MECHANICAL & ENGINEERING SECTION

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THE DIRIGIBLE BALLOON WITH GYROSCOPE CONTROL.

THE NAVIGATION OF THE AIR BY MEANS OF THE DIRIGIBLE BALLOON
OR AIR-SHIP, PROPELLED BY THE RESULTANT OF THE FORCE
OF THE WIND ON ITS SAILS AND THE RESISTANT
FORCE OF THE GYROSCOPE.

THE LEVER IN SPACE WITHOUT A FULCRUM ON THE EARTH.

BY

RUSSELL THAYER.

APPROPRIATE to the brief paper which I will read this evening on the subject in question, I will preface it by quoting the following celebrated lines, which may be taken in the nature of a prophecy, written by Lord Tennyson, Poet Laureate of England, a number of years ago:

"For I dipt into the future, far as human eye could see,
Saw the vision of the world, and all the wonder that would be;

Saw the heavens fill with commerce, argosies of magic sails,
Pilots of the purple twilight, dropping down with costly bales;

Heard the heavens fill with shouting, and there rained a ghastly dew
From the nations' airy navies grappling in the central blue;

Far along the world-wide whisper of the south-wind rushing warm,
With the standards of the peoples plunging through the thunderstorm;

Till the war-drum throbbed no longer, and the battle flags were furled
In the Parliament of man, the Federation of the world."

Before proceeding to explain briefly the details of the particular discovery relating to aerial navigation which I have the honor to bring to the attention of the Institute I should refer, I think, in a consecutive manner to the various steps that have marked the progress of the science since the invention of the balloon, something over a hundred years ago.

I think it may be stated that this discovery by man marked

an epoch in this line of scientific investigation, and my own personal studies relating to this subject, which have now occupied in moments of leisure a number of years, force me to the conclusion that the true solution of the problem of aerial navigation is dependent primarily upon the basic discovery above referred to, and it is not at all likely that what is known as the " heavier-than-air " proposition will ever succeed in becoming either commercial or of any great utilitarian value.

Professor Simon Newcomb, LL.D., in an interesting paper published in the *North American Review* of April, 1908, shows conclusively that the proper solution of the problem is rather in the line of the development of the principles of the balloon, and not in reference to the aeroplane.

To briefly quote from the paper of Professor Newcomb, I may state as follows :

" In a word, physical science shows that the larger you build your ship the more economic she is in the ratio of efficiency to cost of running.

" The same principle applies to the dirigible balloon or any other form of ship that is to float in the air. Double its linear dimensions, make its walls twice as thick if you choose, and you will have eight times the cubical space and eight times the buoyant power. But you will require only four times the propelling power to drive her through the air with a given speed, and therefore only four times the horse-power in her engines."

In contradistinction to the above advantages, let us quote Professor Newcomb from the same paper as to the disadvantages of the aeroplane.

" Our principle of the square and cube applies to the aeroplane and to every form of flying machine, pure and simple, but it is reversed in the application. With every increase in the size of the machine, the weight increases as the cube of the linear dimension, always supposing that the model remains the same. Possibly it might not always be necessary to increase the thickness in the same proportion as the length and breadth, but in every case the weight would necessarily increase in a higher ratio than the square of the length or breadth. But the sustaining power being proportional to the surface, or to the spread of wing, whenever we increase the size of the flyer or of the aeroplane the sustaining power diminishes relatively to the size.

"We see this exemplified in the limitations put upon the size and agility of flying animals—the smaller they are the more easily they fly. There is a certain weight which probably is less than the weight of a man, which no bird can ever exceed.

"The principle we have applied does not, of course, set any precise limit to the weight which a flying machine may possibly be made to carry. It only says that the advantage in increasing the size and weight continually diminishes. There is a certain intermediate size where the maximum weight, perhaps that of one or more men, can be carried and this size can never be exceeded with advantage."

Professor Newcomb continues to dwell upon the facts above enunciated with considerable amplification and finally terminates his paper in the following words:

"Bearing in mind that no limit is to be set to the possible discovery of new laws of nature or new combinations of the chemical elements, it must be understood that I disclaim any positive prediction that men will never fly from place to place, at will. The claim I make is, that they will not do this until some epoch-making discovery is made, of which we have now no conception, and that mere invention has nearly reached its limit."

When the principle of the balloon was first discovered, the conclusion at once reached was, that the practicability of aerial navigation was readily within the reach of man, but we have seen that over a hundred years have passed since that event and in a comparatively few paragraphs we can sum up the results of progress made since that time.

First, with regard to the balloon or air-ship, it may be said that it is only within comparatively recent years that any successful attempts have been made to direct its motion of translation through space, irrespective of the direction of the drift of the wind. And it is only within the last twenty years that so-called dirigible balloons have been successfully constructed, all of them working, however, on the same principle or method of propulsion.

The modern structures of this type are all built cylindrical, or cigar shape, and are either forced or drawn through the atmosphere by means of screw-propellers in the same way that an ocean steamer is driven through the water.

The later constructions of this type of air-ship have the screw in front, the shaft driven by the modern high-speed combustion

engine, and the blades of the screw pitched at a proper angle to draw the structure with some considerable speed through the atmosphere.

In the German type of dirigible as recently designed and built by General Count von Zeppelin, the structure is driven by screw propellers projecting transversely from the axis or rigid deck of the air-ship, the propellers, however revolving on axes parallel to the axis of the ship.

In the French construction as used in the French air-ship "*La Patrie*" type, and other French dirigibles, the screw-propellers are arranged in a fore and aft direction, one propeller exerting to pull upon the structure parallel to the axis of the dirigible and the other to thrust parallel to the same axis. The direction of traverse is controlled more or less by a large rudder at the stern of the ship.

The new British dirigibles are substantially on the lines of the French balloons, although the supporting portion is somewhat different in shape, being generally blunter.

Both the French and British systems of construction produce a rigidity of envelope by means of the enclosed gas under greater pressure than the surrounding atmosphere, whereas in the German construction of General Count von Zeppelin the rigidity of the envelope of the ship proper is materially assisted by longitudinal ribs of aluminum, braced, I understand, more or less transversely, and held in place by circular ribs of the same metal attached to the longitudinal pieces at regular intervals. The skin of the envelope is supported on the framework above briefly described. It must be borne in mind that all these structures are drawn or forced through the atmosphere by means of screw-fans, as above referred to. Therefore, they are quite helpless in an ordinary gale of wind and can make progress from one point to another only when the conditions of the atmosphere are satisfactory for so doing.

Notwithstanding the difficulties of the problem and the limits of the utility of the dirigible air-ship, constructed as above described, it is thought that structures of this class will have in all future wars a far-reaching effect, and the attention of military authorities, particularly in Great Britain, Germany, and France, has been especially directed to the use of the dirigible for war purposes.

All of the countries above named are to-day building dirigible air-ships for the use of their armies in the field.

In contradistinction to the method of aerial navigation above briefly referred to is that which has attracted some considerable attention during the past few years, in what is known as the aeroplane. As the principles and performances of structures of this class have been so completely described in the public press during the last year or so I will not dwell upon this branch of the subject to any extent.

While, for the reasons above enumerated in this paper, I do not see that the aeroplane can come into any very general use for commercial or war purposes, yet great credit must be given to the men who have brought this system of aerial navigation to its present condition. There is no doubt also that for certain purposes the present aeroplane may be utilized conveniently and with some degree of success.

We cannot remove from our minds, however, the fact that aerial transportation by means of the aeroplane as it is at present constructed will always be attended by serious risk, as the slightest accident to the structure itself is quite sure to produce results which will be extremely disastrous. This has been shown in the unfortunate and most serious accident which took place at the Government tests of a machine of the class referred to during the past summer at Fort Meyer, Virginia.

Twenty-four years ago,—in the spring of 1885,—I began to give considerable attention to the matter of aerial navigation for war purposes, and at that time designed and submitted to the United States Government a form of dirigible air-ship, which I thought might be of use for Governmental purposes.

The structure which I then designed was substantially, in fact precisely of the same type as the air-ships now being built for the various Governments of the world, except that the method of propulsion which I suggested to be tried was different.

I submitted a picture taken from the publication known as "*Harper's Weekly*," of May 25, 1885, showing a copy of the air-ship which I then designed for the use of the Government.

The matter was considered by the Ordnance Department of the Army, and I understand that an appropriation was asked for the purpose of building one of these structures at the time, but owing to the lack of interest in the matter nothing was done.

The structure which I suggested was propelled through the atmosphere by a powerful jet of compressed air or steam, acting rearwards, as it seemed to me at that time that the difficulties of generating sufficient power to operate a screw-propeller were considerable; in fact you must remember that this was long before the practical development of the modern internal combustion engine, such as we see in use to-day.

I will now endeavor to explain as briefly as possible the recent investigations that I have made in this line, and state why I believe that the results may be of commercial use in the field of aerial navigation.

I have always been impressed with the fact that after the discovery of the balloon the next most important discovery would be to find some way of directing its course through the atmosphere, irrespective of the drift of the wind-current.

As at present used, nothing is more helpless than the ordinary balloon. It simply is blown with the wind; nothing can divert it from that course.

The construction of the modern dirigible balloon, drawn or pushed through the atmosphere by means of screw-fans, only partially solves the problem, as structures of this class, as I have before remarked, are perfectly helpless in a wind of any power.

I will endeavor to show that the discovery which I have made overcomes this difficulty and utilizes the very power which heretofore has been the great obstacle in the control of the flight of a balloon in a given direction not only to propel the balloon at a high speed in various directions through the air but also for the propulsion of the air-ship in quite the same manner as a ship with sails is sailed upon the ocean.

The slightest preliminary thought on this subject will indicate to any one that the difficulties of the problem are insuperable unless we can find in art or nature a means of devising some point or line of support upon which we can take hold, so to speak, in order to utilize the propelling effect of the wind-pressure upon the sails of our ship.

At first the thought will instantly come to our minds that the solution of such a problem is beyond the range of possibility—that the very idea is contrary to the basic laws of mechanics. We have here a body of considerable bulk, suspended in space a mile or so above the earth and driven aimlessly in any direction

in which the wind may be blowing. It is evidently impossible to obtain any hold upon the earth, and it would seem to be impossible to produce within or adjacent to the floating body itself any material substance possessing inertia upon which we could take hold in order to control to a certain extent the movements of this helpless floating structure.

Something must be devised or discovered against which we can oppose the resultant of the pressure of the wind on the sails of the ship; something in fact that will enable us to produce on this structure a condition of two or more forces struggling in unstable equilibrium.

If this condition of affairs can be produced it will be readily admitted by any one conversant with Kepler's laws that the structure acted upon by two forces such as I have above described will take up a motion of translation through space due to the resultant of the two forces.

After a careful study of the entire field of mechanics, I found that one principle and one alone could be utilized to produce the desired result.

The so-called mechanical paradox (which is not a paradox at all), known as the gyroscope, seemed to me to furnish the means sought, and the investigations and experiments that I have made have confirmed my views.

Before describing the use of the gyroscope adapted to the purpose in question it may be interesting to briefly mention the essential facts in regard to this peculiar instrument.

Its definition may be given as follows:

"The gyroscope is the name given by Foucault to an instrument for the exhibition of various properties of rotation, and the composition of rotations first described by Bohwenberger, in 1817.

"The invention is probably French or German, inventor not known; it dates from about the end of the eighteenth century.

"Its action is based on the principle that if a mass is set in rotation about one of its principal axes of inertia of greatest or least momentum, it will continue to revolve about it, and unless extraneous force is applied the direction of the axis will remain unchanged."

This mechanical device, you will thus see, has been in existence for about seventy-five or a hundred years, and its uses

have been limited to certain commercial and practical purposes, which I will speak of later.

I will describe briefly some facts in relation to the gyroscope, quoting from a paper by Professor Arthur Gordon Webster, Professor of Physics at Clark University, Worcester, Mass., published in the *American Review of Reviews*, July, 1908.

“THE PHYSICAL LAW INVOLVED.”

“Let us begin with the simplest possible mechanical phenomenon. Everybody knows that a body left to itself can do nothing but move in a straight line with unchanging speed. If we wish to hurry it, we must pull it ahead, and it pulls back; if we wish to retard it, we must pull it backwards, when it will pull ahead; and if we wish to divert it from its straight course, we must pull it sidewise, when it will also pull back or resist.

“This is what we mean by the inertia of a body, namely, its apparent unwillingness to do what we try to make it do.

“Thus the axis of a top, or fly-wheel, can take any direction in space, and all the time the centre of gravity of the top is a fixed point. The top can spin as before quite free from the action of gravity, and if it is carefully enough made the motion of its axis can be perceived in a few minutes. A practical application of this property is made use of in the Whitehead torpedo, which when discharged from a torpedo boat must be steered against the enemy, and carries, instead of a human steersman, a small gyroscope, mounted in rings.

“When the torpedo is discharged, the axis of the fly-wheel points at the enemy. If now a torpedo strikes any obstruction and is turned off its course, the axis of the gyroscope, true to its nature, keeps pointing in the same direction, and thus an outside ring turns relatively to the hull of the torpedo, and moves a little lever, which controls the steering engine, moving the rudder, and thus bringing the torpedo back on its course. It is this gyroscopic gear, invented by Austrian Lieutenant Obry, that has made the torpedo the instrument of precision, capable of doing the damage done by the Japanese to the Russian ships.”

“STARTLING PROPERTY OF THE GYROSCOPE.”

“We come now to the unfamiliar property of the gyroscope. If, with the top spinning quietly about its axis, we apply a force tending to change the direction of the axis, we find that the axis

resists the pull (or push), and that instead of moving in the direction in which we pull, it moves off in a direction at right angles. This is the *startling property of the gyroscope*, and if we understand this we understand every phenomenon connected with this supposedly mysterious apparatus.

"We can then explain this property by saying that if that force is exerted on a symmetrical top, tending to change the direction of its axis, the axis will not move in the direction of that force, but will tend to move at right angles thereto."

In the same publication and of the same date, Mr. J. F. Springer, referring to some applications of the gyroscope, particularly the wheel and rail problem of Brennan, and the prevention of rolling of ships at sea, by Dr. Otto Schlick of Berlin (which latter will be referred to at more length in this paper), closes his discussions as follows:

"The principles of the gyroscope are truly wonderful in their character. Some of these promise far-reaching and striking results in the world of practical mechanics. Certain of these applications may appear startling in their results. But that in itself is not sufficient reason to regard them as necessarily impossible.

"Let us view the future of the gyroscope in its engineering applications, not with credulity and an unreasoning acceptance of any and all marvels, but with a mind at once open and critical."

A BRIEF RÉSUMÉ OF THE PRESENT USES OF THE GYROSCOPE.

It is interesting to note the various commercial uses to which the gyroscope has been adapted in order to utilize its curious powers.

To the untrained mind it seems to possess mysterious faculties. It will support itself, for instance, suspended in space, at right angles to a cord, resisting continuously the constant force of gravity, while it is spinning at high speed.

Other interesting phenomena may be demonstrated by its means. The laws of rotating bodies, however, are well understood by mathematicians, and, while it is quite true that the mathematics of the gyroscope are complicated and abstruse, nevertheless there is no mystery about the matter, and the forces developed by the gyroscope follow the established laws of rotating bodies which are free to move and rotate at high speed on what I may term elastic axes.

The peculiar property that the axis of a rotating gyroscope possesses of continuously pointing in a fixed given direction, notwithstanding the motion of translation of the earth through space, and its independent rotation on its own axis, has been used by the astronomer for the useful purpose of maintaining the axis of his astronomical telescope constantly trained upon a star that he may be observing, thus being able to keep it continuously in the field of view while otherwise in a few seconds it would pass across the lens.

One of the first uses to which the gyroscope was adapted was to provide an artificial horizon on a moving vessel in order to make observations in marine navigation. For this purpose the gyroscope is caused to revolve on a vertical axis. This was in use for some time, and I believe is still in use in certain navies.

The gyroscope is used very effectually and almost universally in controlling the direction of traverse of the submarine war torpedo, particularly that deadly instrument of destruction known as the Whitehead torpedo now in general use in all navies of the world. In this case it is placed inside the casing and near the stern of the torpedo, and by an ingenious arrangement operates two small rudders which maintain the direction of traverse of the torpedo on its predetermined course. This action is effected by utilizing the same force that I use in aerial navigation, but, of course, in an entirely different manner.

The mono-rail system of Mr. Louis Brennan, uses the forces of the gyroscope to balance the cars on the single rail roadway that is used in this system.

The well-known and costly experiment of Sir Henry Bessemer, made by that distinguished and accomplished engineer about twenty-five years ago, to utilize the principle of the gyroscope to prevent the rolling of ships in a sea-way at sea, may be also referred to. Sir Henry failed in the experiment, for the reason that he overlooked one of the essential laws of the revolution of the gyroscope, and it is said that he expended about a million dollars on this work.

Dr. Otto Schlick, a German engineer of Berlin, first demonstrated the practical utility of the gyroscope in preventing a ship from rolling in a sea-way. I will quote the description of this from the interesting paper of Mr. Henry Smith Williams, published some months ago. (See also the official report read by Sir William H. White before the Society of Naval Architects,

Great Britain, published in *Engineering*, London, April 5, 1907, also on page 794 of *Engineering*, London, June 7, 1907, "Mono-Rail.")

"In the year 1904 Dr. Schlick elaborated his theory before the Society of Naval Architects in London. His paper aroused much interest in technical circles, but most of his hearers believed that it represented a theory that would never be made a tangible reality. Fortunately, however, Dr. Schlick was enabled to make a practical test, by constructing a wheel and installing it on a small ship—a torpedo boat called the *Sea-bar* discarded from the German navy.

"The vessel is 116 feet in length and a little over 56 tons displacement. The device employed consists of a fly-wheel one metre in diameter weighing just over 1100 pounds and operated by a turbine mechanism capable of giving it a maximum velocity of 1600 revolutions per minute. This powerful fly-wheel was installed in the hull of the *Sea-bar* on a vertical axis, whereas the Brennan gyroscope operates on a horizontal axis. So installed, the Schlick gyroscope does not interfere in the least with the steering or with the ordinary progression of the ship. Its sole design is to prevent the ship from rolling.

"The expectations of the inventor were fully realized. On a certain day in July, 1906, with sea so rough that the ship rolled through an arc of thirty degrees, when the balance wheel was not in revolution, the arc of rolling was reduced to one degree when the great top was set spinning and its secondary bearings released. In other words, it practically abolished the rolling motion of the craft, causing its decks to remain substantially level, when the ship as a whole heaved up and down with the waves."

These remarkable results, with more in kind, were recorded in the paper which Sir William White read before the Institution of Naval Architects in April. He himself had witnessed tests of the Schlick gyroscope, and, in common with his colleagues, he accepted the demonstrations as unequivocal.

THE PRINCIPLE OF THE SCHLICK GYROSCOPE.

"Fully to understand the action of Dr. Schlick's invention, one must know that it is not a mere wheel on a single pivot, but a wheel adjusted in such a fashion that it can oscillate longitudinally while revolving on its vertical axis. In other words,

it is precisely as if one of the two gyroscope wheels used in the Brennan car were so placed that its main axis was vertical, its secondary axis, or axis of oscillation, being horizontal and at right angles to the ship's length. Thus while spinning on its vertical axis the body of the top is able to oscillate, pendulum-like, lengthwise of the ship.

"If you apply a brake to prevent the longitudinal motion of the gyroscope, the effect, even though the fly-wheel still revolves at full speed, is precisely as if you pinioned the arms of a strong man, so that he saw the futility of resistance and made no struggle to free himself. Under such circumstances the gyroscope, though it continues to spin as hard as ever, has no effect whatever in preventing the rolling of the ship; it stands there, like the strong man bound, expressing its discontent with an angry groan.

"But if you release the brake so that the entire mechanism is free to oscillate lengthwise of the ship, all is changed. It is as if you cut the cords that bound the strong man's arms. Instantly the mechanism springs into action. It will no longer allow itself to be swung with each roll of the ship; it will resist and prove which is master. Its mighty mass, pivoted on the lateral trunnions, lunges forward and backward with terrific force, as if it would tear loose from its bearings. It causes the ship to pitch a trifle fore and aft as it does so; but meantime its axis stands rigidly erect in the lateral plane, though the waves push against the sides of the ship as before. The decks of the vessel that were tipping from side to side, so that loose objects slid from one rail to the other, are now held rigidly at a level, scarcely permitted to deviate to the extent of a violent tremor.

"The gyroscope has won the contest. To maintain its victory it must continue its backward and forward plunging; but from side to side its axis will not swerve.

"It was the failure to understand that a gyroscope wheel, to work effectively, must be given the opportunity to oscillate in this secondary fashion that led Sir Henry Bessemer to spend an enormous sum in a vain effort to accomplish on a small scale what Dr. Schlick's gyroscope accomplishes for the entire ship."

I have quoted this description of the use of the gyroscope in marine navigation for the reason that it shows the practicability of its adaptation to the purpose for which I have utilized it; and

while it is true that the two systems are entirely different, and that forces are used in my system that are not considered in the least in the former, and that there is a most radical difference in the two things, yet, you will note the comparatively small wheel that controls the torpedo boat, and its very reasonable rate of revolution, all of which indicate the practicability of my discovery.

THE DIRIGIBLE BALLOON WITH GYROSCOPE CONTROL.

This new discovery for the propulsion of dirigible air-ships is based on the development and application of gyroscope forces, in combination with the force developed by the wind-pressure on the sail of the air-ship.

The following well-known law of mechanics may be taken as the basis of this discovery. It is one of the laws which govern the motions of the celestial bodies, the sun, the planets, and the other stars in their revolutions through space: A body suspended in space and free to move in any direction, if acted upon by two or more extraneous forces will take up a motion of translation in the line of its least resistance, due to the resultant of the forces acting upon it.

The following law relating to and governing the movements of rotating bodies, may also be here referred to, viz.: When a body rotating upon a principal axis is subjected to a force tending to produce another rotation not parallel to the former, the resultant effect is such displacement of the axis of the original rotation, with respect to its support, as is most favorable to the parallelism of the two rotations, and such displacement is at right angles to the direction of the disturbing force.

I have discovered that by utilizing the reactive gyroscopic force manifested upon any attempt to change the direction of the axis of a rotary body, in combination with the wind-pressure upon a balloon floating in the atmosphere and carrying said body; that the movement of the balloon may be variably determined and controlled by correlation of the force developed by the gyroscope and the force of the air-current.

In other words my invention provides means whereby wind-pressure tending to diverge a balloon from a predetermined direction of traverse, may be variably opposed by the gyroscopic effect of a rotary body carried by the balloon under the control

of the operator, so that such wind-pressure may be utilized to propel the balloon in directions oblique to the wind-pressure, as in ordinary marine navigation.

The gyroscopic effect that I refer to is due to the fact that a rotary body tends to maintain constant its plane of rotation and consequent direction of its axis of rotation such effect being increased or diminished in correspondence with the speed of rotation of the body.

It is important to note, however, that to render such reactive effect available it is necessary to so mount the rotary body that its axis of rotation is free to oscillate to a limited extent in a direction parallel with the direction of said axis.

The use of the gyroscopic forces that I have described *gives us a line of support against which we may apply and utilize wind force to propel our craft.* Developing the forces of the gyroscope and utilizing them in combination with the wind-pressure in the manner that I do *actually provides a lever in space without a fulcrum on the earth.* The results following from this fact are very interesting.

By the proper use of sail and rudder and gyroscopic forces the dirigible air-ship may be sailed in various directions through the atmosphere, when the wind is blowing at variable speeds, and, as we are navigating on an ocean some five miles in depth, with no rocks or obstructions, you can readily realize the vast possibilities of the dirigible air-ship, particularly for war purposes.

I will now explain the small model that I have here, which shows the resistance of the gyroscope attached to the deck of a dirigible air-ship to the resultant of the wind-pressure on the sail of a ship.

You will note the manner of suspension of the gyroscope hung beneath the deck of the dirigible in such a manner that it is quite free to oscillate like a pendulum, transversely to the axis of the ship; the horizontal axes supporting the entire structure, or, as you will observe, being above the centre of gravity of the rotating mass.

I will show the effect of wind-pressure on the sail of the ship in two ways; first, where the small mast supporting the sail is attached directly to the deck of the dirigible, and, secondly, where said small mast is attached directly to a vertical arm connected with one of the supporting trunnions of the frame of the gyroscope.

The effect in both cases is similar. Two forces are struggling for the mastery of a body floating in space. The forces referred to are the force developed by the high-speed rotation of the gyroscopic wheel and the resultant of the force of the wind on the sail of the ship.

The former force tends to maintain the axis of the dirigible in a parallel direction; whereas the force of the wind-pressure on the sail tends to twist said axis out of its line of direction.

FIG. 1.

W, wind; *RW*, resultant of wind; *DE*, sail. Draw *AX* parallel to *DE*. From point *D* erect at right angles to *DE*, and prolong same until it intersects *AX* at *B*. Draw *BC* at right angles to *HG* and *CD*=force in direction *H* to propel the ship. The structure being held in the direction *HG* by the gyroscope *G*.

The result of the operation of these two forces is, that the body is acted upon by a resultant force tending to give it a motion of translation through the atmosphere on the line of the resultant aforesaid, and also on the line of the least resistance of the entire structure to motion.

I do not claim absolutely that the dirigible balloon can be driven in any direction through the atmosphere by the forces aforesaid, independent of the direction of the drift of the wind, but

to the sail. GE will be the effective resolution of this component applied to pushing the ship in the direction H .

In Fig. 2 we show the composition and resolution of forces acting upon the deck of the dirigible to drive same in the direction H , as shown. In this drawing W represents the wind. RW represents resultant of wind-pressure. DB represents sail.

Draw Ax parallel to DE . From point D erect perpendicular to DE and prolong same until it intersects Ax at B . Draw BC

FIG. 3.

perpendicular to HG and CD equals force in direction H to propel the ship. The structure being held in the direction HG by the gyroscope G .

CONSTRUCTION OF THE GYROSCOPE.

The gyroscope may be constructed to operate by either a power of steam, electricity, or on the combustion engine principle. I prefer the latter owing to its simplicity, and submit herewith a photograph of a gyroscope consisting of five cast-iron cylinders rotating about the common shaft (Fig. 3). This engine is built

by the Adams Company, Dubuque, Iowa, and is operated in a horizontal position on a vertical axis to propel an automobile. By turning the engine and operating it on a horizontal axis, supported in an oscillatory frame, as shown on the small model herewith submitted, the construction of the gyroscope is at once solved, without the necessity of any expensive experimentation.

The photograph submitted shows engine in a quiescent state and also rotating at a speed of about a thousand revolutions per minute.

THE CONSTRUCTION OF THE ENVELOPE, OR WHAT IS PRACTICALLY THE HULL OF THE SHIP.

Of course in a dirigible it is essential that the envelope should possess a certain degree of rigidity to enable it to be forced through the atmosphere in varying directions and at some considerable speed.

I have heretofore in this paper described the method of construction of the German, French, and English dirigibles, all of which possess the property of rigidity of envelope to a certain degree.

While I do not regard it as at all essential, yet I think it would be quite feasible to construct a dirigible balloon out of plates of rolled aluminum. These plates are $1/100$ in. in thickness and weigh .1396 pounds to the square foot. They will stand a tensile strain of 23,000 pounds per square inch.

I think that it will be feasible to construct the body of the dirigible out of plates of this metal lined on the interior with a silk material impervious to gas.

The following calculations show the lifting power of a dirigible balloon cylinder, 200 feet long, 50 feet in diameter, terminated by cones at both ends each 50 feet in length, the said dirigible balloon being made of aluminum plate above described.

CALCULATIONS.

Weight of cu. ft. of air = .0765 lbs.

Weight of cu. ft. of hydrogen = .00527 lbs.

Weight of sq. ft. Al. $1/100$ in. thick = .140 lbs.

Weight of government envelope = 5.842 oz. per sq. yard, .04 lbs. per sq. ft.

Area of circle = πR^2

R = radius.

Circum. of circle = $2\pi R$.

Volume of cone = $\frac{1}{3}$ area of base $\times$ altitude.

Surface of cone = circumference of base $\times \frac{1}{2}$ slant height.

CALCULATIONS FOR THE CONSTRUCTION OF A DIRIGIBLE AIR-SHIP.

200 ft. in length;
50 ft. in diameter.
Cylindrical in shape (with pointed ends) bow and stern.
The calculation of the cylinder aforesaid.

This calculation is based upon the following data:
1 cu. ft. of air weighs .0765 lbs.
1 sq. ft. of aluminum metal plate, 30 gauge, 1/100 of an inch thick, weighs .140 lbs.
1 cu. ft. of hydrogen gas weighs .00527 lbs.
 $C = 2\pi R = 2 \times 3.1416 \times 25 \text{ ft.} = 157.08 \text{ sq. ft.}$
 $157.08 \times 200 = 31400 \text{ sq. ft.} = \text{surface of cylinder.}$
 $31400 \times .14 = 4396 \text{ lbs.} = \text{weight of cylinder.}$

Area of base of cylinder, $S = \pi R^2 = 3.1416 \times (25)^2 = 1963.5 \text{ sq. ft.}$
 $1963.5 \times 200 = 392700 \text{ cu. ft.} = \text{contents of cylinder.}$
 $392700 \times .0765 = 30041.55 \text{ lbs.} = \text{weight of air displaced.}$
 $392700 \times .00527 = 2069.52 \text{ lbs.} = \text{weight of the hydrogen in the cylinder.}$

Weight of the cylinder = 4396 lbs.
Weight of hydrogen in same = 2069.52 lbs.
Total weight of C. & H. = 6465.52 lbs.

Weight of air displaced by the cylinder which is equal to the buoyant effort = 30041.55 lbs.
Total weight of C. & Hy. = 6465.52 lbs.
Total buoyant effort = 23576.03 = 11 tons +.

THE TWO CONES THAT FORM THE ENDS OF SHIP.

Vol. = $\frac{1}{3}$ area of base $\times$ length.
Area of surface = area of base $\times$ slant height.
Radius of base.
D = 50 ft. R. = 25 ft. $\perp$ = 50 ft. slant height = 70 ft.
Area of base.
Vol. = $\frac{1}{3}$ of 1963.5 sq. ft. $\times$ 50 ft. = 32725.0 cu. ft. contents.
Surface = $\frac{1963.50}{25} \times 70 = 5495 \text{ sq. ft.} = \text{surface of cone.}$

Total 2 cones.....	5006 lbs.
	<u>1883 lbs.</u>

Buoyant effort of both cones.... 3123 lbs.

Cones weight 769.3

Gas weight 172.5

941.8

.2

Total 2 cones weight.....	<u>1883.6</u>
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$32725 \text{ (contents in cu. ft.)} \times .0765 \text{ (wt. of 1 cu. ft. of air)} = 2503.4625 \text{ lbs.} = \text{weight of air in lbs. in cone displacement, and } 32725 \text{ (contents in cu. ft.)} \times .00527 \text{ (wt. of 1 cu. ft. of H.)} = 172.45 \text{ lbs.} = \text{wt. of hydrogen in cone.}$

And

$5495 \text{ sq. ft.} \times .14 \text{ (wt. of 1 sq. ft. of Al. plate)} = 769.3 \text{ wt. of cone.}$

And

$769.3 \text{ (cone wt.)} + 172.5 \text{ (gas wt.)} = 941.8 \text{ lbs.}$
 And $941.8 \text{ lbs.} \times 2 \text{ (two cones)} = 1883.6 \text{ lbs.}$ weight of the two cones, with their gas.
 $2503 \text{ (displacement of 1 cone)} \times 2 = 5006 \text{ lbs.} = \text{wt. of the air displaced by the two cones.}$
 $769.3 \text{ (wt. of 1 cone)} + 172.5 \text{ (gas wt. in 1 cone)} = 941.8 = \text{wt. of cone and H. gas, and } 941.8 \times 2 = 1883.6 \text{ wt. of 2 cones and their H. gas.}$
 Therefore $5006 \text{ lbs. (wt. of the air in both cones)} - 1883 \text{ lbs.} = 3223 \text{ lbs.} = \text{buoyant effort of both cones.}$
 Total $23576.03 \text{ lbs. (buoyant effort of cylinder)} + 3123 \text{ lbs. (buoyant effort of cones)} = 26699 \text{ lbs.} = 13 \text{ tons.}$

As a corollary to the method of controlling a dirigible balloon by means of gyroscopic forces, as hereinabove described, I desire to submit the following suggestion, in regard to explaining the method of flight of certain birds that are enabled to progress for long distances in the horizontal plane, parallel to the surface of the earth, without moving their wings in the least. Of course the motion of translation of soaring birds and also those which are progressing in planes at more or less of an angle to the surface of the earth is a comparatively simple matter to explain, as it is simply a motion of progression dependent upon the use of the incline plane or the helix; but when a bird such as the albatross will hold its wings perfectly rigid and follow a ship for a number of days consecutively, progressing all the time in the horizontal plane, parallel to the surface of the ocean such progress has never been susceptible of explanation.

Mr. Maxim, I think, and others have attempted to explain this matter by imagining vertical currents of air at right angles to the surface of the earth, which assist a bird in its progression in the horizontal plane.

I think that the hypothesis of vertical currents of air assumed to account for the matter is untenable and impossible of proof and contrary to reason.

I have recently had an opportunity to carefully observe and study the method of sailing of the turkey buzzard, and believe that its motion of translation in the horizontal plane without moving its wings is due precisely to the practical development and action of the forces that I have described in connection with the gyroscopic dirigible balloon.

The bird points its head in the direction that it wishes to go, at an angle to the wind, and consequently maintains its body more

or less rigid in the same direction; its wings acting as sails receive the pressure from the wind, which is resisted by the rigidity of the body of the bird, naturally holding himself in the direction that he wishes to travel—the resultant force impels the bird in the horizontal plane at high speed at an angle to the drift of the wind.

The rigidity of the longitudinal axis of the bird is precisely comparable to the rigidity of the longitudinal axis of the deck of the dirigible balloon, held in that line by the force of the gyroscope. The resultant of the forces of the wind-pressure on the sails and the resistance of the gyroscope to be pushed out of its plane of revolution naturally impel the structure to take up a motion of translation in the horizontal plane and in the line of the least resistance.

INDIA'S MICA INDUSTRY.

THE Consul-General of Calcutta, advises that an American company has acquired a mica mine near Kodarma which is on the East India Railway, 250 miles from Calcutta, and is operating with success. The output in 1907 was curtailed somewhat by financial conditions in the United States, whether the whole production of the mine is exported. The company is really a part of a concern operating in the United States in the manufacture of mica goods of all kinds. The company employs 700 hands at Kodarma and a European assistant superintendent, all under a practical mica man, who is a native of the United States. The company shipped in 1907 200 cases of 100 pounds each and expects to increase the amount. The mica-mining industry in other districts is reported to be steadily increasing. The total exports of mica during 1907 increased by \$477,666 over the previous year, or 59.75 per cent.

GROWING EASTERN HARDWOODS IN CALIFORNIA.

The Pacific Coast will soon be the scene of an interesting tree-growing experiment. The United States Forest Service is planning to introduce a number of the more important eastern hardwoods into California, and will this year experiment with chestnut, hickory, basswood, red oak, and yellow poplar or tulip trees. Small patches of these trees will be planted near the forest rangers' cabins in the National Forests, and if these do well larger plantations on a commercial scale will soon be established on wider areas.

There are over 125 different species of trees in California, a number of which produce some of the most valuable varieties of lumber in the country. Although considerably over one-half of the species are hardwood or broad-leaved trees, yet, with the exception of the exotic eucalyptus, there is not a single species of hardwood here ranking in commercial importance with the leading eastern hardwoods. Climatic conditions in many parts of California are undoubtedly favorable for the growth of a number of the valuable hardwoods, and the absence of these trees is due mostly to unfavorable factors of seed distribution.

If the experiments are successful, a valuable asset will have been added to the forest resources of this State, which should prove of special benefit to the local furniture and vehicle industries. Chestnut and red oak are highly esteemed for furniture, while with hickory, basswood, and eucalyptus at its command, California should lead all other States in the vehicle industry.