſue: I, by chance, ſtumbled on this ſubject, by turning over a news-paper, or, in all propability, I ſhould never have thought of canals. I mention this to ſhew, that I do not arrogate to myſelf a great deal of the ingredient which is called Genius; but that ſome of the moſt uſeful diſcoveries is the produce of accident. I found the ſubject intereſting, and I have had the pleaſure, in proſecuting it, to find it worth purſuing. It has alſo been ſome ſatisfaction, that it appears of national importance: and, as I conceive, I have now removed the principal part of the rubbiſh *(except one ſtrong ſtrata of prejudice)*, and got my machines ready to work, I lay the enterpriſe open to the inſpection of all, in order that, if there is any intrinſic worth, it may be aſſayed; and, I have ſome hope, it will not all evaporate in fuſion.

Therefore, I do think it moſt ſeriouſly important, for ſpeculators and their engineers, to conſider this ſubject well, before they bring their bills into parliament, or proſecute another canal. If the ſyſtem is found, the ſooner it is adopted the better; if not, let it be buried in its own inſignificance.

As I venerate liberality and the light of reaſon, I deſpiſe the puſillanimity of the individual, who, like a dark lantern, conceals the light he receives. Therefore, whether this is a gleam radiating from a brilliant reflector, or the pale glimmering of inflammable

flammable vapour, I am determined it ſhall not be confined; and my reaſon is, that many uſeful improvements ſleep for ages, for want of the fire of energy in the projector, while the only mode of proving their utility, is to bring them to the teſt of diſcuſſion: I, therefore, feel myſelf quite ready to meet every objection to this ſyſtem of ſmall canals; and, for this purpoſe, I here call on engineers, or others, who think proper to anſwer the arguments in their favour.

If they cannot do this, I hold myſelf perfectly juſtifiable in criticiſing on the works of thoſe men, who may hereafter either wilfully, or ignorantly, proſecute the lock principle, and draw their employers into the conſequent errors: I will therefore, once more, revert to the comprehenſive view of the ſubject, Which will draw the moſt trade into the channels of water-conveyance, large or ſmall canals; and which conſequently will produce the greateſt benefit to ſociety? It will therefore be a feeble ſubterfuge to attempt to evade the queſtion, by ſaying, this may do for ſome canals, but not for ours.

Such a reply would alſo be impolitic, and exhibit a limited ſenſe of the ſmall ſyſtem; for, as I have before hinted, I will now aſſign my reaſon why the ſmall canals will ruin the large ones.

Which is, that when the ſmall canals are well underſtood, they will become ſo numerous, and perform the work at ſuch low tonnage, as to reduce the lock canals, or their emoluments, which is the ſame thing, to the utmoſt inſignificance, by drawing off their trade, as lock canals now draw the trade out of rivers.

The proprietors of the lock canals, will then have little more than the bulky articles; and it will then be ſeen, what proportion they bear to thoſe of medium dimenſions.

To give ſome idea of this, I beg the proprietors of the Leeds and Liverpool, Lancaſter, Rochdale, Grand Junction, Kennet and Avon, Elleſmere, and various other canals, for river or forty-ton boats*, to ſuppoſe a ſmall canal running ſide by ſide, or to the ſame points; which ſmall canal would carry all articles of medium dimenſions for one-third which the proprietors of the large canal could afford; where then would be the object of transferring cargo?

The ſame tonnage which would produce five per cent. to the large canal, would be fifteen per cent. to the ſmall company; and, as fifteen per cent. is a comfortable profit, they, for the ſake of engroſſing the trade, might continue to reduce the tonnage as the tra d increaſed, which ſtill retaining fifteen per cent. to the ſmall company, would prevent the larger from ever riſing above five. Thus the ſmall canal would abſolutely be a dictator to the larger work, and fix its emoluments, above which it could not ariſe; but might be reduced to leſs than two per cent. if competition or diſputes aroſe, the ſmall canal ſtill receiving five per cent. The reader will now judge, whether I have uſhered this opinion into the world without ſome reaſons to ſupport it: he will alſo conſider, whether any man would ſubſcribe to large canals, taking upon himſelf a part of the riſque attendant on ſuch heavy works, when he could not, at the utmoſt, receive more than five per cent.

From theſe conſiderations, it is alſo a natural concluſion, that the large canal companies will endeavour to prevent thoſe ſmall works interfering with their trade; and, in caſe of danger, fly to Parliament with bills of infinite reſtrictions. But I hope a wiſe

* Twenty-ton boats in like proportion.

Legiſlature

Legiſlature will ſee, that competition is the true poliſh of ſociety; that to reduce the expence of public works, is to improve the nation, and will therefore take off many of the reſtrictions with which they are now ſhackled.

'As far as my judgment extends on this point, I conceive, if Parliament guard landed and mill property, alſo the feeders to eſtabliſhed canals, the relative effect which the trade of one may have on the other, ſhould never be conſidered; if all reſtrictions of this kind were aboliſhed, canal ſpeculations would ſtill find their level; and competition would reduce the expence of carriage, which is the real object of canals: competition always takes as little profit as it can afford, monopoly as much as it can draw out of the freighter; therefore competition ſhould meet with every encouragement, reſtrictions ſhould be as few as poſſible, and circulation as free as the air we breathe. Till this is the caſe, the nation never can receive the full benefit which ought to ariſe from water conveyance.

CHAP. XX.

PLATE XIII. REPRESENTS AN AQUEDUCT OF CAST IRON.

IN conſtructing an aqueduct by this means, the butments and piers being raiſed, it will only be neceſſary to extend two pieces of timber acroſs the ſpan; each to be braced back to the piers, and covered with plank to form a ſtage or ſcaffolding; which will anſwer every purpoſe of centres neceſſary to works of ſtone.

The iron-work, as in the ſection, may all be caſt in open ſand, and of the following dimenſions; ſuppoſing the ſpan one hundred feet, and the ſpring one ſixth of the ſpan.

Firſt, Three ſegments of a circle, each in three pieces, about thirty-ſix feet long, eight inches by four diameter, to be united as at A. Second, three ſtrait bars, to extend from one pier to the other, to be of the above diameters, may alſo be caſt in three pieces; which bars are to extend along the top of the ſegments to the piers, and form a line parallel to the horizon; the bars and ſegments to be united by perpendicular ſtirrups, like B, ten or fifteen feet diſtant from each other.

The mortiſe in the lower end of the ſtirrup being thirteen inches long, will be ſufficient to receive the ſegment, and leave room for a hole two inches ſquare; through which a croſs-brace, C, is to paſs, and faſten the ſegments at proper diſtances; the brace to

have a mortiſe caſt on each ſide of the ſtirrup, in order to tighten the work by wedges.

On the top of the ſtirrup, the ſquare hole to receive the croſs-brace may be beneath the mortiſe, as in the Figure; by which means, the whole may be combined and form an iron ſtage to ſupport the troughs.

The trough plates ſhould be at leaſt one inch thick, the ſide plates ſix feet broad, and as great a length as can conveniently be caſt; which may be performed twelve feet, and perhaps more, in length: the flange to be outſide on theſe plates.

The bottom plates may be ſix feet wide, thirteen feet long, ſeven feet plate, and four arms projecting, each three feet long, in order to ſupport the horſe-path and braces; as exhibited by a bottom and ſide-plate at D.

Two of theſe plates laid acroſs the ſtage, and ſcrewed together, with the flange under, will compoſe a length equal to one of the ſide-plates; which may either meet or break joint as is thought proper. The whole may, in this manner, be ſcrewed together, on packing of wool and tar; and have the ſeams pitched like thoſe of a ſhip.

On the plates compoſing one ſide of the trough, ſmall brackets, about three feet from the top, muſt be caſt, as at E, in order to ſupport the horſe-path; perpendicular rails, eight feet long, being raiſed from the arms of the bottom plates, will ſupport the outſide of the horſe-path, alſo the iron railing, as in the ſection.

By this mode, two patterns will anſwer for the whole of the trough-plates, and but few will be required for the ſprings, rails, and ſpurs; while the ſaving in time and expence will be conſiderable; particularly where it is neceſſary to bring the ſtone by long land-carriage; for the arches being diſpenſed with, and the piers not more than one-third the dimenſions neceſſary to an aqueduct of ſtone, will moſt materially reduce the quantity of maſonry.

But, according to the various circumſtances of ſituation, carriage of ſtone, iron, &c. the diſparity between the two modes will be eaſily determined, added to which, the durability may be of ſome importance.

In aqueducts of ſtone, one of the great difficulties is to line and puddle ſo tight, as to prevent the water penetrating into, and injuring the maſonry; but in one of iron, ſhould a leak take place, it will inſtantly appear; and on ſhutting the ſtop-gates at each end, and diſcharging the water, it may be ſtopped in a few *hours, if not minutes:* this circumſtance, in aqueducts, is, perhaps, one of the greateſt preſervatives; they are conſequently leſs liable to injury, and only ſubject to the corroding tooth of time.

CHAP.

CHAP. XXI.

ON BRIDGES.

THOUGHTS on aqueducts, and their conſtruction of iron, bear ſo near a relation to bridges, that the ideas naturally tend to that ſubject, and hence I am led to offer ſome drawings on their formation of iron and wood.

In this country the attention of engineers, of late years, have been much engaged in bridges of iron, which bridges are progreſſively expanding as experience produces courage; nor ſhould I be ſurpriſed, if genius in time gave the mechanic rainbow of one thouſand feet to wide and rapid rivers.

In ſuch countries as Ruſſia and America, an extenſive arch ſeems to be a conſideration of the firſt importance: in croſſing their rivers, as the rivers, or even rivulets, in time of rain ſuddenly ſwell to a great height, and in the Spring, on breaking up of the ice, the immenſe quantities which is borne down with a rapid ſtream would, if interrupted by ſmall arches and piers, collect to ſuch a weight as ultimately to bear away the whole; it is therefore neceſſary that one arch ſhould be extended as far as poſſible, in ſuch ſituations, and ſo high as to ſuffer every thing to paſs through; or the inhabitants muſt, without ſome other expedient, ſubmit their paſſage to the caſualties of the weather.

The moſt extenſive ſpan of wooden bridges, as far as I am acquainted with the ſubject, are thoſe of Schaffhauſen and Wettingen, in

in Switzerland: the firſt, conſtructed over the Rhine, is formed in two ſpans, one of one hundred and ſeventy-two feet, the other one hundred and ninety-three, amounting to three hundred and ſixty-five, ſupported by one pier, relative to which there has been numerous arguments.

The pier being the remains of an old bridge, and the artiſt having expreſſed his deſire to croſs the river in one ſpan, or arch; but being over-ruled by the magiſtrates, who ordered him to give it a bearing on the pier, it is ſaid he ſeemingly complied with their injunctions, but ſo contrived that no part ſhould actually touch the pier; yet the pier is not in a line with the buttreſſes, but out of the rectilineal direction eight feet, forming an obtuſe angle; and this circumſtance is ſufficient to convince me, that it muſt reſt on the pier; therefore the greateſt arch cannot be conſidered more than one hundred and ninety-three feet; yet certainly a conſiderable ſtretch of genius, and a ſtrong inſtance of the curious fabric in which ſhe frequently reſides, the artiſt, Ubrick Grubenman, being a common carpenter, without the leaſt knowledge of the principles of mechanics.

In a drawing which I have ſeen, the leading beam, compoſed of two pieces laid on each other, riſes in a ſpring of about twenty feet over the pier, ſimilar to the principles of a roof, and braced by perpendiculars and diagonals, in order that it may preſerve its poſition, ſo that in ſome degree it operates like an arch, although in appearance the framing reſembles a right line, the whole being roofed; a man on foot croſſing this bridge will feel the whole fabric tremble, yet it is ſufficient to ſupport waggons heavily loaded, and bears every hardſhip uſual to bridges.

The

The bridge of Wittengen, over the Limmat, is a ſpan of two hundred and forty feet, raiſed about twenty feet from the water, and may be ſaid to hang between two bows, the ſyſtem by which it is ſupported being a ſtrong bow or arch compoſed of eight timbers bolted on each other to create breadth, and back up againſt the weight, one of the bows being on each ſide, forming a ſpring of about twenty-five feet; the horſe road is ſuſpended between the two near the centre of the bend, this is alſo roofed, and by the mode of combining, has more ſimplicity and true mechaniſm than that of Schaffhauſen, although conſtructed by the ſame ſelf-taught *artiſt*.

CHAP.

CHAP. XXII.

PLATE XIV. ON BRIDGES OF IRON.

ALTHOUGH various have been, and are, the opinions relative to the conſtruction of bridges of iron and wood; each artiſt ſeems neceſſitated to reſort to ſomething like an arch, but differing in their mode of producing it: they frequently create labour and expence by erecting a complicated fabric.

But, on this head, I conceive the firſt care is to have ſufficient butments; after which, let each ſegment of a circle, compoſing a rib, be formed of ſingle pieces as long as can conveniently be caſt; and it is evident, a circle muſt be compreſſed into a ſtreight line, or the butments ſeparate before the bridge can come down.

It is therefore only neceſſary to form a ſegment, ſo that it may not change its poſition, by ſinking in one part and riſing in another, by the various weights which it may have to ſupport, alſo guard againſt yielding ſide-ways; for this purpoſe, the great quantity of iron or wood is not ſo material as a judicious arrangement of the parts.

In iron, or wood, the artiſt may be furniſhed with pieces of greater length than poſſibly can be obtained of ſtone; conſequently, there will not be ſuch numerous joinings; and thus the ſpan may be further extended: on which ſee Fig. I.

This

This repreſents a ſegment of iron ſixty feet long, eight inches broad by four thick, and may be conſidered as a ſingle ſtone of that length; which being placed between butments and the ſpring, preſerved in a perpendicular direction, let five weights be ſuſpended at equal diſtance; and, in all probability, though each weight amounted to twenty tons, it would ſupport the whole five equal to one hundred tons: yet, let one weight of twenty tons be ſuſpended between the centre and end, as in Fig. II. and it is reaſonable to ſuppoſe, the whole would come to the ground, as the weight would compreſs one part and raiſe the other, deſtroying the ſhape of the ſegment, and preventing the direct longitudinal preſſure of the parts on each other, for want of counter-weights to preſerve the equilibrium. Therefore, after forming a ſegment, the great point is to diſpoſe of the braces, ſo as to divide the weights equally on the curve.

To effect this, Fig. III. repreſents a ſpan of one hundred and thirty feet, by a ſcale of one inch to twenty feet; and is an arrangement of parts which, I conceive, would ſtand without butments, this may be conſidered as a bow and ſtring; which ſtring, by keeping the bow bent, anſwers the purpoſe of butments; all the other braces being for the purpoſe of preſerving the bow and ſtring in their proper ſituation, by dividing the weight on the bow. For inſtance, a weight over the perpendicular B, will tend to extend 1, and 2; in which caſe, they paſs on A and C, and they pull down the bow at F and G; F and G, by the ſame ſyſtem, pull down H and I, and ſo on, wherever the weight is placed its preſſure will be divided along the bow, which conſequently cannot vary its poſition: according to the width of the bridge required, four or more of ſuch ribs muſt be conſtructed and placed perhaps ten feet diſtant from each other; the whole being faſtened by

croſs-bars paſſing through the ſtirrups, as in the aqueduct, and prevented from yielding ſideways, by the diagonal braces exhibited at A, B, &c. Fig. IV. After which, the whole may be covered with plates of iron, ſoiled and gravelled, or planked, and covered with earth and gravel in like manner.

Although, I conceive, there is little doubt but a bridge, as above deſcribed, would ſtand to the length of two or three hundred feet, yet the multiplicity of pieces of which it is compoſed, in order to preſerve the ſhape of the ſegment and relieve the butments, would evidently occaſion much labour and nicety of workmanſhip; therefore it exhibits the importance of ſimplifying ſuch works, in order to facilitate their formation, and apply every particle of materials, ſo that they may tend to ſtrengthen the whole, and not be liable to alter the poſition.

I ſhall therefore return to the firſt propoſal of adequate butments, to reſiſt the longitudenal preſſure of an arch of any dimenſions. In this it muſt be conſidered, that the butments need not be of the immenſe ſize which firſt ſtrikes the imagination; for whatever dimenſions an arch of iron or wood may be, the quantity of materials is eaſily calculated, and the weight which the butments will have to reſiſt; for inſtance, if an arch weighs five hundred tons, and the butments oppoſed to its preſſure weighs one thouſand tons, they conſequently cannot move, not to mention the weight of earth backing, which tends to render them more permanent; therefore, ſeeing that the foundations are ſecured, and the ſprings, if any, well drained, in order to keep them dry, I ſee no difficulty in conſtructing butments to ſupport an arch of any dimenſions, and that at much leſs expence than butments and piers could be erected for a ſtone bridge; in the ſame ſituation particularly,

larly, if ſuch piers were to be built in water of any conſiderable depth.

Having premiſed the butments to be of ſufficient ſtrength, I conſider the arch, whether it be compoſed of iron or wood, to be like the ſegment of a hogſhead, and the component parts as near as poſſible like the ſtaves: for this purpoſe, in conſtructing one of iron, Fig. VIII. repreſents two ſtaves, each of which might be caſt in open ſand, four feet broad from twelve to fifteen feet long, the pattern being formed to the radius of the ſpring, a flange on the lower ſide of the ſtave ſhould be caſt, about one foot broad, with holes to receive the ſcrew pins; acroſs the ſtave one or more ribs, if thought neceſſary, ſhould be caſt, to give ſtrength to the top plate; theſe ribs and flanges, in uniting the ſtaves would butt on each other, and ultimately compoſe a rib to the whole extent of the bridge.

Having caſt the ſtaves as wide and long as experience may hereafter prove expedient, I will ſuppoſe it neceſſary to erect a bridge one hundred feet ſpan, as in Fig. V.; in building the butments, it would be adviſeable to place two or three ſegments, of the ſame radius, as the bridge, in each butment, they being caſt with arms, or united to binders, in order to take a firm hold on the maſonry, and become a permanent ſupport; the ſegment thus paſſing into the butments, might be conſidered as a part of the arch, which, by this means, would butt againſt the centre of the whole weight of the butment, and muſt puſh the whole away before the arch could yield; but, without this precaution, the arch would reſt ſo near the top of the butment, as to raiſe the ſtone-work and endanger the whole. Having thus prepared the butments, a centre of three or more ſegments, ſo that each ſtave may have two bearings, ſhould be

erected; and the ſtaves being ready, all of one dimenſion, and the ſcrew-pins all of a ſize, the arch might be ſprung in a few days, breaking joint, as in Fig. VII. Thus each flange and rib would butt upon its neighbour, and the ſcrew-pins confining the whole, it would become like one ſolid ſegment of a cylinder one foot thick, *extending into the piers.*

By this mode, the difficulties which ariſe in fitting diagonal, perpendicular and lateral braces, are avoided, the top plate performing the office of all ſuch braces; which top-plates, in other compoſitions, have no tendency to ſtrengthen: thus every particle is applied to reſiſtance, and the materials have but few joinings; which junctions have alſo broad and permanent bearings of one foot on each other, the flange and ribs being caſt of that depth. Thus, I conceive, a bridge of one hundred feet, or perhaps one hundred and fifty feet ſpan, might be erected at a cheap rate, with with a ſmall quantity of materials, yet with the proſpect of great durability. If I ſuppoſe a bridge one hundred feet ſpan, thirty wide, with the top plate one inch thick, five flanges or ribs, each one foot broad and two inches thick, the whole weight of the arch would not be more than ſeventy-eight tons, allowing one pound to every four cube inches of caſt-iron.

So far relates to iron bridges of one hundred or one hundred and fifty feet ſpan; but ſhould it be neceſſary to extend them to a greater length, to ſay three hundred feet, two ſegments would then be requiſite; the firſt, as in Fig. VI. as the principal ſupport; the ſecond, to eaſe the paſſage, ſhould be of ſuch a bend as would admit an eaſy aſcent and deſcent; and, by being part of a curve, it alſo tends to ſtrengthen; thus, if I ſay, ſpan three hundred feet, the firſt ſpring thirty, the ſecond ſpring only ten feet, they both muſt be

be compreſſed into ſtreight lines, before they can come down; they will alſo have twenty perpendicular feet of bearing on the butment, the bearings oppoſite to the two ſegments being oppoſed by ſegments entering the butments, as before deſcribed; the two ſegments muſt be kept aſunder by perpendiculars in the haunches, placed at about ten feet diſtance from each other, as in the Figure. See Plate XV. exhibiting the combination by ribs and braces; alſo Plate XVI. repreſenting the arch of ſtaves.

Having exhibited the mode of conſtruction, I conceive it unneceſſary to comment on the particular formation, or to draw a comparative view of this and other bridges of iron; as in caſes where they may be required; the artiſt will weigh the various circumſtances, inveſtigate the ſeveral modes of building, and chooſe for himſelf; in which there is a leading deliberation, viz. By what means can a given quantity of materials be arranged, ſo as to incur the leaſt expence in erecting, and be rendered moſt permanent; and by which mode will the leaſt materials anſwer the purpoſe?

CHAP.

CHAP. XXII.

PLATE XVII. OF BRIDGES OF WOOD.

THE important objection to bridges of wood, is their rapid decay: and this objection is certainly well founded, when particular ſituations are alluded to, where timber is ſcarce, and conſequently expenſive; but in ſuch countries as America, where wood is abundant, I conceive it will be a fair criterion to judge of their application, by calculating on the expence of a bridge of ſtone and one of wood; then compare the intereſt of the principal ſaved in adopting the wood-bridge, with the expence of its annual repairs.

I have before exhibited the neceſſity of conſtructing bridges in America, of an extenſive ſpan or arch, in order to ſuffer the ice and collected waters to paſs without interruption: and for this purpoſe, it muſt be obſerved, that a wood arch may be formed of a much greater length, or ſpan, than it is poſſible to erect one of ſtone; hence they are applicable to many ſituations, where accumulated waters, bearing down trees and fields of ice, would bruſh a bridge of ſtone from its foundation.

It therefore becomes of importance, to render bridges of wood as permanent as the nature of the material will admit.

Hitherto the immenſe quantity of mortiſing and tennants, which however well done, will admit air and wet, conſequently tend to expedite the decay of the weak parts, has been a material

error in conſtructing bridges of wood; the mode of arranging the parts, by a repetition of bracing, has alſo expoſed almoſt every ſide of the whole of the timbers to the changes of the weather; conſequently, the whole was reduced to the durability of one ſtick, ſimilar to ſuſpending a cage in open air, each ſtick is expoſed to decay, without receiving ſhelter from each other.

It has alſo been uſual to place ſupporters in the water, ſubjecting them to the ſurge of floods, which ſhake the whole fabric; which ſupporters decaying progreſſively let down the upper works.

But to render wood-bridges of much more importance than they have hitherto been conſidered; firſt, from their extenſive ſpan; ſecond, by their durability; two things muſt be conſidered: *firſt*, that the wood-works ſhould ſtand clear of the ſtream, in every part, by which it never would have any other weight to ſuſtain than that of the uſual carriage; *ſecond*, that it be ſo combined as to exclude as much as poſſible the air and rain.

For this purpoſe, in erecting a bridge of wood, I would proceed much on the ſame ſyſtem as in conſtructing the one of iron ſtaves. For inſtance, ſuppoſe a bridge three hundred feet ſpan, thirty feet wide, the butments being rendered ſecure, and centres raiſed on piles; let timbers, if convenient, be procured thirty feet long, and of as great diameter as the country will produce; ſuch timbers being ſquared and planed to the radius of the arch, with the holes to receive a bolt or trundle, about four feet diſtant from each other; the whole operation in ſpringing the arch, will be to tar or paint the junctions with white lead, and inſert the trundle, as at A, Fig. II. and preſs them cloſe, thus lay them ſide by ſide, by which means an arch might be laid in a few days,

tions; the queſtion is, Whether the arrangement of parts is ſo calculated as to guard againſt ſuch accidents? which probably will appear by the following conſiderations:

Firſt, the butments may be made to reſiſt any weight, by giving a greater weight of ſtone than there is weight of materials in the arch.

Second, the timbers being laid ſide by ſide, like ſtaves, and preſſing on each other, leave not the leaſt aperture into which the parts of mortiſed and framed timbers might be compreſſed; hence, ſeveral timbers, in a long arch, muſt abſolutely be compreſſed into nothing, before the ſegment could become a ſtrait line.

Third, that it may not vary its poſition, by ſinking in one part and riſing in another, with the various weights, I will conſider the ſtaves and belts only: it muſt be obſerved, that by bolting down the belts, which belts may be from thirty to forty feet long, and break joint, as in Fig. II. the whole arch will become like one ſolid piece of timber, bent between the piers. I will now ſuppoſe ſuch a bridge forty feet broad, the timbers combined eighteen inches thick; hence, admitting that it was conſtructed of wood as light as fir, each lineal foot would weigh one ton and a half, hence every thirty feet forward would weigh forty-five tons; as a waggon, when loaded, ſeldom weighs more than five tons †.

Although this may not be neceſſary, it is certain; and as it is more my intention to exhibit the poſſibility of conſtructing bridges of a great ſpan, than to point out the preciſe proportion of the parts, I conceive, by ſhewing it poſſible, future deliberations of ingenious men will determine the proportion.

† By this I mean the broad-wheeled waggon of England, the American waggon is ſeldom more than three tons.

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And admitting four ſuch waggons, weighing twenty tons, to ſtand abreaſt on the bridge, in which ſituation they would have the greateſt poſſible preſſure, by acting near the ſame ſpot; yet, to compreſs the part, thirty feet of the bridge, at leaſt, on each ſide, muſt riſe, and this in ſome meaſure raiſing the whole of the ſpring, which would be a weight of at leaſt one hundred tons; hence, as twenty tons cannot move one hundred, without ſuperior leverage, and as there is no leverage obtained, conſequently there is no weight which it is reaſonable to ſuppoſe can come on a bridge at one time can injure it.

The longitudinal preſſure being conſidered, the tendency to yield ſideways may be prevented, by conſtructing it wide at the ends and contracted in the centre; the preſſure will then be reſiſted by an arch in every direction. Having exhibited the conſtruction, and aſſigned my reaſons for its permanency, I hope it will eaſily be admitted, that a bridge of three hundred feet would be perfectly ſafe; but if the reader ſhould heſitate at this, he has my reaſon why it would ſtand, and it will be well to diſcover the reaſon why it would not: but ſuppoſing it admitted, that three hundred feet would be ſafe, I ſee no difference between that and one of five hundred, or even more feet ſpan, the proportions being preſerved by a ſpring one tenth of the ſpan*

* When the true principle of building bridges of wood is diſcovered, their progreſſive extention is as reaſonable, as the increaſed dimenſions of ſhipping; which, in early ages, was deemed a great work if they amounted to one hundred tons burthen; but time and experience has extended the art of ſhip-building to two thouſand tons; and in the combination and arrangement of the various and complicated parts, there certainly is more genius and labour required than in erecting a bridge of five hundred or one thouſand feet ſpan: but the great demand for ſhipping has rendered the formation familiar, and their increaſed bulk gradually grew into the ſenſes: but had a man, in the infancy of naval architecture, hinted at a veſſel of two thouſand tons, I am inclined to think his cotemporary artiſts would fix him with the gentle appellation of mad-man.

Having made this aſſertion, almoſt fear I have forfeited the confidence of my reader, who may now be inclined to doubt the ſtability of my ſenſes; but patience ſhould accompany inveſtigation, and I muſt beg of him to proceed to give ſome idea of the proportion of ſuch a bridge of five hundred feet ſpan, fifty feet ſpring, and forty feet broad: take a board eleven feet long, ten inches wide, and half-inch thick, and bend it between two blocks till it riſes twelve inches, and it will give a model of the ſpring of an arch compoſed of two rows of ſtaves, each a foot thick, amounting to two feet in thickneſs; extend this idea, by meaſuring off five hundred feet in a field, and imagining a perpendicular in the centre fifty feet high, then draw a ſegment by the eye, conceive the whole well wedged and bolted together, the proportions of the timbers preſerved, and deliberate on the part where it could give way.

TO

THOMAS MIFFLIN,

GOVERNOR OF THE COMMONWEALTH OF PENNSYLVANIA.

SIR,

DURING the profecution of my experiments on Canal operations, which are exhibited in the preceding treatiſe, I frequently contemplated their great importance to the States of America, and much wiſhed to awaken the public mind to a full ſenſe of the ſubject; but, on conſidering the habits of the people of the interior country, accuſtomed only to land carriage, I feared much difficulty would ariſe in removing the prejudice in favour of waggoning, and in raiſing a ſum of money adequate to the firſt expence of a canal of importance. In deliberating on the mode of ſurmounting theſe obſtacles, I was ſo fortunate as to meet with your Addreſs to the Houſe of Repreſentatives in 1795, and particularly happy to find your ideas, of the importance of eaſy communications between remote parts of the country, ſo conſonant to my own, and at the ſame time ſo earneſtly recommended to the public attention: which circumſtance has urged me to addreſs this Chapter to you, convinced that your ſenſe of the ſubject will not ſuffer any obſervations which may be uſeful to lie dormant.

I muſt therefore requeſt you deliberately to peruſe the ſyſtem laid down, which you will find, by Chapter VII. totally explodes the old practice, for two reaſons: *Firſt*, Becauſe they may be conſtructed for half the ſum neceſſary to a lock canal; and, *Secondly*, Becauſe on them you may perform diſpatch, and paſs through the moſt mountainous country at the ſpeed of ſix miles per hour; an advantage

advantage which lock canals can never give, and which precludes an immenſity of carriage: yet the ſmall canal takes in every kind of conveyance, and performs the double office of a canal and road; therefore, if founded and governed by ſound principles, a mountainous country may have all the bleſſings of water conveyance, ſo celebrated in the level and fertile plains of Egypt. But how to extend theſe conveniencies into every corner and diſtrict of America, is now to be conſidered.

While the mind hovers over the immenſe continent of America, and views its vaſt interior, inhabited in various diſtricts remote from the marts of trade, with infinite ſcenes for the improvement and nouriſhment of millions of human beings, philanthrophy ſeeks to combine the exertions of the preſent inhabitants to facilitate their labour, extend their intereſts, invite population, and give a cultivating hand to every acre of that extenſive territory.

To ſuch a wiſh, in one point of view, is preſented a great and fertile country, interſperſed with luxuriant vales and numerous mountains, nouriſhing infinite rivulets, which, meandring the country, feed long and rugged rivers, diminiſhing to naked ſhoals in dry ſeaſons, or ſwelling to roaring torrents in time of rain; preſſing their way through ſtupendous cliffs and infinite rocks, preſent objects hoſtile to navigating the ſtreams of nature.

But ſuch are the materials which art muſt bring into uniſon; the performance of which is a ſubject the moſt benevolent and important, and worthy the ſerious contemplation of the penetrating members of ſociety, as a great national queſtion.

On this head it muſt be evident, that in proportion as produce is remote from market its value is diminiſhed, in conſequence of the

the expence of carriage, and hence remote parts are excluded the market, or a facility of exchanging their ſurplus produce for neceſſaries which they may require; thus the nerves of exertion are cramped, the faculties of body and mind are not called forth, and the country remains a dreary and inhoſpitable waſte. But to encourage population and increaſe the value of the lands, the cheapeſt poſſible conveyance of the produce muſt be eſtabliſhed on ſound principles; for, exactly in proportion to the eaſe of reaching the market, the remote countries of equal fertility will be of more or leſs conſequence in the ſcale of ſociety; therefore, to ſum up the idea, would not the lands about Fort-Pit be as valuable as thoſe round Lancaſter, if the produce could be brought to market for the ſame ſum; and would not population conſequently be encouraged?

For this purpoſe, as I have the ſtrongeſt conviction operating on my mind, that canals are the only effectual means of producing eaſy communications, and that they conſequently are of the utmoſt importance; I much wiſh that the public may be made thoroughly ſenſible of their utility, and that each State might eſtabliſh a ſociety to inveſtigate the propriety of forming them in ſuch diſtricts as the preſent ſtate of population and trade may moſt require them; keeping one important object in view, that all future canals may be conſtructed on one ſcale and principle, in order that when the various branches meet the boats, one may navigate the other wherever canals extend. This you will obſerve has been my wiſh throughout, and in which I hope I have been ſo fortunate as to ſucceed; if ſo, canals appear in a new light, and are ſtill more important than formerly, becauſe they may now be fitted to every kind of country, and by their cheapneſs approach near to the expence of conſtructing turnpike roads.

At

At a period when a country is improving by turnpike roads, the queſtion is, whether it is not beſt to adopt canals; and the criterion to judge of the propriety of the canal, will depend on ſimple calculation, to the following effect; 1*ſt*, what is the expence of the road; 2*d*, what is the expence of the canal; 3*d*, what is the expence of carriage by the road; 4*th*, what is the expence of carriage by the canal; and probably it will be found the canal will perform the work ſo cheap, as to juſtify three or four times the ſum being expended in the canal, that would be neceſſary to conſtructing a road of the ſame length; to which one conſideration muſt be added in favour of the canal, viz. on all roads, however good, the great expence of carriage is the number of horſes; but on canals, the principal expence is the tonnage or tolls to the proprietors, as intereſt for the money advanced in forming the canal: yet this tonnage by a judicious arrangement may be reduced, *if not liquidated*, and the carriage on a canal may be ſo regulated, that goods conveyed four hundred or more miles, will not coſt more than thoſe which are navigated eighty or one hundred miles; yet the eighty or one hundred miles canal conveyance will not coſt half the ſum neceſſary to land carriage, on the beſt of roads.

To elucidate this, I will ſuppoſe a canal from Philadelphia to Fort-Pit, or any other long line, to ſay, three hundred and fifty miles; on ſuch a canal a man, boy, and horſe, would convey forty tons twenty miles per day, and arrive at Philadelphia in (*ſay*) eighteen days, at 10*s*. per day, amounting to 180 ſhillings for forty tons, or 4*s*. 6*d*. per ton, the expence of boating, independent of tolls. By a road of the ſame length, four horſes, perhaps five, would ſet out with not more than two tons, and, travelling at the rate of twenty-five miles per day, arrive at Philadelphia in fourteen days; and to ſay only two dollars, or 15*s*. per day, amounting to 210 ſhillings, or 5*l*. 5*s*. per ton for waggoning, independent of turnpike.

pike. This, I hope, will exhibit the immenſe diſparity between the two modes, and ſhew that roads, however good, can never effectually relieve a remote country. The queſtion then is, how to conſtruct a canal in order to reduce the tolls, and completely aſſiſt the diſtant diſtricts; this I conceive will totally depend on the mode of raiſing and appropriating a ſum of money to the firſt fifty or one hundred miles of canal.

In this country, canals are paid by companies of ſubſcribers, who receive a toll on the carriage of goods as an intereſt for the money advanced, and the immenſe quantity of carriage throughout every part of this compact kingdom, uſually produces a conſiderable intereſt for the money expended, while the expence of carriage is reduced below that of land conveyance; but as England is environed with water, with numerous ſea ports, there is no part very remote from the market, and hence, they never will have canals of any comparative length with thoſe neceſſary in America, to ſay ſeven or eight hundred miles; therefore the mode of proprietors receiving tonnage at ſo much per mile, although it will ever be much below land carriage, yet even that tonnage would preclude the market from the remote country, and by no means anſwer for American canals: for inſtance,

	£.	s.	d.
A conſtructs a canal fifty miles long, and receives two-pence per ton per mile -	0	8	4
B ditto - - - - -	0	8	4
C ditto - - - - -	0	8	4
D ditto - - - - - -	0	8	4
E ditto - - - - -	0	8	4
F ditto - - - - -	0	8	4
G ditto - - - - -	0	8	4
350 miles	£. 2	18	4 per ton,

tolls, independent of boating; and hence I conceive the produce could not bear the expence of carriage by this method.

But as it is the produce of the interior country which muſt be drawn forth, the leading canals ſhould be national works, perhaps by the following ſyſtem.

Firſt, That the legiſlature, by ſuch duties or impoſts as they conceive moſt eligible, raiſe a ſum of money adequate to the expence of the firſt ſixty or ſeventy miles of canal; to ſay from Philadelphia to Lancaſter, which perhaps may coſt 150,000l. of which 30,000l. per annum, may be required till the canal is finiſhed. On this canal, ſixty miles long, if I ſuppoſe fifty tons per day to be navigated at two-pence per ton per mile, allowing two hundred and eighty working days per year, it would amount to 7,000l. per annum, which ſhould be applied to extending the canal; the tolls on ſuch extenſion being appropriated in like manner to further extention, and ſo on, the toll to be continually devoted to forming more canal; till canals would pervade the whole country by virtue of their own produce ariſing from the tolls.

If this mode of extending the canal, by appropriating the tolls, ſhould be deemed too tedious for the ſpeedy relief to the interior country, and the funds of the ſtate would admit of the advance of a further ſum, they might immediately extend the canal two hundred miles, and receive the tolls, till the laſt advanced ſum was liquidated; or, as the proprietors of the lands in the interior would be much benefited by their property being raiſed in value, probably they might raiſe the ſum, and receive the tolls till ſuch ſum was liquidated: the lands being increaſed in value, might be deemed

ſufficient intereſt till the principal was diſcharged, which would diminiſh every year.

If by either of theſe modes, or any better which can be deviſed, I ſuppoſe the firſt two hundred miles of canal to be formed, the trade will be more in proportion to the length than on the firſt ſixty miles before eſtimated; becauſe, being more remote from the metropolis, the interior inhabitants will be neceſſitated to fly to the canal, the tonnage will alſo be greater; therefore, if I allow on the two hundred miles one hundred tons per day, to be navigated at twenty ſhillings per ton for the whole length, or in proportion for a ſhorter diſtance, the annual produce would be 2,000l.; and having arrived at ſuch annual income, canals would proceed with diſpatch, and progreſſively increaſe, both in riches and extenſion; each year the produce of tonnage would increaſe, and each year a greater length of canal might be conſtructed.

Therefore, if I proceed with this progreſſive and creative ſyſtem, till a canal reached Fort-Pit, which, with ſome bends, I will call three hundred and ſixty miles; the country, which ſuch canal would accommodate, would widen as it was more remote from Philadelphia. For inſtance, the man who lived twenty miles from Philadelphia, might convey his goods ſeven to the canal; the man at forty miles diſtance might go fourteen or fifteen to the canal; at ſixty miles, twenty to the canal; and ſo on, till at the extremity of three hundred and ſixty miles, they probably would go fifty on each ſide to the canal; hence, if I average the whole, ſuch canal may be ſaid to accommodate a country three hundred and ſixty miles long, fifty miles wide; on which the tonnage muſt now be regulated.

The man who reſides twenty miles from Philadelphia, and ſeven from the canal, ſhould he convey a ton of goods by land, it would be worth at leaſt fifteen ſhillings, as it would employ a man and two horſes two days*.

	s.
The carriage to the canal, ſeven miles in like proportion, - - - - - - -	5
Carriage on the canal, - - - - -	4
Total,	9

Thus the ſaving would be ſix ſhillings, and the tonnage ſhould increaſe to a certain ſum on the firſt hundred miles of canal, keeping much within the limits of land-carriage; then decreaſe as the boating increaſed, in order to draw the trade of the back country into the canal.

The expence of boating a ton twenty miles will be as follows: a man, boy, and horſe, will convey forty tons twenty miles for ten ſhillings, which is three-pence per ton for twenty miles; but to allow contingencies, ſay four-pence per ton, for boating twenty miles; the tonnage and boating on the three hundred and ſixty miles ſhould then be regulated, perhaps, in the following order.

* The Engliſh reader, who may look over this chapter, may perhaps be ſurpriſed at ſtating the land-carriage of America ſo low. But as I do not know the average expence of that country, I eſtimate it low in order to give it every advantage, in a comparative view, with the canal. In England, it would coſt at leaſt one guinea, with all the advantage of good turnpike roads.

Miles.	*Tonnage.*		*Boating.*		*Amount.*	
	s.	*d.*	*s.*	*d.*	*s.*	*d.*
20	4	0	0	4	4	4
40	8	0	0	8	8	8
60	12	0	1	0	13	0
80	16	0	1	4	17	4
100	20	0	1	8	21	8
120	19	8	2	0	21	8
140	19	4	2	4	21	8
160	19	0	2	8	21	8
180	18	8	3	0	21	8
200	18	4	3	4	21	8
220	18	0	3	8	21	8
240	17	8	4	0	21	8
260	17	4	4	4	21	8
280	17	0	4	8	21	8
300	16	8	5	0	21	8
320	16	4	5	4	21	8
340	16	0	5	8	21	8
360	15	8	6	0	21	8

By this ſyſtem, the country at the extremity of three hundred and ſixty miles, would deliver goods at Philadelphia for twenty-one ſhillings and eight-pence; which is the ſame as paid at the diſtance of one hundred miles; to which the land-carriage to the canal muſt be added. But as ſuch a ſyſtem would open a market to the remote country, every acre of ground within reach of the

* This being within the limits of land-carriage, the tonnage muſt now begin to decreaſe as the boating is increaſed.

† If the boats return without back-carriage, the expence of boating, which on the three hundred and ſixty miles is ſix ſhillings, muſt be deducted from the tolls; and in proportion on the various parts of the canal.

canal

canal would become more valuable, and the carriage to the canal muſt be borne for ſome years. But as population increaſed, and the tonnage on the main line became productive, lateral branches would be cut from the canal, and thus further improve the country; the tonnage on ſuch branches being proportioned as before ſtated, according to the diſtance from the city.

The carriage on ſuch canal would conſequently be immenſe; for, as I before ſtated, it would accommodate a country three hundred and ſixty miles long, fifty miles wide, in the main, containing eighteen thouſand ſquare miles, or eleven million five hundred and twenty thouſand acres. If, by further improvement, I allow that only every fiftieth acre will produce one ton of carriage per annum, the amount would be two hundred and thirty thouſand four hundred tons; which appears, by averaging the preceding tonnage, would coſt fifteen ſhillings per ton, in tolls to the canal, amounting to 172,800l. per annum, in order to conſtruct further canal; a ſum adequate to forming, perhaps eighty or one hundred miles per year: having arrived at ſuch a length, it is evident canals would increaſe with aſtoniſhing rapidity, and produce conveniencies, even beyond the limits of calculation; for it muſt be obſerved, and ſtrictly adhered to, that by canals you may equalize the carriage of the near and remote country, as before exhibited by the mode of regulating the boating with the tonnage, in proportion to the extent; inaſmuch as that a ton of goods may be carried three hundred and ſixty miles for 1l. 1s. 8d. Yet, was I to extend the idea to a ſtill more diſtant diſtrict, by reducing the tonnage as the boating increaſed, till the tolls were annihilated, and the boating amounted to 1l. 1s. 8d.; a ton of goods might be boated thirteen hundred miles for that ſum; yet a ton could not be waggoned the ſame diſtance for leſs than 38l. 10s. ſo great is the diſparity between land and water-carriage.

Hence

Hence it muſt be evident, that roads, however good, can never effectually aſſiſt the remote country, each mile is attended with a heavy expence on carriage, till penetrating ſo far, that the value of the produce is conſumed in carriage; it terminates in a luxuriant wilderneſs, ſable and uncultivated as the interior of Africa. But by canals, the conveyance may be ſo eaſy, that they may penetrate the moſt remote diſtricts, draw down the produce to the ports of trade, and bear up the various conveniencies of life; thus each man may exchange his ſurplus labour for the neceſſaries or luxuries which he may require; hence his faculties will be put into action, cultivation will flouriſh, and enjoyment be more equally diffuſed; canals will paſs through every vale, meander round each hill, and bind the whole country in the bonds of ſocial intercourſe; hence population will be increaſed, each acre of land will become valuable, induſtry will be ſtimulated, and the nation, gaining ſtrength, will riſe to unparalleled importance, by virtue of ſo powerful an ally as canals.

Having exhibited the immenſe diſparity between canals and roads, with the mode of extending canals in every direction, by appropriating the tolls; it is evident, that ſuch a ſyſtem will produce infinite navigation. But the mode of conſtructing them muſt be maturely conſidered; and in this, two things muſt be ſcrupulouſly adhered to.

Firſt, that canals may truly benefit a country, it is neceſſary the paſſage ſhould be performed with equal eaſe each way. Second, that the neareſt courſe ſhould be taken to the principal points of the country; and for both theſe reaſons, the beds of the rivers, beyond tide, muſt almoſt univerſally be for-

forſaken *; becauſe torrents, in time of rain, which is extremely injurious to the works of art, with the ſhoals in dry ſeaſons, together with the current ever ſtanding one way, will very frequently interrupt free intercourſe, and render freſh-water river navigations precarious.

The rivers, creeks, and rivulets, which are numerous in all parts, muſt be conſidered as the feeders of canals; and, in this reſpect, having an abundance of water, America is very fortunate; land is alſo cheap and timber plenty, ſo that the great expence of an American canal would be labour.

Therefore, as it is the channels of art, which can only effectually aſſiſt the country, I have conſtantly endeavoured to find a ſyſtem which might paſs by the ſtreighteſt line to a given point; hence you will obſerve the mode of mountinghills, croſſing valleys, rivers, and defiles, by the various machines; which, I hope, will diſplay an eaſy means of extending water communications through a great continent, and bear the mind to thoſe days, when a well-directed œconomy in manual labour will give enlightened and rational enjoyment to many millions of inhabitants: hoping, that this important ſubject will make a part of the deliberation of a wiſe Legiſlature,

I remain, with all poſſible Reſpect,

Yours ſincerely,

ROBERT FULTON.

London, March, 1796.

* By forſaking the beds of the rivers I mean, that they ſhould not compoſe or make a Principle part of a leading canal; yet, however numerous canals may be, it will frequently happen that ſome miles of a river will afford eaſy navigation in particular ſeaſons, and probably touch the leading canals into which the goods, or perhaps boats, may be transferred from the river; for ſmall boats will live on the American rivers in particular parts and ſeaſons, of which there are innumerable inſtances by the batteaus and even canoes.

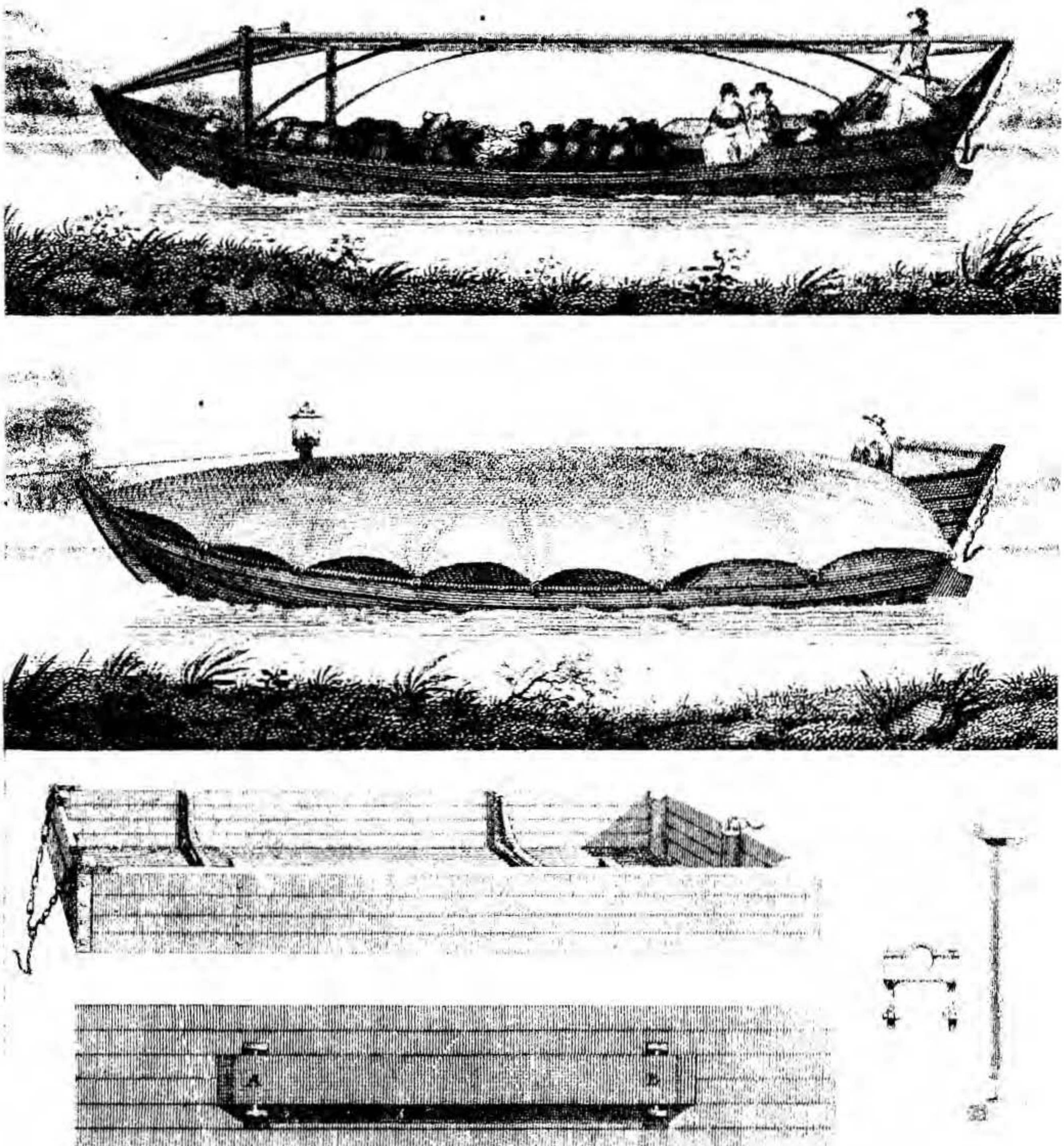
ADDITION

IN conducting a line of canal through a mountainous country, it may, in many inſtances, be extremely difficult to ſupply the top level with water to work the machinery; yet the country may produce ſufficient at the next lower level; for inſtance, at one or two hundred feet below the top pond of canal.

In ſuch caſe, if the ground is ſloping, ſo as to admit of a diſcharge from the bottom of the tub-pit, *or even a water wheel*, the machinery exhibited by the preceding Engravings may be placed at the bottom of the plane, and receive motion from the water of the lower level; by which the boats may be paſſed to and from the ſummit with the ſame facility as if the machinery was on top of the plane, and thus the water of the ſummit level will be preſerved: which exhibits another important advantage over lock canals.

The whole of the apparatus will alſo equally apply, whether there are wheels to the boats or rollers to the plane.

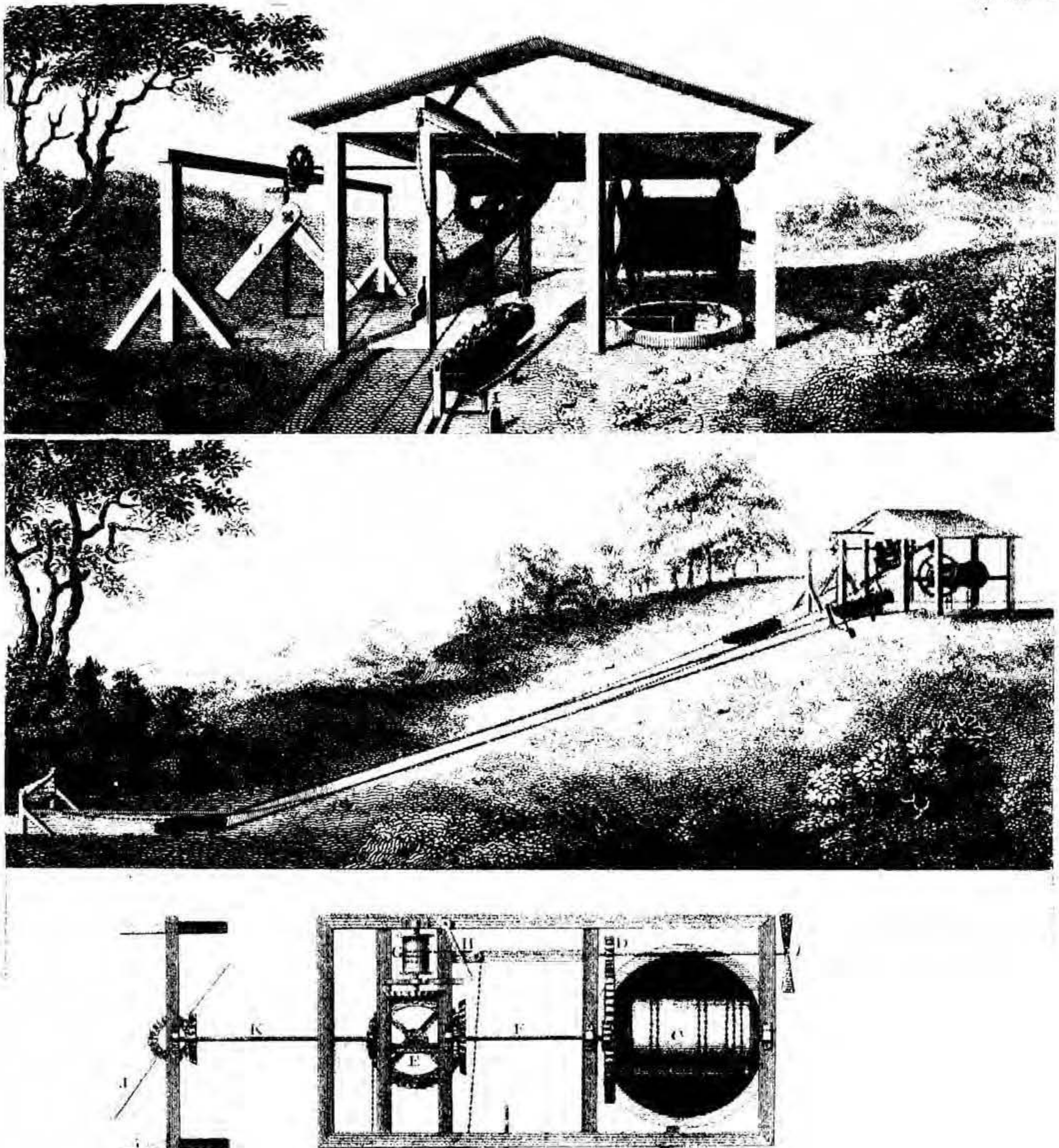
F I N I S.



BOATS

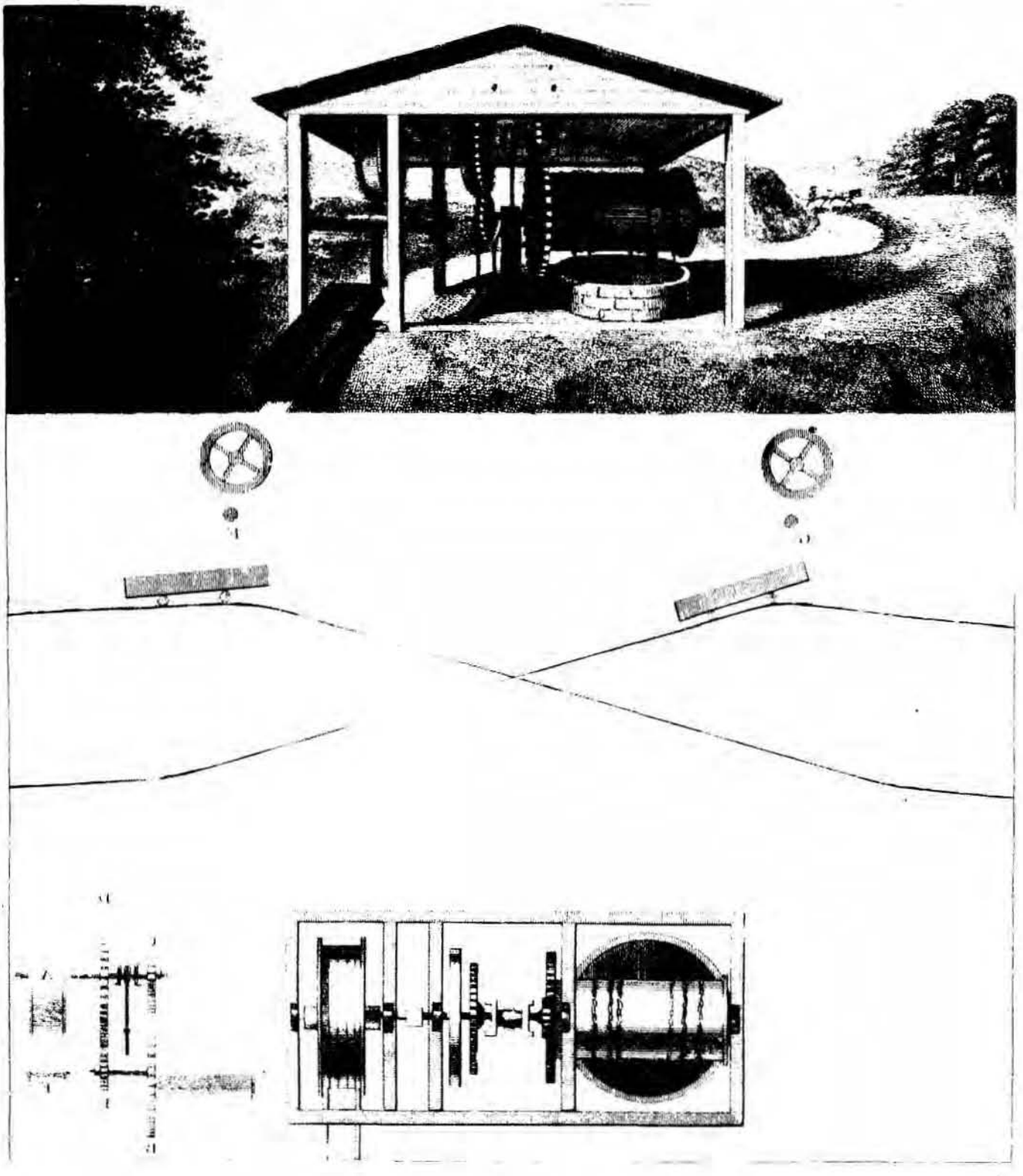
1. The Market or Passage Boat [illegible]

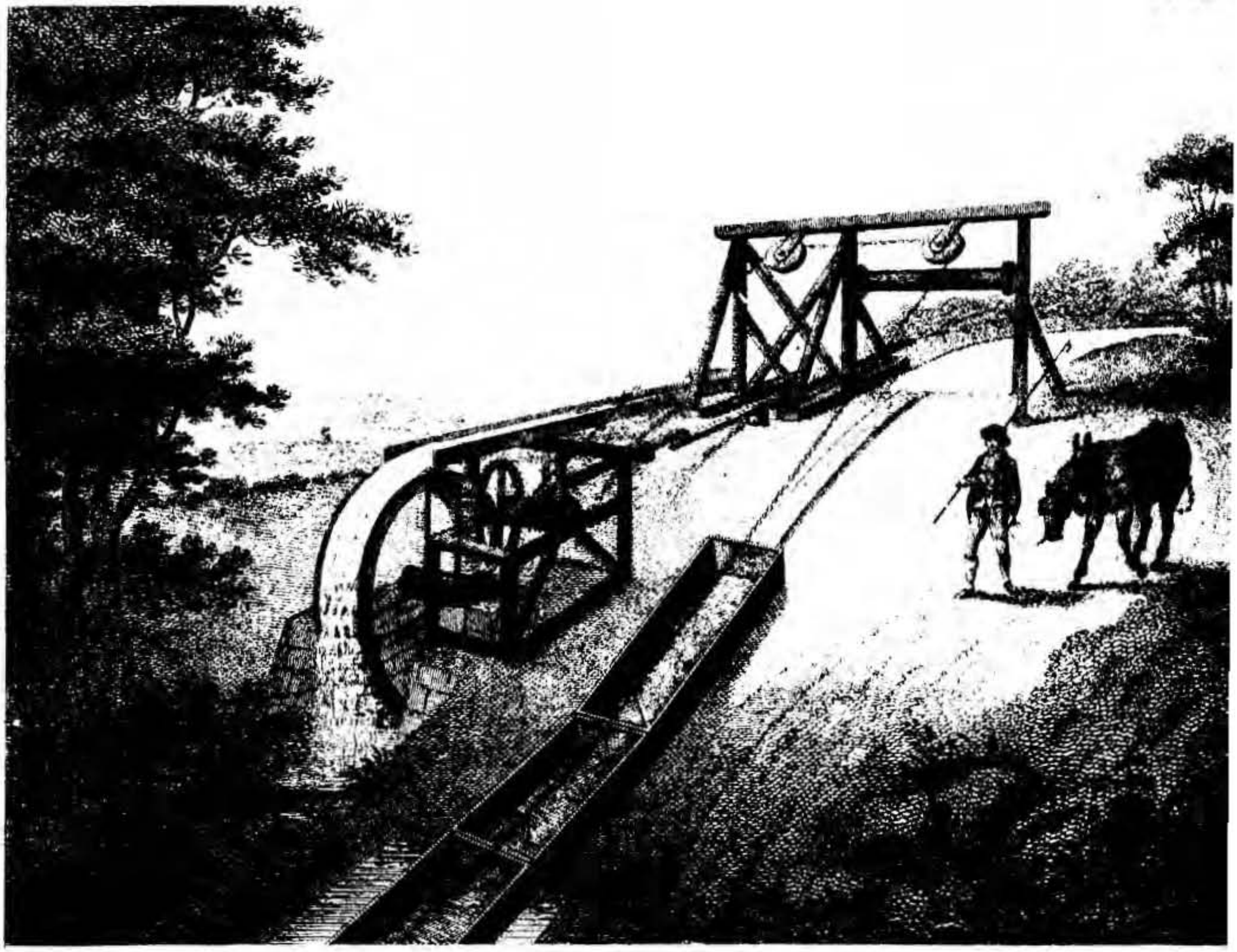
3. The Common [illegible] Boat

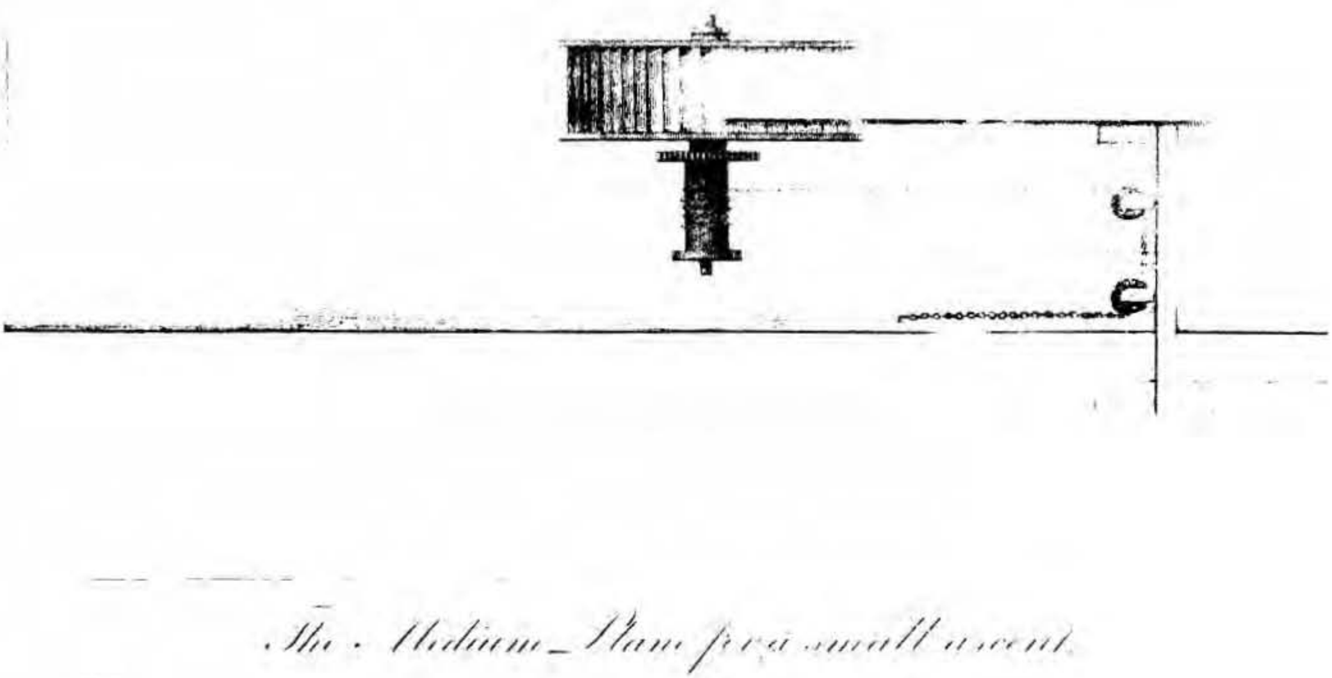


The Double Inclined Plane

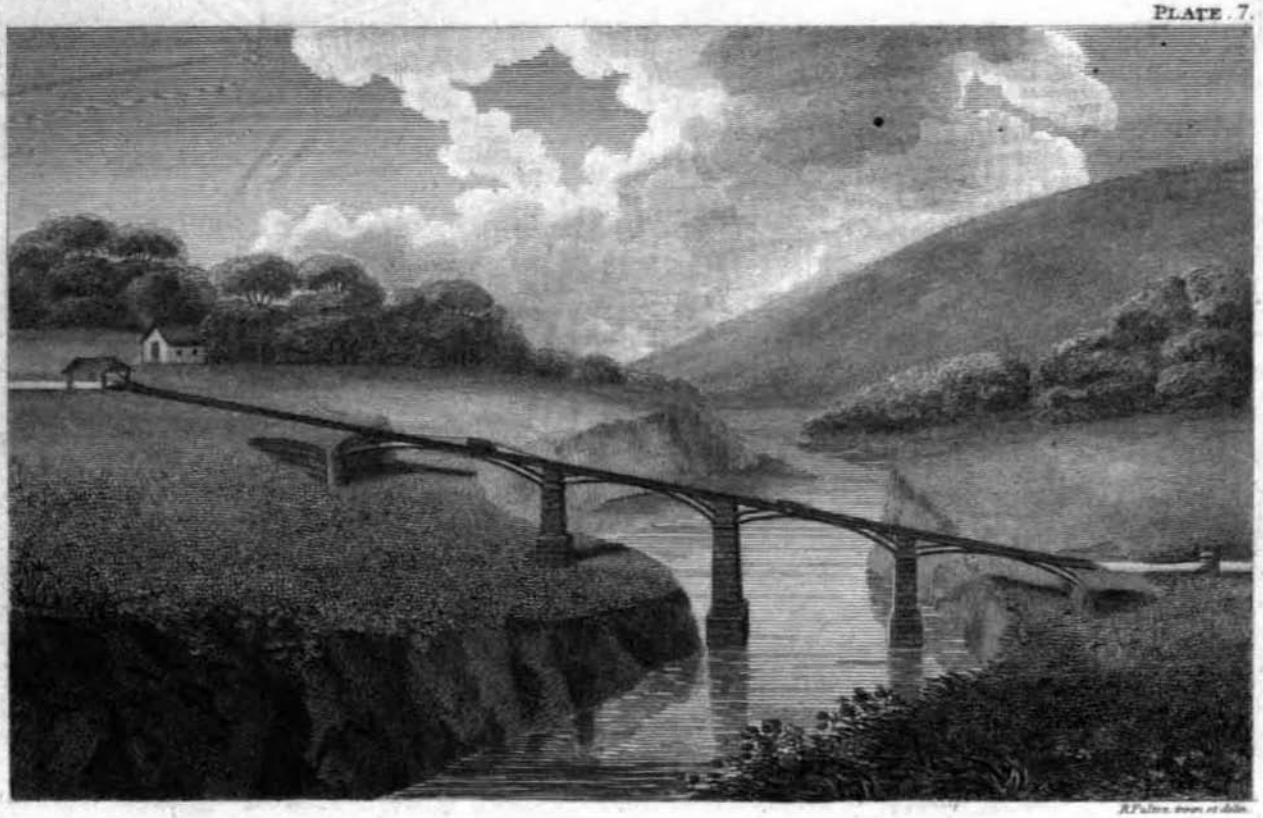
[illegible]







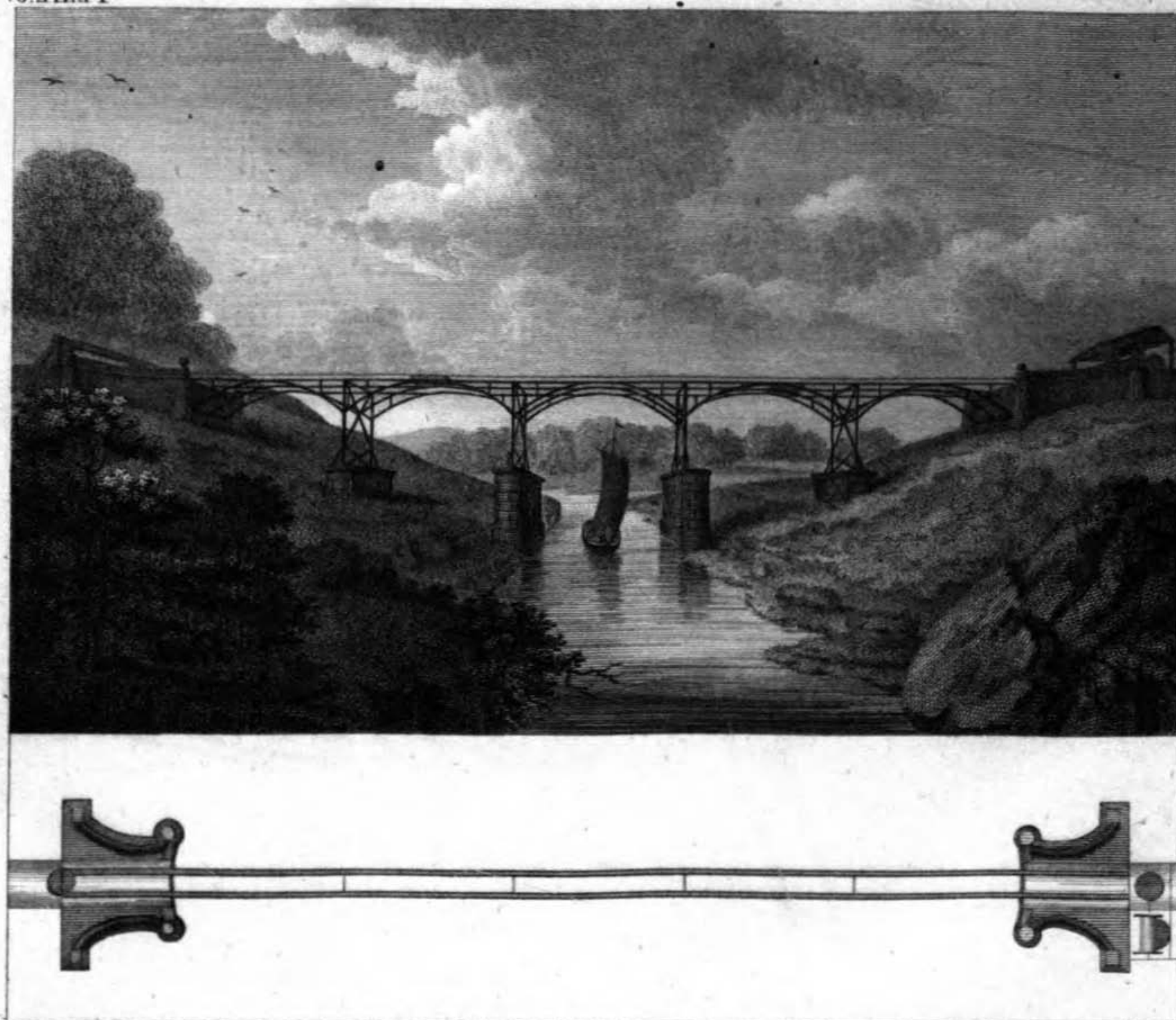
The Medium Plan for a small ascent.



The mode of paſsing Rivers and gaining height at the same time.

London: Publiſhed by I & J. Taylor Holborn March 1 1796.

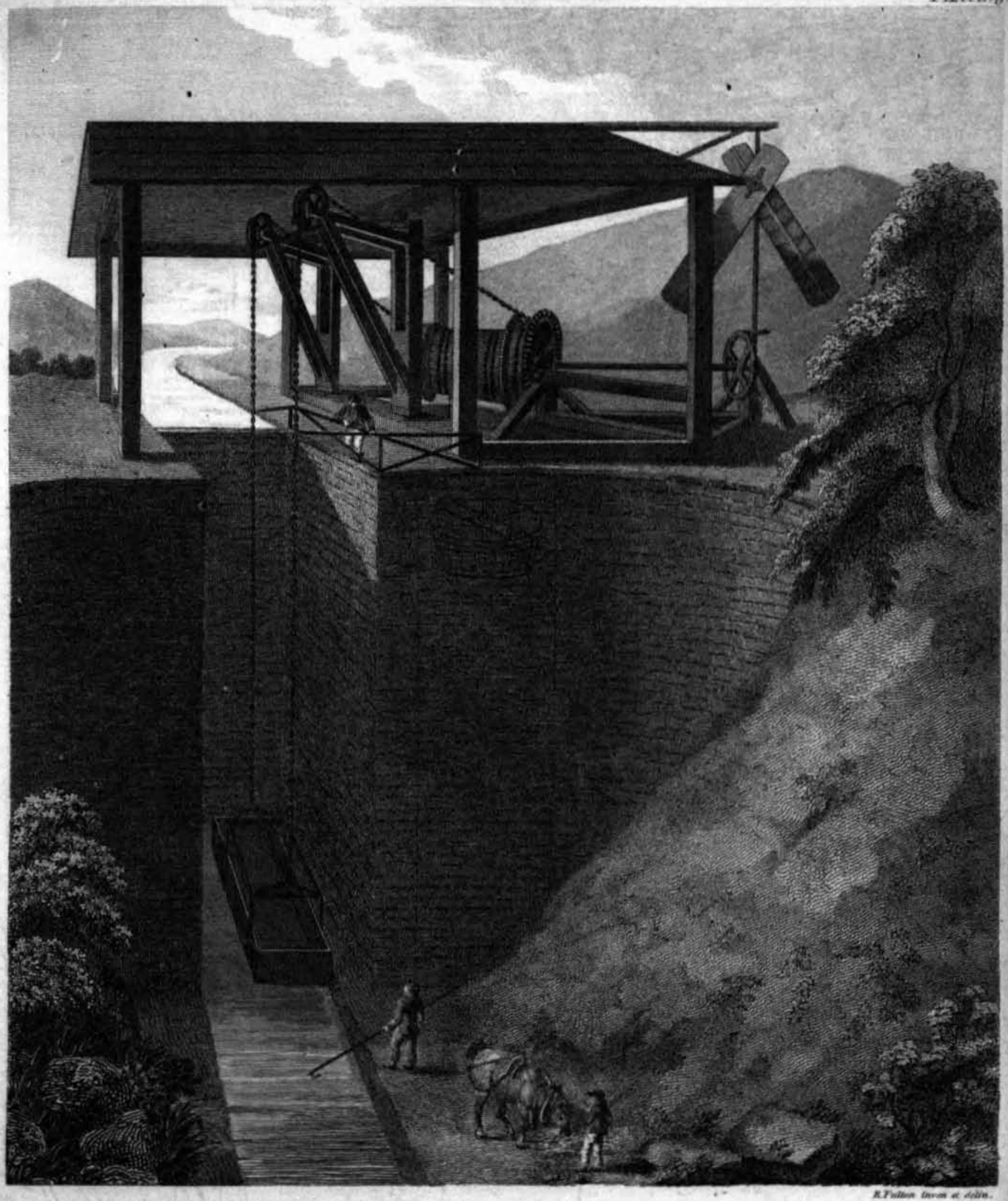
PLATE 8.



R. Fulton, invent et delin.

The Second mode of passing Rivers Independent of Aqueducts.

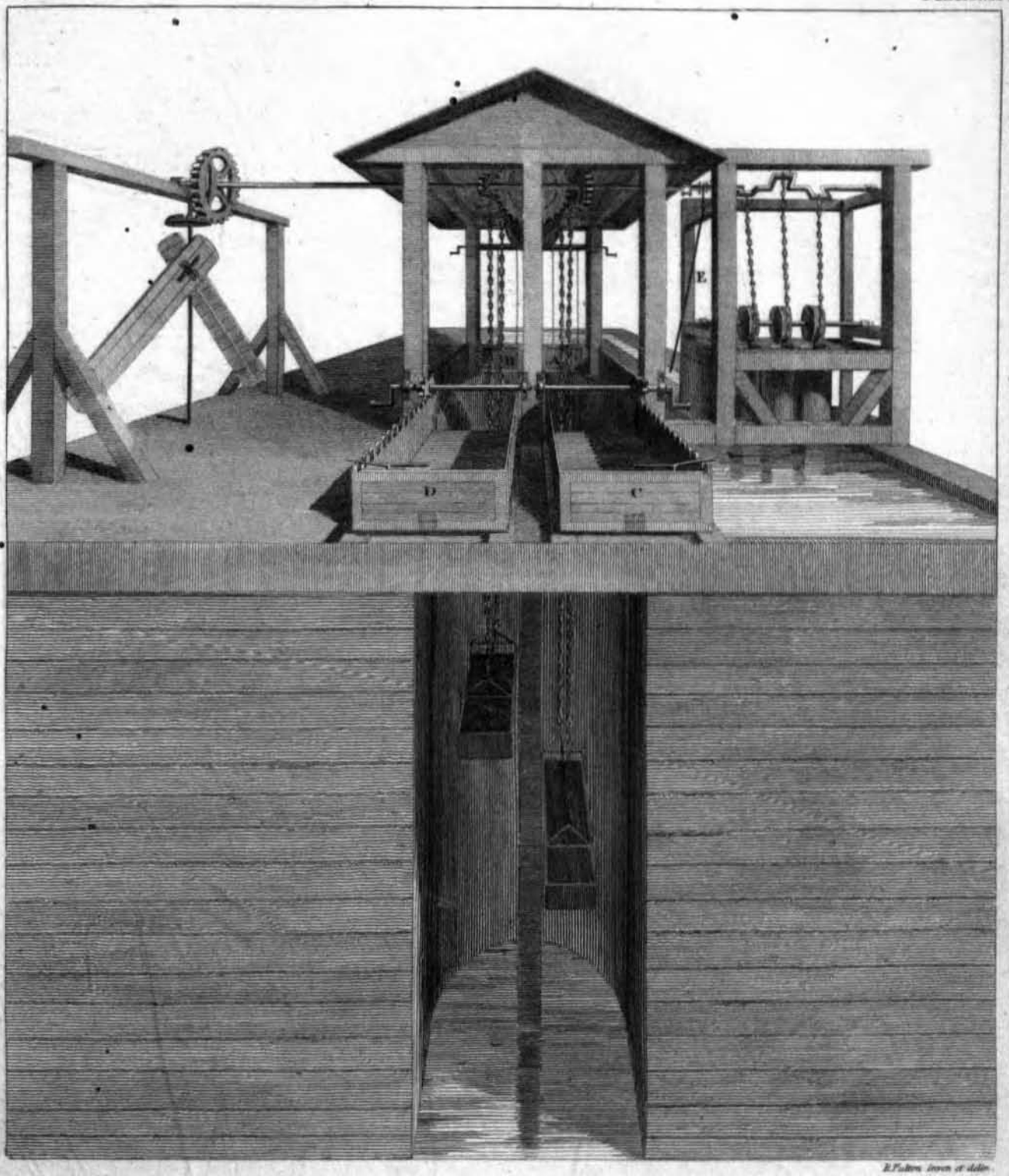
London, Published by I. & J. Taylor Holborn March 1796.



R. Fulton Invent. et delin.

The perpendicular Lift for passing an alternate Trade.

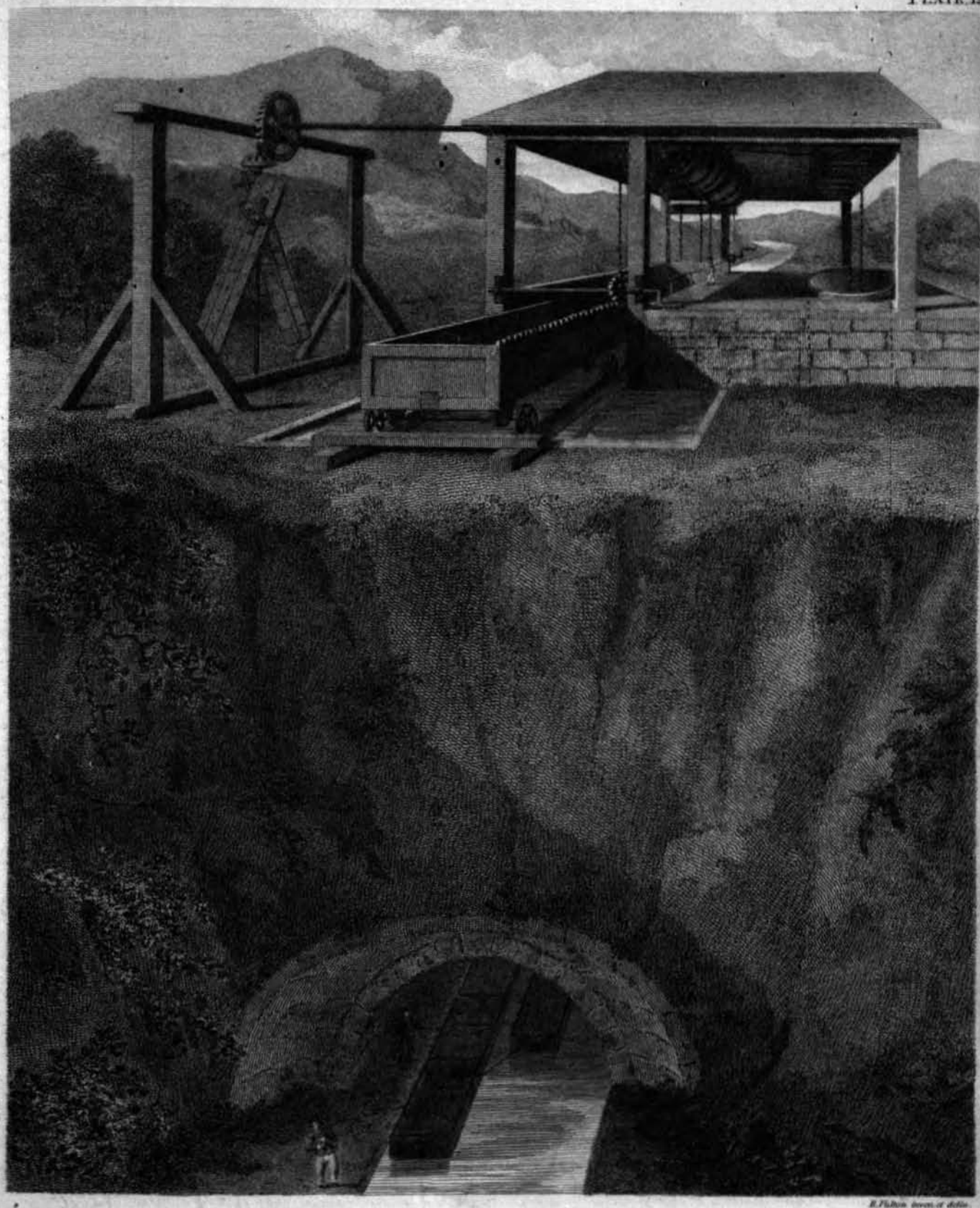
London: Published by I. & J. Taylor Holborn March 1.1796.



R. Fulton. Invent. et delin.

The mode of passing a descending trade and saving the Whole of the Water by means of the pumps.

London Published by I.S. J. Taylor, Holborn March 1.1796



R. Fulton. Invent. et delin.

The Second mode of passing an alternate Trade.

London Published by I. & J. Taylor. Holborn March 1.1796.