THE
HISTORY AND PRACTICE
OF
AEROSTATION.

BY

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PREFACE.

THE art of travelling through the air, lately diſcovered, and rapidly improved, has introduced ſome new words, expreſſive of the various objects which belong to it. The meaning of thoſe words is eaſily underſtood and remembered, ſince they are principally derived from the Latin, *aer*, the air; thus the *aeroſtat*, or the *aeroſtatic machine*, is the general appellation of the flying inſtruments; the *aeronaut* is the perſon who travels through the air with an aeroſtatic machine; and the art itſelf, with whatever belongs to the knowledge of it, is called *the ſubject of aeroſtation*.—The flying machines are likewiſe called *air-balloons*.

The preſent work contains the Hiſtory and Practice of this new ſubject. In the hiſtorical part, the Author has omitted moſt of thoſe experiments, obſervations, and projects, which ſeemed to be either trifling or evidently abſurd; and, on the contrary, he has endeavoured to record every particular that deſerved to be remembered, or that appeared likely to open the way for farther diſcoveries. In the practical part, he has not confined himſelf within the limits of any particular theory; ſince the preſent ſtate of knowledge, relative to the ſubject, has not yet eſtabliſhed all the neceſſary particulars; he has therefore comprehended this part of the work under ſuch general principles, as will be uſeful in caſe of any ſubſequent improvement.

The problems for practice have been rendered as general as poſſible; but they are left without any demonſtration; ſince that would have been uſeleſs to the mathematical reader, and unintelligible to any other, except there had been prefixed a long ſeries of preliminary propoſitions, which the nature of the work could not admit of.— It is for the ſame reaſon, that mathematical phrases, and symbolical calculations, have been avoided, and more familiar expressions have been substituted wherever it has been practicable.

The measures mentioned throughout the work are *English*, and the degrees of the thermometer are according to Farenheit's scale, except when the contrary is expressed.

Accuracy and perspicuity have been the Author's principal objects in the compilation of his work; but, notwithstanding his endeavours, it is more than probable that some inaccuracies, and other deficiencies, may be found in it; on which account, he would deem himself much obliged to any person, who would inform him of any necessary correction, or interesting particular that has been omitted, in order to render the work more perfect, in case of another edition.

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PART I.

HISTORY OF AEROSTATION.

CHAPTER I.

History of Aerostation, from the earliest tradition till the year 1783.

THE tales of antiquity, the poetical productions, the religious tenets, and even the histories, of most nations, shew that to acquire the art of flying, or of imitating the birds, has been the earnest desire, and has exercised the genius, of mankind in every age. The winged horses of the Sun, Juno's peacocks, Medea's dragons, the flying oracles, and innumerable others, are inftances of this obferva-tion; but authentic hiftory furnifhes very fcanty materials concerning any real fuccefs having ever attended the attempts of this fort.

With fome it is a queftion, whether thofe allegorical paffages are merely the produce of the imagination, ever fond of raifing itfelf into the pure and unincumbered regions above the furface of the earth; or whether they indicate the real exiftence of the art of flying amongft men in ages preceding hiftory, but afterwards loft. And indeed, whilft we were unacquainted with any means, by which a man might elevate himfelf into the atmofphere, and the conftant failure of often-repeated experiments had rendered proverbial the vanity of the attempt, we might have eafily been induced to believe the firft part of the queftion; but now, that men in almoft every nation of Europe, by having actually raifed themfelves into the air, and having navigated through it with fafety and pleafure, have fhewn the pof-
fibility,

ſibility, and eaſineſs of the art, we might, perhaps with more juſtice, ſuſpect the ſecond part of the queſtion to be true. However, an art entirely forgotten, has the ſame effect as an art never diſcovered: therefore theſe obſervations may only ſerve to excite the inveſtigation of antiquarians; but as they do not, ſo they are by no means intended to detract from the merit of our contemporaries, who, by the diſcovery and rapid advancement of this art alone, have, in every ſenſe of the phraſe, really raiſed themſelves above the level of their predeceſſors, and will leave to poſterity a laſting, and perhaps uſeful, memorial of the genius of the preſent age.

Before we begin with the narration of what is recorded relating to the art of flying, it will be uſeful to mention, that the attainment of this object has been attempted by two different means; namely, firſt, by giving motion to artificial wings, either by mechanical combination, or by the immediate ſtrength of a man, in imitation of the birds; and ſecondly, by attaching the human body to ſomething, which, being lighter than air, might raiſe itſelf and the annexed weight into the regions of that element. The latter only of theſe methods has been verified by actual experiments; and the principal of what has been done and is known about it, will be related in this work. As to the former, there is great ſuſpicion, that it will be never brought to any perfection; ſince the ſtrength of a man ſeems inadequate to produce the required effect, and the weight of machines will always be too great in proportion to their effects. Borelli, a Neapolitan mathematician of the laſt century, examined this ſubject with great nicety, and, by a compariſon of the muſcles, which in a bird are employed for flying, to the muſcles of the breaſt and arms of a man, finds the latter to be quite inſufficient to produce, by means of any wings, the motion againſt the air, which is neceſſary to raiſe a man into the atmoſphere *. This learned author, as well

* Borelli on the motion of animals, Chap. xxii.

as

as Leibnitz, formally denied the poſſibility of a man's flying, by any of the means at that time known.

The flight of Abaris round the earth, as related by Diodorus of Sicily; the oracle of the famous temple of Hierapolis, which raiſed himſelf into the air*; the fate of Icarus; and many other ancient ſtories of the like ſort, being, according to the judgment of intelligent perſons, either entirely fabulous, or only alluding to ſomething quite different from real flying, do not deſerve any particular narration, or confutation.

The earlieſt account of any thing relating to flying, which has the appearence of authenticity, is that of Archytas's pigeon. This famous geometrician of Taranto was of the Pythagorean ſchool, and flouriſhed in the fourth century before

* Aliud quoque dicam, quod me præſente fecit. Sacerdotes illum in humeros ſublatum ferebant: ille verò, iis inferiùs in terra relictis, ſolus in aëre ferebatur. Lucian. de Syria Dea.

the Chriſtian æra. Aulus Gellius relates, that Archytas conſtructed a wooden pigeon, which could fly by means of mechanical powers, and by an encloſed ſpirit. His words, tranſlated, are the following:—" It is affirmed by many of " the beſt Grecian writers, and by the " learned philoſopher Favorinus, that " Archytas had conſtructed a wooden " pigeon, which could fly by mechanical " means. To wit, it was thus ſuſpended " by balancing, and was animated by an " occult and encloſed aura of ſpirit*.

It is remarkable, that immediately after theſe words, Aulus Gellius tranſcribes the paſſage of Favorinus, wherein no mention is made of the encloſed ſpirit. " Ar- " chytas," ſays the paſſage, " philoſopher " of Taranto, conſtructed a wooden pi- " geon, which could fly; but if it fell, it " could not lift itſelf up any more."

Much has been ſaid and done, eſpecially

* Aulus Gellius, Noctes Atticæ, Lib. x. cap. xii.

in

in the laſt century, in order to imitate this flying artificial bird, as the reader may gather from the works of father Laurette Laure, Schott, Cardan, Scaliger, Fabri, and Lana: though his curioſity will be ill rewarded for his trouble; thoſe attempts to imitate and to explain Archytas's pigeon, being moſtly errors of too groſs a nature even for the laſt century.

Since the invention of aeroſtatic machines, ſeveral perſons have ſuſpected, that by the *encloſed ſpirit*, in Gellius's paſſage, might poſſibly be underſtood *inflammable* or *rarefied air*, by means of which Archytas's pigeon was rendered lighter than common air; the mechanical artifice ſerving only to let it proceed forward. But various circumſtances, when duly conſidered, ſeem to render this conjecture quite improbable. The bird being made of wood, it muſt have been of an immenſe magnitude, before the exceſs of weight between the encloſed inflammable air, and an equal bulk of common air, could equal the weight of the materials

 employed.

employed. No mention is made of a fire, which, in caſe of rarefied air, was abſolutely neceſſary; nor of any preparation having been uſed previous to the bird's flying, which, if inflammable air was made uſe of, muſt have been too great to eſcape notice. Beſides, if the flying of this artificial bird was executed by ſuch means, the ſimplicity of the principle, when once diſcovered, could have hardly paſſed ſo eaſily into oblivion.

As this machine is ſaid to have repreſented a pigeon, and not the leaſt mention is made of its being of any extraordinary ſize, it is probable, that by the *encloſed ſpirit*, or *aura*, nothing more was meant, than a ſort of animation, which that machine appeared to have been poſſeſſed of in conſequence of its extraordinary mechaniſm; it being very natural to attribute a kind of life to any thing, which moves of itſelf, without the intervention of any other apparent agent, for a certain time; and *aura*, *ſpirit*, or *breath*, having been commonly employed to expreſs life.

In

In Rome, under the reign of Nero, it is ſaid, that a man, by means of artificial wings, elevated himſelf high into the atmoſphere; but that he loſt his life in the enterpriſe. Another very uncircumſtantial account of a man, who was ſeen flying at Rome, is related by Antonius Beyerlink. In ſeveral authors we meet with vague accounts of ſinging and flying artificial birds †. But whilſt oppreſſion and ignorance kept Europe in ſlavery and ſuperſtition, it is no wonder that accounts, generally abſurd, and always doubtful, of flying machines, flying veſſels, flying ſaints, and flying witches, were very common; and the religious hiſtorians, as well as other writers, make frequent mention of them.

Roger Bacon, who lived in the 13th century, and contributed much towards the revival of learning, wrote ſeveral works with freedom of thought, but often with obſcurity. This great man, deſcrib-

† See Caſſiodorus, Michael Glycas, and Con. Manaſſe.

ing,

ing, or rather defcanting on the power of art and nature, fays, "There may be "made fome flying inftruments, fo that "a man fitting in the middle of the inftru-"ment, and turning fome mechanifm, "may put in motion fome artificial wings, "which may beat the air, like a bird fly-"ing." And in the next page he fays, "There is certainly a flying inftrument, "not that I ever knew a man that had "feen it, but I am particularly acquainted "with the ingenious perfon who con-"trived it*."

Thefe paffages have induced feveral perfons to confider Roger Bacon as the inventor of flying machines; but, I hope, my reader will not want a formal refutation of this opinion. Since Bacon, there have not been wanting patrons of the art of flying. Some differtations have been written exprefsly on the fubject; projects of teaching children to fly gradually from their infancy, have been propofed, and various fchemes of artificial wings have

* De Mirabili Poteftate Artis et Naturæ.

been

been actually tried, which, though ſometimes attended with the appearance of partial ſucceſs, on account of the wind, or the largeneſs of the wings, which prevented a precipitate fall; yet they generally ended with the death, or at leaſt with the fracture of the limbs, of the experimenters.

It is related by ſeveral authors *, each of whom muſt have copied the fable from his predeceſſor, that the famous John Muller, commonly called Regiomontanus, at Norimberg made an artificial eagle, which flew to meet the Emperor Charles the fifth, and accompanied him back to the town. What ſhews the abſurdity of this ſtory, is, that Regiomontanus died in the year 1436; whereas Charles the fifth was born in the year 1500. It is likewiſe affirmed, that the ſame author conſtructed an iron fly, which, when let out of his hand, flew to ſeveral places about the room, and afterwards returned to his hand:

* Sixtus biſhop of Ratiſbon, F. Kircher, Porta, Schott, Gaſſendus, Lana, biſhop Wilkins, and others.

but

but the immenſe difficulty of executing ſo great a mechaniſm in ſo narrow a compaſs, and the fly being made of iron, ſeem to ſhew that probably this was only a magnetic trick.

Cuperus, in his treatiſe on the excellence of man, ſays, that the great painter Leonardo da Vinci attained the art of flying; but this fact is by no means authentic.

John Wilkins, Lord Biſhop of Cheſter, who died in the year 1672, in his Diſcovery of the New World, and in the 14th propoſition, ſays, "It is a pretty notion "to this purpoſe, mentioned by *Albertus* "*de Saxonia*, and out of him by *Francis* "*Mendoca*; that the air is in ſome part of "it navigable; and that upon this ſtatick "principle, any braſs or iron veſſel (ſup"poſe a kettle) whoſe ſubſtance is much "heavier than that of the water; yet be"ing filled with the lighter air, it will "ſwim upon it, and not ſink. So ſup"poſe a cup, or wooden veſſel, upon the "outward borders of this elementary air, "the

"the capacity of it being filled with fire, "or rather æthereal air, it muſt neceſ-"ſarily, upon the ſame ground, remain "ſwimming there, and of itſelf can no "more fall, than an empty ſhip can "ſink."

But in his *Dedalus*, or treatiſe on mechanical motions, he treats expreſsly of the art of flying; and it ſeems proper to tranſcribe in this place ſome of his moſt remarkable paſſages, in order to remove the falſe notions of ſeveral perſons, who imagine that biſhop Wilkins knew the art of flying. In the 6th chapter of the above-mentioned treatiſe, he ſays, "*Sca-"liger* conceives the framing of ſuch vo-"litant *automata* to be very eaſy. *Vo-"lantis columbæ machinulam, cujus autorem "Archytam tradunt, vel facillimè profiteri "audeo.* Thoſe ancient motions were "thought to be contrived by the force "of ſome included air: So *Gellius, Ita "erat ſcilicet libramentis ſuſpenſum, et aurâ "ſpiritûs incluſâ atque occultâ conſitum,* "&c.

" &c. As if there had been ſome lamp,
" or other fire, within it, which might
" produce ſuch a forcible rarefaction as
" ſhould give a motion to the whole
" frame.

" But this may be better performed by
" the ſtrength of ſome ſuch ſpring as is
" commonly uſed in watches. This ſpring
" may be applied unto one wheel, which
" ſhall give an equal motion to both the
" wings; theſe wings having unto each of
" them another ſmaller ſpring, by which
" they may be contracted and lifted up:
" ſo that being forcibly depreſſed by the
" ſtrength of the great and ſtronger ſpring,
" and lifted up again by the other two;
" according to this ſuppoſition, it is eaſy
" to conceive how the motion of flight
" may be performed and continued."

In his 7th chapter he enumerates four different ways whereby flying in the air hath been or may be attempted; namely: 1. by ſpirits or angels; 2. by the help of of fowls; 3. by wings faſtened immediately to the body; and 4. by a flying chariot.

I need not ſay a word about the firſt of thoſe methods. As for the ſecond, the high degree of improbability will eaſily occur to any thinking perſon. Relating to the others, ſomething has been already mentioned, and more will be ſaid in the courſe of this work. Biſhop Wilkins thus expreſſes himſelf about them: " It is the " more obvious and common opinion, " that this may be effected by wings " faſtened immediately to the body, this " coming neareſt to the imitation of na- " ture, which ſhould be obſerved in ſuch " attempts as theſe. This is that way, " which *Fredericus Hermannus*, in his " little diſcourſe *de arte volandi*, doth only " mention and inſiſt upon; and if we may " truſt credible ſtory, it hath been fre- " quently attempted, not without ſome " ſucceſs. 'Tis related of a certain Engliſh " monk, called Elmerus, about the Con- " feſſor's time, that he did by ſuch wings

" fly from a tower above a furlong; and
" ſo another from St. *Mark*'s ſteeple in
" *Venice*; another at *Norimberg*; and *Buſ-*
" *bequius* ſpeaks of a *Turk* in *Conſtantino-*
" *ple*, who attempted ſomething this way.
" Mr. *Burton*, mentioning this quotation,
" doth believe that ſome new-fangled wit
" ('tis his cynical phraſe) will ſome time
" or other find out this art. Though
" the truth is, moſt of theſe artiſts did un-
" fortunately miſcarry, by falling down,
" and breaking their arms or legs, yet
" that may be imputed to their want of
" experience, and too much fear, which
" muſt needs poſſeſs men in ſuch dange-
" rous and ſtrange attempts. Thoſe things
" that ſeem very difficult and fearful at
" the firſt, may grow very facil after fre-
" quent trial and exerciſe: and therefore
" he that would effect any thing in this
" kind, muſt be brought up to the con-
" ſtant practice of it from his youth; try-
" ing firſt only to uſe his wings, in run-
" ning on the ground, as an oſtrich or
" tame gooſe will do, touching the earth
" with his toes; and ſo by degrees learn
" to

" to riſe higher, till he ſhall attain unto " ſkill and confidence. I have heard it " from credible teſtimony, that one of " our own nation hath proceeded ſo far in " this experiment, that he was able, by " the help of wings, in ſuch a run- " ning pace, to ſtep conſtantly ten yards " at a time."

And he concludes the chapter with the following words: " But now, becauſe " the arms extended are but weak, and " eaſily wearied, therefore the motions by " them are like to be but ſhort and ſlow, " anſwerable, it may be, to the flight of " ſuch domeſtic fowl as are moſt conver- " ſant on the ground, which of them- " ſelves we ſee are quickly weary; and " therefore much more would the arm of " a man, as being not naturally deſigned " to ſuch a motion.

" It were therefore worth the enquiry, " to conſider whether this might not be " more probably effected by the labour of " the feet, which are naturally more

" ſtrong and indefatigable: in which con-
" trivance, the wings ſhould come down
" from the ſhoulders on each ſide, as in
" the other, but the motion of them
" ſhould be from the legs, being thruſt
" out, and drawn in again, one after ano-
" ther, ſo as each leg ſhould move both
" wings; by which means a man ſhould
" (as it were) walk or climb up into the
" air; and then the hands and arms might
" be at leiſure to help and direct the mo-
" tion, or for any other ſervice propor-
" tionable to their ſtrength. Which con-
" jecture is not without good probability,
" and ſome ſpecial advantages above the
" other.

" But the fourth and laſt way ſeems unto
" me altogether as probable, and much
" more uſeful than any of the reſt. And that
" is by a flying chariot, which may be ſo
" contrived as to carry a man within it;
" and though the ſtrength of a ſpring might
" perhaps be ſerviceable for the motion
" of this engine, yet it were better to have
" it aſſiſted by the labour of ſome intelli-

" gent

"gent mover, as the heavenly orbs are "ſuppoſed to be turned. And therefore, if "it were made big enough to carry ſundry "perſons together, then each of them in "their ſeveral turns might ſucceſſively "labour in the cauſing of this motion; "which thereby would be much more "conſtant and laſting, than it could other-"wiſe be, if it did wholly depend on the "ſtrength of the ſame perſon. This con-"trivance being as much to be preferred "before any of the other, as ſwimming in "a ſhip before ſwimming in water."

The frequent mention of this author's ſuppoſed knowledge of the art of flying, and the difficulty of finding copies of his book, has made me tranſcribe ſo much of it, as, I think, is more than ſufficient to ſhew, that Wilkins's vague diſcourſe not only contains nothing preciſe about flying, but ſeems incapable even to furniſh any hints uſeful to a rational ſchemer.

One John Baptiſt Dante, towards the middle of the laſt century, is ſaid to have framed certain wings, by means of which he flew ſeveral times, but at laſt had the misfortune of breaking one of his thighs in an attempt of that ſort *. In the *Journal des Savans* of the 12th September 1678, mention is made of one Beſnier, who conſtructed four wings, which he attached to his body, and by moving them with his own ſtrength alone, he could deſcend from an eminence very gently and obliquely on the ground; ſo that by this means one might paſs over a river, or ſuch like ſpace, when he has the opportunity of a contiguous eminence †.

Amongſt the projectors of flying machines, of the laſt century, the only perſon who grounded his ſcheme upon ſolid principles, is the Jeſuit Francis Lana ‡; and though the conſtruction of his flying machine was never, and perhaps will never,

* See Bourgeois's Recherches ſur l'Art de Voler.

† See alſo the Phil. Tranſactions, No. 1. p. 15.

‡ See the ſixth chapter of his *Prodromo, o ſaggio di alcune invenzioni nuove premeſſo all' arte maeſtra. Breſcia*, 1670.

be

be executed, on account of ſeveral practical impediments, and becauſe the late diſcoveries afford methods incomparably ſuperior to it; yet his reaſoning and his thoughts are deſerving of notice. The writers of that age, who treated on the art of flying, propoſed ſchemes either entirely hypothetical, or without any deſcription and calculation of particulars. Thus we find it directed to fill a great many egg-ſhells with dew; for, as the ſun rarefies, and conſequently elevates the dew; ſo the egg-ſhells, when expoſed to that luminary, would riſe, together with ſome other weight that might be attached to them, in conſequence of the dew, which they contained, being rarefied. We find it likewiſe aſſerted, that if a veſſel were placed upon the limit of our atmoſphere, and were filled with fire or ethereal air, it would ſwim like a veſſel upon water, which is filled with air *; for then it was believed by ſome, that the elementary fire was placed over the atmoſphere, which was thought to have a well-defined

* This is analogous to what is mentioned by Biſhop Wilkins in the above-tranſcribed paſſages.

limit; ſo that the atmoſphere of fire was imagined to ſtand over the aerial atmoſphere, in the ſame manner as the aerial atmoſphere ſtands over the water of the ſea*. But the judicious Lana, conſidering the real weight of the atmoſphere, juſtly infers, that a globular veſſel (and indeed a veſſel of any other form) exhauſted of air, would weigh leſs than when filled with that fluid. He alſo conſidered, and it is mathematically true, that the capacity of ſpherical veſſels increaſes much faſter than their ſurface; ſo that if there are two ſpherical veſſels, the diameter of one of which is half the diameter of the other; then the capacity of the latter is equal to eight times the capacity of the former, whereas the ſurface of the latter is only equal to four times the ſurface of the former: and if we take a ſphere, the diameter of which is three times that of another ſphere; then its capacity will be twenty-ſeven, and its ſurface will be nine times, that of the other.

* Albert de Saxe, F. Mendoca, Schott, and F. Gallien, in his work, entitled *L'Art de Naviger dans les Airs, Amuſement phiſique & geometrique, &c.* publiſhed at Avignon in the year 1755.

From

From this demonſtrated principle, F. Lana deduces, that it is poſſible to make a ſpherical veſſel of any given matter, and thickneſs, and of ſuch a ſize, as, when emptied of air, it will be lighter than an equal bulk of atmoſpherical air, and will aſcend, together with any additional weight, into that element. After ſtating theſe demonſtrated principles, F. Lana makes the calculations neceſſary to determine the ſize of four globular veſſels of copper, which, when emptied of air, might take up into the atmoſphere a veſſel with paſſengers, &c. to which they are faſtened by ropes.—I need not tranſcribe thoſe calculations in this place; ſince the truth of the theory, and, at the ſame time, the difficulty attending the execution of ſuch a ſcheme, will eaſily occur to any ingenious perſon.

A letter, dated Liſbon, the 10th of February, 1784, which was lately publiſhed in France, contains the copy of an addreſs preſented to the king of Portugal, in the year 1709, by a friar called Bartholomew Laurence de Guſman; in which the petitioner reprefents his having invented a flying machine, capable of carrying paffengers, and of navigating through the air very fwiftly; and he requefts the privilege of being the fole poffeffor of fuch machine, prohibiting any other perfon to conftruct a machine of the like nature, under fome penalty, &c. In confequence of which petition, the king was pleafed to grant the following order:

"Agreeably to the advice of my council,
" I order the pain of death againft the
" tranfgreffor. In order to encourage the
" fuppliant to apply himfelf with zeal
" towards improving the new machine,
" which is capable of producing the effects
" mentioned by him, I grant unto him
" the firft vacant place in my college of
" Barcelos or Santarem, and the firft pro-
" fefforfhip of mathematics in my Uni-
" verfity of Coimbra, with the annual
" penfion of 600,000 reis, during his life.
" Lifbon, the 17th of April, 1709.

The defcription and drawing of this intended

tended machine is of so strange and romantic a nature, that it will be hardly necessary to add, that it was never afterwards seen or heard of. The drawing represents a vessel somewhat in the shape of a bird; and the description says that it contained several tubes, through which the wind was to pass, in order to swell a kind of sails, and thus was to elevate the machine; which effect, when the wind was wanting, was to be produced by bellows concealed within the body of the machine.—To a sort of canopy spread over the vessel, several pieces of amber were attached, which were intended to pull upwards the lower part of the machine. Two magnets were also enclosed in two spheres.—But it is useless to dwell any longer on such childish absurdities.

Mr. D. Bourgeois, in his *Recherches sur l'Art de Voler*, asserts, that in the abovementioned account, *De Gusman* is wrongly annexed to *Bartholomew Laurence*, they being two distinct persons; to wit, *Bartholomew Laurence*, the person who presented the petition, &c. and *De Gusman*, another

another perſon; of whom he relates the following remarkable ſtory:—It is ſaid, that in the year 1736, De Guſman made a wicker baſket, of about ſeven or eight feet in diameter, and covered with paper, which baſket elevated itſelf as high as the tower of Liſbon, which is about 200 feet high. The ſame author adds, that he received this account from a very creditable perſon, who had been preſent at the experiment; but that, for better confirmation of it, he wrote to a diſtinguiſhed merchant of Liſbon; who anſwered him, that the fact was true, and that many perſons ſtill remembered it, though they attributed it to witchcraft.

It is remarkable, that a Portugueſe book, entitled *Phyſical Recreations*, publiſhed by Joſeph Francis d' Almeida, in the year 1751, contains a dialogue on the art of flying; and yet it takes no notice of either of the two above-mentioned accounts of *Laurence* and *De Guſman*.

The accounts of ſeveral other ſtories ſtill more abſurd, and of ſtrange projects never verified, might have been inſerted in this chapter; but thoſe already related may ſuffice to ſhew the reader, that, before the preſent age, nothing uſeful nor certain had been done relative to the art of flying; and that thoſe attempts, of which pretty authentic records are extant, ſerved only to ſhew, that to fly by mechanical means was next to impoſſible; beſides which no other method was known with certainty, or even with any reaſonable probability.

The art of navigating through the air has been at laſt diſcovered, and it has ſucceeded on two principles; to wit, on the ſpecific gravity of inflammable air, which is much lighter than common atmoſpheric air of the ſame temperature; and on the ſpecific gravity of heated air, which is lighter than air of the ſame ſort when colder. It ſeems therefore neceſſary to begin the hiſtory of this wonderful invention, with the account of the diſcovery of theſe two principles.

The weight and elaſticity of the air was known to the ancient philoſophers, as may be deduced from ſeveral paſſages in their works*. Borelli relates an experiment of a Florentine, called Candido Buono, which ſhews that air rarefied by heat becomes lighter, and aſcends amidſt the colder air. This eaſy, and at the ſame time ſatiſfactory experiment, conſiſts in bringing a red-hot iron under one of the ſcales of a balance, when that inſtrument hangs in equilibrio; for as ſoon as the red-hot iron is brought under one of the ſcales, the air heated and rarefied by it will aſcend, and will impel the ſaid ſcale upwards, the oppoſite ſcale deſcending as if a weight were put into it. Theſe properties, in proceſs of time, gave origin to ſeveral uſeful inſtruments; as the ſyphon, the air-gun, the baro-

* Ariſtotle de Cœlo. "In ſua enim regione omnia gravitatem habent præter ignem, aër ipſe; ſignum autem eſt, utrem inflatum plus ponderis, quam vacuum habere." See alſo Stobæus's Eclog. Phyſ. Plutarch. de Placitis, lib. i. cap. 12. Galen's Hiſt. Philoſ. de Reſpiratione. Heron's, the Alexandrine, Spiritalia. Cteſibius. Philo the Byzantine. Seneca's Quæſt. Nat. lib. v. and vi.

meter, &c. But ſince the invention of the air-pump, which was made towards the middle of the laſt century, the air's weight and expanſibility, either by means of fire or by a removal of the preſſure, have been ſhewn in an endleſs variety of ways, firſt by the indefatigable Mr. Boyle, and afterwards, with more accuracy, by many other obſervers, who were furniſhed with better inſtruments. It has been aſcertained—1ſt, That a quantity of air contracts itſelf in exact proportion to the preſſure it ſuſtains; ſo that by doubling the preſſure, a quantity of air will be contracted into half the ſpace it occupied before; by trebling the preſſure, it will be contracted into one third part of that ſpace; and, on the contrary, if half the preſſure, which confines a quantity of air into a certain ſpace, is removed, that air will expand itſelf into a ſpace, which is double the former; and ſo on.—2dly, That heat expands, and cold contracts, the air; though not near ſo much as can be effected by adding or removing the preſſure; the heat of quite red-hot iron expanding a quantity of air into a ſpace, which is barely four times the ſpace it it occupies naturally in a temperate degree of heat. One degree of heat, according to the ſcale of Farenheit's thermometer, ſeems to expand the air about one five hundredth part.—And, 3dly, That in a mean temperature and gravity of the atmoſphere, near the ſurface of the earth, the weight of air, compared to the weight of water, is as 1 to 840; ſo that a cubic inch of air in that ſtate weighs about $\frac{301}{1000}$ parts of a grain.

As for the inflammable air, its exiſtence was known many years ago, eſpecially to miners, who had frequently experienced the fatal effects of its combuſtion in ſubterraneous places; but Mr. Henry Cavendiſh was the firſt perſon, who aſcertained with exactneſs the weight, as well as other properties, of it; an account of which obſervations is publiſhed in the 56th vol. of the Philoſophical Tranſactions, for the year 1766. This learned philoſopher obſerved, that inflammable air is, at leaſt, ſeven times lighter than common air*.

Soon

* "If common air" ſays he, "is 800 times lighter "than water, then inflammable air is 5490 times "lighter than water, and ſeven times lighter than "common

Soon after this diſcovery of Mr. Cavendiſh, it occurred to the ingenious Dr. Joſeph Black, of Edinburgh, that a veſſel might be made, which, when filled with inflammable air, might aſcend into the atmoſphere, in conſequence of its being altogether lighter than an equal bulk of common air. This idea of the Doctor's has been mentioned to me by two or three different perſons; but lately the Doctor himſelf wrote a candid account of it to Dr. James Lind, Phyſician at Windſor: and here follows part of the letter, which I have permiſſion to publiſh.

"Edinburgh, the 13th Nov. 1784."

"Dear Sir,

"The perſon who firſt diſcovered with "exactneſs the ſpecific gravity of inflamma-"ble air, was, ſo far as I know, Mr. Caven-"diſh: I never heard of any experiments "made with that intention, before his ap-

"common air; but if common air is 850 times light-"er than water, then inflammable air is 9200 times "lighter than water, and 10,8 times lighter than "common air." Becauſe he found that an empty bladder weighed 41 grains more than when it contained 80 meaſures of inflammable air.

"peared

" peared in the Philofophical Tranfactions
" for the year 1766. It had been my
" conftant practice before, to fhew, every
" year, in what manner it burns when pure
" or unmixed with air, and how it explodes
" when air is mixed with it before it is
" fired; but Mr. Cavendifh made a variety of
" fuch mixtures by rule and meafure, and
" defcribes in the fame paper the manner in
" which they feverally explode. As foon as
" I read the above paper, it occurred to me,
" as an obvious confequence of Mr. Caven-
" difh's difcovery, that if a fufficiently thin
" and light bladder were filled with inflam-
" mable air, the bladder, and air in it, would
" neceffarily form a mafs lighter than the
" fame bulk of atmofpheric air, and which
" would rife in it; this I mentioned to
" fome of my friends, and in my lectures,
" the next time I had occafion to fpeak of
" inflammable air, which was either in
" the year 1767 or 1768; and, as I thought
" it would be an amufing experiment for
" the ftudents, I applied to Dr. Monro'
" diffector, to prepare for me the allantois
" of a calf. The allantois was prepared
" but

"but not until after ſome time had paſſed, "and when I was engaged with another part "of my courſe, and did not chooſe to interrupt the buſineſs then going on; ſo I "dropped the experiment for that year, "and in the ſubſequent years I only mentioned the thing as an obvious and ſelf-evident conſequence of Mr. Cavendiſh's "diſcovery; but finding generally ſome "difficulty in providing an allantois at the "proper time, I never made the experiment, "which I conſidered as merely amuſing. "About two months ago I was informed, "by a gentleman in the ſouth of Ireland, "that he had tried it, and that it ſucceeds "perfectly well."

It appears from this letter, that Dr. Black never actually tried the experiment; nor do I know that any other perſon attempted it, before my experiments on this ſubject, which were made in the year 1782. The poſſibility of conſtructing a veſſel, which, when filled with inflammable air, would aſcend into the atmoſphere, had occurred to me when I firſt began to ſtudy the ſubject

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of air and other permanently elaſtic fluids, which was about eight years ago; but early in the year 1782 I actually attempted to perform this experiment; and the only ſucceſs I had, was to let ſoap-balls, filled with inflammable air, aſcend by themſelves rapidly into the atmoſphere; which was perhaps the firſt ſort of inflammable-air balloons ever made. I failed in ſeveral other attempts of the like nature; and, at laſt, being tired with the expences and loſs of time, I deferred to ſome other time the proſecuting of thoſe experiments, and contented myſelf with giving an account of what I had done to the Royal Society, which was read at a public meeting of the Society on the 20th of June 1782. The following is an exact copy of that part of the ſaid account, which relates to the preſent ſubject.

An Account of Experiments relating to the property of common and inflammable air pervading the pores of paper.

It has been commonly believed, that common air would not pervade the pores of of paper, ſuch as is uſed for common printing, or writing; and, that paper is permeable to water, and not to air, has been alledged by ſome perſons as an inſtance tending to prove, that ſome fluids have the property of paſſing through certain ſubſtances, and others have it not; although the particles of the former are of a groſſer, heavier, or more tenacious nature towards each other.

Admitting, according to the common notion, this impermeability of paper to common air, and preſuming that it was impervious to other permanently elaſtic fluids alſo, I determined to make uſe of paper for an experiment; which, though repeatedly attempted with other ſubſtances, had never ſucceeded. The experiment was, to conſtruct a veſſel, or ſort of bag, which, when inflated with inflammable air, might be lighter than an equal bulk of common air, and conſequently might aſcend, like ſmoke, into the atmoſphere; it being well known, that inflammable air is ſpecifically lighter than common air.

The weight of inflammable air, the mean weight of atmoſpheric air, and the weight of the ſubſtance of which the veſſel is to be formed, being aſcertained; it is eaſy thence to determine, by calculation, the dimenſions of a veſſel, which, when filled with inflammable air, might be lighter than an equal bulk of atmoſpheric air. In this manner, and for the above-mentioned purpoſe, I tried bladders, the thinneſt and largeſt that could be procured. Some of them were cleaned with great care, removing from them all the ſuperfluous membranes, and other matter, that could be poſſibly ſcraped off; but, notwithſtanding all theſe precautions, the lighteſt and largeſt of theſe prepared bladders being gaged, and the requiſite calculation made, it was found, that, when filled with inflammable air, it would be, at leaſt, ten grains heavier than an equal bulk of common air, and conſequently it would deſcend, inſtead of aſcending, in that element.—Some ſwimming bladders of fiſhes were alſo found too heavy for the experiment; nor could I ever ſucceed to make any durable light balls

by

by blowing inflammable air into a thick ſolution of gums, thick varniſhes, and oil paint. In ſhort, ſoap-balls, inflated with inflammable air, were the only things of this ſort, that would aſcend into the atmoſphere; but as they are very brittle, and altogether untractable, they do not ſeem applicable to any philoſophical purpoſe.

As various of my acquaintances, in attempting to make ſuch ſoap-balls with inflammable air, have not ſucceeded, it ſeems not improper briefly to ſubjoin, in this place, the mention of thoſe particulars, which may facilitate the performance of this diverting experiment.

The method by which I am more certain to ſucceed in this experiment, is— 1ſt. To introduce the inflammable air into a bladder that has a glaſs tube tied to its neck. For this purpoſe, a perforated cork is adapted to a bottle, containing the materials which produce the inflammable air; then the glaſs tube of the bladder is thruſt-ed into the perforation of the cork; but, previous to this operation, the common air muſt be expelled as much as poſſible. Thus the inflammable air, as it is yielded by the materials in the bottle, enters and ſwells the bladder.—The glaſs tube of the bladder ſhould be about five or ſix inches long, its aperture ſhould not exceed one tenth of an inch in diameter; the ſubſtance of the glaſs ſhould be rather thick, and the extremity of it muſt be made very ſmooth, by means of a lamp and blow-pipe; for if the tube has any ſharp edges, it is almoſt impoſſible to make any ſoap-balls with it.—2dly. When the bladder is full of inflammable air, its neck is compreſſed, juſt below the extremity of the glaſs tube, in order to prevent the eſcape of the inflammable air, and the glaſs tube is withdrawn from the cork of the bottle. Now the end of this tube, being dipped into a thick ſolution of ſoap (Windſor ſoap anſwers very well), the neck of the bladder is looſened, and by compreſſing the bladder, the inflammable air is forced out of it, and it makes a ſoap-ball, which when it becomes of about two

or

or three inches in diameter, if diſengaged from the glaſs tube, by gently ſhaking it, will aſcend into the air, and will break againſt the ceiling of the room. When one ſoap-ball has been made, the neck of the bladder is immediately preſſed, to prevent the loſs of inflammable air; the end of the tube is dipped again into the ſolution of ſoap, and another ball is made. Thus with a large ox bladder full of inflammable air, more than twenty ſoap-balls may be made, provided the experiment is performed with care.

As the ſoap-balls are much more brittle when made with inflammable, than when made with common air, great attention ſhould be had to avoid all the cauſes, which may occaſion them to break: on which account the experiment ſhould be performed in a room wherein the air is agitated as little as poſſible. The ſoap-ball muſt be made by very ſmall degrees; viz. by compreſſing and letting the inflammable air out of the bladder very ſlowly. The extremity of the glaſs tube ſhould at firſt be kept inclined downwards, and then ſhould be gradually turned upwards, becauſe thoſe ſoap-balls are at firſt heavier than common air, hence they tend downwards; but, when they are become of a certain ſize, they become lighter than an equal bulk of atmoſpheric air, and turn gradually upwards; in which caſe, if the glaſs tube is not turned upwards alſo, the ſoap-ball ſoon breaks.—Thus far of the conſtruction of ſoap-balls lighter than common air.

Amongſt various attempts for the performance of the above-mentioned experiment, I thought of trying paper; by means of which, it ſeemed that a veſſel or bag might be eaſily made, which, when filled with inflammable air, would be lighter than common air. Accordingly, having procured ſome fine China paper, its weight was aſcertained, and, after making the neceſſary calculation, a veſſel or bag of a cylindrical ſhape, terminated by two ſhort cones, was made of ſuch dimenſions, as, when inflated with inflammable air, it muſt have been lighter than an equal bulk of common

common air, by at leaſt twenty-five grains; conſequently, it muſt have aſcended, like ſmoke, into the atmoſphere.

After trying this paper veſſel by inflating it with common air, the uſual mixture of iron filings, and diluted vitriolic acid, for the production of inflammable air, was put into a large bottle; and, by means of a glaſs tube adapted to the neck of the bottle, and likewiſe to the aperture of the paper bag, which was ſuſpended over the bottle, and out of which the common air had been expelled by compreſſion, the inflammable air, as ſoon as it was produced, was made to enter the veſſel: but I was ſurpriſed to obſerve, that, notwithſtanding the production of inflammable air was very copious, the paper veſſel was not inflated in the leaſt, and the ſmell of the inflammable air in the room was very ſtrong. Suſpecting that a hole in the paper might give exit to the inflammable air, the whole apparatus was attentively examined, the efferveſcing mixture was renewed, and every precaution, I could think of, was taken; but, after

after all, nothing else could be concluded, but that the inflammable air passed through the pores of paper, just like water through a sieve. After this observation, it was necessary to examine that property with more accuracy, and by more decisive trials; and for this purpose the following experiments were made, &c.

CHAPTER II.

Messrs. Montgolfier's discovery of the Aerostatic machine, or rarefied-air Balloon.

THE various accounts of Montgolfier's discovery of the aerostatic machine, mostly written with haste soon after its date, are far from giving complete satisfaction relative to the private experiments, which were made previous to the public experiment of the 5th of June 1783; but, as every account records some particular circumstance, I have taken from each, what seemed interesting, which, joined to the verbal relation of of persons acquainted with the inventors, have furnished the materials for this account.

It is said, that the two brothers, Stephen and John Montgolfier, began to think on the experiment of the aerostatic machine as early as the middle or latter end of the year 1782. The natural ascension of the smoke and the clouds in the atmosphere suggested the first idea; and to imitate those bodies, or to enclose a cloud in a bag, and let the latter be lifted up by the buoyancy of the former, was the first project of those celebrated gentlemen.

Stephen Montgolfier, the eldest of the two brothers, made the first aerostatic experiment at Avignon, towards the middle of November 1782. The machine consisted of a bag of fine silk, in the shape of a parallelopipedon, the capacity of which was equal to about 40 cubic feet. Burning paper applied to its aperture served to rarefy the air, or to form the cloud; and when this was sufficiently expanded, the machine ascended

cended rapidly to the ceiling *. Thus the diſcovery was made; and the reader may imagine the ſatisfaction it muſt have given to the inventor.

A ſhort time after this firſt attempt, Mr. Montgolfier, being returned to *Annonay*, a town in the *Vivarais*, about 36 miles diſtant from Lyons, was ſolicitous to repeat the experiment in the open air. Accordingly he, in company with his brother, repeated the experiment with the ſame machine, which aſcended to the height of about 70 feet.

Encouraged by the ſucceſs of theſe two attempts, the ingenious brothers reſolved to make the experiment more at large; and for this purpoſe they conſtructed a machine, the capacity of which was equal to about 650 cubic feet. The experiment with it anſwered ſo well, that the aeroſtat broke the ropes which confined it, and, after aſcending rapidly to the height of about 600 feet, it fell on the adjoining ground.

* See Le Rapport fait a l'Academie des Sciences, December the 23d, 1783, ſigned by ſeveral members.

Soon after this, they conſtructed another machine of the like ſort, but much larger; its diameter being 35 feet. With this machine they attempted to make the experiment on the third of April 1783; but were hindered by the violence of the wind. On the 25th of the ſame month, the weather being more favourable, they made a ſecond attempt, which anſwered exceedingly well. The machine had ſuch force of aſcenſion, that, eſcaping abruptly from its confinement of ropes, it roſe to the height of above 1000 feet, and, being carried by the wind, it fell at the diſtance of about three quarters of a mile from whence it had been launched.

At laſt, on the 5th of June, this ſingular experiment, with the ſame machine, was repeated in the preſence of a reſpectable aſſembly, and a great multitude of people. This public experiment, recorded with all the accuracy it deſerves, was immediately announced to the world; accounts of it having been immediately ſent to the court of France, to ſeveral members of the Academy of Sciences, and almoſt wherever lite-

rary

rary and entertaining correſpondence could reach.

The particular account of this exhibition is as follows:—On Thurſday the 5th of June 1783, the States of Vivarais, being aſſembled at Annonay, Meſſrs. Montgolfier invited them to ſee their new aeroſtatic experiment. An immenſe bag of linen lined with paper, and of a ſhape nearly ſpherical, had its aperture, which was on its inferior part, attached to a wooden frame of about 16 feet ſurface, upon which it laid flaccid like an empty linen bag. When this machine was inflated, it meaſured 117 Engliſh feet in circumference. Its capacity was equal to about 23,430 cubic feet; and it had been calculated, that when filled with the vapour proper for the experiment, it would have lifted up about 490 pounds weight, beſides its own weight, which, together with that of the wooden frame, was equal to 500 pounds; and this calculation was found to be pretty true by experience. The bag was compoſed of ſeveral parts, which were joined together by means of buttons

buttons and holes; and it is ſaid, that two men were ſufficient to prepare and to fill it; though eight men were required to prevent its aſcenſion when full.

Meſſrs Montgolfier began the operation of filling the machine, which was done by burning ſtraw and chopped wool under its aperture; and the ſpectators were told, that this bag would be ſoon ſwelled into a globular form, after which it would aſcend by itſelf as high as the clouds. The expectations of the whole aſſembly, the incredulity of ſome, the predictions of others, and the confuſion of opinions, may be eaſily imagined, eſpecially by thoſe who have been preſent at experiments of this nature when the certainty of the ſucceſs had been well eſtabliſhed.—The machine, however, immediately began to ſwell, ſoon acquired a globular form, ſtretched on every ſide, made efforts to mount, and at laſt, the ſignal being given, the ropes were ſet free, and the aeroſtat aſcended with an accelerated motion into the atmoſphere; ſo that in about ten minutes time it had reached the height of about 6000 feet.—The diſcordant minds of the ſpectators were inſtantly brought to an equal ſtate of ſilent aſtoniſhment, which ended in loud and unfeigned acclamations, due to the genius, and moſtly to the ſucceſs, of Stephen and John Montgolfier.

The aeroſtatic machine, after having attained the above-mentioned elevation, went in an horizontal direction to the diſtance of 7668 feet, and then fell gently on the ground.

The hiſtory, which records the diſcovery and improvements of an art or ſcience, though not intended to deſcribe the lives of thoſe, who contributed towards its advancement, ſhould nevertheleſs take ſome notice at leaſt of the firſt diſcoverers: in fact, we regret, that the inventors of printing, of gun-powder, of the ſea-compaſs, &c. are not more preciſely known, or their lives more particularly recorded. It ſeems, therefore, proper to conclude this chapter with a ſhort account of the Montgolfiers.

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IT is reported, that they are natives of Annonay, and that in their youth the former had aſſiduouſly ſtudied the mathematics, but the latter had attended to natural philoſophy and chymiſtry. They were not intended for any particular way of buſineſs, but the death of a brother obliged them to put themſelves at the head of a conſiderable paper manufactory at Annonay. In the intervals allowed by their buſineſs they applied themſelves to ſeveral philoſophical purſuits; but it does not appear, that the philoſophical world had ever heard their names before the diſcovery of the aeroſtatic machine. It would be perhaps impoſſible, and uſeleſs, to know all the particular ſteps and ideas, which finally produced this diſcovery; but it ſeems, that the real principle, upon which the effect of the aeroſtatic machine depended, was unknown even for a conſiderable time after its diſcovery. Mr. Montgolfier attributed the effect of the machine, not to the rarefaction of the air, which is the true cauſe; but to a certain *gas*, ſpecifically lighter than common air, which was ſuppoſed to be developed from burning ſubſtances, and which was commonly called Mr. Montgolfier's gas, eſpecially in the affidavit of the firſt voyage, that a human being ever made in an aeroſtatic machine, which was ſigned by the Dukes of Polignac and de Guines, the Counts de Polartron and de Vaudreuil, Dr. Franklin, and Meſſrs. Faujas, Deliſle, and Le Roy of the Academy of Sciences. Beſides, Mr. Montgolfier's projects to effect this experiment, as his idea of an artificial cloud, of the effect of electricity, &c. * ſhew that this diſcovery, though the honour of it is undoubtedly due to the Montgolfiers, or at leaſt to the eldeſt of the brothers; yet it was made by very indirect ways. But this obſervation is of no diſcredit to the inventors, ſince it has been the fate of almoſt every diſcovery of importance, to have been accompliſhed either undeſignedly, or by very improper ſteps.

* See his Diſcourſe, read at the Academy of Sciences and Belles Lettres of Lyons, in November 1783.

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CHAPTER III.

The Invention of the Inflammable-air Balloon.

NO ſooner had the news of Montgolfier's aeroſtatic experiment reached Paris, than the ſcientific people of that metropolis began to think of repeating ſo ſingular an experiment. The certificate tranſmitted from Annonay, by the States of Vivarais, mentioned that Meſſrs. Montgolfiers had filled their machine with a ſpecies of gas, which was half as heavy as common air; but without any farther ſpecification. In conſequence of which, the philoſophers of Paris imagined, that a new ſort of gas had been diſcovered by the Montgolfiers, of which they were utterly ignorant, and concluded it could not be inflammable air, that being incomparably lighter; its weight being about the eighth or tenth part of the weight of common air; and beſides, it would have been very difficult to produce ſo great a quantity of inflammable air as muſt have been wanted for that experiment. But if a gas half as heavy as common air produced the effect, they juſtly concluded, that inflammable air would anſwer much better, and immediately reſolved to try the experiment with inflammable air. Accordingly a ſubſcription was immediately opened by Mr. Faujas de Saint-Fond, to defray the expences attending the experiment. Meſſrs. Roberts were appointed to conſtruct the machine, and Mr. Charles, profeſſor of experimental philoſophy, was appointed to ſuperintend the work, which was to be begun as ſoon as a ſufficient ſum of money was collected.

This project being immediately known, perſons of every rank ran with eagerneſs to ſign their names; ſo that the required ſum was raiſed with a quickneſs, which does honour to the French nation, and to the ſcientific ſpirit of the preſent age.

The obſtacles, which oppoſed the accompliſhment

compliſhment of this, as they do of any firſt attempt, were many indeed; but the two principal difficulties were, to produce a large quantity of inflammable air, and to find a ſubſtance ſufficiently light to make the bag of, and, at the ſame time, impermeable to the inflammable air. At laſt they conſtructed a globular bag of a ſort of ſilk ſtuff called *luteſtring*; which, in order to render it impervious to the inflammable air, was varniſhed with a certain varniſh, ſaid to conſiſt of diſſolved elaſtic gum (*caoutchouc*). The diameter of this bag, which, from its ball-like ſhape, was called a *Balloon*, and gave the name of air-balloons to thoſe flying machines in general, was twelve feet two inches French, or about thirteen feet Engliſh meaſure. It had only one aperture, like a bladder, to which a ſtop-cock was adapted. The weight of the balloon, when empty, together with the ſtop-cock, was twenty-five pounds.

On the 23d of Auguſt, 1783, the balloon being completed, they attempted to fill it with inflammable air; but they met with a great deal of difficulty and disappointment, the particular account of which will serve to shew how far this process has been improved, in so short a period as is elapsed between the filling of this first inflammable-air balloon and the present time.

The balloon being suspended at some distance from the earth, by means of a rope fastened to its top, which was the part diametrically opposite to the stop-cock, at eight o'clock in the morning the operation was begun; having first expelled, by compression, all the common air from the balloon. The mixture of iron filings and diluted vitriolic acid, for the production of inflammable air, was put into an odd sort of apparatus. It was somewhat like a chest of drawers, lined with sheet lead, every one of the drawers communicating with a common pipe, to which the stop-cock of the balloon was adapted. Thus the inflammable air, as soon as it was produced by the materials in the drawers, passed through the common pipe and stop-cock, into the balloon.

balloon. In this manner they went on for ſome hours, producing inflammable air, and waſting more of it than what actually entered into the balloon. At laſt, convinced of the inſufficiency of the apparatus, they removed it, and, at two o'clock, ſubſtituted, in its ſtead, a ſingle caſk ſet ſtrait up. In the flat end of this caſk, which was uppermoſt, they made two holes, to one of which a tin tube was fixed, and with it a tube of varniſhed leather was connected, to the end of which the ſtop-cock of the balloon was adapted. The other hole ſerved to introduce the iron and diluted vitriolic acid into the caſk, which materials they were obliged to recruit pretty often; and ſince, for this purpoſe, the hole in the caſk was occaſionally opened, care was taken to ſhut up the ſtop-cock of the balloon at the ſame time. Notwithſtanding the vigilance and ſkill of the operators, this apparatus laboured under many conſiderable inconveniencies, the principal of which was, that the effervefcence produced a great degree of heat, which being communicated to the ſtop-cock, and to the

 balloon,

balloon, rendered the former almoſt unmanageable, and endangered the latter, ſo that they were obliged to keep pumping water againſt it. Beſides this, a great deal of water, which came in the form of vapour, together with the inflammable air, was continually collecting in the balloon; which water was expelled at intervals by interrupting the operation, &c. In ſhort, at nine o'clock in the evening, after working the whole day, not above one third part of the balloon was filled; and in this ſtate the machine was left, having diſcontinued the operation and ſecured the apparatus.

At day-break on the following day, the operators returned with great anxiety, and greater expectations of ſucceſs; but they were exceedingly ſurpriſed to find the balloon quite full, and perfectly diſtended; whereas, on the preceding evening, not above one third of it had been left full. The ſurpriſe however ſoon vaniſhed, when, on examining the apparatus, they found that the ſtop-cock had been inadvertently left open, in consequence of which the common air had entered into the balloon, and had distended it by mixing with the inflammable air *. This disagreeable accident, instead of discouraging the undertaking, animated the operators with new zeal, and taught them to use greater precaution. The operation for producing the inflammable air was begun anew, and being continued with assiduity, they had the satisfaction of observing, that, at six o'clock in the evening, the balloon shewed signs of having become altogether lighter than an equal bulk of common air, and at seven

* This phenomenon, as it appears at first sight very extraordinary, deserves to be explained, especially because it may easily occur to others. The spontaneous introduction of common air into the balloon, is owing to the inflammable air occupying the upper part of the balloon, on account of being much lighter than common air; hence the upper part of the balloon being swelled into a segment of a sphere, the sides of it, below that segment, must naturally stand apart, and consequently must admit the common air. Then the common air mixing with the inflammable air, forms a compound likewise lighter than common air, which, of course, must produce a similar effect, and so on.

o'clock

o'clock its levity was increaſed ſo far as to make a conſiderable effort againſt the ropes, which confined it. The continuation of the operation was then deferred to the next day; having ſecured every thing againſt accidents.

Early on the morning of the 25th, having found the balloon very ſafe, the operators introduced ſome freſh inflammable air into it. At ſix o'clock in the morning the balloon's levity was tried by detaching it from the confinement of ropes, and ſuſpending known weights to it, by which means they found that it would lift up twenty-one pounds; and, as the public exhibition of the experiment was fixed for the 27th, they did not fill the balloon any more on that day. At nine o'clock in the evening, having examined the balloon again, they found that it would take up only eighteen pounds weight, ſo that in the courſe of the day it had loſt about three pounds of levity, in conſequence of the eſcape of ſome inflammable air through the pores or needle-holes.

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On the morning of the 26th, the balloon was found to have loſt a proportionable quantity of levity. They then introduced a little more inflammable air into it; and at eight o'clock in the morning, having diſengaged it from its confinement, they faſtened ſome ſmall cords to it, and diverted themſelves with letting it aſcend repeatedly to the height of about 100 feet, and then drawing it down again. This partial flight brought together an immenſe number of curious ſpectators, ſo that it was thought neceſſary to replace the balloon where it had been filled, and a guard of ſoldiers, both horſe and foot, was procured, in order to prevent the outrages of the multitude, which at laſt broke through the preſcribed limits, and crouded to behold the extraordinary object.

The balloon had been filled and ſtood near the *Place of Victories*, from whence it was to be conducted to the *Camp of Mars*, which had been appointed to be the place of the grand exhibition. The diſtance between the two places is about two miles; and in in order to prevent, as much as poſſible, a great concourſe of people, the balloon was tranſported before day-break, on the morning of the 27th. However, this extraordinary proceſſion brought together a conſiderable number of people; and their curioſity, their ſurpriſe, and their enthuſiaſm, together with the nocturnal appearance of the extraordinary machine, amidſt flambeaus and lanterns, are livelily deſcribed by Mr. Faujas de Saint-Fond, and others. The balloon was tranſported on a cart.

The *Camp of Mars* was lined with guards; and every houſe, to its very top, and every avenue, were crouded with anxious ſpectators. In this place ſome more inflammable air was introduced into the balloon, which ſerved at the ſame time to give to the public an idea of the operation. At laſt the diſcharge of a cannon gave the ſignal for the experiment, at 5 o'clock in the afternoon. Then the balloon, being diſengaged, roſe majeſtically before the eyes of many hundred thouſand ſpectators, and amidſt a copious ſhower of rain.—In two minutes time

time it roſe to the height of 3123 feet (488 toiſes *.) In this elevation the balloon was loſt in a dark cloud, and the diſappearance was announced by the diſcharge of another gun. In a ſhort time it appeared again for an inſtant, and then was finally loſt in the clouds.

The balloon, after remaining in the atmoſphere only three quarters of an hour, fell in a field near *Goneſſe*, a village about 15 miles diſtant from the *Camp of Mars*, where it was immediately found by ſome peaſants, who treated it rather roughly, in return for the aſtoniſhment, which this extraordinary object had given them. Its fall was attributed to a rupture found in it; and it was reaſonably imagined, that the expanſion of the inflammable air, when the balloon had reached a much leſs denſe part of the atmoſphere, had burſt it. When the balloon went up, it was 35 pounds lighter than an equal bulk of common air.

* This height was aſcertained by obſervations made with proper mathematical inſtruments.

CHAPTER

CHAPTER IV.

The introduction of small inflammable-air balloons; and Mr. Montgolfier's experiments before the Royal Family, and the Commissaries of the Academy.

AS soon as the youngest Montgolfier arrived at Paris, which was not long after the experiment at Annonay, he was invited by the Academy of Sciences to repeat his new aerostatic experiment; and the Academy offered to pay the necessary, but unlimited, expences. In consequence of this invitation, Mr. Montgolfier began to construct a new machine, of about 72 feet in height; which being finished, he first tried the experiment with it on the 12th of September following; keeping secret, in the mean while, the method of filling it, or, as he gave to understand, the manner of producing the gas. But in this interval of time, and after the successful experiment of the inflammable-air balloon, on the 27th of Auguſt, the project of making balloons was generally adopted; and thoſe who wiſhed only to make the experiment on the ſmalleſt ſcale, ſoon calculated the neceſſary particulars, and found that the performance of the experiment was far from being either difficult or expenſive. One Mr. Deſchamps, a painter at Paris, propoſed to the Baron of Beaumanoir, to try that ſort of ſkin, which gold-beaters uſe for their work. The Baron, ſtruck with the appearance of that ſubſtance, had a balloon made out of ſeveral pieces of it glued together, which was little more than 19 inches in diameter. This balloon, being very eaſily filled with inflammable air, was firſt tried, and then launched on the 11th of September, and aſcended into the atmoſphere, till it went out of ſight. It is ſaid, that it was afterwards found at a conſiderable diſtance.

Notwithſtanding the eaſineſs with which this balloon was both made and filled, yet there were not wanting perſons, who, after the experiment of the Baron of Beaumanoir, endeavoured to make balloons ſtill ſmaller;

ſmaller; and they actually made ſome of about ſix inches in diameter, which weighed between 30 and 40 grains. Theſe were filled with the utmoſt facility, and ſerved well enough to ſhew the experiment in a room; but as they were neceſſarily formed of ſkins extremely fine, and conſequently more porous than the uſual thicker ſkins, the inflammable air ſoon eſcaped from them, and the diminutive balloons hardly floated above a minute or two.

The larger balloons of this ſort; to wit, of between 9 and 18 inches in diameter, ſoon began to be manufactured by thoſe who were anxious to derive a pecuniary profit from the improvements of philoſophy; and, as the price of theſe balloons did not exceed a few ſhillings, almoſt every family ſatisfied its curioſity relative to the new experiment, and in a few days time balloons were ſeen very frequently flying about Paris, and ſoon after were ſent abroad. Thus this curious experiment was ſpread in the world with an unparalleled rapidity.

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Mr. Montgolfier, whom we left conſtructing a large aeroſtatic machine, in compliance with the deſire of the Academy, having accompliſhed the work, made the preliminary experiment with it on the 11th of September, and had the ſatisfaction of filling it with rarefied air in nine minutes time. The force of aſcenſion of the balloon was ſuch, that it actually lifted up eight perſons who held it, ſome feet from the ground; and would undoubtedly have raiſed them much higher, had not more force been immediately applied to detain it.

In conſequence of this ſucceſsful trial, the Commiſſaries of the Academy, viz. Meſſrs. Cadet, l'Abbé Boſſut, Briſſon, Lavoiſier, and Deſmareſt, were invited to be preſent at the experiment, which was to be performed at eight o'clock the following morning, September the 12th. Accordingly, the gentlemen of the Academy attended, together with a numerous company of other ſpectators; and every thing being got in readineſs, the machine was inflated

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by means of the combuſtion of 50 pounds weight of dry ſtraw in bundles, upon which about 12 pounds weight of chopped wool was thrown at intervals. The machine ſoon ſwelled, endeavoured to aſcend, and immediately after ſuſtained itſelf in the air, together with the charge of between 4 and 500 pounds weight. It was evident, that if the cords had been cut, the machine would have aſcended to a great height; but that they did not chooſe to do, becauſe the machine was deſtined for a repetition of the experiment before the king and royal family, at Verſailles. The violent rain, which unfortunately fell at that time, and a ſtrong wind, obliged the operators to put an end to the experiment for that day: but the gentlemen of the Academy remained perfectly ſatisfied with the ſucceſs of the experiment; and without heſitation ſigned a certificate of what they had ſeen, which contains a ſummary of the preceding account.

This machine had a very odd ſhape; yet it is ſaid, that when inflated, it looked exceedingly well. Its middle part was priſ-

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matic, of about 25 feet height; its top was a pyramid, of 29 feet; and its loweſt part conſiſted of a truncated cone, of near 20 feet in height; ſo that the whole machine, from the upper to the lower extremity, meaſured about 74 feet, and its diameter was near 43. When diſtended, it looked ſpheroidical. It was made of canvaſs, covered with paper both within and without; and it weighed 1,000 pounds.

In order to facilitate the filling of this machine, two maſts were ſet up in the ground, on both ſides of it: then a rope, which proceeded from the top of the machine, paſſed through two pullies, one placed on the top of each maſt, and ſerved to lift up the machine gradually as it was filling.

This vaſt aeroſtatic machine had been conſtructed in the place where the above-mentioned experiment was tried, which is a garden of one Mr. Revillon, proprietor of a manufactory of painted paper, at Paris. This gentleman not only gave the uſe of his garden for this experiment, but endeavoured to employ all the assistance he could towards the accomplishment of it, for which he is deservedly commended by Mr. Montgolfier and others.

The 19th of the same month had been appointed for the performance of the experiment before the king and royal family; which was only seven days after the last-mentioned experiment. But notwithstanding the shortness of the time, the 74 feet machine was so essentially damaged, that Mr. Montgolfier, who had determined to give all the satisfaction possible, thought it necessary to construct a new machine; which accordingly, owing to the extraordinary diligence of Mr. Montgolfier, and his friends, was finished by the 18th; so that in the evening of that day they made an essay, in presence of the Commissaries of the Academy. This machine consisted of cloth made of linen and cotton thread, and was painted with water colours both within and without. Its height was near 60 feet, and its diameter about 43.

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It is remarkable, that this great machine was made, painted, and decorated, in four days and four nights only.

On the 19th, the king, queen, the court, and innumerable people of every rank and age, aſſembled at Verſailles. The preparation for filling the machine conſiſted of an ample ſcaffold, raiſed ſome feet above the ground; in the middle of which was a well or chimney, about 16 feet in diameter; in the lower part of which, near the ground, the fire was made. The aperture of the aeroſtat was put round the chimney or well, and the reſt of it was laid down over the well and upon the ſurrounding ſcaffold. By 12 o'clock, every thing being got in readineſs, the king, with the royal family, honoured Mr. Montgolfier with their preſence on the apparatus, where every particular was explained to them by Mr. Montgolfier. About one o'clock the fire was lighted, in conſequence of which the machine began to ſwell, acquired a convex form, ſoon ſtretched itſelf on every ſide, and in eleven minutes time, the cords being cut, it aſcended, together with a wicker cage, which was faſtened to it by a rope. In this cage they had put a ſheep, a cock, and a duck, which were the firſt animals that ever aſcended into the atmoſphere with an aeroſtatic machine. When the machine went up, its power of aſcenſion, or levity, was 696 pounds, allowing for the cage and animals.

For the ſake of brevity, I ſhall omit mentioning the ſurpriſe, the ſatisfaction, and the applauſe, of the ſpectators; the frequent repetition of which ſeems rather tireſome, eſpecially when the leaſt imagination of the reader can eaſily form ſome idea of the effect, which ſo ſurpriſing an experiment muſt produce in ſo auguſt an aſſembly.

The machine raiſed itſelf to the height of about 1,440 feet; and being carried by the wind, it fell gradually in the wood of Vaucreſſon, at the diſtance of 10,200 feet from Verſailles, after remaining in the atmoſphere only eight minutes. Previous to the experiment, Mr. Montgolfier had preſented to the king a liſt of ſeveral particulars

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culars relative to it; amongſt which there was mentioned, that the machine would remain in the air for about 20 minutes, and that it would go to the diſtance of about 12,000 feet. The experiment not coinciding with this prediction, was juſtly attributed to two ruptures, above ſeven feet long, in the upper part of the machine, which had been occaſioned by a ſudden guſt of wind, a ſhort time before the machine aſcended; beſides which, the machine had ſeveral imperfections, which were the conſequence of a haſty conſtruction. It was likewiſe owing to the above-mentioned accident, that 80 pounds weight of ſtraw, and five of wool, were conſumed to fill it; whereas 50 pounds of ſtraw would have been quite ſufficient, if the machine had been perfectly ſound.

Two game-keepers, who were accidentally in the wood, ſaw the machine fall very gently, ſo that it juſt bent the branches of the trees upon which it alighted. The long rope to which the cage was faſtened, ſtriking againſt the wood, was broken, and the cage came to the ground without hurting in the leaſt the animals that were in it, ſo that the ſheep was even found feeding. The cock, indeed, had its right wing ſomewhat hurt; but this was the conſequence of a kick it had received from the ſheep, at leaſt half an hour before, in preſence of at leaſt ten witneſſes.

CHAPTER V.

Aeroſtatic experiments in which men firſt ventured to aſcend into the atmoſphere with an aeroſtatic machine.

THE preceding part of this hiſtory has ſhewn the rapid progreſs of the ſubject, and has ſufficiently demonſtrated by experiments, that little or no danger is to be apprehended for a man, who aſcends with ſuch a machine into the atmoſphere. The ſteadineſs of the aeroſtat whilſt in the

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air, its gradual and gentle deſcent, the ſafety of the animals that were ſent up with it in the laſt-mentioned experiment, and every other obſervation that could be deduced from all the experiments hitherto made in this new field of enquiry, ſeem more than ſufficient to expel any fear for ſuch an enterpriſe; but as no man had yet ventured in it, and as moſt of the attempts of flying, or of aſcending into the atmoſphere, on the moſt plauſible ſchemes, had from time immemorial deſtroyed the reputation or the lives of the adventurers, we may eaſily imagine, and forgive, the heſitation that men might expreſs, of going up with one of thoſe machines: and hiſtory will probably record, to the remoteſt poſterity, the name of Mr. Pilatre de Rozier, who had the courage of firſt venturing to aſcend into the atmoſphere with a machine, which, a few years hence, the moſt timid woman will perhaps not heſitate to truſt herſelf to.

Scarce ten months had elapſed ſince Mr. Montgolfier made his firſt aeroſtatic experiment,

riment, when Mr. Pilatre de Rozier publicly offered himſelf to be the firſt adventurer in the newly-invented aerial machine. His offer was accepted; his courage remained undaunted; and on the 15th of October, 1783, he actually aſcended into the atmoſphere, to the aſtoniſhment of a gazing multitude.—The following are the particulars of this experiment.

The accident which happened to the aeroſtatic machine at Verſailles, and its imperfect conſtruction, induced Mr. Montgolfier to conſtruct another machine of a larger ſize, and more ſolid. With this intent, ſufficient time was allowed for the work to be properly done; and by the 10th of October the aeroſtat was completed, in a garden in the Fauxbourg St. Antoine. It had an oval ſhape, its diameter being about 48 feet, and its height about 74. The outſide was elegantly painted and decorated with the ſigns of the zodiac, with cyphers of the king's name, fleurs-de-lys, &c. The aperture or lower part of the machine had a wicker gallery about three feet broad,
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with a baluſtrade both within and without, about three feet high. The inner diameter of this gallery, and of the aperture of the machine, the neck of which paſſed through it, was near 16 feet. In the middle of this aperture an iron grate, or brazier, was ſupported by chains, which came down from the ſides of the machine. In this conſtruction, when the machine was up in the air, with a fire lighted in the grate, it was eaſy for a perſon who ſtood in the gallery, and had fuel with him, to keep up the fire in the mouth of the machine, by throwing the fuel on the grate through port-holes made in the neck of the machine. By this means it was expected, as indeed it was found agreeable to experience, that the machine might have been kept up as long as the perſon in its gallery thought proper, or whilſt he had fuel to ſupply the fire with.—The weight of this aeroſtat was upwards of 1,600 pounds.

On Wedneſday, the 15th of October, this memorable experiment was performed. The fire being lighted, and the machine inflated,

inflated, Mr. Pilatre de Rozier placed himſelf in the gallery, and, after a few trials cloſe to the ground, he deſired to aſcend to a great height; the machine was accordingly permitted to riſe, and it aſcended as high as the ropes, which were purpoſely placed to detain it, would allow, which was about 84 feet from the ground. There Mr. de Rozier kept the machine afloat during 4 minutes and 25 ſeconds, by throwing ſtraw and wool into the grate to keep up the fire: then the machine deſcended exceedingly gently; and ſuch was its tendency to aſcend, that after touching the ground, the moment Mr. de Rozier came out of the gallery, it rebounded up again to a conſiderable height. The intrepid adventurer, returning from the ſky, aſſured his friends and the multitude, which had gazed on him with admiration, with wonder, and with fear, that he had not experienced the leaſt inconvenience, either in going up, in remaining there, or in deſcending: no giddineſs, no incommoding motion, no ſhock whatever. He received the compliments due to his courage and activity;

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vity; having ſhewn to the world the accompliſhment of what had been for ages deſired and attempted in vain.

On the 17th, Mr. Pilatre de Rozier repeated the experiment with nearly the ſame ſucceſs as he had two days before. The machine was elevated to about the ſame height, being ſtill detained by ropes; but the wind being ſtrong, it did not ſuſtain itſelf ſo well, and conſequently did not afford ſo fine a ſpectacle to the concourſe of people, which at this time was much greater than at the preceding experiment.

On the Sunday following, which was the 19th, the weather proving favourable, Mr. Montgolfier employed his machine to make the following experiments.—At half after four o'clock, the machine was filled in five minutes time; then Mr. Pilatre de Rozier placed himſelf in the gallery, a counterpoiſe of 100 pounds being put in the oppoſite ſide of it, to preſerve the balance.—The ſize of the gallery had now been diminiſhed.—The machine was permitted to aſcend

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to the height of about 210 feet, where it remained during ſix minutes, not having any fire in the grate; and then it deſcended very gently.

Soon after, every thing remaining as before, except that now a fire was put into the grate, the machine was permitted to aſcend to about 262 feet height, where it remained ſtationary during eight minutes and a half. On pulling it down, a guſt of wind carried it over ſome large trees of an adjoining garden, where it would have been in great danger, had not Mr. de Rozier, with great preſence of mind and addreſs, increaſed the fire by throwing ſome ſtraw upon it; by which means the machine was extricated from ſo dangerous a ſituation, and roſe majeſtically, amongſt the acclamations of the ſpectators, to the ſituation in which it ſtood before. On deſcending, Mr. de Rozier threw ſome ſtraw upon the fire, which made the machine aſcend once more, and then it deſcended to the ground.

This

This experiment ſhewed, that the aeroſtat may be made to aſcend and deſcend at the pleaſure of thoſe who are in it; to effect which, they have nothing more to do, than to increaſe or diminiſh the fire in the grate: which was an important point in the ſubject of aeroſtation.

After this, the machine was raiſed again with two perſons in its gallery, Mr. Pilatre de Rozier, and Mr. Girond de Villette; the latter of whom was therefore the ſecond aeroſtatic adventurer. The machine aſcended to the height of about 330 feet, where it remained perfectly ſteady for at leaſt nine minutes; hovering over Paris, in ſight of its numerous inhabitants, many of whom could plainly diſtinguiſh, through teleſcopes, the aeroſtatic adventurers, and eſpecially Mr. de Rozier, who was buſy in managing the fire.

The machine being come down, the Marquis of Arlandes, major of infantry, took the place of Mr. Villette, and the aeroſtat was let up once more. This laſt experiment

experiment was attended with nearly the ſame ſucceſs as the preceding: and they all proved and confirmed, that the perſons, who aſcended with the machine, did not ſuffer the leaſt inconvenience; which was owing to the gradual and gentle deſcent or aſcent of the machine, and to its ſteadineſs or equilibrium whilſt it remained in the atmoſphere.

If we conſider for a moment the ſenſation which theſe firſt aerial adventurers muſt have felt in their exalted ſituation, we can hardly prevent an unuſual ſublime idea in ourſelves.—Imagine a man elevated to ſuch an height, into an immenſe ſpace, by means altogether new, viewing under his feet, like a map, a vaſt tract of country, with one of the greateſt towns exiſting, the ſtreets and environs of which were crowded with ſpectators, attentive to him alone, and all expreſſing, in every poſſible manner, their amazement, and their anxiety. Reflect on the proſpect, the encomiums, and the conſequences; then ſee if your mind remains in a ſtate of quiet indifference.

An

An inſtructive obſervation may be derived from thoſe experiments, which is, that when an aeroſtatic machine is kept confined by ropes, eſpecially at a conſiderable height above the ground, the wind blowing on it, muſt drive it in its own horizontal direction; ſo that the cords which hold the machine muſt make an angle with the horizon, which is greater when the wind is ſtronger, and contrarywiſe; in conſequence of which the machine muſt be much fatigued; it being acted on by three forces, in three different directions; namely, its power of aſcenſion; the confinement of the ropes, which is oppoſite to the firſt; and the action of the wind, which is acroſs the other two. It is therefore infinitely more ſafe to abandon the machine entirely to the air, becauſe then it ſtands perfectly balanced, and therefore is not at all fatigued.

In conſequence of the report of the foregoing experiments, ſigned by the Commiſſaries of the Academy of Sciences, that learned and reſpectable body ordered, 1ſt. That the ſaid report ſhould be printed and

 publiſhed;

publiſhed; and 2dly, That the annual prize of 600 livres, according to the eſtabliſhment of an anonymous citizen, be given to Meſſrs. Montgolfier, for the year 1783.

I ſhall conclude this chapter with an aeroſtatic experiment made at Lyons, by the eldeſt Montgolfier. He made a paper machine, conſiſting of two truncated quadrangular pyramids, which were joined to each other by their baſes. Its capacity was equal to about 300 cubic feet. In the inſide of this machine, and rather near its aperture, four wires held a cylinder of iron wire, 13 inches long, and 6½ inches in diameter. A roll of 30 ſheets of paper, dipped in olive-oil, was put into the wire cylinder, the combuſtion of which kept the air rarefied within the machine.

This paper aeroſtat roſe rapidly into the atmoſphere; it went firſt towards the north, but aſcending ſtill higher, was ſeen to enter into a current of air E.S.E. Continuing ſtill to aſcend, and proceeding with the wind, it went quite out of ſight in 22 minutes.

CHAPTER VI.

Account of the first aerial voyage.

THE experiments hitherto made, especially those of the 19th of October, having prepared the way for a fair aerial navigation, the attempt was fixed for the 20th of November 1783; every thing being prepared for it at La Muette, a royal palace in the Bois de Boulogne. Notwithstanding that no advertisement relative to the experiment had been mentioned in the public papers, a vast multitude assembled in the garden at La Muette, on the morning of the above-mentioned day. The necessary operations were begun; but the rain and the wind, which came on suddenly, obliged Mr. Montgolfier to defer the performance of the experiment to the following day; provided the weather proved more favourable.

Accordingly, on the 21st, the wind, which

which blew at intervals, and the appearance of large clouds, threatened a ſecond diſappointment; notwithſtanding which, every thing being got in readineſs, the machine was filled in a few minutes time, and Mr. P. de Rozier, together with the Marquis d'Arlandes, placed themſelves in the gallery, one on one ſide of it, and the other on the oppoſite, in order to preſerve the equilibrium. But as Mr. Montgolfier intended to make ſome preliminary experiments relative to the power of aſcenſion of the machine, &c. the aeroſtat was kept confined by ropes, in conſequence of which the wind agitated it violently, and at laſt forced it to the ground, which damaged and tore it in ſeveral places; and it would have been entirely burned had not timely aſſiſtance prevented it. Notwithſtanding this diſagreeable accident, by an extraordinary exertion of the workmen, the aeroſtat was replaced on the ſcaffold, and was repaired in leſs than two hours*. They

* This was the ſame aeroſtat, of 74 feet height, which is deſcribed in the preceding chapter.

then

then filled it again, put into the gallery the neceſſary fuel, and the two intended travellers entered the gallery with courage and eagerneſs. The whole weight of the machine, travellers and all, was between 1600 and 1700 pounds.

The aeroſtat left the ground at 54 minutes paſt one o'clock, paſſed ſafely over ſome high trees, and aſcended calmly and majeſtically into the atmoſphere. The aeronauts having reached the altitude of about 280 feet, took off their hats and ſaluted the ſurpriſed multitude. They then roſe too high to be diſtinguiſhed, ſo that the machine itſelf was ſcarce perceivable. When they roſe, the wind was very nearly north-weſt, and it is ſaid that the machine, in riſing, made half a turn round its own axis. The wind drove them horizontally over the river Seine, and over Paris. They paſſed between *l'Hotel des Invalides* and *l'Ecole Militaire*, and approached *Saint-Sulpice*; but as they were rather low, the fire was increaſed in order to clear the houſes, and in riſing higher they met with a current of air, which carried them ſouthward. They paſſed the *Boulevard*; and at laſt, ſeeing that the object of the experiment was fully anſwered, the fire was no longer ſupplied with fuel, and the machine deſcended very gently in a field beyond the new *Boulevard*, about 9000 yards diſtant from the palace *de la Muette*, which diſtance they ran in between 20 and 25 minutes time. The Marquis d'Arlandes ſtepped out of the gallery the moment it touched the ground; but the machine collapſing immediately after, Mr. de Rozier, who ſtood on the ſide oppoſite to the wind, was covered by the canvas, from which dangerous ſituation however he ſoon extricated himſelf. Otherwiſe they had ſuffered no inconvenience whatever.

When they came down, about two thirds of the fuel was ſtill remaining in the gallery; ſo that they might have kept themſelves up a much longer time. The machine was ſoon folded up, and being put on a cart, was ſent to the place where it had been originally conſtructed, in the Fauxbourg St. Antoine.

Thus

Thus far has been collected from the accounts given by various spectators, and especially from the affidavit of the experiment, which was signed by the Dukes of Polignac and de Guines, Counts de Polastron and de Vaudreuil, Dr. Franklin, and Messrs. Faujas de Saint-Fond, Delisle, and Leroy, of the Academy of Sciences. But, as the transactions of the aeronauts, during their voyage, can only be learned from themselves, and as those circumstances seem to be peculiarly useful and instructive, I shall subjoin the translation of part of a letter, written by the Marquis d'Arlandes to Mr. Faujas de Saint-Fond, on this subject.

" At this time Mr. Pilatre said, *You do*
" *nothing, and we shall not mount.* Pardon
" me, I replied.—I threw a truss of straw
" upon the fire, stirring it a little at the
" same time, and then quickly turned my
" face back again; but I could no longer
" see *la Muette*. Astonished, I gave a look to
" the direction of the river. - - Mr. Pilatre
" then said, *Behold, there is the river, and*

" *observe that we descend.* Well then, my " friend, *let us increase the fire*; and we " worked away. But instead of crossing " the river, as our direction seemed to in- " dicate, which carried us over the house " of the *Invalides*, we passed along the " island of Cygnes, re-entered over the " principal bed of the river, and ad- " vanced up it as far as the gate *de la* " *Conference*. I said to my intrepid com- " panion, Behold, there is the river, &c. " I stirred the fire, and took with the fork " a truss of straw, which, from being too " tight, did not take fire very easily. I " lifted and shook it in the middle of the " flame. The next moment I felt as if I " were lifted up from under the arms, " and said to my companion, Now we " mount, &c. At the same time I " heard a noise towards the top of the ma- " chine, as if it were going to burst; I " looked, but did not see any thing. How- " ever, as I was looking up, I felt a " shock, which was the only one I experi- " enced. The direction of the motion " was from the upper part downwards.

" I said

" I said then, What are you doing? Are
" you dancing? I don't stir, said he. So
" much the better, replied I, it is then a
" new current, which, I hope, will push
" us over the river. In fact, I turned
" myself in order to see where we were,
" and I found myself between *l'Ecole Mili-*
" *taire* and *les Invalides*, beyond which
" place we had already gone about 2500
" feet. Mr. Pilatre said, at the same time,
" *We are on the plain*. Yes, said I, and
" we advance. Work on, said he. I then
" heard another noise in the machine,
" which appeared to be the effect of a rope
" breaking. This fresh admonition made
" me examine attentively the interior of
" our habitation. I saw that the part of
" the machine, which was turned towards
" the south, was full of round holes, many
" of which were of a considerable size. I
" then said, *We must descend*, and at the
" same time, I took the spunge, and easily
" extinguished the fire, which was round
" some holes that I could reach; but lean-
" ing on the lower part of the linen, to
" observe whether it adhered firmly to
" the

" the surrounding circle, I found that the
" linen was easily separated from it, on
" which I repeated, that it was necessary to
" descend. My companion said, *We are*
" *over Paris.* Never mind that, said I,
" but look if there appears any danger for
" you on your side—are you safe? He said
" Yes. I examined my side, and found that
" there was no danger to be apprehended.
" Farther, I wetted with the spunge those
" cords, which were within my reach.
" They all resisted, except two, which
" gave way. I then said, We may pass
" over Paris. In doing this, we ap-
" proached the tops of the houses very
" sensibly; we increased the fire, and
" rose with the greatest ease. I looked
" below me, and perfectly discovered the
" *Mission Etranger.* It seemed as if we
" were going towards *Saint-Sulpice*, which
" I could perceive through the aperture of
" our machine. On rising, a current of
" air made us leave this direction, and
" carried us towards the south. I saw on
" my left a sort of forest, which I took to
" be the Luxembourg; we passed over the
" Boulevard,

" Boulevard, and I then ſaid, Let us now de-
" ſcend. The fire was nearly extinguiſhed;
" but the intrepid Mr. Pilatre, who never
" loſes his preſence of mind, and who went
" forward, imagining that we were going
" againſt the mills that are between the
" little *Gentilly* and the *Bouvelard*, admo-
" niſhed me. I threw a bundle of ſtraw
" on the fire, and ſhaking it in order to
" inflame it more eaſily, we roſe, and a
" new current carried us a little towards
" our left. Mr. Rozier ſaid again, Take
" care of the mills: but as I was looking
" through the aperture of the machine,
" I could obſerve more accurately that we
" could not meet with them, and ſaid,
" *We are arrived.* The moment after, I
" obſerved that we went over a piece of
" water, which I took for the river, but
" after landing, I recollected that it was
" the piece of water, &c. The mo-
" ment we touched the ground, I raiſed
" myſelf up in the gallery, and perceived
" the upper part of the machine to preſs
" very gently on my head, I puſhed it
" back, and jumped out of the gallery, and
" on

"on turning myſelf towards the machine, "expected to find it diſtended, but was "ſurpriſed to find it perfectly emptied, "and quite flattened." &c.

CHAPTER VII.

Account of the firſt aeroſtatic experiment made in England.

IT is ſomewhat remarkable, that more than five months had elapſed, ſince Mr. Montgolfier made his firſt public aeroſtatic experiment at Annonay, the news of which, as well as of his ſubſequent experiments, was rapidly and univerſally ſpread, and yet no experiment of the kind had been made out of France, at leaſt, none is authentically recorded. In this iſland, where the improvements of arts and ſciences find their nurſery, and many their birth, no aeroſtatic

aeroſtatic machine was ſeen before the month of November 1783. It was, perhaps, owing to a perſuaſion, that this new field of experiment was in the hands of perſons fully capable to improve it in France; and conſequently, that it would be uſeleſs to loſe time, trouble, and expence, about experiments, which others were actually making elſewhere. At leaſt, the curioſity of the learned might have been ſatisfied with an experiment in ſmall; but it often happens in a nation, that a ſort of ſtupor prevents even the moſt neceſſary and eaſy exertions, in particular caſes, for which omiſſion, a ſhort time after, no perſon can aſſign any plauſible reaſon. However, it muſt be confeſſed, that the news of the firſt aeroſtatic experiments was far from giving any exact account of the practical part, or of the principles themſelves.

Let this be as it may, the matter of fact is, that the firſt aeroſtatic experiment was ſhewn in London, in the month of November, 1783. One Count Zambeccari, an ingenious Italian, who happened to be in

London;

London, made a balloon of oil-ſilk, which was 10 feet in diameter, and weighed 11 pounds. It was gilt, both in order to render it more beautiful, and more impermeable to the inflammable air. This balloon was publicly ſhewn for ſeveral days in London; and at laſt, on the 25th of the above-mentioned month, three quarters of it were filled with inflammable air; a direction, for any perſon who ſhould afterwards find it, incloſed in a tin box, was faſtened to it, and, in the preſence of many thouſand ſpectators, it was launched from the Artillery Ground, at one o'clock in the afternoon.

Two hours and a half after; viz. at half paſt three o'clock, this balloon was found at Graffam, near Petworth, in Suſſex, 48 miles diſtant from London; ſo that it went at the rate of near 20 miles an hour. A rent found in it, which was certainly the conſequence of the rarefaction of the inflammable air, when the balloon came into a much lighter part of the atmoſphere, muſt have been the occaſion of its deſcent.

We

We muſt now return to the aeroſtatic experiments made in France; and muſt defer deſcribing thoſe made in England, till the order of time renders it neceſſary.

CHAPTER VIII.

Account of the firſt aerial voyage made with an inflammable-air Balloon.

THE ſucceſs of the experiment with the inflammable-air balloon, made in the *Champ de Mars*, and the other experiments made after that, with Mr. Montgolfier's aeroſtat, naturally ſuggeſted the idea of attempting a voyage in an inflammable-air balloon; every conſideration, excepting the dearneſs of the inflammable air, ſeeming to give the preference to the inflammable-air balloon, as a vehicle for an aerial voyage.

The

The plan for ſuch a voyage, and every neceſſary calculation, being made, the balloon was conſtructed by the Roberts, two brothers, very intelligent in mechanics. Their project was firſt announced to the public in the *Journal de Paris*, of the 19th of November, 1783; and a ſubſcription was opened, in order to defray the expences, which, as it was calculated, would amount to about 10,000 livres.

As ſoon as the balloon was finiſhed, it was inflated with common air; and was publicly ſhewn in one of the great chambers of the Thuilleries, till the 26th, on which day it was ſuſpended to a rope ſtretched between two trees, before the Thuilleries.

This balloon was made of gores of ſilk, covered with a varniſh, ſaid to be a ſolution of elaſtic gum *(caoutchouc)*. Its form was ſpherical, meaſuring 27 feet and an half in diameter. A net went over the upper hemiſphere, and was faſtened to a hoop that went round the middle of the balloon,

balloon, and was therefore called its equator. To this equator was ſuſpended, by means of ropes, a ſort of car, or rather a boat, which ſwung a few feet below the balloon. In order to prevent the burſting of the machine, by the expanſion of the inflammable air, a valve was made in it, which, by pulling a ſtring, was opened to let out ſome of the inflammable air. There was likewiſe a long ſilken pipe, through which the balloon was filled. The boat, made of baſket-work, was covered with painted linen, and was beautifully ornamented. Its length was near 8 feet, its breadth 4, and its depth 3 and an half. It weighed 130 pounds.

The apparatus for filling it, conſiſted of ſeveral caſks placed round a large tub full of water, every one of which had a long tin tube, which terminated under a veſſel or funnel, that was inverted into the water of the tub. A tube, proceeding from this funnel, communicated with the balloon, which ſtood juſt over it. Iron filings and diluted vitriolic acid were put into the caſks; and the inflammable air, which was produced from theſe materials, paſſed through the tin tubes, through the water of the tub, through the funnel, and was laſtly lodged in the balloon.

It appears, that in filling this balloon they worked a long time with very little effect; but at laſt, being aſſiſted by an able chymiſt, the operation went on incomparably better. The balloon ſoon began to acquire a convex form, inflated apace, and by one o'clock, or a little after, it was ready to aſcend.—This famous experiment was performed on Monday, the 1ſt of December, 1783.—The Thuilleries, the *Pont Royal*, every houſe, and every adjacent place, were crouded with ſpectators. A numerous guard of ſoldiers preſerved order, and protected the operation. Mathematical perſons, with proper inſtruments, were conveniently ſtationed for the purpoſe of calculating the height, rate of going, and other particulars concerning the balloon. Signals were given by the firing of a cannon, waving of pendants, &c. A ſmall balloon of ſix feet in diameter was launched by Mr. Montgolfier, which ſerved to ſhew the direction of the wind, and likewiſe to amuſe the people. The boat was then attached to the balloon; Mr. Charles, and one of the Roberts, ſeated themſelves in it, with proper inſtruments, plenty of proviſions, clothing, and the ballaſt, conſiſting of ſand-bags*; and at three quarters after one o'clock the machine left the ground, and aſcended with a moderately accelerated courſe. The aſtoniſhed ſpectators ſtood ſilent.

* The balloon, men, ballaſt, &c. being weighed and calculated, it was found, that the weight of the common air, diſplaced by the inflammable gas, was 771 pounds and a half; the joint weight of the ſtuff, of which the balloon was formed, of the two men, boat, ballaſt, &c. was 604 pounds and an half; and the power of aſcenſion of the balloon, or its actual levity, when it aſcended, was 20 pounds, which being added to the weight of the ſtuff, men, boat, &c. makes 624 pounds and an half, which therefore was the weight ſuſtained by the inflammable air; and if we ſubtract this from the weight of the common air diſplaced, i. e. 771 pounds and an half, there remains 147 pounds for the real weight of the inflammable air contained in the balloon; from whence it follows, that the ſpecific gravity of the inflammable air, at leaſt of ſuch a ſort as was contained in this machine, was to the ſpecific gravity of common air nearly as one to $5\frac{1}{4}$.

When the balloon had reached the altitude of about 600 yards, the two aerial navigators indicated their safety by frequently waving two pendants, though they themselves could not be distinguished from the ground. The spectators were by this time awakened from their astonishment; enthusiasm took the place of silence, and nothing but expressions of praise and applause were by every mouth annexed to the names of Charles and Robert.

At the time they went up, the thermometer, according to Farenheit's scale, stood at 9°, and the quicksilver in the barometer stood at 30,18 inches. In the atmosphere the machine ascended till the quicksilver in the barometer stood at 27 inches, from which they deduced their altitude to be nearly 600 yards. During the rest of their voyage, the quicksilver in the barometer was generally between 27, and 27,65 inches, rising and falling according as part of the ballast was thrown out, or some of the inflammable air escaped from the balloon. The thermometer stood generally between 53° and 57°.

Soon

Soon after their ascent, they remained stationary for a short time; then they went horizontally, in the direction of N. N. W. They crossed the Seine, and passed over several towns and villages, to the great astonishment of the inhabitants, who did not expect, and perhaps had never heard of this new sort of experiments. This delicious voyage lasted one hour and three quarters. At last they descended in a field near *Nesle*, a small town, about 27 miles distant from Paris, it being then three quarters past three o'clock; so that they had gone at the rate of about 15 miles per hour, without feeling the least inconvenience; and the balloon underwent no other alteration, than what was occasioned by the dilatation and contraction of the inflammable air, according to the vicissitudes of heat and cold.

A short time after their descent, they were overtaken by the Dukes of Chartres and de Fitz-James, who had rode after the balloon, and did them the honour to add their names to the certificate of their descent, which had been already drawn up and ſigned by other perſons, who had arrived ſooner.

The balloon ſtill containing a conſiderable quantity of inflammable air, Mr. Charles determined to aſcend once more. Mr. Robert then got out of the boat, which lightened the balloon of 130 pounds. This weight they intended to ſupply with ballaſt; but not finding any conveniency to take up any earth or ſtones very readily, and the ſun being near ſetting, Mr. Charles, without loſing more time, gave the ſignal to the peaſants who held down the machine, to let go; "And I ſprung up," *ſays he*, "like a bird. In twenty minutes, I was "1,500 toiſes high; out of ſight of all "terreſtrial objects. I had taken the ne- "ceſſary precautions againſt the exploſion "of the globe, and prepared to make the "obſervations which I had promiſed my- "ſelf. In order to obſerve the barometer "and thermometer, placed at the end of "the car, without altering the centre of "gravity, I knelt down in the middle, "ſtretching forward my body and one leg, "holding

" holding my watch and paper in my left " hand, and my pen and the ſtring of the " valve in my right, waiting for the event. " The globe, which, at my ſetting out, was " rather flaccid, ſwelled inſenſibly. The " air eſcaped in great quantities at the " ſilken tube. I drew the valve from time " to time, to give it two vents; and I " continued to aſcend, ſtill loſing air, " which iſſued out hiſſing, and became " viſible, like a warm vapour in a cold at- " moſphere. The reaſon of this pheno- " menon is obvious. On earth, the ther- " mometer was 7 degrees above the freezing " point *; after ten minutes aſcent, it was " five degrees below †. The inflammable " air had not had time to recover the equi- " librium of its temperature. Its elaſtic " equilibrium being quicker than that of " the heat, there muſt eſcape a greater " quantity than that, which the external " dilatation of the air could determine by " its leaſt preſſure. For myſelf, though " expoſed to the open air, I paſſed in ten

* Equal to about 47° of Farenheit's ſcale.

† Equal to 21° of Farenheit's ſcale.

" minutes from the warmth of ſpring to
" the cold of winter: a ſharp dry cold, but
" not too much to be borne. I declare,
" that in the firſt moment I felt nothing
" diſagreeable in the ſudden change. When
" the barometer ceaſed to fall, I marked
" exactly 18 inches 10 lines *, the mer-
" cury ſuffering no ſenſible oſcillation.
" From this I deduct a height of 1,524
" toiſes †, or thereabouts, till I can be
" more exact in my calculation. In a few
" minutes more, my fingers were benumb-
" ed by the cold, ſo that I could not hold
" my pen. I was now ſtationary as to the
" riſing and falling, and moved only in an
" horizontal direction. I roſe up in the
" middle of the car to contemplate the
" ſcene around me. At my ſetting out,
" the ſun was ſet on the vallies; he ſoon
" roſe for me alone, who was the only lu-
" minous body in the horizon, and all the
" reſt of nature in ſhade; he, however,
" preſently diſappeared, and I had the plea-
" ſure of ſeeing him ſet twice in the ſame

* Equal to 20,01 inches Engliſh.

† About 3,100 yards.

" day.

"day. I beheld, for a few ſeconds, the "circumambient air, and the vapours riſing "from the vallies and rivers. The clouds "ſeemed to riſe from the earth, and collect "one upon the other, ſtill preſerving their "uſual form, only their colour was grey, "and monotonous from the want of light "in the atmoſphere. The moon alone "enlightened them, and ſhewed me, that "I was tacking about twice; and I ob-"ſerved certain currents that brought me "back again. I had ſeveral ſenſible devi-"ations; and obſerved, with ſurpriſe, the "effects of the wind; and ſaw the ſtreamers "of my banners point upwards. This "phenomenon was not the effect of the "aſcent or deſcent, for I then moved ho-"rizontally. At that inſtant I conceived, "perhaps a little too haſtily, the idea of "being able to ſteer one's courſe. In the "midſt of my tranſport, I felt a violent "pain in my right ear and jaw, which I "aſcribed to the dilatation of the air in "the cellular conſtruction of thoſe organs, "as much as to the cold of the external "air. I was in a waiſtcoat, and bare-"headed.

"headed. I immediately put on a woollen "cap, yet the pain did not go off, but as "I gradually defcended. For feven or "eight minutes I had ceafed to afcend; the "condenfation of the internal inflammable "air rather made me defcend. I now re-"collected my promife to return in half "an hour, and, pulling the ftring of the "valve, I came down. The globe was "now fo much emptied, that it appeared "only an half globe. I perceived a fine "ploughed field near the wood of *Tour du* "*Lay*, and haftened my defcent. When "I was between 20 and 30 toifes from the "earth, I threw out haftily two or three "pounds of ballaft, and became for a mo-"ment ftationary, till I defcended gently "in the field, above a league from the "place whence I fet out. The frequent "deviations and turnings about, make me "imagine that this voyage was near three "leagues; and I was gone about 33 mi-"nutes. Such is the certainty of the com-"binations of our aeroftatic machine, that "I might have kept in the air at leaft for "24 hours longer."

Mr.

Mr. de Meunier, who made ſeveral calculations concerning this voyage, thinks that Mr. Charles muſt have aſcended at leaſt one thouſand ſeven hundred toiſes, equal to about three thouſand five hundred yards Engliſh meaſure.

It is ſaid, that the ſmall balloon, which was launched by Mr. Montgolfier, a little before Meſſrs. Charles and Robert aſcended, was afterwards found at Vincennes, in a direction oppoſite to that taken by the great balloon; which ſhews that there happened to be two currents of air, perhaps at different heights.

CHAP.

CHAPTER IX.

Aeroſtatic experiments made in the remainder of the year 1783.

SINCE the ſmall inflammable-air balloons were firſt introduced, many curious perſons began to employ them for philoſophical purpoſes, as well as for the ſatisfaction of thoſe, who had never before ſeen any experiment of that ſort; and we find many of thoſe experiments recorded in ſeveral publications, with more preciſion, and better authenticated, than they really deſerved. By this obſervation I do not mean to depreciate any philoſophical inquiry, of whatſoever ſort it may be, nor do I think, that the aſcertaining of the leaſt particular, relative to the works and operations of nature, is undeſerving of notice: but the hiſtory of a ſcience, or an art, muſt record only the improvements of that particular ſubject; and it would be no longer a ſcientific hiſtory, if it deſcended to relate the

the endleſs repetition of the very ſame experiment, with perhaps no other change than that of the date, and names of places, experimenters, &c.

Each of the experiments related in the preceding pages, advances the ſubject a good ſtep forward, and it was therefore neceſſary to deſcribe all the circumſtances, that ſeemed at all intereſting; but as the repetition of ſeveral of theſe experiments doth not always ſhew any new obſervation or improvement, I ſhall, for the future, take notice only of thoſe experiments and obſervations, which ſeem in any way tending to improve the ſubject, and as for the reſt, they ſhall be either entirely omitted or only ſlightly mentioned.

On the 11th of December a ſmall balloon, made of gold-beater's ſkin, was publicly launched at Turin. It was the firſt experiment of the kind exhibited in that place, and conſequently it gave great ſatiſfaction to the ſpectators. They ſaw it penetrate the clouds; it appeared ſtationary for

for ſome time; then it aſcended ſtill higher, and at laſt it entirely diſappeared, 5 minutes and 54 ſeconds after its firſt aſcent.

To employ an aeroſtatic machine for diſcovering the electricity of the atmoſphere, eſpecially in calm weather, was a natural conſequence of the experiments made long before with electrical kites; and immediately after Mr. Montgolfier's firſt experiment, it occurred to ſeveral intelligent perſons, that one of thoſe machines, faſtened to the extremity of a long ſtring, and floating in the air, would bring down the electricity of the atmoſphere, in the ſame manner as the ſtrings of electrical kites were wont to do, and even better; ſince the kites cannot be raiſed in calm weather, nor will they ever go beyond a very moderate height; whereas an aeroſtatic machine could both go incomparably higher, and would riſe in calm weather. But the Abbé Bertholon appears to have been the firſt perſon who uſed thoſe machines for experiments on the atmoſpherical electricity, at Montpellier. He raiſed ſeveral air-balloons,

to

to which long and ſlender wires were attached, the lower extremity of the wire being faſtened to a glaſs ſtick or other inſulating ſubſtance; and hereby he obtained from the wire, electric fluid ſufficient to ſhew the attraction, repulſion, and even the ſparks of electricity. He uſed to arm ſome of thoſe globes with metallic points, in order to let them imbibe the electricity more readily; and he directs that a ſtring ſhould be uſed, containing a very fine wire of gold or other metal, exactly as is made uſe of for electrical kites *. It is obvious, that the greateſt inconvenience, in this ſort of experiments, is the action of the wind againſt the balloon, which will fatigue the machine, and will drive it in a direction much inclined to the horizon.

An accident that happened in England, about this time, deſerves to be mentioned, in order to warn other people, who may happen to be in ſuch-like dangerous circumſtances. It is ſaid that an inflammable-air balloon, launched by one Mr. Gell, from Hopton, near Matlock, was found by two men in

* See the writers on Electricity.

the

the neighbourhood of Cheadle, in Staffordſhire, who took that, to them ſtrange, machine into a room of a farm-houſe, where, after ſome conſideration, they concluded that it was ſomething like a half-blown bladder, and began to fill it quite up, by applying a pair of bellows to an aperture that was in it; but as ſome of the gas was ſtill coming out, the approach of a candle unfortunately ſet it on fire, in conſequence of which, the balloon exploded with a report much louder than a cannon, which ſtruck four perſons down to the floor. They ſoon recovered from the fall, but were ſo ſtunned, as not to be ſenſible of fire, till they perceived their heads in a blaze: their beards and eye-brows were burned quite off, and their faces terribly ſcorched. The windows were forced out with great violence, and the houſe was otherwiſe much damaged *.

At this time the Academy of Lyons offered a prize of fifty pounds to the author

* The account of this accident has been extracted only from the daily news-papers.

of

of the beſt eſſay on the following ſubject, viz. "To diſcover the ſafeſt, leaſt expenſive, and moſt effectual means of directing air-balloons at pleaſure." The candidates were to give in their diſſertations before the firſt of February 1784.

CHAPTER X.

Aeroſtatic experiments made in January 1784.

AT Grenoble, a city of Dauphinè, in France, one Mr. de Barin launched a balloon on the 13th of January, at 40 minutes after three o'clock. It aſcended with a direction very little inclined to the north for the firſt minute; but afterwards, meeting with another current of air, it went in the direction of ſouth-eaſt; and about a quarter of an hour after, it fell, at the diſtance of near three quarters of a mile.

On the ſame day, an aeroſtatic machine, about 37 feet in height, and 20 in diameter, was launched from the caſtle *de Piſançon*, near *Romans*, in Dauphinè. This machine had been conſtructed by a ſociety of that town, under the direction of *l'Abbé de Mably*. It roſe with a ſurpriſing velocity, and, as the wind was north, it went towards the ſouth; but when the machine had aſcended to the height of about 1300 feet, it went back towards the north; and in leſs than five minutes time it aſcended to the height of above 6000 feet, according to the beſt calculation the experiment could admit of. In leſs than 10 minutes it fell, at the diſtance of near four miles from whence it had aſcended.

On the 16th of the ſame month, the Count *d'Albion* launched, from his garden at Franconville, an inflammable-air balloon, made of ſilk, covered with a ſolution of glue and gum arabic. It was of an oblong form, being 25 feet high, and near 17 in diameter. A wicker baſket was attached to it, in which three animals were encloſed—

closed—two Guinea pigs, and a rabbit. When the cords, which confined the balloon, were cut off, the machine ascended with surprising velocity to an enormous height. Five days after, it was found at the distance of about 18 miles; and it is remarkable, that notwithstanding the coldness of the weather, and particularly of that region of the atmosphere, to which the machine ascended, the animals were found not only alive, but perfectly well.

In this same month, the greatest aerostatic machine hitherto made was launched at Lyons, with no less than seven persons in its gallery. The particulars of which experiment being both entertaining and instructive, it is necessary to give a circumstantial account of them.

A subscription being opened, in September of the preceding year, for the purpose of constructing a large aerostatic machine, capable of taking into the atmosphere a horse, or other large animal, &c. Mr. Montgolfier was requested to take the management of the business; and accordingly, under his direction, with the assistance of other intelligent persons, a machine was constructed, consisting of a double envelope of linen, enclosing three thicknesses of paper between, all being stitched together at intervals. It was moreover strengthened with strings and ribands. The form of this machine was that of a sphere extended towards its inferior part, where it terminated in a truncated cone, round which a gallery of wicker work was adapted. The height of the machine was about 131 feet, and its diameter about 104. When it went up, its weight, including the passengers, gallery, &c. was 1600 pounds.

On the 7th of January, the pieces, which were to form this immense machine, were brought out of Lyons into one of the suburbs, called Brotteaux, and the two following days were employed to join those pieces together. In the morning of the 10th they made the first essay. The fire was lighted, and in 20 minutes the machine was perfectly inflated, and in this state the

the cords, which were to hold the gallery, were begun to be fixed. On the 12th they inflated the machine again, in order to fix more of the ropes for the gallery; and, in ſhort, they worked inceſſantly till the 19th to fix the ropes, to attempt the aerial voyage, and to repair the rents and other damages, which the machine continually received from being often inflated, and from the injuries of the weather; for the rain, the ſnow, the froſt, and almoſt all the elements, ſeemed angry with this unfortunate machine; which, being conſtructed of bad materials, was little able to ſuſtain thoſe injuries. Nevertheleſs, in various trials, it had ſhewn its ſurpriſing power; and once, on putting a bundle of ſtraw, upon which ſpirit of wine had been ſprinkled, on the fire, the ſudden flame occaſioned ſuch a rarefaction, that the machine, notwithſtanding the efforts of 50 perſons, who were employed to hold it, roſe three feet from the ground, and went to the diſtance of 15 feet.

At laſt, on the 19th, the weather was

pretty clear, with very little wind, the ſun ſhewing itſelf at intervals. The thermometer ſtood at 45°. Every thing was got ready for the experiment, and a prodigious croud of ſpectators aſſembled about the place; but as the machine had been wet, and in the night it had frozen very hard, it was neceſſary to thaw the ice by degrees, which was effected by making ſeveral ſmall fires under the ſcaffold; but this naturally took up a conſiderable time; ſo that the experiment could not be begun before noon. The fire was now lighted, and the machine ſoon began to ſwell, aſſuming the beſt form that could be wiſhed; but the ſpectators, who had been often diſappointed, ſhewed at this time a great deal of anxiety; their minds ſeeming to fluctuate between hope and fear. In 17 minutes the machine was filled, and was ready to aſcend; the intended ſix paſſengers took their places in the gallery, and nothing was wanting but the ſignal of departure from Mr. Duroſier. But this gentleman, conſidering the indifferent condition of the machine, that had greatly ſuffered in the preceding trials, was

9 of

of opinion that the experiment would certainly fail, if more than three perſons aſcended with it: his remonſtrances were of no effect; for none of the adventurers would leave his place on any account whatever. Upon this, the interpoſition of Mr. le Fleſſelles, the intendant, was requeſted; but his authority could not prevail on them to caſt lots. At laſt, their obſtinacy being unconquerable, the ſignal of departure was given, with reluctance and with fear, and the ropes were cut off. A very remarkable inſtance of enthuſiaſm, rather than courage, happened at this inſtant. The machine was not raiſed above a foot or two from the ground, when a ſeventh perſon, one Mr. Fontaine, jumped into the gallery, which occaſioned a ſudden depreſſion of the machine; but by increaſing the fire in the grate, the whole aſcended majeſtically, and with moderate rapidity. On meeting with the wind, it was turned from the eaſt, inſtantly, towards the weſt; but it afterwards proceeded eaſt-ſouth-eaſt, aſcending at the ſame time, till it was at leaſt 1000 yards high. The effect produced on the ſpectators by this ſpectacle, is deſcribed as the moſt extraordinary that was ever occaſioned by any production of human invention. It was a mixture of the ſtrangeſt nature. Vociferations of joy, ſhrieks of fear, expreſſions of applauſe, the ſound of martial inſtruments, and the diſcharge of mortars, produced an effect more eaſily imagined than deſcribed. Some of the people fell on their knees, and others elevated their ſuppliant hands to the heavens; ſome women fainted, and many wept: but the confident travellers, without ſhewing the leaſt appearance of fear, were continually waving their hats out of the gallery. The wind ſhifted again, but it was very feeble, ſo that the machine ſtood almoſt ſtationary for about 4 minutes.

Unfortunately, about this time, which was near 15 minutes after the aſcent, a rent was made in the machine, which occaſioned its deſcent; and when it came within about 600 feet of the ground, it deſcended with a very great celerity. It is ſaid, that not leſs than ſixty thouſand people, beſides the

the Marechauſſée, ran to the ſpot, with the greateſt apprehenſion for the lives of thoſe adventurous aerial travellers. They were immediately helped out of the gallery, and luckily none of them had received any hurt, except Mr. Montgolfier an inſignificant ſcratch. The machine was torn in ſeveral places, beſides a vertical rent of upwards of 50 feet in length; which ſhews very clearly how little danger is to be apprehended from the uſe of thoſe machines, eſpecially when they are properly conſtructed and judiciouſly managed.

The following are the names of the ſeven travellers: Mr. Joſeph Montgolfier, Mr. Pilatre de Rozier, Count de Laurencin, Count de Dampierre, Prince Charles de Ligne, Count de Laporte d'Anglefort, and Mr. Fontaine.

CHAP-

CHAPTER XI.

Aeroſtatic experiments made in February and March, 1784.

THE Marquis *de Bullion*, on the 3d of February, launched a paper machine, near 15 feet in diameter; which was kept floating by means of a flat ſponge, one foot broad, ſoaked in a pint of ſpirits of wine, and placed in a tin pan. This balloon was launched at Paris, at 45 minutes paſt two o'clock; and it was found, at about three, in a vineyard near *Baſville*, which is near 27 miles diſtant from Paris.

On the 15th of the ſame month, at three o'clock, Mr. *Gellard de Chaſtelais* launched a paper aeroſtat, the air of which was kept rarefied by the combuſtion of rolled paper and a ſponge ſoaked in oil, ſpirits of wine, and greaſe. A baſket containing a cat was faſtened

faſtened to it. In 35 minutes, the machine aſcended ſo high, as to appear like a very ſmall ſtar. At 5 o'clock, it was found upon ſome trees, at the diſtance of between 45 and 48 miles from *Mâcon*, from whence it had been launched; ſo that it went at the rate of about 23 miles an hour. The cat was found dead; but nobody could gueſs at the cauſe of its death.

The firſt balloon that croſſed the Engliſh channel, was launched from Sandwich in Kent, on Friday, the 22d of February, 1784. It was an inflammable-air balloon, five feet in diameter; which was let looſe at half paſt 12 o'clock, in the preſence of a great many ſpectators. The balloon roſe rapidly, and was carried over the ſea by the wind, which was weſt by north; ſo that the direction of the balloon was eaſt by ſouth. It was found, at 3 o'clock of the ſame day, in a field near *Warneton*, in French Flanders, nine miles from Liſle, by a boy; who carried it to Monſieur Betrayle, at Warneton; and, there being a ticket on the balloon, in which it was requeſted that an account

account of the time when, and place where, the ſaid balloon ſhould be found, might be ſent to William Boys, Eſquire, at Sandwich; ſuch requeſt was politely complied with.—The ſtraight diſtance between Sandwich and Warneton is 74 miles and an half; ſo that this balloon went at the rate of above 30 miles an hour.

The Chevalier Paul Andreani, of Milan, was the firſt perſon in Italy, who had an aeroſtatic machine made at his own expence, for the purpoſe of making an aerial voyage; in which attempt he actually ſucceeded, on the 25th of February, 1784. The project was entirely his own; but for the practical execution of the work, he employed the brothers Auguſtin and Charles Gerli, perſons of a mechanical genius.

The machine was ſpherical, of about 68 feet in diameter, made of linen, lined with fine paper. In the inſide, towards the middle of the machine, there was a wooden zone or hoop; and another hoop, of 14 feet in diameter, was round its aperture. On the

the top of the machine there was a ſort of hat, or round piece of wood, ſtrengthened with an iron hoop, from which ropes proceeded, which went down along the ſeams of the machine, and were laſtly faſtened to the hoop of the aperture. Other ſmaller cords were faſtened to the linen, and croſſing the larger ropes, made a ſort of network. Some ſhort wooden arms, which proceeded from the hoop of the aperture, held the fire-place, or copper brazier, of about 6 feet and an half in diameter. Cords proceeding from the ſame hoop, held a circular baſket, which ſtood under the brazier, at a moderate diſtance from it; ſo that the perſons in it might eaſily ſupply the fire with fuel, and at the ſame time were not incommoded by the heat.

The machine being conſtructed, was ſecretly tranſported to a ſeat of the Chevalier, called *Moncucco*, which is 8 miles diſtant from the town. Two ineffectual trials were made; each time the machine was perfectly inflated in 15 minutes; but it did not lift up the annexed weight from the ground:

ground: however, on the 25th, at about noon, the fire under the machine was lighted; it was ſupplied at firſt with very dry wood, and afterwards with a compoſition of bituminous ſubſtances. The machine now made evident endeavours to riſe; and, it being imagined, that giving more freedom to the air under it, would increaſe its power, the Chevalier judiciouſly ordered thoſe who held the ropes, to let the machine riſe a little; which was attended with the deſired effect. The machine inſtantly manifeſted it had acquired an increaſe of power; in conſequence of which, the Chevalier, and the two brothers Gerli, put themſelves into the gallery, or circular baſket; the ropes were let looſe, and the machine, with the three adventurers, immediately aſcended, with a ſlow and almoſt horizontal motion, directing itſelf towards the building: to avoid which, the fire was increaſed, and then the machine aſcended with rapidity to a great height; ſo that it was ſeen from the city, which was 8 miles off. At this height they met with a current of air, which ſeemed to drive the machine towards the

adjoining

adjoining mountains; but as this was not an eligible direction, and as the fuel was almost exhausted, they thought proper to descend; and accordingly, the fire being diminished, the machine gradually descended. In coming down, the aerostat was going directly over a large tree; but, by a proper management of the fire, it just cleared the tree; after which, the people, that had run to its assistance, laid hold of the ropes that were swinging down, and conducted the machine to a safe place, where the intrepid travellers alighted without the least inconvenience. In consequence of the loss of this weight, the machine acquired such power, that it required the assistance of many persons to detain it. The machine being thus capable of keeping itself swelled, they availed themselves of its condition, and carried it, in that inflated state, over trees and other obstructions, to the place where it had been filled, which was not above a quarter of a mile distant. The machine remained in the atmosphere for about 20 minutes. It is remarkable, that this machine, notwithstanding the various trials it had undergone, had not suffered the least

damage.

damage. Its upper part eſpecially, like that of the machine uſed in the experiment at Verſailles, and that alſo at la Muette, was neither ſcorched, nor in any other manner affected by the fire; which is a circumſtance deſerving of notice, particularly, becauſe it has been commonly ſaid, that the upper part of thoſe machines would be always burned or ſcorched.

From the calculations made relating to the power and capacity of this machine, it appears, that, by the action of the greateſt fire they could make in it, the air was not rarefied above one third; ſo that the quantity of air in the machine when rarefied, was not leſs than two-thirds of that, which would have filled the machine, when of the ſame temperature with the external air.—Indeed, from this as well as from other accurately made experiments, it ſeems that this is the utmoſt degree of rarefaction, that can be reaſonably expected to take place in ſuch machines.

On the 19th of February, an inflammable-air balloon, of 5 feet in diameter, was launched from Queen's College, at Oxford. It was of a ſpherical form, made of varniſhed Perſian ſilk; and it ſeems that this was the firſt balloon ſeen in that town.

The next aerial voyage we are to deſcribe, was made by one, who, as will appear from the ſequel of this hiſtory, has performed a greater number of theſe excurſions than any other perſon, previous to February, 1785; and is the firſt who croſſed the Engliſh channel with an aeroſtatic machine. This ingenious Frenchman; Mr. Jean-Pierre Blanchard, had, for ſeveral years before Mr. Montgolfier's diſcovery, buſied himſelf in attempts to fly by mechanical means; but it appears, from a paſſage in a letter of his to the editors of the *Journal de Paris*, that he never ſucceeded in this undertaking*: but as ſoon

* "Je rends donc un hommage pur & ſincère à "l'immortel Montgolfier, ſans le ſecours duquel "j'avoue que le mécaniſme de mes aîles ne m'au- "roit peut-être jamais ſervi qu'à agiter un élément "indocile qui m'auroit obſtinément repouſſé vers la "terre comme le lourd autruche, moi qui comptois "diſputer à l'aigle le chemin des nues."

as the diſcovery of the aeroſtatic machine was made, he immediately reſolved to uſe one of thoſe machines for the lifting power, and to add the wings of his former ſcheme, for directing his courſe through the air.

After a great deal of contrivance, and ſome calculation, Mr. Blanchard at laſt conſtructed an inflammable-air balloon, of 27 feet in diameter, with a boat made and ſuſpended nearly in the ſame manner as that of Charles and Robert, only he added two wings and a rudder *(gouvernail)* to his boat. He had likewiſe a ſort of large umbrella ſpread horizontally between the balloon and the boat, which, in caſe the balloon ſhould burſt, would check the fall.

With this balloon, Mr. Blanchard made his firſt aerial voyage, on the 2d of March, 1784. As the incidents of this voyage are of a very ſtrange and romantic nature, I think that a particular account of them, will not be unacceptable to the reader.—The balloon, with the reſt of the machinery, and apparatus for filling it, was carried to the *Champ*

Champ de Mars, the place from whence the first inflammable-air balloon had been launched; and, as usual on similar occasions, an immense number of people assembled about the place. The machine being filled, Mr. Blanchard, and a Benedictine Friar, seated themselves in the boat; the ropes were cut off, and they ascended, but not higher than about 15 feet from the ground. Then, the balloon being leaky, and the weight in the boat rather too great, the whole fell very rapidly; and on touching the ground, the boat received an unpleasant shock: in consequence of which, the Friar was persuaded to abandon his seat. But the intrepid Mr. Blanchard was not at all intimidated by the accident: he immediately repaired the little damage the apparatus had received from the fall, and was going to ascend again by himself; but just as he was setting off, a young gentleman forced his way thro' the crowd, jumped into the boat, and, without any right or reason, insisted upon going up with Mr. Blanchard. Every expostulation or remonstrance of Mr. Blanchard, and of many persons of the first rank who were present, was ineffectual to perſuade the young gentleman to give up this deſperate attempt. His anſwer was, That he was provided with the king's licence; and on being deſired to ſhew it, he preſented his ſword, with which it is ſaid he wounded Mr. Blanchard on the wriſt. At laſt, the Marquis *de Conflans*, at the riſk of his life, pulled the young enthuſiaſt out of the boat, and, delivering him to the guards, ordered them to confine him. This ſtrange conteſt being over, Mr. Blanchard alone, without fear or heſitation, aſcended with his balloon very rapidly into the atmoſphere; but, notwithſtanding his endeavours, the wings and rudder of the boat ſeemed to have no effect, and the wind drove the balloon in its direction. It croſſed the river, and went over *Paſſy*; but Mr. Blanchard found a perfect calm, ſo that he remained ſtationary for about 14 minutes. Then he croſſed the river a ſecond time; and in this paſſage the clouds appeared under his feet. He now felt the heat of the ſun's rays, which was rather ſtrong, and ſtood ſtationary again for about 15 minutes; the balloon being, at the ſame time, agitated

by

by two oppofite currents of air: on which he threw 4 pounds of ballaft out of the boat, and afcending higher, met with that current of air in which he had gone at firft, and which carried him very rapidly again acrofs the river. Here he was obliged to throw out more ballaft, by which means the voyage was prolonged as far as the plain of *Billancourt*, near *Seve*, where he defcended at 35 minutes paft one o'clock, after having been in the atmofphere an hour and a quarter; during which time he had experienced heat, cold, hunger, and an exceffive drowfinefs. On his return to the earth, he was welcomed by many thoufands of people, who had watched his progrefs all the way.

It appears, from a letter of Mr. Blanchard to Mr. de Saint-Fond, that the wings and rudder of his boat had very little power, if any at all, to guide the balloon from the direction of the wind *.

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* The following note was communicated by Mr. *de la Lande*.

The altitude of Mr. Blanchard's balloon, feen from the

On the 13th of March, the Chevalier Andreani, and two other perſons, aſcended a ſecond time into the atmoſphere, with a rarefied-air machine, from the ſame place where he had performed his firſt experi-

the royal obſervatory, at 35 minutes paſt noon, was 16° 30′, according to Count de Caſſini.

At 38 minutes paſt noon, it changed its direction.

At 42 minutes paſt noon, it aſcended perpendicularly, and its altitude was 25°.

At one o'clock, the balloon appeared as if it was emptying itſelf, Its altitude at this time being 48° 25′.

At 2 minutes paſt one, the altitude was 51° 41′.

At 3 minutes paſt one, the diameter of the balloon being ſuppoſed to be $27\frac{7}{10}$ feet, the angle it ſubtended was 11′ 50″, which makes the diſtance 8,050 feet; and its height being 52°, the elevation of the balloon above the earth muſt have been 6343 feet.

At one o'clock, Mr. Meſſier, from the Hotel de Clugny, obſerved the angle ſubtended by the balloon, and found it to be 7′; from which he deduces the elevation of the balloon to be 7500 feet.

At 15 minutes paſt one, he found the elevation to be 5659 feet; but at 53 minutes paſt noon it was much higher; and probably its altitude was 9591 feet.

The balloon came down at 35 minutes paſt one o'clock.

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ment. The machine attained to the height of 5200 feet, and travelled to the diſtance of 7 miles.

In a letter, dated Geneva, March the 26th, 1784, Mr. de Sauſſure mentions his having made ſome experiments on the atmoſpherical electricity, with an aeroſtatic machine, which was raiſed by means of the combuſtion of ſpirits of wine, and was faſtened to a long ſtring. In a cloudy day he obtained a poſitive electricity, ſtrong enough to afford ſparks.

It was about this time that Mr. Argand, an ingenious gentleman of Geneva, being in England, had the honour of exhibiting the aeroſtatic experiment, with an inflammable-air balloon of about 30 inches in diameter, in the preſence of the king, queen, and royal family, at Windſor.

After the month of February, balloons of both kinds, but eſpecially filled with rarefied air, became very common in England,

land, as well as in other parts of Europe. In London, during the ſpring, the ſummer, and the autumn, paper balloons, raiſed by means of ſpirit of wine, and generally from 3 to 5 feet in diameter, were ſeen flying by night as well as by day. All ranks of people ſeem to have found pleaſure in ſuch kind of experiments; and ſo much had the ſubject engaged general attention, that, both in earneſt, and in jeſt, the epithet of *balloon* was annexed to articles of dreſs, of houſe-furniture, of inſtruments, &c. Thus, one commonly heard of balloon hats, balloon colours, balloon coaches, and ſuch-like empty phraſes.

CHAP-

CHAPTER XII.

Aeroſtatic experiments made in the Months of April, May, June, and July, 1784.

ON the 25th of April, Meſſrs. *de Morveau* and *Bertrand*, at Dijon, aſcended into the atmoſphere with an inflammable-air balloon; which, according to their barometrical obſervations, ſeems to have been elevated to the height of about 13000 feet, where the air was conſiderably cold; the thermometer ſtanding at 25 degrees.— They remained in the atmoſphere during one hour and 25 minutes; in which time they went to the diſtance of about eighteen miles.

Mr. *de Morveau* had prepared a piece of machinery, conſiſting principally of certain oars, with which he intended to direct the balloon through the air; but, unfortunately, a guſt a guſt of wind damaged this machinery juſt when they were going to aſcend; it appeared however, that by working two oars, which remained unhurt, a ſenſible effect was produced in reſpect to the motion of the machine.

Meſſrs. *Bremond* and *Maret*, at Marſeilles, aſcended with an aeroſtatic machine, on Montgolfier's principle, of 50 feet in diameter, on the 8th of May. They remained in the atmoſphere only 7 minutes; in which time they travelled about one mile and a half.

At Straſburg, on the 15th of the ſame month, a balloon was raiſed with two perſons; but it came down immediately.

At Paris, on the 20th of May, Mr. Montgolfier made a private experiment with an aeroſtatic machine of 74 feet in height, and 72 in diameter, with which four ladies aſcended in the atmoſphere. This machine was raiſed from the Fauxbourg Saint-Antoine; and was elevated above the higheſt

 buildings

buildings of Paris, where it remained confined by ropes for a confiderable time. Thofe courageous ladies were the Marchionefs de Montalembert, the Countefs of the fame name, the Countefs de Podenas, and Mademoifelle de Lagarde; and they were accompanied by the Marquis de Montalembert and Mr. Artaud de Bellevue *.

Mr. Blanchard afcended a fecond time with the fame balloon, from Rouen, on the 23d of May, at 20 minutes paft 7 in the evening, and remained in the atmofphere for about one hour; when he defcended, at about 12 miles diftance from Rouen. It was obferved, that in this aerial voyage, Mr. Blanchard's wings or oars could not carry him in any other direction than that of the wind; fo that he fhewed none of thofe manœuvres, which he had promifed to perform. The quickfilver in the barometer, he fays, defcended as low as 20,57 inches; but on the earth, before

* See the Supplement to the fecond volume of Mr. de Saint-Fond's *Defcription des Experiences Aeroftatiques*.

he

he aſcended, the quickſilver ſtood at 30,16 inches.

On the 29th of the ſame month, Meſſrs. Maret and Bremond went up a ſecond time, with the ſame machine they had uſed before. They now aſcended rather higher than in the former attempt; but the machine taking fire, they ſaved themſelves with difficulty.

Towards the latter end of May, the following remarkable accident happened at Dijon: it is related by the ingenious Mr. de Morveau.—A balloon, intended to be filled with inflammable air, being completed, was, by way of trial, filled with common air; and in this ſtate was kept in the open air. Now it was obſerved, and indeed a ſimilar obſervation had been made before, that the air within the balloon was much hotter than the circumambient air; the thermometer in the former ſtood at 120°, whereas in the latter, and when the ſun ſhone upon it, the thermometer ſtood at 84°. This ſhewed a conſiderable degree of rarefaction within the balloon; and, conſequently, ly, it was ſuſpected, that by means of this rarefaction alone, eſpecially if it were to increaſe a little, the balloon might aſcend. On the 30th, about noon, the wind, being rather ſtrong, agitated the balloon ſo that two men were employed to take care of it; but, notwithſtanding their endeavours, the balloon eſcaped from its confinement, and lifting up about 65 pounds weight of cords, equatorial circle, &c. roſe ſeveral feet high, and paſſing over ſeveral houſes, went to the diſtance of about 250 yards, where it was at length properly ſecured.

At Aix, on the 31ſt of May, Mr. Rambaud aſcended with an aeroſtatic machine of a globular form, about 50 feet in diameter, which was furniſhed with a gallery, fire-place, &c. as uſual. It remained in the air during 17 minutes, in which time it aſcended to the height of about 2450 feet, and went to the diſtance of about 2900 yards. On touching the ground, Mr. Rambaud deſcended from the gallery; in conſequence of which, the machine aſcended by itſelf

itſelf rapidly into the atmoſphere, took fire, and was preſently conſumed.

At Lyons, on the 4th of June, in the preſence of the king of Sweden, two perſons, namely Mr. Fleurant and Madame Thible, aſcended with an aeroſtatic machine called *le Guſtave*, which was 70 feet in diameter. They went to the diſtance of about two miles, in 45 minutes. The greateſt altitude reached in this excurſion is eſtimated at about 8500 feet.—This experiment will probably be long remembered, ſince it was the firſt time that a woman made an aerial voyage.

On the 12th of the ſame month, at Dijon, Mr. de Morveau and Mr. de Virly aſcended with a balloon, at 7 minutes paſt 7 in the morning. They remained in the air one hour and two minutes; after which they deſcended voluntarily, at the diſtance of 14 miles from Dijon.

At Nantes, on the 14th of June, a balloon filled with inflammable air, extracted from

from zinc, was raiſed, with two perſons, namely, Mr. *Couſtard de Maſſi*, and Mr. *Mouchet*. The diameter of this balloon was 32 feet and a half; and the boat of it, or rather the whole machine, was named *le Suffrein*. It aſcended at half an hour after ſix o'clock in the afternoon, elevated itſelf to a great height, and in 58 minutes went to the diſtance of 27 miles, when it ſafely deſcended, near *Getes*, in *Anjou*. This machine, as well as all the apparatus belonging to it, had been deſigned by Mr. *L'Eveque*, *Ingenieur de la Marine*.

On the 16th of June, at Bourdeaux, three perſons, namely, Meſſrs. Darbelet, Deſgranges, and Chalfour, aſcended with a rarefied-air machine. They went to the height of about 2700 feet; and remained in the atmoſphere during one hour and 14 minutes; ſhewing repeatedly, that they could aſcend and deſcend at pleaſure, by properly managing the fire. At laſt they deſcended ſafely in a vineyard, at no great diſtance from the place of their aſcenſion.

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On the 23d of June, a large aeroſtat, on the principle of rarefied air, was elevated at Verſailles, in the preſence of the royal family, and the King of Sweden, who travelled under the name of Count Haga. The height of this machine was 91 feet and a half, and its diameter 79. Mr. Pilatre de Rozier and Mr. Prouts aſcended with it. The machine was filled in 35 minutes, and it left the ground at 45 minutes after 4 o'clock. In three quarters of an hour it went to the diſtance of 36 miles, when it ſafely deſcended in a field, which, having no name, was, by order of the Prince de Condè, called *Pilatre de Rozier*, in honour of that celebrated firſt aerial traveller; who had likewiſe gone with this machine, and to whom, after this experiment, the king was pleaſed to grant a penſion of 2000 livres.

On the 15th of July, the Duke of Chartres, the two brothers Roberts, and another perſon, aſcended with an inflammable-air balloon from the Park of St. Cloud, at 52 minutes paſt 7 o'clock in the afternoon. This

This balloon was of an oblong form, meaſuring 55 feet and a half in length, and 34 in diameter. It aſcended with its greateſt extenſion nearly horizontal; and, after remaining in the atmoſphere about 45 minutes, it deſcended at a little diſtance from whence it had aſcended, and at about 30 feet diſtance from the lake *de la Garenne*, in the Park of *Meudon*. But the incidents that happened in this aerial excurſion deſerve to be particularly deſcribed, as nothing like it had happened before to any of the aerial travellers. This machine contained an interior ſmaller balloon, filled with common air; by which means, according to a ſcheme hereafter to be mentioned, the machine was to be made to aſcend or deſcend without any loſs of inflammable air or ballaſt. The boat was furniſhed with a helm and oars, intended to guide it, &c.

On the level of the ſea the barometer ſtood at 30,25 inches, and at the place of departure it ſtood at 30,12. Three minutes after its aſcending, the balloon was loſt in the clouds, and the aerial voyagers loſt ſight of the earth, being involved in a denſe vapour. Here an unuſual agitation of the air, ſomewhat like a whirlwind, in a moment turned the machine three times from the right to the left. The violent ſhocks, which they ſuffered, prevented their uſing any of the means prepared for the direction of the balloon, and they even tore away the ſilk ſtuff, of which the helm was made. Never, ſaid they, a more dreadful ſcene preſented itſelf to any eye, than that in which they were involved. An unbounded ocean of ſhapeleſs clouds rolled one upon another beneath, and ſeemed to forbid their return to the earth, which was ſtill inviſible. The agitation of the balloon became greater every moment. They cut the cords, which held the interior balloon, which conſequently fell on the bottom of the external one, juſt upon the aperture of the tube, which went down into the boat, and ſtopped it up. At this time the thermometer ſhewed a little above 44°. A guſt of wind from below drove the balloon upwards, to the extremity of the vapour, where the appearance of the ſun ſhewed them the exiſtence

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of nature; but now both the heat of the ſun, and the diminiſhed denſity of the atmoſphere, occaſioned ſuch a dilatation of the inflammable air, that the burſting of the balloon was apprehended; to avoid which, they introduced a ſtick through the tube that proceeded from the balloon, and endeavoured to remove from its aperture the inner balloon, which cloſed it; but the dilatation of the inflammable air puſhed the inner balloon ſo violently againſt the aperture of the tube, that every endeavour proved ineffectual. During this time, they ſtill continued to aſcend, until the mercury in the barometer ſtood not higher than 24,36 inches, which ſhews their height above the ſurface of the earth to be about 5100 feet. In theſe dreadful circumſtances, they thought it neceſſary to make a hole in the balloon, in order to give an exit to the inflammable air; and the Duke of Chartres took himſelf one of the banners, and made two holes in the balloon, which tore open between ſeven and eight feet. They then deſcended very rapidly, ſeeing at firſt no object either on earth or in the heavens; but a moment after they diſcovered the fields, and were deſcending ſtraight into a lake, wherein they would inevitably have fallen, had they not quickly thrown overboard about 60 pounds weight of ballaſt, which occaſioned their coming down at about 30 feet beyond the edge of the lake. Notwithſtanding this rapid deſcent, occaſioned by the great quantity of gas, which eſcaped out of the two rents in the balloon, none of the four adventurers was hurt; and it is very remarkable, that out of ſix glaſs bottles full of liquor, that were ſimply laid down in the boat, only one was found broken.

On the 18th of July, Mr. Blanchard made his third aerial voyage, with the ſame inflammable-air balloon, from Rouen. He was accompanied by one Mr. Boby; and in the account of the voyage he ſays, that when they aſcended, there were 210 pounds of ballaſt, beſides their weight, in the boat. In this voyage Mr. Blanchard had a barometer and a thermometer, the former of which, on the ground, ſtood at 30,1 inches, and the latter at 45°. The wind was north-west. They set off, at a quarter past five o'clock in the afternoon, from the Barracks of *Rouen*, and in seven minutes time the barometer fell 4,76 inches, and the thermometer 40°. During the voyage, Mr. Blanchard says, that by agitating the wings of his boat, he often ascended, descended, went side-way, and even, in some measure, against the wind; but one of the certificates says, that, previous to the final descent, Mr. Blanchard, in order to gratify the spectators, descended and re-ascended three times at pleasure, by means of the wings. However, this might have been occasioned by merely rebounding on the earth, or by letting out alternately some ballast, and some inflammable air; which seems rather likely to have been the case, since, in the voyages which Mr. Blanchard afterwards made in England, with the same balloon, the wings of his boat, in spite of his endeavours, seemed to produce no particular effect.

At half an hour past seven, they descended safely in the plain of *Puissanval*, near *Grandeour*, which is 45 miles distant from Rouen; 110 pounds weight of ballaſt ſtill remaining in the boat.

One of the certificates, ſigned by many perſons, teſtifies, that for this experiment the balloon was filled by Mr. Vallet, in the remarkable ſhort time of one hour and a half. The laſt certificate, that is annexed to the account of this voyage, ſays, that the balloon remained full all the night; and that on the following day, having anchored it by means of ropes, which permitted it to aſcend only to about 80 feet, divers ladies aſcended ſucceſſively with it, and they found the experiment far from being dangerous or diſpleaſing.

The balloon was at laſt evacuated of its gas; to effect which, not only the valve was opened, but a great aperture was made towards the inferior part of the balloon, which was laid on its ſide, and preſſed; and yet more than an hour was required to empty it; from whence may be concluded, that if a rent of three feet ſhould be made in ſuch a balloon, whilſt in the atmoſphere, the loſs of inflammable

air

air would not be sufficient to occasion a dangerous fall.

On the 26th of July, at Bourdeaux, the same three persons, who had ascended with an aerostatic machine on the 16th of June, made a second aerial voyage in the same machine. They crossed the Garonne and Dordogne, and descended at Airac, near 20 miles distant from Bourdeaux.

It is said that, in the course of this summer, two persons, viz. one in Spain, and another near Philadelphia, in America, were very near losing their lives by going up with rarefied-air machines. The former, on the 5th of June, was scorched by the machine taking fire, and so hurt by the subsequent fall, that his life was long despaired of. The latter, having ascended a few feet, was wafted by the wind against the wall of a house, and some part of the machinery was entangled under the eaves, from whence he could not extricate it. At last the violent ascent of the machine broke the ropes or chains, and the man fell from the height of about 20 feet. The machine presently after took fire, and was consumed *.

I shall conclude this chapter with part of a letter of Mr. James Watt, to Dr. James Lind, of Windsor, dated Birmingham, December the 26th, 1784, which relates a remarkable experiment, made in the course of the summer, with an inflammable-air balloon.

" The history of Mr. Boulton's explosive
" balloon, is as follows:—He made a bal-
" loon of thin paper, and varnished it with
" an oil varnish. The size was about 5
" feet diameter. It was filled with a mix-
" ture of about one part common air, and
" two parts inflammable air from iron.
" In the neck of the balloon he tied a
" common squib, or serpent, to which was
" fastened a match of about two feet long,
" which was made very quick at the end

* Those two accounts have been extracted only from the daily news-papers.

" next

" next the ſerpent. When the balloon " was filled, the match was lighted, and " the balloon was launched.

" The night was very dark, and nearly " calm; but the match being cut rather " too long, it was about five minutes be- " fore the exploſion took place, in which " time the balloon had got above two " miles from the place where it was let off. " A conſiderable number of people were " aſſembled to ſee the experiment, and as " they loſt ſight of the match ſoon after " the balloon was let go, they expected it " was gone out, and that they ſhould ſee " or hear no more of it; but when the " match kindled the ſerpent, their mur- " murs were turned into joy, which they " expreſſed by a general ſhout; which " happening when the balloon exploded, " the noiſe of the exploſion was very indiſ- " tinctly heard; though the people, who " happened to be in the neighbourhood of " it when it exploded, ſaid that it made a " noiſe like thunder, and almoſt as loud. " Indeed they took the balloon for a

" meteor,

" meteor, and the explosion for real thun-
" der.

" Our intention in the experiment was, " to determine whether the growling of " thunder is owing to echoes, or to success- " sive explosions; but by means of that ill- " timed shout the question could not be " solved, otherwise than by the report of " those who were near it, who said that " it growled like thunder; but their ob- " servations upon it were very inaccurate, " and rendered more so by their being un- " prepared for such a phenomenon. I was " not at the place the balloon was let off " from, but was at my own house, which " is at least three miles from the place " where the explosion happened. All I " could observe was, that the explosion was " very vivid and not instantaneous; it " seemed to last about one second, and the " materials of the balloon taking fire, ex- " hibited a fine fire-work for a few se- " conds more. These are all the particu- " lars which I remember, or which are of " any consequence to be known, in a mat- " ter so easily repeated."

CHAP-

CHAPTER XIII.

Aerostatic experiments made in August and September, 1784; containing the first aerial voyage made in England.

AT Rodez, a town of Guienne, in France, the Abbè Carnus, professor of Philosophy, and Mr. Louchet, professor of Belles Lettres, ascended, on the 6th of August, with an aerostatic machine of 57 feet in diameter. This experiment appears to have been made and described with a great deal of accuracy and judgment; though it does not ascertain any thing very remarkable and new.

At 17 minutes past eight o'clock in the morning, the fire began to be lighted under the machine, and 11 minutes after it ascended. The wind being very weak, the machine did not travel farther than about 14900 yards in 46 minutes; after which time

time the want of fuel obliged the aeronauts to descend; they and the machine being quite safe. According to their barometrical observations, the height they reached was at least 3920 yards above the level of the town. They saw the horizon well defined, filled two bottles with the air of that high region, and observed that the thermometer descended not lower than the 66th degree, which was 34 degrees lower than what it stood at on the earth before the machine ascended. They had the curiosity to introduce a thermometer into the machine, and found that it ascended to between 167 and 179 degrees. On examining the air of one of the bottles, that had been filled above, they found that it contained a quarter less air than if it had been filled at about the level of the sea; this air, being tried by the admixture of nitrous air, was found to suffer a greater diminution, and consequently to be purer, than the air near the surface of the earth. If this superior degree of purity of the air above is constantly true, as indeed it seems probable, we may expect to see patients sent up with

a balloon

a balloon for a certain time every day, or week, in order to breathe a purer air in their own country, inſtead of being ſent abroad.

On the 6th of September, at Nantes, Meſſrs. Couſtard de Maſſy and Delaynes made an aerial voyage with the ſame machine, which had before aſcended from that place. They went up at 35 minutes paſt 12 at noon, and deſcended ſafely, after having remained in the atmoſphere during 2 hours and 32 minutes.

The firſt aerial voyage ſeen in England, was performed in London, on the 15th of September, by one Vincent Lunardi, a native of Italy. The difficulties Mr. Lunardi met with in this enterpriſe—the ſucceſs, rather unexpected—the concurrence of many fortunate circumſtances—and the enthuſiaſtic applauſe with which he was afterwards honoured, and perhaps poiſoned—have expoſed him to a variety of ſcrutinies and remarks, which were dictated generally by envy, often by miſinformation, but ſometimes by juſtice. The general converſation has been long occupied by thoſe topics; and,

and, as the preſent work has been written in the very ſame place where thoſe tranſactions happened, it was requeſted, and expected by divers of my acquaintance, that a circumſtantial account of thoſe facts ſhould be inſerted in this hiſtory. But, it being neither my inclination, nor the duty of an impartial hiſtorian, to ſwell the work with the particular narration of what is altogether foreign to the ſubject, and in itſelf trifling, I ſhall content myſelf with the account of what relates merely to the aeroſtatic experiment, and ſhall leave the enquiry into other particulars, to thoſe whom it may concern.

The balloon was made of oiled ſilk, painted alternately in ſtripes of blue and red. It meaſured 33 feet in diameter. A net went over about two thirds of the balloon, from which 45 cords deſcended to a hoop that hung juſt below the balloon, and to which the gallery was attached. The balloon had no valve; and its neck, which terminated ſomething like a pear, was the aperture, through which the inflammable

air

air was introduced, and through which it might be let out.

On the 14th of September the balloon was placed in the Artillery Ground, which was the place appointed for the exhibition of the experiment. The operation of filling the balloon was begun in the night, the inflammable air being produced from zinc, by means of diluted vitriolic acid; which mixture was put into two very large casks. This operation continued the whole night, and till half an hour after one in the afternoon of the 15th, at which time, about two thirds of the balloon were full; but as the time of performing the experiment was elapsed, and some disturbance arising from the impatience of the assembled multitude, the balloon was removed from over the casks, and, after trying its lifting power, the gallery was attached to it, which had two oars, or wings, and Mr. Lunardi, with another gentleman, one Mr. Biggin, who was to be his fellow traveller, got into the gallery; but they found, that the balloon had not nearly power sufficient

to

to raiſe them. The diſappointment was great, eſpecially for Mr. Biggin, who appeared exceedingly anxious of aſcending: however, there was no murmur nor heſitation; and, as no time was to be loſt, he calmly reſigned his place, and Mr. Lunardi, full of courage and determination, remained in the gallery, with a cat, a dog, and a pigeon, with which he departed at about two o'clock.

The balloon, after aſcending about 20 feet, went horizontally for a few feet, and then deſcended; but the bottom of the gallery had ſcarce touched the ground, when Mr. Lunardi, inſtantly throwing out ſome ſand, aſcended triumphantly, amidſt the acclamations of an immenſe multitude; the greateſt part of whom never expected that the experiment would have ſucceeded, imagining that the foreign accounts, of aerial voyages performed abroad, were *aerial* in the metaphorical ſenſe, in which that word was underſtood before Montgolfier's diſcovery.

The

The weather was very clear and temperate, and the wind ſouth-eaſt by eaſt; ſo that the balloon went nearly north-weſt by weſt, aſcending to a great height. When Mr. Lunardi was a little higher than St. Paul's Cathedral, he dropped a flag, which he had been continually waving ſince he left the ground; and a little after, he dropt one of his oars. When the machine had reached a great, but unaſcertained, height, it evidently met with another current of air; for now it went very nearly north, whereas below the wind continued as before. At about half an hour after three, Mr. Lunardi deſcended very near the ground, on the common of South Mimms, where he landed the cat, which was almoſt periſhed with cold; then riſing again, he proſecuted his voyage. In his account of the voyage, Mr. Lunardi ſays, that he made this deſcent by the ſole action of his remaining oar, which he calls his invention, though it had been uſed and deſcribed by many other perſons before—perhaps not exactly of the ſame ſhape. But, as he ſays that in reaſcending he threw out ſome ballaſt, it ſeems more natural to ſuſpect, that his deſcent was occaſioned by the loſs of in-flammable air, ſince, if he had deſcended by the action of the oar, he would have aſ-cended by ceaſing that action. After this, Mr. Lunardi went as far as near Ware, in Hertfordſhire; and, at 10 minutes paſt 4 o'clock, he finally deſcended in a ſpacious meadow, in the pariſh of Standon, where he was helped by ſome labourers; and ſoon after, was overtaken by ſeveral gentlemen, ſome of whom had followed him all the way from London. This laſt deſcent alſo, Mr. Lunardi aſſures us he accompliſhed by means of the oar. "I again," *ſays he*, "betook myſelf to my oar, in order to de-"ſcend; and, by the hard labour of fifteen "or twenty minutes, I accompliſhed my "deſign, when my ſtrength was nearly "exhauſted. My principal care was to "avoid a violent concuſſion at landing, and "in this my good fortune was my friend." —His being afraid of a violent concuſſion, ſeems to ſhew, that he deſcended rather in conſequence of the gravity of the balloon, boat, &c. than by the action of the oar; which

which is rendered more likely, by his ſaying, that a conſiderable while before, he had thrown out the little remainder of ſand, the knives, forks, an empty bottle, and, in ſhort, every thing he could conveniently part with; ſo that after this circumſtance, and till he deſcended, a conſiderable quantity of the inflammable air muſt naturally have eſcaped from the balloon, which was ſufficient to occaſion its deſcent.

It appears that he had no philoſophical inſtrument beſides a thermometer, which he ſays, in the courſe of his voyage, fell as low as 29 degrees; in conſequence of which, the drops of water, which collected round the balloon, were frozen.

Beſides thoſe romantic obſervations which might be naturally ſuggeſted by the proſpect ſeen from that elevated ſituation, and by the agreeable calm, which he felt after the fatigue, the anxiety, and the accompliſhment of the experiment, Mr. Lunardi ſeems to have made no particular philosophical observation, or such as may either tend to improve the subject of aerostation, or to throw light on any operation of nature.

We come now to the account of an aerial voyage, which is the longest and the most interesting of any that was ever made.— The same balloon which conducted Messrs. Charles and Robert, in December last, having been destined to carry a greater weight, was cut through the middle, and a cylindrical piece was added between the two hemispheres; so that the whole together formed a kind of oblong spheroid, 46½ feet long, and 27½ in diameter. It was made to float with its longest part parallel to the horizon. A net went over it as low as about the middle, from which limit cords came down to the edge of the boat, which was near 17 feet long. The wings or oars were shaped like an umbrella without the handle; to the top of which a stick was fastened, which stood parallel to the aperture of the umbrella. Five of those oars were disposed round the boat; and from the account

count of the voyage, it appears, that they were of conſiderable uſe.

On the 19th of September, at Paris, the balloon was filled, in three hours time, by Mr. Vallet; the two Meſſrs. Roberts, and Mr. Collin Hullin, entered into the boat, and, with the addition of 450 pounds of ballaſt, they were perfectly balanced. At noon they threw out 24 pounds of ballaſt; in conſequence of which, they began to riſe very gently. At that time the mercury in the barometer, on the level of the ſea, ſtood at 29,61 inches; and the thermometer ſtood a little above 27 degrees. Soon after, they threw out 8 pounds of ballaſt, in order to avoid going againſt ſome trees; in conſequence of which, they roſe to 1400 feet. At this elevation, perceiving ſome ſtormy clouds near the horizon, they went up and down, endeavouring to find ſome current of air, which might carry them out of the way of the ſtorm; but from 600 feet height, to 4200 feet, the current of air was quite uniform. Having loſt one of the oars, they ſuppreſſed another on the oppoſite ſide of the boat, and by working with the remaining three, found that they accelerated their courſe. "We travelled," *ſays their account*, "at the rate of 24 feet per "ſecond; and the manœuvring of the oars "helped us about a third." At 40 minutes paſt 3 o'clock, they heard a thunder clap, and, three minutes after, they heard another, much louder; at this time the thermometer, from 77 degrees came down to 59. This ſudden cold, occaſioned by the approach of the ſtormy clouds, condenſed the inflammable air, and made the balloon deſcend very low; hence they were obliged to throw out 40 pounds of ballaſt.—They had the curioſity to examine the degree of heat within the balloon, and, introducing a thermometer into one of the appendices, the quickſilver roſe immediately to 104 degrees; whereas the external thermometer ſtood at about 63. The barometer ſtood at 23,94 inches. In this region of the atmoſphere they were ſo becalmed, that the machine did not go even two feet a minute; and, availing themſelves of that opportunity to try the power of their oars, they worked

them

them for about 35 minutes, and, by obſerving the ſhadow of the machine on the ground, they found that they had deſcribed an elliptical track, the ſmalleſt diameter of which was about 6000 feet.

The reſt of this voyage being very intereſting, is beſt deſcribed in their own words.—" We perceived below us ſome
" clouds, that ran very rapidly from ſouth
" to north. We deſcended to the level of
" thoſe clouds, in order to follow that cur-
" rent, the direction of which was changed
" ſince our departure. The cloſe of day-
" light being near, we determined to fol-
" low that current for 40 minutes only:
" increaſing our velocity by the uſe of our
" oars, we endeavoured to deviate from the
" direction of the current; but we could
" not obtain a deviation greater than 22
" degrees towards the eaſt. The length
" of our route, during about one hour and
" a quarter, was 2100 feet. Willing to
" try whether the wind nearer the earth
" was ſtrong, we deſcended to the height
" of 300 feet, where we met an exceed-

" ingly rapid current. At ſome diſtance
" from Arras, we perceived a wood, over
" which we did not heſitate to paſs, though
" there was hardly any day-light upon the
" earth; and in 20 minutes time we came
" near Arras, on the plain of Beuvry, diſ-
" tant nearly three quarters of a mile from
" Béthune, in Artois. As we could not
" diſtinguiſh, amongſt the ſhadows, the
" body of an old mill, upon which we
" were going to deſcend, we avoided it by
" the help of our oars, and deſcended
" amidſt a numerous aſſembly of inhabi-
" tants."

When they deſcended, which was at 40 minutes paſt ſix o'clock, there were above 200 pounds weight of ballaſt ſtill remaining in the boat. The way they had travelled was about 50 leagues, or 150 miles. The account of this voyage is concluded with the following remarks:—" Thoſe ex-
" periments ſhew, that, far from going a-
" gainſt the wind, as is ſaid by ſome per-
" ſons to be poſſible, in a certain manner,
" and ſome aeronauts pretend to have ac-

" tually

" tually done it; we have only obtained,
" by means of two oars, a deviation of 22
" degrees: it is however certain, that if
" we could have uſed our four oars, we
" might have deviated about 40 degrees
" from the direction of the wind; and as
" our machine would have been capable of
" carrying ſeven perſons, it would have been
" eaſy for five perſons to have gone, and to
" have put in action eight oars, by which
" means a deviation of about 80 degrees
" might have been obtained.

" We have already obſerved, that if we
" did not deviate more than 22 degrees, it
" was becauſe the wind carried us at the
" rate of 24 miles an hour: And it is na-
" tural to judge, that if the wind had been
" twice as ſtrong as it was, we ſhould not
" have deviated more than half what we
" actually did; and, on the contrary, if
" the wind had been only half as ſtrong, our
" deviation would have been proportion-
" ably greater."

CHAP.

CHAPTER XIV.

Aerostatic experiments made in the remainder of the year 1784.

THE second aerial voyage made in England, was performed by Mr. Blanchard, and Mr. Sheldon, professor of anatomy to the Royal Academy, who is therefore the first Englishman that ascended with an aerostatic machine. This experiment was performed at Little Chelsea, about two miles distant from London, on the 16th of October.

The same balloon and boat, with which Mr. Blanchard had made three other voyages in France, were used for this experiment; the only alteration consisting in the removal of the equatorial hoop and umbrella, which experience had shewn to be useless. On one end of the boat there was adapted a fly, or sort of ventilator, that could

could be turned round by means of a handle. This ventilator, together with the wings and helm uſed in the former voyage, were to ſerve for manœuvring, or for directing the machine at pleaſure, which Mr. Blanchard had repeatedly promiſed to do, as ſoon as he ſhould be elevated above the ground.

The balloon was filled in about an hour and a half; and at noon, being ſufficiently full, the operation was diſcontinued; the boat, after being attached to it, was loaded with the two travellers, with a variety of philoſophical and muſical inſtruments, refreſhments, ballaſt, and other articles. At 9 minutes paſt 12 o'clock the balloon aſcended, but after a few feet elevation, it returned again to the ground; it hit likewiſe againſt an adjoining wall; and in ſhort, the boat was loaded with too much weight. This obliged the two gentlemen to throw out ſeveral things that were of no immediate uſe; in conſequence of which, the machine at laſt roſe with great velocity, almoſt perpendicularly, and took a courſe nearly ſouth-weſt. The weather being hazy, it went ſoon

ſoon out of ſight; but as long as it remained in view, it appeared to go in one invariable direction. The balloon, unable to ſuſtain long the weight of two perſons, began to deſcend, after having been up about half an hour. As the barometer was out of order, in conſequence of an accidental blow, Mr. Blanchard uſed an ingenious, and at the ſame time eaſy method of obſerving whether the balloon was aſcending or deſcending. It was merely to put a riband out of the boat, which being impelled upwards by the air, ſhewed that they were deſcending. Small downy feathers might anſwer this purpoſe ſtill better. —The throwing down a bottle prolonged their deſcent; but at laſt the machine alighted in a meadow near the village of Sunbury, in Middleſex, which is about 14 miles diſtant from London; it being then 50 minutes paſt 12 o'clock. There Mr. Sheldon came out of the boat; and Mr. Blanchard, after taking a quantity of ballaſt, nearly equivalent to the weight of Mr. Sheldon, which employed near 30 minutes, reaſcended alone, and continued the voyage.

In

In this ſecond aſcenſion, Mr. Blanchard's account ſays, that he was carried at firſt by a north-eaſt current, and ſoon after, meeting with another current, he was carried eaſt ſouth-eaſt of Sunbury; but finding the balloon too much diſtended, he opened the valve at the top of it, and deſcended again into the north-eaſt current, it being then juſt 26 minutes paſt one. Four minutes after, he entered into a thick fog, in which he remained 5 minutes. This fog occaſioned the balloon to contract conſiderably. At 38 minutes paſt one, the heat of the ſun became exceſſive, in conſequence of which the globe was again diſtended. In the courſe of this voyage, Mr. Blanchard ſays, that he went ſo high as to experience great difficulty in breathing; he likewiſe relates a curious circumſtance, which is, that a pigeon, which had been taken in the boat, being affrighted by the burſting of a bladder full of air, flew away, labouring very hard with its wings, in order to ſuſtain itſelf in the rarefied air of that elevated region of the atmoſphere. The poor animal wandered about for a good while; but at laſt, finding no other place to ſtand upon, returned to the boat, and reſted on one ſide of it.

At 58 minutes paſt one, the cold being intolerable, Mr. Blanchard deſcended a conſiderable deal lower, ſo as to diſtinguiſh men, and hear their noiſe, on the earth. Some time after he again aſcended higher; then was becalmed for a ſhort time; and thus, after ſeveral ſuch-like viciſſitudes, he came in ſight of the ſea; the approach to which, at laſt determined him to put an end to the voyage, and accordingly he deſcended, at half an hour after four, in a plain, which lay in the vicinity of Rumſey, in Hampſhire, about 75 miles diſtant from London.

On firſt aſcending, Mr. Blanchard was juſtly cenſured for not ſhewing any of the manœuvres, which he had promiſed to perform: as an excuſe for which, he alledges, that the handle of one of the wings was inadvertently thrown over-board, together with ſeveral other articles, when he left the ground. By the motion of the fly and helm, they could turn the boat and balloon round their common vertical axis; but the wing, which Mr. Blanchard ſays he often uſed with ſome effect, ſeems to have produced no deviation of the machine's track from the direction of the wind; ſince, if a ſtraight line is drawn upon a map between Chelſea and Rumſey, it will be found to paſs juſt thro' thoſe places, over which, as may be gathered from Mr. Blanchard's account, he actually paſſed.

Several philoſophical inſtruments, retained in the boat after throwing out ſundry articles on firſt aſcending, were degraded to anſwer the humble office of ballaſt; for not a ſingle obſervation was made with any of them, not examining even the thermometer. Mr. Sheldon indeed ſtaid a very ſhort while, and it being the firſt time he aſcended with a balloon, he may be excuſed if the novelty of the magnificent ſcene prevented his confining himſelf to any particular obſervation; but Mr. Blanchard might have done ſomething more.

It

It was related in the news-papers, that at Oxford, on the 4th of October, one Mr. Sadler ascended with a rarefied-air balloon; but, after strict enquiry, it was found that nobody saw him either ascend or descend. However, on the 12th of the following month, he really ascended, with an inflammable-air balloon, from the Physic Garden at Oxford, in the presence of surprising numbers of people of all ranks. The balloon being sufficiently filled by a little before one o'clock, Mr. Sadler placed himself in the boat, which was fastened by ropes to the net that went over the balloon; then the machine, being abandoned to the air, ascended with such velocity, that in three minutes time it was hid in the clouds, but a few moments after became visible again, and thus it appeared and disappeared three or four times, seeming always to ascend, and at the same time moving with great rapidity in the direction of the wind, which blew rather hard from the south-west. In this voyage Mr. Sadler crossed Otmoor, Thame, and other places; but an aperture made in the balloon, almost as soon as it was launched,

launched, exhausting the inflammable air very fast, obliged him to throw out successively all his ballast, provisions, instruments, &c. and at last forced him to descend at Hartwell, near Aylesbury, which is about 14 miles distant from Oxford; which length he travelled in 17 minutes; so that he went at the rate of near 50 miles an hour. He found himself exceedingly wet in passing through the heavy clouds; and, in descending, had the misfortune of being entangled in a tree, afterward swept the ground, and rebounded to a considerable distance, but at last alighted safe.

It is said, that Mr. Sadler was the sole projector, architect, workman, and chymist, in this experiment.

On the 30th of November, Mr. Blanchard made his fifth aerial voyage, in his old balloon, being his second voyage in London; he was accompanied by Dr. J. Jeffries, a physician, and native of America, and ascended from the Rhedarium, in Park Street, Grosvenor Square, at about two o'clock in the afternoon. Mr. Blanchard was now furnished with wings or oars, which he worked very fast; but their action seemed to produce no effect on the course of the machine. His direction being about east by south, he passed over London; but the weather being very hazy, the machine did not shew so fine a spectacle as could have been wished. It does not appear that either of the two travellers made any particular philosophical observation, though they were provided with several instruments. They descended near the Thames, in the parish of Stone, in Kent, at the distance of 21 miles from London.

I shall conclude this chapter, with just mentioning, that two large aerostatic machines, on Montgolfier's principle, were burned in London, without ever ascending, viz. one in August, and another in October, of this year. The want of success in the former, was attributed to an excessively bad construction; and in the latter, principally to its imperfect figure, and to its having been painted with drying oil; whereas water-

colours,

colours, alum, and ſuch-like ſubſtances, which are not eaſily combuſtible, ſhould be uſed for this kind of aeroſtatic machines.

CHAPTER XV.

Aeroſtatic experiments made in the beginning of the year 1785.

ON the 4th of January, 1785, Mr. Harper aſcended with an inflammable-air balloon, from Birmingham. The weather was very rainy, hazy, and foggy, and the barometer ſtood at 28,4; the thermometer ſtood at 40°. At about a quarter before one o'clock he aſcended, in preſence of an immenſe multitude of ſpectators, and amidſt a very hard rain, which increaſed to an uncommon degree for ſix minutes after; but in 4 minutes more the aerial adventurer got above the clouds, and enjoyed the vivifying influence of the ſun, and a purer air.

At about two o'clock, Mr. Harper deſcended at Millſtone Green, near Newcaſtle, in Staffordſhire, about 50 miles diſtant from Birmingham. In this voyage the thermometer never came lower than 28 degrees; and Mr. Harper experienced no other inconvenience than what might be expected to ariſe from the changes of wet and cold, except a temporary deafneſs.

We come now to the account of a voyage, which deſerves to be long remembered. It is nothing leſs than the croſſing of the Engliſh channel, in an aeroſtatic machine. The ſame balloon which had carried the enterpriſing Mr. Blanchard five times through the air, ſerved for this remarkable experiment.

On Friday January the 7th, being a fine clear morning, after a very froſty night, and the wind about N. N. W. but hardly perceptible, Mr. Blanchard, accompanied by Dr.

Dr. Jeffries, departed in the old balloon from Dover-Caſtle, directing their courſe for the French coaſt. The balloon was begun to be filled at about 10 o'clock; and whilſt the operation was going on, two ſmall balloons were launched, in order to explore the direction of the wind. The apparatus was placed at about 14 feet diſtance from the perpendicular cliff; and at three quarters after 12 o'clock, the boat being attached to the net which went over the balloon, ſeveral neceſſaries, and ſome bags of ſand for ballaſt, were put in it. The balloon and boat, with the two adventurers, now ſtood within two feet of the brink of the cliff, that identical precipice ſo finely deſcribed by Shakſpeare, in his King Lear. At one o'clock the intrepid Blanchard deſired the boat to be puſhed off; but the weight being too great for the power of the balloon, they were obliged to throw out a conſiderable quantity of ballaſt, in conſequence of which they at laſt roſe gently and majeſtically, though making very little way, with only three ſacks of ballaſt, of ten

 pounds

pounds each. At a quarter after one o'clock the barometer, which on the cliff ſtood at 29,7, was fallen to 27,3, and the weather proved fine and warm. Dr. Jeffries, in a letter to Sir Joſeph Banks, Bart. P. R. S. deſcribes with rapture the proſpect which at this time was before their eyes. The country to the back of Dover, interſperſed with towns and villages, of which they could count 37, made a beautiful appearance. On the other ſide, the breakers on the Goodwin Sands appeared formidable. They paſſed over ſeveral veſſels, and enjoyed a view perhaps more extended and diverſified than any that was ever beheld by mortal eye. The balloon was much diſtended, and at 50 minutes paſt one o'clock it was deſcending, in conſequence of which they were obliged to throw out one ſack and a half of ballaſt, in order to riſe again. They were now one third of the way from Dover, and had loſt diſtinct ſight of the caſtle. A ſhort time after, ſeeing that the balloon was deſcending very faſt, all the ballaſt was thrown out, but that not being ſufficient to lighten the boat, a parcel of books was next thrown overboard, when they roſe again, being at about midway between the Engliſh and French coaſts. At a quarter paſt two o'clock, the riſing of the mercury in the barometer ſhewed that the balloon was again deſcending, which obliged them to throw away the remaining books. At 25 minutes after two they were at about three fourths of the way, and an enchanting view of the French coaſt appeared before their eyes; but the lower pole of the balloon was collapſed, in conſequence of the loſs or condenſation of the inflammable air, the machine was deſcending, and they, Tantalus like, were uncertain whether they ſhould ever reach the beautiful land. Proviſions for eating, the wings of the boat, and ſeveral other articles, were ſucceſſively thrown into the ſea.—"We threw away," ſays Dr. Jeffries, "our only bottle, which in its "deſcent caſt out a ſteam like ſmoke, "with a ruſhing noiſe; and when it ſtruck "the water, we heard and felt the ſhock "very perceptibly on our car and balloon." Anchors, cords, &c. were thrown out next;

but, the balloon ſtill approaching the ſea, they began to ſtrip, caſt away their clothes, and faſtened themſelves to certain ſlings, which proceeded from the hoop to which the boat was faſtened, intending to cut the boat away for a laſt reſource: but they had the ſatisfaction to find that they were riſing; their diſtance from the French ſhore was about four miles, and they were approaching it very faſt. Fear was now vaniſhing apace; the French land ſhewed itſelf every moment more beautiful, more extended, and more diſtinct; Calais, and above 20 other towns and villages, were clearly diſtinguiſhed. Their actual ſituation, with the idea of their being the two firſt perſons who croſſed the channel in ſuch an unuſual vehicle, made them little ſenſible of the want of their clothes; and I doubt not but the ſympathizing reader will feel an unuſual ſenſation of admiration and joy in imagining their ſituation. Exactly at three o'clock they paſſed over the high grounds about midway between Cape Blanc and Calais, and it is remarkable that the balloon at this time roſe very faſt, ſo that it it made a magnificent arch. The balloon rose higher than it had ever done in any other part of the voyage, and the wind increasing, varied a little its direction. The two adventurers now threw away their cork jackets, which they had taken for safety, and of which they were no longer in want. At last they descended as low as the tops of the trees in the forest of Guinnes, and Dr. Jeffries, laying hold of a branch of one of the trees, stopped their progress. The valve of the balloon was opened, in consequence of which the inflammable air got out with a loud rushing noise, and some minutes after they came safely to the ground, between some trees, which were just open enough to admit them; after having accomplished an enterprise, which will perhaps be recorded to the remotest posterity.

About half an hour after, they were overtaken by some horsemen, &c. who had followed the balloon, and who shewed every possible attention to the fortunate aeronauts.

The next day a magnificent feaſt, made at Calais, ſolemnized the event. The freedom of the city was preſented to Mr. Blanchard in a gold box; and the Police of Calais wrote to the miniſtry, to have the balloon purchaſed, and depoſited, as a memorial of the experiment, in the church of Calais; and alſo deſign to erect a marble monument on the ſpot where the intrepid adventurers deſcended.

Some days after, Mr. Blanchard received an order to appear before the King; and in a letter to Mr. Sheldon, the companion of his fourth aerial voyage, he mentions that his Majeſty was pleaſed to grant him a gift of 12000 livres, and a penſion of 1200 livres a year.

The moſt remarkable circumſtance in the account of this voyage, is that of the bottle, the ſtriking of which on the water occaſioned ſome agitation on the boat and balloon. This deſerves to be carefully repeated, at another opportunity, before we attempt an explanation of the phenomenon.

The

The balloon approaching the ſea very faſt, or, which is the ſame thing, going very low whilſt over the ſea, and riſing very high when it got over land, has been by ſeveral perſons attributed to a pretended attractive power of the ſea-water; but if the various circumſtances, which concur in this experiment, be duly conſidered, there ſeems to be no reaſon to admit ſo ſtrange a ſuppoſition. It ſhould be recollected, that in the two preceding voyages, made with the ſame machine, it was found that the balloon could not ſupport two men long in the atmoſphere, it ſhould therefore occaſion no wonder, if, in the laſt voyage, it ſhewed the ſame weakneſs of power. As for its riſing higher juſt when it got over the land, that may be eaſily accounted for: in the firſt place, the two travellers threw out their clothes juſt about that time; ſecondly, in conſequence of the wind's then increaſing, the balloon travelled at a much greater rate than it had done whilſt over the ſea, which increaſe of velocity leſſened its tendency to deſcend; beſides which, the viciſſitudes of heat and cold may produce a

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very confiderable effect; for if we fuppofe, that the air over the land was colder than that over the fea, the balloon coming from the latter into the former, continued to be hotter than the circumambient air for fome time after; and, confequently, it was comparatively much lighter when in the cold air over the land, than when in the hotter air over the fea; hence it floated eafier in the former than in the latter cafe.

CHAPTER XVI.

General Remarks on the preceding Hiftory.

THE art of navigating through the air, fought after from time immemorial, has been difcovered, and fo far improved, within thefe two years, that above 40 different perfons have performed the experiment, and not a fingle inftance is known of any perfon having loft his life in the attempt;

tempt; and, excepting two or three, who have been hurt in confequence of accidents, owing, not to the principle of the invention, but rather to the want of proper judgment, all have unanimoufly teftified the fafety, eafe, and beauty of the experiment: and it is very remarkable, that no man or woman, who afcended into the atmofphere by this new-invented means, experienced any ficknefs or giddinefs, fuch as is generally the confequence, at firft, of afcending high buildings, or of going in a boat on water. It is juftly queftioned whether the firft forty perfons, who trufted themfelves to the fea in boats, efcaped fo fafe.

The method, far from being complicated or troublefome, is perhaps as fimple as might have been wifhed by the warmeft imagination; and fo eafy for the aeronaut, that he has abfolutely much lefs trouble with his machine, than a failor with a fhip in the moft favourable circumftances. With a moderate wind, the aerial navigators have often gone at the rate of between forty and fifty miles an hour, but very commonly at the

the rate of thirty miles, and that without any agitation, and without feeling the wind; for in fact the wind goes with them, and therefore they are respectively in a calm, and without uneasiness. Compare this mode of travelling with any other known method of going from place to place; then judge of the merit and importance of the discovery.

Ignorance, curiosity, and often the supercilious wisdom of the splenetic, ask whether it is possible to bring this discovery to be of any use?—and the want of a decisive answer, which it is not in the power of any man to give at present, makes such generally decide against air-balloons; endeavouring to depreciate them still farther by the ridiculous idea of emptiness, which has been often allegorically expressed by the words *aerial*, *full of air*, *empty balls*, and *bags full of wind*. Some persons often wonder, that *air-balloons* should engross the public attention, that they are become the object of scientific societies, and have acquired the patronage of the great and the learned. They should first consider how much human

man attention, human life, human labour, human peace and tranquillity, have been engrossed, disturbed, and checked by unmeaning words and ideal powers; perhaps they would then allow some attention to be bestowed upon one of the greatest discoveries of human industry.

The principal objection started against aerostation is, that those machines cannot be guided against the wind, or in every direction at pleasure; and the enemies of innovations would set aside even the idea of air-balloons, because, two years after their discovery, the subject has not been so far improved as to steer them in any direction whatsoever. But, as the advantages and merit of an invention may be comprehended by comparison, better than by other means, it should be considered, that vessels on water cannot be guided against the wind, nor even within many degrees of the contrary direction; and indeed, if the lee-way of a vessel going close to the wind be taken into account, it will be found, that, in reality, a vessel at sea can hardly be guided

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in a direction nearer than a right angle to the point of the wind: for instance, with a northerly wind, a vessel cannot go in a direction above a few degrees northward of east, or northward of west. Now, an aerostatic machine has been carried in a course so far as 22 degrees from the direction of the wind, by the use of oars, which were neither all the oars that could have been used, nor of the most advantageous construction; so that there is great probability, that an improved construction, and proper management, may enable an aerostatic machine to go across the wind, if not still nearer to the point from whence it blows.—See page 169.

An aeronaut, in the atmosphere, has two advantages which are very considerable; first, that if the wind does not prove favourable, he may descend, provided he is over land; and secondly, as currents of air, going in different directions, have been very often observed at the same time in the atmosphere, the aeronaut may, by ascending or descending into an higher or lower region,

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go with that current which is proper for him. Indeed, it is not known that thoſe different currents always exiſt; but it is not unlikely that they, as has been the caſe with the currents of various ſeas, may be better aſcertained by future experience and inveſtigation; and we have now in our power the means of examining them at any time. The reader ſhould here obſerve, that the above-mentioned means of directing aeroſtatic machines, are not ſchemes of theoretical projectors, but the produce of experience, and in great meaſure confirmed by many inſtances in the preceding hiſtory.

The incomparably greater velocity of an aeroſtatic machine, and its very ſeldom or never loſing time by being becalmed *, are likewiſe two advantages, which aeroſtation

* An inſtance of an aeroſtatic machine remaining in the atmoſphere ſtationary for want of wind, has happened very ſeldom, and then it has never laſted above a few minutes. And every body knows, that, in the calmeſt weather, the clouds always appear to be in motion.

has above navigation.—But, as my object is to inform those, who wish to know what has been done in this subject, and not to persuade the unwilling, I shall conclude this chapter, and the First Part of my work, with a summary recapitulation of the most interesting particulars that have been ascertained, in order to exhibit to the mind of the reader a comprehensive view of the subject in a few lines.

Two substances having been discovered to be specifically much lighter than common air; namely, inflammable air, and common air when heated; large bags have been formed, which would contain so great a quantity of either of these substances, as that the excess of weight of a body of common air, above that of an equal bulk of hot or inflammable air, might be greater than the weight of the bag, or at least equal to it: those bags, therefore, thus filled, being lighter than an equal bulk of the circumambient air, float in it, and are driven by the wind; and for the same reason, a piece of wood in a river floats upon the water, and proceeds with the stream.

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As air will not long remain hotter than the ſurrounding medium, thoſe bags or balloons, which are filled with hot air, muſt contain a fire capable of keeping the air ſufficiently hot; by which means they may continue to float for an indefinite time; otherwiſe, in a very ſhort time, the air in them cools, and they fall. The other balloons, which contain inflammable air, continue to float as long as a ſufficient quantity of that fluid remains in them; ſo that they would float for ever, if the envelope did not permit any inflammable air to eſcape through its pores.

It is mathematically true, that the aſcenſional power of balloons, or their exceſs of levity above an equal bulk of common air, increaſes incomparably faſter than the proportion of their diameters: for inſtance, if an air-balloon of a certain diameter can lift up into the atmoſphere a weight of 10 pounds, another balloon of twice that diameter (every thing elſe, as the thickneſs of the ſtuff, &c. remaining the ſame) will lift up more than 80 pounds; and a balloon of three times that diameter will lift up more than 270 pounds weight. Upon this principle, balloons have been made of ſuch a ſize as would carry up any required weight; in various parts of the world, men have aſcended with them, and have ſafely travelled thro' the air, at the rate even of about 50 miles an hour.

Wherever thoſe experiments have been made, perſons of every rank have gazed with the greateſt anxiety, and have ſhewn unequivocal marks of aſtoniſhment and ſatisfaction: the aeronauts, returning from their aerial excurſions, have been generally received with the greateſt applauſe, have been carried in triumph; medals have been ſtruck, and plates engraven, in commemoration of the perſons who have moſt diſtinguiſhed themſelves in ſuch performances, or of their particular experiments; premiums and penſions have been granted them by learned ſocieties, and by many great perſons, eſpecially by the court of France, whoſe patronage and generoſity, in this reſpect, muſt be ever acknowledged and praiſed by all impartial and difcerning people. Thus mankind, by thefe acts of admiration, of fatisfaction, and generofity, has fhewn and confirmed its approbation of the difcovery. The viciffitudes of human affairs, may at times retard or accelerate the ufe and improvement of aeroftatic machines; but the intereft and curiofity of man will doubtlefs for ever retain the knowledge of the fubject—a fubject infantile indeed, but endowed with manly features.

It has been often difcuffed, whether the preference fhould be given to the inflammable-air machines, or to thofe raifed by means of hot air. Each of them has its peculiar advantages and difadvantages; a juft confideration of which feems to decide in favour of thofe with inflammable air. The principal comparative advantages of the rarefied-air balloons are—their being filled with little or no expence—their not requiring to be made of fo expenfive materials—and the combuftibles neceffary to fill them being found almoft every where; fo that when the provifion of fuel is exhausted, the aeronaut may descend and recruit his fuel, in order to proceed on his voyage. But then they must be larger than the other sort of balloons, in order to take up the same weight; and the presence of a fire is a continual trouble, and a continual danger: in fact, amongst the many aerial voyages made and attempted with such machines, very few have succeeded without some inconvenience of one sort or other; whereas the aerial excursions made with inflammable-air machines have all answered exceedingly well, and in but few instances have the machines been damaged, and then very inconsiderably.—But, on the other hand, the inflammable-air balloon must be made of a substance impermeable to the subtile gas; the gas itself cannot be produced without a considerable expence; and it is not easy to find the materials and apparatus necessary for the production of it in every place. Nevertheless, an inflammable-air balloon of 30 feet in diameter, according to the present state of knowledge, may be made so tight, as to be capable of keeping two persons, and a considerable quantity of ballast,

ballaſt, up in the air for above 24 hours, if properly managed; and poſſibly one man might be ſupported by the ſame machine for three days: and it is very probable, that the ſtuff for theſe balloons may be ſo far improved, as to be quite impermeable to the inflammable air, or nearly ſo; in which caſe, the machine, once filled, would continue to float for a vaſt while. At Paris, they have already attained to a great degree of perfection in this point; and ſmall balloons have been kept floating in a room for many weeks, without loſing any conſiderable quantity of their levity: but the method of preparing the ſtuff is ſtill kept ſecret. However, there ſeems to be no great difficulty in making ſmall balloons ſo very tight; the difficulty is in the large ones; becauſe, in a large machine, the weight of the ſtuff itſelf, the weight and ſtreſs of ropes and boat, the folding it up, &c. may eaſily crack or ſcrape off the varniſh, in ſome place or other; which is not the caſe with ſmall balloons.

As for the dearneſs of the inflammable air, it muſt be obſerved, that divers experiments and obſervations ſhew, that a method of obtaining it incomparably cheaper is not far from being aſcertained; and indeed there are ſeveral manufactories, in which abundance of inflammable air is daily produced, and loſt for want of due attention, or of veſſels proper to confine it; but, as its utility becomes known, there can be no doubt that means will be contrived to preſerve it, wherever it may be abundantly produced; ſo that we may ſhortly expect to ſee repoſitories of inflammable air, where one may go to fill a balloon for a certain ſum.

In regard to philoſophical obſervations, derived from the new ſubject of aeroſtation, there have been very few made; the novelty of the diſcovery, and of the proſpect enjoyed from the gallery of an aeroſtatic machine, has generally diſtracted the attention of the aeronauts; and beſides, many, if not the greateſt number of the aerial voyages,

ages, though ſaid to be purpoſely made for the improvement of ſcience, were performed by perſons abſolutely incapable of accompliſhing this purpoſe; and who, in reality, had either pecuniary profit alone in view, or were ſtimulated to go up with a balloon, for the ſake of the proſpect, and the vanity of adding their names to the liſt of aerial adventurers.

The agreeable ſtillneſs and tranquillity experienced up in the atmoſphere, has been a general obſervation.—Some machines have aſcended to a great height, even as far as two miles; they have generally penetrated through fogs and clouds, and have enjoyed the vivifying heat of the ſun, whilſt the earth beneath was actually covered by denſe clouds, that poured abundance of rain.—In aſcending very high, the aeronauts have often experienced a pain in their ears, ariſing from the air, within a certain cavity of thoſe organs, being not of the ſame denſity as the external air; but that pain generally went off ſoon after.—There

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is one experiment recorded, in which the air of a high region, being brought down, and examined by means of nitrous air, was found to be purer than the air below.—The temperature of the upper regions is much colder than that of the air near the earth; the thermometer, in ſome aeroſtatic machines, having deſcended many degrees below the freezing point of water, whereas on the earth, at the ſame time, it ſtood conſiderably higher than that degree.—The electricity brought down by ſtrings, faſtened to balloons floating in the atmoſphere, proves nothing more than what was known before, and had been aſcertained by other means, viz. the exiſtence of a continual electricity, of the poſitive kind, in a clear atmoſphere *.

Having juſt mentioned the electricity of the atmoſphere, it will be proper to take notice of a ſort of danger juſtly ſuſpected to attend the inflammable-air balloons, and which ariſes from this principle. It is,

* See the Author's Treatiſe on Electricity.

that a ſtroke of lightning, or the ſmalleſt electric ſpark, happening near the balloon, might ſet fire to the inflammable air, and deſtroy the machine and the adventurers.—But ſeveral conſiderations ſeem to render this apprehenſion of no great weight, though they do not entirely remove it, according to the preſent ſtate of knowledge. Firſt, This accident never actually happened, though inflammable-air balloons have been up in every ſeaſon of the year, and at the very time, when thunder was actually heard: ſecondly, In caſe of danger, the aeronauts may eaſily come down to the earth, or aſcend above the clouds, viz. above the region of thunder-ſtorms: thirdly, The balloon, being made of materials that are not conductors of electricity, is not likely to receive a ſtroke of lightning, eſpecially as it ſtands inſulated; for it is a maxim pretty well eſtabliſhed by electricians, that the lightning, in coming to the earth, does not ſtrike any intermediate body, except that body can aſſiſt its paſſage; thus, a houſe that contains a great deal of metal, and is ſituated upon ground that is a good con-

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ductor of electricity, especially if near a river, is more likely to be struck by the lightning, than a house which stands upon dry and hardly-conducting ground. This has been confirmed by many instances. It may be said, that a stroke of lightning may strike the balloon in passing from one cloud to another; but the same reasons, which shew that the balloon is not likely to be affected in the former case, are applicable to the latter: however, at present, it seems impossible to give a proper decisive answer relative to this point; and nothing but experience can shew how far the aeronaut may be in danger of the lightning. Lastly, It may be observed, in regard to this circumstance, that inflammable air by itself, viz. unmixed with a certain quantity of common air, will not burn, and consequently, even if a spark of electricity was to pass thro' the balloon, it would not set fire to the inflammable air, except a hole was to be made in the envelope; in that case, the inflammable air coming out of the hole, would mix with the common air, and might easily be inflamed by electricity.

In

In the course of the preceding hiſtory, I have ſcarcely mentioned a word relative to the numberleſs ſchemes that have been propoſed for directing the aeroſtatic machines. The projects of this ſort have been numerous indeed; but hardly ever had the appearance of probability. Some imagined that an aeroſtatic machine might be guided by means of ſails, like a veſſel at ſea; forgetting, that there is no wind with reſpect to an aeroſtatic machine; for it goes with the wind, and therefore is reſpectively in a calm; in which caſe the ſails cannot act. Others would direct it from the wind by the action of a ſteam-engine or eolipile: and others again by means of gunpowder fired out of a tube, in a direction contrary, or inclined to the wind. But, without troubling the reader any farther with ſuch chimerical ſchemes, it muſt be acknowledged, that there have been a few projects, for this purpoſe, which, are far from being groundleſs, and conſequently deſerving of notice: but theſe will be better examined in the Second Part of this work; which contains the Practice of Aeroſtation,

ſtation, laid down in the manner which ſeemed beſt adapted to inſtruct thoſe, who are willing to employ their time and attention on this ſubject.

PART

PART II.

PRACTICE OF AEROSTATION.

CHAPTER I.

General Principles of Aerostation.

THE whole earth, together with all the bodies that are upon it, is surrounded by an invisible fluid called air; which has weight, and also elasticity, viz. may be easily compressed. Invert a common wine glass, and, in that inverted situation, let it down into a bason of water; and it will be found that the water cannot enter within the glass. That substance, which prevents

prevents the water entering within the glaſs, is the air. Let the glaſs lower down into the water, and it will be found that the water riſes a little way within the glaſs; which ſhews the elaſticity of the air: for the higher the water is above the aperture of the glaſs, the greater will the preſſure be upon the air, which of courſe contracts itſelf into a ſmaller ſpace. Incline the glaſs a little, and a bubble of air will come out. Incline it ſtill farther, and more air will come; till at laſt all the air comes out, and the glaſs becomes entirely full of water. Thus the exiſtence and elaſticity of the air is eaſily proved.—Its weight is found by weighing a glaſs veſſel, firſt when full of air, and then when exhauſted of that fluid by means of an air-pump; the difference of which two weights is the weight of a quantity of air equal to the capacity of that veſſel. Thus it has been aſcertained, after various trials, that a cubic foot of air weighs about one ounce and one fifth, or about one ounce and 87 grains averdupoiſe.

Heat expands the air; ſo that if a quan-

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tity of air is heated only one degree according to Farenheit's thermometer, its bulk will be increaſed one five hundredth part; and about 500 degrees of heat will juſt double the bulk of a quantity of air: from which it follows, that heated air is lighter than air that is colder, and the diminution of weight is juſt in proportion to the heat; for inſtance, if a cubic inch of air weighs N grains, when that air is expanded into a double bulk by heat, a cubic inch of this heated air muſt weigh half N grains, becauſe this cubic inch is half the original quantity of air before it was heated.

When a body is immerſed in a fluid, if its weight is leſs than the weight of a quantity of fluid equal to its bulk, then it will ſwim towards the ſurface of that fluid; if equal, it will remain where it is left; and if heavier, it will deſcend. Thus a piece of deal will ſwim on the ſurface of water, becauſe it is lighter than an equal bulk of that fluid; and for the ſame reaſon ſmoke will aſcend into the atmoſphere; and likewiſe hot air will aſcend in air that is colder, and consequently heavier, which is very easily and satisfactorily shewn by the experiment mentioned in the preceding Part *. A piece of wood will not only swim by itself on water, but will support some other weight besides, provided the sum of its own, and that other weight, is not greater than the weight of an equal bulk of water. Thus, suppose a piece of iron, weighing one ounce, which of itself could not swim on water, is fastened to a piece of wood, which weighs six ounces, and that a quantity of water, equal to the bulk of the wood and iron together, weighs more than 7 ounces, then the wood will support the iron and itself on the surface of the water; hence also an empty bottle will swim on water, and a bladder full of air will swim because the levity of the enclosed air keeps it up. For the same reason, if so great a quantity of hot air is enclosed in a bag, as that the excess of the weight of an equal bulk of common air, over the weight of the hotter air, is greater than the weight of the bag, then that quantity of hot air will ascend with

* See page 28.

the bag into the atmoſphere: and this is Montgolfier's aeroſtatic machine.

In order to ſhew this power of hot air, in a very ſimple and convincing manner, roll up a ſheet of common writing paper into a conical form, and, by thruſting a pin through it near the apex, prevent its unrolling; then faſten it with its apex under one ſcale of a balance by means of ſome thread, as repreſented in fig. 1. plate I. and by putting ſome weights into the oppoſite ſcale, let it hang in equilibrio, or rather let the ſide with the paper cone be a little heavier, for inſtance five or ſix grains. This done, keep the balance ſuſpended from A, and bring the flame of a candle under the aperture of the cone of paper; the conſequence of which will be, that the air under the paper being heated, will lift up this cone, and the oppoſite ſcale will of courſe deſcend. On removing the candle, the cone, or bag of paper, will not immediately deſcend, but will continue to remain up for ſome minutes, viz. till the air cools within it, and then it will deſcend.

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If it be aſked, Why does not the hot air eſcape out of its apexture? the anſwer is, Becauſe the hot air is impelled by the colder air towards the apex of the cone, and conſequently cannot go over the edge of the aperture of the bag, except the cone was to be inverted; for then it would eſcape, in the ſame manner as a bubble of air eſcapes out of a glaſs inverted in water, and inclined a little, as was mentioned towards the beginning of this chapter.

Beſides common air, there are many other elaſtic fluids, which are inviſible and compreſſible like common air, but are diſtinguiſhable from that element on account of ſome other properties that are particular to each or divers of them; for inſtance, ſome will not aſſiſt reſpiration, and which are called *gaſſes*; others are ſoon abſorbed by water, &c. Amongſt theſe gaſſes there is one called *inflammable air*, from its peculiar property of burning when fire is communicated to it by means of a candle, an electric ſpark, &c. This elaſtic fluid, beſides its inflammability, has another remarkable

markable peculiarity, which is its being incomparably lighter than common air; whereas the other elaſtic fluids are very little heavier or lighter than that element, the difference being very trifling indeed.

Now, if a bag be filled with inflammable air, of ſuch a ſize as that the exceſs of the weight of an equal bulk of common air, over the encloſed inflammable air, be greater than the weight of the bag, then the bag will aſcend into the atmoſphere, for the reaſons mentioned above: and this is the other ſort of aeroſtatic machines, namely, the inflammable-air balloons.

The air which forms the atmoſphere round the earth, being elaſtic, is of different denſities at different heights, becauſe the air next to the ſurface of the earth, being preſſed by all the reſt of the air above in a perpendicular direction, muſt be much more compreſſed and more heavy than the air at a mile above the earth, which has a mile leſs of air to compreſs it; and ſo on, the higher you aſcend, the lighter is the air.

There is another property of the atmosphere necessary to be mentioned, which is, that the weight of the atmosphere is changeable, it being somewhat heavier at one time than at another. The barometer is the instrument commonly used to shew the variations of the weight of the atmosphere: in England, when the barometer stands in one and the same place, or on the same level, the difference in the perpendicular height of the mercury in it, occasioned by the varying weight of the atmosphere, is barely three inches; so that the mercury in it stands always between 28 and 31 inches perpendicular height; rising when the atmosphere is heavy, and falling when the atmosphere is lighter. But when the barometer is raised above the surface of the earth, then the mercury will fall much lower, and that according to the height to which it is elevated.

CHAP-

CHAPTER II.

Of Inflammable Air.

INFLAMMABLE air is a permanently elaſtic fluid, ſpecifically lighter than common air, and is the production both of natural and artificial proceſſes. In general, the putrefaction or decompoſition of animal and vegetable ſubſtances, and the decompoſition of ſuch minerals as contain abundance of the inflammable principle, generate inflammable air; hence this ſort of gas is produced wherever thoſe proceſſes are going on: thus it is found in mines, eſpecially coal-mines; in places where putrid ſubſtances are accumulated; and in the waters of moſt lakes, ditches, and rivers, eſpecially thoſe which contain a great deal of putrid matter; from which waters it may be extracted by ſtanding a long time, or by boiling in proper veſſels, as for inſtance, a veſſel with a pretty long neck, to the mouth of which a flaccid bladder is tied.

In the ſummer, eſpecially in hot climates, abundance of inflammable air eſcapes out of ſtagnating and even river water; but in all the ditches and ponds about London, particularly in the ſummer and autumn, inflammable air may be catched very plentifully in the following manner:—Fill a wide-mouthed bottle with the water of the pond, and keep it inverted therein, then with a ſtick ſtir the mud at the bottom of the pond, juſt under the inverted bottle, ſo as to let the bubbles of air, which come out of it, enter into the bottle, and that is inflammable air. When by thus ſtirring the mud in various places, and catching the air, the bottle is filled, a cork or glaſs ſtopper muſt be put over it, &c. It would be a preferable method, to adapt a funnel to the bottle, as by this means much more inflammable air may be catched, than otherwiſe.

In the common proceſſes of diſtilling volatile

latile alkali, of ſmelting ores, and various others, a conſiderable quantity of inflammable air is loſt. The moſt advantageous methods of obtaining inflammable air are—by the action of acids on certain metals—by expoſing animal, vegetable, and ſome mineral ſubſtances, in a cloſe veſſel, to a ſtrong fire,—and laſtly, to tranſmit the vapour of certain fluids through red-hot tubes.—In the particular deſcription of theſe methods, I ſhall only take notice of thoſe circumſtances, which ſeem uſeful for the ſubject of aeroſtation, referring the reader, who is anxious to examine the reſt, to my Treatiſe on Air, &c. or to the works of other authors, who have written on the ſubject of inflammable air.

Iron, tin, and zinc, are the metallic ſubſtances which yield plenty of inflammable air, when acted on by diluted vitriolic or marine acid, which is commonly called ſpirit of ſalt; but, as the tin and the marine acid are much dearer than the other ſubſtances, therefore iron, zinc, and vitriolic acid are the materials moſt uſed for this purpoſe.

If

If the vitriolic acid, commonly called oil of vitriol, is very ſtrong and concentrated, it will not extract any inflammable air from iron, or ſo ſmall a quantity of it as is next to nothing; and, in order to let it extract the greateſt poſſible quantity of inflammable air from iron, it muſt be diluted with about five or ſix parts of water; however, it is almoſt impoſſible to give very preciſe directions relative to it, becauſe the ſtrength of vitriolic acid is different almoſt according to the different ſhops that ſell it, and according as it is kept more or leſs expoſed to the air and other ſubſtances that contaminate it; therefore the beſt expedient for practice is, to put a little iron, in ſmall bits, or filings, into a phial, over which put as much water as may be equal to four or five times the weight of the iron, then pour a little of the oil of vitriol, and obſerve what effect it has; if it does not produce a quick ebullition in about a minute's time, add a little more; and thus, by adding gradually more and more oil of vitriol, one may eaſily find out when it makes the greateſt or a very quick ebullition. But

in

in order to ascertain the proportion of water required by that sort of vitriolic acid, the water that is put into the phial must be weighed, and likewise the bottle, out of which the vitriolic acid is poured into the phial, must be previously weighed; and afterwards, being weighed again, the difference of these weights is the weight of the oil of vitriol; which, being compared with the weight of the water put into the phial, gives the required proportion. The same thing is understood when zinc is used instead of iron.

The utmost quantity of inflammable air, which may be obtained from iron, by means of diluted vitriolic acid, is about 1800 times its own bulk; but in the common way, when the iron is not very pure, and one does not stand to extract the smallest quantities of air, which are yielded after the first ebullition is over (which, at most, does not last an hour) then the iron may be expected to yield about 1700 times its own bulk of gas; or one cubic foot of inflammable air to be produced by about 4½ ounces of iron.

iron. Zinc yields lefs inflammable air than iron; one cubic foot of the gas being produced by about fix ounces of zinc. If the vitriolic acid is of the ftrongeft fort, that is generally fold in large quantities, an equal weight of it is required to diffolve iron or zinc, and muft be diluted with five times its weight of water; fo that in the common way of producing inflammable air for an air-balloon, where all the little niceties cannot be attended to, nor a very fudden effervefcence is required, it may be faid that 4½ ounces of iron, the like weight of oil of vitriol, and five times that weight, viz. 22½ ounces, of water, are required in order to produce one cubic foot of inflammable air. And about the fame quantity of gas is produced by fix ounces of zinc, an equal weight of oil of vitriol, and 30 ounces of water.

A confiderable degree of heat is produced by the effervefcence that generates inflammable air, which is greater when the effervefcence is more rapid, and contrarywife. In order to prevent this heat, in great meafure, ſure, it is more proper to uſe the turnings of great pieces of iron, as of cannons, &c. than the filings of that metal; beſides, the turnings admit the diluted acid through their interſtices, when they are heaped together, whereas the filings ſticking cloſer together, often prevent the acid from going quite to the lowermoſt of them.

As the vitriolic acid corrodes moſt metals, and ſome other ſubſtances, the beſt veſſels to contain the materials for the production of inflammable air are the glaſs ones, when no great quantity of the gas is required; but for very large quantities wooden caſks are the moſt ſerviceable.

The weight of the inflammable air thus obtained by means of acid of vitriol, is the leaſt of any ſort of inflammable air; and, when made in the common way, eſpecially in large quantities, its weight is generally one-ſeventh part of the weight of common air, or rather more; but when made with all the precautions that a philoſophical experimenter may uſe, then its

4 weight

weight is even leſs than one-tenth part of the weight of common air.

Together with the inflammable air, there are ſometimes two other ſorts of elaſtic fluid generated, though not in great quantities, which are rather prejudicial to the aeroſtatic experiment; but, as theſe are eaſily abſorbed by water, the beſt expedient is to let the inflammable air paſs through water, in which it is much better to diſſolve ſome quick-lime, previous to its being introduced into an air-balloon; which precaution, beſides ſeparating the other elaſtic fluids, cools it, and thus prevents its overheating the balloon.—I ſhall now deſcribe the method of producing inflammable air in ſmall quantities; and ſhall reſerve the method of operating in large, for a ſubſequent chapter.

Take a common quart bottle, adapt a cork to its aperture, and make a hole quite through the cork with a hot iron or other inſtrument. Faſten a glaſs tube, or the ſtem of a tobacco-pipe, to a bladder, and adjuſt it ſo that this tube may go very tight into the cork of the bottle, as is repre-ſented in fig. 2. plate I.—Things being thus prepared, put about two ounces of iron into the bottle, over which pour about ten ounces of water, then pour upon it about two ounces of good ſtrong oil of vitriol, which will immediately occaſion an effervеſcence, and a production of inflam-mable air, which may be perceived by its ſtrong and diſagreeable ſulphurous ſmell; but immediately after pouring the oil of vitriol into the bottle, the cork, with the bladder annexed, muſt be put upon it, and the inflammable air, being produced by the materials in the bottle, will enter into, and will ſwell, the bladder; which, when full, may be removed, and another bladder, like-wiſe furniſhed with a tube, may be put in its place. It is almoſt needleſs to mention, that the bladder, before it is adapted to the bottle, muſt be preſſed very accurately, ſo as to expel all the common air from it; and, as ſome bladders are very ſtiff, and con-ſequently don't admit being eaſily ſqueezed, it is uſeful in that caſe to ſoften them in lukewarm water, previous to their being uſed. When the full bladder is removed

from

from the bottle, in order to prevent the escape of the contained inflammable air, a string should be tied round its neck, just below the inner extremity of the glass tube; but if, instead of the glass tube, those bladders were furnished with brass stop-cocks, the operation would be both more elegant and more convenient.

Instead of a quart bottle, as directed above, any sort of glass bottle may be used; but care should be taken not to fill it above half, or rather less, with the materials that produce the inflammable air; otherwise the violence of the effervescence will often force part of the liquor out of the neck of the bottle.

When the inflammable air is required to be passed through water, which in general should be done, then the following apparatus must be used. A glass tube, or indeed a tube of any other substance, but shaped somewhat like an S, see A B, fig. 3. of plate I. must be fastened with one end in the hole of the cork of the bottle which contains

contains the materials for producing inflammable air. The other end of the tube muſt be below the ſurface of the water in a baſin. Things being thus prepared, fill another bottle C quite full with water, and, putting a finger or ſomething elſe over the mouth of it, invert it into the baſin. When the mouth of it is below the ſurface of the water of the baſin, remove the finger, and the bottle will remain full. Now put the proper materials for the production of inflammable air into the bottle D, then put the cork with the bent tube upon it, keep the other end of the tube below the ſurface of the water in the baſin, and place the mouth of the bottle C juſt over it; taking care not to raiſe the mouth of this bottle above the ſurface of the water in the operation. Thus the inflammable air produced from the materials in the bottle D, will paſs through the tube AB, and will enter into the bottle C, which when full, is corked under water, and then is removed.

For this purpose, glaſs bottles with bent glaſs tubes, which terminate in ground glaſs ſtopples, are found ready made in the ſhops, and they are incomparably more convenient.

As by this method the inflammable air is introduced only into bottles, or ſuch veſſels as do not collapſe like bladders, the following is an apparatus, which is exceedingly proper to fill bladders, or balloons as large as two or three feet in diameter, with inflammable air, after paſſing it through water. See fig. 4, plate I.

A is the bottle with the ingredients that produce the gas. B C D is a tube faſtened with one extremity into the neck of this bottle, and, paſſing through a hole of the ſtopper of another bottle E, goes as far as almoſt to touch the bottom of this bottle, which is nearly full of water. To another hole made in the cork of the ſame bottle E, another tube is adapted, to the outward extremity of which a bladder, or the aperture

ture of the balloon, is tied. Thus it is plain, that the inflammable air coming out of the aperture D of the tube, will paſs firſt through the water of the bottle E, and then into the bladder or balloon. Two ſmall caſks may be uſed inſtead of the bottles A and E.

When the inflammable air is required very pure, the cork with the bent tube ſhould not be put upon the bottle with the materials immediately after pouring in the vitriolic acid, but a ſhort time ſhould be allowed, in order that the inflammable air, which is produced at firſt, may expel, in a great meaſure, the common air from the bottle.

Beſides the action of acids, and eſpecially the vitriolic, plenty of inflammable air may be obtained, at a much cheaper rate, by the action of fire on various ſubſtances; but the gas thus obtained is not ſo light as that produced by the efferveſcence of acids and metals; however, it is far from being uſeleſs for aeroſtatic experiments, and I make no doubt, but that this method, on account of its cheapneſs, may ſoon ſuperſede the uſe of vitriolic acid and iron or zinc.

The method, in general, is to encloſe the ſubſtances in earthen or iron veſſels, and thus expoſe them to a ſtrong fire, ſufficient to make the veſſel red hot; by which means the inflammable air is yielded by the encloſed ſubſtances, and, coming out of the aperture of the veſſel, to which a tube, or refrigeratory, muſt be adapted, paſſes through the tube or worm, and is at laſt collected in a balloon or other veſſel. A gun-barrel has been often uſed for eſſays of this ſort. The ſubſtance to be tried has been put in it, ſo as to fill ſix or eight inches of its loweſt part; the reſt of the barrel has been filled with dry ſand; then a tube, adapted to the aperture of the barrel, has been brought into the baſon of water under an inverted receiver, as above deſcribed. The part of the barrel which contains the ſubſtance to be tried, being put into the fire, and made red hot, the inflammable air has been collected in the inverted receiver. But

But the gun-barrel cannot ſerve for producing a large quantity of inflammable air; for which purpoſe the veſſel muſt be much larger: and the following is the moſt advantageous ſhape:—Let a veſſel be made of clay, or rather of iron*, in the ſhape of a Florence flaſk, ſomewhat larger, and with a longer and larger neck. See fig. 5, of plate I. Put the ſubſtance to be uſed for the production of inflammable air into this veſſel, ſo as to fill about four fifths, or leſs, of its cavity A B. If the ſubſtance is of ſuch a nature as to ſwell much by the action of the fire, lute a tube of braſs, or firſt a braſs and then a leaden tube, to the neck C of the veſſel; and let the extremity D of the tube be ſhaped as ſhewn in the figure, ſo that going into the water of a tub H I, it may terminate under a ſort of inverted veſſel E F, to the upper aperture of which,

* The earthen veſſels, after being made red hot, generally crack in cooling, for which reaſon they can ſeldom ſerve for more than one experiment. It would perhaps be eaſier to make ſuch veſſels of copper; but they muſt not contain any ſolder, otherwiſe they cannot be made red hot.

the balloon, or a tube going to the balloon, is adapted. Things being thus prepared, if the part A B of the veſſel is put into the fire, and is made red hot, the inflammable air produced will come out of the tube C D, and, after paſſing through the water of the tub, will at laſt enter into the balloon G. Before the operation is begun, as a conſiderable quantity of common air remains in the inverted veſſel E F, which it is more proper to expel, the veſſel E F ſhould have a ſtop-cock K, through which the common air may be ſucked out, and the water will be made to aſcend as high as the ſtop-cock.

As people who are not converſant with this kind of experiments, may have ſome difficulty in determining the dimenſions of ſuch an apparatus, I ſhall ſubjoin the particular meaſures of one, which ſeems to be of the moſt advantageous conſtruction.

Diameter

Diameter of the largeſt part of the veſſel A B C - - -	7 inches.
Length of the whole veſſel -	16
Diameter of its aperture - -	1
Diameter of the cavity of the tube C D - - -	¼
Lower aperture of the veſſel E F, at leaſt - - -	6
Height E F of this veſſel, at leaſt	24
Its upper aperture F, about -	2

The diameter of the tub H I is immaterial, only the aperture of the veſſel E F ſhould be at leaſt one foot below the ſurface of the water in H I.

When the quantity of inflammable air to be produced is very great, the veſſel A B C may be made larger, though not much, on account of the difficulty of making the whole of its contents red hot; but ſeveral of theſe veſſels may be made to work at once, and all their tubes may be made to terminate in one tub, and under the ſame inverted veſſel E F, which in that caſe muſt be made proportionably larger, and eſpecially its upper aperture, in order to give a

 free

free passage to the inflammable air. This construction is very advantageous to recruit the materials in some of the vessels whilst the others continue to produce the inflammable air; and thus the operation may be continued at pleasure.

Care should be taken, that the fire to be used in this process be at a sufficient distance from the tub H I; because, if very near, it may easily happen that some of the inflammable air, which may escape out of the vessel E F, or out of the balloon, may, by catching fire, occasion some disagreeable accident; the tube C D therefore should be made sufficiently long, and it would be much better to have the fire, with the vessel or vessels A B C, in a room, and to keep the tub H I out of it, as the tubes may be easily made to pass through holes made in the wall, or through a window, &c.

We are now to examine the substances which produce inflammable air in this method, and the particular circumstances attending them.

Pit-coal,

Pit-coal, expoſed to a red heat, gives abundance of inflammable air, which, whether it be paſſed through water or not, weighs about one fourth of the weight of an equal bulk of common air, and one pound of it produces about three cubic feet of inflammable air. However, it muſt be obſerved, that different ſpecies of coal produce different quantities of inflammable air, and ſomewhat different in ſpecific gravity; but it is eaſy to aſſay the quantity of air that is produced by a given ſpecies of pit-coal, before it be uſed in great quantities *.

Aſphaltum, amber, rock-oil †, and other minerals, produce likewiſe inflammable air, but of a greater ſpecific gravity, and leſs abundantly than coal.

Wood gives a great quantity of inflammable air by this means, but mixed with a good

* See Memoire ſur l'Air inflammable, tiré de différentes ſubſtances, rédigé par M. Minkelers. Louvain, 1784.

† When oil and other fluids are to be tried in this method, the beſt expedient is to ſoak dry ſand with it, and thus to put it into the veſſel.

deal

deal of another elaſtic fluid, which is ſeparable by waſhing in water, and eſpecially in lime-water; on which account it is proper to put ſome quick-lime into the water of the tub, through which the inflammable air is to paſs. Various quantities of inflammable air are yielded by different ſorts of wood, and even by wood of the ſame ſpecies, but of different age or dryneſs. Oak gives, perhaps, more gas than any other ſort of wood. The weight of the inflammable air of wood is generally between one half and two thirds of the weight of atmoſpheric air; and conſequently much heavier than that of pit-coal.

Camphire yields a ſurpriſing quantity of inflammable air; the ſpecific weight of which is to the weight of common air nearly as 10 to 24.

Oil, ſpirits of wine, and ether, yield inflammable air, heavier than half the weight of common air.

Animal ſubſtances produce inflammable

air

air in various quantities by this means; but its weight is generally greater than half the weight of common air.

It appears, therefore, that pit-coal is the ſubſtance which may be moſt advantageouſly uſed for the production of inflammable air in aeroſtation; and, though the ſpecific weight of this gas is greater than that of metals, when extracted by means of acids, yet the cheapneſs of the materials makes ample amends; and in order to enable the aeroſtatic machine to lift up a given weight, its ſize muſt be a little larger, when it is to be filled with the gas of coal, than when that produced by metals and acids is to be made uſe of *.

In this method of extracting inflammable air, there is a remarkable circumſtance to be noticed, which was firſt diſcovered by Dr. Prieſtley. It is, that animal or vegetable ſubſtances will yield ſix, and even ten times more inflammable air, when the

* On the Continent, various ſmall balloons have been filled with the inflammable air of pit-coal, and have floated exceedingly well.

fire is ſuddenly increaſed, than when it is gently raiſed, though it be afterwards made very ſtrong.

In this proceſs, the various ſubſtances mentioned above, generally yield all their inflammable air in about one hour's time.

The laſt method of obtaining inflammable air was lately diſcovered by Mr. Lavoiſier, and was ſoon farther examined by Dr. Prieſtley; but as the various particulars relative to it have not been yet aſcertained, or, at leaſt, not publiſhed, ſo as to reduce the method to a certain operation, I ſhall content myſelf with giving only a general deſcription of it.—If iron is made red-hot, and in that ſtate the vapour of boiling water is made to paſs by it, inflammable air is produced, which is ſaid to be much lighter, if it is not made to paſs through water.

Iron and copper tubes have been uſed for this experiment, and in the following manner:—A tube of about three quarters of an inch in diameter, and about three feet long;

long, is filled with iron turnings, then the neck of a retort, or close boiler, is luted to one of its ends, and the worm of a refrigeratory, such as is used for common distilling, is adapted to its other extremity. This done, the middle part of the tube is surrounded with burning coals, so as to keep about one foot length of it red-hot, and likewise a fire is made under the retort or boiler, sufficient to let the water in it boil very fast. Thus it will be found, that a considerable quantity of inflammable air comes out of the worm of the refrigeratory. It is said that iron yields one half more air by this means, than by the action of vitriolic acid.

As the iron and copper tubes are soon corroded in this operation, perhaps earthen tubes may be found to be preferable.

The vapour of spirits of wine, of ether, and of oil, when passed through red-hot tubes, likewise produces inflammable air.

CHAP-

CHAPTER III.

Of the Shape, Capacity, Construction, and Power of Aerostatic Machines.

IT has been demonstrated by the mathematicians, that of all the possible shapes, the globular admits the greatest capacity under the least surface; so that if there are two bags of cloth capable of containing the same quantity of any substance, but one of them is spherical, and the other of any other shape, then the former will contain the least quantity of cloth, or the least surface; and again, if two bags have an equal surface, as for instance, each contains ten yards of cloth, but one of them is spherical, and the other is oblong, or of any other shape whatsoever, then the spherical will contain a greater capacity than the other bag.

Next to the spherical, those shapes admit of greater capacity under less surface, which approach

approach nearer the figure of a ſphere; for inſtance, the ſpheroid contains leſs ſurface than a cylinder, a cylinder leſs than a cube, a cube leſs than a parallelopipedon, &c. when they all are of ſimilar capacities.

In the conſtruction of aeroſtatic machines, wherein levity is the greateſt object, and conſequently the quantity of ſtuff which forms the envelope muſt be diſpoſed to the greateſt advantage, viz. to admit of the greateſt capacity; it is plain, that the globular ſhape muſt be preferred to all others. However, there is one reaſon, for which the ſpherical has not been conſidered as the moſt advantageous form, which is, that when the aeroſtatic machine is required to be guided in a calm, or in a courſe different from the direction of the wind, the ſpherical ſhape oppoſes a greater ſurface to the air, and conſequently a greater obſtruction to the action of the oars or wings, than ſome other ſhape might do; as for inſtance, a conical, or oblong figure, going with the narrow end forward. But it muſt be conſidered, that by making the machine of of an oblong ſhape, its ſurface, and conſequently the weight of the envelope, muſt be conſiderably augmented, in order to let the machine have as much lifting power as a ſphere would have, not only becauſe any other ſhape beſides a ſphere, contains, under the ſame ſurface, a ſmaller capacity, but becauſe it muſt actually contain a greater capacity, in order to compenſate for the augmentation of weight. For inſtance, ſuppoſe that a ſpherical aeroſtatic machine contains 100 cubic feet of inflammable air, in conſequence of which, it would aſcend into the atmoſphere with one pound of additional weight beſides the weight of its envelope: now, if a machine be made of the ſame kind of ſtuff, but of an oblong ſhape, and capable of containing likewiſe 100 cubic feet of inflammable air, its ſurface being much larger, muſt conſequently weigh much more, than the envelope of the ſpherical one; but the quantity of inflammable air being the ſame in both, the oblong machine muſt, of courſe, lift up a much leſs weight than one pound, and therefore it muſt be made capable of con-

taining

taining more inflammable air, if it be required to lift up as much weight as the ſpherical machine.

Beſides this obſervation, it ſhould be conſidered, that to keep the oblong machine with the ſmalleſt part forward in the atmoſphere, is not eaſily accompliſhed; and that if it were to turn ſideway, then that ſame ſhape, which, in a proper ſituation, would be of ſome advantage, will in this caſe be of very great diſadvantage; ſo that, conſidering every circumſtance, it ſeems that the ſpherical figure is in general the moſt advantageous. We ſhall therefore conſider only this ſhape of aeroſtatic machines, in the following pages; it being very eaſy for a ſchemer to calculate the properties of any other ſhape, from the general principles already deſcribed.

The ſtuff to form the envelope of the inflammable, or rarefied air, deſerves to be firſt conſidered in the conſtruction of an aeroſtatic machine. After the original ſcheme of Father Lana, deſcribed in the first chapter of the History, several persons have proposed to construct a balloon of copper, or of tin; and, notwithstanding the weight of the metal, and of the solder necessary to join the various copper or tin plates, the size of one capable of carrying a man, is not so great as might be suspected at first view. This balloon might indeed be made very tight, in consequence of which it could be kept up for a vast while: but is subject to various inconveniences; the principal of which would be, first, the filling it with inflammable air; for, not being compressible, it would be very difficult to take away the common air from within it*: and secondly,

* There are three ways of filling such a balloon with inflammable air: the first is, To fill it with water, in a convenient place, and then to displace the water by introducing the inflammable air: secondly, To put a tube through a hole at the bottom of the balloon, and to let the extremity of this tube go as far as the upper part of the balloon; then the inflammable air introduced through this tube, on account of its specific levity compared to common air, would occupy the upper part, and would gradually expel the common air through a hole in the lower part of the balloon:

condly, when this balloon descended, after an aerial excursion, the difficulty would be great to remove it from the place where it fell, or to carry the apparatus, necessary to fill it again, to that place.

Silk stuff, especially what is called *lute-string*, properly varnished, has been hitherto the most used for inflammable-air balloons, and common linen for rarefied-air machines. Indeed silk would do as well, if not better, for the latter, only it would be more expensive, as the rarefied-air machine must be proportionably larger than the others, in order to have an equal power; and, on the other hand, varnished linen would do very well for the inflammable-

balloon: and thirdly, Another balloon, of oiled silk, might be swelled with common air within the copper balloon, so as to fill its whole cavity, then the inflammable air being introduced between the two balloons, through a hole in the copper one, would gradually fill its cavity, and at the same time the common air would be forced out of the inner balloon, &c. But it is evident that every one of these methods is subject to several practical inconveniences.

air balloons, but, being heavier, the balloon in that caſe ought to be made larger, which would be very diſadvantageous, on account of the dearneſs of inflammable air.

Varniſhed paper is as impermeable to the inflammable air as varniſhed ſilk is, but not being ſtrong, it can only ſerve to make ſmall balloons of. As for the ſmall rarefied-air balloons, they are eaſily made of ſimple paper, without varniſh or any other preparation. Goldbeaters ſkins are good enough to make ſmall inflammable-air balloons; but they are very porous, and the inflammable air ſoon eſcapes from them, excepting they were to be varniſhed; but then paper or ſilk would do as well, and would be cheaper; only the balloons ought to be made a little larger, in order to float; and indeed I don't ſee what purpoſe can be anſwered by making balloons exceſſively ſmall.

Parchment, leather, and ſome other ſubſtances, have been propoſed, and actually tried; but it does not ſeem that any of them have

have hitherto ſuperſeded the uſe of varniſhed ſilk and linen for the large machines, and of paper for the ſmall balloons.—Some of the ſmall inflammable-air balloons are ſtill made of membranes analogous to thoſe uſed by the goldbeaters, which are moſtly the membranes of the inteſtines of oxen.

It is now time to deſcribe the problems which are neceſſary for the conſtruction of aeroſtatic machines.

PROB. I. *Given the diameter, to find the circumference and ſurface of a ſphere.*

The diameter multiplied by 3,1416 gives the circumference of a circle or of the ſphere, and that circumference multiplied by the diameter gives the ſurface of the ſphere in ſquare dimenſions; thus, if the diameter of a ſphere is 6 feet, multiply 6 by 3,1416, and the product, 18,8496 feet, is the circumference; then multiply 18,8496 by 6, and the product, 113,0976 ſquare feet, is the ſurface of the ſphere.

N. B. If the length of the diameter is expreſſed in feet, the ſurface will be denoted alſo in ſquare feet; but if the diameter is expreſſed in inches, or in yards, then the ſurface will be likewiſe had in ſquare inches or ſquare yards, &c.

PROB. II. *Given the diameter, to find the capacity of a ſpherical veſſel.*

The cube of the diameter multiplied by 0,5236 gives the capacity in cubic inches, feet, or yards, &c; according as the diameter has been expreſſed by any of thoſe meaſures; thus, in the preceding example, the diameter being of 6 feet, the cube of 6 is 216; which, being multiplied by 0,5236, the product, 113,0976, is the capacity of the ſphere in cubic feet. And again, if the diameter of a ſphere is 9 feet, its ſurface is 254,4696 ſquare feet, and its capacity or ſolid contents is equal to 381,7044 cubic feet.

The following table ſhews the ſurfaces and capacities of ſpheres of various diameters;

ters: the numbers of which anſwer for every ſort of meaſure; for inſtance, if the numbers in the firſt column are taken for inches, then the numbers of the ſecond column denote ſquare inches, and in the third they denote cubic inches; if the numbers of the firſt column are taken for Engliſh or French feet, or yards, &c. then the numbers of the ſecond column denote ſquare Engliſh or French feet or ſquare yards, and the numbers in the third column denote cubic meaſures of the like ſort.

Diameters.	Surfaces.	Capacities.
1	3,141	0,523
1½	7,068	1,767
2	12,567	4,188
2½	19,635	8,181
3	28,274	14,137
4	50,265	33,51
5	78,54	65,45
6	113,097	113,097
7	153,938	179,594
8	201,062	268,083
9	254,469	381,704
10	314,159	523,6
11	380,1	696,9
12	452,5	904,8

Diameters.	Surfaces.	Capacities.
13	530,9	1150,3
14	615,8	1436,7
15	706,9	1767,1
16	804,2	2145.
17	907,9	2572.
18	1017,9	3054.
19	1134,1	3591.
20	1256,6	4189.
21	1385,4	4849.
22	1520,5	5575.
23	1661,9	6371.
24	1809,6	7238.
25	1963,5	8181.
26	2124.	9203.
27	2290.	10306.
28	2463.	11494.
29	2642.	12770.
30	2827.	14137.
31	3019.	15598.
32	3217.	17157.
33	3421.	18817.
34	3632.	20580.
35	3848.	22449.
36	4072.	24429.
37	4301.	26522.
38	4536.	28731.
39	4778.	31060.
40	5026.	33510.
45	6362.	47713.
50	7854.	65450.

Diameters.	Surfaces.	Capacities.
55	9503.	87114.
60	11310.	113098.
65	13273.	143794.
70	15394.	179595.
75	17671.	220804.
80	20106.	268083.
85	22698.	321556.
90	25447.	381704.
95	28353.	448922.
100	31416.	523599.

PROB. III. *Given the weight of a ſquare foot of the envelope, and the diameter of a balloon, to find out the weight of the whole envelope or bag.*

Find the ſurface anſwering to the given diameter in ſquare feet, either by the table or by problem I. and, multiplying this by the given weight of one ſquare foot, the product gives the anſwer. Thus, if a balloon of 85 feet diameter is made of ſuch ſilk as weighs two ounces a ſquare foot, the weight of the whole envelope will be 45396 ounces, or 2837¼ pounds.

PROB.

PROB. IV. *Given the diameter and weight of the envelope of a balloon, to find its levity, or ascending power, when filled with rarefied or inflammable air.*

First, find the capacity of the balloon, either by the table, or by problem II; then multiply that capacity by the weight of common air, noting the product; multiply the capacity again by the weight of inflammable or rarefied air; subtract this product from the former; and from the remainder subtract the weight of the envelope; the remainder of which subtraction is the required levity: thus, suppose that the diameter of a balloon is 8 feet, that a square foot of the envelope weighs half an ounce, that a cubic foot of common air weighs 1,2 ounce, and a cubic foot of the inflammable air, of which the balloon is filled, weighs half as much as common air, viz. 0,6 of an ounce, then by the table we have 201,1 square feet for the surface; which, multiplied by half an ounce, which is the weight of one square foot of the bag, gives 100,55 ounces, or near 6 pounds and

and $4\frac{1}{2}$ ounces, for the weight of the whole envelope. Again, by the table, we find that the capacity of the balloon is 268,1 cubic feet; which, multiplied by 1,2 ounce, which is the weight of one cubic foot of common air, gives 321,72 ounces; and, being multiplied again by 0,6 of an ounce, which is the weight of one cubic foot of inflammable air, gives 160,86 ounces; which being ſubtracted from the other product, 321,72, there remains 160,86 ounces; from which ſubtract the weight of the envelope, and there remains 60,31 ounces, or near $3\frac{3}{4}$ pounds, for the required levity of the balloon.

PROB. V. *To find out how many yards of ſilk or linen, of a known breadth, are required to make a balloon of a given diameter.*

If the ſtuff is one foot wide, it is plain, that to make a balloon, the ſurface of which is 60 ſquare feet, there is required the ſame number of feet length of ſtuff, viz. 60, or 20 yards. But when the ſtuff is more or leſs wide than one foot, then uſe the following rule:—Take the breadth of the ſtuff in inches; reduce the ſurface of the balloon alſo into inches, by multiplying its number of ſquare feet by 144. Divide this product by the breadth of the ſtuff in inches, and again, divide the quotient by 36, and this laſt quotient is the required number of yards. Thus it will be found, that if the ſilk is 13 inches wide, near $96\frac{2}{3}$ yards of it are required for a balloon of 10 feet in diameter.

N. B. This problem is founded upon a ſuppoſition that none of the ſtuff is cut to waſte, nor is any allowance made for the ſeams; to which two particulars, however, due regard muſt be had in practice.

PROB.

PROB. VI. *Being given the weight of a square foot of silk or other stuff, and likewise the weights of a cubic foot of common air, and of a cubic foot of inflammable or rarefied air—to find out the diameter of a balloon, which, being made of that silk or other stuff, and being filled with that inflammable or rarefied air, will just float.*

Multiply the weight of one cubic foot of common air, in ounces or decimals of an ounce, by 0,5236; and again, multiply the weight of one cubic foot of inflammable air, in ounces and decimals of an ounce, by the same number 0,5236, and subtract this product from the former, noting the remainder. Then multiply the weight of one square foot of the stuff, in ounces or decimals of an ounce, by 3,1416; and lastly, divide this product by the above-mentioned remainder, and the quotient expresses the required diameter in feet.

If the weight of a cubic foot of common air is expressed in grains, then the weight of of the inflammable or rarefied air, and the weight of the ſtuff, muſt be likewiſe expreſſed in grains; the reſt of the calculation remaining as before.

Thus, for example, if the weight of a cubic foot of common air is 1,2 ounce, the weight of the inflammable air is half the weight of the common air, and a ſquare foot of the ſtuff, of which the balloon is to be made, weighs three ounces *, it will be found that a balloon made of that ſtuff, and filled with that ſort of inflammable air, muſt be 30 feet in diameter, in order to float in the atmoſphere. If its diameter is leſs than 30 feet, it will not lift

* In order to aſcertain the weight of a ſquare foot of ſilk or other ſtuff, there is no need of having exactly a ſquare foot of it; a ſmaller piece being enough. Suppoſe, for inſtance, that you have a piece which is 60 ſquare inches; weigh that piece, and imagine its weight to be a quarter of an ounce; then ſay, by the rule of three, if 60 ſquare inches weigh 0,25 of an ounce, what is the weight of 144 ſquare inches, which are equal to one ſquare foot? and the anſwer is 3,6; ſo that one ſquare foot of that ſtuff weighs 3 ounces and 6 tenths of an ounce.

itſelf above the ground; and if the diameter is greater than 30 feet, it will aſcend in the air.

N. B. In this problem, ſome allowance muſt be made for the weight of the ſeams or joinings, of whatſoever ſort they may be. This allowance is beſt made by increaſing a little the weight of the ſquare foot of ſtuff.

The denſity of the atmoſphere decreaſing according to the diſtance from the ſurface of the earth; it follows, that a balloon, which will juſt float at a little diſtance above the ſurface of the earth, will not float higher up; and, in general, the equilibrium takes place when the weight of the balloon, and incloſed air, &c. is equal to the weight of a body of the circumambient air that is equal to the bulk of the balloon. Were the heat and gravity of the atmoſphere, and likewiſe the heat and ſhape of a balloon, always the ſame, or regular, it would be eaſy to calculate at what height a balloon of a given diameter, &c. would ceaſe

ceaſe to aſcend; but the inconſtancy and uncertainty of the various cauſes which concur to affect this equilibrium, render every effort uſeleſs; it is therefore better to omit any farther conſideration of this problem, than to perplex the reader with what can be of little or no uſe.

PROB. VII. *To deſcribe the pattern for the pieces of ſilk, or other ſtuff, which are to form a balloon.*

The pieces of ſilk, linen, paper, or other ſtuff, of which balloons are generally formed, being flat ſurfaces; it is plain, that a balloon made of them muſt be compoſed of many flat ſurfaces, which, when put together, come very near to the ſpherical figure; however, when the pieces of ſtuff are properly cut and joined, they will, after once inflating the balloon with common air, ſtretch a little towards their middle, and by this means acquire a ſhape which is ſo nearly ſpherical, as hardly to be diſtinguiſhed, in ſome place or other, to be otherwiſe.

The beſt way to cut the pieces of ſilk that are to form a balloon, is to deſcribe a pattern of wood or ſtiff card paper, and then to cut the ſilk or other ſtuff upon it. In order to form a clear idea, imagine two points on the ſurface of the globe, diametrically oppoſite to each other, and let a plane, paſſing through the axis which joins thoſe two points, cut the ſphere in many ſlices, as is commonly uſed to cut melons. Suppoſing then that thoſe ſlices are equal, one of them, ſtretched flat, will be a pattern to cut others, that are to ſerve for the conſtruction of a balloon of the required dimenſions.

Fig. 6, of plate I. exhibits one of thoſe ſlices, or the pattern for cutting the pieces of a balloon. The edges of ſuch a pattern, being not arches of circles, cannot be deſcribed by a pair of compaſſes; and the beſt way of drawing them is the following, when the diameter of the required balloon, and the number of pieces of which it is to be formed, are known.

First, Draw on a flat ſurface two right lines, A E and B C, perpendicular to each other. Secondly, Find the circumference anſwering to the given diameter, in feet and decimals of a foot, and make A D and D E each equal to a quarter of the circumference; ſo that the whole length A E of the pattern will be equal to half the circumference. Thirdly, Divide A D into 18 equal parts, and to the points of diviſion apply the lines *fg*, *bi*, *kl*, &c. parallel to each other, and perpendicular to A D. Fourthly, Divide the whole circumference in twice the given number of pieces, and make D C and B B each equal to the quotient of this diviſion; ſo that the whole B C is equal to the greateſt breadth of one of thoſe pieces. Fifthly, Multiply the above-mentioned quotient, viz. the length of D C, by the decimals annexed to *fg*, viz. 0,99619, and then the product expreſſes the length of *fg*; again, multiply the ſame length of D C by the decimals annexed to *bi*, and the product expreſſes the length of *bi*; and, in ſhort, the product ariſing from the multiplication of the length of D C by the decimals annexed to each of the parallel lines, gives the length of that line. Laſtly, Having thus found the lengths of all thoſe lines, draw by hand a curve line, paſſing through all the extremities of the ſaid lines, and that is the edge of one quarter of the pattern. As for the other quarters, A B D, E B D, E D G, they may be eaſily deſcribed by applying a piece of paper equal to A D C on any one of them.

Suppoſe, for example, that the diameter of the balloon to be conſtructed is 20 feet, and that it is required to make it of 12 pieces: then, in order to draw the pattern for thoſe pieces, find the circumference of the balloon, which is 62,83 feet, and, dividing it by four, the quotient is 15,7 feet; make therefore A D equal to 15,7 feet, and D E likewiſe of the ſame length. Divide the circumference 62,83 by 24, which is double the number of pieces that are to form the balloon, and the quotient, 2,618 feet, is the length of D C, and likewiſe of B D; ſo that BC is equal to 5,236 feet. Then, having divided the line A D into 18 equal parts, and having drawn the parallel lines from thoſe points of diviſion, find the length of each of thoſe lines by multiplying 2,618 by the decimals annexed to that line; thus, 2,618, multiplied by 0,99619, gives 2,608 feet for the length of *fg*; and again, multiplying 2,618 by 0,98481, gives 2,578 feet for the length of *hi*; and ſo of the reſt.

N. B. In cutting the pieces after ſuch a pattern, care ſhould be had to leave the piece about half or three quarters of an inch all round larger than the pattern, which will be taken up by the ſeams.

Having thus deſcribed the problems that are moſt uſeful for the conſtruction of balloons, it is now neceſſary to deſcribe the various ſorts of varniſhes, and other things, for the preparation of the ſilk and other ſubſtances of which the aeroſtats may be formed.

It

It is evident, that the aeroſtatic machines which are to aſcend by means of hot air, require a different preparation from thoſe that are raiſed by means of inflammable air. The envelope of the former muſt be prepared ſo as to reſiſt fire as much as poſſible; that of the latter is required to prevent the eſcape of the inflammable air; and both ſhould be of ſuch a nature as not to be damaged by water. But here lies the great difficulty; for if the ſtuff for a rarefied-air machine is prepared with glue, alum, ſal ammoniac, and water-colours, which ſubſtances will defend it againſt the fire, then the rain will eaſily waſh them off; and if any oily or reſinous ſubſtances are uſed, which will not be hurt by the rain, then the fire has again power upon them: however, for a large aeroſtatic machine upon Montgolfier's principle, the beſt way to prepare the cloth is, firſt to ſoak it in a ſolution of ſal ammoniac and ſize; uſing one pound of each to every gallon of water; and when the cloth is quite dry, to paint it over with ſome earthy colour and ſtrong ſize or glue; but then it ſhould be ſheltered from the rain as much as poſſible.

The very ſmall machines of this kind are beſt made of paper, without any preparation whatſoever; but if it were required to make the paper for thoſe machines likewiſe incombuſtible, it may be ſoaked in a ſolution of ſal ammoniac and glue, or ſize, as above directed, but uſing rather a leſs proportion of water.

Alum may likewiſe be uſed inſtead of ſal ammoniac; and indeed many other ſalts would have nearly the ſame effect.

Oil, or varniſh of any ſort, is very bad for ſuch machines, becauſe the heat of the fire, drying up thoſe ſubſtances, produces an inflammable vapour within the machine, which may catch fire and deſtroy it. It has been tried, to ſoak the cloth firſt in the above-mentioned incombuſtible ſolution, and then to varniſh it over; and though this method is ſubject to ſome inconveniences,

conveniences, yet it anſwers better than either of the two preparations ſingly.— Upon the whole, I would recommend firſt to ſoak the cloth in the deſcribed ſolution, then to paint it within with any earthy colour and ſize; and, when perfectly dry, to varniſh it with ſome ſtiff oily varniſh, that would dry before it penetrates quite thro' the cloth. Simple drying linſeed-oil, perhaps, will anſwer as well as any, provided it be not very fluid.—If the machine conſiſted of a double envelope, this preparation would be more eaſily and more advantageouſly applicable.

The inflammable-air balloons have already attained to a great degree of perfection, relative to this particular; and there ſeems to be no doubt, but that, in a ſhort time, they will be made quite impermeable to the inflammable air, or very nearly ſo. Paper of that ſort which is commonly uſed for writing, when twice painted, viz. once on each ſide, with drying oil, and is thoroughly dry, is ſo far impermeable to the inflammable air, that ſmall balloons may be ſafely made of it. I have kept ſome inflammable air in a ſmall paper bag, thus prepared, for three days; after which the gas appeared to be as inflammable as before. But good oil varniſh anſwers this purpoſe ſtill better, though the paper is generally rendered more brittle by it.

The balloons made of goldbeaters ſkins do not in general retain the inflammable air long, on account of the many ſmall pores that are in thoſe ſkins; and for this reaſon, ſome of them cannot be filled by applying their aperture immediately to the bottle containing the materials which produce the inflammable air, becauſe the gas eſcapes through their pores almoſt as faſt as it is produced; but, in order to fill them, the gas muſt be firſt introduced into bladders, and then muſt be paſſed very quickly from the bladders into the balloon. For ſuch, it is very proper to uſe any ſort of varniſh; though ſometimes they are ſo ſmall, that the weight of the varniſh renders them too heavy to aſcend when they are filled with inflammable air.

The

The varniſhes for the ſilk or linen of large inflammable-air balloons ſhould have the following properties, viz. impermeability to the inflammable gas—pliableneſs—and, at the ſame time, dryneſs ſufficient to adhere firmly to the ſtuff, without ſoiling the fingers or coming off very eaſily. In France they talk a good deal of the élaſtic gum varniſh, of the compoſition of which (if elaſtic gum is really the principal ingredient) they make a ſecret. However, this ſingular ſubſtance, having been examined by various able chymiſts, has been found to be diſſoluble in divers eſſential oils, but the ſolution always forms a varniſh, which never dries perfectly, remaining clammy and diſagreeable to the touch*. Vitriolic ether, when very pure, diſſolves elaſtic gum; and the ſolution, when dried up, which it does very readily, exhibits a ſubſtance exactly like the elaſtic gum before the ſolution, being of the ſame

* See Mr. Berniard's Diſſertation in the xviith vol. of Le Journal de Phyſique—Mr. Aſchard's Diſſertation on the ſubject—and Mr. Faujas de Saint-Fond, on the Aeroſtatic Machines.

colour,

colour, elaſticity, degree of dryneſs, &c.*; but ſuch ſolution is ſo exceſſively dear, that I doubt whether it will ever become of any great uſe.

The copal varniſh or amber varniſh dries too hard, ſo as not to be pliable, which is likewiſe the fault of various other varniſhes. A varniſh made by boiling two ounces of gum anemi and one ounce of bees-wax in drying linſeed-oil, has been found tolerably good. The following has been recommended as very good; though I don't know that it was ever uſed for large balloons:— To one pint of linſeed-oil, add two ounces of litharge, two ounces of white vitriol, and two ounces of gum ſanderack; boil the whole for about an hour over a ſlow fire; after which let it cool, and, when ſufficiently cold and ſettled, ſeparate it from the ſediment, or ſtrain it through a ſieve, and dilute it with a ſufficient quantity of ſpirits of turpentine.

* See my paper in the Philoſophical Tranſactions, vol. LXXI. page 511.

But

But the beſt varniſh for an inflammable-air balloon is made with bird-lime. This varniſh is deſcribed by Mr. Faujas de Saint-Fond*, and is recommended by many who have uſed it.—Having made ſeveral experiments on this ſubject, I imagine that my way of making it is rather preferable: but I ſhall firſt deſcribe that of Mr. de Saint-Fond, and then my own, that the practitioner may chooſe as he thinks beſt.

"Take one pound of bird-lime, put it in-
"to a new proper earthen pot that can reſiſt
"the fire, and let it boil gently for about
"one hour, viz. till it ceaſes to crackle, or,
"which is the ſame thing, till it is ſo far
"boiled as that a drop of it, being let fall
"upon the fire, will burn: then pour up-
"on it a pound of ſpirits of turpentine,
"ſtirring it at the ſame time with a wooden
"ſpatula, and keeping the pot at a good
"diſtance from the flame, leſt the vapour
"of this eſſential oil ſhould take fire.

* Deſcription des Experiences Aeroſtatiques, Tome ii. page 263.

"After

"After this, let it boil for about fix mi-
"nutes longer; then pour upon the whole
"three pounds of boiling oil of nuts, or of
"linfeed, or of poppy, rendered drying by
"means of litharge; ftir it well, let it
"boil for a quarter of an hour longer, and
"the varnifh is made.

"After it has refted for 24 hours, and
"the fediment is gone to the bottom, de-
"cant it into another pot; and when you
"want to ufe it, warm it, and apply it
"with a flat brufh upon the filk ftuff
"whilft that is kept well ftretched. One
"coat of it may be fufficient; but if two,
"it will be proper to give one on each
"fide of the filk, and to let them dry
"in the open air whilft the filk remains
"extended."

The following is my method: — In order to render linfeed-oil drying, boil it, with two ounces of faccarum faturni, and three ounces of litharge, for every pint of oil, till the oil has diffolved them, which will be accomplifhed in about half an hour.

hour. Then put a pound of bird-lime, and half a pint of the drying oil, into a pot (iron or copper pots are the ſafeſt for this purpoſe) the capacity of which may be equal to about one gallon, and let it boil very gently over a ſlow charcoal fire till the bird-lime ceaſes to crackle, which will be in about half or three quarters of an hour; then pour upon it two pints and a half more of drying oil, and let it boil for about one hour longer, ſtirring it very frequently with an iron or wooden ſpatula. As the varniſh, whilſt boiling, and eſpecially when it is nearly done, ſwells very much, care ſhould be had to remove, in thoſe caſes, the pot from the fire, and to replace it when the varniſh ſubſides, otherwiſe it will boil over. Whilſt the ſtuff is boiling, the operator ſhould, from time to time, examine whether the varniſh has boiled enough; which is thus known:— Take ſome of it upon the blade of a large knife, and then, after rubbing the blade of another knife upon it, ſeparate the knives, and when, on this ſeparation, the varniſh begins to form threads between the two knives,

knives, you may conclude the varniſh is done; and, without loſing time, it muſt be removed from the fire. When it is almoſt, though not quite cold, add about an equal quantity of ſpirit of turpentine; mix it well together, and let it reſt till the next day, when, having warmed it a little, ſtrain it and bottle it: if it is too thick, add ſome more ſpirit of turpentine.

When this varniſh is laid upon the ſilk or linen, the ſtuff ſhould be perfectly dry, and ſtretched; ſo that the varniſh, which ought to be uſed lukewarm, may fill up the pores of the ſtuff. The varniſh ſhould be laid once very thin upon one ſide of the ſtuff, and, about 12 hours after, two other coats of it ſhould be laid on, viz. one on each ſide; and, 24 hours after, the ſilk may be uſed, though in cold weather it may be left to dry ſome time longer.——Thus far of the varniſhes; and as, in the preceding pages, the manner of cutting the pieces, which are to form a balloon, has been ſufficiently deſcribed, there remains very little to be added relative to the conſtruction of thoſe machines.

The

The ſpherical is the ſhape, which in general ſhould be adopted, for all ſorts of aeroſtatic machines, or a very ſmall variation from the ſpherical; but for very ſmall paper machines, conſtructed merely for the ſake of ſeeing them flying in the atmoſphere, it is much eaſier to make theſe cylindrical in the middle, and conical at the two extremities; for in this conſtruction there is no occaſion for any pattern, nor are there many pieces to be paſted together; an oblong piece of paper being paſted round, makes the middle part, and two cones of paper paſted to the ends of the middle part, compleat the machine; but then one of the cones muſt be truncated, in order to form the aperture of the aeroſtat; to which muſt be affixed a hoop of iron wire, with a croſs or frame likewiſe of wire, in the middle of which a wire ſocket receives the cotton or carded wool ſoaked in ſpirits of wine, &c.—Fig. 7 and 8, of plate I. exhibit the ſections of two ſmall machines of this ſort, one of which is globular, and one of the other above-mentioned ſhape; below which is a plan of the hoop and frame of the aperture.

The

The paper moſt commonly uſed for theſe ſmall aeroſtats is of a fine and looſe texture; but if the ſpherical ones are above two feet in diameter, they may be made of the fine writing-paper.—If they are ſhaped like fig. 8, they ſhould be at leaſt about two feet in diameter, and three feet high. Their aperture, which muſt be about 9 inches in diameter, is paſted round a circle of iron wire of about the ſize of the fineſt netting needles. A croſs of the ſame wire is faſtened in this circle, and in the middle of the croſs a ſocket is made, or four ſhort wires are raiſed, capable of containing a ball of cotton, or rather of wool, about the ſize of a large egg.

When one of thoſe machines is required to be raiſed, firſt unfold it, as well as you can, by putting your hand or a ſtick in it; then hold it at arm's length by the top, to which part a piece of thread ſhould always be put, in conſtructing thoſe machines; and by moving the machine a few times up and down, the air will eaſily ſwell it. Now let the ball of cotton be ſoaked in good ſpirits of wine, and put it in the

wire

wire ſocket of the machine, taking care that none of the ſpirits falls upon the paper. This done, roll up a ſheet of paper in a looſe manner, ſet the end of it on fire, and when it makes a good flame, put it juſt under the aperture of the machine, and the flame of it will not only ſet fire to the ſpirits, but will likewiſe help to rarefy the air within the machine; in conſequence of which, the aeroſtat will ſoon become lighter than an equal bulk of common air, and, if you let it go, it will aſcend into the atmoſphere, and will be carried away by the wind.

The large aeroſtatic machines require a great many precautions, and a great deal of judgment muſt be uſed in their conſtruction. The moſt advantageous ſhape, as we ſaid above, for all aeroſtatic machines, is the ſpherical; but thoſe with rarefied air have been made moſtly of an oblong ſpheroidical figure, for the ſake of removing, as much as poſſible, the top of the machine from the flame of the fire, which muſt neceſſarily be uſed in them: however, ſome of thoſe machines have been made truly ſpherical, and it does not appear that their upper part was particularly damaged by the fire.

Without confining the practitioner to any ſhape in particular, which would be exceedingly improper in the infancy of the ſubject, I ſhall only point out the various circumſtances which ſhould be kept in view.—I. The aſcenſion of an aeroſtatic machine on Mr. Montgolfier's principle, is owing to the endeavour which the rarefied air makes perpendicularly upwards againſt the upper part of the machine; from which it follows, that ſuch endeavour is proportional to the height of the column of hot air; and as in a ſpheroid having its longeſt axis perpendicular to the horizon, the column of hot air is longer than in a ſphere of the ſame capacity, it is plain that the upper part of the ſpheroid muſt ſuſtain a greater preſſure than the upper part of a ſphere. II. As the preſſure of the hot air is exerted only againſt the upper part of the machine, it is clear that this part muſt be made ſtronger than the reſt. III. The aperture of the machine ſhould be between

one

one third and one quarter of the diameter of the machine, if this is above fifty feet; but if leſs, then the aperture ſhould be rather larger: a neck, or cylindrical production of the ſtuff of which the machine is made, ſhould be added to the aperture. IV. On the outſide of this cylindrical production the gallery for the aeronauts muſt be placed, and in the inſide the fire-place is ſituated. V. The gallery is beſt made of wicker-work, and ſhould be at leaſt three feet high and 18 inches broad. The inner baluſtrade of this gallery is faſtened to the neck of the machine, and the upper edge of it needs not be more than three feet from the ſpherical ſurface of the machine; and, as the cylindrical production is not to come lower than the bottom of the gallery, it follows, that the length of this production is about 6 feet. The external baluſtrade of the gallery is beſt faſtened by ropes proceeding from the very top of the machine, all along the outſide of it; and thoſe ropes, from the equator of the machine upwards, ſhould be interſected by croſs ropes, making a kind of net-work. VI. The fire-place is beſt made of iron; and it ſhould conſiſt of iron wire, or rather of bars not very ſlender, becauſe it has been obſerved, that when the machine is in the atmoſphere, the fire burns with ſuch rapidity as to conſume the fine iron wire very faſt. The diameter of the grate ſhould be rather leſs than one third of the diameter of the aperture. The grate may be ſupported by iron chains proceeding from the upper part of the inner baluſtrade of the gallery, and it ſhould not ſtand higher than about a foot above the edge of the cylindrical production, which terminates with the bottom of the gallery. VII. In the neck of the machine, and juſt over the edge of the gallery, port-holes muſt be cut, through which the fire is ſupplied with fuel, and which at the ſame time may ſerve to give air to the fire; for ſometimes, eſpecially when the grate is placed too high, the fire will not burn well, for want of a proper ſupply of freſh air.

It is evident that theſe remarks are not ſufficient for any perſon who wants to conſtruct ſuch a machine; but the preſent ſtate of of knowledge, relative to the ſubject, does not admit of more preciſe rules, and even thoſe mentioned above may admit of conſiderable variations; experience, and the ingenuity of the operator, muſt ſupply the deficiencies ſhewn by daily practice.

The inflammable-air balloons may be conſtructed with much more certainty and preciſion than the other ſort of aeroſtatic machines. The pieces, of which a balloon of this kind is to be formed, muſt be cut when the varniſh is ſufficiently dry. In order to join them together, the edges of two pieces are laid flat againſt each other, for about the depth of half an inch or a little more, then they are once folded, both together, and are ſtitched in that ſituation, which naturally forms an elevation or ridge, which remains towards the inſide of the balloon; but a better, though not the quickeſt way of joining the pieces of a balloon, is to lay about half an inch of the edge of one piece over the edge of the other, and thus ſew them by a double ſtitching. This method is clearly ſhewn in fig. 9 of

 plate

plate I, where A B C D is one piece of ſilk, E F G the other; and the two dotted lines ſhew the double ſtitching.

To the upper part of the balloon there muſt be a valve, which opens within; a ſtring that proceeds from it, and paſſes through the balloon, goes to the boat ſuſpended below it, from whence the aeronaut may pull it, &c. This valve ſerves to let the inflammable air out of the balloon; and may be conſtructed in the following manner. See fig. 10, of plate I.—A braſs plate A B, has a hole C D, in the middle, about 2 or 3 inches in diameter, and is covered on both ſides with ſtrong and ſmooth leather. On the part of it which is to go within the balloon, there is a ſhutter E, likewiſe of braſs, and covered with leather; its office is to cloſe the hole C D, ſo that it muſt be about two inches larger in diameter than the hole. It is faſtened to the leather of the plate A B, by means of a production of its own leather, on one ſide of it; and is kept againſt the hole by means of a ſpring, which needs not be very ſtrong, ſince, when the balloon is full of inflammable air, the elaſticity of the gas itſelf will help to keep it ſhut. A ſtring faſtened to this ſhutter muſt paſs quite through the balloon, and come out of it through a hole made in a ſmall round piece of wood that is faſtened to the loweſt part of the balloon, and diametrically oppoſite to the valve.—No great loſs of inflammable air is to be apprehended thro' this hole, not only becauſe it is ſmall, but alſo becauſe it lies at the loweſt part of the balloon, towards which the inflammable air never preſſes, except when the balloon is quite diſtended. A ſmall ſtring ſhould be placed from the ſhutter to the plate A B, and of ſuch length as will not allow the ſhutter being opened beyond a certain degree.

From the upper part of the balloon, where the plate A B with the valve is to be applied, the ſilk muſt be cut off, making a hole about 6 or 8 inches in diameter; and to this hole the plate with the valve is thus applied:—Let the leathers, which cover the plate A B be ſewed together, cloſe to the edge of the plate, but then projecting about 6 inches farther all round: let the ſilk, viz. the edge of the hole at the top of the balloon, be encloſed between the two leathers, and thus be ſewed all three together, viz. the ſilk in the middle, and the leather on each ſide of it, with a double or treble row of ſtitches.

To the lower part of the balloon two tubes of the ſame ſtuff muſt be attached; each of them may be fixed about two or three feet from the lowermoſt point of the ſpherical ſurface. Their diameters ſhould be at leaſt ſix inches for a balloon of 30 feet, but much larger for a balloon of 40 feet or upwards; and their length ſhould be ſuch as that their extremities may reach the boat, that is to be ſuſpended to the balloon.—Small balloons, viz. leſs than about 18 feet in diameter, are made with one ſhort tube or neck. Theſe tubes are the apertures through which the inflammable gas is introduced into the balloon.

Before

Before the plate with the valve is placed at the top of the balloon, it is proper to put ſome varniſh on the ſeams within the balloon, in order to ſtop up, as much as poſſible, the needle-holes. It may be done by turning the inſide of the balloon outward. At leaſt, it would not be uſeleſs to put ſome varniſh on the outſide of thoſe ſeams.

The boats for ſuch balloons have been made of various materials, and in different ſhapes, nor does it ſeem neceſſary to be confined to one conſtruction, provided it be made ſufficiently ſtrong and ſafe, in caſe of accident, as if it were to fall upon water, &c. It would be very proper to make it of wicker-work, and to cover it with leather, either well painted or varniſhed over. Thus it would be light, it would float very well upon water; and, in caſe of a fall, or of ſtriking againſt any thing hard, it would not eaſily break.

The propereſt method of ſuſpending the boat, is by means of ropes proceeding from the net which goes over the balloon.

The

The net muſt be formed as much as poſſible to the ſhape of the balloon, and ſhould go as far down as the middle of the machine; from whence various cords proceed to the circumference of a circle *, about two feet below the balloon; and from which the ſame or other ropes go to the edge of the boat.

Count Zambeccari, who has made a beautiful balloon, with which he intends ſhortly to aſcend, made the net of it ſo, as to have its meſhes ſmall at the top of the balloon, and to increaſe in proportion as they recede from the top. This judicious contrivance not only appears more beautiful, but likewiſe adds greater ſtrength to thoſe parts of the balloon, againſt which the incloſed inflammable air exerts the greateſt preſſure.

In the firſt aerial voyage made in an inflammable-air balloon, and in a few others,

* This circle may be made of wood, or rather of many pieces of ſlender cane bound together. Its diameter may be about three or four feet, for a balloon of about thirty.

a hoop

a hoop was put round the middle of the balloon, to which the net was faſtened; but afterwards the uſe of it was ſuperſeded, upon the perſuaſion that it was uſeleſs. Indeed, there ſeems to be no abſolute neceſſity for it; but it appears very evident, that the balloon muſt be leſs confined when a hoop is round it; whereas, without the hoop, the ropes not only rub againſt it, but generally preſs it into an oblong form. This hoop may be made of ſlender pieces of cane bound together, and covered with leather.

CHAPTER IV.

Of the various means, either uſed or propoſed, for raiſing higher, or lowering, the aeroſtatic machines, and likewiſe for directing them.

THE method generally uſed for elevating higher, or lowering, the aeroſtatic machines with rarefied air, has been the

the augmentation or diminution of the fire, which is entirely at the command of the aeronaut, as long as he has any fuel in the gallery. This method is ſo natural, ſimple, and effectual, that there ſeems to be no need of inveſtigating any other.

The inflammable-air balloons have been generally raiſed and lowered by diminiſhing the weight in the boat, and by letting out ſome of the inflammable air through the valve; for which purpoſe it is neceſſary, that a conſiderable quantity of ballaſt be put into the boat on firſt aſcending, and, as the inflammable air is continually eſcaping out of the machine, part of the ballaſt muſt be thrown out from time to time, in order to keep the machine up. It is plain, that this inconvenience will be leſſened in proportion as the ſtuff, of which the balloons are made, is improved, ſo as to be rendered leſs, or entirely, impermeable to the inflammable air.

If the perſon, who travels with an inflammable-air balloon through the atmo-
ſphere,

ſphere, throws out juſt ſo much ballaſt as will prevent its deſcent, a well-made balloon will be ſeveral hours before it loſes 100 pounds of its levity; but if, by various deſcents and aſcents, ſome inflammable air, and ſome ballaſt, be alternately thrown out, the machine will preſently become too heavy to float.

If in the atmoſphere there were any thing heavier than common air to be found, the aeronaut willing to deſcend lower, inſtead of diminiſhing the levity of the balloon, by letting out the inflammable air, might increaſe its weight, by taking in a proportionate quantity of that ſubſtance; which he might again throw out when he wanted to aſcend; thus the machine might be kept up much longer than otherwiſe: but as in the atmoſphere there is nothing but air that can be eaſily taken into a bag or other veſſel, and as that air would not increaſe the weight of a bag, except it were condenſed and rendered ſpecifically heavier than an equal bulk of the circumambient air; therefore it has been propoſed to condenſe the air in a veſſel annexed to the balloon, by means of a ſyringe or a good pair of bellows, and thus to increaſe the weight of the machine, when required to lower it; and to expel this compreſſed common air again when required to reaſcend. For this purpoſe, the veſſel or bag, in which the air is to be condenſed, muſt be very ſtrong and very large, conſidering that the weight of a cubic foot of common air is little more than an ounce; ſo that ſuppoſing the capacity of the veſſel to be equal to 20 cubic feet, and that a double atmoſphere were condenſed in it, viz. twice as much air as its capacity would contain without any condenſation, then the weight thus added to this veſſel would barely amount to one pound and a half; and the endeavour exerted by the elaſticity of the condenſed air againſt the ſides of the veſſel would be above 14 pounds for every ſquare inch of ſurface; to reſiſt which the veſſel ought to be conſiderably ſtrong.

In order to ſtrengthen ſuch a veſſel from without, by means of ſomething which did not

not add any weight to the balloon, it has been propoſed to incloſe one balloon within another, to fill the outward balloon with inflammable air, and the inner one with common air, through a tube made to paſs through the invelope of the outward balloon; for the inflammable air, preſſing on the outſide of the inner balloon, would ſtrengthen it, ſo that the common air might be in a great meaſure condenſed in it, &c.

This method is certainly very ingenious; but, if we conſider the trifling weight, which may be thus added to the balloon, the time required to throw into the inner balloon, or other veſſel, ſuch a quantity of common air as would weigh eight or ten pounds, and the apparatus required for it, we may eaſily perceive that this method may be applied only when the balloons are ſo far improved, and rendered impermeable to the inflammable air, as to be raiſed or lowered by adding or removing the weight of a few ounces, or at moſt a pound or two*.

Another

* Beſides the eſcape of the inflammable air, or the throwing out of the ballaſt, there is another very powerful

Another ingenious scheme for lowering or raising higher an aerostatic machine is the following:—It has been proposed to put a small aerostatic machine with rarefied air, under an inflammable-air balloon, by means of ropes, and so distant from it as that the fire of the former might not inflame the inflammable air of the latter; for which purpose the distance of about 30 or 40 feet would be fully sufficient. The boat or gallery ought to be placed so near the rarefied-air machine, as that the aeronaut might easily regulate the fire of it. With this apparatus, it is plain that the whole machinery might be raised higher, or lowered, by only increasing or diminishing the fire in the lower aerostatic machine. This method has not, as far as I know, been tried yet, but seems to be promising of success.

The ballast hitherto used for aerostatic machines has been generally sand, which is

powerful cause, which occasions the balloons to rise or fall. This is the condensation and rarefaction of the inflammable air, arising from heat and cold, and which very commonly produces an effect equal to many pounds weight.

certainly

certainly very proper, not only on account of its considerable weight, and no great bulk, but likewise, because in falling upon any person, or any brittle thing, it cannot occasion any damage. Water would be equally proper, if it were not subject to be congealed by the cold, which is generally met with in the upper regions of the atmosphere.

The wings or oars frequently used with the boats of inflammable-air balloons, seem to have helped the ascent or descent of the machine very little or nothing; and at most, they may have just prevented the fall of the balloon upon some particular disadvantageous spot, as a tree, a house, &c.

It should be considered, that a balloon in the atmosphere does not descend or ascend exactly like a piece of iron or wood in water, because the atmosphere is of different degrees of density within very short distances, which is not the case with a quantity of water; hence, if a piece of iron, or other substance, specifically heavier than water, being left upon the furface of that fluid, defcends a few inches, it will continue to defcend as far as the bottom; and if a piece of wood, or other fubftance, lighter than water, rifes a few inches above the bottom of a veffel full of water, it will continue to rife as far as the furface of the water. But a balloon which could be juft made to defcend a few feet lower, from the height of 1000 yards, by the addition of one pound weight, would require more and more weight in order to defcend lower and lower, becaufe, if the air at 1000 feet height is too rare to fupport it, the air at the height of 900 yards is juft fufficiently denfe to keep it up, the air at 800 yards is more denfe than fufficient to fupport it, and fo on: the contrary may be faid of the balloon's afcenfion. Hence it appears, that if the action of the wings is hardly capable of caufing it to defcend or afcend a few feet, it muft be much lefs capable of lowering or raifing it through a greater diftance.

The means propofed for directing the aeroftatic machines horizontally, have been numerous

numerous indeed, eſpecially ſince the Academy of Lyons offered a premium to the author of the beſt Eſſay on the ſubject. Some of thoſe projects have been built upon evidently wrong principles, others are of a very doubtful and complicated nature; but there are a few which deſerve to be examined, tried, and perhaps improved. Of the firſt ſort are thoſe, which propoſe annexing ſails to the balloon, or other machinery to be moved by the wind; ſince the aeroſtatic machines, being at reſt with reſpect to the air that ſurrounds them, feel no wind, and conſequently the ſails cannot poſſibly act.

The compariſon of the veſſels at ſea, is generally uſed to explain the ſuppoſed action of the wind on the ſails of a balloon; but the caſe is quite different, becauſe the ſhip at ſea will, in any caſe, move with a velocity incomparably leſs than that of the wind that impels it, and therefore the difference between the velocity of the wind and the velocity of the ſhip, is the real wind felt by the ſails. If it be aſked, What prevents the veſſel moving with the ſame velocity of the wind? the anſwer is, The reſiſtance of the water. But a balloon, finding no reſiſtance, acquires the ſame velocity with the ſurrounding air, and therefore it can feel no wind.

The moſt rational projects for directing an aeroſtatic machine, are thoſe which propoſe to exert a force or endeavour againſt the ambient air on one ſide of the machine, by which means the machine would be moved in the oppoſite direction; and indeed this ſeems to be the only principle upon which we may depend, and upon which experiments and contrivances ſhould be made.

It has been propoſed to puſh againſt the air on one ſide of the machine, by means of the ſtream iſſuing out of an eolipile, or fire-engine, in order to move the machine the oppoſite way; but it is apprehended that the weight and bulk of the apparatus would be too great, in proportion to the effect that might be expected from it.

It has been proposed to produce the same effect by means of gun-powder; for instance, by rockets fastened to the machine, and fired so that their stream might be opposite to the course intended; but it would be dangerous to apply these too near the inflammable air of a balloon filled with it.—However, the effect that might be produced by this means deserves to be examined.

Oars or wings are the only means of this sort that have been used with some success; and these seem to be capable of considerable improvement, tho' perhaps they can never be expected to produce a very considerable effect, especially when the machine goes at a great rate; however, it would be of very great advantage, if they only impelled the balloon 30 or 40 degrees from the direction of the wind *. The best me-

* The very little effect which those wings have produced, with respect to the motion of a balloon, shews how difficult, if not impossible, it would be, not only to move along, but also to raise up the weight of a man, by means of wings alone, however mechanically they may be contrived.

thod of moving thoſe oars or wings is by the immediate ſtrength of a man, applied nearly in the ſame manner as is uſed for the oars of boats on water; every other complication of mechaniſm ſeeming rather to hinder than to help the effect *.

The ſhape of thoſe wings has been made different almoſt in every trial, nor do I mean to recommend any one in preference, ſince no deciſive trials, which might authorize it, have hitherto been made. But it is neceſſary to obſerve, that they ſhould be made as large and light as can be conveniently managed, and might at the ſame time be ſufficiently ſtrong.

* About 30 years ago, the Rev. Mr. Wilkie, Profeſſor of Natural Philoſophy, propoſed, that in a ſcheme of flying by mechanical means, the artificial wings might be ſo contrived as to be moved, not by the hands, but by extending the legs, the ſtraps or ſtrings which pulled them down being faſtened to the feet, becauſe, by this means, a much greater power might be exerted. See Deſagulier's Experimental Philoſophy.—A mechaniſm contrived on this principle might be uſed for moving the wings of a ballon.

They

They may be made, in general, of ſilk ſtretched between wires, tubes, or ſticks; and it muſt be remembered, that if they are flat, they muſt be turned edgeways, when they are moved in the direction in which the machine is intended to be impelled, but flat in the oppoſite direction.

Fig. 11. of plate I. is the repreſentation of one of the wings uſed by Mr. Blanchard. Fig. 12. is one of thoſe uſed by Mr. Lunardi, which conſiſts of many ſilk ſhutters or valves, ABCD, DECF, &c. every one of which opens on one ſide only; viz. ADBC opens upon the line AB, DECF opens upon the line DC, &c. In conſequence of which conſtruction, this ſort of oars do not need being turned edgeways. Fig. 14. repreſents one of the wings uſed by the brothers Roberts, in the aerial voyage of the 19th Sept. 1784. And fig. 13. repreſents one of the wings conſtructed by Count Zambeccari, which is nothing more than a piece of ſilk ſtretched between two tin tubes ſet at an angle; but theſe wings are ſo contrived as to turn edgeways

by themſelves, when they go in one direction.

The greateſt effect produced by the wings of an aeroſtatic machine, was in the above-mentioned voyage of the Roberts: and the remarks made in their account are ſo juſt *, that I have nothing further to add, excepting the deſire that thoſe, as well as any other ſort of wings or impulſive power, were tried in ſtill air. A large hall, a church, or the like, might ſuffice for the experiment. When their real power has been once aſcertained, it will be eaſy from thence to calculate how far an aeroſtatic machine may be made to deviate from the direction of the wind, when going at a known rate. For inſtance, ſuppoſe that the machine, either by the action of wings, or by other means, may be made to move from A to B, fig. 15 and 16, in a given direction; and ſuppoſe that, by the action of the wind alone, it would move from B to C; it is plain, that by both powers together, the machine would be impelled in

* See page 168.

a coma compound direction, and at the end of that given time it would be found at D, having percurred the diagonal BD of the parallelogram, which, when the two forces are in the ſame, or in quite oppoſite directions, becomes one right line; and then the two forces would be either added or ſubtracted from each other.

A helm has ſometimes been uſed with the boats of aeroſtatic machines; but it does not appear that it had any particular power of directing its courſe; and indeed it ſeems as if it could have none, when the machine is only moved by the wind, becauſe the circumambient air is at reſt with reſpect to the machine. The caſe is quite different with a veſſel at ſea, becauſe the water, over which the veſſel floats, ſtands ſtill, whilſt the veſſel goes along.

CHAPTER V.

Manner of filling large aerostatic machines exemplified.

THE method of filling large aerostatic machines with rarefied air, has not been brought to such a certainty, as the method of filling the inflammable-air balloons; and what is exemplified in this chapter, is only the result of what the greatest number of successful experiments seems to point out as the best hitherto known.

A scaffold ABCD, fig. 1. pl. II. is raised about 6 or 8 feet above the ground, the size of which must be in proportion to the diameter of the balloon, its breadth being at least equal to two-thirds of the diameter of the machine. In the middle of this stage is a well EF, which goes as far as the ground, where it has

has a door or two, through which the fire that is made within the well is ſupplied with fuel, &c. Above the ſcaffold, the well ſhould be raiſed about two or three feet, though ſometimes it has been made to terminate even with the ſcaffold. The diameter of the well ought to be a little ſmaller than the neck of the machine, and it would be proper to build it very ſlightly with brick; but if made of wood, it muſt be well plaiſtered, ſo as to prevent its being burned.

The fire within the well may be made quite on the ground; but it would be better if it were raiſed a foot or two from the ground, in order to give it more air.

Two maſts, H I, K L, are ſet ſtraight up, one on each ſide of the ſcaffold, having each a pulley at the top; and they ſhould be rendered more ſteady, (eſpecially to prevent their bending towards each other) by means of ropes, GK, KP, HP, GH.

When

When the aeroſtatic machine is to be filled, the gallery being faſtened to it, is ſituated on the ſcaffold and round the aperture of the well, ſo that the neck of the machine juſt coincides with it. A rope that paſſes through the pullies of both maſts, and through a ring or ſtrong loop at the top of the machine, ſerves to lift the balloon about 15 feet or more above the ſcaffold, when its extremities are pulled. The reſt of the machine is ſpread over the ſcaffold, in the manner indicated by the dotted repreſentation MNO. About the equator of the machine, rings or loops ſhould be adapted, thro' which ropes are paſſed, which, when the machine is filling, are held by men ſtationed round the ſcaffold, and ſerve to prevent not only its being agitated by the wind, but likewiſe its aſcending before the proper time. As the ropes run freely thro' the rings, when the machine is to aſcend, if the perſons that hold them let go one end of each rope, and pull the other, the rope will eaſily ſlip through; and in the ſame manner the rope which paſſes over the machine is diſengaged, when the machine

chine is ſo far filled as to ſuſtain itſelf, which will take place within a few minutes after lighting the fire. Things being thus prepared, the fire is lighted in the well; and here it is proper to take notice, that it is not the ſmoke, but the hot air, that is required to be introduced within the machine. Indeed the ſmoke cannot be prevented entering into it; but my meaning is, that the combuſtibles ſhould be choſen with a view to their burning quick and clear, rather than of producing a great deal of ſmoke. Small wood and ſtraw have been found to be very fit for this purpoſe *.

The fire determining a current of hot air upwards, the machine is preſently ſwelled, and will lift itſelf up from over the ſcaffold, and from over the gallery, which hitherto

* In conſequence of ſeveral experiments made by the author, with ſmall aeroſtatic machines ſuſpended to one end of the beam of a balance, it ſeems that ſpirits of wine is upon the whole the beſt combuſtible, not only to fill the machines of this ſort, but alſo to keep them up; but its being very dear, will perhaps ever prevent its being uſed for large machines.

had

had been entirely covered by it. Then the paſſengers, fuel, inſtruments, &c. are placed in the gallery. When the machine ſhews evident efforts to aſcend, the ropes round it muſt be ſo managed, by thoſe who hold them, that the aperture of the machine may be brought ſideway of the well, a little above the ſcaffold. There the fire-place is quickly ſuſpended in it; the fire, which muſt be all quite ready, is lighted in the grate, and, the lateral ropes being ſlipped off, the machine is abandoned to the air.

Fig. 2, of plate II. is a repreſentation of ſuch a machine in the atmoſphere.

In eſtimating the power of thoſe machines, it muſt be obſerved, that by the moſt accurate experiments, made with large as well as with ſmall machines, ſuſpended under one ſcale of a balance, and their power examined by weights put in the oppoſite ſcale, it appears, that only one third of the common air can be expelled from the large machines; ſince the utmoſt fire that can be made in the ſmall machines, will not expel above

above half the contained common air; and it is therefore evident, that in the large machines, wherein the fire cannot poſſibly be made proportionably ſo ſtrong, not above one third of the common air can be expelled by rarefaction. At moſt, the levity, or the aſcending power of the rarefied air in them, can be only eſtimated as equal to half an ounce averdupoiſe for every cubic foot.

In order to fill an inflammable-air balloon, the quantity of materials neceſſary for the production of inflammable air muſt be firſt conſidered; then the reſt of the apparatus, which principally conſiſts of the caſks that are to contain thoſe materials, is eaſily determined.

Suppoſe that the balloon is 30 feet in diameter, then its capacity is 14137 cubic feet; and for the production of ſuch a bulk of inflammable air, there are required about 3900 pounds of iron turnings, 3900 pounds of vitriolic acid, and 19500 pounds of water. As the balloon ſhould not be above three quarters filled, it is evident that the above-mentioned quantities are rather greater than required; but it is always proper to have more materials than what are juſt ſufficient.

Fig. 3, of plate II, repreſents the apparatus. A A are two tubs, about 3 feet in diameter, and nearly two feet deep, inverted in larger tubs, B B, full of water. In the bottom of each of the inverted tubs a hole is made, and a tube E, of tin, is adapted, which is about ſeven inches in diameter, and ſeven or eight long. —To thoſe tubes, the ſilken tubes of the balloon are to be tied. Round each of the tubs B, five, ſix, or more ſtrong caſks are placed *; in the top of each, two holes are made, and to one of thoſe holes a tube of tin is adapted, and ſo ſhaped that,

* The number of thoſe caſks is not very material; but if they are few, they muſt be the larger; in ſhort, their capacity and number ſhould be ſo regulated, as that, when the whole quantity of materials is equally divided among them, each caſk might be rather leſs than half full.

paſſing

paſſing over the edge of the tub B, and through the water, it may terminate with its aperture under the inverted tub A. The other hole of thoſe caſks ſerves for the introduction of the materials, and is ſtopped with a wooden plug. The tin tubes of the caſks need not be larger than 3 inches and a half in diameter; and the other holes may be ſmaller.

Two maſts, with a rope, &c. are uſed for this as well as for the other ſort of aeroſtatic machines; though with this there is no great need for them, becauſe, if by means of a narrow ſcaffold, or otherwiſe, the balloon (no matter whether all extended or not, provided it be not much folded up) is elevated five or ſix feet above the level of the tubs A, A, that is fully ſufficient.

When the balloon is to be filled, put the net over it, and let it be ſuſpended, as ſhewn by C D F; and, having expelled all the common air from it, faſten its ſilk tubes round the tin tubes E, E*; then put the juſt proportion

* This balloon ſhould be ſteadied by means of lateral ropes, like the rarefied-air machines; but in this the

portion of materials into the caſks, beginning with the iron, next pouring in the water, and laſtly the vitriolic acid.

The inflammable air generated will immediately begin to ſwell the envelope, and in a ſhort time the balloon will be capable of ſupporting itſelf in the air, without any need of the rope G H, which may then be ſlipped off. As the balloon continues to be filled, the net is adjuſted properly round it; the cords that proceed from it are faſtened to the hoop M N; then the boat I K, being placed between the two ſets of caſks, is faſtened to the hoop M N, and every thing that is required to be ſent up, as the ballaſt, inſtruments, &c. is placed in it. At laſt, when the balloon is little more than three-quarters full, the ſilken tubes are ſeparated from the tin tubes of the inverted tubs, and, their extremities being tied up, are placed in the boat. Laſtly, the aeronauts being ſeated in the boat, the

the rings or loops for the lateral ropes muſt be fixed upon the net, and not upon the ſtuff of the balloon itſelf.

lateral ropes are ſlipped off, and the machine is abandoned to the air.

Fig. 4, of plate II. exhibits a view of an inflammable-air balloon in the atmoſphere.

In eſtimating the power of thoſe aeroſtatic machines, the aſcending power of the inflammable air ſhould be conſidered as equivalent to one ounce averdupoiſe for every cubic foot, which is juſt one-ſixth of the weight of common air; for though the inflammable air itſelf may be ſomewhat lighter, yet, as it is almoſt impoſſible to prevent ſome common air from entering the balloon, or ſome moiſture, &c. it is always more ſafe to undervalue than to over-rate the power of the machine. If, therefore, an inflammable-air balloon, the capacity of which is 12000 cubic feet, is filled three-quarters with inflammable air, from iron and diluted vitriolic acid, the aſcending power or levity of that gas may be ſafely eſtimated at 9000 ounces, or 562½ pounds weight; from which the weight of the

 envelope,

envelope, boat, ropes, &c. muſt be ſubtracted.

I ſhall conclude this chapter with a ſhort enumeration of thoſe things which have been found peculiarly uſeful, or wanting, in an aerial voyage; though this is impoſſible to be done with preciſion, or very extenſively, ſince what is uſeful to one perſon, and in one climate or ſeaſon, may be uſeleſs to another, under different circumſtances. This is particularly the caſe with philoſophical inſtruments, which are entirely uſeleſs, if the aeronaut is not ſufficiently ſkilled in the uſe of them.

Clothes ſufficient to defend from a conſiderable degree of cold are neceſſary, and a cloak of varniſhed ſilk would be very uſeful in paſſing thro' fogs, clouds, and miſts.

As for refreſhments, there is no need to mention them, ſince hardly any aeronaut will forget them.

Some ropes, and a hook ſomewhat like an anchor, are very uſeful in deſcending,

particularly

particularly to prevent the machine rebounding.

A ſpeaking trumpet has been likewiſe found uſeful.

A memorandum book and pencil ſhould be alſo uſed, for ſetting down the occurrences that are worth notice.

The inſtruments for obſervations are principally the following, provided the aeronaut knows how to uſe them :—A watch that ſhews ſeconds; a good barometer, ſuch a one as is uſed for meaſuring the heights of mountains; a couple of thermometers, a hygrometer, a magnetic compaſs, a teleſcope, a ſextant, and an electrometer. As for other inſtruments, they muſt be provided according to the various experiments that are intended to be made

CHAPTER VI.

Experiments and obſervations proper to be made in the courſe of an aerial voyage.

TO enable an aeronaut to make philoſophical experiments and obſervations in the atmoſphere, there is required a conſiderable knowledge of natural philoſophy and mathematics, and likewiſe ſome experience in performing experiments; therefore this chapter cannot contain any thing more than the bare mention of general and more eaſy experiments, without explaining the theory of their principles, or deſcribing the particulars of the practice.

The principal objects to be determined by the aeronaut are, his height above the ſurface of the earth, and when he is aſcending or deſcending; which are done by the barometer.—As for his aſcending or deſcending,

ſcending, that is immediately indicated by the deſcent or aſcent of the quickſilver in the barometer; but for determining the height, there is required a good deal of calculation, which is beſt done after the deſcent; and whilſt in the air, the aeronaut ſhould only ſet down the different heights of the barometer, and at the ſame time the degrees of heat indicated by the thermometer.

In order to find out the height of one place above another, by barometrical obſervations, two barometers and four thermometers are required, viz. by one barometer and two thermometers ſet in each place; a thermometer being attached to each barometer, which ſerves to ſhew the expanſion of its mercury, which is generally of a different degree of heat from that of the ſurrounding air. The other thermometer ſerves to ſhew the heat of the air.

The height of the quickſilver in both barometers, and the degree of heat of all the four thermometers, ſhould be obſerved at the ſame time, becauſe, if one is examined before the other, the gravity of the atmoſphere may have varied in the mean time, and then the obſervation would be uſeleſs. But as theſe cotemporary obſervations cannot be always made, in the caſe of an aerial voyage, the beſt that can be done is to obſerve the barometer and thermometers, before the aeronaut aſcends, and then, comparing this obſervation with thoſe made in the atmoſphere, he may find his height very nearly.—If by means of ſignals, or by appointing the time, a perſon was to obſerve upon the earth, at the ſame time that an aeronaut obſerves in the atmoſphere, it would be much better.

I ſhall now proceed to deſcribe the method of eſtimating the height of one place above another, ſuppoſing that a barometer and two thermometers, viz. an attached and a detached one, are obſerved at the ſame time in each place.

RULE

RULE I. *For correcting the effect of expansion and contraction of the quickſilver in the barometers.*

A column of quickſilver, 30 inches high, is increaſed in length 0,0032 of an inch, by the effect of one degree of heat, according to Farenhei ts thermometer; and conſequently, every one of thoſe 30 inches is increaſed 0,0001067 of an inch by one degree of heat.

If the barometers to be corrected differ very little, as about one inch, or one inch and a half, from 30 inches height, multiply the quantity of expanſion for one degree of the thermometer (viz. 0,0032) by the difference of the two attached thermometers. Thus, if that difference is 3°, the product is 0,0096. Add the product to that barometer, the attached thermometer of which ſtands loweſt, and you have the equated heights of the barometers. If the barometers differ three or four inches, or more, from 30 inches height, then the effect of of expanſion occaſioned by one degree of heat, viz. 0,0032, on a column of 30 inches, ſhould be diminiſhed proportionably.

Now, the difference of the common logarithms (omitting their indexes) of the equated heights of the mercury in the two barometers, ſhews the firſt difference of altitude between the two places, in fathoms and thouſandth parts, obſerving to reckon the three right-hand figures as decimals *; which being multiplied by ſix, is reduced into feet, and decimals of a foot.

N. B. The logarithms to be uſed for this purpoſe muſt conſiſt of ſeven places of figures.

RULE II. *For correcting the effect of expanſion and contraction of the column of air between the upper and lower barometer.*

If the mean heat, ſhewn by the two detached thermometers, be 32°, no correction

* This is the ſame thing as to divide that difference by 1000.

is

is to be made; the height found before being the true anſwer. But if the mean heat be greater or leſs than 32°, then take the difference between it and 32°, and multiply that difference by 2,4 (viz. two and four tenths): multiply the height already found by the product of this multiplication; then divide this laſt product by 1000, and the quotient will be a number of feet and decimals of a foot, which muſt be added to the height already found, if the mean heat was greater than 32°, but if leſs, it muſt be ſubtracted from it; and thus you will have the required height or perpendicular diſtance between the two places.

EXAMPLE. Suppoſe it be required to find the height of a hill from the following obſervations.

			Attached Thermometers.	Detached Thermometers.
Barometer at the foot of a hill	29,988	Inches	65	63
Barometer at the top of the hill	28,974	Inches	62	57

Difference of attached thermometers, three degrees.

Equated

Equated barometers, according to rule the first $\left\{\begin{matrix}29,988\\28,9836\end{matrix}\right\}$ and their logarithms, without the indexes, $\left\{\begin{matrix}4769475\\4621493\end{matrix}\right\}$; the difference of which, divided by 1000, is 147,982, and being now multiplied by 6, gives the altitude of 887,892 feet: which must be corrected by the following operation:

Mean of the detached thermometers 60°: the difference between which and 32° is 28°, which, being multiplied by 2,4, gives 67,2.

Multiplying 887,892 by 67,2 (which is the product last found) and dividing the product by 1000, we have 59,6663424 for the second correction; which, added to the altitude found above (887,892) gives 947,558 feet for the required height of the hill.

Besides the barometer, the height of a balloon may be ascertained by other means, and especially by observing the angle which the

the horizon ſubtends at the eye of the aeronaut, by means of a ſextant or quadrant. Thus, ſuppoſe that ABCD, fig. 5, plate II. repreſents the earth, and F the place of the aeronaut, who obſerves the angle A F C, the half of which is E F C. But becauſe F E is perpendicular to the point B of the earth, it muſt paſs through the center E; and becauſe F C is a tangent, and E C a radius, E C F is a right angle, and conſequently all the three angles of the triangle F C E are known. But E C is equal to the ſemi-diameter of the earth, therefore by trigonometry the ſide F E may be found; from which take away B E, equal to the ſemi-diameter of the earth, and the remainder is F B, viz. the required height.

It ſhould be obſerved whether a teleſcope, that magnifies about 100 times, may be kept ſteady enough for obſerving celeſtial objects from the gallery or boat of an aeroſtatic machine, and whether it ſhews thoſe objects much clearer from a certain height above the earth, when the viſual ray muſt paſs through a leſs portion of the atmo-

ſphere.

ſphere. Perhaps Jupiter and Venus, or even ſome fixed ſtar, may be ſeen with the naked eye in the day-time.

The air at different heights ſhould be put in bottles, and its quality ſhould be afterwards aſcertained.

The electricity of the higheſt regions of the atmoſphere ſhould be attentively and repeatedly examined, in reſpect to its quality and intenſity; though it may be doubtful whether the electrometer will act at all, as the balloon ſtands inſulated.

It is very proper to examine whether the compaſs is ſubject to the ſame variations when high up in the atmoſphere, as when ſtanding on the earth. And now, on mentioning the compaſs, it is proper to obſerve, that when the aeronaut has loſt ſight of any particular object on the earth, he cannot diſcover which way he is going by the compaſs, becauſe he has no fixed point with which he may compare the direction of the magnetical needle; unleſs it

were

were to be found that one particular part of the aeroſtatic machine goes always before, which is not unlikely, and deſerves to be examined with attention.

The inclination of the magnetic needle, high up in the air—the formation of clouds, fogs, and rain—the decreaſe of gravity of bodies, by means of a ſpring weighing inſtrument—the propagation of ſounds—and innumerable other things, deſerve likewiſe to be attentively examined and aſcertained.

Laſtly, it will be proper to recommend to the aeronaut, whenever he ſets down any obſervation, to record at the ſame time the height of the barometer, time, temperature, and other cotemporary remarks; for, as thoſe obſervations are moſtly depending on each other, they would be uſeleſs by themſelves.

CHAPTER VII.

Uſes to which Aeroſtation may be applied.

IT can hardly be expected, that, in the preſent ſtate of the ſubject, all, or even a few of the uſes, to which the aeroſtatic machines may be applied, ſhould be precisely known, ſince the deciſive proof of experience has not yet been ſufficiently ſhewn. The moſt obvious uſes will eaſily occur to any perſon of the leaſt ingenuity; and to propoſe others, of a leſs apparent nature, can only ſerve to give ſome obſcure and perhaps ridiculous hints to future experimenters; I ſhall therefore make this laſt chapter of my work as ſhort as poſſible, contenting myſelf with a conciſe enumeration of a few of the uſes to which the aeroſtatic machines may be applied, eſpecially as they have been moſtly already hinted at in the preceding pages.

The

The ſmall balloons, eſpecially thoſe made of paper, and raiſed by means of the flame of ſpirits of wine, which are eaſily made and more eaſily elevated, may ſerve to explore the direction of the winds in the upper parts of the atmoſphere, particularly when there is a calm below: they may elevate into the atmoſphere a ſtring or wire, one extremity of which is on the earth, and by this means they may convey down the electricity of the atmoſphere: they may ſerve for ſignals, in various circumſtances, in which no other means can be uſed; and letters, or other ſmall things, may be eaſily ſent by them; as for inſtance, from ſhips that cannot ſafely land, on account of ſtorms, &c.—from beſieged places, iſlands, and the like.

The larger aeroſtatic machines may anſwer all the above-mentioned purpoſes in a better manner; and they may beſides be uſed as a help for a man who wants to aſcend a mountain, a precipice, or to croſs a river, &c.—and perhaps one of thoſe machines, tied to a boat by means of a long rope, may in ſome caſes be a better ſort of ſail than any that is uſed at preſent.

The largeſt ſort of machines, by which I mean thoſe which can take up one or more men, may be evidently ſubſervient to various œconomical and philoſophical uſes. Their conveying people from place to place with great ſwiftneſs, and without trouble, will be of eſſential uſe, even if the art of guiding them in a direction different from the wind is never diſcovered. By means of thoſe machines, the ſhape of certain ſeas and lands may be better aſcertained: men may aſcend to the tops of ſeveral mountains that were never viſited before; they may be carried over marſhy and dangerous grounds; they may by that means come out of a beſieged place, or an iſland; and they may, in hot climates, aſcend to a cold region of the atmoſphere, either to refreſh themſelves, or to obſerve the ice, which is never ſeen below; and, in ſhort, thus they may be eaſily taken to ſeveral places, to which human art knew of no conveyance before the diſcovery of the aeroſtatic machines.

The

The philosophical uses to which those machines may be subservient, are numerous indeed; and it may be sufficient to say, that hardly any thing of what passes in the atmosphere is known with precision, and that principally for want of a method of ascending into the atmosphere. The formation of rain, of thunder-storms, of vapours, hail, snow, and meteors in general, require to be attentively examined and ascertained. The action of the barometer, the refraction and temperature of the air in various regions, the descent of bodies, the propagation of sound, &c. are subjects which all require a long series of observations and experiments, the performance of which could never have been properly expected, before the discovery of those machines. We may therefore conclude, with a wish that the learned, and the encouragers of useful knowledge, may unanimously concur in endeavouring to promote the subject of aerostation, and to render it as useful as possible to mankind.

ADDITIONS AND CORRECTIONS.

TO the Hiſtorical Part ſhould be added:—That in France a large aeroſtatic machine, on the principle of rarefied air, was made by l'Abbé Miolan and Janinet, during the laſt ſummer. It was about 120 feet high, and nearly 90 in diameter; furniſhed with a gallery, and a kind of rudder to direct it.

In June, 1784, two eſſays were made with this machine, in the ſecond of which the machine ſhewed ſuch a power of aſcenſion, as to lift nine perſons, beſides other weight, from the ground; and would have actually eſcaped from the hands of many perſons that were employed to hold it, if the fire in it had not been diſcontinued. On the 11th of July, the weather being very hot, they endeavoured, in vain, to raiſe the machine; and after a good deal of fruitleſs work, whether by the fury of the diſappointed populace, or by ſome other accident, the machine was entirely deſtroyed.

To

To the Practical Part the following observations ſhould be added:—White vitriol is ſaid to be ſold much dearer than the vitriol of iron. If this is true, it will be a ſaving to make the inflammable air by means of zinc and vitriolic acid, rather than of this acid and iron; becauſe the ſale of the white vitriol, ariſing from the former, will, in a great meaſure, compenſate for the expence of the materials.

A very expeditious method of joining the pieces of a balloon made of varniſhed ſilk, was lately communicated to me by Mr. Blanchard. It is nothing more than laying about half an inch of the edge of one of the pieces flat over the edge of the other, and paſſing a hot iron over it; in doing which, a piece of paper ought to be laid both under and over the ſilk, ſo as to prevent the iron or the table from ſticking to the ſtuff. Thus the pieces are joined very firmly together; and the joining may be rendered even more ſecure by running it with a ſilk thread, and ſticking a riband over it. But it muſt be obſerved, that this ſort of joining will not do with thick ſilk, nor with every ſort of varniſh.

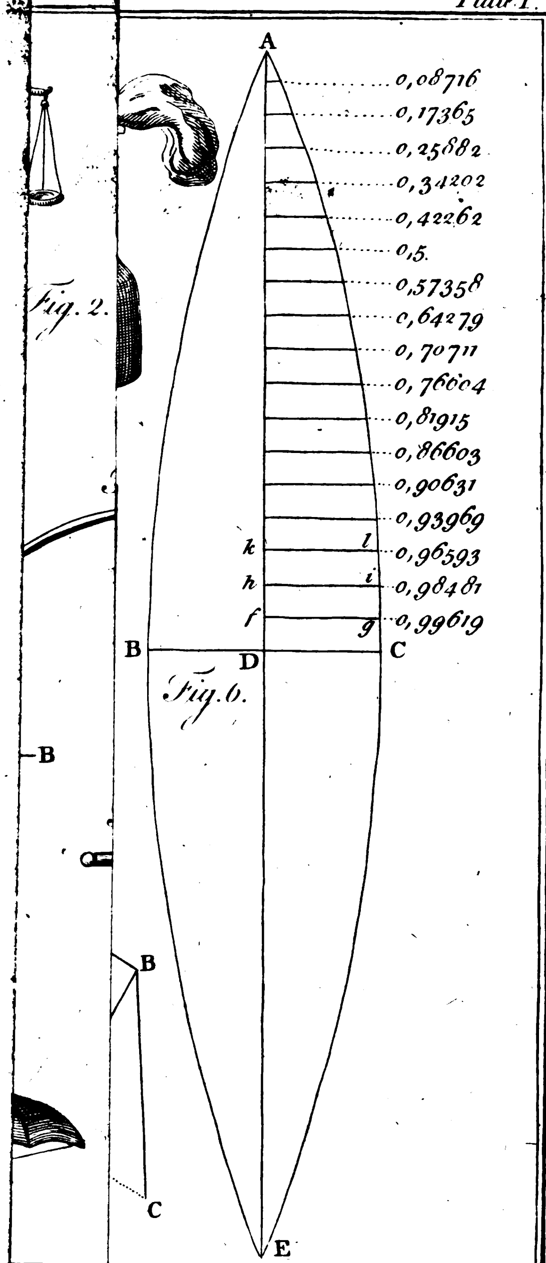
When ribands are required to be laid over the ſeams, (which is not only uſeful to prevent the eſcape of the inflammable air, but will likewiſe ſtrengthen the balloon) they may be ſtuck with common glue, provided the varniſh of the ſilk is properly dried. When the glue is quite dry, thoſe ribands ſhould be varniſhed over, in order to prevent their being unglued by the rain.

I am juſt informed, by Mr. Blanchard, of the following method of making elaſtic gum varniſh for the ſilk of a balloon:—Diſſolve elaſtic gum, cut ſmall, in 5 times its weight of ſpirits of turpentine, by keeping them ſome days together: then boil one ounce of this ſolution in 8 ounces of drying linſeed oil for a few minutes: laſtly, ſtrain it.—Uſe it rather warm.

ERRATA.

Page 43, line 5, *for* John *read* Joſeph.
Page 48, line 6, *for* John *read* Joſeph.

Plate I.



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0,90631
0,93969
k
l
0,96593
h
i
0,98481
f
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0,99619
B
D
C
E
Fig. 2.
B
B
C

Fig. 6.

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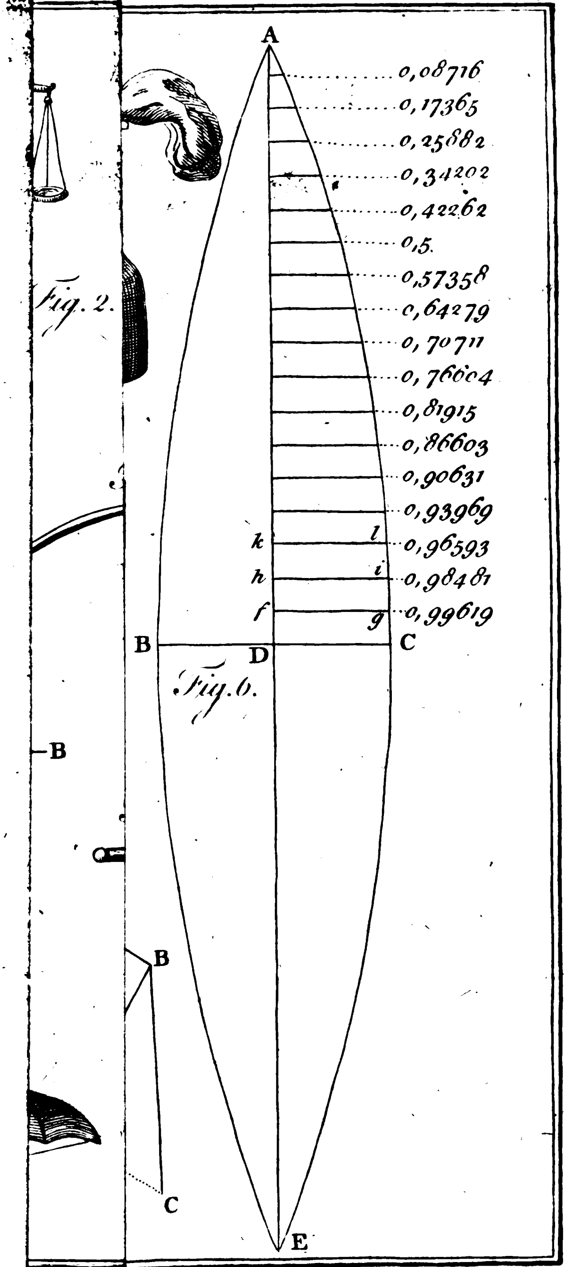

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Fig. 6.
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Fig. 2.
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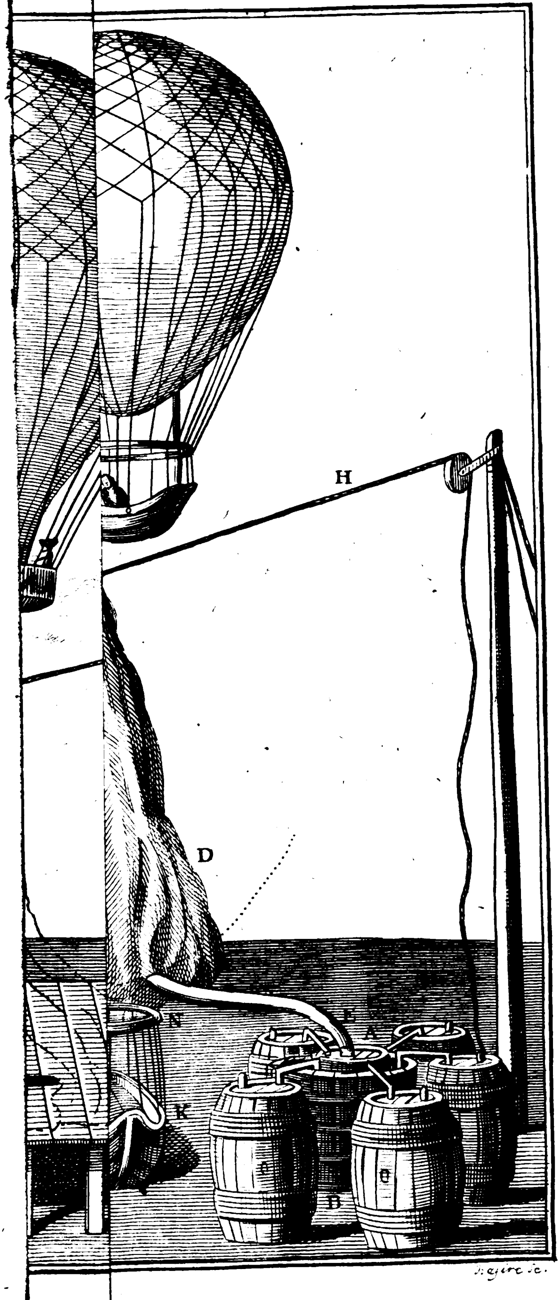
Plate II.



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Fuel

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