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.

Published by I. and J. TAYLOR at the ARCHITECTURAL LIBRARY, HIGH HOLBORN.

1796.


राष्ट्रीय पुस्तकालय | National Library
सं. | No. Imp 38049
दि. | Date. 03-08-10

CONTENTS.

MINUTES

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

ceſſary 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 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

immediate conſideration; fourth, by the diſcuſſion I propoſe, the uſeful or imperfect parts will be more immediately exhibited, and the miſapplication of the old mode will be detected: hoping that this ſyſtem, *to its extent*, will meet the moſt candid and liberal inveſtigation, and be deliberately conſidered and compared with the old practice for the various canals in contemplation, or which may hereafter be conſtructed.

I remain, with all poſſible reſpect,

Gentlemen,

Your moſt obedient,

ROBERT FULTON.

London, March 1, 1796.

PREFACE.

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

But if we conſider for a moment, how much men are the ſons of habit, we ſhall find, that almoſt the whole operations of ſociety are the produce of accident, and a combination of events, rendered familiar by cuſtom, and interwoven into the ſenſes by time; inſomuch, that it is mere chance if the ideas are awakened to a ſenſe of particular errors. But in ſuch caſe it is fortunate, when they ariſe in a mind active to inveſtigate, and which feels only contented to reſt on the baſis of reaſon; for without this, man muſt ever remain in a fixed point, and improvement will be at an end: the adventurer muſt therefore arm himſelf with

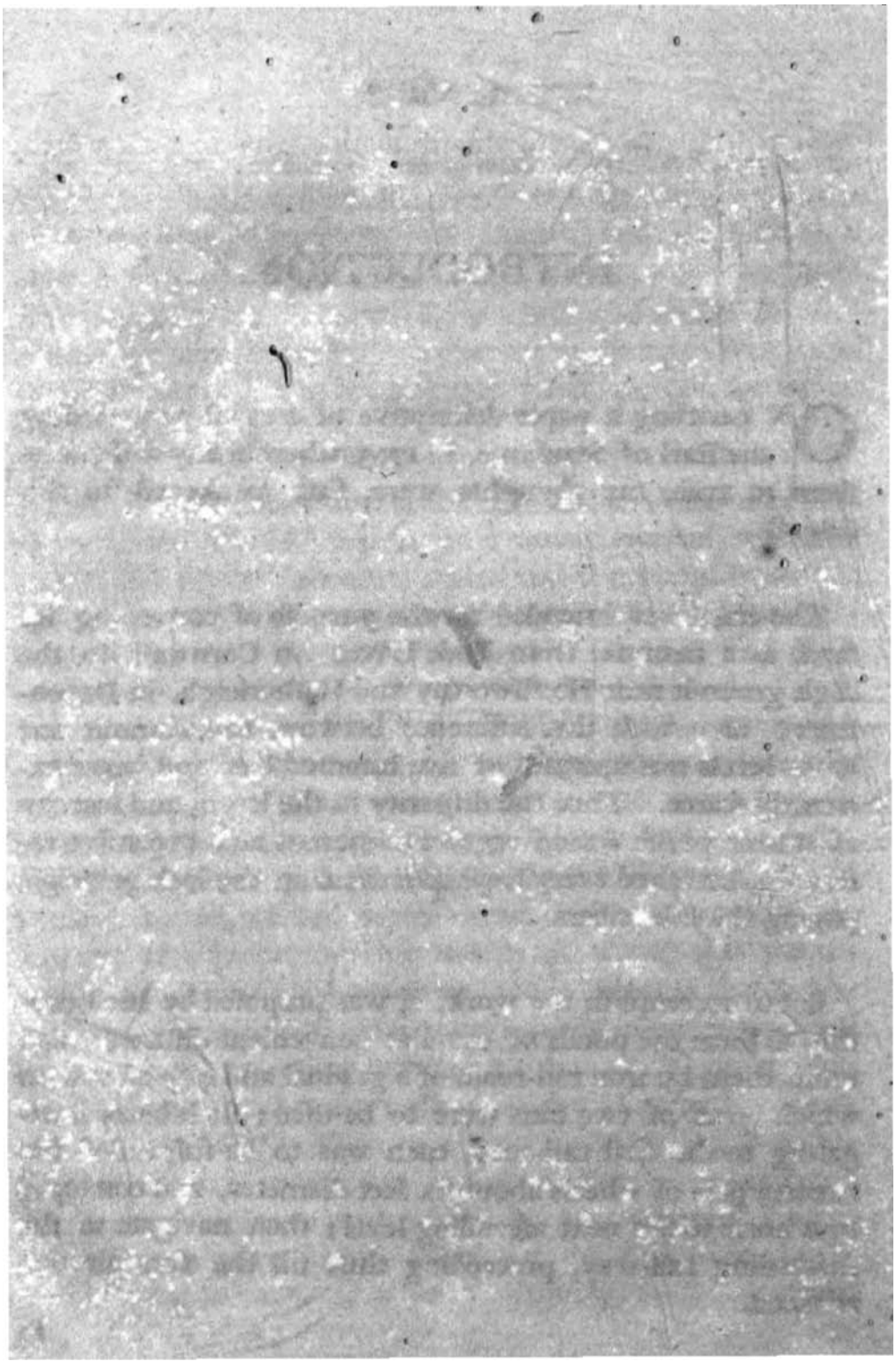
fortitude to meet the attacks of illiberality and prejudice, determined to yield to nothing but ſuperior reaſon; reſting aſſured, that every virtuous mind will commend an exertion to remove the rubbiſh from around the Temple of Truth, even ſhould the undertaking fail.

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.

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.



INTRODUCTION.

ON peruſing a paper deſcriptive of a canal projected by the Earl of Stanhope, in 1793, where many difficulties ſeem to ariſe, my thoughts were firſt awakened to this ſubject.

The canal was intended for the purpoſe of conveying ſea ſand, as a manure, from Bude Haven, in Cornwall, to the high grounds near Houlſworthy and Hatherleigh, in Devonſhire: on which the difference between the ſummit and lower levels was upwards of five hundred feet, and water extremely ſcarce. Thus the diſparity in the levels, and ſcarcity of water, which would require numerous and expenſive reſervoirs, baniſhed every hope of a canal on the lock principle paying the ſubſcribers.

But to accompliſh the work, it was propoſed by his Lordſhip to form the ponds of canal at convenient diſtances, and unite them by iron rail-roads of a gradual and eaſy aſcent, on which boats of two tons were to be uſed; ſuch boats navigating to the firſt rail-road, each was to be ſuſpended between a pair of wheels about ſix feet diameter, and conveyed by a horſe to the next aſcending level; then navigate to the ſucceeding rail-way, proceeding thus till the ſummit was attained.

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

Seeing theſe difficulties, and the neceſſity of an eaſy communication with hilly countries, I was impreſſed 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 horſes.

To produce ſuch a machine, the firſt 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, raiſe the boat on an inclined plane. But in great aſcents, I found the wheel deſtroy more water than locks; I then thought of a preponderating ciſtern of water, and was ſo certain of obtaining the power by that means, that I immediately conceived I had accompliſhed the machine; and having ſome communication with his Lordſhip, *on the practicability of navigating veſſels by ſteam*, I ſent him a ſketch of my plan: his Lordſhip, in anſwer, was pleaſed to compliment me on the thought; but at the ſame time informed me, it was the ſame as deſcribed by Mr. Edmund Leech, about ſixteen years ſince. Here, for the firſt time, I diſcovered that the idea of a preponderating body of water,

was

was by no means new. But, on inveſtigating Mr. Leech's work, I found, that although our ideas of the ciſtern were nearly ſimilar, yet we were far diſtant from the point to be attained; each uſing it on an inclined plane, without any certain mode of getting the boat in and out of the upper canal. I then changed the ciſtern from the inclined plane, to a perpendicular deſcent; becauſe, in a perpendicular, the deſcending body acts with a force equal to its whole weight, *friction excepted*; while, on the plane, its deſcending force is loſt 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, eaſe, and expedition, ſo as to preſerve 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 deſcribed by the annexed Plates, each of which works with great certainty and eaſe, *varying from double to ſingle machines*; and have at leaſt eſtabliſhed the practicability of paſſing boats to and from the different ponds of canals; independent of locks, rail-roads, or ſteam-engines.

Having accompliſhed a mode of paſſing the diſparity of the levels, the next important conſideration in reducing the expence of canals, was to croſs rivers, or deep and wide valleys, without aqueducts. The following Plates will alſo 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.

Theſe

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.

A

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.

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.

It

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

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

* 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,

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.

Of

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

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.

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 upper canal; and, although it is only calculated for a *deſcending* trade, ſuch as from colleries, or lime works *(in which caſes the loaded boat, deſcending, raiſes that which is empty)*, yet by its operation ſmall boats have been introduced into practice; and for ſuch introduction every future improver will feel infinitely indebted to Mr. REYNOLDS; however greatly his engine may be improved 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

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,

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

gant 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 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 maintenance. 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.

were

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 III.

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

HAVING in ſome degree exhibited the importance of canals, the next conſideration is to point out a mode of extending their advantages. In this it muſt be evident, that they can only be advantageouſly conſtructed through ſuch diſtricts, as produce a trade equal to an intereſt for the money advanced in their formation; and on this point the difficulty of extending canal communications ſeems to depend: public roads, bridges, harbours, docks, and other works, admit of a variation, and may be conſtructed 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 preſent ſyſtem * of conſtructing canals, there is a certain point to which they ſeem to deſcend †, and below which they cannot be further contracted. The ſum required for their conſtruction therefore muſt be equal to the forming them of thoſe dimenſions; and the trade expected muſt be ſufficient to pay the intereſt of the ſum, or the country remain hopeleſs of the conveniencies of water carriage; unleſs a canal be executed in the frenzy of ſpeculation, which indeed is ſometimes the caſe; and rather injures than promotes ſuch works; for ſubſcribers being diſappointed of the intereſt with which they had flattered themſelves, are deterred from entering

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

† For navigating twenty-five or twenty ton boats.

into

into ſimilar undertakings, though of more rational adventure. The ill ſucceſs alſo ſpreads like a contagion, and ſickens the ſoul of enterprize in others; yet the failure is perhaps not for want of materials to be conveyed by the canal, but in conſequence of the expence of getting at ſuch materials.

Had the ordinary engines of conveyance admitted of no diminution below broad-wheel waggons, thoſe waggons would, in every reſpect, increaſe the expence of roads, and the carriage of the various materials; and the country could not poſſibly be ſo commodiouſly ſupplied as by carts, or even cars. Or had that incomparable apparatus, the ſteam engine, been confined to a two-hundred horſe power, the innumerable advantages ariſing from proportioning its powers down to any degree, which fits it to every ſituation, could never have been experienced, and the engine itſelf would be of very little uſe.

A ſimilar power of proportioning a canal to the particular demand of carriage upon it, in like manner, would be attended with benefits which at preſent are not even thought of; but canals are the only things, which I can at preſent recollect, which ſeem to be fixed to a certain point; in this reſpect, conſequently, they are limited in their extenſion, imperfect in their principle, and incapable of effectually ſpreading the bleſſings of water communications by their preſent mode of conſtruction; to prove this aſſertion it is only neceſſary, for a moment, to conſider the operation of a lock.

On viewing the operation of locks, it appears that if they were conſtructed for ſmall boats, *ſuppoſe boats of four tons*, the delay in paſſing would be ſo great that an important trade could not be tranſacted, as it requires almoſt as much time to paſs a ſmall

as

as a larger boat; for inſtance, on a man arriving with ſix four-ton boats *(equal to what is uſualy conveyed in a boat of twenty-five tons)* at a lock conſtructed for ſmall boats, he would be obliged to ſeparate them, and paſs them ſingly; which would be an operation of three minutes at leaſt to each boat, together with the time neceſſary for uniting them when paſſed through, ſay 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 confuſion wherever there were a number of boats paſſing, even if paſſing the ſame way. How this would be increaſed by thoſe moving the contrary way, may eaſily be conceived. Yet the twenty-five ton boat would move through the firſt lock in five minutes, at the utmoſt, and paſſing through the ſucceeding eleven locks with the ſame expedition, would riſe to the ſummit 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 ſufficiently prove the impropriety of conſtructing locks for ſmall boats; hence ſmall 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 cauſe of increaſing the expence of all the other parts of the canal; in tunnels, bridges, aqueducts, land, reſervoirs, digging, &c. &c. which evidently exclude every diſtrict which cannot ſupport theſe heavy expences, and preclude every hope of giving to agriculture and commerce the full force of ſo powerful an agent as water conveyance.

But as the true criterion for judging of all improvements, *where the object is to increaſe the produce of labour*, is the cheapneſs with which the work may be performed; that mode which will convey the moſt goods for the leaſt money will conſequently be the beſt, whether by roads, railways, large or ſmall canals, or any other mode. It is therefore

therefore neceſſary impartially and deliberately to inveſtigate this ſubject.

First, In proportion as a canal is large the expence on all its parts will increaſe: tunnels, locks, reſervoirs, aqueducts, bridges, land, and digging, are uſually allowed to be one-third more expence in a canal for forty-ton boats, than in thoſe conſtructed for boats of twenty-five tons; twenty-five ton boats, alſo, require a canal of greater dimenſions than boats of four tons: in a word, it is evident that the expence of a canal will decreaſe, in proportion as the boats are reduced; the object therefore is to find the proper medium.

The boat ſhould be of ſuch a ſize as not to exclude any but unuſual articles; for this purpoſe I conceive a boat of four tons ſufficiently large; being twenty feet long, four wide, and two feet ten inches deep; ſuch a boat, being larger than the cheſt of a waggon, will contain almoſt every thing but long timber*, one horſe conveying ten boats.

Such boats will contain lime, lime-ſtone, coals, lead, iron ore, grain, flour, iron ware, pottery, and all bodies ponderous and compact, as well as boats of any ſize whatever; they will contain hogſheads, boxes, and bale goods, not exceeding four feet in width, *which are ſeldom of greater dimenſions*; each boat will receive fifteen ſacks of hops, cotton, or wool; and although the fifteen ſacks will not weigh four tons, yet the ſame circumſtance is attendant on all other boats, it being impoſſible to give the weight of tonnage

* For timber I have made a proviſion (ſee the Deſcription of the double-inclined Plane, and Plate of Parts); planks, and all ſcantlings under twenty feet, will go into the boats.

by

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.

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, that to 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 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

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.

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 booking 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 rolling the machinery.

Secondly, The poſſibility of the wheels being injured.

Thirdly, The reſiſtance on the water, in conſequence of the wheels, and ſhape of the boat.

To the *firſt* it muſt be obſerved, That, while the boat is out of water, it will ever act on a regular plane of caſt iron, and never be ſubject to inequalities, and although the friction will be ſomething more in conſequence of the ſmall wheels, yet, as ſufficient power may be obtained to raiſe her, the friction ariſing from their ſmall diameter will be no conſiderable impediment.

To the *ſecond*, I conceive the wheels are not ſubject 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 enſues by a long courſe of time, only, can affect the boat in this part; and, to this, it muſt be obſerved, that ſhe will not undergo ſo much hardſhip in paſſing two hundred miles, as a common waggon in moving one mile on the uſual roads.—But, even admitting frequent repairs ſhould be neceſſary, ſmall ſlips may be conſtructed at proper ſituations, where a man, by a common windlaſs, would draw the boat out of water, and repair her, with the ſame facility as he would remedy a defect in a cart, or a waggon; the proceſs of dry docks neceſſary to large boats, is by no means required in repairing theſe.

In the *third* objection, the reſiſtance in the water may appear to ariſe from two cauſes; firſt, from the projection of the wheels in ſome degree from the bottom; and, ſecond, from the flatneſs of the boat on the ends. But it muſt be obſerved, that boats of this conſtruction are deſigned to move ſlow, conſequently the reſiſtance ariſing from the particular conſtruction will be very trifling, and of little importance, reſiſtance being much more

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

To give a general idea of this, it is merely neceſſary to remark, that ſhould a man attempt to drive a horſe ſixty miles *per* day, he could ſcarce convey a boat of the lighteſt conſtruction at that rate; yet the ſame horſe would convey one hundred tons twelve miles *per* day with eaſe, and arrive at the end of ſixty miles in five days; which is equal to twenty tons per day moving through the whole ſpace of ſixty miles.

This I hope will be ſufficient to ſhew that reſiſtance from ſhape, in ſlow movements, is inconſiderable; alſo, that the true principle of conveying goods cheap, when expedition is not required, is, to move ſlow and take a quantity *; and in this reſpect I ſhall now conſider their ſuperiority over boats of twenty-five tons.

Seeing

To the reader who may wiſh to enter more into the abſtract, it may be proper to remark, that a body moving in a fluid is reſiſted from two cauſes; firſt, from the coheſion of the parts of the fluid: for a body in motion ſeparating the parts of the fluid wherein it moves muſt overcome the force with which thoſe parts coheſe,

The ſecond cauſe is, the *inertia*, or inactivity, of matter; whereby a certain force is required to move the particles from their place, in order to ſuffer the body to paſs. When the ſame body moves through the ſame fluid with different velocities, the reſiſtance increaſes, in proportion to the number of particles ſtruck, in an equal time, which number is as the ſpace run through in that time; *i. e.* as the velocity. But further, it increaſes in proportion to the force with which the body ſtrikes againſt every part; which force is alſo as the velocity of the body; and therefore if the velocity be triple, the reſiſtance is triple, from a triple number of parts to be removed. It is alſo triple from a ſtroke three times ſtronger againſt every particle; therefore the whole reſiſtance is nine-fold, *i. e.* as the ſquare of the velocity; hence a body moving in a fluid is reſiſted, partly in a ratio to the velocity, and partly in a duplicate ratio of the velocity.

Moſt authors have conſidered it as a rule, that while the ſame body moves in the ſame medium, it is always reſiſted in the duplicate proportion of its velocity; that is, if the reſiſted body move in one part of its track with *three* times the velocity with which it moved in ſome

Seeing that the true principle is to move ſlow and take quantity, *in the uſual trade*, it muſt be obſerved that a twenty-five ton boat is a limited quantity, and more cannot with propriety be applied to the horſe, conſequently he muſt reſort to ſpeed, and combat the reſiſtance.

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 alſo ſo long that, in making the bends in the courſe of the canal, they ſeparate the fluid by ſide preſſure; the bow of the firſt ſeparates the fluid, *for inſtance*,

other part, then the reſiſtance of the greater velocity will be nine times the reſiſtance of the leſſer; and if the velocity in one place be *four* times the velocity in another, the reſiſtance of the greater will be ſixteen times the reſiſtance of the leſſer, and ſo on. *See Chambers on Motion.*

Hence, as reſiſtance is more in proportion to velocity than weight; if I ſuppoſe a boat and cargo to weigh twenty tons moving at the rate of two miles per hour, ſhe 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 reſiſtance will, in conſequence, be double. But, as the ſpeed is not increaſed, all the reſiſtance which would ariſe from increaſed velocity, by the force with which the particles would be ſtruck, is avoided; therefore quantity, to create reſiſtance equal to what ſpeed produces, is nearly as follows: in which I will ſuppoſe a horſe to convey thirty-ſix tons at the rate of two miles per hour, and diminiſh the quantity as the ſpeed is increaſed.

Miles per hour.	*Square of reſiſtance 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 reſiſtance, ſo is ſixteen to thirty-ſix in quantity; and ſo on, in the ſucceeding numbers, the quantity diminiſhing as the ſpeed is increaſed; which determines, that to convey four tons ſix miles per hour, requires as much power as to convey thirty-ſix tons two miles in the ſame time: thus, although the ſpeed is but triple, the quantity is reduced to one ninth part, or as four is to thirty-ſix—and ſo on in the other numbers.

to

to the right, and the ſtern repels it to the left; the bow of the ſecond boat brings it to the right again, and then the ſtern drives it to the left; which agitation conſequently will retard the motion of both boats: hence, on a canal for twenty-five ton boats, one boat muſt be the allowance of one horſe; he cannot have more; but muſt endeavour to accompliſh quantity by ſpeed, and encounter the conſequent reſiſtance.

But of the four-ton boats, ten, fifteen, or twenty, may be linked together, to compoſe any weight which is thought proper, according to time and diſtance; 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 horſe-path with a boat-hook; hence, by the ſyſtem of ſmall boats, a horſe may take any quantity, and move with a proportionate velocity.

From boats of this conſtruction, another material advantage ariſes to proprietors of colleries, lime, delphs, &c.; frequently a canal may paſs near ſuch works; and yet it is inconvenient, or inconſiſtent, with the quantity of trade, to extend the water level to the very ſpot; which circumſtance frequently obliges ſuch proprietors to conſtruct rail-ways, and keep waggons, which they muſt be at the expence firſt of loading, before they can deliver the commodity to the boats, and frequently of forming a depoſit on the canal banks, from whence they muſt again load into the boats. But if ſuch works lie above the canal, and not more than ſix hundred yards diſtant, ſo that a regular deſcent could be obtained; a ſingle road might be formed, and the boat floating on additional wheels might be raiſed to the pit by the ſteam-engine employed in pumping, or by the mode deſcribed by D. in the Plate of Parts.

But if ſuch a regular declivity could not be obtained, ſuppoſing the aſcent was eaſy, the boat, on a carriage prepared for the purpoſe,

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 collieries 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.

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

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

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

4*th*, 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.

5*th*,