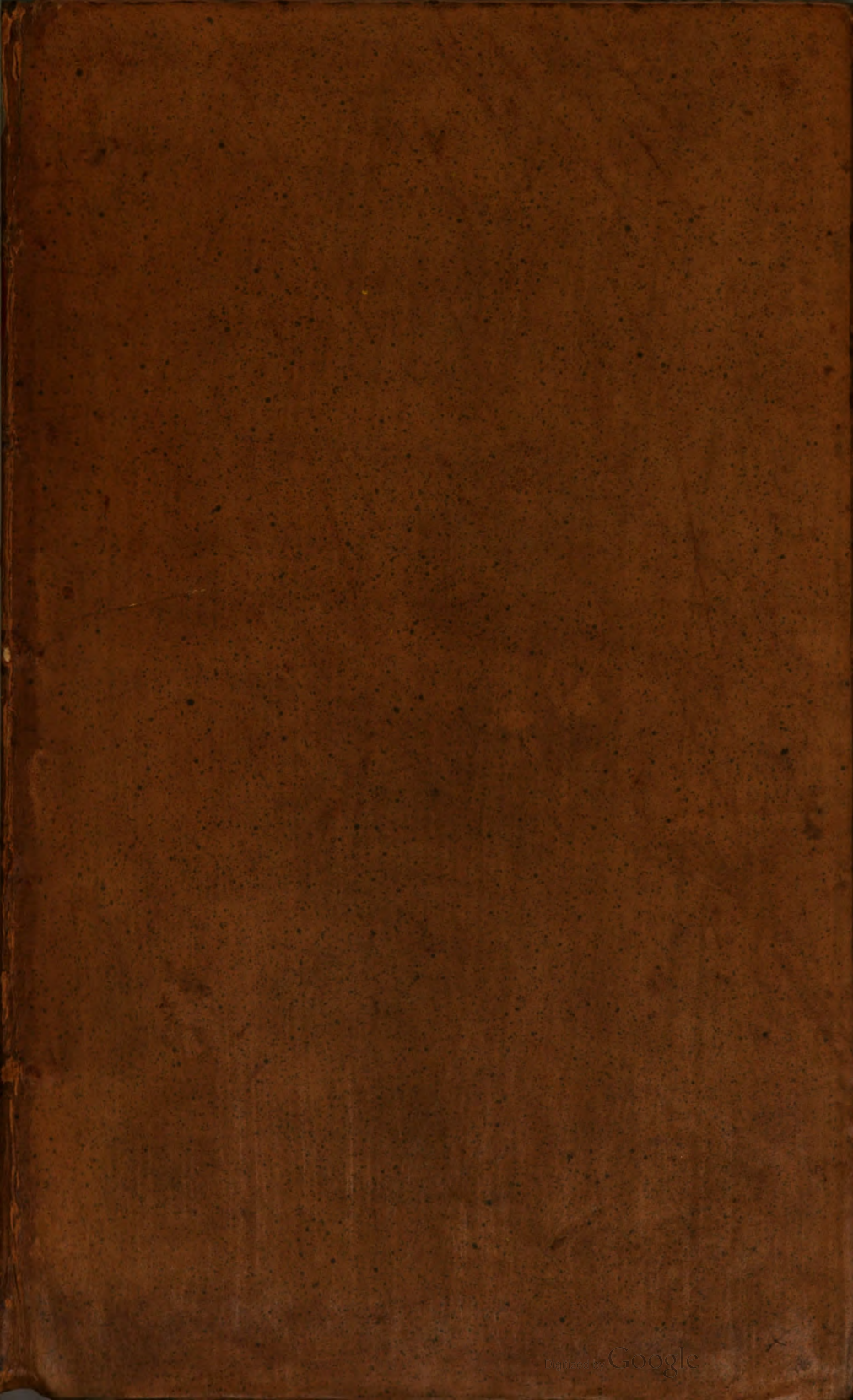

This is a reproduction of a library book that was digitized by Google as part of an ongoing effort to preserve the information in books and make it universally accessible.

Google™ books

<https://books.google.com>





B.S. 8:
C/160.

T H E
HISTORY AND PRACTICE
O F
AEROSTATION.

BY
TIBERIUS CAVALLO, F.R.S.

L O N D O N :

PRINTED FOR THE AUTHOR,
AND SOLD BY C. DILLY, IN THE POULTRY;
P. ELMSLY, IN THE STRAND;
AND J. STOCKDALE, IN PICCADILLY:

M.DCC.LXXXV.

5 0 7

P R E F A C E.

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 mathemati-
tical

P R E F A C E.

v

tical 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 Fahrenheit'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.

C O N-

C O N T E N T S.

P A R T I.

HISTORY OF AEROSTATION.

CHAP.

- I. *HISTORY of Aerostation, from the earliest tradition till the year 1783* page 1
- II. *Messrs. Montgolfier's discovery of the aerostatic machine, or rarefied-air balloon* 42
- III. *The invention of inflammable-air balloons* 51
- IV. *The introduction of small inflammable-air balloons; and Mr. Montgolfier's experiments before the Royal Family, and the Commissaries of the Academy* 62
- V. *Aerostatic experiments in which men first ventured to ascend into the atmosphere with an aerostatic machine* 72
- VI. *Account*

CONTENTS,

vii

CHAP.	page
VI. <i>Account of the first aerial voyage</i>	83
VII. <i>Account of the first aerostatic experiment made in England</i>	92
VIII. <i>Account of the first aerial voyage made with an inflammable-air balloon</i>	95
IX. <i>Aerostatic experiments made in the remainder of the year 1783</i>	108
X. <i>Aerostatic experiments made in January 1784</i>	113
XI. <i>Aerostatic experiments made in February and March 1784</i>	122
XII. <i>Aerostatic experiments made in the months of April, May, June, and July, 1784</i>	137
XIII. <i>Aerostatic experiments made in August and September, 1784; containing the first aerial voyage made in England</i>	155
XIV. <i>Aerostatic experiments made in the remainder of the year 1784</i>	170
XV. <i>Aerostatic experiments made in the beginning of the year 1785</i>	179
XVI. <i>General remarks on the preceding History</i>	188

PART

PART II.

PRACTICE OF AEROSTATION.

CHAP.	page
I. <i>General principles of aerostation</i>	207
II. <i>Of inflammable air</i>	215
III. <i>Of the shape, capacity, construction, and power of aerostatic machines</i>	238
IV. <i>Of the various means, either used or proposed, for raising higher, or lowering, the aerostatic machines, and likewise for directing them</i>	283
V. <i>Manner of filling large aerostatic machines exemplified</i>	298
VI. <i>Experiments and observations proper to be made in the course of an aerial voyage</i>	310
VII. <i>Uses to which Aerostation may be applied</i>	320
ADDITIONS and CORRECTIONS	324
INDEX.	

PART

2 HISTORY of AEROSTATION.

rable others, are instances of this observation; but authentic history furnishes very scanty materials concerning any real success having ever attended the attempts of this sort.

With some it is a question, whether those allegorical passages are merely the produce of the imagination, ever fond of raising itself into the pure and unincumbered regions above the surface of the earth; or whether they indicate the real existence of the art of flying amongst men in ages preceding history, but afterwards lost. And indeed, whilst we were unacquainted with any means, by which a man might elevate himself into the atmosphere, and the constant failure of often-repeated experiments had rendered proverbial the vanity of the attempt, we might have easily been induced to believe the first part of the question; but now, that men in almost every nation of Europe, by having actually raised themselves into the air, and having navigated through it with safety and pleasure, have shewn the possibility,

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 attach-

4 HISTORY of AEROSTATION.

ing 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 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 appearance 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 præsentē fecit. Sacerdotes illum in humeros sublatum ferebant: ille verò, iis inferiùs in terra relictis, solus in aëre ferebatur. Lucian. de Syria Dea.

6 HISTORY of AEROSTATION.

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. " Archytas," says the passage, " philosopher of Taranto, constructed a wooden pigeon, 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.

8 HISTORY of AEROSTATION.

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

HISTORY of AEROSTATION. 9

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 enterprize. 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. Mannasse,

ing,

ing, or rather descanting on the power of art and nature, says, "There may be made some flying instruments, so that a man sitting in the middle of the instrument, and turning some mechanism, may put in motion some artificial wings, which may beat the air, like a bird flying." And in the next page he says, "There is certainly a flying instrument, not that I ever knew a man that had seen it, but I am particularly acquainted with the ingenious person who contrived it*."

These passages have induced several persons to consider 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 dissertations have been written expressly on the subject; projects of teaching children to fly gradually from their infancy, have been proposed, and various schemes of artificial wings have

* De Mirabili Potestate 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

12 HISTORY of AEROSTATION.

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 constum,*
 “ &c.

14 HISTORY of AEROSTATION.

“ &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
 C “ strong

18 HISTORY of AEROSTATION.

“ 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 premeffe all' arte maestra*. Brescia, 1670.

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 physique & 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 peti-

24 HISTORY *of* AEROSTATION.

tioner represents his having invented a flying machine, capable of carrying passengers, and of navigating through the air very swiftly; and he requests the privilege of being the sole possessor of such machine, prohibiting any other person to construct a machine of the like nature, under some penalty, &c. In consequence of which petition, the king was pleased to grant the following order :

“ Agreeably to the advice of my council,
“ I order the pain of death against the
“ transgressor. In order to encourage the
“ suppliant to apply himself with zeal
“ towards improving the new machine,
“ which is capable of producing the effects
“ mentioned by him, I grant unto him
“ the first vacant place in my college of
“ Barcelos or Santarem, and the first pro-
“ fessorship of mathematics in my Uni-
“ versity of Coimbra, with the annual
“ pension of 600,000 reis, during his life.
“ Lisbon, the 17th of April, 1709.

The description and drawing of this in-
tended

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 above-mentioned 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

26 HISTORY of AEROSTATION.

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

28 HISTORY of AEROSTATION.

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 equilibrium; 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-

* Aristotele de Cælo. "In sua enim regione omnia gravitatem habent præter ignem, aër ipse; figurum 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

30 HISTORY of AEROSTATION.

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 $\frac{3}{1000}$ 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 con-
 tained 80 measures of inflammable air.

“peared

32 HISTORY *of* AEROSTATION.

“ peared in the Philosophical Transactions
“ for the year 1766. It had been my
“ constant practice before, to shew, 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. Cavendish made a variety of
“ such mixtures by rule and measure, and
“ describes in the same paper the manner in
“ which they severally explode. As soon as
“ I read the above paper, it occurred to me,
“ as an obvious consequence of Mr. Caven-
“ dish’s discovery, that if a sufficiently thin
“ and light bladder were filled with inflam-
“ mable air, the bladder, and air in it, would
“ necessarily form a mass lighter than the
“ same bulk of atmospheric air, and which
“ would rise in it; this I mentioned to
“ some of my friends, and in my lectures,
“ the next time I had occasion to speak of
“ inflammable air, which was either in
“ the year 1767 or 1768; and, as I thought
“ it would be an amusing experiment for
“ the students, I applied to Dr. Monro’
“ dissector, 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 inter-
 “ rupt the business then going on; so I
 “ dropped the experiment for that year,
 “ and in the subsequent years I only men-
 “ tioned 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 attempt-
 ed 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 as-
 cend into the atmosphere, had occurred to
 me when I first began to study the subject

D

of

34 HISTORY of AEROSTATION.

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

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-

38 HISTORY of AEROSTATION.

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 (Windfor 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

40 HISTORY of AEROSTATION.

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

42 HISTORY of AEROSTATION.

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

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

44 HISTORY of AEROSTATION.

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 aërostat 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 à l'Académie 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 literary

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 aërostat ascended with an accelerated motion into the atmosphere; so that in about ten minutes time it had reached the height

48. HISTORY *of* AEROSTATION,

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.

IT

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 com-

E

mon

mon 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 Guinès, the Counts de Polatron 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.

CHAP-

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

52 HISTORY of AEROSTATION.

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 effervescence produced a great degree of heat, which being communicated to the stop-cock, and to the

E 4

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

58 HISTORY of AEROSTATION.

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.

On

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 crowded 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

60 HISTORY of AEROSTATION.

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 lively 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 crowded 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 *Gonessé*, 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;

64 HISTORY of AEROSTATION.

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.

Mr.

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, Briffon, 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

F

by

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 prismatic,

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 spheroidal. 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 pullics, 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. It

HISTORY of AEROSTATION. 69

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 aërostat 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 as-

cended, 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 Vaucreffon, 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

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
air,

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,

74 HISTORY of AEROSTATION.

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,
with

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 aërostat 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;

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
to

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 aërostat 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 aërostation.

After this, the machine was raised again with two persons in its gallery, Mr. Pilatre de Rozier, and Mr. Girond de Vilette; the latter of whom was therefore the second aërostatic 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 aërostatic 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. Vilette, and the aërostat 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 Commissioners of the Academy of Sciences, that learned and respectable body ordered, 1st. That the said report should be printed and
G
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 $6\frac{1}{2}$ 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 advertifement 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,

G 2

which

84 HISTORY of AEROSTATION.

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 aërostat 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 aërostat was replaced on the scaffold, and was repaired in less than two hours*. They

* This was the same aërostat, 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 cur-

rent 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 Mulette*. Astonished, I gave a look to
 “ the direction of the river. - - Mr. Pilatre
 “ then said, *Behold, there is the river, and*
 “ *observe*

“ 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 *Cygnés*, 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 sponge, 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

90 HISTORY of AEROSTATION.

“ 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 sponge 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
 “ surpris'd 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 Zambecari, an ingenious Italian, who happened to be in London,

94 HISTORY of AEROSTATION.

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 Suffex, 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

H

the

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 crowded 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.

ple. 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 Fahrenheit'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
 “ filken 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 descended. For seven or
 “ eight minutes I had ceased to ascend; the
 “ condensation of the internal inflammable
 “ air rather made me descend. I now re-
 “ collected my promise to return in half
 “ an hour, and, pulling the string of the
 “ valve, I came down. The globe was
 “ now so much emptied, that it appeared
 “ only an half globe. I perceived a fine
 “ ploughed field near the wood of *Tour du*
 “ *Lay*, and hastened my descent. When
 “ I was between 20 and 30 toises from the
 “ earth, I threw out hastily two or three
 “ pounds of ballast, and became for a mo-
 “ ment stationary, till I descended gently
 “ in the field, above a league from the
 “ place whence I set 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 aerostatic machine, that
 “ I might have kept in the air at least 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.

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.

I

On

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 ma-

nagement 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 surprizing 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

I 3

pretty

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

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 Fleffelles, 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 pro-

duced 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

the Marechauffée, 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.

C H A P-

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 *Bafville*, 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 aërostat 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 ailes 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 in-

effectual 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 opposite currents of air : on which he threw 4 pounds of ballast out of the boat, and ascending higher, met with that current of air in which he had gone at first, and which carried him very rapidly again across the river. Here he was obliged to throw out more ballast, by which means the voyage was prolonged as far as the plain of *Billancourt*, near *Seve*, where he descended at 35 minutes past one o'clock, after having been in the atmosphere an hour and a quarter ; during which time he had experienced heat, cold, hunger, and an excessive drowsiness. On his return to the earth, he was welcomed by many thousands of people, who had watched his progress 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 *.

On

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

The altitude of Mr. Blanchard's balloon, seen from

K 3

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 $16^{\circ} 30'$, 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 $48^{\circ} 25'$.

At 2 minutes past one, the altitude was $51^{\circ} 41'$.

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.

ment,

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 Sauffure mentions his having made some experiments on the atmospheric 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 Eng-

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,

C H A P-

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

138 HISTORY of AEROSTATION.

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 *Mâret*, 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
2 buildings

buildings of Paris, where it remained confined by ropes for a considerable time. Those 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 direktion 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 *Description 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, fireplace, &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.

On

On the 23d of June, a large aérostat, 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

L

sight

fight 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

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-

I west.

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 *Puiffanval*, 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 waisted 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

L 4

from

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 indif-
“ 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 succes-
“ five 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.”

C H A P-

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 re-ascending he threw out some ballast, it

M

seems

seems more natural to suspect, that his descent was occasioned by the loss of inflammable air, since, if he had descended by the action of the oar, he would have ascended 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 descend; 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 aërostation, 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, $46\frac{1}{2}$ feet long, and $27\frac{1}{2}$ 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

site 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-
 M 4 “-ingly

“ 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 remain-
 ing in the boat. The way they had tra-
 velled 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 Rumsley, 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
 7 helm,

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

176 HISTORY of AEROSTATION.

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,

HISTORY of AEROSTATION. 177

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

N

the

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,

HISTORY of AEROSTATION. 179

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 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
2 parcel

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 enterprize, 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
 very

very considerable effect; for if we suppose, that the air over the land was colder than that over the sea, the balloon coming from the latter into the former, continued to be hotter than the circumambient air for some time after; and, consequently, it was comparatively much lighter when in the cold air over the land, than when in the hotter air over the sea; hence it floated easier in the former than in the latter case.

CHAPTER XVI.

General Remarks on the preceding History.

THE art of navigating through the air, sought after from time immemorial, has been discovered, and so far improved, within these two years, that above 40 different persons have performed the experiment, and not a single instance is known of any person having lost his life in the attempt;

tempt; and, excepting two or three, who have been hurt in consequence of accidents, owing, not to the principle of the invention, but rather to the want of proper judgment, all have unanimously testified the safety, ease, and beauty of the experiment: and it is very remarkable, that no man or woman, who ascended into the atmosphere by this new-invented means, experienced any sickness or giddiness, such as is generally the consequence, at first, of ascending high buildings, or of going in a boat on water. It is justly questioned whether the first forty persons, who trusted themselves to the sea in boats, escaped so safe.

The method, far from being complicated or troublesome, is perhaps as simple as might have been wished by the warmest imagination; and so easy for the aeronaut, that he has absolutely much less trouble with his machine, than a sailor with a ship in the most favourable circumstances. 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

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 aërostation 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
in

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,

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.

O

has

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.

As

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

O 2

three

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 im-

HISTORY of AEROSTATION. 197

partial and discerning people. Thus mankind, by these acts of admiration, of satisfaction, and generosity, has shewn and confirmed its approbation of the discovery. The vicissitudes of human affairs, may at times retard or accelerate the use and improvement of aerostatic machines; but the interest and curiosity of man will doubtless for ever retain the knowledge of the subject—a subject infantile indeed, but endowed with manly features.

It has been often discussed, whether the preference should be given to the inflammable-air machines, or to those raised by means of hot air. Each of them has its peculiar advantages and disadvantages; a just consideration of which seems to decide in favour of those 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 so expensive materials—and the combustibles necessary to fill them being found almost every where; so that when the provision of fuel is exhausted,

198 HISTORY of AEROSTATION.

hausted, 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

is

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 conductor

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 colipile: 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,

206 HISTORY *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 Aeroftation.

THE whole earth, together with all the bodies that are upon it, is furrounded by an invifible fluid called air; which has weight, and alfo elasticity, viz. may be eafily compressed. Invert a common wine glafs, and, in that inverted fituation, let it down into a bafon of water; and it will be found that the water cannot enter within the glafs. That fubftance, 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 quantity

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,

P

and

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

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.

If it be asked, Why does not the hot air escape out of its aperture? 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.

CHAPTER II.

Of Inflammable Air.

INFLAMMABLE air is a permanent-ly 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,

P 4

a vessel

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 caught 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 caught, 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 aërostation, 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 $4\frac{1}{2}$ ounces of iron.

iron. Zinc yields less inflammable air than iron; one cubic foot of the gas being produced by about six ounces of zinc. If the vitriolic acid is of the strongest sort, that is generally sold in large quantities, an equal weight of it is required to dissolve iron or zinc, and must be diluted with five times its weight of water; so 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 sudden effervescence is required, it may be said that $4\frac{1}{2}$ ounces of iron, the like weight of oil of vitriol, and five times that weight, viz. $22\frac{1}{2}$ ounces, of water, are required in order to produce one cubic foot of inflammable air. And about the same quantity of gas is produced by six ounces of zinc, an equal weight of oil of vitriol, and 30 ounces of water.

A considerable degree of heat is produced by the effervescence that generates inflammable air, which is greater when the effervescence is more rapid, and contrarywise. In order to prevent this heat, in great measure,

sure,

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

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 represented 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 effervescence, and a production of inflammable 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, likewise 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 consequently 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.

Q

For

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 basin 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.

230 PRACTICE of AEROSTATION.

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 CD, 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

PRACTICE of AEROSTATION. 231

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 - - -	$\frac{1}{2}$
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

Q 4 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

234 PRACTICE *of* AEROSTATION.

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 fix, 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.

236 PRACTICE of AEROSTATION.

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
9 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

240 PRACTICE *of* AEROSTATION.

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 containing

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

R

first

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.

R 3

N. B. If

246 PRACTICE of AEROSTATION.

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 ;

PRACTICE of AEROSTATION. 247

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

R 4

13

248 PRACTICE of AEROSTATION.

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 filk as weighs two ounces a square foot, the weight of the whole envelope will be 45396 ounces, or 2837½ pounds.

PROB.

250 PRACTICE of AEROSTATION.

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

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

252 PRACTICE of AEROSTATION.

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.

P R O B.

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

254 PRACTICE of AEROSTATION.

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

256 PRACTICE of AEROSTATION.

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.

S

First,

258 PRACTICE of AEROSTATION.

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

2

length

length of DC 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, ABD, EBD, EDG, they may be easily described by applying a piece of paper equal to ADC 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 AD equal to 15,7 feet, and DE 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 DC, and like-

S 2

wise

wise of BD ; so that BC is equal to 5,236 feet. Then, having divided the line AD 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 bi ; 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

262 PRACTICE *of* AEROSTATION,
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

264 PRACTICE *of* AEROSTATION.

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—pliability—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 elastic 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,

266 PRACTICE of AEROSTATION.

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

268 PRACTICE of AEROSTATION.

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

“ After it has rested for 24 hours, and
“ the sediment is gone to the bottom, de-
“ cant it into another pot; and when you
“ want to use it, warm it, and apply it
“ with a flat brush upon the silk stuff
“ whilst that is kept well stretched. One
“ coat of it may be sufficient; but if two,
“ it will be proper to give one on each
“ side of the silk, and to let them dry
“ in the open air whilst the silk remains
“ extended.”

The following is my method: — In order to render linseed-oil drying, boil it, with two ounces of *faccarum saturni*, and three ounces of litharge, for every pint of oil, till the oil has dissolved them, which will be accomplished 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

PRACTICE *of* AEROSTATION. 271

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 spheroidal 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

T

machines

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

276 PRACTICE of AEROSTATION.

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

T 3

plate

plate I, where ABCD is one piece of silk, EFG 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 AB, has a hole CD, 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 CD, so that it must be about two inches larger in diameter than the hole. It is fastened to the leather of the plate AB, 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 Zambecari, 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 atmosphere,

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

PRACTICE of AEROSTATION. 287

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 envelope 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

288 PRACTICE *of* AEROSTATION.

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

U water,

water, being left upon the surface of that fluid, descends a few inches, it will continue to descend as far as the bottom; and if a piece of wood, or other substance, lighter than water, rises a few inches above the bottom of a vessel full of water, it will continue to rise as far as the surface of the water. But a balloon which could be just made to descend 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 descend lower and lower, because, if the air at 1000 feet height is too rare to support it, the air at the height of 900 yards is just sufficiently dense to keep it up, the air at 800 yards is more dense than sufficient to support it, and so on: the contrary may be said of the balloon's ascension. Hence it appears, that if the action of the wings is hardly capable of causing it to descend or ascend a few feet, it must be much less capable of lowering or raising it through a greater distance.

The means proposed for directing the aerostatic 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,

U 2

What

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.

I

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 Defagulier'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. ADCB 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 Zambecari, 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

U 4

by

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 compound direction, and at the end of that given time it would be found at D, having percurr'd 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, HI, KL, 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

300 PRACTICE *of* AEROSTATION.

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 pulleys 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

10

three

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 CDF; and, having expelled all the common air from it, fasten its silk tubes round the tin tubes E, E*; then put the just pro-
 portion

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

X

the

306 PRACTICE *of* AEROSTATION.

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.

I

lateral

lateral ropes are flipped 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 $562\frac{1}{2}$ pounds weight; from which the weight of the

X 2

envelope,

308 PRACTICE *of* AEROSTATION.

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

312 PRACTICE *of* AEROSTATION.

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 Farenheits 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

314 PRACTICE of AEROSTATION.

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

PRACTICE of AEROSTATION. 315

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		62	57

Difference of attached thermometers,
three degrees.

Equated

316 PRACTICE of AEROSTATION.

Equated barometers, according to rule the first $\left\{ \begin{array}{l} 29,988 \\ 28,9836 \end{array} \right\}$ and their logarithms, without the indexes, $\left\{ \begin{array}{l} 4769475 \\ 4621493 \end{array} \right\}$; 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 $AF C$, the half of which is $EF C$. But because FE is perpendicular to the point B of the earth, it must pass through the center E ; and because FC is a tangent, and EC a radius, ECF is a right angle, and consequently all the three angles of the triangle FCE are known. But EC is equal to the semi-diameter of the earth, therefore by trigonometry the side FE may be found; from which take away BE , equal to the semi-diameter of the earth, and the remainder is FB , 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 atmosphere.

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

Y

rope,

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 æconomical 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 aërostation, 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

326 ADDITIONS *and* CORRECTIONS.

fort of joining will not do with thick silk, nor with every sort of varnish.

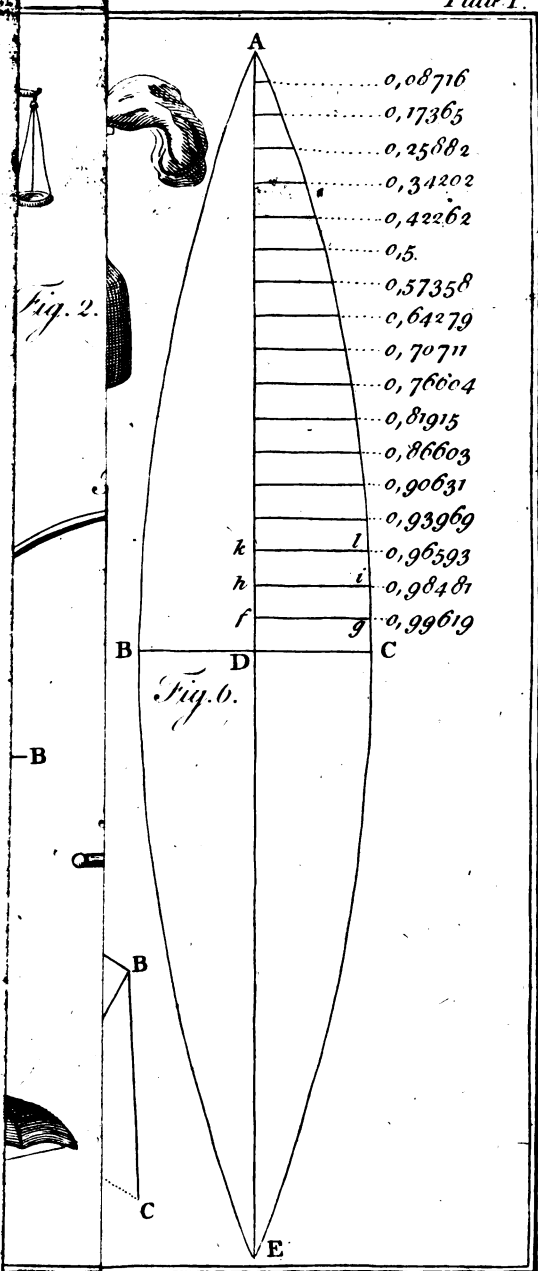
When ribands are required to be laid over the seams, (which is not only useful to prevent the escape of the inflammable air, but will likewise strengthen the balloon) they may be stuck with common glue, provided the varnish of the silk is properly dried. When the glue is quite dry, those ribands should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



326 ADDITIONS *and* CORRECTIONS.

sort of joining will not do with thick silk, nor with every sort of varnish.

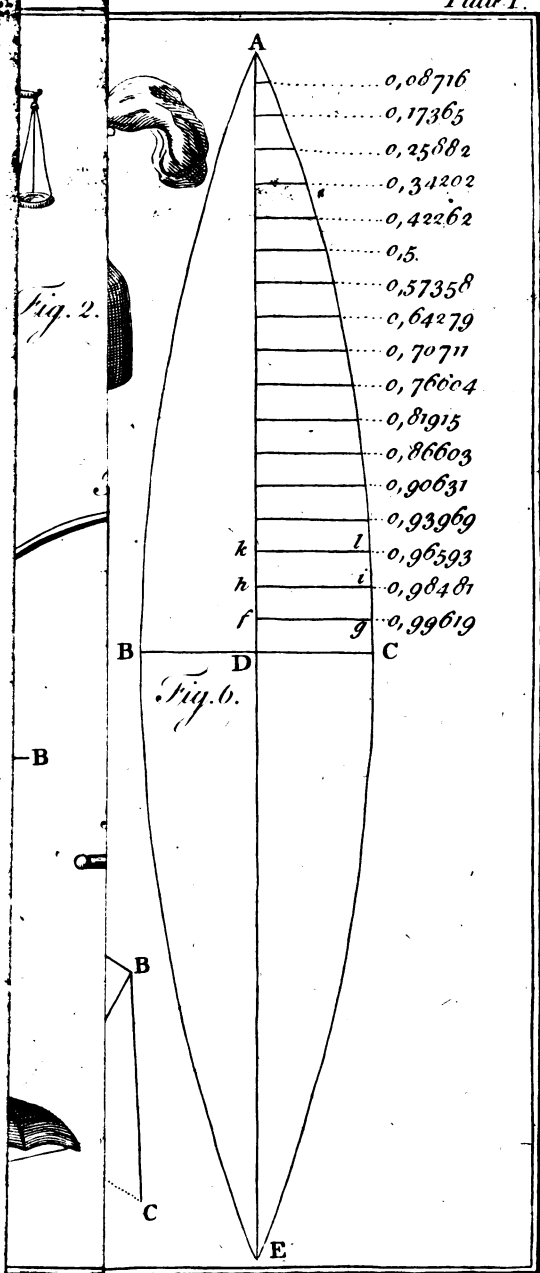
When ribands are required to be laid over the seams, (which is not only useful to prevent the escape of the inflammable air, but will likewise strengthen the balloon) they may be stuck with common glue, provided the varnish of the silk is properly dried. When the glue is quite dry, those ribands should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

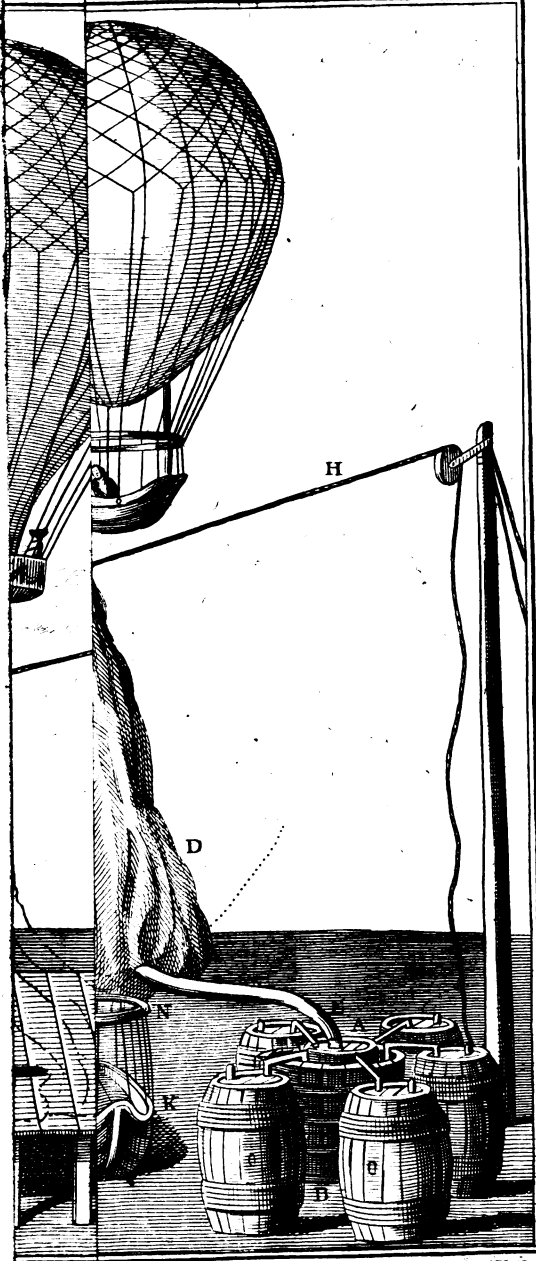
I am just informed, by Mr. Blanchard, of the following method of making elastic gum varnish for the silk of a balloon:— Dissolve elastic gum, cut small, in 5 times its weight of spirits of turpentine, by keeping them some days together: then boil one ounce of this solution in 8 ounces of drying linseed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





I N D E X.

ACCIDENTS happened in ascending with
aerostatic machines, 146, 151.

Aerial voyage, see *Voyage*.

Aeronauts honoured, 196.

Aerostatic experiment attempted, 34.—first made,
43.—first in England, 93.—first at Turin,
109.

Aerostatic machine, discovery of, 43.—what,
211.—first publicly exhibited, 46.—with in-
flammable air, attempted, 34.—first made,
51.—more safe to abandon it to the air, 81.—
seldom becalmed, 193.—of what sort pre-
ferable, 197.—methods of directing the,
205.—which shape is preferable, 238.—
first that crossed the Channel, 123.—first
launched in England, 93.—first launched
at Oxford, 128.—small ones become com-
mon in England, 135.—remarkable ex-
periment with one, 140, 152.—construc-
tion of, 238.—construction of small ones,
271.—construction of large ones, 273.—pro-
per shape of, 239.—proper stuff for the en-
velope of, 241.—problems for the construc-
tion, &c. of, 245.

Y 4

Aerostation

I N D E X.

Aerostation compared with navigation, 191, 193.—comprehensive view of, 194.—general principles of, 207.

Air, common, its weight and elasticity, 28, 29, 207.—how much rarefied in aerostatic machines, 128, 302.—of the upper regions, found to be purer, 156.—its bulk increased by heat, 200.—shewn to be lighter when rarefied, 28, 211.

Animals first sent up with an aerostatic machine, 70.—do not suffer any great inconvenience in an aerial voyage, 72, 115, 188.

Apparatus for filling aerostatic machines, 298, 364.

Archytas, his wooden pigeon, 5.

Articles necessary for an aeronaut, 308.

Ascent and descent of a balloon, how known, 310.—projects to effect it, 283.

Atmosphere is of various densities, 213, 289.—its weight changeable, 214.

Bacon, Roger, his passage relative to flying, 9.

Ballast proper for a balloon, 288.

Balloon, see *Aerostatic* machine.

Barometer, its use and motion, 214.—indicates the ascent and descent of a balloon, 310.—determines the height, 311.

Bartholomew Laurence, his petition to the King of Portugal, 23.

Besnier, his wings, 20.

Black, Dr. his project for making an inflammable-air balloon, 31.

Bladders,

I N D E X.

Bladders, too heavy for air-balloons, 36.—useful for the production of inflammable air, &c. 222, 264.

Blanchard, his flying scheme ineffectual, 129.—his first aerial voyage, 148.—his second aerial voyage, 139.—his third aerial voyage, 148.—his fourth aerial voyage, 170.—his fifth aerial voyage, 177.—his sixth aerial voyage, in which he crosses the Channel, 180.—his method of joining the pieces of a balloon, 325.

Boats for a balloon, 281.

Borelli, his thoughts on the subject of flying, 4.

Boulton's experiment with the explosive balloon, 152.

Buono, Candido, his experiment, which shews that air becomes lighter when heated, 28.

Capacities of balloons, how determined, 246.—table of, 247.

Cavallo, his project of making inflammable-air balloons, 33, 34, 40.

Channel, English, first crossed by an aerostatic machine. 123.—first aerial voyage over the, 180.

Chartres, Duke of, his aerial voyage, 144.

Dante, John Baptist, his wings, 19.

Electricity of the atmosphere brought down by means of aerostatic machines, 110, 135, 202, 321.—deserves to be examined, 318.

Experiments proper to be made in an aerial voyage, 310.

Fuel

I N D E X.

Fuel proper for a balloon, 272, 301.

Filling of aerostatic machines, 272, 298.

Fire-place for a balloon, 275.

Gallery for a balloon, 275.

Gusman, story relating to him, 26.

Height above the surface of the earth, greatest attained by aerostatic machines, 201.—ascertained by means of the barometer, 311.—ascertained by trigonometry, 317.

Helm for a balloon, 297.

Inflammable air, its existence, 30.—what, 212, 215.—its specific gravity, 30, 313, 221, 233.—used for soap-balls, lighter than common air, 34, 37.—first used for balloons, 51.—specific gravity of that used by Charles and Roberts, 99.—how produced, 215, 216.—quantity of produced from iron, 219, 220.—quantity produced from zinc, 220.—quantity produced from coal, 233.—other permanently elastic fluids generated with it, 222.—apparatus for the production of, 225, 226, 304.—to pass it through water, 226, 304.—produced by the action of fire, 227.—remarkable circumstance attending its production, 235.

Inflammable-air balloons, what, 213.—whether likely to be damaged by lightning, 202.—see *Aerostatic* machines.

Lana,

I N D E X:

Lana, Francis, his flying project, 20. A

Means proposed for directing balloons, 290. A

Montgolfier, his discovery of the aerostatic machine, 43.—short account of the two brothers, 49.—their receiving the annual prize from the Academy, 82.—experiment made by him at Lyons, 82.

Muette, la, aerostatic experiment made at, 83.

Net for a balloon, 282.

Observations, remarkable, 140, 183, 186.—general on the history, 188.—proper to be made in an aerial voyage, 310, 317, 318, 319.

Oars, see *Wings*.

Pattern for the pieces of a balloon, 256.

Pieces for a balloon, pattern of the, 256.—how cut, 257.—joined, 260, 325.

Pigeon, flying, 5.—Mr. Blanchard's, 173.

Pilatre de Rozier first ascended with an aerostatic machine, 74, 76.—his name given to a place, 144.

Power of aerostatic machines, 302, 307.

Premium offered by the Academy of Lyons, 112.

Preparation of the stuff for a balloon, 261.

Problems for the construction, &c. of balloons, 245.—for determining the height by the barometer, 311.

Regiomontanus,

I N D E X.

Regiomontanus, his flying eagle, 11.—his flying iron fly, 11.

Ribands laid over the seams of a balloon, 326.

Roger Bacon, see *Bacon*.

Ropes to steady the balloons, 300, 305.

Rozier, see *Pilatre*.

Soap-balls lighter than common air, 34.—method of making them, 37.

Surfaces of balloons determined, 245.—table of, 247.—do not increase in proportion to the capacities, 22, 238.

Tibbe, Madame, the first woman that made an aerial voyage, 142.

Valve for a balloon, 278.

Varnish for a balloon, 263.—required properties of, 265.—of elastic gum, 265, 326.—of bird-lime, 267.—how used, 270, 326.

Voyage, aerial, the first, 83.—the first with an inflammable-air balloon, 95.—at Lyons, 118.—Andreani's first at Milan, 124.—Andreani's second, 134.—Blanchard's, see *Blanchard*.—at Dijon, 137.—at Marseilles, 138.—at Strasburg, 138.—Maret and Bremond's second, 140.—at Aix, 141.—first made by a woman at Lyons, 142.—at Dijon, second, 142.—at Nantes, 142.—at Bourdeaux, 143.—at Versailles, in presence of the King of Sweden, 144.—the Duke de Chartres's, 144.—at Bourdeaux, second, 151.—at Rodez, 155.—at Nantes, second, 157.—first in England,

I N D E X.

land, 157.—the longest, 164.—Sadler's, at Oxford, 176. —Harper's, at Birmingham, 179.—first over the sea, 180.

Uses to which the aerostatic machines may be applied, 320.

White vitriol is sold dearer than the vitriol of iron, 325.

Wilkins, Bishop, his passages relative to the art of flying, 12.

Wings, or oars, their power, 168, 289, 293, 296.—of different shape, 294.

F I N I S.

Works published by the same Author.

A TREATISE ON ELECTRICITY, in THEORY and PRACTICE, with original Experiments. Octavo, with Plates. Second Edition.

An ESSAY on the THEORY and PRACTICE of MEDICAL ELECTRICITY. Octavo, with a Plate. Second Edition.

A TREATISE on the NATURE and PROPERTIES of AIR, and other permanently Elastic Fluids; to which is prefixed, an Introduction to Chymistry. Quarto, with Plates.

