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L'invenzione di Quirico Filopanti:

Theory of Air-ships
(Teoria del dirigibile)

Trascrizione del manoscritto e di articoli apparsi su alcuni giornali Americani nel 1851

a cura di Pier Gabriele Molari

La nave aerea (Air-ship)

Notizia sul Daily Tribune: New-York 27/1/1851
Manoscritto: Theory of Airships

Si tratta del primo studio sistematico di un dirigibile mosso da una macchina a vapore, adatto ad essere impiegato nei luoghi che non possono essere raggiunti né da ferrovie né da navi a vapore.

Dopo una introduzione, che fa il punto dello stato dell'arte e che sfata i pregiudizi, il lavoro tratta la convenienza nell'impiegare un sistema galleggiante nell'aria, la forma più adatta della nave aerea, la necessità di avere grandi dimensioni, la potenza da impiegare per il movimento etc.

Il lavoro viene presentato al Medical College di New-York il 24 gennaio 1851. Il Daily Tribune ne dà notizia il 27 gennaio 1851

Filopanti pensa di poter trasportare, senza impianti fissi e a bassi costi, un elevato numero di persone da una costa all'altra degli Stati Uniti. Vede infatti gli europei addensati sulla costa est e vede il grande vantaggio che ne avrebbero se potessero coltivare le pianure interne fino ad arrivare alla costa ovest.

Discute la cosa ad alto livello e progetta di massima una nave aerea per trasportare 328 persone. Pensa questa nave di forma oblunga di 292 metri, a sezione circolare di diametro pari a 36 metri, riempita di aria portata ad una temperatura più alta rispetto all'aria esterna di 170 °C. Calcola che, impiegando una macchina a vapore da 179 KW, si possa raggiungere la velocità di circa 18 Km/ora. Stima il costo approssimativo inferiore a 20,000 $ di allora.

Fig. 1 Schizzo del dirigibile tratto da appunti per lezioni

Anche in questo caso, costruisce un prototipo in scala, si preoccupa di analizzare tutti i dettagli e afferma di voler devolvere il ricavato dell'invenzione a beneficio degli emigrati Europei.

Nota

Il fascicolo riguardante la Theory of Airship è conservato nella Biblioteca dell'Archiginnasio, consta di due parti: una di appunti su fogli bianchi, ed una seconda su fogli azzurri, che appaiono come una trascrizione ordinata dei primi.

I fogli di colore azzurro sono numerati da 1 a 31. E' senza contenuto il foglio 8, mancano i fogli dal 20 al 24, è aggiunto il foglio 26 bis.

I fogli azzurri sono inseriti all'interno del fascicolo con fogli bianchi.

Si trascrive il contenuto dei fogli azzurri conservando la divisione del testo nei fogli e nelle righe dell'originale.

Si ringrazia l'ing. Adrian Lutey per la revisione finale del testo.

Pier Gabriele Molari

Bologna, 10 settembre 2012

New-York Daily Tribune 16/1/1851

AERIAL NAVIGATION

Some days ago we alluded to a notice in an evening paper of a solution of the problem of Aerial Navigation, founded upon mathematical calculation. We are at present, possessed of better information, both concerning the project and its author. The latter is a friend of ours, N Filopanti, late member of the Constituent Ro= man Assembly. We are enabled by him to give our readers a summary sketch of his invention.

Both the aeronauts and the locomotive appara= tus will be upheld by the ordinary means of buoyancy in the air, a bag filled with hydrogen gas; but it is an essential feature of the system that the form shall be both oblong and of colossal dimensions, in order to present the least com= parative resistance to the air -- the degree of resis= tance being proportional to the vertical section, and the latter to the volume, the volume growing like the cube of any homologous dimension, while the section grows simply as the square. The mov= ing power will be afforded by a steam-engine in the style of railroad locomotives, with necessary modifications; among which is a thick metallic wire net enclosing it. The locomotive will set in motion two mammoth pair of wings, composed of many rectangular parts, which stand vertically when they strike back, and horizontal when they are returning.

Prof, Filopanti has made elaborate and pro= found calculations, based upon experience and theory, to find the degree of the resistance of the air, the power of steam, and the quantity of fuel and water necessary to overcome that resistance: and what is the necessary size of the balloon, or air-ship, as he calls it, to support so enormous a weight. He directed his calculations to ascertain the conditions for obtaining a velocity of ten to twelve miles in quiet air, at a slight elevation above the ground; or even to make his way (of course at a less speed) in a moderate wind blowing either directly or obliquely against the prow of the vessel. Should the wind be both contrary and of a velocity greater than ten or twelve miles per hour, the air ship would retrograde, and de= scend at the nearest station.

It is desired that the first aerial voyage be made from New York to Philadelphia on the An= niversary of American Independence. Prof. F. however, will not make his scheme the object of any interested view. He suggests that the ne= cessary funds be raised by subscription in both cities, and entrusted to a committee. Paid tickets of admission will not be issued.

If the invention, by further improvements, should prove a practicable and cheap means of conveyance, be intends applying for a patent--not for himself, but for the benefit of European immi= grants, to be carried from our Atlantic shores to the interior parts of the United States, and to be assisted in agricultural enterprises.

M. Filopanti thinks favorably of Mr. Wise’s project, and is of opinion that both the distin= guished aeronaut's and his own discovery will be the complement of each other. If so, the long= sought application of aerostatics would be at once an European American discovery.

A model of M. Filopanti's invention has already been constructed, and he will soon lecture upon it, first to a number of persons skilled in mathe= matics and then before the public.

Prof. F. has made himself favorably known to the scientific world, having occupied the chair of Hydraulics and Mechanics in the University of Bologna previous to the late revolution in Italy: and has also distinguished himself by a successful invention to prevent the inundations of rivers, which has been successfully applied to the river Po. If human ingenuity is destined to triumph over the difficulties surrounding the great problem of atmospheric navigation, it will be through the combined power of inventive genius and of the profoundest resources of mathematical science.

New-York Daily Tribune Monday January 27 1851

M. Filopanti's Lecture on Air-Ships -- Prof Filopanti delivered a lecture at the Medical College on Thursday last, in explanation of his project for navigating the air, before a number of scientific gentlemen invited for the purpose. Among those present were Gen. Talmadge, Pres=ident of the American Institute, Profrs. Draper, Gibbs, Loomis, and others. He made an erudite development of his views on Aerial Navigation the most essential part of which have already been given in our article of the 16th inst. The only new point of importance was an opinion that the application of the rarefied air would afford a practicable and cheap means of convey=ance through countries not possessed of railroads and steamers. As an illustration of this, he said that it is possible to make an air-ship of the cyl=indro-spherical form proposed by him, to go to California at the average rate of eleven miles an hour [17,63 km/h], and capable of holding 328 men. The cost of such a machine would not exceed $20,000.
Some intermediate stations, however, would be required, to take in supplies of fuel and water
The machine should have a diameter of 120 feet [36,576 m], a total length of 960 feet [292,608 m], a locomotive of 240 horse-power [179 kW], and the inside air at 340 Fah. [171 °C] above the temperature of the external air.

foglio 1

THEORY OF AIRSHIPS

by

Q. Filopanti

Late Professor of Mechanics and Hydraulics
in the University of Bologna

=
Introduction

When first the genius of Montgolfier lif= ted above the clouds a body of vast proportions by the virtue only of its specific gravity, it was said by another man of genius, Benjamin Franklin, there is an invention, which will either remain always a child or grow up a giant. Hitherto nothing be= sides the first part of this prediction has been fulfilled. Balloons, originally proposed by a country= man of mine, the Jesuit Lana, afterwards tried upon a small scale by another Italian, Cavallo, then carried out successfully by the brothers Mont= golfier in the year one thousand seven hundred and eighty two by inflating a large linen bag with air rarefied by fire, improved next year by the Philosopher Charles, by the substitution of hydrogen gas by Pilâtre de Rozier at the end of the same year, may be said in all truth not to have received any essential improvement from that epoch down to the enlightened middle of the nineteenth century. What may be the cause of so bright an invention lingering so long in a state of sterile infancy?

foglio 2

Are the currents of
the atmosphere more terrible than the waves and
the rocks of the ocean? Or is a small infe=
rior animal by the aid of a few frail feathers
able to perform what man, endowed
with the much more powerful wings of rea=
son and science will eternally fail to ac=
complish? But if so, whence does that
kind of implicit faith come, which the most soundmin=
ded men seem to place in the future discovery
of the rules of aerial navigation? On the other
hand, if the solution of the problem is possible,
how is it that it has not yet been found out, after so many
inquiries in so inventive an age?

The reason is, in my opinion, because the re=
solution of this problem is neither so easy as some
men flattered themselves it was, nor so difficult
as regarded by others. In other departments
of human industry, unscientific men made often
great discoveries, because their natural genius
afforded them an instinctive knowledge of principles. And
their personal experience and trials filled up
the want of learning in the application of those princi=
ples: but in our case, for special reasons, the
experiments must be made upon a gigantic scale, or
they are of no service: therefore even a man of
genius, without the assistance of calcule, and of a
large fortune will never succeed in the direction
of aerostats. On the contrary if the problem is re=
duced to the fundamental principles of the science
of motion, and treated with the methods of
mathematical analysis, the solution will occur of

foglio 3

itself. Unhappily very few among mathematicians
apply themselves to any thing else than abstract
questions, generally of high intellectual beauty,
but seldom of any immediate and living service
to society at large. Also there are many more
among learned men generally, who are possessed of abi=
lities of a high order, than of that intellect=
ual courage and firmness, which may fairly be cal=
led the faith of science. The number
is not very large of men who would be ready, without
the least fear and doubt, to put their life and
reputation at stake, to test practically whether
twice two make really four in the fact, or only
in the Pythagorical table.

The object of this little treatise is to propose and ex=
plain a solution of the problem of atmospheric naviga=
tion, founded on mathematical calculations. I have faith in
their correctness.
Nevertheless I shall make no special
attempt to any practical execution: not because I put it in doubt
that success would attend a trial properly made, but
because I think I am unable personally to triumph over
the torrent of prejudices existing even in the most
enlightened countries against projects of aerial naviga=
tion. I may be permitted to say, that, after all, men's
minds are much more difficult to be
pushed in a wanted direction than balloons
themselves. I could, notwithstanding, afford a disinter=
ested cooperation to any man better fitted by circum=
stances, than I am, to overcome the moral difficulties

of a first attempt. At any rate I give the pub=
lic the result of my studies. Possibly they
will be taken into consideration, at least as an
inquiry of some scientific interest. Should the
man, whom Providence has destined to be the first
successful navigator of the air, be helped in
any way by these studies, I would be the last
of men to grudge him the glory which would
be bestowed on him by a world, accustomed
to worship facts, and revile their mother, the
idea. That a project should be disdained simply
because of its being a project, is perfectly absurd:
but to honor successful
executors is just, as
to execute is often much harder
than to conceive.

$1

Convenience of employing a buoyant system.

It may be the purpose, before undertaking any
thing like a theory of the direction of the aerostats,
briefly to show the unsoundness of a very poor but
extremely common objection against the very possibili=
ty of navigating the air any how. It is pretended
that air cannot be navigated, because balloons run
in a single medium, air, instead of two, air and
water, like ships. The gentlemen, who object this,
forget that birds fly through air alone, and fishes
swim wholly immersed in water. Steamers propel=
led by screws have their moving apparatus under
water, and steam vessels of any description, like fishes and birds, subdue the resi=
stance of the medium before them, by the resis=
tance of the same medium in a contrary direction.

foglio 5

True it is that ships, being only partially plunged in
water, have the advantage of being kept in
a constant horizontal plane, without any effort on the
part of seamen: balloons, on the contrary, are liable
continually to ascend or descend in the air; and
therefore besides
a force capable of communicating to them the necessary
impulse, and a contrivance suited to control their
horizontal deviation either on the left or
on the right, like ships, they want also another
contrivance calculated to check their tendency to
decline from the wanted line either upward or
downward. The only logical consequence of this
is that it is more difficult to navigate
air than water: but to say it is impossible, is a
very different thing.

There are others admitting that men will at
last walk in the air, but denying that it is possi=
ble to do so with balloons. Fasten a small bal=
loon, they say, to a bird, and see whether it will
fairly fly. That is true; neither could a bird
fly with four wheels fastened under its feet: would
it then be a good reason that neither carts should
have wheels? The bigness of the truth is, that although an
aerostat makes powerful impediment to a rapid motion in
the air, still it affords more advantage in sustaining
the weight of the aeronauts than disadvantage in retar=
ding their progress: because the display of mechanic power
necessary to uphold in the air a given number of men
by the dynamic resistance of the air itself, is far grea=
ter than the force sufficient to propel at a moderate
velocity both the men and an aerostat as large as it
is required to support them and the moving apparatus and all. Until
we shall have
nothing whose moving power will bear a greater propor=

tion to the weight both of the engine and of its
alimentary supply, it will be impossible for us to fly,
properly speaking.
It is quite singular that such
a statement of rational mechanics may be illustra=
ted by a very vulgar culinary notion. Every one
may easily have remarked that the most fleshy bit
in a cooked bird is the breast: even more: the
volume of flesh on their breast is larger than
all the rest of flesh in the other parts put together. Now it
is well known that flesh is nothing else but the
popular name of what is called by anatomists the
muscles, or the organs of motion. Then let us seek
in zoological physiology what is the office of the mus=
cles of the breast in birds: it is exactly to set
the wings in motion. The muscular part of the breast of a bird
is composed of the great, the small, and
the middle pectoral. The two former muscles act
in pushing back and lowering the wings: the latter
acts as their antagonistic muscle, drawing the wings
to the anterior position. Now the very remarkable
circumstance of these three muscles having
alone more development then all the other mus=
cles together, suffices to show how
unexampled a ratio the flying power
of birds has to the weight of their body, and
how utterly impossible it is for man to fly by the
sole muscular force of his limbs. That the ratio
of power to weight in birds
is greater also than in engines hitherto used, has been demonstrated by
Navier in a report of his to the Academy of
Sciences of France. And though birds have compara=
tively so extraordinary a power for moving their wings,
they are obliged to employ the greatest part of
it, not to run through the air, but to keep themsel=
ves up in it; as a flying bird keeps its body

foglio 7

and wings in a slight inclination, partaking much
more of the horizontal than of the vertical position,
and consequently the wings are struggling in beating
air much more downward than backward.

I do not mean, however, that air navigation foun=
ded on the principle of the flight of birds is impos=
sible. I am so little inclined to say so, that I free=
ly profess my opinion, that {*as*} long [as] we shall have
machines of a much lighter bulk for a given power
than we now have, and then we shall be able
to fly, properly speaking, through the air, at a
far greater speed, safety, and economy than it is
to the expected even from any improved system of
balloons. Meanwhile I will say to the partisans of
the bird system: gentlemen we are all yet in
the case of a man wanting to cross a river with=
out any boat and being unacquainted with swim=
ming. Let him tie to his shoulders an inflated blad=
der (a very large one, indeed, in our case) so as
to insure him from sinking to the bottom of the
river; if he succeeds in crossing the river with this
imperfect expedient, he may learn afterwards to
cross it without any bladder. In other words:
<u>your system would go to attack two great
difficulties at once: help me in surmounting first a single
one of them; perhaps I may be able, afterwards,
to give you some feeble assistance to overcome the other
also.</u>

foglio 8
BIANCO

$ II
On the most proper form of airships.

A greater error would be to give balloons the form either of birds or of fishes, as suggested by many persons. It should be borne in mind that Nature, in fashioning the bodies of animals, had not simply their loco=motive faculties in view, but the particular wants of their living organisation, and that balloons are by no means living bodies. The ordinary form of balloons, however, is very unfit for the purpose of lessening the resistance of the air. This resistance is generally independent of the length, and only proportional to the greatest transverse vertical section: consequently to augment the volume and by it the ascending power of the aerostat, without augmenting the resistance the air will oppose to it, it must have an oblong form.

To be true, the globe being the most capacious among isoedrical solids, the envelop of a round spherical balloon will weigh less than that of other balloons of equal capacity and different form: but this consideration, capital as it is for small balloons having no other object than to exhibit a useless spectacle, will be of little consequence for colossal airships, as we must have, where the surface will bear a much less ratio to the capa=city than in ordinary balloons.

Let us suppose eight spherical balloons of equal size being contiguous to each other upon a single horizontal line, and the intervals between them to be covered and wrapped round by longitudinal envelope of cylindrical form: it is obvious that the resistance this compound body would find in the air, moving horizon=

tally through it, is simply the resistance which air opposes to the single spherical balloon forming its fore part: although the whole volume of the cylindroid contains eight of such balloons, and moreover the intermediate spaces around them. Geometry, indeed, by the theorems of Archimedes, shows that the volume of such a body, composed as it is of a cylinder having a length equal to seven of its diameters, and one hemisphere at each of its ends, has a ratio to a single one of the inscribed globes, as 23:2, and is consequently eleven times and a half larger than each of them. Now this is the form of aerostats I propose: <u>a cylindroid body having its axis horizontal, and composed of a cylinder with two half globes, one at each end of the cylinder, the total length of the cylindroid being equal to eight of its diameters</u>. Compare the advan= tages of this form to that of an ordinary balloon. A cy= lindroid of our supposed form meets with a resistance to its progressive horizontal motion, in the air, nearly equal to that of a single common balloon having its own diameter, but is eleven times and a half larger than the latter: consequently while the common balloon may be unable to support the moving appa= ratus necessary to propel it at a moderate speed, our cylindroid, having an ascending power more than eleven times greater, may be very well enabled to uphold both a greater number of men, and a greater store of moving power. Or else suppose a spherical balloon equal in volume to our cylindroid: that balloon will have less length, but a much greater diameter than our cylindroid, the vertical section of the former will be a circle nearly five times larger, than the vertical section of the latter: wherefore the balloon being able to carry with it a moving power singly equal to that of our cylindroid is nevertheless obliged to overcome

a resistance of air five times as large
as we have.
I do not propose this form as the most perfect,
but as one of the most conve=
nient, not only for the economy of moving power, but also
for the facility of construction, and agreeableness to the
expansive nature of gas. Experience alone may suggest
some improvement: now, in the absence of experience, let us
try this one, which has at least theory on its side.
Some will naturally think that an acuminated prow
would be preferable to either of the hemispheres pro=
posed as extremities to our cylindroid: because they are
accustomed to see that wedge like bodies are better able
to penetrate into solid matter.
A wedge, indeed, would experience less
resistance in the air, moving forward by its sharp part than by its
back, but certainly not with so considera=
ble a difference as with respect to solid bodies: well since
it is obvious to remark, that the wedge can tolerably penetrate wood
by the thin edge, and not at all by the apposite end;
but it can move perfectly well through air
either on one side or any other. This is enough to
prove that the resistance of solid and fluid bodies is
governed by different rules. It is proved by most dili=
gent experiments that
a body, with a spherical {*bow*}, like the one here proposed
by me, finds an easier way or less resistance, in the air, than the cylinder
would without any prow, in the remarkable ratio of 2:5; but
a cone of height a little greater
than the diameter of its basis, resists something
more to the air, even moving with its
pointed part forward, than a globe of equal dia=
meter.
It may be supposed, that the resistance of water
being more kindred to that of air, a form approaching
that of ships would perhaps be more

suitable. A deeper consideration, however, will disclose
that the actual form of ships has been prefer=
red to others, not simply by a regard to the least
resistance of water, but also to the safety of the ship.
Should, for instance, a ship of two thousand tons burden be construc=
ted in the shape of a half of one of such cylin=
droids as proposed by me for airships, such ship would
sail with a greater velocity than one of an equal
weight and equal sails, but of
the ordinary form, because the former would have a much
smaller transversal section; but she would be very
unfit for a rough sea, either from the danger of
upsetting laterally, or for the sluggishness of lifting
up her bow when she is assailed abreast by a
heavy and high surge. No such inconveniences existing in
our system of air navigation, we must principally look for
the lessening of the {*midship*} of transverse vertical section. For kindred reasons
steamers are longer than ships, and steamboats proportio=
nally larger than steamers: and the former would, even mo=
re than they do, approach the form proposed by me for
airships, were it not that often the surface of rivers
is considerably boisterous.

As a geometrical illustration of what has been advanced
by me, let us suppose an airship in the form of an ellipsoid,
with its whole length equal to four times its transver=
sal diameter. It would be more analogous to
the form of common ships, and of a more elegant appearance.
Nevertheless let us imagine a cylindroid of our proposed mi=
xed form, with the same diameter and transversal
section as the ellipsoid. By the theorem of integral calcule
stating that either a sphere or an ellipsoid are but two thirds
of the circumscribed cylinder, it will easily be found, that
the volume of the ellipsoid, and therefore its ascensive power,
would be to the volume and to the ascensive power of
the cylindroid in the ratio of only eight to twenty three,
their resistance to air being nearly the same.

foglio 13

$ III

Necessity of large dimensions.

<u>The greatness of dimensions of the airship is not an accessory but an essential feature of this system.</u> It may be demonstrated by calculation that a robust man working at his best advantage with {*mass*} could drive a spherical balloon of twenty four feet diameter at the rate of two miles an hour in a quiet air. Practically this amounts to
nothing, as ordinary balloons float generally in a high atmospheric region, where the currents have, on the average, some thirty miles an hour velocity. Let us however suppose the air perfectly still: two miles an hour would yet be a very poor velocity. To obtain a double velocity, still with a balloon of twenty four feet diameter, not a simply double power is required, but one eight times greater, or equal to the joint power of eight men; as the necessary moving power is in the ratio of the cube of the velocity. Then let us make another balloon of forty eight feet diameter; sup=posing, for the facility of the present calculation, that the envelop is made thicker in the ratio of the diameter, this second balloon will sustain just eight men, if the first was able to uphold a single one. These eight men would have just powder enough to drive the first at the rate of four miles: but air will oppose to the second larger balloon a resistance in the ratio of the sections, or of the square of the diameter, namely four times greater than to the former: consequently the eight men carried by the second balloon, are insufficient to drive it at the required speed: to be driven
at four miles an hour, it would require the power of thirty two men, though it can only lift eight of them. Very well: let a third balloon be constructed holding this

number of men: unfortunately,
again, the new balloon, on account of its greater sur=
face, finds more resistance than the second, and
even its crew of thirty two men is insufficient.
There is however an end to this kind of mathema=
tical race. It is true that a larger balloon, requi=
res a greater power to be driven at a given rate of
speed; but this resistance, proportional
to its surface, grows in the ratio of the square of the diameter,
while its volume, and, with it, its ascensive pow=
er grows in a greater ratio, that of the cube of
the diameter. Therefore by increasing more and
more its diameter, we must finally reach a li=
mit, where its ascensive power will be so great,
as to be able to support all the men or ma=
chinery capable of impelling it with the desired speed.
It is impossible to obtain sufficient results from
the application of any force to small balloons;
it will be possible with very large ones, pro=
vided we continue the greatness of dimensions, with
the fittest form.

To show the joint influence of different dimensions,
forms and velocities, I will anticipate the results
of some calculations depending on principles to
be explained hereafter. The least number of men
capable of driving, by their muscular exertions, an air=
ship of our cylindroidical form, at the rate of
eleven miles an hour, would be 2078, its diame=
ter should be 120 feet, its length 960. To drive
at the same rate a spherical balloon, it would
take not less than the enormous number of
two hundred thirty thousand men, and its diame=
ter should be one thousand two hundred and seventy six
feet; although we have said that a single
man could drive at the rate of two miles an hour

a balloon of twenty four feet diameter. The reason of these immense differences does not depend simply on the fact that a balloon has a transverse section five times greater than a cylindroid of ours of equal volume, and the necessary moving powers for velocities of eleven and two miles are respectively 1331 and 8, their cubes. The difference depends mainly on the fact that by augmenting the section we augment again the weight of moving power necessary to propel it, and this augmenta= tion of weight in its turn requires a greater vo= lume to support it, then the greater volume, once more, requires a greater moving weight, and so on, till the limit is reached.

$IV

The moving power.

If it be possible to obtain the effect of the pro= pulsion of airships by any kind of force already known and used in common practice, that of course will be preferable in order to diminish the moral and physical difficulties and changes of a first trial. Let us set aside, for instance, electromag= netism, and compressed air, by the reason just now ex= pressed, if not by better ones. It is easily percei= ved, that among the five common sources of force, wind, water, animals, man, and steam, the two latter are the only one worthy to be tried. A previous declaration, however, is to be made with regard to wind. That we cannot avail ourselves of it, after the man= ner of sailing vessels, is absolutely and mathemati= cally certain, though it would take a too little long time to demonstrate it to persons unequainted with theoretical dynamics. But I do not exclude the possibility of availing ourselves of it in the manner al=

ready proposed by many, namely to seek, among the different aerial currents, the one favorable to our direction, and profit by it. But, unless we have a proper means of propulsion, enabling us to deviate from aerial currents, and also to make our way against them,
they will be of no practical use to us; first because very seldom there will be any current in the precise direction wanted by us, then because there being any, we would not know where it is, and last because even the most favorable current would not allow us to descend at the required place and moment.
Whether men or steam are preferable as a propelling power for airships, is a question mainly dependent on the relative weight of the human body and steam engines, with their necessary supply of water and fuel.
<u>The weight of dressed adult man may be reckoned on the average; at a hundred and fifty avoirdupois pounds.</u>
Men’s average dynamic work is various according to the manner it is employed. It has been observed that the greatest effect is obtained by the muscular human power, when employed in a manner kindred to their most habitual and univer=sal exercise, walking. In our particular case the best system would be to dispose the men seated in a long gallery suspended from the cylindroid, and pushing alternately, with their feet, small cross beams of an organ of Borgnis’s, while this organ, by a proper system of wheelworks and cranks transfers the impul=se to a system of wings, to be explained hereafter.
Mechanic effects are usually estimated by comparing them with gravity raising weights to different heights, the effect being reckoned, as it really is, the greater, in the compound ratio of the raised weight, and of the elevation to which it is raised.

So it has been found that a man working with
his feet on the organ of Borgnis, is capable of raising
in ten hours two millions of pounds to the height
of one foot, or one pound to the height of two
millions of feet. I purposely reduce french measurements
to these full and commodious numbers in english measures, neglecting
trifling differences.

In steam engines working at a low pressure of
a single atmosphere, or fifteen pounds per square inch,
every cubic inch of water is converted into a vo=
lume of steam nearly equal to a cubic foot, or one
thousand and twenty eight times larger. Let us suppose
a cylinder whose transverse section is equal to a square
foot, and the length of stroke of the piston, one foot:
consequently the space, to be filled by steam,
equal to a cubic foot. Any cubic inch of water in the
boiler is capable of filling this whole capacity of the
cylinder, under the aerial form of steam. Since
the surface of the piston, on both sides, is one squa=
re foot, or 144 square inches, at the rate of 15
pounds per inch, it supports a pressure, alterna=
tely on either side, of 2160 pounds. Now, as the
distance to be passed over by the piston is one foot,
its mechanical effect at every stroke may be considered
equal to 2160 pounds raised one foot. Every cubic
inch of water is capable of causing one of such oscil=
lations of the piston: and as
a cubic foot of water, or 1728 cubic in=
ches, weigh one thousand ounces, it is an easy
calculation to find that
sixteen ounces of water, that is to say one pound, being
converted into steam at the aforesaid pressure, are ca=
pable of raising a weight of 9720 pounds to one foot. As there
are several causes of loss of power, let us take
the round number 50,000, which agrees pretty well

with practice.
In high pressure engines, the volume of steam sup= plied by any given volume of water is less than in low pressure engines, and consequently will cause the piston to make a less number of strokes; but, by compensa= tion, being denser, it has a greater tension, and pushes the piston with greater force: and it is easily per= ceived that a single stroke of the piston at a high pressure of six atmospheres, will have the same effect as six stro= kes of it, by the pressure of a single atmos= phere. <u>Practically it may very well be admitted, that either at high, middle or low pressure, the dynamic effect of the evaporation of every pound of water is equivalent to fifty thousand pounds raised one foot.</u>

As for the quantity of fuel necessary to obtain a given quantity of mechanical power, should there be no dispersion of heat, the evaporation of a given quantity of water would demand nearly the same quantity of fuel at any pressure, because, al= though the steam of a higher pressure can only be obtained with a higher temperature, the higher tem= perature will cause a more rapid and more abundant evaporation. As, however, the waste of radiating calo= ric from the external surface of the boiler and of the cylinder is the greater in proportion of the temperature, so it is common to see high pressure engines con= summing a little more fuel than condensing engines of an equal power. According the experience, it may be stated that in either case a pound of coal will evapo= rate from six to seven pounds of water: we take the former number: then as any pound of water {*breeds*} a power of 50,000 pounds raised one foot, we shall lay down the following canon = to produce an effect equiva= lent to 300 000 pounds raised one foot it takes five pounds of water and one of coal.

In our case coke is preferable to coal, as it produces a cleaner smoke, no flame, and a little greater quan= tity of heat, at equal weight. We shall however calcula= te the necessary weight of coke according the superior canon.

Now for the weight of the engine itself. It will im= mediately strike any reflecting man, that high pressure engines being dispensed with the large quantity of water necessary for the condensation of steam in low pres= sure engines, and with the cumbersome apparatus of the condenser, the former are preferable to the latter in our case. And whereas, among the several kinds of high pressure engines, the railroad loco= motive is destined to an object quite kindred to ours, and nowhere greater efforts of human ingenuity have been expended to have a most powerful machine within the narrowest possible limits of weight and bulk, it is an engine in the stile of loco= motives, which we must prefer to any other.

From practical intelligence obtained both from builders and drivers of locomotives, and effective measu= rements taken by myself, I have calculated what follows. A large locomotive engine, from the Patterson fabric, on the New Jersey railroad, with cylinders thirteen inches by twenty, ordinary pressure 90 pounds per square inch above the external atmospheric pressure, and with driving wheels six feet diameter, weighs twenty tons, wheels included, and twenty eight thousand pounds, wheels not included. From the foregoing data it results that the effect of every stroke or course of both pistons is equal to nearly 40000 pounds raised to one foot. From the ve=

locity of the train being often thirty miles an hour,
or 2640 feet per minute, and the stro=
kes of the piston being two at any revolution of the
driving wheels, and the circumference of the latter being $18^{6}/_{7}$ feet,
the consequence is that there are 280
strokes per minute and per piston; and the total effect
of the engine, at every minute is equal to
11,200,000 pounds raised one foot. Or, the power of one
steam horse being reckoned at the rate of 33,000
pounds raised one foot high every minute, the lo=
comotive hitherto alluded to has a power of nearly
340 horses.

We have now at last got able to compare the
relative weight of men's and steam power. A strong
man, as we said, working at his best advantage with
his feet, is capable of doing a work of two millions pounds to a foot
in a day, which is nearly three thousand
and three hundred pounds raised to height of
a foot in a minute, or the tenth part of
a steam horse. This leads to the consequence that
the just now calculated engine has the enor=
mous power of three thousand and four hundred
men. According to the canon already demonstrated by
us, that a mechanic effect of 300 000 pounds
raised to one foot, consumes six pounds of water and
one of coal, she would require for a continual
work of ten hours 22,400 pounds coal and 134,400
pounds water. To which add the proper weight of
the engine, 28,000, it makes on the whole a weight
of 184,000 pounds. Now the 3400 men, whose power
she is equivalent to, weighing on the average 150 pounds
each, all together would weigh not less than 510,000
pounds: <u>a weight nearly treble than the one
just now calculated, belonging to the engine
and her total supply necessary to do all the work these
men can can perform in a whole day.</u> No doubt, thereof=
re, that <u>for our purpose, steam power is by far more economical
than men's power, not only on the account of the price,
but also of the weight.</u>

Mancano fogli da 21 a 24

foglio 25

This could not be done with the necessary quickness and lightness of means, were not each wing subdivided into many parts, to which the same principle and process is to be applied. To this effect let each one of the wings be divided into many rectangular windows by horizontal and vertical bars: to every window a shutter (let us call it so) is to be applied, formed of a light frame and a canvas spread over it. But the fra= mes of all the shutters, as well of the windows, of every row are to be transpierced throughout a little above their centre of gra= vity, by a common horizontal verge, performing the of= fice of pivots, round which the shutters shall be made to describe a quarter of revolution. When the entire compact of the wing moves abaft, the gravity of the shutters comprises with the resistance of the air and with an appropriate mechanism to close them promptly to the frames: when they return afore, the same agents cause the shutters to stretch themselves in a horizontal position. To have this more conveniently done, the shutter must be inserted to the window in such a manner as to make the inferior sash of the shutter, when closed, to be juxtaposed abaft to the frame of the window, and the superior sash of the shutter to juxtapose itself to the frame of the window afore. Their mutual coming in contact, or rather approach, must be softened by spiral springs: which will also assist a reopening the shutters, as soon as the pressure of the air turns on the contrary past. Other springs properly disposed concur with the pressure of the air in not allowing the shutter, when opening, to trespass bey= ond the horizontal position.

$ VII

Theory of the wings.

The mechanic theory upon which the use and effect of this system of wings is to reft, may be summed up in the following leading propositions: it [is]

not an hypothetical and arbitrary theory, but
soundly based upon experiences carefully
made and controlled by authors, where ability and
spirit of exactitude cannot be called in doubt.
The pressure or resistance of the air striking perpendi=
cularly a plain surface is proportional to the area of
the surface and to the square of the velocity.

Whether the air or wind flows against the bo=
dy, or the body moves through the air,
or both have are in motion at the same
time, the resistance is the same, if the relative velo=
city be the same.

When the air strikes with no great obliquity a
plane surface, the resistance considered in the direction of the air itself is in the
compound ratio of the surface, of the square of the
velocity, and of the cube of the {*sinus*} of incidence.

The resistance of a square foot to a perpen=
dicular wind of ten feet per second is nearly equal to
the weight of two and half avoirdupois oun=
ces.

The resistance of a spherical body, like the bow of
our airship, to a wind of ten feet per minute has been
proved to be nearly equal to an ounce per square foot
of transversal section or basis. Here also the
resistance, with different velocities, is proportio=
nal to the square of the velocity.

The pressure of the air against the fore part
of the airship (this must always be under=
stood of the pressure as generated by the motion,
the pure hydrostatic pressure on any side being of no consequence,
as exactly counteracted by an equal pressure on the
opposite side) will be equal to the mean pressure
exercised on the air abaft by the two closed wings,
minus the pressure exercised by the air afore against
the closed wings. To demonstrate

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this, we may consider the whole system of our airship as subjected to five parallel forces: one of them is the pressure of the air to the forepart of the airship: a pressure acting backward; another is the pressure of the air in the hind part of the wings going backward; this pressure acts forward: a third force is the pressure of the air in the fore part of the opened returning wings; a pressure acting backward; the fourth is the pressure of the steam on the piston, and, through it and the intermediate organs, to some point of the wings: this force acts alternately forward and backward: the fifth and last force is the pressure of the steam on either of the ends of the cylinder. By the theory of parallel forces, when the velocity of the ship has beco= me uniform, the sum of the forward or positive forces, must be equal to the backward or negative ones. Now the two immediate pressures of the steam on the piston and of the end of the cylinder are alternately afore and abaft, and always equal and contrary to each other. Hence it follows that the pressure on the bow of the airship, that is say the resis= tance of the air to her motion, is equal to the difference between the resistance of the wings moving backward and the resi= tance of the two wings returning forward.

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The following proportions will assist us both in deter= mining the surface of the wings, and to calculate before hand their effect in given circumstances. They are not only applicable to airship, but to steamboats, and steam= ships also: and I have already published a part of them elsewhere, with reference to the paddle wheels of transatlantic steamers.

Let us first suppose, for the facility of analytical proceedings, that the resistance of the wings returning back is reduced to nothing, and that they act constantly in a direction parallel to the axis of the cylindroid. Let $\underline{A}$ be their reduced surface according to this hypothesis, let $\underline{u}$ be the absolute velocity by which the strike backward the air, $\underline{v}$ the airship's ve= locity, and $\underline{b}$,$\underline{c}$,$\underline{d}$,$\underline{e}$, etc constant coefficients whatever. The resistance of the air to the airship's advancement will be $\underline{b}\ \underline{v}^2$, that of the air in the opposi= te direction to the backward motion of the wings will be $\underline{c}\ \underline{A}\ \underline{u}^2$; these two resistances or pressures equilibrate each other; and we have therefore

$$\underline{v}^2 = dA\ u^2$$

Let now the constant quantity of steam expanded by the engine in the unit of time be called $\underline{C}$. This quantity is in the compound ratio of the density of steam in the cylinders, and of the number of strokes of the pistons in the unit of time. Now, the density of steam being proportional to its pressure on the pistons, which pressure must be in a constant ratio with the pressure $\underline{c}\ \underline{A}\ \underline{u}^2$ of the wings, and the number of strokes in a given time being proportional to the velocity of the wings, relative to the airship, while they are going backward, which relative velocity is $\underline{v} + \underline{u}$, it follows that

$$\underline{C} = \underline{e}\ \underline{A}\ \underline{u}^2\ (\underline{v}+\underline{u})$$

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If the valor of A, taken from this equa=
tion, be substituted in the former, we shall have

$$v^2 = (f\ C) / (v+u)$$

Here it is visible, that f and C being constant quantities, the smaller u, the greater v will be: namely, <u>to obtain the greatest speed of the airship with a given expense of steam, we must give to backward motion of the wings the least possible velocity.</u> But it is evident from the second equation, that u cannot be diminished without increasing A, that is to say, that we must supply by the great=
ness of surface of the wings their little back=
ward velocity. Therefore the larger the wings, the greater will be the speed of the air=
ship.

The same conclusion may be reached by another way. The resistance of the air to the progress of the vessel, being equal to the hind pressure $c\ A\ u^2$ of the wings, the useful effect, will be equal to that pressure multiplied by the voyage v made in the unit of time, that is to say equal to $g\ A\ u^2\ v$. But the power employed by the engines to obtain that effect is $h\ A\ u^2\ (v+u)$; therefore the ratio of the expended power to the useful effect is proportional to

$$v / (v + u)$$

Their equality is a limit never to be arrived at, since it requires u to be nothing, and consequent=
ly A infinite. But the useful effect will come the nearer being equal to the expended power, the

smaller is the
value of $\underline{u}$ in the denominator of the fraction.
But as we cannot diminish $\underline{u}$, without increasing $\underline{A}$,
the waste of power will be the less, and the
relative useful effect the greater, the greater is
the surface of the wings.

We cannot, however, indefinitely augment them, becau=
se it augments also their weight, even is a greater
ratio than the surface. I propose that $\underline{u}$ shall be made
equal to half $\underline{v}$; then, as far as the immediate
effect of back motion of the wings is concerned, the
useful effect is to the expended power as two to
three. Then the velocity of the wings
relative to the airship, either in their going
abaft or afore, will be $^3/_2\ \underline{v}$; consequently their absolute
velocity, in returning ahead will be $^5/_2\ \underline{v}$. Let the
endeavour be made to have the reduced resisting
surface of the wings in the return $^1/_{125}$ of the clo=
sed surface: as, however, the absolute velocity of
their returning motion is five times greater, than
the velocity in the backward motion, the noxious resistan=
ce of the air to the returning wings will be not less
than $^1/_5$ of its useful resistance to their backward
motion. The impulsion communicated by the wings to the airship
is equal to the pressure of the wings going backward, minus
the pressure of the other two going ahead; the useful effect
will be equal to this impulsion multiplied by
the voyage $\underline{v}$ made in the unit of time, and it may therefore
be expanded by

$$\underline{A}\ \underline{v}\ \{\ \underline{u}^2 - {}^1/_{125}\ (2\underline{v} + \underline{u})^2\ \}$$

But to obtain this effect the engine must overcome
the sum of the pressure both of the going and returning
wings, as both pressures, though in a contrary direction, are
equally opposed to the rotary motion of the wings. Let $\underline{m}$

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be the ratio of the distances of the pivots respectively from the center of resistance of the wings and from the point of application of the connecting rod to the wings.
The pressure which
the connecting rod is to exercise may be represented by

$$\underline{m}\,\underline{A}\,\{\,\underline{u}^2 + {}^1/_{125}\,(2\underline{v} + \underline{u})^2\}$$

But the velocity of the center of resistance of the wings, re= latively to any part of the ship, being $\underline{v} + \underline{u}$, that
of the connecting rod will be $(\underline{v}+\underline{u}) / \underline{m}$; therefore the force expended by the engine to set the wings in motion will be proportional to $\underline{A}\,(\underline{v} + \underline{u})\,\{\,\underline{u}^2 + {}^1/_{125}\,(2\underline{v} + \underline{u})^2\}$
The ratio of useful effect to the power immediately
applied to the wings will be

$$[\underline{v}\,\{\,\underline{u}^2 - {}^1/_{125}\,(2\underline{v} + \underline{u})^2\,\}]\;/\;[(\underline{v} + \underline{u})\,\{\,\underline{u}^2 + {}^1/_{125}\,(2\underline{v} + \underline{u})^2\}$$

an expression which does not contain $\underline{m}$, or any quantity dependent from it; which shows that the rate of the useful effect is independent from the greater or less distan= ce of the pivot from the point of application of
the moving power. If in the upper formula we substitute $^1/_2\,\underline{v}$ for $\underline{u}$, its valor will be found $^4/_9$.
It must be acknowledged that it
is a considerably little ratio: but it would be hard to have a more favorable rate without meeting with worst inconveniences of another order.
I think it is an inherent
disadvantage of air navigation; that whatever system we may choose for the resolution of the difficult problem, we shall always be obliged to expand propor= tionally a greater amount of power to produce a wan= ted effect, than a corresponding effect in water navigation should require. We shall nevertheless ma= ke a further liberal allowance for the frictions, and

suppose that they destroy not less than one fourth part of the brute power: on the whole, then, the ratio of the useful effect to the employed power, will be $^1/_3$. So <u>we shall calculate the power of the engine, and the quantity of water and fuel to be taken in, at the rate of three times the effect we propose to ourselves to obtain.</u>

The extent of the surface of the wings depends on the foregoing theory and from the number of degrees of the arch they are defined to describe, as a greater resisting area is required to obtain the wanted effect with the average obliquity at which they are to work, than if they should always propel the vessel in an exact horizontal direction. Supposing they are made, to describe an arch from forty to sixty degrees, and go back with half the velocity of the air ship, the united surface of the four must be about equal to four times and a half the square of the diameter of the cylindroid.

I will not end this chapter without remarking, that by the system of wings proposed by us, as the whole power of the engine and the wings is commu= nicated to the cylindroid through the pivot, and the staves laterally embracing it, the resultant of the propelling force is made to coincide nearly with the axis of the cylindroid. Were it otherwise the resultants of the propelling power and of the resistance of the air could not be brought to the coincidence necessary to equilibrium, without considerably deranging the horizontality of the axis, and augmenting, thereby, the resistance of the air. As for the form dimensions and posi= tion proposed by me for the wings, I had it in view to have the greatest extent of surface with nearly the least possible weight of the frames, and that the position of their centers of gravity should not be changed during their oscilla= tions.