FULTON'S

TREATISE

Jas. Tomkins

A

TREATISE

ON THE IMPROVEMENT OF

CANAL NAVIGATION;

EXHIBITING

THE NUMEROUS ADVANTAGES TO BE DERIVED FROM

SMALL CANALS.

AND BOATS OF TWO TO FIVE FEET WIDE, CONTAINING FROM TWO TO FIVE TONS BURTHEN.

WITH A DESCRIPTION OF THE

MACHINERY for facilitating CONVEYANCE by WATER through the most Mountainous Countries, independent of LOCKS and AQUEDUCTS:

INCLUDING

Observations on the great Importance of Water Communications,

WITH

THOUGHTS ON, AND DESIGNS FOR, AQUEDUCTS AND BRIDGES OF IRON AND WOOD.

ILLUSTRATED WITH SEVENTEEN PLATES.

BY R. FULTON, CIVIL ENGINEER.

LONDON.
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1796.

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Minutes *of a* Committee *of the* Board *of* Agriculture, *holden* Friday, March 4*th*, 1796.

THIS Committee having taken into consideration the reference concerning Mr. Fulton's invention, and having examined the Model of his Machines for improving Inland Navigation, by Inclined Planes, and various other apparatus, are of opinion:

That the invention is deserving the attention of those who are engaged in the business of forming Inland Navigations.

The above Resolution was afterwards confirmed by the Board of Agriculture, at its meeting on the 8th of March following.

John Sinclair, President.

TO THE BOARD OF AGRICULTURE.

My Lords and Gentlemen,

When a subject is first brought forward, which has the appearance of novelty, however sound and rational the principle may be on which it rests, yet it is with much difficulty the prejudice in favour of established practice can be removed. The frequent failure of new designs also strengthens the arguments of opposition, and seems to justify those who are disposed to persist in the habits of their ancestors.

On the other side, a warm imagination is the usual companion of those by whom any new plan is formed; hence it becomes neceſſary that cool, deliberate, and penetrating men ſhould analyze the ideas, and preſerve ſuch as are of intrinſic worth and utility. For this purpoſe I have a particular pleaſure in placing the following pages before the ſcrutinizing eye of the Board of Agriculture; in which I have no doubt but there are numerous errors, which partiality to a favourite purſuit has prevented me from perceiving: nor have I a wiſh that any part of this Work ſhould meet with favour, unleſs it can ſtand the teſt of the ſtricteſt inquiry, and be ſupported by reaſon.

To reduce the expence of canals, and extend the benefit of eaſy conveyance into every diſtrict, whatever natural obſtacles may preſent themſelves, is certainly an important conſideration; but if I have not been ſo fortunate as to point out the method, there undoubtedly is one among the infinite materials in the repoſitory of Genius which will be brought into light by energy and inveſtigation. I ſhall therefore feel happy, ſhould this Work prove a ſtimulus to induce ingenious men to direct their attention and talents to further improvement.

With the moſt ſincere thanks for the meaſure which the honourable Board has been pleaſed to take, in order to bring the ſubject of ſmall canals to the teſt of diſcuſſion and experience, I remain,

My Lords and Gentlemen,

With the utmoſt gratitude and reſpect,

Your obedient and very humble ſervant,

ROBERT FULTON.

TO

TO MESSRS. JESOP, WHITWORTH, OUTRAM, MILN, AND RENNIE.

GENTLEMEN,

IN ſome obſervations on the utility of ſmall canals, which I printed in the *Star* of July the 30th, 1795, and in which I called on you to ſtate your objections to the ſyſtem, the Printer, by miſtake, having placed the words, *whoſe merits I eſteem*, immediately after Mr. Whitworth's name, inſtead of inſerting it after the names were repeated, it might appear that Meſſrs. Outram, Miln, and Rennie, were excluded from that reſpect which I ever feel for men of ſcience. I therefore take this opportunity to explain the error, in order to rectify any bad impreſſion which it might occaſion; and I hope this will be deemed a ſufficient apology.

At the ſame time I think it perfectly conſonant to the nature of this Work, again to call on you, together with Meſſrs. Telford, Cockſhot, Chapman, and Benet, to deliberately weigh the following pages on ſmall canals, and favour me with your opinion, or tranſmit it to the public, in order that they may be put in the poſſeſſion of the arguments for and againſt the ſyſtem. In this requeſt I conceive myſelf perfectly juſtified: Firſt, Becauſe the improvement of canals is of national importance; ſecond, it is the duty of every man engaged in public works, to inveſtigate every plan which has the appearance of facilitating ſuch works; third, many uſeful works remain unnoticed, for ages, for want of

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immediate confideration; fourth, by the difcuffion I propofe, the ufeful or imperfect parts will be more immediately exhibited, and the mifapplication of the old mode will be detected: hoping that this fyftem, *to its extent*, will meet the moft candid and liberal inveftigation, and be deliberately confidered and compared with the old practice for the various canals in contemplation, or which may hereafter be constructed.

I remain, with all poffible refpect,

Gentlemen,

Your moft obedient,

ROBERT FULTON.

London, March 1, 1796.

PREFACE.

PREFACE.

THE fear of meeting the oppofition of envy, or the illiberality of ignorance, is, no doubt, the frequent caufe of preventing many ingenious men ufhering opinions into the world, which may deviate from the common practice. Hence, for want of energy, the young idea is fhackeled with timidity, and a ufeful thought is buried in the impenetrable gloom of eternal oblivion.

But if we confider for a moment, how much men are the fons of habit, we fhall find, that almoft the whole operations of fociety are the produce of accident, and a combination of events, rendered familiar by cuftom, and interwoven into the fenfes by time; infomuch, that it is mere chance if the ideas are awakened to a fenfe of particular errors. But in fuch cafe it is fortunate, when they arife in a mind active to inveftigate, and which feels only contented to reft on the bafis of reafon; for without this, man muft ever remain in a fixed point, and improvement will be at an end: the adventurer muft therefore arm himfelf with

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fortitude to meet the attacks of illiberality and prejudice, determined to yield to nothing but ſuperior reaſon; reſting aſſured, that every virtuous mind will commend an exertion to remove the rubbiſh from around the Temple of Truth, even ſhould the undertaking fail.

There is alſo frequently a ſecret pride which urges many to conceal their ſpeculative enquiries, rather then meet criticiſm, or not be thought the firſt in their favourite purſuit; ever anxious to claim the merit of invention, they cannot brook the idea of having their works diſſected, and the minute parts attributed to the genius of other men. But in mechanics, I conceive, we ſhould rather conſider them improvements than inventions, unleſs improvement may be called invention, as the component parts of all new machines may be ſaid to be old; but it is that nice diſcriminating judgment, which diſcovers that a particular arrangement will produce a new and deſired effect, that ſtamps the merit. And this may perhaps, with propriety, be called either invention or improvement; which certainly exhibits that the artiſt has that penetration which is uſually dignified with the term Genius. Therefore the mechanic ſhould ſit down among levers, ſcrews, wedges, wheels, &c. like a poet among the letters of the alphabet, conſidering them as the exhibition of his thoughts; in which a new arrangement tranſmits a new idea to the world.

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It is for want of this diſcrimination, that many a worthy man, of eaſy demeanor, is tormented by the criticiſm of ignorant inſignificance; for men of the leaſt genius are ever the firſt to depreciate, and the laſt to commend; and, for an obvious reaſon, they have not ſenſe to know the produce of genius when they ſee it: But,

> "Men of true genius glow with lib'ral ſpirit,
> And bind a garland round the buſt of merit;
> While blockheads, void of wiſdom's grateful light,
> Bury diſtinction in eternal night."
>
> MOREHEAD.

INTRO-

INTRODUCTION.

ON perufing a paper defcriptive of a canal projected by the Earl of Stanhope, in 1793, where many difficulties feem to arife, my thoughts were firft awakened to this fubject.

The canal was intended for the purpofe of conveying fea fand, as a manure, from Bude Haven, in Cornwall, to the high grounds near Houlfworthy and Hatherleigh, in Devonfhire: on which the difference between the fummit and lower levels was upwards of five hundred feet, and water extremely fcarce. Thus the difparity in the levels, and fcarcity of water, which would require numerous and expenfive refervoirs, banifhed every hope of a canal on the lock principle paying the fubfcribers.

But to accomplifh the work, it was propofed by his Lordfhip to form the ponds of canal at convenient diftances, and unite them by iron rail-roads of a gradual and eafy afcent, on which boats of two tons were to be ufed; fuch boats navigating to the firft rail-road, each was to be fufpended between a pair of wheels about fix feet diameter, and conveyed by a horfe to the next afcending level; then navigate to the fucceeding rail-way, proceeding thus till the fummit was attained.

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In a country with little water, and fo great a difparity between the levels, and where coals could not be obtained to work fteam-engines, fuch a plan was certainly a good medium between navigation and cartage; but as the whole trade was to go up the country, I was aftonifhed to find, by calculation, that the horfes to perform the eftimated four hundred tons per day, would amount to 7,000l. per annum on the rail-roads only.

Seeing thefe difficulties, and the neceffity of an eafy communication with hilly countries, I was impreffed with the importance of an apparatus, which might transfer boats and their cargoes, to and from the different levels; independent of locks and their demand of water, or rail-roads and their appendage of horfes.

To produce fuch a machine, the firft thing that occurred to my imagination, was a water-wheel, to be put in motion by water from the upper level; and, by that means, raife the boat on an inclined plane. But in great afcents, I found the wheel deftroy more water than locks; I then thought of a preponderating ciftern of water, and was fo certain of obtaining the power by that means, that I immediately conceived I had accomplifhed the machine; and having fome communication with his Lordfhip, *on the practicability of navigating veffels by fteam,* I fent him a fketch of my plan: his Lordfhip, in anfwer, was pleafed to compliment me on the thought; but at the fame time informed me, it was the fame as defcribed by Mr. Edmund Leech, about fixteen years fince. Here, for the firft time, I difcovered that the idea of a preponderating body of water, was

by no means new. But, on inveftigating Mr. Leech's work, I found, that although our ideas of the ciftern were nearly fimilar, yet we were far diftant from the point to be attained; each ufing it on an inclined plane, without any certain mode of getting the boat in and out of the upper canal. I then changed the ciftern from the inclined plane, to a perpendicular defcent; becaufe, in a perpendicular, the defcending body acts with a force equal to its whole weight, *friction excepted*; while, on the plane, its defcending force is loft in proportion to the angle; after which, my whole difficulty has been to get the boats in and out of the upper canal, with certainty, eafe, and expedition, fo as to preferve a regular movement, and avoid much wear on the works.

To effect this, I have tried various experiments, and ultimately determined on the *four* modes defcribed by the annexed Plates, each of which works with great certainty and eafe, *varying from double to fingle machines*; and have at leaft eftablifhed the practicability of paffing boats to and from the different ponds of canals, independent of locks, rail-roads, or fteam-engines.

Having accomplifhed a mode of paffing the difparity of the levels, the next important confideration in reducing the expence of canals, was to crofs rivers, or deep and wide vallevs, without aqueducts. The following Plates will alfo exhibit the cheap mode by which this part of the work may be performed; and the reader will judge of the facility with which it may be executed.

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These points being gained, there is no doubt but much room is left for improvement, and that will be progreſſive as in all other machines: but the reſult of my experiments I now lay before the public; where, I hope, they will meet with a candid inveſtigation, and the utility of ſmall canals be deliberately conſidered.

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TREATISE

ON THE IMPROVEMENT OF

CANAL NAVIGATION.

CHAP. I.

OF THE ORIGIN AND PROGRESSIVE IMPROVEMENT OF CANALS.

IN contemplating the infinite operations of Art, and reflecting on their progreſſive improvement, it is an inexhauſtible fund of amuſement to trace them back to the time when genius called forth the mental powers of our ſpecies, and conducted humanity from the wilds of ſavage life to the cultivated plains of ſcience and refinement.

Ever anxious to diſſipate the cloud which intercepts our view of remote times, we endeavour to diſcover the origin of the ſubjects we inveſtigate, and to trace them through their various meandrings; pleaſed, if we find improvement cheer the way, and induſtry diffuſe her bleſſings through ſociety.

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Such deliberations have a happy tendency, by exhibiting our comparative ſituation with that of former ages, to teach us the abſurdity of preſuming on preſent perfection, or of fixing a boundary to any purſuit; they contribute to obliterate the prejudices reſulting from eſtabliſhed cuſtom; and to open an unbounded field of the moſt luxuriant ſoil, gratefully productive to the hand of cultivation, and richly rewarding the toil of the labourer.

For this purpoſe, I conceive it will not be unintereſting to take ſome notice of the infant operation of canals, and of their progreſs from Eaſtern to Weſtern climes; in which, we ſhall find, their importance did not eſcape the obſervation of ſome of the early improvers of ſociety.

From the beſt hiſtorical accounts it appears, that in the Mediterranean ſea navigation originated and flouriſhed, that ſea being the greateſt inlet in the known world, and without tides, conſequently ſeldom exceſſively agitated; alſo, containing numerous iſlands, and ſhores within ſight of each other, it was particularly favourable to the young adventurer. Time, with ſuch advantages, having improved the navigator in knowledge, and the ſurrounding countries in cultivation, the mind began to ſeek, in ſtreams of artificial direction, thoſe conveniencies it had enjoyed on the watry expanſe of nature.

The firſt enterprize of this kind, of which we have any account, is related by Herodotus, of the Cnidians, a people of Caria, in Aſia Minor, who deſigned to cut through the iſthmus which joins that peninſula to the continent; but who were ſo ſuperſtitious as to relinquiſh the undertaking becauſe of an interdiction by an oracle.

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It was alſo a favourite project with both the Greeks and Romans, to cut a canal through the Iſthmus of Corinth; and open a communication between the Archipelago and the Ionian Sea; to accompliſh which, Demetrius, Julius Cæsar, Caligula, and Nero, made numerous, but unſucceſsful, attempts.

The important junction of the Mediterranean and the Red Sea, by a canal through the Iſthmus of Suez, has at various times occupied the attention of ſeveral kings of Egypt; Pharaoh Necho attempted a canal from the Nile to the Red Sea, and 120,000 men periſhed in the attempt. In this great undertaking, it is alſo ſaid, that, in after ages, Soliman II. Emperor of the Turks, employed 50,000 men; and that the work was completed under the caliphate of Omar; but afterwards was ſo entirely choked up by the ſhifting ſands, and looſe ſoil, as entirely to obliterate their immenſe labours.

As it has been frequently queſtioned in Europe, whether ſuch a canal was practicable, in order to open a route to India nearer than that by the Cape of Good Hope, I ſhall beg leave to quote Mr. Volney, who made it a part of his enquiry during a reſidence at Cairo and Suez in 1782; and who, having a juſt ſenſe of the ſubject, exhibits the impracticability of conſtructing a permanent canal;—for the following reaſons:

" *Firſt*, It is certainly true, that the ſpace which ſeparates the two ſeas is not more than 18 or 19 ordinary leagues; it is true, alſo, that this interval is not interſected by mountains; and that from the tops of the terraces at Suez we cannot diſcover with any teleſcopes a ſingle obſtacle on the naked and barren plain to the North Weſt; it is not, therefore, the difference of levels which

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prevents the junction*: but, the great difficulty arises from the nature of the corresponding coasts of the Mediterranean and the Red Sea, which are of a low and sandy soil; where the waters form lakes, shoals, and morasses, so that vessels cannot approach within a considerable distance. It will, therefore, be found scarcely possible to dig a permanent canal amid these shifting sands; not to mention that the shores are destitute of harbours, which must be entirely the work of art. The country, besides, has not a drop of fresh water; and to supply the inhabitants it must be brought as far as from the Nile.

"The best, and only, method, therefore of effecting this junction, is, that which has been already successfully practised at different times; which is, by making the river itself the medium of communication, for which the ground is perfectly well calculated; for, Mount *Mokattam* suddenly terminating in the latitude of Cairo, forms only a low, and semicircular, mound, round which is a continued plain, from the banks of the Nile as far as the point of the Red Sea. The ancients, who early understood the advantage to be derived from this situation, adopted the idea of joining the two seas by a canal, connected with the river. STRABO, *lib.* 17, observes, "that this first was executed under SESOSTRIS, who reigned about the time of the Trojan war; and the work was so considerable, as to occasion it to be remarked, that it was a hundred cubits (or 170 feet) wide, and deep enough for large vessels."

This work has been repeatedly choked up, and repeatedly repaired, and so sensible were the ancient Egyptians of the utility of canals;

* The ancients were of opinion, that the Red Sea was *higher* than the level of the Mediterranean; but, admitting this to be the case, it would be a trifling obstacle in the present improved state of mechanics, and knowledge of locks.

canals, that, according to HERODOTUS, SESOSTRIS caused such numbers to be constructed, that they superseded the use of wheeled carriages, which had been in practice till that time. Those works are now buried beneath the wreck of government; are overwhelmed by drifting sands, and sediment deposited from the inundations of the Nile; insomuch that no mark of their course is left.

In times more modern, when Europe was but emerging from the gloom of Gothic barbarity, the active genius of CHARLEMAGNE projected a plan of uniting the Rhine and the Danube, by a canal, in order to open a communication between the ocean and the Black Sea; in this immense work he employed numerous armies, but the extreme difficulties he had to encounter, after infinite labour and expence, obliged him to abandon the undertaking.

Thus we see, in various periods of society, the most vigorous exertions to open water communications between distant provinces; which works were ever under the particular guidance of the most eminent characters, and prosecuted by such immense numbers of men that the labour is almost incredible; but as manual labour, unaided by mechanic ingenuity, is utterly inadequate to works of this kind, their various failures must be attributed to their ignorance of the genuine principles of science.

The ancients were totally unacquainted with locks, or any other mode of passing vessels from one level, or pond of canal, to another; they, consequently, would be necessitated to pursue the level of that part on which they commenced, be that level what it might; and this in a mountainous country would lead them into high grounds. It is also probable, they would attempt to navigate such vessels as traversed

verſed the ocean; while perforating rocks, or making tunnels for thoſe veſſels, would never intrude on their imagination. Such circumſtances would conſequently defeat every undertaking in an irregular country; it is therefore natural to conclude, that each Egyptian canal muſt have preſerved one level; particularly when we conſider, that Lower Egypt *(in which they were formed)* is a flat and uniform country.

But although the Egyptians, Greeks, and Romans, were unacquainted with any mode of paſſing boats to, and from, different levels of water; there is great reaſon to believe the Chineſe have long been familiar with an apparatus for this purpoſe. Their machine conſiſts of an inclined plane, and a cradle to receive the boat; beneath the cradle are ſeveral rollers acting on gudgeons; into this the boat is floated, which fits it ſo exactly as to give equal preſſure on all its parts; the whole is then raiſed to the next level, or pond of canal (or let down, as the caſe may be), by men at a capſtan (others ſay, by a water wheel); but it is probable both modes are practiſed, according to the abundance, or the ſcarcity, of water. The imperfect accounts of China, which have reached Europe, leave us much in the dark as to the ſpecific operation; and a European mechanic cannot conceive how the power obtained by a capſtan, or any other apparatus where manual exertion is the acting force, can be ſufficiently quick to accommodate a conſiderable trade, without incurring a prodigious expence by the number of men employed; as it would occupy at leaſt thirty men during fifteen minutes, to raiſe a boat of twenty tons to the height of ten feet; the boat, cradle, and cargo, ſuppoſed to equal thirty tons; and a repetition of this operation, for inſtance, ſo often as is neceſſary to mount a boat 200 feet, muſt not only be tedious but expenſive; yet all writers agree as to the magnificence of theſe canals, and their aſtoniſhing length: the canal from Canton to Pekin

Pekin being 825 miles long, through which an immenſe trade is conducted. Indeed, ſo vigilant are the Chineſe over theſe works, that they come under the immediate protection of the executive power, and in the inſtructions given to governors of provinces, theſe objects are recommended to their particular care. In conformity to this principle, the opinion which the court forms of their conduct is greatly influenced by the attention which they appear to have paid to this part of their inſtructions: this branch of the police is, conſequently, well attended to; and their canals have the reputation of being infinitely ſuperior to any thing of the kind in Europe. Hence, notwithſtanding the great extent of the empire of China, the vaſt multitude of its inhabitants, and variety of its climate, the conſequent productions of all parts are tranſported to, and from, the different provinces, with ſuch facility as to open a home market ſufficient to ſupport extenſive manufactures.

Machines, ſimilar to thoſe of the Chineſe, have been erected in Flanders, on river navigations, where interrupted by falls, or ſhoal water; while another mode adopted has been to erect a dam, or wear, acroſs the river below the fall, in which was placed two ſtrong buttreſſes of ſtone, with perpendicular grooves; after paſſing the boat above the buttreſs, a ſtrong gate was let down the grooves, which ſtopped the water till it roſe to a ſufficient height to enable the boat to paſs; this apparatus, tedious in the proceſs, profuſe of water, and liable to injury from every flood, in all probability gave the firſt hint of locks. And this ingenious invention opened a new ſcene in canal navigation, in conſequence of the facility of paſſing to and from the different levels. Since which, numerous important works have been executed in the Netherlands, and in different parts of Europe.

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Of theſe, perhaps, the moſt conſiderable is the canal of Languedoc: I mean, moſt conſiderable, not only from its length, and national importance; but in conſequence of the capacity requiſite to the conſtruction of it.

It has in fact been the model for all canals down to the preſent day; in this work, locks, reſervoirs, aqueducts, tunnels, and embankments, are plainly exhibited; and the ſyſtem which has been purſued fully eſtabliſhed. This canal, which opens a communication between the Mediterranean and the Bay of Biſcay, is 192 miles long; it commences with a reſervoir 4000 paces in circumference; and is furniſhed with 104 locks, each of 8 feet riſe. It was begun (in 1666) and finiſhed under LOUIS XIV. by FRANCIS RIQUET, in little more than thirteen years; the expence amounting to upwards of thirteen millions of livres; which, at twenty-eight livres the mark of ſilver, the value of French money in the laſt century, amounts to upwards of 900,000*l.* ſterling. On finiſhing this great work, the tolls were given to M. RIQUET, as a reward of merit, and an inducement to keep it in repair; and the emoluments have been ſo important as to produce great eſtates to different branches of that gentleman's family: while, as a public work, it is unqueſtionably the nobleſt monument of the monarch who patronized it.

Nor did theſe uſeful works eſcape the penetrating genius of the Czar PETER during his reſidence in Holland; who, immediately on his return home, procured engineers, and commenced a canal to open a communication between Moſcow and Peterſburgh. It would be a very extenſive undertaking to deſcribe the numerous canals which had been formed in various parts of Europe, previous to their introduction into this iſland: but though England was the laſt to encourage

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encourage canals, it is now the moſt active in promoting them; tenacious of eſtabliſhed cuſtoms, Engliſhmen are difficult to ſet in motion, but their ſenſes being awakened to intereſt they are diligent and perſevering.

The firſt canal in England which deſerves notice * was conſtructed by the *Duke* of BRIDGEWATER, and has not been completed 30 years; during the proceſs, ſo unacquainted were the people with the uſe of canals, and ſo prejudiced in favour of the old cuſtom of river navigations, that the undertaking was deemed chimerical, and ruin was predicted as the inevitable reſult of his Grace's labour; here tunnels, aqueducts, reſervoirs, and embankments, familiar to foreign nations, ſtruck the aſtoniſhed Engliſhman with wonder; the apparent expence ſurpaſſed all calculation of an adequate return; particularly with a rival running by its ſide †: yet it was not long finiſhed when the eyes of the people began to open; the Duke could work on his canal when floods, or dry ſeaſons, interrupted the navigation of the Merſey; this gave a certainty, and punctuality, in the carriage of merchandize, and inſured a preference to the canal; the emoluments ariſing to the Duke were too evident to be miſtaken; and perſeverance having vanquiſhed prejudice, the fire of ſpeculation was lighted, and canals became the ſubject of general converſation.

But as local prejudices oppoſed the Duke's canal, in the firſt inſtance, prejudice equally ſtrong as firmly adhered to the principle on which it was conſtructed; and it was thought impoſſible to lead one through a country, or to work it to any advantage, unleſs by

* The Romans made a ſmall cut between the Nyne and Witham, below Peterborough, purſuing one level, without machinery or any diſplay of mechanical ability.

† The river Merſey runs nearly parallel to the Duke's canal, and navigates to and from the ſame port of Liverpool.

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locks,

locks, and boats of at leaſt twenty-five tons, till the genius of Mr. William Reynolds, of Ketley, in Shropſhire, ſtepped from the accuſtomed path, conſtructed the firſt inclined plane, and introduced boats of five tons *. This, like the Duke's canal, was deemed a viſionary project, and particularly by his Grace, who was partial to locks; yet this is alſo introduced into practice, and will in many inſtances ſupercede lock canals.

Thus we find the majority of men adhere ſtrongly to eſtabliſhed cuſtoms; and prejudice the common enemy of every new work. Senſible of the power of ſuch an opponent, I ſhall ſeek alliance in the inveſtigation of truth; requeſting thoſe who take the trouble to peruſe this work, to abide by the teſtimony of common ſenſe; to conſider that, as ſcience is progreſſive, there is yet room to improve, and that the infinite variety of applications to which ſcience is competent, leaves ample opportunity for ſuggeſtions no leſs advantageous than thoſe which have already ſtood the teſt of experiment, and received the ſanction of ſucceſs.

* Mr. Reynolds's machine is an ingenious combination of an inclined plane, and locks: two locks being conſtructed on the top of the plane, for the purpoſe of getting the boats in, and out of, the npper canal; and, although it is only calculated for a *deſcending* trade, ſuch as from collieries, or lime works *(in which caſes the loaded boat, deſcending, raiſes that which is empty)*, yet by its operation ſmall boats have been introduecd into practice; and for ſnch introduction every future improver will feel infinitely indebted to Mr. Reynolds; however greatly his engine may be inproved in conſtruction or varied in its operation.

CHAP

CHAP. II.

OF THE IMPORTANCE OF CANAL NAVIGATIONS, AND THE BENEFITS ARISING TO SOCIETY BY EASY COMMUNICATIONS.

ALTHOUGH the numerous canals which have been executed within the laſt thirty years, have exhibited their utility to ſuch perſons as have reflected on the ſubject, yet I may venture to ſay, that many ſee their advantages in a limited view, while more than half the inhabitants of England are totally ignorant of their importance, to every diſtrict through which they paſs.

Like the government of China, the legiſlature of every country ſhould be particularly attentive to the reduction of the expence and delays of carriage, and to the formation of eaſy communications between different and diſtant provinces; as agriculture and commerce will improve, and happineſs ſpread, in proportion as the facility of conveyance increaſes.

In the early and limited aſſociations of ſociety, while men were kept aſunder by foreſts, moraſſes, and inacceſſible hills, their knowledge muſt have been circumſcribed; and their conveniencies few. The rude implements employed in mechanics and tillage, would occaſion much labour in proportion to the produce, and though artiſans, either by deſign or by accident, might greatly facilitate their work by a ſuperior contrivance of inſtruments, yet the difficulty of intercourſe would confine the knowledge of ſuch advantages, and

preſent

prevent the improvement extending to others who might equally require it; hence, in different diſtricts, particular expedients might be uſed in performing the various operations; yet, being practiſed in a limited circle, each community might remain ignorant of the other's advantage; and this ſtate of things in great meaſure continues in every country, but particularly between diſtant nations.

The Chineſe, for inſtance, poſſeſs many advantages of which we are ignorant; and they certainly are unacquainted with many of ours: yet, was a free communication between the two countries eſtabliſhed, the particular improvements of each, in all probability, would be combined to the benefit of both. But, even under the ſame government, or in the ſame province, it is ſome time before a combination of knowledge can take place; but in proportion as the difficulty of communication is removed, the ſpirit of enterprize increaſes, and neighbouring aſſociations begin to mingle, their habits and cuſtoms aſſimilate, each tranſmits its improvements to the other, and each feels the beneficial effects reſulting from the union.

This ſyſtem of intercourſe, and benefit, would continue to extend, as the difficulties which withheld, or obſtructed, it were removed; and eventually ſmall ſocieties would become a large and ſocial compact; bringing their various improvements into one common ſtock: a knowledge of mechanics would ſpread, and greater comforts would reſult from leſs labour.

An active man thus ſituated, and feeling himſelf by this means in poſſeſſion of more than was abſolutely neceſſary for his ſubſiſtence, would indulge his natural propenſity to barter: each would wiſh to diſpoſe of the ſurplus of his particular labour, in order to purchaſe a portion of the labour of others, which his neceſſities, or luxury, might require; thus the farmer barters his ſurplus with the tradeſmen; the tradeſman his with the farmer; the towns exchange the work of their artiſans for that of the country; the country its produce for that of the towns; the carpenter, the ſmith, the weaver, the taylor, the tanner, the ſhoemaker, the butcher, the brewer, &c. artiſans, and profeſſions of all kinds, have reciprocal demands on each other; for not only the elegancies, but even neceſſaries, of life.

It is indeed curious to reflect how, by the refinement of art, and diviſion of labour, the united exertions of thouſands combine to produce thoſe things which familiarity exhibits as trifling, yet abſolutely neceſſary to the comforts of exiſtence.

"Obſerve," *ſays* ADAM SMITH, "the accommodation of the moſt common artificer or day-labourer in a civilized and thriving country; and you will perceive that the number of people of whoſe induſtry a part, though but a ſmall part, has been employed in procuring him this accommodation, exceeds all computation: the woollen coat, for example, which covers the day-labourer, as coarſe and rough as it may appear, is the produce of the joint labour of a great multitude of workmen; the ſhepherd, the ſorter of the wool, the wool-comber or carder, the dyer, the ſcribbler, the ſpinner, the weaver, the fuller, the dreſſer, with many others, muſt all join their different arts in order to complete even this homely production. How many merchants and carriers, beſides, muſt have been employed in tranſporting the materials from ſome of thoſe workmen to others; who often live in a very diſtant part of the country? How much navigation and commerce in particular; how many ſhip-builders, ſailors, ſail-makers, rope-makers, muſt have been employed in order to bring together the different drugs made uſe of by the dyer, which often comes from the remoteſt corners of the

the world? What a variety of labour is neceſſary in order to produce the tools of the meaneſt of thoſe workmen? To ſay nothing of ſuch complicated machines, as the ſhip of the ſailor, the mill of the fuller, or even the loom of the weaver, let us only conſider what a variety of labour is requiſite in order to form that very ſimple machine, the ſhears with which the ſhepherd clips the wool; the miner, the builder of the furnace for ſmelting the ore, the feller of the timber, the burner of the charcoal to be made uſe of in the ſmelting-houſe, the forger, the ſmith, muſt all be joined in their different arts in order to produce them: were we to examine, in the ſame manner, all the different parts of his dreſs, and houſehold furniture, the coarſe linen ſhirt which he wears next his ſkin, the ſhoes which covers his feet, the bed he lies on, and all the different parts which compoſe it, the kitchen grate in which he prepares his victuals, the coals which he makes uſe of for that purpoſe, dug from the bowels of the earth, and brought to him perhaps by a long ſea and a long land carriage, all the other utenſils of his kitchen, all the furniture of his table, the knives, the forks, the earthen or pewter plates, upon which he ſerves up and divides his victuals, the different hands employed in preparing his bread, and his beer, the glaſs window which lets in the light, and keeps out the wind and rain, with all the knowledge and art requiſite for preparing that beautiful and happy invention, without which the northern parts of the world could ſcarce have afforded a comfortable habitation, together with the tools of all the different workmen employed in producing theſe different conveniencies; if we examine, I ſay, all theſe things, and conſider what a variety of labour is employed about each of them, we ſhall be ſenſible that, without the aſſiſtance and co-operation of many thouſands, the very meaneſt perſon in a civilized country could not be provided, even according to what we may falſely imagine, the eaſy and ſimple manner in which he is commonly accommodated: compared, indeed, with the more extravagant luxury of the great, his accommodation muſt no doubt appear extremely ſimple and eaſy; and yet it may be true, perhaps, that the accommodation of an European Prince does not always ſo much exceed that of an induſtrious and frugal peaſant, as the accommodation of the latter exceeds that of an African king, the abſolute maſter of the lives and liberties of ten thouſand naked ſavages."

Hence we ſee conveniencies, eſteemed the moſt trivial, are the produce of reciprocity; each has a variety of wants which muſt be ſupplied by the labours of others; and for which he gives his labour, or the produce of his labour, which is the ſame thing, in exchange. An eaſy communication with foreign nations, or the diſtant parts of the ſame country, extends the market, and facilitates the transfer; while the eaſe of transfer ſtimulates the active powers to exertion.

Thus an eaſy communication brings remote parts into nearer alliance, combines the exertions of men, diſtributes their labours through a variety of channels, and ſpreads with greater regularity the bleſſings of life.

Men in commercial intercourſe mingling with men, imperceptibly loſe their local prejudices, and their cuſtoms gradually aſſimilate; while people remote from each other, and deſtitute of eaſy communication, retain thoſe prejudices, injurious to the maſs of ſociety.

Eaſy communications to the different diſtricts of a nation, alſo renders it more independent of its neighbours, by collecting and bringing forth its internal reſources; which circumſtance muſt have greatly

greatly contributed, perhaps have conſtituted, the entire independence of Egypt, China, and India: it is worthy of obſervation, that, in theſe countries, where canals were moſt in uſe, they never encouraged foreign commerce; but ſeem to have arrived at their great opulence by a home trade, circulated through their extenſive and numerous navigations; indeed, if agriculture and its dependencies may be conſidered as the ſtamina of ſociety, a well directed, and judicious, labour, would eaſily produce the comforts *(if not the elegancies)* of life: Egypt, though not ſo extenſive as England, in former ages contained many millions of inhabitants, and, as it is before obſerved, they did not draw their reſource from other countries; the produce of agriculture muſt have been immenſe, and the principal ſupport of the great body of the people. We are taught to believe, they were ſo attentive to this, that not an inch of ground was loſt; the whole country being like a continued garden. This ſeems the more probable, when the peculiar advantages of the country are conſidered.

Egypt is a ſtripe of land 550 miles in length; and in the greateſt width, from *Alexandria* to *Damietta*, not more than 125 miles; from thence it decreaſes in width till it approaches *Nubia*; where it is confined between two chains of mountains, and contracted to little more than twelve or fifteen miles in breadth: through the whole length, the Nile deſcends to the Mediterranean Sea; it may therefore be conſidered as a rich valley well watered. As the country is flat, and of an eaſy deſcent from one extremity to the other, it enabled the Egyptians to cut canals from any level they thought proper; and to commence ſo high as to continue the ſame level to any determined point; thoſe cuts, which anſwered the double purpoſe of reſervoirs to retain the waters of the Nile, and of canals to convey

vey the various produce, were ſo numerous as not only to touch at every town and village, but even at many of the farm houſes; added to theſe extraordinary advantages of water carriage, nature performed a moſt material work for the farmer, by mingling with the ſtream the ſoil of Abyſſinia and Nubia, which being depoſited as a ſediment, and ſpread over every field and corner of Egypt, by the overflowings of the Nile, formed a rich and fertilizing manure.

We cannot conceive a more regular diſtribution of the nutritious particles of earth, than was produced by theſe inundations; which not only enriched, but meliorated, the ſoil; hence little more was left for the diligence of the farmer than to ſow his grain, and cover it with a harrow; thus the Egyytian obtained an abundant harveſt with a moderate degree of labour.

Here it is intereſting to take a comparative view of ſuch a level country as Egypt, and one diverſified by mountains. The nearer a hilly country can approach, by art, to ſuch an equal diſtribution of manure as the Nile effected, ſo much nearer it will be to the perfecting of agriculture, and the enjoyments of life; it is, indeed, curious to conſider the infinity of labour which the inundations ſaved, and which conſequently might have been directed to other works; the whole proceſs of collecting, preparing, and depoſiting the compoſt on the grounds, was ſaved to the Egyptian labourer, with numerous other preparations requiſite to the agriculture of an irregular country.

But obſerve the immenſe number of hands employed in ſuch a country as England; in digging marle, and foſſile ſand, in quarrying lime-ſtone, in mining for coal to burn the lime; and, in burning it, remark the engines, kilns, implements, and apparatus,

 requiſite

requiſite to facilitate theſe operations; from thence the labour neceſſary in their conveyance to the grounds, the wear of roads, waggons, carts, harneſs, &c. &c. the wheel-wrights, ſmiths, and other artiſans employed in conſtant repairs; alſo, the waggoners, the carters, and, above all, the number of horſes employed, each of which conſumes the portion of manual labour which would ſupport a human being *; of the whole train of which the Egyptians

* I conceive it a fair calculation, that each horſe conſumes that produce of manual labour which would ſubſiſt an individual; particularly in a populous country, where every field pays rent. If their keep is conſidered throughout the kingdom, from thoſe heavy animals in broad-wheel waggons, down to the pony, calculating the intereſt on the purchaſe, the caſualties, provender, attendance, ſhoeing, wear of harneſs, &c. &c. it will amount to upwards of 25l. per annum, which is more than is ſpent on an average by the labouring people, and their children; conſequently, if improved conveyance can diſpenſe with the horſe, 25l. in produce of manual labour is ſaved to ſociety, as a fund to other works; which, throughout England, would be many millions per annum, conſidering that every 40,000 horſes amounts to 1,000,000l. per annum in maintenanee. But theſe being rendered uſeleſs by improved ſyſtem, would produce an eaſy ſupport to 40,000 inhabitants.

It is eſtimated, that, in the agriculture of England and Wales, one million of horſes are employed, and if to theſe are added the number of mail coach, ſtage coach, and poſt chaiſe horſes, with thoſe of country and bye carriers, from colleries, lime-works, iron works, &c. alſo thoſe for the convenience of individuals, in the environs of manufacturing and other towns, with the great number employed in the heavy and fly waggons, *the principal part of which may be diſpenſed with*, I conceive the number will be little leſs than two millions, which will amount to the immenſe ſum of 50,000,000l. per annum in maintenance. If from this number of horſes, which may be conſidered as carriers *(not to mention the immenſity of pleaſure horſes)*, one fifth could be diſpenſed with; the annual ſaving would be 10,000,000l. a ſum equal to the maintenance of 400,000 inhabitants, allowing 25l. to each perſon, which would conſequently permit the labours of 400,000 men to be directed to other improvements.

From ſome recent calculations preſented the Board of Agriculture, it appears, that a farm horſe does not conſume more than three acres of the fruits of the earth in a year; but a horſe kept on the roads eats yearly, in hay and corn, the full produce of five acres; a man at a pound of bread and a pound of meat per day, or in proportion, not quite an acre and a quarter; ſo that one of theſe horſes eats as much as four men: I conſequently have ſtated the ſaving by the reduction of horſes at a very low computation. Which further exhibits the great importance of diminiſhing their number.

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were relieved, and, being diſpenſed with, ſaved ſo much nouriſhment to the people.

Deliberate on theſe circumſtances, and the diſparity is certainly great, which loudly calls for the exertion of mental faculties, and the improvement of mechanics. Here art ſhould aſſemble all her engines to ſupply the defect of ſituation; man muſt open the repoſitories of nature; mix, with chymic ſkill, the various ingredients, and ſtrew them on his fields. Nature having diſtributed her fructifying particles in wild confuſion; it is with them as with the cultivation of man, to render them productive, they muſt be brought into union; and this can only be accompliſhed by improved conveyance. In this operation, canals may be conſidered like the looms of the draper or hoſier; or thoſe improved machines, which, reducing the labour, yet multiply the produce; and conſequently render the neceſſaries, and conveniencies, of life more abundant: by being more abundant they are obtained by every member of ſociety, *within their circulation*, with greater eaſe; the eaſy means of procuring the accomodations of life increaſes the population of a country, and population, creating a greater demand, proceeds to further improvement. Such have been the progreſſive ſteps of civilization; and to which there appears no boundary!

CHAP.

CHAP. III.

ON THE FORMATION OF CANALS, AND THE MODE OF EXTENDING THEM INTO EVERY DISTRICT.

HAVING in fome degree exhibited the importance of canals, the next confideration is to point out a mode of extending their advantages. In this it muft be evident, that they can only be advantageoufly conftructed through fuch diftricts, as produce a trade equal to an intereft for the money advanced in their formation; and on this point the difficulty of extending canal communications feems to depend: public roads, bridges, harbours, docks, and other works, admit of a variation, and may be conftructed great and magnificent, or contracted and cheap, in proportion to the trade, agriculture, or population of the country which they are to accommodate; but, according to the prefent fyftem * of conftructing canals, there is a certain point to which they feem to defcend †, and below which they cannot be further contracted. The fum required for their conftruction therefore muft be equal to the forming them of thofe dimenfions; and the trade expected muft be fufficient to pay the intereft of the fum, or the country remain hopelefs of the conveniencies of water carriage; unlefs a canal be executed in the frenzy of fpeculation, which indeed is fometimes the cafe; and rather injures than promotes fuch works; for fubfcribers being difappointed of the intereft with which they had flattered themfelves, are deterred from entering into fimilar undertakings, though of more rational adventure. The ill fuccefs alfo fpreads like a contagion, and fickens the foul of enterprize in others; yet the failure is perhaps not for want of materials to be conveyed by the canal, but in confequence of the expence of getting at fuch materials.

* By this I mean the prevailing fyftem; there are but two canals yet conftructed on the inclined plane principle, that of Ketly, and the Shrophfhire.

† For navigating twenty-five or twenty ton boats.

Had the ordinary engines of conveyance admitted of no diminution below broad-wheel waggons, thofe waggons would, in every refpect, increafe the expence of roads, and the carriage of the various materials; and the country could not poffibly be fo commodioufly fupplied as by carts, or even cars. Or had that incomparable apparatus, the fteam engine, been confined to a two-hundred horfe power, the innumerable advantages arifing from proportioning its powers down to any degree, which fits it to every fituation, could never have been experienced, and the engine itfelf would be of very little ufe.

A fimilar power of proportioning a canal to the particular demand of carriage upon it, in like manner, would be attended with benefits which at prefent are not even thought of; but canals are the only things, which I can at prefent recollect, which feem to be fixed to a certain point; in this refpect, confequently, they are limited in their extenfion, imperfect in their principle, and incapable of effectually fpreading the bleffings of water communications by their prefent mode of conftruction; to prove this affertion it is only neceffary, for a moment, to confider the operation of a lock.

On viewing the operation of locks, it appears that if they were conftructed for fmall boats, *fuppofe boats of four tons*, the delay in paffing would be fo great that an important trade could not be tranfacted, as it requires almoft as much time to pafs a fmall

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as a larger boat; for inftance, on a man arriving with fix four-ton boats *(equal to what is ufualy conveyed in a boat of twenty-five tons)* at a lock conftructed for fmall boats, he would be obliged to feparate them, and pafs them fingly; which would be an operation of three minutes at leaft to each boat, together with the time neceffary for uniting them when paffed through, fay four minutes, amounting in all to twenty-four minutes; a repetition of this operation, to mount only one hundred feet by twelve locks, would be a delay of four hours forty-eight minutes: this would not only be tedious, but create confufion wherever there were a number of boats paffing, even if paffing the fame way. How this would be increafed by thofe moving the contrary way, may eafily be conceived. Yet the twenty-five ton boat would move through the firft lock in five minutes, at the utmoft, and paffing through the fucceeding eleven locks with the fame expedition, would rife to the fummit level in one hour: hence the twenty-five ton boat will have an advantage in time of three hours forty-eight minutes. This calculation, I hope, will fufficiently prove the impropriety of conftructing locks for fmall boats; hence fmall and cheap canals cannot be formed on the lock principle; locks demand large boats, that an important trade may be performed; and large boats are the caufe of increafing the expence of all the other parts of the canal; in tunnels, bridges, aqueducts, land, refervoirs, digging, &c. &c. which evidently exclude every diftrict which cannot fupport thefe heavy expences, and preclude every hope of giving to agriculture and commerce the full force of fo powerful an agent as water conveyance.

But as the true criterion for judging of all improvements, *where the object is to increafe the produce of labour*, is the cheapnefs with which the work may be performed; that mode which will convey the moft goods for the leaft money will confequently be the beft, whether by roads, railways, large or fmall canals, or any other mode. It is therefore

therefore neceffary impartially and deliberately to inveftigate this fubject.

First, In proportion as a canal is large the expence on all its parts will increafe: tunnels, locks, refervoirs, aqueducts, bridges, land, and digging, are ufually allowed to be one third more expence in a canal for forty-ton boats, than in thofe conftructed for boats of twenty-five tons; twenty-five ton boats, alfo, require a canal of greater dimenfions than boats of four tons: in a word, it is evident that the expence of a canal will decreafe, in proportion as the boats are reduced; the object therefore is to find the proper medium.

The boat fhould be of fuch a fize as not to exclude any but unufual articles; for this purpofe I conceive a boat of four tons fufficiently large; being twenty feet long, four wide, and two feet ten inches deep; fuch a boat, being larger than the cheft of a waggon, will contain almoft every thing but long timber*, one horfe conveying ten boats.

Such boats will contain lime, lime-ftone, coals, lead, iron ore, grain, flour, iron ware, pottery, and all bodies ponderous and compact, as well as boats of any fize whatever; they will contain hogfheads, boxes, and bale goods, not exceeding four feet in width, *which are feldom of greater dimenfions*; each boat will receive fifteen facks of hops, cotton, or wool; and although the fifteen facks will not weigh four tons, yet the fame circumftance is attendant on all other boats, it being impoffible to give the weight of tonnage by

* For timber I have made a provifion (fee the Defcription of the double-inclined Plane, and Plate of Parts); planks, and all fcantlings under twenty feet, will go into the boats.

by ſuch materials: yet a horſe may take the greater number of boats, in order to make up a weight equal to his ſtrength.

Conſidering the articles enumerated, and deliberating on the ſize, and weight, of other commodities, I conceive there are few things excluded; and the queſtion is, Whether a company ſhould expend one hundred thouſand pounds inſtead of fifty thouſand? Thereby ſinking two thouſand five hundred pounds per annum, in order to accommodate the few things which boats of theſe dimenſions cannot contain, when, in all probability, the articles accommodated would not in tonnage produce 100l. per annum.

Thus ſeeing that moſt things may be conveyed in ſmall boats, and ſmall boats diminiſh the expence of canals; the next thing to be conſidered is how to paſs them to, and from, the different levels, or ponds, of which the canals conſiſt. To perform this, ſee the annexed Plates of Machines. But firſt give me leave to premiſe the objects in view:

The *firſt* object is, to conſtruct ſuch cheap navigations as may extend into diſtricts which produce but a ſmall trade: to perform this, I find it indiſpenſably neceſſary to reduce the boats to ſmall dimenſions.

The *ſecond* object is, as the trade may increaſe, and become of conſequence, it is prudent to provide againſt ſuch an event, as it will then be neceſſary to perform an important trade on a ſmall and cheap canal. For this purpoſe; if we reflect that the boats may be multiplied as the trade increaſes, and that the canal may be full of ſuch boats from one extremity to the other; conſequently the canal, and boats, are adequate to any quantity of trade which the moſt ſanguine imagination can conceive.

But

But, the principal conſideration is, how to prevent ſtagnation at the machinery; hence it becomes neceſſary to conſtruct the apparatus in ſuch a manner that the boats may paſs with the greateſt poſſible expedition; and this quick transfer is the more neceſſary, in conſequence of dividing the trade into ſmall portions of four tons, each of which muſt paſs ſeparate. Succeſs in theſe objects will conſequently produce ſyſtem; for, as the canal, though ſmall, and ſuited to a ſmall trade, is alſo adequate to a trade of the firſt importance, it will be impolitic to form any other than cheap and ſmall navigations; hence the boats of one may navigate the other, wherever canals extend.

A third object is, by forming them cheap, and ſuited to diſtricts with a ſmall trade, it will be the greateſt poſſible inducement to conſtruct them. The ſubſcriber feeling himſelf guarded againſt any material loſs, with every advantage which a larger work could give*; theſe circumſtances may juſtly be expected to extend them through the remote parts of the country, open its numerous reſources, and ſpread the produce in every direction. Whether I have ſucceeded in theſe points, the candid reader will determine.

* Locks are attended with a certain and heavy expence, whatever the trade may chance to be.

E CHAP.

CHAP. IV.

ON CUTTING CANALS FOR COASTING VESSELS, RIVER, OR FORTY-TON BOATS, IN ORDER TO SAVE THE TRANSFER OF CARGO TO BOATS OF SMALLER DIMENSIONS *.

IT has been a prevailing opinion, and many canals have been conſtructed, and are executing, on the principle, tha tto form them ſufficiently large to receive coaſting veſſels, river, or forty-ton boats, would produce a conſiderable advantage, by ſaving the transfer of cargo to ſmall veſſels.

While there was no alternative but forty or twenty-five ton boats, there might be ſome reaſon in ſuch a practice, as the difference in conſtructing the canals for ſuch boats does not appear to be materially great; but, if we eſtimate a canal for a forty, and then for a four-ton boat, the ſaving, by adopting the latter, is ſo important as to render the expence of transfer inconſiderable.

In every ſituation where a canal is to be formed for forty-ton boats, one-third of the ſum neceſſary for that purpoſe would pay the expence of a canal for boats of four tons †. Hence, if a com-

* If it ſhould be ſaid, that it is not ſo much in order to ſave the transfer of cargo, as to accommodate things which cannot be conveyed in ſmall boats; ſee the Calculations on ſuch accommodation in the preceding Chapter.

† In theſe calculations, I take no medium between forty and four-ton boats, for, if the cargo is to be transferred, it ſhould be to the cheapeſt poſſible conveyance.

pany

pany are about to expend 300,000l.* where 100,000l. would anſwer the purpoſe, 10,000l. per annum is ſunk to ſave transfer. It muſt be obſerved, that in all goods paſſing inland from the coaſt, there is only one change of cargo, *viz.* to the ſmall boat; when the ſmall boat unloads up the country, the expence is the ſame as if the larger had proceeded to the ſame point. In all goods paſſing to the rivers, or coaſt, one transfer into the large boat, the firſt reception into the ſmall boat being the ſame as into the large one. Hence all goods going up the country may be taxed two-pence per ton, the price of transfer, and the ſame on all goods deſcending: it muſt alſo be conſidered, that although a canal may be connected with the river, or ocean, the principal part of the trade will not require transfer, being taken up, and depoſited, in various places on the paſſage, without deſcending to the river, or the ocean.

The trade of a canal muſt, indeed, have a very material connection with a river, where there is occaſion to transfer five hundred tons per day; which, at two-pence per ton, allowing 280 working days, would amount to 1166l. 13s. 4d. per annum; yet, to ſave this, the principal of 10,000l. per annum is ſunk.

* To thoſe unacquainted with canal ſpeculations, 300,000l. may appear a great ſum; but the following will give him ſome idea at the moneys expended in ſuch works, of which the eſtimates are:

	£.	*Miles long.*
The Rochdale canal, - - - -	291,900	31½
Elleſmere ditto, - - - -	400,000	57
Kennet and Avon ditto, - - -	420,000	70
Grand Junction ditto, - - -	500,000	90
Leeds and Liverpool, - - -	800,000	129

By

By adopting ſmall boats, the clear gain to the company would be 8833l. 6s. 8d. per annum, even provided they paid the expence of transfer; but I conceive this expence will ultimately fall on the freighter, or he muſt have an admirable alternative, much ſuperior to land-carriage, if the two-pence per ton for transfer can prevent him ſending his goods by the canal; and therefore, if the freighter or carrier pays the transfer, the 10,000l. per annum is a clear ſaving to the company.

This reduces a deciſion on the queſtion of the adoption of ſmall boats in various ſituations, to a very ſimple criterion. Let the intereſt of the ſaving made by adopting a ſmall canal, inſtead of a large one, be compared with the expence of transfering cargoes: keeping this in view, that the expence of transfer will fall on the freighter or carrier, who can have no alternative to relieve him from this mode of conveyance; not even if a large canal ran to the ſame point. No large canal can rival a ſmall one, for evident reaſons. Suppoſe, for inſtance, a large and ſmall canal running ſide by ſide, the large canal coſting 300,000l. (*or, in proportion, three times the expence of the ſmall one*), and the ſmall one 100,000l. *one penny* per ton per mile, to the ſmall canal, would be as good intereſt as three-pence to the larger work; conſequently the ſmall canal company could lower their tonnage, ſo as to favour the freighter, and render the expence of transfer of no conſequence; they would even grow rich, by lowering the tonnage; which would draw the trade from the large canal, and leave it a ſtagnate and uſeleſs pool *.

* I do not heſitate to prognoſticate the annihilation of lock-canals, by improved ſcience; in like manner as improvement on machinery renders the old apparatus uſeleſs.

The

The facility and cheapneſs of the ſmall canal alſo invites and encourages connection from every quarter; but the difficulty of conducting large boats through a country precludes, or at leaſt moſt materially limits, their extenſion.

Conſidering theſe circumſtances, I conceive there are few ſituations which can warrant a canal for large boats; ſhort cuts uniting the arms of rivers, or through a flat country to an adjoining town, where there is no great expence, and much to be gained, the latter may be adviſeable.

But, to view internal navigation on the broad ſcale of national improvement, I conceive the river navigations ſhould be extended as far as convenient; but, the moment the courſe of the river is left to direct water conveyance towards the interior country, ſmall boats ſhould commence.

In the light of national improvement, the produce of labour is the real wealth of a country; the more the labour will produce, ſo much more the nation improves. As a man who improves a machine, from ſpinning one pound of cotton per day, to ſpin twenty; in the ſame time, and with the ſame labour, evidently obtains his comforts with greater eaſe. It is therefore worthy of remark, that, within little more than three years, the immenſe ſum of 5,300,000l. has been ſubſcribed, in order to pay the expence of conſtructing the various navigations which have been propoſed within that time: this ſum, averaged at 5000l. per mile, will execute 1060 miles; yet, to a certainty, 2120 miles might be formed on the ſmall ſcale for the above ſum, adequate, in every part, to the various kinds of trade, and thus give to the nation the advantage of 1060 miles additional water carriage, the benefits of which would certainly be immenſe.

Of

Of the canals already cut, or in ſuch forwardneſs as not to admit of an alteration, I conſider them in the ſame view as rivers; but all future works to be guided by the before-mentioned criterion, of comparing the expence of transfering cargoes, with the intereſt of the money ſaved, by adopting the ſmall, inſtead of large boats.

CHAP.

CHAP. V.

OF THE PARTICULAR CONSTRUCTION OF THE BOATS, AND THEIR APPLICATION TO VARIOUS SITUATIONS.

HOWEVER novel the formation of the boats may appear, at firſt ſight, I hope to be able to exhibit ſufficient reaſon for the particular mode of conſtructing them: I therefore beg the accurate attention of the reader to this part of the combination, as on this eſpecially I conceive the whole ſyſtem of ſmall canals is ſupported.

I have already aſſigned reaſon for the boats being ſmall; I have alſo hinted at the neceſſity of their paſſing ſpeedily over the machinery: I muſt again repeat, and impreſs this conſideration, that the trade being divided into ſmall portions, will, conſequently, create a great number of movements at the machinery; it is therefore indiſpenſably neceſſary, that ſuch movements ſhould be performed with the greateſt poſſible expedition, in order that an important trade may be tranſacted.

In deliberating on this part of the operation, I found it would be the means of great loſs of time, if the boats were to be placed on any kind of carriage, or cradle, for the purpoſe of paſſing the plane; that ſuch carriage or cradle would alſo prevent one movement on the machinery, which is the great means of expedition *; hence, to prevent loſs of time, and that the boats

* The rotatory movement of the leading chains, which ſhall be particularly deſcribed in the firſt machine.

might

might come prepared to paſs the plane, I was neceſſitated to compoſe the plane of rollers, or to give wheels to each boat: after weighing theſe two modes of conſtruction, I ultimately determined on wheels to the boats. Rollers being attended with many ſeeming difficulties, firſt, that of forming them in a ſtraight line; ſecondly, that of keeping them true; thirdly, ſhould any rollers be out of repair, the machinery and trade would be ſtopped, for ſo long a time as the repairs continued in hand*. But, if a boat was damaged, that boat only would be retained till repaired, which might quickly be done, in conſequence of being light, and eaſily handled.

Having therefore adopted wheels, I ſhall endeavour to obviate ſuch objections as ſeem moſt natural to ariſe againſt this combination of a boat and waggon, after deſcribing their mode of formation. For this purpoſe, ſee PLATE I. which repreſents three modes of conſtructing boats to convey different articles; either by a ſlow, or by a quick movement, as particular circumſtances may require.

Fig. 1. Exhibits the market, or paſſage, boat.

Fig. 2. The diſpatch for the purpoſe of conveying ſuch goods as require expedition.

Fig. 3. The common trader.

This laſt boat is twenty feet long, four wide, two feet ten inches deep, in the clear; flat at the bottom, and ends like a box; it may be compoſed of three-inch deal, bolted and ſcrewed in the

* Yet it is poſſible rollers may be found of uſe in ſome caſes.

uſual

uſual mode, and ſtayed at the corners; with two knees, or ribs, inſide, exactly above the wheels, and about five feet from the ends, which will leave ten feet in the centre.

Two keels of ſcantling, about ſix inches ſquare, and eighteen inches aſunder, muſt be laid along the centre of the bottom to receive the wheels; or if this is not found ſufficient, a framing, of the ſame dimenſions as the bottom of the boat, may be conſtructed to receive the wheels, and on this framing the boat may be built, which will be ſufficient to ſupport the weight while ſhe is out of water.

The wheels, which may be from ſix to ten inches in diameter, are to be two feet diſtance from the extremities; and may be caſt, axle and wheel, in one piece, and turned at the ſhoulders; or a wrought iron axle if neceſſary, which axle may move on braſs or iron ſteps.

The wheels being thus ſmall, and ſhort in the axle, will lie cloſe under the bottom of the boat, ſecure from the poſſibility of touching the ſides of the canal, or receiving injury; the keels, or platform, which compoſe the bottom, being caſed with thin board, will cover every thing but a part of the wheel rim, as repreſented at A. B. The chains on the end are for the purpoſe of hooking the boat to the leading chains of the inclined plane. In regard to objections which may be ſuggeſted againſt the formation of this boat, I conceive only THREE can ariſe.

Firſt, The diameter of the wheels being ſmall may occaſion ſome additional friction, in paſſing the machinery.

Secondly, The poſſibility of the wheels being injured.

F *Thirdly*,

Thirdly, The refiftance on the water, in confequence of the wheels, and fhape of the boat.

To the *firft* it muft be obferved, That, while the boat is out of water, it will ever act on a regular plane of caft iron, and never be fubject to inequalities, and although the friction will be fomething more in confequence of the fmall wheels, yet, as fufficient power may be obtained to raife her, the friction arifing from their fmall diameter will be no confiderable impediment.

To the *fecond*, I conceive the wheels are not fubject to receive injury, but while the boat is out of water; and, even then, I do not perceive wherein they are liable to damage; the wear which enfues by a long courfe of time, only, can affect the boat in this part; and, to this, it muft be obferved, that fhe will not undergo fo much hardfhip in paffing two hundred miles, as a common waggon in moving one mile on the ufual roads.— But, even admitting frequent repairs fhould be neceffary, fmall flips may be conftructed at proper fituations, where a man, by a common windlafs, would draw the boat out of water, and repair her, with the fame facility as he would remedy a defect in a cart, or a waggon; the procefs of dry docks neceffary to large boats, is by no means required in repairing thefe.

In the *third* objection, the refiftance in the water may appear to arife from two caufes; firft, from the projection of the wheels in fome degree from the bottom; and, fecond, from the flatnefs of the boat on the ends. But it muft be obferved, that boats of this conftruction are defigned to move flow, confequently the refiftance arifing from the particular conftruction will be very trifling, and of little importance, refiftance being much more

more in proportion to the velocity, than either fhape or weight.

To give a general idea of this, it is merely neceffary to remark, that fhould a man attempt to drive a horfe fixty miles *per* day, he could fcarce convey a boat of the lighteft conftruction at that rate; yet the fame horfe would convey one hundred tons twelve miles *per* day with eafe, and arrive at the end of fixty miles in five days; which is equal to twenty tons per day moving through the whole fpace of fixty miles.

This I hope will be fufficient to fhew that refiftance from fhape, in flow movements, is inconfiderable; alfo, that the true principle of conveying goods cheap, when expedition is not required, is, to move flow and take a quantity *; and in this refpect I fhall now confider their fuperiority over boats of twenty-five tons.

Seeing

* To the reader who may wifh to enter more into the abftract, it may be proper to remark, that a body moving in a fluid is refifted from two caufes; firft, from the cohefion of the parts of the fluid: for a body in motion feparating the parts of the fluid wherein it moves muft overcome the force with which thofe parts cohefe,

The fecond caufe is, the *inertia*, or inactivity, of matter; whereby a certain force is required to move the particles from their place, in order to fuffer the body to pafs. When the fame body moves through the fame fluid with different velocities, the refiftance increafes, in proportion to the number of particles ftruck, in an equal time, which number is as the fpace run through in that time; *i. e.* as the velocity. But further, it increafes in proportion to the force with which the body ftrikes againft every part; which force is alfo as the velocity of the body; and therefore if the velocity be triple, the refiftance is triple, from a triple number of parts to be removed. It is alfo triple from a ftroke three times ftronger againft every particle; therefore the whole refiftance is nine-fold, *i. e.* as the fquare of the velocity; hence a body moving in a fluid is refifted, partly in a ratio to the velocity, and partly in a duplicate ratio of the velocity.

Moft authors have confidered it as a rule, that while the fame body moves in the fame medium, it is always refifted in the duplicate proportion of its velocity; that is, if the refifted body move in one part of its track with *three* times the velocity with which it moved in fome other

Seeing that the true principle is to move flow and take quantity, *in the ufual trade*, it muft be obferved that a twenty-five ton boat is a limited quantity, and more cannot with propriety be applied to the horfe, confequently he muft refort to fpeed, and combat the refiftance.

Two twenty-five ton boats cannot be hooked to each other; as the helm of one will not govern the other, and they are too ponderous to be managed by a boat-hook; they are alfo fo long that, in making the bends in the courfe of the canal, they feparate the fluid by fide preffure; the bow of the firft feparates the fluid, *for inftance*,

other part, then the refiftance of the greater velocity will be nine times the refiftance of the leffer; and if the velocity in one place be *four* times the velocity in another, the refiftance of the greater will be fixteen times the refiftance of the leffer, and fo on. *See Chambers on Motion.*

Hence, as refiftance is more in proportion to velocity than weight; if I fuppofe a boat and cargo to weigh twenty tons moving at the rate of two miles per hour, fhe will remove a certain number of particles in that time; if the weight is *doubled*, twice the number of particles will be removed, and the refiftance will, in confequence, be double. But, as the fpeed is not increafed, all the refiftance which would arife from increafed velocity, by the force with which the particles would be ftruck, is avoided; therefore quantity, to create refiftance equal to what fpeed produces, is nearly as follows: in which I will fuppofe a horfe to convey thirty-fix tons at the rate of two miles per hour, and diminifh the quantity as the fpeed is increafed.

Miles per hour.	*Square of refiftance from velocity.*	*Tons.*
2	4	36
3	9	16
4	16	9
5	25	6
6	36	4

Hence, as nine is to four in refiftance, fo is fixteen to thirty-fix in quantity; and fo on, in the fucceeding numbers, the quantity diminifhing as the fpeed is increafed; which determines, that to convey four tons fix miles per hour, requires as much power as to convey thirty-fix tons two miles in the fame time: thus, although the fpeed is but triple, the quantity is reduced to one ninth part, or as four is to thirty-fix—and fo on in the other numbers.

to

to the right, and the ftern repels it to the left; the bow of the fecond boat brings it to the right again, and then the ftern drives it to the left; which agitation confequently will retard the motion of both boats: hence, on a canal for twenty-five ton boats, one boat muft be the allowance of one horfe; he cannot have more; but muft endeavour to accomplifh quantity by fpeed, and encounter the confequent refiftance.

But of the four-ton boats, ten, fifteen, or twenty, may be linked together, to compofe any weight which is thought proper, according to time and diftance; being only twenty feet long they incline to the bendings of the canal like the links of a chain, and follow in the wake of each other, being guided by a man walking on the horfe-path with a boat-hook; hence, by the fyftem of fmall boats, a horfe may take any quantity, and move with a proportionate velocity.

From boats of this conftruction, another material advantage arifes to proprietors of colleries, lime, delphs, &c.; frequently a canal may pafs near fuch works; and yet it is inconvenient, or inconfiftent, with the quantity of trade, to extend the water level to the very fpot; which circumftance frequently obliges fuch proprietors to conftruct rail-ways, and keep waggons, which they muft be at the expence firft of loading, before they can deliver the commodity to the boats, and frequently of forming a depofit on the canal banks, from whence they muft again load into the boats. But if fuch works lie above the canal, and not more than fix hundred yards diftant, fo that a regular defcent could be obtained; a fingle road might be formed, and the boat floating on additional wheels might be raifed to the pit by the fteam-engine employed in pumping, or by the mode defcribed by D. in the Plate of Parts.

But if fuch a regular declivity could not be obtained, fuppofing the afcent was eafy, the boat, on a carriage prepared for the purpofe, poſe, might be conveyed to the works, *any where within a mile*, by a horſe; there taking in her cargo, deſcend from thence to the canal, and be immediately ready for navigation.

It may alſo be adviſeable, in ſome caſes, for the proprietor to reduce his boats to two tons, being twenty feet long, two feet ſix inches wide, and the ſame depth; by placing wheels on theſe boats, of the ſame dimenſions as thoſe of four tons, they will paſs the ſame machinery, and navigate wherever canals ſo adapted extend; and the advantage to the proprietor would be, that ſuch narrow boats would paſs through a tunnel, not more than three feet ſix inches wide and nine feet high, which may be conſtructed ſo cheap as to enable him to drive a water level into the centre of his works *: ſo far relates to the ſquare ended, ſlow mover, and common trading boat.

But as various circumſtances may require diſpatch, ſuch as boats to market, paſſage boats, or quick communications between trading towns, where valuable merchandize may require ſpeed; Figure the *firſt* and *ſecond*, repreſents boats for this purpoſe, being conſtructed thirty feet long, four wide, two feet ten inches deep; flat at bottom, with wheels as before mentioned, and ſharp at the bow, as ſpeed is required, containing from four to five tons: in building theſe boats ſtern poſts muſt be raiſed about five feet high (as in the Plate), to which the chains are fixed; thus, the chains being raiſed will prevent the leading chains of the machine from preſſing on the goods, or incommoding paſſengers. Of the operation of theſe boats I ſhall treat in Chapter the Seventh, on the Syſtem of Navigation.

* I have not been able, *in time for the preſs*, to procure an exact account of the length of the various tunnels which extend to his Grace the Duke of Bridgewater's colleries at Worſley: but it is ſaid they amount to ſixteen miles, which, at 6l. per lineal yard on an average, would coſt 168,960l. half of which, 84,480l. might have been ſaved by employing the two-ton boats.

CHAP.

CHAP. VI.

DESCRIPTION OF THE SECOND PLATE, EXHIBITING A DOUBLE-INCLINED PLANE, FOR THE PURPOSE OF PASSING BOATS, AND THEIR CARGOES, TO, AND FROM, THE DIFFERENT PONDS, OR LEVELS, IN CANAL NAVIGATION.

AS a thorough intelligence of the principles of this machine will give a good introductory idea to the ſucceeding apparatus, I will endeavour to be particular in the deſcription of it; therefore I hope to be excuſed if it appear a little tedious, to thoſe who are familiar with ſome of its component parts; as my wiſh is to explain the principle to thoſe perſons who are totally unacquainted with the ſubject, which I know by experience to be ſomewhat difficult; I will therefore firſt enumerate the parts which compoſe it.

1ſt, A double-inclined plane, extending from one pond or level of canal to the other, and running into each canal about ſixty feet.

2d, A pit (or well) in depth equal to the difference between the levels of the two canals.

3d, A ſough from the bottom of the pit, to communicate with the lower canal.

4th, A tub, or ciſtern, to move in the pit, into which water is drawn from the upper canal in order to create a power to put the machine in motion.

5th,

5th, A trough to convey the water from the upper canal to the tub.

6th, A drum wheel, over the pit, to which the tub is fuſpended; which wheel gives motion to the remainder of the apparatus; with a ſmall fan to regulate the increaſed velocity of the tub, in riſing from the bottom to the top of the pit.

7th, A weight ſuſpended to the oppoſite ſide of the drum; which muſt be ſomething ſuperior to the empty tub.

8th, Balance chains, which are equal in length to the depth of the pit; theſe muſt be faſtened, one end to the bottom of the tub, the other to the bottom of the weight.

9th, A horizontal wheel at the bottom of the plane, and over the lower canal; alſo, a wheel inclined on the ſame angle as the plane, to be placed at the top; round theſe two wheels the leading chains are continued, and perform a rotatory movement.

10th, A lying ſhaft with two wheels multiplied movement, to convey the motion from the drum to the inclined wheel.

11th, A ſmall wheel receiving motion from the back of the inclined wheel; in order to draw the boat out of the upper canal on the bridge of the plane.

12th, A ſtopper on the plane near the bridge, to prevent the boat deſcending till the man is ready.

13th, A pair of centrifugal fans to regulate the movement.

14th, A lying ſhaft, multiplied movement, to communicate the motion with the fans and inclined wheel.

15th, Building to cover and ſupport the works, with ſome levers and valves, to be deſcribed.

To erect ſuch a machine; the firſt conſideration is, in ſurveying the propoſed line of the canal, to run it to ſuch points of hills as will admit of the greateſt poſſible riſe at one time; as this will prevent much machinery and reduce the number of operations.

The ſlope of the hill muſt then be formed into a regular plane of any angle under forty-five degrees, to which the ground is beſt adapted; and extending from one pond to the other, as in Fig. II. Two planes muſt then be formed, in width two feet one inch, and each diſtant from the other ſix feet; the ground work of theſe planes may be timber, framed together and laid on a bed of rubble, or rough aſhlar, or the aſhlar covered with coping ſtones, each of which ſhould be at leaſt three feet long croſſing the plane, and not leſs than one foot diameter, neatly dreſſed and jointed; this mode would form a permanant plane of ſtone, the two ſhould be united by wood binders at about every fifteen feet, or caſt iron rails would be much better in conſequence of their duration. Having formed the plane by either of theſe modes, the iron rails caſt with a flange, and ſix or more feet long, muſt be carefully placed two feet one inch apart from flange to flange; if laid on wood, ſtrong ſpikes will be ſufficient ſecurity, and if laid on ſtone they ſhould be carefully bedded, and the ſpikes or pins faſtened by melted lead, obſerving to fill every aperture to prevent the admiſſion of water, which freezing in winter might ſplit the ſtone; ſuch a plane of iron and ſtone is moſt adviſeable as it is moſt laſting.

Of ſuch plane about ſixty feet muſt deſcend into the lower canal, but of a leſs angle then the firſt; it ſhould not exceed four degrees, that by lying flat it may let the boat into the canal without danger of filling. At the part where this laſt plane joins the firſt, in entering the lower canal the angle muſt not be left ſharp, but the union formed by a hollow curve, which will let the boat down with a regular motion, without the danger of her bow, or ſtern, touching either of the planes; which would be the caſe if the two planes were joined by a ſharp angle.

Again, on the ſummit where the plane turns into the upper canal, the union muſt be a regular curved bridge, which will prevent the bottom of the boat between the wheels from touching the planes; which would be the caſe if the planes were united in a ſharp point, (comparatively) like the ridge of a houſe.

Each of thoſe planes, as they proceed into the upper and lower canals, muſt widen from two to about three feet; or have two rails, placed juſt above the water, in order with the greater eaſe to guide the boat to the exact ſituation; that her wheels may touch in the right part of the plane, and prevent her miſſing the iron rails.

2dly, Having formed the planes (ſee the Top Drawing, which repreſents the Upper Works), A, in the ground plan, exhibits the mouth of the tub pit, and ſhould be ſufficiently large to receive a tub which will contain eight tons of water. A tub nine feet diameter and five deep will contain upwards of nine tons, therefore ſufficient room for eight without danger of ſpilling; hence, if the pit is from ten to eleven feet diameter it will be ſufficient; which pit may be walled with brick, or ſtone, as moſt convenient, like a common coal-pit ſhaft or well.

3dly,

3dly, From the bottom of the pit a ſough, B, to the lower canal, which needs not be more than three or four feet diameter; in fact, as ſmall and cheap as the nature of the meaſures will admit; as it is of no other uſe than to let off the water diſcharged from the tub in the pit.

4thly, A tub muſt be formed, as before mentioned, capable of containing eight tons of water, nine feet diameter, five deep; this may be made of wood, or ſheet iron, like the boiler of a ſteam engine, and having in the bottom a hole from twelve to eighteen inches diameter, acroſs the hole a ſtrong bar of iron, and in a right line with the bar one muſt be placed acroſs or near the top of the tub; through each of the bars, and exactly in the centre of the tub, there muſt be a hole to receive a perpendicular bar, ſomething more than one inch diameter; on the laſt bar a valve is placed, ſufficiently large to cover the hole in the tub; and ſo placed on the perpendicular, that when it is ſhut the bar will project about eighteen inches below the bottom of the tub: hence the valve will play perpendicularly, being guided by the perpendicular paſſing through the croſs bars of the tub. The uſe of the eighteen-inch projection below, is in order that, when the tub deſcends to the bottom of the pit, the bar may ſtrike the bottom of the pit, and riſing with the valve by means of the blow, may diſcharge the water from the tub. See the Figure of the Tub in the Plate of Parts *.

5thly, A trough muſt be formed, from about three feet below the top water of the upper canal, to the centre of the diameter of the pit, in which a common valve may be placed of twelve or eighteen inches diameter, in order to draw water into the tub.

* There may alſo be guides, to preſerve the tub in a direct perpendicular through the pit.

 6thly,

6thly, C repreſents the drum-wheel, which ſhould be about half the diameter of the tub, and ſo placed that one ſide may come exactly over the centre of the pit. Care muſt be taken that this wheel be made ſufficiently ſtrong to ſupport ten or twelve tons, *which indeed is not ſo much as the ordinary weight of a conſiderable water wheel:* its length may be from eight to twelve feet, but if kept ſhort it will have the more ſtrength. On one end of this drum a ſpur-wheel, D, muſt be conſtructed, that the motion may begin to multiply. For it muſt be obſerved, that as the plane will be ſometimes ſix, ſeven, eight, or more times the length of the pit, the boat will have to paſs through ſo much more ſpace than the tub; hence the movements muſt multiply in proportion. I will, in this, ſuppoſe the plane ſix times as long as the pit is deep, therefore let the ſpur-wheel on the drum be three times the diameter of the drum, which will multiply the movement three times, leaving three to be made on the other parts of the machine; the drum and ſpur-wheel being formed, a pinion may work in the ſpur *, to the ſhaft of which a pair of fans will regulate the increaſed velocity of the tub in returning. The drum being fixed, the tub is to be ſuſpended by two or more chains, and on the oppoſite ſide a weight ſomething ſuperior to the tub; the uſe of this weight, is to return the tub to the top of the pit when the water is diſcharged.

Balance chains, equal in length to the depth of the pit, *and equal in weight to the tub chains, three feet of one, for inſtance, being juſt as heavy as three feet of the other*, muſt be fixed, one end to the bottom of the tub, the other to the bottom of the weight; and thus, as the tub and weight riſe and deſcend alternately, there will ever be the ſame quantity of chain pendent, which will preſerve a balance on the works; but, without this chain, ſuppoſe the tub to be ſituated at bottom, the weight would have to raiſe not only the tub, but its chain

* See Fig. I. in the Ground Plan.

4 alſo;

alſo; and the tub would have a ſimilar weight to raiſe when the weight was at bottom; but now whichever is at top has the whole of the balance chain hanging to its bottom, therefore an aſſiſtant to raiſe the oppoſite chains and prevent them from being a tax on the machine. (See the Balance Chains in the Plate of Parts).

E, a horizontal, or rather inclined wheel, being on an angle with the plane. This wheel ſhould be of ſuch a diameter, that its extremities might come exactly oppoſite the centre of the two planes, which will be about eight feet, therefore eight feet diameter; about ten inches broad on the ſole, and two flanges: to keep the chain on the wheel round the rim, ſtrong pins, or teeth, muſt be fixed, on which the links of the chain catch promiſcuouſly, to prevent them ſlipping; the beſt mode of forming this will be by ſegments of iron caſt with the flanges, and a row of holes in the centre and end of each, and acroſs the ſegment, at about one inch diſtant from each other. In faſtening the ſegments to the wood, the ſcrew-heads may be left pointed, and projecting about one inch, which will anſwer the purpoſe of catching the links; on the upper part of this wheel, ſegments of bevil gear muſt alſo be ſcrewed, of the ſame diameter as the wheels. A wheel of the ſame ſize and conſtruction, *excepting the bevil gear*, muſt be placed at the bottom of the plane, and over the lower pond of canal *this muſt be horizontal*. Round theſe wheels the leading chains perform a rotatory movement; a ſtopper being placed on the upper wheel to prevent it turning back. (See the Plate of Parts.)

F, a lying ſhaft, to convey the power from the drum to the inclined wheel. By this the remainder of the multiplied movement is performed; by a ſmall pinion working in the ſpur-gear of the drum, and a large bevil working in the bevil of the inclined

wheel,

wheel, the pinion end muſt be made to caſt in and out of the drum-gear at pleaſure, particularly to let the tub return.

G, is a bevil wheel with a ſmall ſhaft, receiving motion from the inclined wheel: to the ſhaft a rope is fixed, and continued round a pulley, to a beam projecting from the front of the building; the uſe of this is to draw the boat out of the upper canal on the bridge of the plane, by means of the deſcending boat, or tub, giving motion to the inclined wheel. When the rope is hooked to the boat, a pull will draw a knot, *which anſwers as a ſtopper*, home to the lever H, which moving, the lever drops the wheel into gear. When it has raiſed the boat to a certain point, another knot, drawing the lever H inwards, lifting the wheel out of gear, it remains inactive, although the other parts of the machine are in motion. This mode of raiſing the boats out of the upper canal, on the bridge of the plane, keeps a conſtant ſupply ready to deſcend*.

I, *(ſee the Top-works.)* This is to ſtop the boat, when drawn on the bridge of the plane, from deſcending till the man is ready. To place this, a ſpace muſt be made in the plane, between the rails, about five feet long. The ſtopper may be a frame of wood, projecting about five feet above the plane, and deſcending beneath it, where it muſt be framed into a ſhaft, working on gudgeons, one end of the ſhaft projecting about three feet from the ſide of the plane; to the ſhaft a weight muſt be ſuſpended by a chain, which weight will raiſe it to a perpendicular, after the boat has paſſed; by which it faſtens under the end of the lever, and ſtops the next boat, and ſo on†. On the upper end of the ſtopper there muſt

* As a diſtinction, this rope may be called the Preparer, in conſequence of preparing the boats to deſcend.

† See the Plate of Parts.

muſt be a roller, rather hollow on the face, to eaſe the chain as it paſſes.

J, are the centrifugal fans, compoſed of wood, and hung to a perpendicular ſhaft, by boſſes on the fans, and a gudgeon through the ſhaft. The object of theſe is to regulate the movement of the various weights, without the attention of the workmen, which will conſequently be a means of ſaving time; theſe fans, as the weights are heavy, and increaſe in velocity, expand, creating reſiſtance by their action on the air, by which they retard the motion; and, although the weight of the boats may vary, they preſerve nearly an equal movement, which will render any attention to this part of the operation uſeleſs.

K, is a lying ſhaft with two wheels; one ſmall, working in the inclined wheel, another of a diameter four, or more, times larger than the firſt, working on the pinion of the fan-ſhaft, which is to multiply the ſpeed of the fans; they conſequently will create greater reſiſtance.

See the Plate of Parts, Fig. I. which repreſents the boat entering the upper canal, and the mode of ſeparating from the leading chains, in conſequence of the form of the hook, which hook is to be made with a pin about four inches long, croſſing at a right angle through the head; by this means, ſo long as the boat-chains are in a diagonal direction, in aſcending or deſcending, the hook will hold faſt to the leading chain; but on entering the different ponds, the roller cauſes the boat-chains to riſe in a perpendicular direction, by which the pin preſſes on the link, and turns out the bill of the hook, leaving the boat at liberty to run into the canal, without ſtopping the machine for that purpoſe, which is is the means of faving much time, the man paying no attention to the unhooking of the boats. It muft be evident, that if the machine was ftopped to unhook, at top and at bottom, the man would have to pafs from one place to another for that purpofe, and confequently lofe much time, but, by the hooks cafting off, the man's whole attention is employed in preparing boats to rife, or defcend; hence the machine is capable of being kept in almoft conftant motion, and the boats rife and defcend, in regular fucceffion, with very little interruption; the fame mode of cafting off being performed both at top and bottom of the plane, taking care that the roller at top is fufficiently within the bridge, that the boat may tend towards the upper canal, previous to the hook feparating from the chain.

E, in the Plate of Parts, exhibits the mode of paffing long timber, *all twenty-foots being put into the boats*, each plane is prepared with a carriage for this purpofe; and the timber being chained in four-ton parcels, or rafts, is floated on the canal, one horfe conveying eight, ten, or twelve, fuch rafts. On arriving at the plane, each, in fucceffion, is to be floated on the carriage, and, being hooked to the leading chain, they will confequently mount or defcend the plane, with the fame facility as a boat, and, by this means, timber of any length, or dimenfions, may be tranfported by a fmall canal.

In Ruffia and America, all timber is rafted in a fimilar manner, as far as it is poffible to convey it by fuch means: and I fee no reafon for objecting to fuch an operation on canals, the mode of paffing to and from the different levels being accomplifhed.

Having

Having defcribed the formation and ufe of the particular parts of this machine, I will now go through the operation of paffing the boats; in which obferve, that, in confequence of the chains performing a rotatory movement, the defcending boats will ever pafs on one plane, and the afcending on the other: hence the boats will rife, or defcend, in a regular fucceffion, and in the fame order, as they arrive at the plane; nor will the afcending boats ever incommode the defcending, or the defcending be any obftruction to thofe that afcend.

Firft, it will be neceffary to go through the operation of a defcending trade, fuch as is frequent from coal-works, lime, delphs, &c. where the loaded boats defcending return thofe that are empty.

In this cafe, let it be fuppofed a number of loaded boats are at top, and empty boats at bottom; the man hooks the preparer to a loaded boat in the upper canal, and the man below hooks an empty boat to the leading chains; water is then admitted into the tub, which, giving motion to the whole machine, draws the loaded boat over the bridge, to the ftopper, and at the fame time raifes the empty boat near to the fummit of the plane; this done, the preparer is hooked to a fecond boat; the loaded boat is hooked to the leading chains, and alfo another empty boat is hooked below. The tub being caft out of gear to relieve the works, the man lets go the ftopper; and now the loaded boat, by its defcending weight, raifes a fecond on the bridge, draws the firft empty boat into the upper canal, and raifes a fecond empty boat into the place quitted by the firft; thus a regular rotation of paffing is kept up, in a defcending trade, without the ufe of water

 to

to any but the firſt boat; the firſt prepares the ſecond; the ſecond the third; and ſo on, to any number of boats.

The ſame operation, in all its parts, is performed in an aſcending or alternate trade; with this addition, that water is drawn into the tub, to create a ſufficient power to raiſe the loaded boats.

It now comes to ſpeak of the expedition produced by this ſyſtem.

Firſt, It muſt be evident to every one, particularly thoſe who have ſeen any ſimilar operation, that if an alternate movement was adopted, and a boat was to come up the ſame plane where one went down, the boat could not be raiſed on the bridge of the plane while the other was paſſing, becauſe it would occupy the ſituation where the aſcending boat muſt paſs; neither could the deſcending boat draw the aſcending into the upper canal, the deſcending boat loſing its power in touching the lower canal; conſequently the aſcending boat would not paſs through more ſpace than the deſcending, therefore a ſtop would take place below the bridge of the plane, as is now the caſe; but it is the deſcent of the ſecond boat which draws the firſt over the bridge, into the upper canal, and raiſes a ſecond boat into the place of the firſt; this ſecond is alſo drawn in by the third deſcending boat, and ſo on, which is the conſequent reſult of a rotatory movement, which rotatory movement could not be applied if any kind of cradle, or carriage, was uſed to convey the boat, as ſuch carriage muſt neceſſarily riſe, and deſcend, on the ſame plane, and conſequently give an alternate movement. Hence the neceſſity of wheels to the boats, or of rollers to the plane.

Secondly,

Secondly, The centrifugal fans regulating the movement, and the caſt-off hook diſcharging the boats from the chains, is a great means of ſaving time, and, in fact, leaves little more for the men to do than hook boats *to the chains*, in ſucceſſion, they riſing, and deſcending, in regular rotation, which admits of ſuch extraordinary ſpeed, that two four-ton boats may paſs a plane, whoſe perpendicular is 200 feet, in three minutes, as will appear by the following ſtatement:

	Minutes.
Hooking the preparer to the boat, - - - -	0 ½
Hooking the boat to the leading chains, - - -	0 ½
Drawing water into the tub, if neceſſary, - - -	0 ½
During this the man below has ſufficient time to hook his boat.	
Paſſing the plane, - - - - - -	1 ½
	3 0

During the paſſing of the plane, the man above, having nothing elſe to do, may be getting his line of boats forward to the ſituation for the preparer, or pull forward thoſe boats which have aſcended; or this might be the work of a boy, at 1s. 6d. per day. Hence 1920 tons may be performed in twelve hours; and, if this is not ſufficient, there can be no difficulty in working ſuch a machine by night, changing the ſets of men, who might live in the building over the machine; and thus, 3840 tons may be performed in twenty-four hours, at one plane, which, I hope, is adequate to the greateſt canal trade which the moſt ſanguine imagination can conceive; particularly when it is conſidered, that there is no canal yet known, where 1000 tons per day throughout the year paſſes at one point of the canal: on a canal ſixty miles long, for inſtance, 5000 tons might move on its various

parts,

parts, the transfer of which would be divided among feveral machines; but, fo far as I can learn, there is no canal in England where 700 tons per day moves through one point; therefore, confidering every circumftance, I conceive a fmall canal, and machinery, adequate to a trade of the firft importance.

A Com-

A Comparative View *of the* Expence *of rifing* 100 Feet, *by* Locks, *or* Inclined Planes, *the ufual Expence of Locks for twenty-five ton Boats being* 70*l. per foot, and for forty-ton Boats* 100*l. which, in the* firft *cafe, would coft* 7000*l. and in the* fecond 10,000*l.*

In this I fhall confider the average of fituations and circumftances, as to the form of the ground, carriage of materials, &c. the plane on an angle of 20 degrees.

	£.	s.	d.
Removing 4000 cube yards, in forming the flope of the hill, at 5d. per yard, - - - -	82	10	0
To forming the ends of canal, top and bottom, -	100	0	0
536 cube yards rubble walling, at 5s. per yard, - -	134	0	0
268 yards fquared afhlar coping, 18 inches thick, 3 feet long, at 15s. the running yard, - - -	201	0	0
536 yards caft-iron rails, 100 cwt. per yard, 15s. per cwt. - - - - - - -	402	0	0
Bedding the rails in the coping, lead and pins, 2s. per yard, - - - - - - -	53	12	0
26 caft-iron binders to unite the planes, 200 cwt. each, at 15s. per cwt. - - - - -	39	0	0
Two horizontal wheels, eight feet diameter, fix inches on the face, - - - - - -	100	0	0
Carried over, £.	1,112	2	0

Brought

Brought over,	£. 1,112	2	0
800 feet chain, 2s. per foot, - - - -	80	0	0
34 yards tub pit, 11 feet diameter, 4l. 10s. per yard,	153	0	0
110 yards fough, at 12s. per yard, - - -	66	0	0
One wrought-iron tub, - - - - - -	60	0	0
700 feet of chain to the tub, weight, and balance, 4s. per foot, - - - - - -	140	0	0
Drum-wheel, eight feet long, four diameter, fpur-gear, &c. - - - - - -	100	0	0
Two lying fhafts, ftopper, and centrifugal fans, -	150	0	0
Trough to convey the water to the pit, - -	10	0	0
Sixty rollers to bear the chains off the plane, 5s. each,	15	0	0
Building to cover the works, and anfwer as an office,	200	0	0
	2,086	2	0
Contingencies, 10 per cent. - - - -	208	12	0
Total,	£. 2,294	14	0
Locks for twenty-five ton boats, 100 feet rife, -	7,000	0	0
Double plane to the fame height, - - -	2,294	14	0
Saving, - - - - - - -	£. 4,705	6	0
Locks for forty-ton boats, 100 feet rife, -	10,000,	0	0
Double plane to the fame height, - - -	2,294	14	0
Saving, - - - - - - -	£. 7,705	6	0

In cafe of a trade totally defcending, the loaded boats raifing thofe that are empty, the tub, pit, drum-wheel, and all that part of the machine for creating power, may be faved, amounting to 599l. the contingent expences being reduced in proportion; in which cafe, a double inclined plane, to the height of 100 feet, would coft 1,635l. 16s.

This, compared with the expence of locks for twenty-five ton boats, will be a faving of 5,364l. 4s. and on locks for forty-ton boats 8,364l. 4s.

In this operation, when a number of loaded boats have to pafs down during the day, it is only neceffary to leave a loaded boat on the bridge of the plane, which will be a power in referve to begin work in the morning; or, if this is not confiftent with the nature of the trade, the firft boat may be raifed on the bridge, by the man, with a common windlafs, tooth, and pinion, which may be a work of about ten minutes; but, that done, it will raife all the remaining boats on the bridge, ready to defcend, as before defcribed. Thus the machine may be conftructed for an alternate, or a defcending trade; which laft will frequently be required in lateral cuts, particularly in the lime and coal trade; but, fhould future extenfion open an alternate trade, the water-tub, and all the parts for creating power, may be added to the plane, with the fame propriety as in the firft inftance; and this may be done without interrupting the trade one hour.

I now begin to apply the various apparatus to the feveral directions and portions of trade, in order that the expence may be contracted in proportion as the trade is fmall, yet enlarged with facility as trade varies in direction, or increafes in quantity: thus a canal may commence, like a man, on a fmall capital, and rife to confequence out of its own earnings.

As the machine is reduced in expence, the quantity which it will perform is alfo contracted: in the defcending trade about nine hundred tons will be the work of twelve hours.

CHAP.

CHAP. VII.

OF THE SYSTEM OF NAVIGATING.

AS a plane will rife from fifty to two hundred feet at one time, confequently, the ponds of canal may be longer, without interruption, than on the lock principle; and as men will be ftationed at each machine, whofe bufinefs it muft be to pafs the boats at fo much *per* ton *, I conceive the beft mode of navigating will be, when a man arrives with his ten, or more, boats at a plane he fhould immediately leave them for the men to transfer, and, taking fuch boats as are ready, return to the fource or machine from whence he came.

When the boats have been paffed by the engine-men, they are navigated by a man to the next machine, and fo on, till the voyage is completed. In a trade of lime-ftone, coals, iron-ore, flate, flags, deals, and various other articles, it could not make the leaft difference, in fuch materials, if a boat remained a few hours at a plane waiting for transfer; but in cafe of the arrival of merchandize, it fhould be paffed immediately, leaving the other boats for that purpofe.

By this mode the fame boatman will not navigate the whole line of canal, but will always work on one pond; which I conceive to

* On the Ketley and Shropfhire canals, a five-ton boat is paffed at a plane for 3d. the empty boats return *gratis*.

I be

be a convenience: for if I ſuppoſe the ponds between the planes from one to ten miles long, it will be eaſy to calculate the number of trips which a man can perform *per* day, on each reſpective length, from which his wages may be determined; he will ſet out without fear of interruption by lock-keepers, or of being delayed by numerous boats meeting at the ſame lock or locks; and he may ever work in the neighbourhood of his own habitation.

In the courſe of a voyage a perſon at a particular place may want to receive four, eight, or more, tons of coals, lime, or other materials, who has no occaſion for more; thus one, two, or more boats may be left at the moſt convenient ſituation to unload, without detaining the remainder, and the boats ſo left may be emptied by the purchaſer, before the boatman's return: but, in the caſe of a twenty-five ton boat, the whole muſt be detained till the quantity purchaſed is diſcharged.

This mode of a man always working on the ſame pond, and in the neighbourhood of his own houſe, will be productive of boatmen, as any kind of horſe will ſet a poor man up in buſineſs; the ſize of the boats enabling him to take a weight proportioned to the ſtrength of his horſe, mule, or even aſs. Beſides, as the whole object is merely to get them conveyed from one machine to another, he needs but little capacity, as he has nothing to do with machinery. Thus almoſt any kind of man will do for a boatman, and hence a competition will ariſe on the different ponds, and competition will not only produce attention, and civility, but alſo moderate charges.

It now remains to conſider, how this ſyſtem will operate on a home, or extended, trade. As the property will paſs through various hands,

hands, or rather come under the care of many, during its paſſage to any great diſtance.

To take a general view of this, the practice which moſt reſembles it, is the mode of ſending valuable merchandize by the mail or other coaches, for inſtance, from Scotland to London; which property paſſes through the hands of various coach proprietors and changes of coaches, yet arrives at the deſtined ſpot with certainty: or it reſembles the practice of a merchant, who ſhips goods for the continent; in which caſe they have firſt water, and then land carriage, ſometimes for many hundred miles: he and his correſpondent have their agents eſtabliſhed in various parts to facilitate the tranſit; who being alſo agents for many others, find it worth their while to pay a proper attention to the goods, and thus the articles ſafely reach the foreign market to which they are conſigned; cuſtom and regularity having rendered the mode familiar and eaſy.

Intereſt will alſo bend men to the various circumſtances, if one mode can be proved cheaper than another; it is therefore almoſt impoſſible for a mode to be pointed out, which may be preciſely followed on theſe navigations. But I will mention ſuch as I conceive will anſwer; and this by eſtabliſhed agents.

Suppoſe, for inſtance, a man of good capacity reſides near or in the building over the machinery, where at leaſt he might have a counting-houſe; this man might be toll-collector to the company, and at the ſame time agent to the various traders who uſed the canal; which employment probably would produce a handſome annual profit, and his agency might be performed at ſo much *per* ton: on a canal, for inſtance, with a trade of three hundred tons *per* day, allowing two hundred and eighty working days in the year, one farthing

farthing *per* ton would produce him 87l. 10s. *per annum*; which, with toll-collecting, might amount to upwards of 100l. a fum fufficient to induce a very clever man to fill the office. For this farthing he fhould take boats and cargoes under his care for at leaft ten miles; if two machines were in that fpace, he fhould govern both, but if they were twenty miles diftant from each other, he fhould have all goods paffing on that pond under his guidance, in which cafe the agency might be raifed. Therefore, averaging the agency at one farthing *per* ton, for ten miles, the expence of it could not be felt on the value of any kind of materials; the agency of one hundred miles being performed for two-pence halfpenny *per* ton. But as even ten-pence *per* ton on one hundred miles would be no object to the feller or buyer of the goods fent, I will therefore raife the agency to one penny *per* ton for ten miles, confequently feventy-five tons *per* day would pay an agent 87l. 10s. *per annum* on a canal with fmall trade.

Having thus eftablifhed agents at proper fituations, who may be confidered fomewhat analogous to the book-keeper at a coach-office, alfo to collectors of turnpikes, *they collecting the tolls*, each proprietor of boats fhould have his name, and number, marked on each boat.

I will now fuppofe him to difpatch ten boats, to be left in different places; with thefe boats he fhould fend a ticket to the firft agent, and perhaps to the following effect:

Date.

Date.		Proprietor's Name.								Tons.
To Whom.	*Refidence.*	Boats Number.								
			No.	No.	No.	No.	No.	No.	No.	
A. B.	Manchefter,		4	6	10	14				16
C. D.	Stockport,		3	11						8
E. F.	New Bridge,		7							4
G. H.	Romely,		8	9						8
C. W.	Chadkih,		1							1

The agent, on receipt of fuch ticket, would draw a line over the numbers to be left in his diftrict, make out a direction for each, and deliver it to the next boatman; with the firft ticket to be forwarded to the next agent with fuch boats as pafs over the next machine, and come under his care, and fo on. The agent, knowing the time of the boats paffing, would alfo know when the empty boats, or full ones, fhould return; he would likewife have the boatman on his pond immediately under his control, as well as the men at the machine, therefore could correct any negligence, and the proprietor would know where to apply if they were anywife remifs in their duty. The work might be fo regular, as even to afcertain when any particular boats paffed each machine, and when it arrived at its deftination, by marking the hour on the ticket.

This mode of reducing the work to fyftem, and rendering every man by habit familiar with his part, I conceive, will facilitate navigation, and render the paffage of goods of all kinds, to the moft diftant parts of the country, extremely fimple; boats, for inftance, from Manchefter to London, being carefully packed and covered with a tarpawling, would pafs with the ticket, by the various agents,

agents, with the ſame certainty as others would go thirty miles, one ſyſtem being preſerved throughout *.

The perquiſites of the agent, already ſtated, would be ſufficient to warrant the company in demanding a bond to a conſiderable amount for the true performance of his office; the company would be reſponſible to the freighter for any loſſes, and the agent anſwerable to the company for neglect: this would not only link the various ponds of canal together, but would produce a continued chain of ſelf-intereſt, the moſt prevailing ſtimulus to urge men to be active, and do what is right; the agent's emoluments ariſing out of the tons conveyed, I conceive to be much better than a fixed ſalary; as his profits will, in ſome degree, depend on his attention: which attention might be the means of influencing proprietors of goods to ſend articles on the canals that might otherwiſe be tranſported by different means.

Hence, even by this plan, I ſee no difficulty in conveying goods into the moſt diſtant, and leſs important, parts of the country; and time, with concurrent circumſtances, will no doubt infinitely improve this method.

* It has been obſerved, that ſome difficulty would attend ſending goods to diſtant parts by theſe boats, as a man could not follow his property, or appoint a perſon to accompany it, in conſequence of paſſing through ſuch various hands and boatmen; but the ſame objection might ariſe againſt the ſending of game to London; a man might ſay he could not go with the game to ſee it delivered: but, what is much better, agency performs this part of the buſineſs, nor do I know any conveyance where property is followed or accompanied by the proprietor. Property is given to the care of others, who are reſponſible for the delivery into ſafe hands; letters, for inſtance, which paſs through the various poſt-offices, are by their ſize much more liable to miſcarriage or miſtake, from agency, than a four-ton boat, or goods conveyed by it; yet cuſtom has rendered the transfer of letters perfectly eaſy and ſecure, millions of property being conveyed by letters, circulated into the moſt obſcure parts of the country every week.

To

To this regularity, I conceive expedition will, in many caſes, be added, as before mentioned of the market, paſſage, and diſpatch boats. Many valuable kinds of merchandize will bear ſome additional expence in carriage; and it may be of more importance to the merchant to have them in market, in a given time, than to ſave the difference in expence between the ſlow and the more rapid conveyance.

I will therefore ſuppoſe a canal from the great trading town of Mancheſter to London, diſtant 182 miles, to which add 38 miles for the bonds, amounting to 220 miles, and on this length of canal twenty-two agents, one to every ten miles.

A carrier at London, or at Mancheſter, we ſuppoſe to have his diſpatch-boats ready, which, containing from four to five tons, might be conveyed at the rate of ſix miles per hour, by one horſe; as they would arrive periodically, each machine-man would know when to look for them; and the boatmen on the various ponds, in like manner, would be prepared with their horſes, ſimilar to the operation with the ſtage-coaches; the boat, thus navigated, would arrive at London, or at Mancheſter, in about forty hours; of which the expence would be nearly as follows. Allowing one horſe to navigate a boat ten miles forwards, and ten back, in twenty-four hours, the horſe and driver may be eſtimated at ſix ſhillings, all caſualties included; which will amount to three ſhillings *per* boat for ten miles, and the total expence of ten miles will ſtand thus:

Three-

	£.	s.	d.
Three-pence per ton per mile to the company, -	0	10	0
Horfe and boatman, - - - -	0	3	0
Agency, - - - - -	0	0	2
Paffing machine, - - - -	0	0	2
Wear of the boat, - - - - -	0	0	2
For 10 miles, - - - -	0	13	6
For 220 ditto, - - - -	14	13	4

or 3l. 13s. 4d. per ton: what the carrier might expect for his trouble cannot be eftimated, but it is probable this mode would not amount to half of what is now paid to broad-wheeled waggons; the expence from London to Manchefter being about 8l. 10s. per ton*, and the faving in time would be near three days.

By the flow movement of the boats, every expence, except the horfe, will be the fame as the above; but by the flow movement a horfe would take forty tons twenty miles for fix fhillings, which is about three-pence halfpenny per boat for ten miles, thus the horfe-hire on a boat to London would be £. 0 6 5
But by the quick movement the horfe-hire is 3 6 0

2 19 7

which is 14s. 10¾d. per ton cheaper by the flow than the quick conveyance.

Thus feeing that difpatch may be produced by fmall boats, they may become the means of conveying paffengers, and paffage-boats rife to much national importance; a convenience for paffengers might be conftructed in a boat fuch as laft defcribed, or

* If the tonnage was fixed at two-pence the ton per mile, which would be good tonnage on a canal, the expence to London would be 2l. 15s. per ton, in which cafe there would be little doubt but the goods might be delivered for half the fum they now coft by waggons.

a boat

4

a boat might be built for the purpofe, fimilar to the Firft Figure in the Plate of Boats; which I fuppofe to be thirty feet long, four wide, and twenty feet in the centre for the accommodation of the paffengers. This fpace would give ample room to fifteen perfons, which fifteen perfons would not weigh one ton and a half on an average; confequently, fome repofitory fhould be conftructed for parcels, to endeavour to complete a cargo, and pay the boatman or proprietor.

I will now fuppofe fuch a paffage-boat to navigate from London to Manchefter. In this cafe, as the weights would differ in almoft every journey, in proportion to the number of paffengers, it would be proper to contract with the company at a certain fum *per* mile, loaded or empty; and, as the boat would feldom have more than two tons, fuch contract at 4*d.* *per* mile would, perhaps, be the beft encouragement to paffage-boats, and a fair toll to the company; if fo, the expence of fuch a boat to London would be as follows:

	£.	s.	d.
220 miles at 4*d.* *per* mile to the company, - -	3	13	4
Horfe hire, - - - - - -	3	6	0
Agency, at 22 machines, 2*d.* each, - - -		3	8
Paffing 22 machines, 2*d.* each, - - -		3	8
Wear of boat, - - - - - -		3	8
Total,	£. 7	10	4

So that fifteen paffengers, at 10*s.* each, would pay the expences; not to mention the carriage of parcels, which are very productive; I will therefore fuppofe every paffenger to pay 20*s.* that the

K proprietors

proprietors may be guarded againſt caſualties; yet 20*s.* would be a cheap conveyance for two hundred and twenty miles, and not one-third of the ſum which is now paid to the mail or ſtage coaches; while the expedition with which the boat may proceed, in conſequence of being ſmall, may be equal to the ſpeed of the ſtage coaches.

Thus we ſee that the ſmall boats, from being ſuited to a ſlow progreſs, or to the moſt expeditious conveyance, and being alſo governed by one regular ſyſtem, would produce numerous conveniencies, well calculated to draw conveyance of all kinds to ſuch canals.

But ſuch convenience never can be attained on the lock principle, for evident reaſons: ſmall boats cannot paſs locks ſufficiently quick; a man could not paſs one hundred feet lockage in leſs than one hour. But a four-ton boat may paſs a plane whoſe perpendicular is two hundred feet in four minutes; beſides the loſs of water would be ſo great in locking ſmall boats, as totally to exclude theſe quick movements; nor could the expedition be performed by a large boat, as the boat in itſelf is a load for the horſe in a quick movement; this, together with the delay of locks, would prevent large boats from reaching London from Mancheſter in leſs than nine days, by the uſual mode of navigating.

To the advantages enumerated, may alſo be added, the convenience of ſhort trips to market, or quick communication to and from the manufactories, in the environs of great trading towns. In all ſuch caſes, farmers, or manufacturers, may have their private boats, which they may diſpatch at pleaſure, with the

the facility of a cart, without waiting for an aſſocation of intereſts to compoſe a cargo, as in large boats; and thus the ſmall boats paſſing machinery are ſuited to the various kinds of trade, ſituations, and circumſtances; and have a direct tendency to draw almoſt the whole carriage of a country into the channels of canal conveyance.

 CHAP.

CHAP. VIII.

ON THE SAVING OF WATER.

EVERY one acquainted with canals, muft be fenfible of the importance of faving water, and many have been the expedients reforted to for this purpofe; locks being frequently conftructed of only four, or four and a half, feet rife, in order to leffen the confumption of this neceffary fluid; but fo fmall a rife, on the other hand, increafes the operations, and lofes fome time. Canal acts have alfo various reftrictions on boats paffing particuar locks, unlefs the water flows over certain weirs, on particular ponds*. The following calculations will therefore exhibit the proportions of water ufed at locks, and inclined planes.

A lock for a twenty-five ton boat is, ufually, eight feet rife, eighty feet long, feven feet fix inches wide; containing one hundred and thirty-three tons of water. A loaded boat, afcending, by preffing its weight (*boat and cargo thirty tons*) into the lower canal from the lock, will require one hundred and fixty-three tons of water to lock to the next afcending pond; while a loaded boat, defcending, will prefs her weight out of the lock into the upper pond, will ufe one hundred and three tons in defcending; hence the average is one hundred and thirty-three tons, ufed at every locking. Averaging empty boats in like manner, they will ufe alfo one hundred and thirty-three tons. To this it may be faid, that two boats will pafs with one lock of water; one up and one down; but this can only be the cafe when two boats fortunately meet at the fame lock in that precife order; but as this can be by no means common, it is not worth taking into account; I will therefore allow to every twenty-five tons cargo, *confidering empty and full boats*, one hundred and thirty-three tons of water, which, on a trade of five hundred tons *per* day, would amount to two thoufand fix hundred and fixty tons.

* Such reftrictions may be neceffary to fave water; but confidering canals on the broad fcale of national improvement, and individual convenience, it is much the fame, as if a cart fhould not pafs a turnpike without a certain load. If a boat muft exceed particular dimenfions and weight, before it can pafs fuch lock or locks, in feafons when water is fcarce, it is evident that boats under fuch dimenfions muft return, and their cargoes be transferred to the larger boats belonging to the canal fo reftricted, or be fent by fome other conveyance; which, in either cafe, is an interruption of free intercourfe: on the fmall boat principle, fuch reftrictions will be ufelefs; if one boat ftops, all muft ftop; wherever one can navigate, all can go; wherever canals extend, whatever may be their weights or their cargo, the ufe of water will be in proportion.

On the inclined plane the boats defcending pafs without water*, as before obferved; it is only the afcending boats which demand water to raife them; and they will have the advantage of a defcending boat, to affift in drawing them up: it may therefore be calculated that eight tons of water will raife four tons of cargo, four tons being allowed to enfure an ample weight for the purpofe, to overcome friction, and for the weight of the boat itfelf; hence, if eight tons of water are ufed to an afcending boat, and none to a defcending boat, the average is one ton of water to one of cargo: thus, in a trade of five hundred tons *per* day, five hundred tons of water will be ufed, which is not one-fifth part of the quantity

* The trifle to the firft boat, of about two tons, to raife her on the bridge of the plane, when one thoufand tons may pafs in rotation afterwards, may be confidered as no object.

quantity in demand for twenty-five ton boats, and locks; or one tenth part of water required in locks for forty-ton boats; independent of leakage at gates, which is very confiderable after fome years wear. This faving of water will confequently fave fome expence by the reduction of refervoirs, and materially facilitate all cafes of defcending trade from high countries; where the faving of water is an important confideration.

CHAP.

CHAP. IX.

DESCRIPTION OF THE SINGLE INCLINED PLANE, PLATE III.

THIS plane muft be conftructed in every refpect like one of the planes in the firft machine; alfo the pit, tub, and balance chains, fimilar; the drum-wheel about the fame diameter, and placed over the pit in the fame manner; the remainder of the apparatus varying from the firft machine, for the following reafons:

On this plane, the boats will both rife and defcend; therefore, there is two degrees of power required, and two portions of fpace to pafs through.

The firft, in raifing the boat out of the upper canal over the bridge of the plane, will not require fo much power or fpace as the fecond, in raifing her from the lower to the upper canal.

To effect this, A, in Fig. III. is a vertical wheel, eight feet diameter*, three or four feet broad on the face, on which the leading chain or rope is to lap; the fhaft of this wheel extending towards the drum, has two wheels of different diameters; two of different diameters are alfo on the drum fhaft: fuppofe the plane four hundred feet long, and the pit one hundred deep, the works

* In this, I fhall ufe round numbers, in order to tranfmit the idea with greater eafe; but the diameters of the wheels muft vary, in proportion as the boats pafs through more fpace than the water-tub.

muft

muſt multiply four times in order to raiſe the boat from the lower to the upper canal; hence let the drum be four feet diameter, B eight feet, C two feet; thus C, and the vertical wheel A, on the ſame ſhaft, will make four revolutions, while the drum performs one, and raiſe the boat four hundred feet while the tub deſcends one hundred.

Again, when the boat is to be raiſed out of the upper canal on the bridge of the plane, ſhe will move through a ſpace of about fifty feet, while the tub deſcends one hundred; thus the ſpeed is reverſed, the tub paſſing through more ſpace than the boat: for this purpoſe, let the diameter D be eight feet, and the diameter E two feet, *which is half the diameter of the drum*; and the vertical-wheel, A, will perform but one revolution while the drum makes two; and the tub will deſcend one hundred feet while the boat moves fifty, riſing out of the upper canal on the bridge of the plane; thus the two movements are produced by reverſing the diameters: and, to caſt them in and out of gear, C and D work on a round part of the ſhafts, and may turn round though the ſhaft ſtood ſtill, *which will be the caſe on the return of the water tub*; between the two there is a boſs, on the ſquare part of the ſhaft, which allows it to move from ſide to ſide, but cannot turn except with the ſhaft: when it is neceſſary C, and B, ſhould be in action for the quick movement, the boſs is caſt into C, by means of the lever, and D turns round on the ſhaft without confining the works; when the ſlow movement is to be performed, in raiſing the boat out of the upper canal, the boſs is caſt into D, and C is left at liberty; by this means, the teeth of the wheels are always in gear, and the boſs fixes that to the ſhaft which is to act, leaving the other to turn as the revolution of its opponent requires; the boſs will alſo leave

leave both wheels at liberty, as in the Drawing, which muſt be the caſe while the tub returns to the top of the pit.

For the purpoſe of raiſing the boat out of the upper canal, there is a roller placed beneath the vertical-wheel, as at F and G, Fig. II. round which the chain makes a double; in raiſing the boat to the upper canal, ſhe muſt be hooked at the ſtern, or lower end; and before the chain comes to a perpendicular, under the vertical-wheel, the boat will paſs the bridge of the plane and run into the upper canal, conveying with it the chain under the roller, at F, which repreſents the boat entering the upper canal.

On raiſing the boat out of the upper canal, ſhe is alſo hooked behind, as at G; the machine being then put into action, and the chain bearing on the roller G, will draw her over the bridge; when caſting off the water-tub, ſhe immediately begins to deſcend without further trouble, the movement being regulated either by a break or centrifugal fans.

At bottom, ſhe is unhooked, and a boat linked to the chain, the man at top caſting the boſs into C, draws water into the tub till a power is created; and the boat will riſe the plane, paſs the bridge, and run into the upper canal, the man caſting off the boſs on paſſing the bridge.

The whole of this operation may be performed in ſix minutes, conſequently, four tons up and four down, in ſix minutes, will amount to nine hundred and ſixty tons in twelve hours: ſhould the trade ſurpaſs this quantity, the machine may work by night, as mentioned of the firſt apparatus; conſequently, one thouſand nine hundred and twenty tons may be performed in twenty-four hours;

hours; which, I hope, exhibits the power of executing a very important trade at a single plane, even admitting the operation twice as long as here estimated; it is therefore well suited to lateral cuts, or such districts as produce about five hundred tons in twelve hours.

Estimate for a single Inclined Plane, one hundred Feet rise, the Plane on an angle of twenty Degrees, the Average of Situations being considered.

	£.	s.	d.
Removing 3000 cube yards in sloping the hill, at 5d. per yard, - - - -	62	10	0
Forming the ends of canal top and bottom, -	100	0	0
268 yards rubble walling at 5s. per yard, - -	67	0	0
134 yards squared ashlar coping, 18 inches thick, 3 feet long, at 15s. the lineal yard, - -	100	10	0
268 yards cast-iron rails, 100 cwt. per yard, 15s. per cwt. - - - - -	201	0	0
Bedding the rails in the coping, lead and pins, at 2s. per yard, - - -	26	6	0
60 Rollers to bear the chains of the plane 5s. each, -	15	0	0
1 vertical wheel, 8 feet diameter, - - -	50	0	0
400 feet chain, 2s. per foot, - - - -	40	0	0
34 yards tub pit, 11 feet diameter, 4l. 10s. per yard,	153	0	0
110 yards sough, at 12s. per yard, - - -	66	0	0
1 wrought-iron tub, - - - - -	60	0	0
700 feet chain to the tub, balance, and weight, at 4s. per foot, - - - - -	140	0	0
Drum-wheel, 8 feet long, 4 diameter, spur-gear, &c.	100	0	0
Carried over, £.	1,181	6	0

Pinions,

	£.	s.	d.
Brought over, £.	1,181	6	0
Pinions, boss, and wheels, - - - -	60	0	0
Centrifugal fans, or break, - - - -	40	0	0
Trough to conduct the water to the pit, - -	10	0	0
Building to cover and support the works, - -	100	0	0
	1,391	6	0
Contingencies, 10 per cent. - - -	139	0	0
Total, £.	1,530	6	0

	£.	s.	d.
Locks for 25 ton boats, 100 feet rise, -	7,000	0	0
Single inclined plane to the same height, - -	1,530	6	0
Saving, - - - - - - £.	5,469	14	0

	£.	s.	d.
Locks for 40 ton boats, 100 feet rise, - -	10,000	0	0
Single inclined plane to the same height, -	1,530	6	0
Saving, - - - - - £.	8,469	14	0

 CHAP.

CHAP. X.

DESCRIPTION OF THE MEDIUM PLANE FOR A SMALL ASCENT, BEING A MEDIUM BETWEEN LOCKS AND PLANES. (PLATE IV.)

IN purfuing the fmall canal fyftem, long floping grounds will fometimes intervene, where it would be impoffible to obtain a rife of fufficient importance to erect the whole of either of the machines before defcribed, as a building, wheels, &c. would be the fame to a twenty as a two hundred feet afcent; the expence would confequently increafe on the works, and the number of enginemen would add to the expence of conveyance.

Nor would it be fyftematic or advifeable to ufe locks in fuch fituations, although the lock might be fo conftructed as to take in ten boats at a time, five in length and two in breadth; yet the man feparating his line of boats in the centre, and placing them fide by fide to pafs the lock, then forming the line, and again fide by fide to pafs the next lock, and fo on, when he could rife or defcend but eight feet by fuch operation, would be a tedious work.

Or if two or three boats only were to pafs at a time, the wafte of water would be fo great as might produce reftrictions on paffing a fmall number in dry feafons, as before obferved of canals on the lock principle, which would confequently be an interruption of free intercourfe; nor could the quick trade, which I have propofed, be conducted with facility by fuch means.

The

The medium will therefore exhibit the mode of mounting from twenty to thirty feet at one time, which are heights that can be obtained in any country, and probably one or two may rife, fufficient to extend a pond to fuch fituation as will produce a plane of one or two hundred feet perpendicular.

In forming this I will fuppofe a rife of twenty feet, where a fingle plane, on an angle of about twenty degrees, is to be extended from one pond to the other; alfo fixty feet of fuch plane paffing into each canal, turned hollow on entering the lower pond, and bridged on turning into the upper level. On the top and near the centre of the bridge a ftrong framing is to be conftructed, croffing the plane, in which a roller is placed fimilar to that under the vertical wheel in the laft machine, and for the fame purpofe; two pulleys are alfo fixed to the frame in order to guide the leading chains over the centre of the plain.

A water-wheel muft then be erected near the fide of the plain to create the neceffary power *(fee the Ground Plan)*, on the fhaft of which a pinion working in a wheel will put a roller or drum in motion, on which the leading chains are to lap, which roller may be caft in and out of gear by a lever; three hundred and fifty feet of chain muft then be fixed to the roller, and pafs through the pulleys over the plane.

I will now fuppofe ten or any lefs number of boats ready to defcend at one operation; the leading chain, making a double under the roller, is hooked to the ftern of the third boat; and the wheel being put in motion it will draw the three firft boats over the bridge of the plane, the other feven following: the three boats being now on the fharp angle will have power fufficient to draw

out

out the remainder; the water is then ftopped from the wheel, and the chain ftill continuing hooked to the boat, they will begin to defcend in regular rotation; the chain, defcending with the boats, will turn the water-wheel backwards and anfwer as a break to regulate the velocity. On a man arriving at a plane the whole operation is to hook the chain to the third boat, if there are three, or to the ftern of one, if there is no more, and fet the wheel in motion; on that boat to which the chain is hooked, mounting the bridge, the water is ftopped from the wheel, and the whole line of boats begin immediately to defcend into the lower canal; during which the man attends to the break, and the time in performing this operation, I conceive, will be as follows:

	Minutes.
Hooking the leading chain, - - - - -	3
Drawing the firft boat out with the wheel, - -	1
Defcending the plane, - - - -	1
Unhooking the leading chain and applying the horfe, -	2
	7

Hence, in a defcending trade, forty tons may pafs in feven minutes.

In afcending, the fpeed will confequently be in proportion to the power of the water-wheel; it will therefore be advifeable to give power to the wheel in order to fave time; in rifing there will be three boats out of water on the plane at a time, the plane out of water being fixty feet long; the boats and their cargoes will weigh about feventeen tons, this, on a plane of twenty degrees, will be a refiftance of about five tons, friction confidered, perhaps fix tons; to raife this if I fuppofe an overfall wheel fifteen feet diameter, and the roller

roller on which the chain laps one foot and a quarter, or to that effect, by tooth on pinion, the power will increafe as one to twelve, and one ton actual purchafe on the wheel will raife twelve on the plane; the wheel fhould therefore be conftructed to give one and a half tons purchafe, or nearly fo; and, for this purpofe, fhould hold about two tons of water; fuch a wheel would perform twelve revolutions in one minute, and draw the boats forty-five feet up the plane in that time, or two hundred and feventy feet in fix minutes, by which they would enter the upper canal.

To perform this operation, the leading chain is continued over the ten boats in the lower canal, and hooked to the ftern of the laft boat; the hook of each boat is alfo fixed in a link of the chain; thus the ten chains, being hooked to the leading chain, the wheel is put in motion, and the whole moving forwards afcend the plane, cafting off from the leading chain as they pafs the bridge, and run into the upper canal, where they are immediately ready for navigation: the whole of this afcending operation may be performed in ten minutes, the defcending boats being paffed in feven, the average may be eftimated nine minutes; hence, forty tons paffing in nine minutes, three thoufand two hundred may be transferred in twelve hours.

By the before calculation on the water-wheel, in which a very fufficient power is allowed to raife forty tons of cargo, twenty feet would require, - - - 288 tons water.
In forty tons defcending - - - 48 tons do.

336

This

This will average one hundred and sixty-eight tons of water to forty of cargo, one, two, or more, boats uſing water in proportion; but a lock to raiſe forty tons would require about two hundred and ſixty-ſix tons; hence there is ſome water ſaved. It is alſo probable, that theſe machines will be conſtructed on the lower ponds, where water will not be ſo important, the ſupply being obtained with greater eaſe; the following will exhibit the expence of conſtructing ſuch an apparatus:

Eſtimate for a Medium Twenty Feet Riſe.

	£.	s.	d.
180 feet plane, 1l. 10s. per foot, - - -	270	0	0
Water-wheel, - - - - -	100	0	0
Drum-wheel, and pinion, - - -	40	0	0
350 feet chain, at 4s. per foot, - - -	70	0	0
Wheel leet, - - - - - -	60	0	0
Trough, - - - - - -	10	0	0
Two large Pulleys - - - -	2	0	0
Timber and workmanſhip, - - -	60	0	0
	612	0	0
Contingencies 10 per cent. - - -	61	4	0
Total,	£. 673	16	0

Locks for 25 ton boats, twenty feet riſe, -	1,400	0	0
Medium, - - - - - -	673	4	0
Saving, - - - - - -	£. 726	16	0

 Locks

Locks for 40 ton boats, 20 feet riſe, - -	£. 2,000	0	0
Medium, - - - - - -	673	4	0
Saving, - - - - -	1,326	16	0

This machine harmonizes the whole ſyſtem of ſmall canals, and fits them to every ſituation *(where water can be found)*, and preſerves regularity.

CHAP. XI.

OF CONSTRUCTING AQUEDUCTS.

HAVING exhibited the mode of paſſing the boats to and from the different ponds of canal, and ſhewn the great difference in expence between the method deſcribed, and locks; the next conſideration of the moſt importance, in proſecuting navigations, is the expence of conſtructing AQUEDUCTS.

In ſeeking to extend the benefit of water-carriage, and paſs to certain towns or diſtricts by the neareſt rout, wide and deep valleys will frequently preſent their extenſive chaſms, and ſeem to exclude connection; which, on the lock principle, would, in numerous inſtances, be the caſe; for if I ſuppoſe a valley two hundred feet deep, and ſix hundred yards wide, what country could produce a trade to pay for an aqueduct in ſuch a ſituation? That there are an infinite number of ſimilar ſituations, where it would be deſirable to paſs in order to open a near communication, I conceive no one will deny; and in ſuch a ſituation, 200,000l. would not pay the expence of an aqueduct. To lock down and up would be almoſt equally difficult, conſidering waſte of water and loſs of time; and, if practicable, to go by a circuitous rout, the diſtance might to be ſo great as raiſe the material to the expence of land-carriage: conſequently, the happy effect of a water intercourſe between ſuch diſtricts, could never be experienced on the lock ſyſtem. But, to ſurmount theſe difficulties, and open an eaſy communication, ſee Plate VI. repreſenting the CONJUNCTION.

This

This is ſimply two ſingle inclined planes in conjunction, expanding from hill to hill, and binding the two countries in the bonds of reciprocity.

Each plane extending down the ſide of the hill, they are united at bottom by a double plane, in the form of a long oval, on which the boats paſs each other. *See the Ground Plan.* On the ends of the oval, there are guides working on a bolt, which move from ſide to ſide of the plane alternately, as the boats paſs, which prevents the two boats ever landing on one plane, or interrupting the paſſage of each other.

In this the operation at top is exactly the ſame as the ſingle inclined plane; but at bottom a man is placed where the boats are to paſs; and on each engine letting down a boat, the man at bottom removes the chain from one boat to the other, and giving the ſignal to the men above, each draws up his opponent's boat; thus they are transferred acroſs the valley to the different ponds of canal.

In performing the operation on the ſingle plane, ſix minutes is allowed to paſs two boats, one down and one up; in doing this, the time will not be much more; for each man at top working at the ſame time the ſame operation, the two boats will be moving down the planes towards the centre at the ſame time, where the man can transfer the chains in nearly the ſame time that he could hook a boat; but as they may not all work regularly at the ſame time, I will allow eight minutes to each operation, amounting to one ton per minute, or ſeven hundred and twenty in twelve hours, or one thouſand four hundred and forty in twenty-four hours; a quantity ſufficient to ſhew, that if each

operation

operation was much longer than here eftimated, yet a very important trade may be performed.

In the eftimate of expences, each man letting down and raifing a boat for threepence*; and the man at bottom transferring the chains for threepence on two boats, would amount to one penny and a fraction per ton; but confidering empty with full boats, I will allow one penny halfpenny per ton for paffing this apparatus, which I conceive adequate to every contingency; and the following will exhibit the probable expence of conftructing the machine.

Eftimate for a Conjunction Two Hundred Feet high, Six Hundred Yards in Width.

First Half.	£.	s.	d.
380 yards inclined plane, 4l. 10s. per yard, -	1,710	0	0
67 yards tub pit, 4l. 15s. per yard, - -	318	0	0
320 yards fough, 15s. per yard, - - -	240	0	0
Vertical-wheel, - - - - - -	50	0	0
1,000 feet chain, at 2s. per foot, - -	100	0	0
Wrought-iron tub, - - - - -	60	0	0
1,400 feet tub and balance chains, at 4s. per foot,	280	0	0
Drum-wheel, - - - - -	100	0	0
Pinions, bofs, and levers, - - - -	60	0	0
Carried over,	£. 2,918	0	0

* Threepence for two boats I confider fufficient wages, when it is confidered a man will pafs forty boats, amounting to 5s. in five hours and twenty minutes; hence, in working twelve hours, in a brifk trade, he might earn 11s. 10d. halfpenny, a fum fufficient to fupport different fets of men.

Brought

	£.	s.	d.
Brought over,	£. 2,918	0	0
Centrifugal fans, - - - - -	60	0	0
Building and timber to fupport the works, -	200	0	0
	3,178	0	0
Second Half, - - - -	3,178	0	0
	6,356	0	0
In the paffing place, 60 yards plane, 4l. 10s. per yard,	270	0	0
Culvert or bridge, - - - - -	200	0	0
	6,826	0	0
Contingencies 10 per cent. - - - -	682	10	0
Total,	£. 7,508	10	0

As the whole water ufed in raifing the boats will defcend to the valley, and be loft from the canal, it will amount, on a trade of five hundred tons per day, to about two thoufand tons wafte, equal to about eight lockings for forty-ton boats, which paffing from the upper ponds of canal, where water is fcarce, to the lower, where it is of little importance, water being there more abundant from various fources, *is fimilar to the above wafte.*

In conftructing the conjunction, there is alfo the advantage of gaining height; one plane may rife higher than the other if neceffary, and thus gain any number of feet which the ground will admit of, yet perform the transfer with the fame facility; and if one pond muft be replenifhed with water from the other, a pipe may be laid along the fide of the planes for that purpofe.

Having

Having exhibited the difficulties which may be overcome by this machine; I hope criticifm will pardon my attempting to difplay the advantages which will accrue, if I eftimate the probable expence of a canal without feeing the ground.

But fuppofe it neceffary to fupply a town with the very neceffary article of coal, the works diftant ten miles with fuch a valley, and two hundred feet rife intervening; in this, which is rather a difficult fituation, the expence would probably be as follows:

	£.	s	d.
Conftructing the conjunction, - - -	7,508	10	0
Two fingle inclined planes, 100 feet rife each, -	3,056	6	0
Refervoir, - - - - - -	3,000	0	0
Land, 5 acres per mile, 100 l. per acre, -	5,000	0	0
Cutting. planting quick, &c. 500l. per mile, -	5,000	0	0
Bridges and culverts, 300l. per mile, - -	3,000	0	0
	26,564	16	0
Contingencies, act of Parliament, &c. - -	2,656	9	7
	£. 29,221	5	7
The intereft of 29,221l. 5s. 7d. at 5 per cent. per ann. - - - -	1,461	1	3
On this canal, 50 tons per day, allowing 280 working days, and 3d. per ton per mile, would produce, per annum, - - -	1,750	0	0
Which, after paying the fubfcribers 5 per cent. leaves for agency and repairs, - -	£. 288	18	9

Thus,

Thus, on a trade of no more than fifty tons per day, the fubfcribers would have a fair profpect of receiving 5 per cent: And although threepence per mile may appear high tonnage for coals, yet they arrive at town for the following fum per ton, carriage:

	s.	d.
Threepence per ton per mile to the company, -	2	6
Paffing two inclined planes, - - - -	0	2
Paffing the conjunction, - - - - -	0	1½
Boatman 6s. 8d. per day, or to that amount, - conveying 10 loaded, and returning 10 empty, boats in one day, - - - -	0	2
Total per ton for ten miles, - - -	2	11½
Which could not be conveyed by land for lefs than	7	6
Hence a faving to the inhabitants per ton, -	4	6½

Which might produce a further faving as the trade increafed; in which cafe the tonnage fhould be lowered: when one hundred tons per day is performed, and the company receive more than 10 per cent. the tonnage by the act fhould be reduced, on rude produce, to 2d. per mile.

When one hundred and fifty tons per day is performed, and the company receive more than 15 per cent. the tonnage or rude produce fhould be three halfpence per mile, but never lower by the act; competition among canals will regulate the carriage of courfe, and competition will be a benefit to the county. It is therefore good policy in Parliament, to allow ample tonnage, that fubfcribers may have a profpect of a return on a fmall trade,

7 which

which will be an encouragement to ſpeculators; the reduction of tonnage on rude produce to be governed by the returns; but on merchandiſe, to ſtipulate for a certain ſum, which the proprietors might reduce as policy dictates. And thus canals will be extended in every direction, in conſequence of the beſt of all encouragement, that of receiving a fair intereſt on a ſmall trade; and the proſpect of this intereſt increaſing to a very important return of wealth from a ſmall capital.

CHAP.

C H A P. XII.

THE MODE OF CROSSING RIVERS AND GAINING HEIGHT AT THE SAME TIME, PERFORMING THE DOUBLE OPERATION OF AN AQUEDUCT AND LOCKS. (PLATE VII.)

THIS apparatus is the double-inclined plane in all its parts, either for a deſcending or alternate trade; the ſtone piers ſupporting iron rails which compoſe the plane.

It would be difficult to draw the exact difference, in expence, between this machine and an aqueduct to croſs a river, than locks to gain height; but if the immenſe labour in conſtructing an extenſive and high aqueduct is conſidered, I conceive the ſaving will be found very important. The great quantities of ſtone *(which ſhould be of a good quality)*, hewn to certain ſquares and templets; the frequent long carriage, the timber for centres, and the various preparatory works, all tend to load aqueducts with heavy expences, and render them one of the greateſt obſtacles in proſecuting canals.

If I ſuppoſe it neceſſary to carry a canal one hundred feet high *, and three hundred feet in length, over a river, it is a moderate calculation, conſidering the average of ſituations, to eſtimate it at the

round ſum of - - - -	£20,000
To which add one hundred feet lockage for twenty-five ton boats, - - - -	7,000
Amounting to - - - - -	£. 27,000

* There are ſome aqueducts in contemplation of greater dimenſions than here ſpecified.

Yet

Yet a ſimilar ſituation may be croſſed, and the height gained, in one movement, as appears by calculation, for about 8,000l.; conſequently 19,000l. is ſaved, which is almoſt the whole expence of the aqueduct.

Without entering into tedious eſtimates to prove this, I conceive the common ſenſe of thoſe who have the leaſt knowledge of the ſubject, will inform them of the reaſon of theſe ſavings; but to the ſpeculating reader, if he obſerves by the plate that the part croſſing the river is a ſimple ſtage, the weight of which, compared with the load of water and ſtone which preſs on the piers of an aqueduct, is trifling; conſequently the piers are but as columns without arches, and the maſonry, which in aqueducts is almoſt the whole expence, is here ſo contracted as to be, comparatively, ſcarce worth mentioning; iron arches or braces being adopted, the expence of which is not more than the centres to build an arch of ſtone, and the continued plane performing the part of locks, of which he has had a comparative view, I conceive it will exhibit the obvious reaſon of ſuch important ſavings.

This combination is indeed ſo material, that, in projecting a line of canal where a river or deep valley is to be croſſed, it ſhould be well conſidered, whether it can conveniently be brought to ſuch a ſituation that the ground will admit of riſing at the time of croſſing; which, even on the ſmall ſyſtem, will ſave time and expence.

CHAP.

CHAP. XIII.

PLATE VIII. repreſents the parallel plane for ſuch ſituations where height cannot be obtained; it is to extend acroſs the river, or valley, and deſcends about ſixty feet into each canal.

On each end, and over the canal, a horizontal wheel is placed, to one of which is fixed the whole machinery, *except the preparer and ſtopper*, of the double-inclined plane; the chains performing the rotatory movement.

To paſs the boats, one is hooked to each chain; after which, water being drawn into the tub till a power is created, the boats will riſe on the plane, paſſing to the different ponds of canal, and ſo on, in regular rotation.

This is the moſt expeditious of all the machines: the man having little more to do than hook the boats to the chains, and draw water into the tub; the caſt off hooks acting as in the double plane. In this the water to paſs the boats deſcends to the river, or valley, and is loſt to the canal; but as this plane is level, the reſiſtance will not be great; in proportion as the length of the plane is to the depth of the pit, water will be required; but averaging ſituations, one ton of water will paſs one of cargo: while its expence, conſidering the various ſituations and circumſtances, will be about one third the ſum neceſſary to an aqueduct.

But although rivers, or valleys, may be paſſed with eaſe by the three modes deſcribed, yet, in many inſtances, it will be adviſeable

N 2 to

to conſtruct aqueducts, particularly where there is no great difficulties to encounter; which aqueducts may be formed of iron, *as in Plate* XIII. averaging the ſituations, much cheaper than of ſtone.

But the deciſion on the erecting of an aqueduct, or its particular conſtruction, muſt depend on a variety of circumſtances; ſuch as, the ſupply of water, ſaving of time, carriage of ſtone, or iron, &c. &c. adopting that mode which will on inveſtigation produce the greateſt ſaving, yet anſwer the intended purpoſe.

CHAP.

CHAP. XIV.

ON PERPENDICULAR LIFTS TO PASS BOATS.

ALTHOUGH I have already explained the mode of paſſing the boats, which, I conceive, will be productive of ſyſtematic navigation, and ought to be univerſally adopted till a better is diſcovered; yet the four following Plates will exhibit machines for transferring the boat by perpendicular lift. Theſe machines were originally intended for ſmall canals, as lateral cuts from thoſe of greater dimenſions, in order to extend into ſuch diſtricts as could produce from fifty to four hundred tons per day; principally to convey manure and fuel, and thereby relieve the country by a medium carriage, between the large canals and cartage.

This, for a long time, was the extent of my thoughts; the idea of an univerſal ſyſtem did not ariſe, till I diſcovered the great ſaving which would be produced by ſuch lateral cuts. I then wiſhed to render the canal equal to a trade of more than four hundred tons per day, and capable of performing the work of a large canal; in which, there was nothing wanting but an improvement in the machinery to produce expedition; but this baffled every experiment for ſome months. At length the rotatory movement, and boats with wheels, occurred; and they exhibited the power of paſſing valleys. On revolving the thought, I found it would anſwer the purpoſe, by performing the moſt important trade, producing ſyſtem, and ſimplifying the machinery: it has conſequently raiſed ſmall canals (*in my opinion*) from lateral cuts, to the moſt extenſive and important communications.

CHAP.

CHAP. XV.

DESCRIPTION OF THE PERPENDICULAR LIFT, PLATE IX AND X.

IN conftructing this apparatus, the canal being run to fuch a point of a hill as will admit of a quick rife; the hill, if fteep, may be laid open, as in the Plate, or have two pits funk equal in depth to the difference between the levels of the two canals; one of the pits of an oval form, and fufficiently large to fuffer a boat twenty feet long, four feet fix wide, to pafs through; the other, eleven feet diameter, for a preponderating tub. The two to be united to the canal by a tunnel.

Having formed the tunnel and pits, two cranes are to be conftructed, each fifteen feet high, capable of bearing three tons each, which muft be placed on the fide of the upper canal, and oppofite the junction of the canal and pit, as in Plate X.

Thofe cranes muft ftand twelve feet apart from gudgeon to gudgeon, and their gibs to be united by a lever, alfo twelve feet long, as at A in Plate X.; by this means, the cranes will ever move parallel to each other, and keep their chains equi-diftant.

Behind the cranes, and over the pit C, there is a drum-wheel of two diameters; to the largeft the crane chains are faftened, and thofe of the tub to the fmall diameter; to the crane-chains a cage of iron is fixed to receive the boat; thus fufpended, the cage and tub will move alternately between the fummit and lower canals.

2 For

For the purpofe of raifing the boat out of the upper canal, in order to move her over the pit previous to defcending, there is a refervoir, D, formed in the fide of the tub-pit near the bottom, *Fig.* 3. *Plate* 10, and of a fize to contain about thirty tons of water: at the time the cage is in the upper canal, the tub will be beneath this refervoir, from which water muft be drawn into the tub till a preponderating power is created; the tub will then defcend about eight feet, raifing the cage and boat out of the upper canal. The cranes are then moved over the pit, and a portion of water difcharged from the tub, till the boat preponderates; which, defcending to the lower canal, will raife the tub to near the upper level, in the fituation exhibited in the third Figure; where a valve opening, by means of the lever at E, the water from the tub paffes into a pipe, and defcends to the refervoir, *in order to raife the next boat out of the upper canal*, leaving the boat to float in the lower pond.

To raife a boat from the lower pond, and pafs her into the upper canal, water muft be drawn from the upper canal into the tub by the pipe F, till a preponderating power is created; which defcending, will raife the boat about one foot above the upper pond; the cranes are then turned over the canal, and the water being difcharged from the tub, the boat will immediately float in the upper level.

To regulate the movement of this machine, the centrifugal fans are applied, as reprefented in Plate IX. Alfo the balance chains to the tub, as in Plate X. Fig. III.

The

The operation of this machine is eaſily performed, and a four-ton boat may be transferred through a ſpace of one hundred feet high, in eight minutes, or three hundred and ſixty tons in twelve hours.

The expence of conſtructing one hundred foot lift, averaging the ſituations, will be about 2,500l.

CHAP.

CHAP. XVI.

DESCRIPTION OF PLATE XI.

EXHIBITING a machine for a deſcending trade, in which the whole of the water is ſaved, while the trade deſcends; yet ſhould it be found neceſſary, by a further extenſion of the canal, to form the apparatus for an alternate trade, the water tubs may be applied.

In the firſt caſe of a deſcending trade, there is but one pit, which muſt be thirty feet diameter, a capacity ſufficient to ſuffer two boats to paſs; over the pit a building muſt be erected, to cover and ſupport the works; in the centre of which a drum-wheel of one diameter is placed. On each ſide of the drum, two chains and a cage to receive the boat is ſuſpended; which cage will move alternately between the upper and lower canals; on the end of the upper canal, and on the ſide of the pit, there are two gates, balanced ſo as to riſe perpendicular, as at A and B; and oppoſite the gates, parallel to the canal, two lock-carriages, C and D, worked by rack and pinion, moving on iron rails; which carriages are conſtructed with one end open, and of a ſize to receive the cage and boat.

When the lock-carriage is moved forwards, it fits cloſe to the end of canal in a groove; and the gate being opened, the water of the canal fills the carriage; which enables the man to float his boat in the cage; after which, the gate being ſhut, and a valve opened in the hind part of the carriage, below C D, to difcharge the water, the carriage is run back and leaves the boat fufpended over the pit; during this operation, the man below having placed an empty boat in the lower cage, the two boats are now ready to pafs; the loaded one defcending, raifing that which is empty; and at the fame time, by a crank movement taken off the end of the drum, three pumps are put in motion; and they raife the water, which was difcharged from the lock-carriage, *into a fide pond*, about twelve feet high, into the upper canal; by which the whole is faved. The empty boat having afcended, the fecond lock-carriage is run forward, and the gate of the canal being opened, the water filling the carriage, will float the boat into the upper canal; another for the purpofe of defcending, is then moved into the cage, and fo on alternately.

To regulate this machine, the centrifugal fans are applied, as in the other apparatus; but the balance-chains will be of no confequence, as the loaded boat defcending will be fufficient to raife the weight of pendent chain, if the depth is not more than one hundred feet, alfo work the pumps and raife the empty boat; four tons defcending would alfo raife three, by cafting the pumps out of gear, by the lever E, fo that fome alternate trade might be performed.

But fhould future extenfion produce an alternate trade, the pits and tubs may be added to this apparatus, converting it to a double machine; for a return trade, this machine would transfer two boats in about eight minutes; confequently, in the defcending trade, about three hundred and fixty tons might defcend, returning the empty boats, in twelve hours. In the alternate trade, twice the

the above quantity would be performed by raifing loaded boats at the feveral movements.

Its expence for the defcending trade, one hundred feet deep, about, - - - - -	£. 2,500	0	0
For the alternate trade, - - -	3,500	0	0
	6,000	0	0

Which is about half the expence of locks.

 CHAP.

CHAP. XVII.

DESCRIPTION OF PLATE XII. REPRESENTING THE SECOND MODE OF PASSING THE ALTERNATE TRADE BY A PERPENDICULAR LIFT.

IN conſtructing this machine, the tunnel and two pits are ſimilar to the firſt lift, and the drum-wheel of two diameters, which muſt be ſo placed, that one ſide may be over the centre of the pit; the cage chains being fixed to the large, and the tub to the ſmall diameter.

One gate muſt then be placed on the end of the upper canal, as in the laſt machine; alſo one lock-carriage, moving parallel to the canal.

On the ſide of the machine, and below the hind end of the lock-carriage, a ſmall pond is formed to receive the water diſcharged from the lock-carriage; which water is afterwards drawn into the tub, to create the preponderating power, and anſwer the double purpoſe of floating the boat into the cage, and then raiſing one from the bottom to the top canal.

To regulate the movement of this machine, the centrifugal fans are applied, as before deſcribed.

The expence of one hundred feet riſe, about 2,500 l. and the execution near three hundred and ſixty tons in twelve hours.

In theſe three machines, the quantity eſtimated being the work of twelve hours, it conſequently may be doubled by working at night; which, I hope, exhibits that lateral cuts might have been extended to great advantage by theſe machines.

CHAP. XVIII.

OF CAST-IRON RAIL ROADS.

RAIL-ROADS have hitherto been conſtructed as a medium between lock-canals and cartage; in conſequence of the expence of extending the canal to the particular works in its neighbourhood.

But as the ſmall boats ſo materially reduce the expence of canals, they come nearer to the expence of rail-roads, with which they muſt now be compared. The uſual eſtimate of rail-roads is about 1,600 l. per mile, which are ſingle, with paſſing places, and only calculated for a deſcending trade; the whole being formed of a gradual deſcent from the works to the canal; generally ſo calculated, that a horſe may return the empty waggons with the ſame eaſe the full ones deſcend; on theſe the average work is about five tons to a horſe, deſcending at the rate of three miles per hour, or one ton aſcending, at near the ſame ſpeed; on which the wear of waggons is very conſiderable; which wear muſt generally fall on the company; while the loading into waggons, then unloading at the canal, where there is uſually a depoſit for want of boats, and again, loading into boats, tends to increaſe the expence of conveyance, and injure the various articles.

There can no idea be formed of the expence of a canal compared with a rail-road, without being acquainted with the circumſtances; but theſe ſhould be well conſidered before a rail-way is laid down; and the canal ſhould conſiderably ſurpaſs the expence of the rail-road, *particularly if the length is greater than two miles,*

miles, in order to induce fubfcribers to relinquifh it for a rail-way; and my reafons are, that when a rail-way is laid down, it excludes, in a great meafure, the return trade, and fhuts out the profpect of extenfion; the county, beyond its extremity, has no more hope of affiftance, than before its conftruction; nor will any company unite with it; for if it is added to, the difficulties increafe, as paffing places are inadequate to an important trade; confequently, it would be neceffary to form them double, increafing the expence and repairs; without the power of raifing fuccours to the high and interior country.

Yet the fmall canal is fufficiently wide to pafs at every part, and transfers a trade with equal eafe; meandering the hills, it holds out affiftance to the fun-burnt fields, and feems to invite connection: In a country, through which a rail-way or canal is conftructed, there is fome hope of progreffive improvement and future extenfion; which ultimately brings this enquiry to two queftions: Whether do canals, or rail-ways, prefent the beft profpect of extenfion? And, Which will moft facilitate conveyance by a union of branches?

It is therefore prudent to confider well the various circumftances, before a rail-way, of even one mile in length, is laid down.

Rail-ways of one mile, or thereabouts, will no doubt be frequently neceffary, where it may be difficult to find water at the extremity; or when the trade from the works is not fufficient to pay the expence of machinery, and its extent being but one mile, can be of little importance to the country.

But

But to bring thefe fhort fpaces into the general fyftem as much as poffible, fee D, in the Plate of Parts: which reprefents the apparatus for returning the empty boats to the colleries, or other works, in cafes where a regular defcent can be obtained. Suppofe, for inftance, fuch works diftant fix hundred, or perhaps, more yards, a fingle rail-way may be conftructed; on the fummit of which the apparatus D is formed; and a carriage being conftructed to receive the boat, the leading rope laps round the vertical wheel F; which wheel works by a multiplied movement in the wheel of the fhaft G, to which a weight is fufpended; on a loaded boat defcending the rail-road, its power will wind up the weight; which weight is kept up by a ftopper on the wheel, and is a power in referve to draw up an empty boat; hence, when a loaded boat defcends, it winds up the weight, and on entering the canal, the fhaft of F and G are caft out of gear, which fuffers the carriage to defcend fufficiently to allow the boat to float: an empty boat is then placed in this carriage; and the ftopper being caft off the wheel on the G fhaft, the defcending weight will raife the empty boat; the movement being regulated by a break, on the fhaft of F there are two pinions of different diameters, which are, that the wheel F performs more revolutions in a boat afcending than defcending. When the boat defcends, raifing the weight, fhe lofes her power on entering the canal; confequently, the pinions muft be caft out of gear in order to give more length of rope for the carriage to defcend, and allow the boat to float; therefore, the portion of rope thus let off, muft be wound up by the power of the weight, on returning the empty boat; which is done by cafting the fmall diameter into gear. In the return movement, this mode of working will be found a very confiderable faving to the proprietor, in confequence of a fingle plane and rope anfwering the purpofe; and, in order that the plane may

be

be conſtructed cheap, a carriage to receive the boat ſhould be made; the carriage to have from ten to twenty ſmall wheels, which will divide the weight on ſo many points, and eaſe the plane; conſequently the rails may be light and cheap.

But where the nature of the ground will not admit of a regular plane, or the diſtance is too great, the boats may float on a carriage for the purpoſe, with ſix or eight wheels, and be conveyed to the pits or delphs by a horſe; there take in her cargo, and deſcending to the canal, be immediately ready for navigation.

The reader, by reverting to the various operations theſe ſmall boats paſs through; many of which, *where the trade is great*, muſt be performed with the utmoſt expedition, from which the greateſt part of the numerous advantages ariſe, I hope, will now ſee the neceſſity of their wheels; which, like a boat and waggon combined, has, in a great meaſure, the properties of both: or, like an amphibious animal, the double advantage of living in two elements. Therefore, if it is neceſſary to give them a name, in order to diſcriminate from other boats; *as ſmall boats* do not divide the idea, in ſpeaking of them, I have thought *Beavers* might be applicable.

CHAP.

CHAP. XIX.

ON CONCLUSION OF THE SMALL CANAL SYSTEM.

HAVING exhibited the various machines for transferring the ſmall boats, and gone through the operations, in which I have endeavoured impartially to preſent the fair comparative view of the general effect of large and ſmall boats; I ſhall now take a ſummary review of the whole proceſs, the object in view, and the effect which ought to be produced by canals.

Firſt, in the true ſenſe of national improvement, to facilitate agriculture and merchandize, the whole ponderous carriage of a kingdom ſhould, *as much as poſſible*, be conveyed by canals, thus reducing expence, opening eaſy communications, exchanging the produce of one diſtrict for another, improving the country, reducing the number of horſes, rendering manual labour more productive, and ſpreading with greater regularity the comforts of life. Hence there ſhould be a power of extending canals into every diſtrict, in order to draw from every ſource; but it is evident this can only be done by portioning the expence of the canal to the trade.

Yet, however deſirable this may be, it cannot poſſibly be performed by lock canals; locks load a canal with certain and heavy expences which deſcend to one point, *for twenty-five ton boats*, below which there is no reduction, whatever the trade may chance to be: every country, therefore, which cannot produce a trade equal to thoſe heavy expences, muſt be ſhut out from the benefit of water-carriage, and this is by much the greater part of the kingdom.

P Wherever

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

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

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 difcuffion may be conftrued into felf-importance in me, by oppofing my opinion to all others: but be that as it may, I deem it indifpenfably neceffary in all improvements of a public nature.

A man, unthinking, may turn up a tuft of earth, and find a vein of gold, which intereft will urge him to purfue: I, by chance, ftumbled on this fubject, by turning over a news-paper, or, in all propability, I fhould never have thought of canals. I mention this to fhew, that I do not arrogate to myfelf a great deal of the ingredient which is called Genius; but that fome of the moft ufeful difcoveries is the produce of accident. I found the fubject interefting, and I have had the pleafure, in profecuting it, to find it worth purfuing. It has alfo been fome fatisfaction, that it appears of national importance: and, as I conceive, I have now removed the principal part of the rubbifh *(except one ftrong ftrata of prejudice)*, and got my machines ready to work, I lay the enterprife open to the infpection of all, in order that, if there is any intrinfic worth, it may be affayed; and, I have fome hope, it will not all evaporate in fufion.

Therefore, I do think it moft ferioufly important, for fpeculators and their engineers, to confider this fubject well, before they bring their bills into parliament, or profecute another canal. If the fyftem is found, the fooner it is adopted the better; if not, let it be buried in its own infignificance.

As I venerate liberality and the light of reafon, I defpife the pufillanimity 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 fhall not be confined; and my reafon is, that many ufeful improvements fleep 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 teft of difcuffion: I, therefore, feel myfelf quite ready to meet every objection to this fyftem of fmall canals; and, for this purpofe, I here call on engineers, or others, who think proper to anfwer the arguments in their favour.

If they cannot do this, I hold myfelf perfectly juftifiable in criticifing on the works of thofe men, who may hereafter either wilfully, or ignorantly, profecute the lock principle, and draw their employers into the confequent errors: I will therefore, once more, revert to the comprehenfive view of the fubject, Which will draw the moft trade into the channels of water-conveyance, large or fmall canals; and which confequently will produce the greateft benefit to fociety? It will therefore be a feeble fubterfuge to attempt to evade the queftion, by faying, this may do for fome canals, but not for ours.

Such a reply would alfo be impolitic, and exhibit a limited fenfe of the fmall fyftem; for, as I have before hinted, I will now affign my reafon why the fmall canals will ruin the large ones.

Which is, that when the fmall canals are well underftood, they will become fo numerous, and perform the work at fuch low tonnage, as to reduce the lock canals, or their emoluments, which is the fame thing, to the utmoft infignificance, 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 feen, what proportion they bear to thofe of medium dimenfions.

 To

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 trad 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.

Q CHAP.

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

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-crofs-bars paffing through the ftirrups, as in the aqueduct, and prevented from yielding fideways, by the diagonal braces exhibited at A, B, &c. Fig. IV. After which, the whole may be covered with plates of iron, foiled 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 defcribed, would ftand to the length of two or three hundred feet, yet the multiplicity of pieces of which it is compofed, in order to preferve the fhape of the fegment and relieve the butments, would evidently occafion much labour and nicety of workmanfhip; therefore it exhibits the importance of fimplifying fuch works, in order to facilitate their formation, and apply every particle of materials, fo that they may tend to ftrengthen the whole, and not be liable to alter the pofition.

I fhall therefore return to the firft propofal of adequate butments, to refift the longitudenal preffure of an arch of any dimenfions. In this it muft be confidered, that the butments need not be of the immenfe fize which firft ftrikes the imagination; for whatever dimenfions an arch of iron or wood may be, the quantity of materials is eafily calculated, and the weight which the butments will have to refift; for inftance, if an arch weighs five hundred tons, and the butments oppofed to its preffure weighs one thoufand tons, they confequently cannot move, not to mention the weight of earth backing, which tends to render them more permanent; therefore, feeing that the foundations are fecured, and the fprings, if any, well drained, in order to keep them dry, I fee no difficulty in conftructing butments to fupport an arch of any dimenfions, and that at much lefs expence than butments and piers could be erected for a ftone bridge; in the fame fituation particularly,

larly, if fuch piers were to be built in water of any confiderable depth.

Having premifed the butments to be of fufficient ftrength, I confider the arch, whether it be compofed of iron or wood, to be like the fegment of a hogfhead, and the component parts as near as poffible like the ftaves: for this purpofe, in conftructing one of iron, Fig. VIII. reprefents two ftaves, each of which might be caft in open fand, four feet broad from twelve to fifteen feet long, the pattern being formed to the radius of the fpring, a flange on the lower fide of the ftave fhould be caft, about one foot broad, with holes to receive the fcrew pins; acrofs the ftave one or more ribs, if thought neceffary, fhould be caft, to give ftrength to the top plate; thefe ribs and flanges, in uniting the ftaves would butt on each other, and ultimately compofe a rib to the whole extent of the bridge.

Having caft the ftaves as wide and long as experience may hereafter prove expedient, I will fuppofe it neceffary to erect a bridge one hundred feet fpan, as in Fig. V.; in building the butments, it would be adviseable to place two or three fegments, of the fame radius, as the bridge, in each butment, they being caft with arms, or united to binders, in order to take a firm hold on the mafonry, and become a permanent fupport; the fegment thus paffing into the butments, might be confidered as a part of the arch, which, by this means, would butt againft the centre of the whole weight of the butment, and muft pufh the whole away before the arch could yield; but, without this precaution, the arch would reft fo near the top of the butment, as to raife the ftone-work and endanger the whole. Having thus prepared the butments, a centre of three or more fegments, fo that each ftave may have two bearings, fhould be

R 2 erected;

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

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,

days, and as ſoon as the laſt timber is placed, the centres may be removed, and each piece preſſing on its neighbour, will tend to render the whole compact; this being done, bolt down the belts C and D, diſtant from each other, in a lateral direction, about ten feet; then cover the whole with old ſail-cloth, or tarpawling, tar, and ſand; of the tar and ſand, two or three coats may be laid on, which will fill every apperture, and form a permanent cover to the total excluſion of the air and rain. The arch being thus covered and kept dry, would preſent a ſegment of a cylinder, at leaſt one foot thick, guarded from the change of ſeaſons, and in all probability would laſt many ages. The firſt ſegment being formed, proceed to raiſe the perpendiculars off the belts to ſupport the ſecond or upper ſegment; which ſegment ſhould be coated in like manner with tar, &c. previous to laying on the earth and gravel; which earth and gravel ſhould be, perhaps, eighteen inches thick, in order that wheels might never wear to the timbers or coating. Having deſcribed the conſtruction, and exhibited the formation, by the engraving, it is but neceſſary to obſerve, that the ſtaves compoſing the arch are not eat away by mortiſing, but preſerve their whole ſtrength; thus being joined like ſtaves, two ſides only of each ſtick is expoſed, which being coated, the whole of the timber is completely covered from the weather. I will now leave my reader to reflect on the ſtrength and durability of this arrangment; and then proceed to conſider to what extent of ſpan ſuch bridges may be conſtructed.

In this I muſt call to mind my former remarks, that the ſegment of a circle muſt be compreſſed into a ſtrait line, or ſink in one part and riſe in another, or the butments ſeparate before it is poſſible for a bridge to fall; by longitudinal preſſure, the lateral *tendency ſhall hereafter be obſerved,* admitting the above proportions; 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.

And

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 extenſion 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, I 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 treatife, I frequently contemplated their great importance to the States of America, and much wifhed to awaken the public mind to a full fenfe of the fubject; but, on confidering the habits of the people of the interior country, accuftomed only to land carriage, I feared much difficulty would arife in removing the prejudice in favour of waggoning, and in raifing a fum of money adequate to the firft expence of a canal of importance. In deliberating on the mode of furmounting thefe obftacles, I was fo fortunate as to meet with your Addrefs to the Houfe of Reprefentatives in 1795, and particularly happy to find your ideas, of the importance of eafy communications between remote parts of the country, fo confonant to my own, and at the fame time fo earneftly recommended to the public attention: which circumftance has urged me to addrefs this Chapter to you, convinced that your fenfe of the fubject will not fuffer any obfervations which may be ufeful to lie dormant.

I muft therefore requeft you deliberately to perufe the fyftem laid down, which you will find, by Chapter VII. totally explodes the old practice, for two reafons: *Firft*, Becaufe they may be conftructed for half the fum neceffary to a lock canal; and, *Secondly*, Becaufe on them you may perform difpatch, and pafs through the moft mountainous country at the fpeed of fix miles per hour; an advantage

advantage which lock canals can never give, and which precludes an immenfity of carriage: yet the fmall canal takes in every kind of conveyance, and performs the double office of a canal and road; therefore, if founded and governed by found principles, a mountainous country may have all the bleffings of water conveyance, fo celebrated in the level and fertile plains of Egypt. But how to extend thefe conveniencies into every corner and diftrict of America, is now to be confidered.

While the mind hovers over the immenfe continent of America, and views its vaft interior, inhabited in various diftricts remote from the marts of trade, with infinite fcenes for the improvement and nourifhment of millions of human beings, philanthrophy feeks to combine the exertions of the prefent inhabitants to facilitate their labour, extend their interefts, invite population, and give a cultivating hand to every acre of that extenfive territory.

To fuch a wifh, in one point of view, is prefented a great and fertile country, interfperfed with luxuriant vales and numerous mountains, nourifhing infinite rivulets, which, meandring the country, feed long and rugged rivers, diminifhing to naked fhoals in dry feafons, or fwelling to roaring torrents in time of rain; preffing their way through ftupendous cliffs and infinite rocks, prefent objects hoftile to navigating the ftreams of nature.

But fuch are the materials which art muft bring into unifon; the performance of which is a fubject the moft benevolent and important, and worthy the ferious contemplation of the penetrating members of fociety, as a great national queftion.

On this head it muft be evident, that in proportion as produce is remote from market its value is diminifhed, in confequence of the

the expence of carriage, and hence remote parts are excluded the market, or a facility of exchanging their furplus produce for neceffaries 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 inhofpitable wafte. But to encourage population and increafe the value of the lands, the cheapeft poffible conveyance of the produce muft be eftablifhed on found principles; for, exactly in proportion to the eafe of reaching the market, the remote countries of equal fertility will be of more or lefs confequence in the fcale of fociety; therefore, to fum up the idea, would not the lands about Fort-Pit be as valuable as thofe round Lancafter, if the produce could be brought to market for the fame fum; and would not population confequently be encouraged?

For this purpofe, as I have the ftrongeft conviction operating on my mind, that canals are the only effectual means of producing eafy communications, and that they confequently are of the utmoft importance; I much wifh that the public may be made thoroughly fenfible of their utility, and that each State might eftablifh a fociety to inveftigate the propriety of forming them in fuch diftricts as the prefent ftate of population and trade may moft require them; keeping one important object in view, that all future canals may be conftucted on one fcale and principle, in order that when the various branches meet the boats, one may navigate the other wherever canals extend. This you will obferve has been my wifh throughout, and in which I hope I have been fo fortunate as to fucceed; if fo, canals appear in a new light, and are ftill more important than formerly, becaufe they may now be fitted to every kind of country, and by their cheapnefs approach near to the expence of conftructing turnpike roads.

At

At a period when a country is improving by turnpike roads, the queftion is, whether it is not beft to adopt canals; and the criterion to judge of the propriety of the canal, will depend on fimple calculation, to the following effect; *1ft*, what is the expence of the road; *2d*, what is the expence of the canal; *3d*, what is the expence of carriage by the road; *4th*, what is the expence of carriage by the canal; and probably it will be found the canal will perform the work fo cheap, as to juftify three or four times the fum being expended in the canal, that would be neceffary to conftructing a road of the fame length; to which one confideration muft be added in favour of the canal, viz. on all roads, however good, the great expence of carriage is the number of horfes; but on canals, the principal expence is the tonnage or tolls to the proprietors, as intereft 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 fo regulated, that goods conveyed four hundred or more miles, will not coft more than thofe which are navigated eighty or one hundred miles; yet the eighty or one hundred miles canal conveyance will not coft half the fum neceffary to land carriage, on the beft of roads.

To elucidate this, I will fuppofe a canal from Philadelphia to Fort-Pit, or any other long line, to fay, three hundred and fifty miles; on fuch a canal a man, boy, and horfe, would convey forty tons twenty miles per day, and arrive at Philadelphia in (*fay*) eighteen days, at 10*s*. per day, amounting to 180 fhillings for forty tons, or 4*s*. 6*d*. per ton, the expence of boating, independent of tolls. By a road of the fame length, four horfes, perhaps five, would fet 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 fay only two dollars, or 15*s*. per day, amounting to 210 fhillings, 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,

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

fufficient intereft till the principal was difcharged, which would diminifh every year.

If by either of thefe modes, or any better which can be devifed, I fuppofe the firft two hundred miles of canal to be formed, the trade will be more in proportion to the length than on the firft fixty miles before eftimated; becaufe, being more remote from the metropolis, the interior inhabitants will be neceffitated to fly to the canal, the tonnage will alfo be greater; therefore, if I allow on the two hundred miles one hundred tons per day, to be navigated at twenty fhillings per ton for the whole length, or in proportion for a fhorter diftance, the annual produce would be 28,000l.; and having arrived at fuch annual income, canals would proceed with difpatch, and progreffively increafe, both in riches and extenfion; each year the produce of tonnage would increafe, and each year a greater length of canal might be conftructed.

Therefore, if I proceed with this progreffive and creative fyftem, till a canal reached Fort-Pit, which, with fome bends, I will call three hundred and fixty miles; the country, which fuch canal would accommodate, would widen as it was more remote from Philadelphia. For inftance, the man who lived twenty miles from Philadelphia, might convey his goods feven to the canal; the man at forty miles diftance might go fourteen or fifteen to the canal; at fixty miles, twenty to the canal; and fo on, till at the extremity of three hundred and fixty miles, they probably would go fifty on each fide to the canal; hence, if I average the whole, fuch canal may be faid to accommodate a country three hundred and fixty miles long, fifty miles wide; on which the tonnage muft now be regulated.

 The

The man who refides twenty miles from Philadelphia, and feven from the canal, fhould he convey a ton of goods by land, it would be worth at leaft fifteen fhillings, as it would employ a man and two horfes two days*.

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

Thus the faving would be fix fhillings, and the tonnage fhould increafe to a certain fum on the firft hundred miles of canal, keeping much within the limits of land-carriage; then decreafe as the boating increafed, 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 horfe, will convey forty tons twenty miles for ten fhillings, which is three-pence per ton for twenty miles; but to allow contingencies, fay four-pence per ton, for boating twenty miles; the tonnage and boating on the three hundred and fixty miles fhould then be regulated, perhaps, in the following order.

* The Englifh reader, who may look over this chapter, may perhaps be furprifed at ftating the land-carriage of America fo low. But as I do not know the average expence of that country, I eftimate it low in order to give it every advantage, in a comparative view, with the canal. In England, it would coft at leaft one guinea, with all the advantage of good turnpike roads.

 Miles.

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 canal

* 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 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 unparaleled 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 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,

London, March, 1796. *ROBERT FULTON.*

* 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.

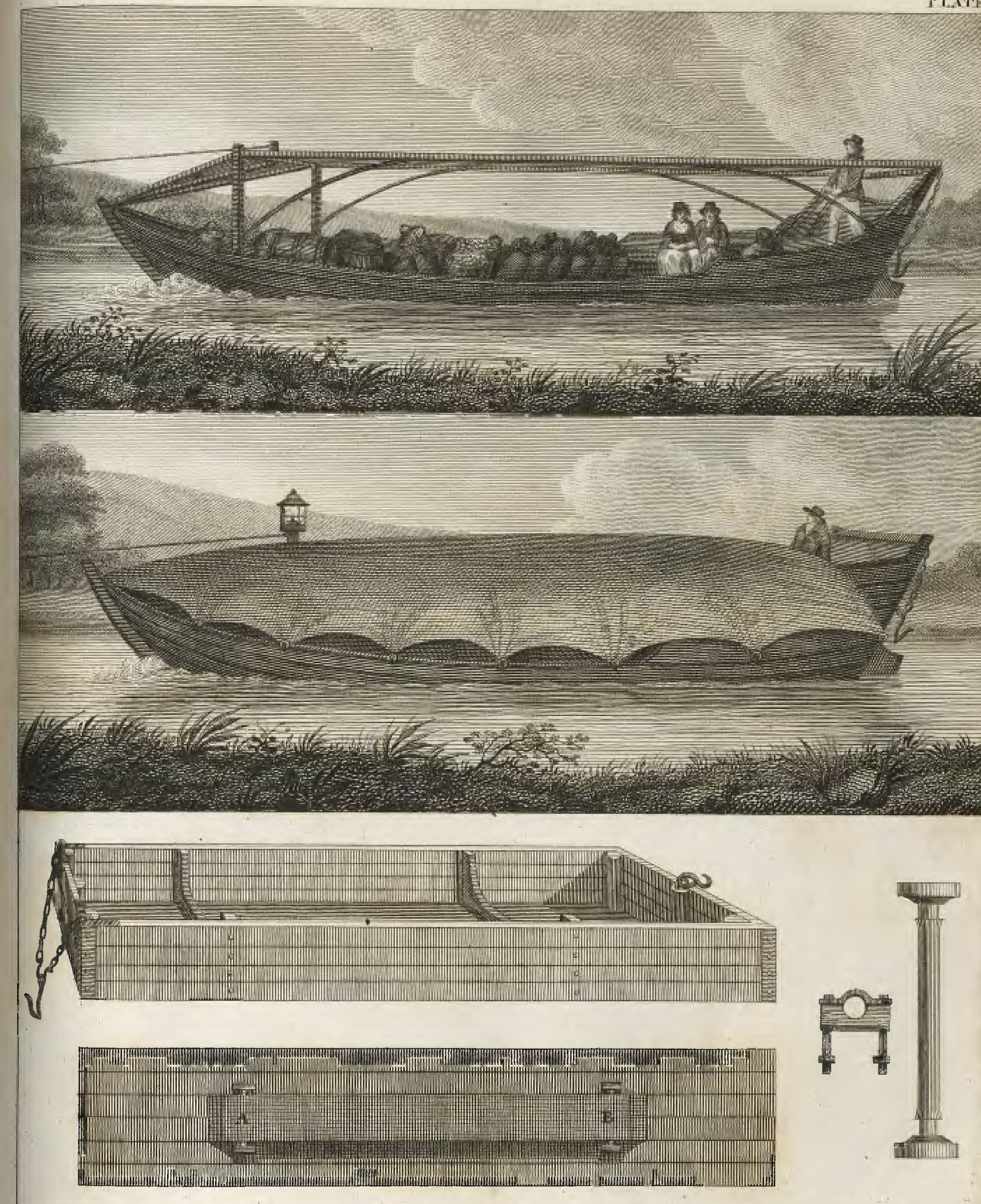
ADDITION.

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.

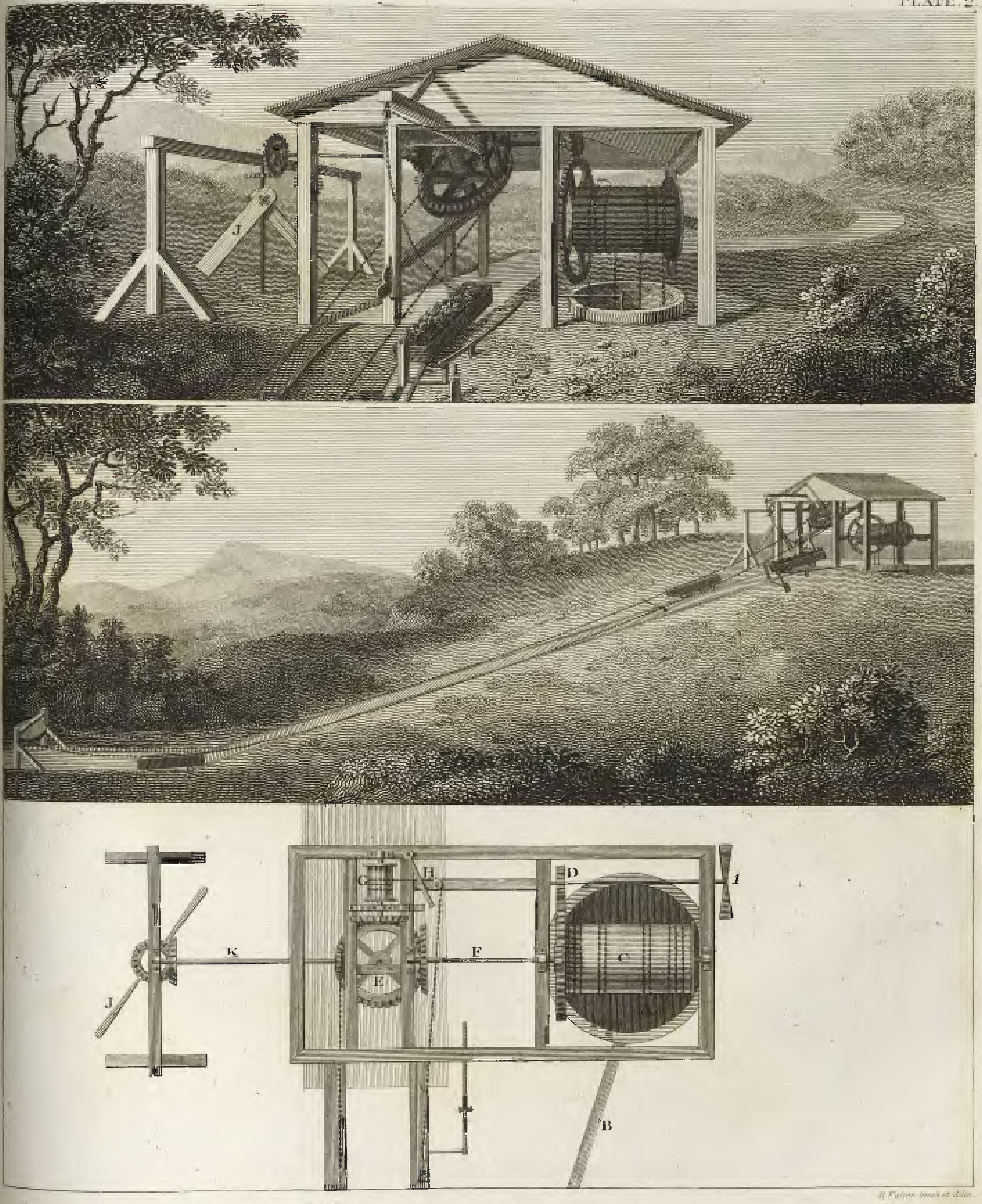


R. Fulton, inven. et delin.

BOATS,

1. The Market or Paſsage Boat. — 2. The Diſpatch Boat.
3. The Common four ton Boat.

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

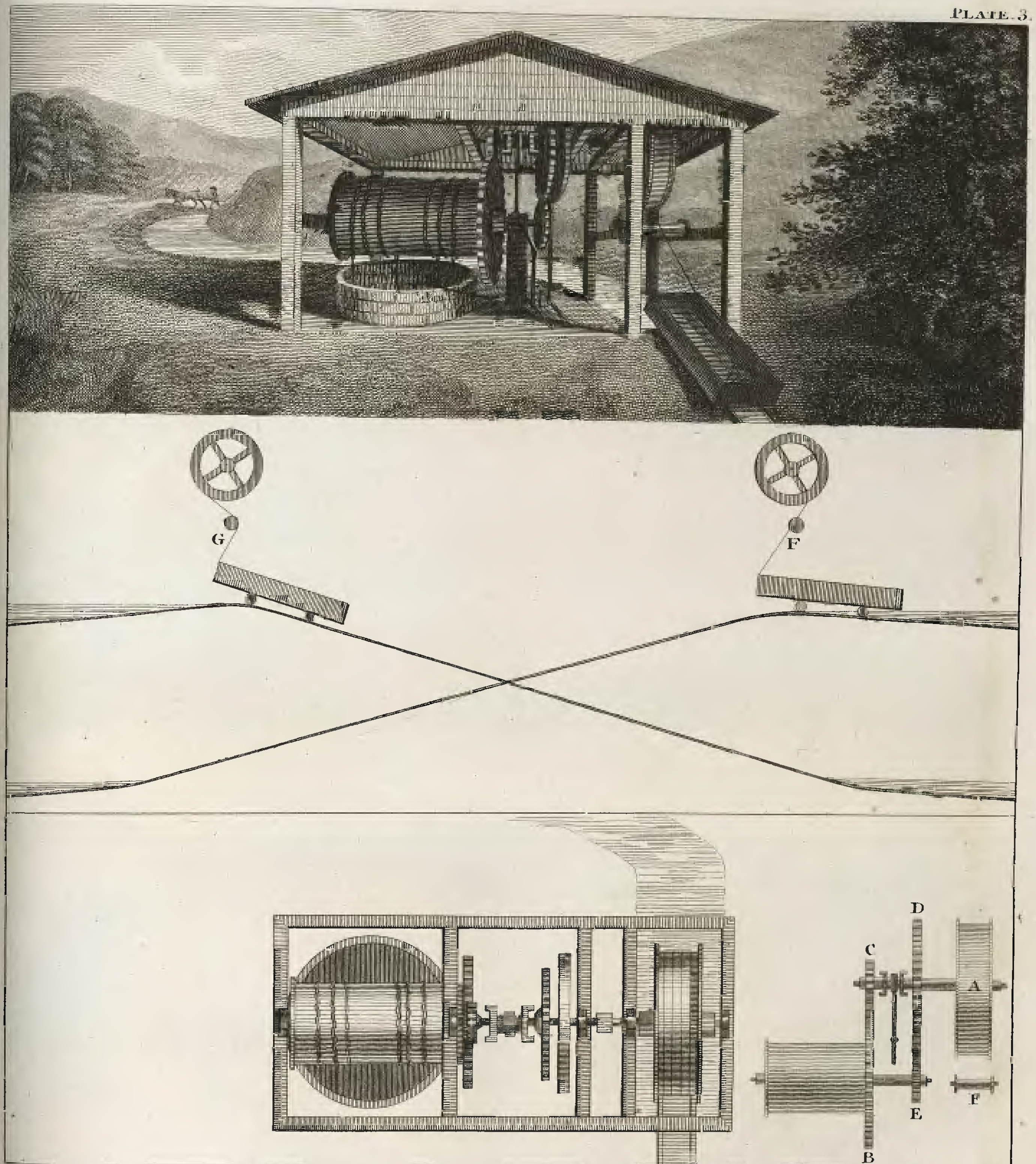


R. Fulton invt et delin.

The Double Inclined Plane.

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

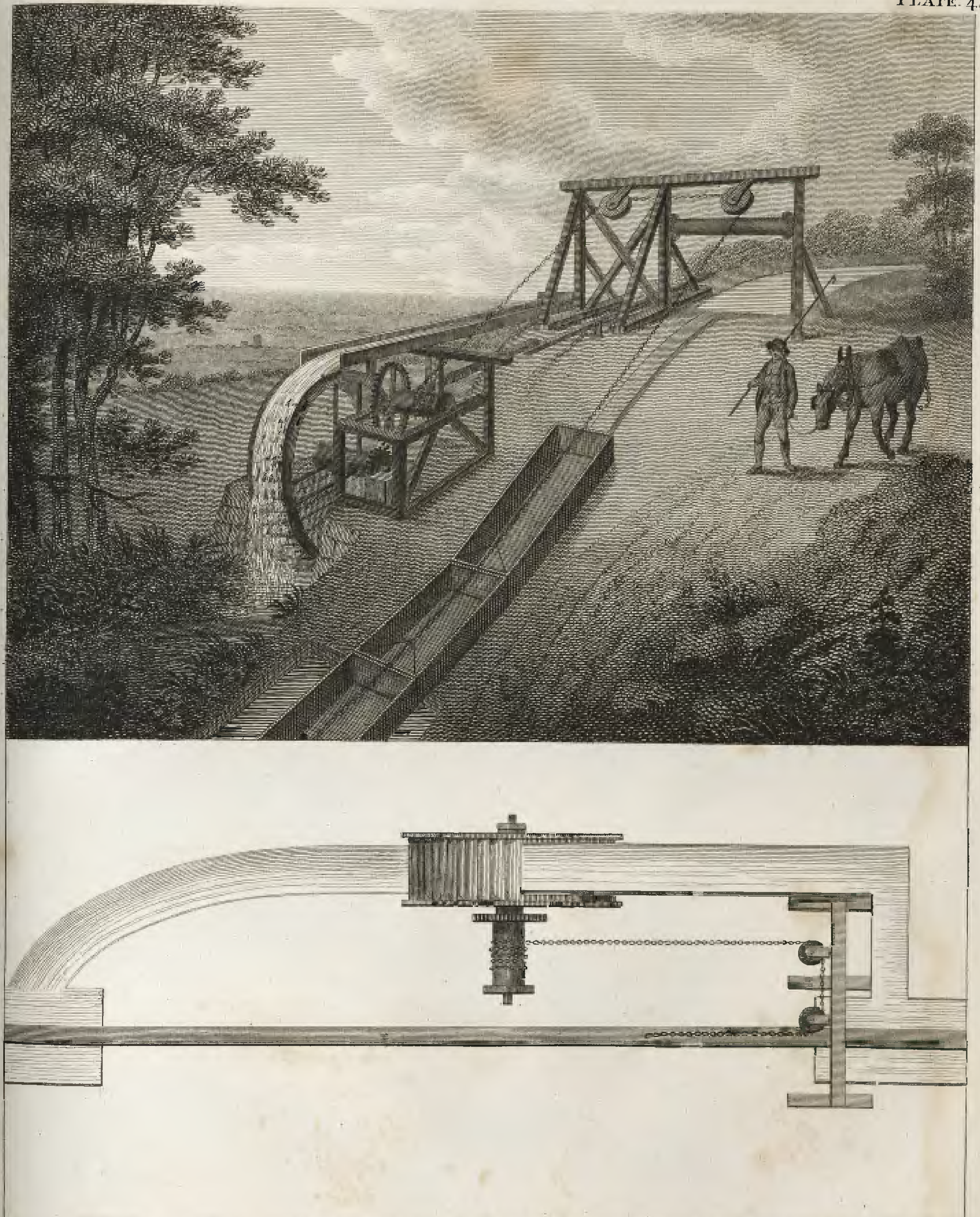
PLATE. 3.



R. Fulton, invent. et delin.

The Single Inclined Plane.

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



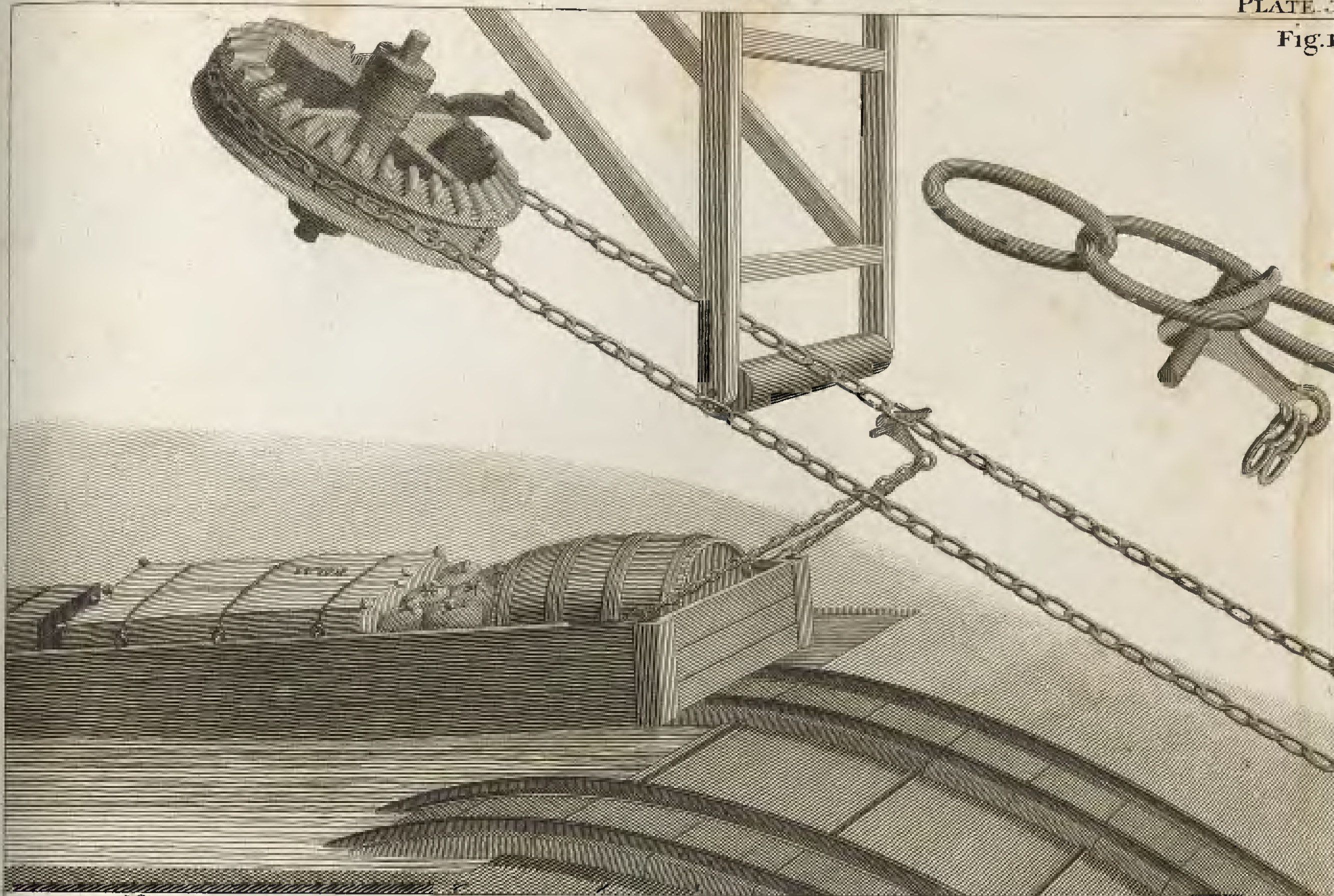
R. Fulton invent et delin.

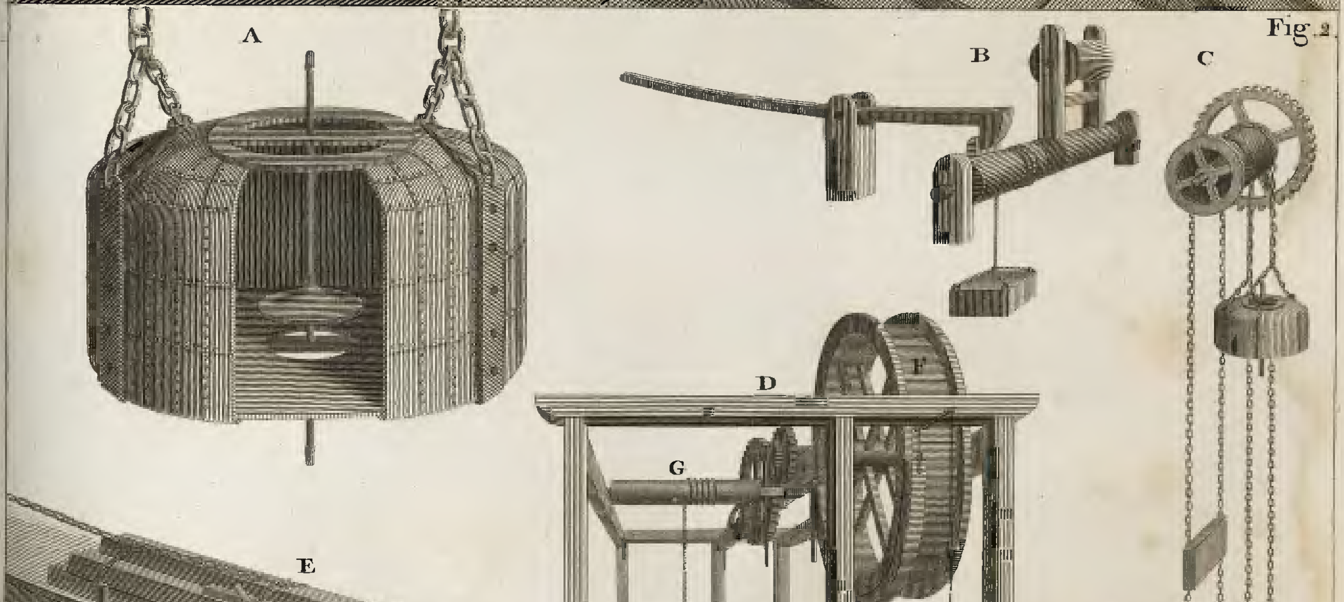
The Medium Plane for a small ascent.

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

PARTS OF THE MACHINERY.

PLATE. 5.





R. Fulton, inven. et delin.

Fig. 1. *the Cast off hook, which Seperates from the Leading Chains on the Boat entering the Various Levels, Also the Inclined wheel with teeth to prevent the Chain Slipping.*

Fig. 2. A *the Water Tub,* B *the Stopper,* C *the Balance Chains,* D *the apparatus to Return the empty Boats to the Coal pits &c.* E *the mode of passing timbers of any length.*

R. Fulton, inven et delin.

The First mode of passing wide and deep Valleys.

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

PLATE . 7.

R.Fulton. invt. et delin.

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

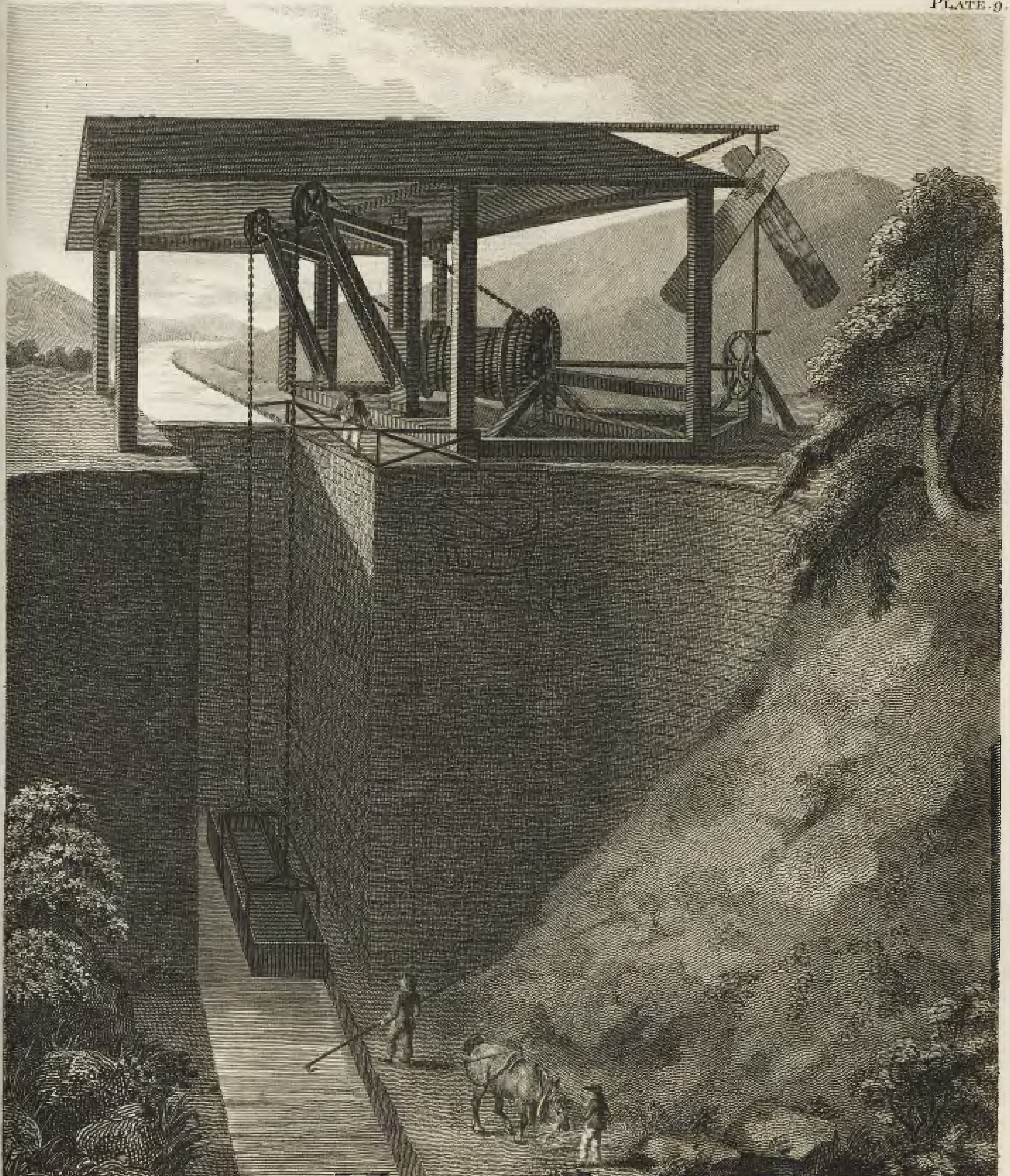
London: Published by I & J. Taylor Holborn March 1.1796.

PLATE. 8.

R. Fulton, inven et delin

The Second mode of passing Rivers Independent of Aqueducts,

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



R. Fulton inven. et delin.

The perpendicular Lift for passing an alternate Trade.

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

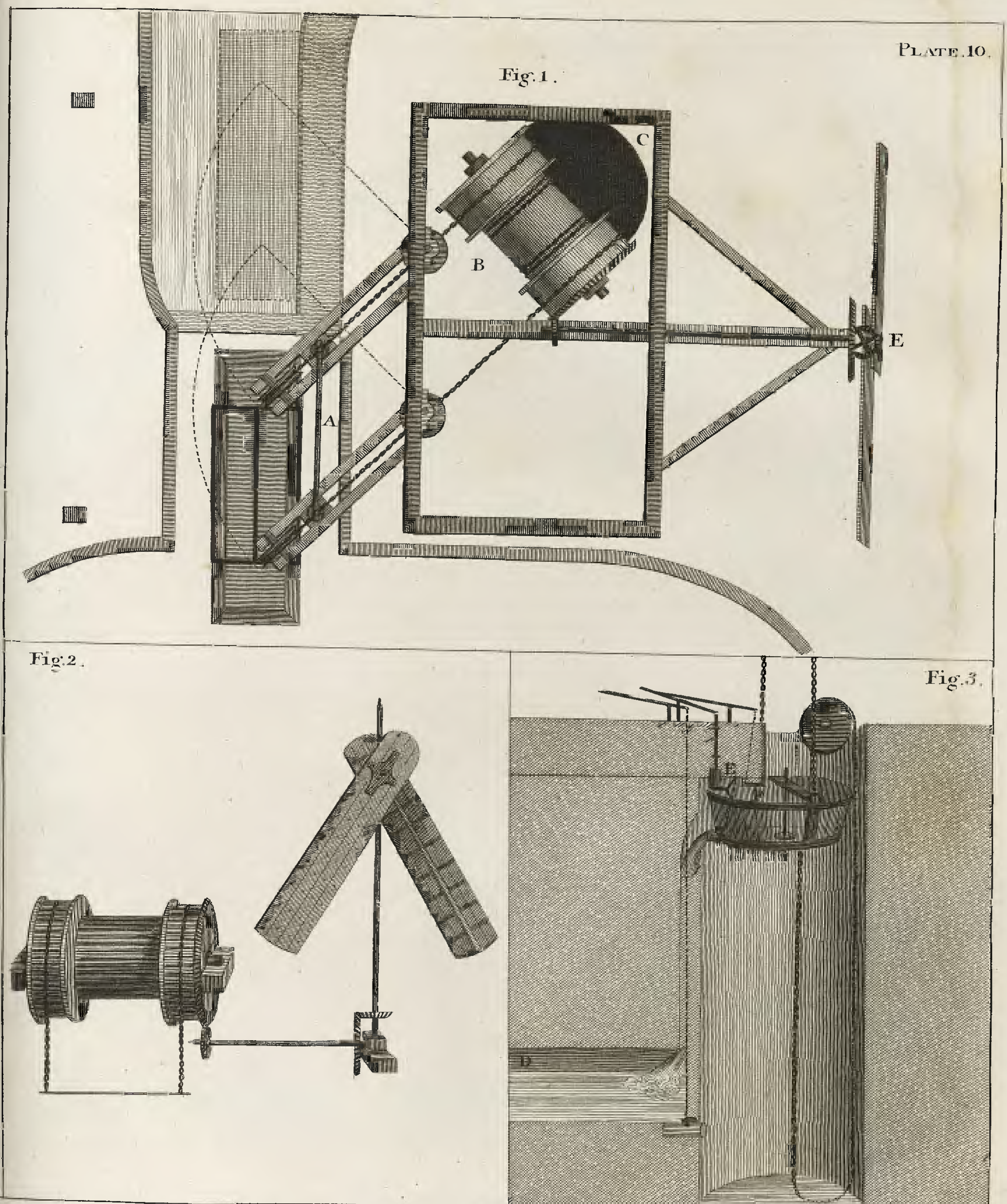
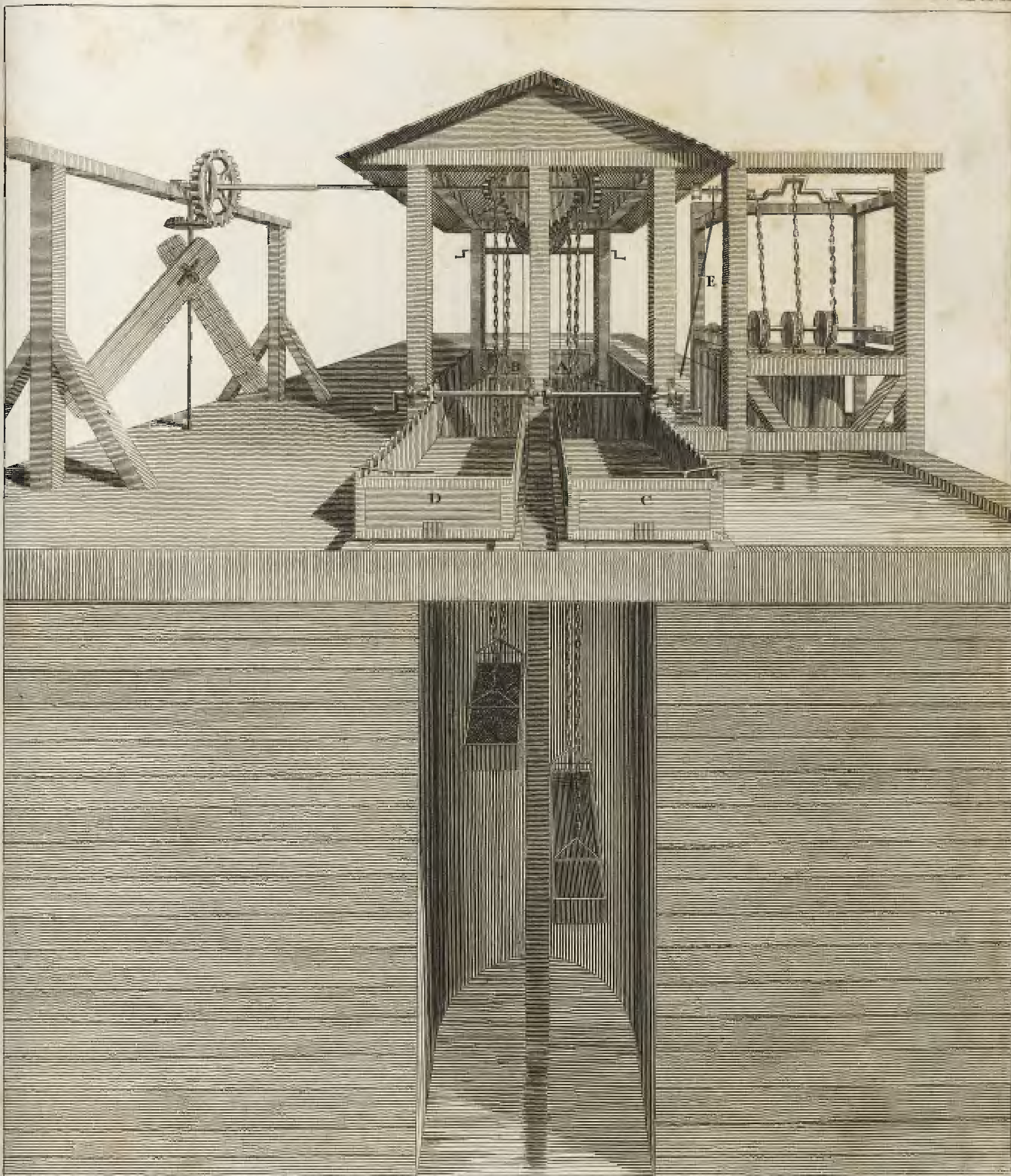


Fig. 1. *Plan of the Machinery with the mode of keeping the Cranes parellel by the Lever* A.
Fig: 2. *The drum Wheel and Centrifugal Fans*
Fig. 3. *The Water tub with the mode of discharging the Raised Water into the Reservoir* D.

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. & J. Taylor, Holborn March 1. 1796.

R. Fulton invt. et delin.

The Second mode of passing an alternate Trade.

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

Fig. 2.

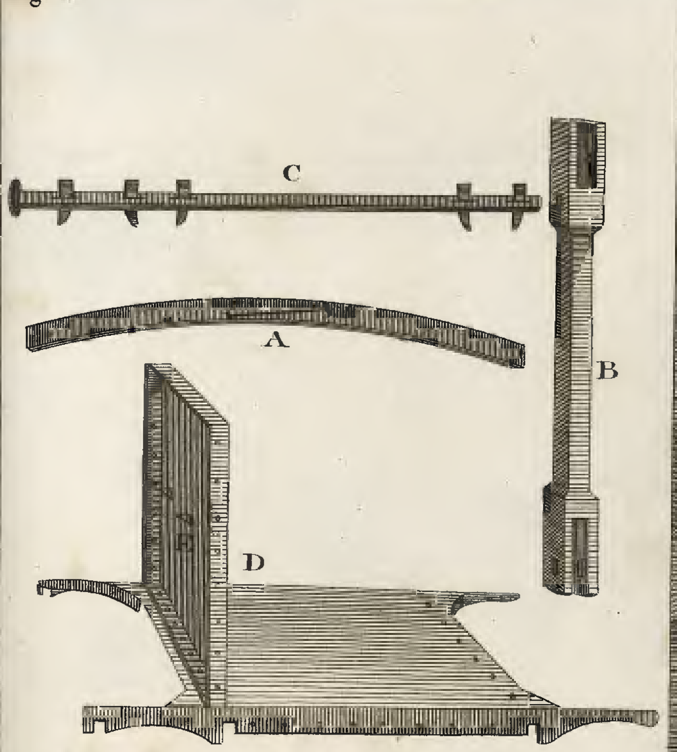


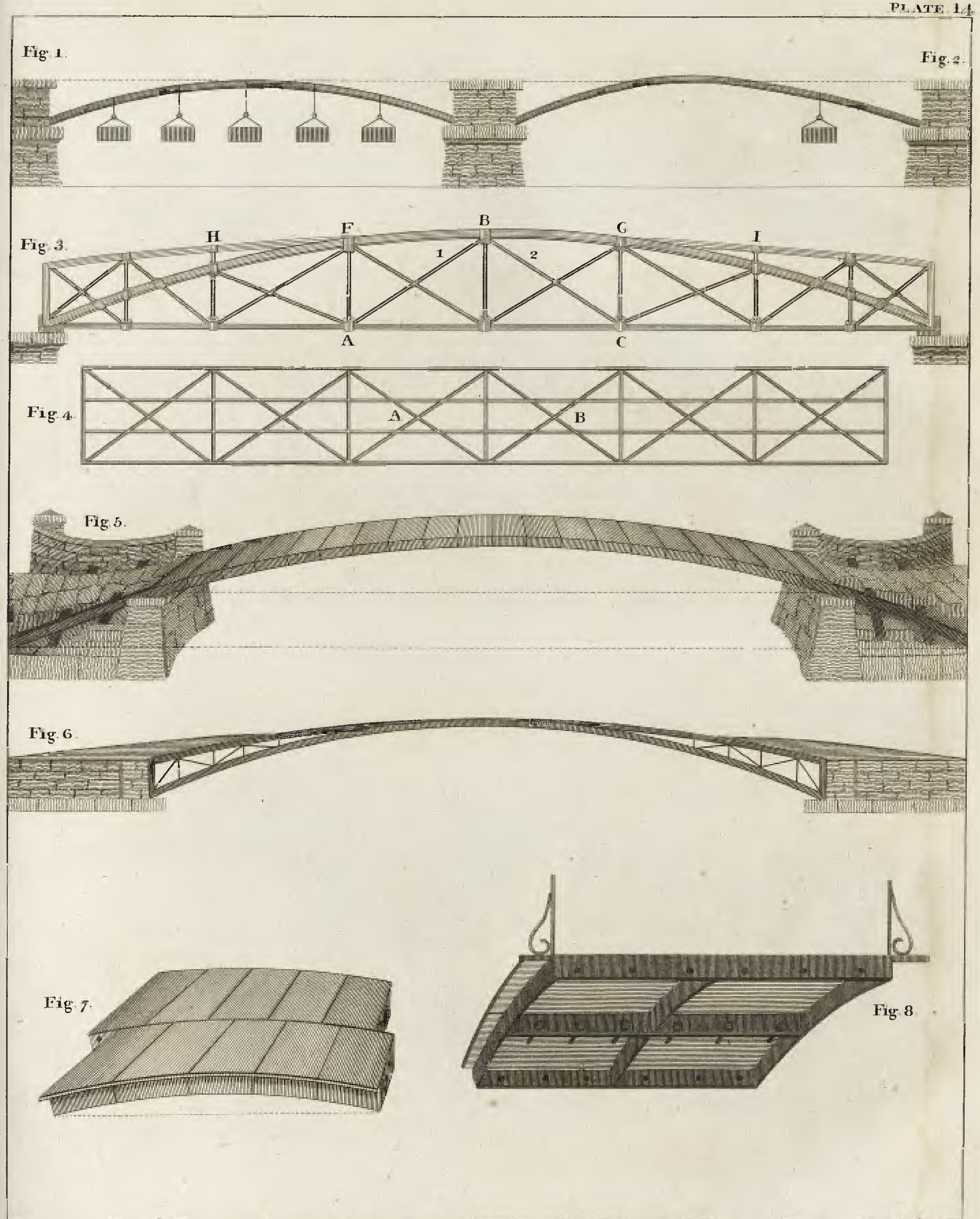
Fig. 1.

R. Fulton, inven. et delin.

An Iron Aqueduct Scale 1½ Inch to 100 Feet.

Fig. 1. *Section 1 Inch to 6 Feet.* — Fig. 2. *Parts 1 Inch to 4 Feet.*

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

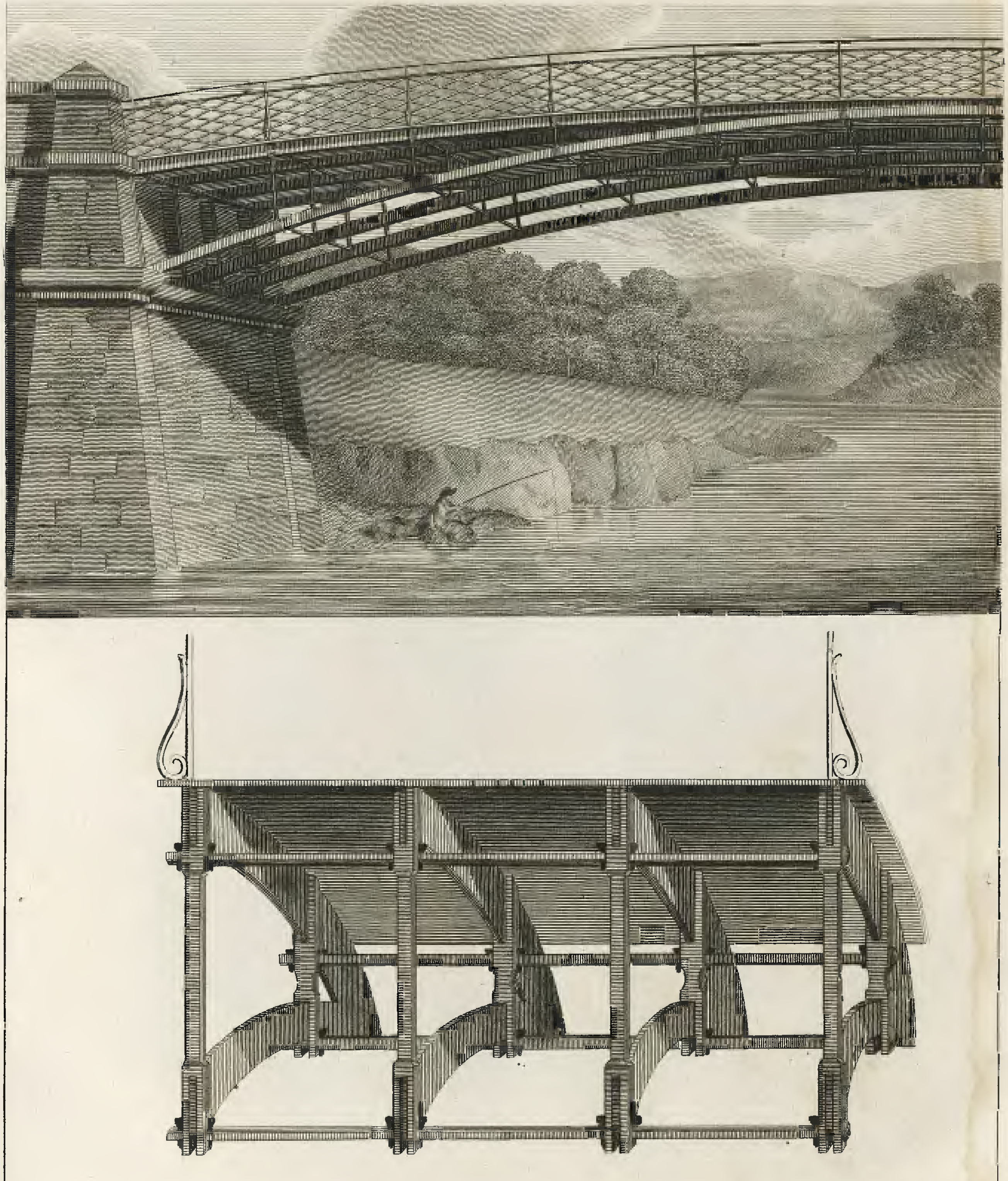


R. Fulton invent et delin.

Parts of Iron Bridges.

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

PLATE.15.



R. Fulton. invent et delin.

Design for an Iron Bridge Scale 1 Inch to 10 Feet.
The Section Shews the Ribs and Braces Scale 1 Inch to 4 Feet.

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

PLATE. 16.

R. Fulton invenit delin.

Part of a Bridge composed of Iron Staves.

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

R.Fulton invenit et delin.

Design for a Bridge of Wood, Scale 1 Inch to 50 feet, With the mode of Combining the Timbers.

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