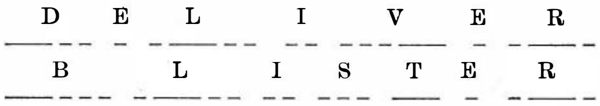
her husband had also sailed without fail to New York. Another class of errors is that due to defects in the apparatus. Printing telegraphs, especially new ones, drop letters occasionally. In one instance in London the letter *z* was missed from the address "Zurich," so that the message read "Urich." By some unhappy chance there is a town named Urich in Montana, in the United States, and the telegram accordingly went to America instead of Switzerland. The mistake was not discovered till the message had come back from Urich in America, undelivered, two days afterwards.

On the other hand, it is the general experience that good printing telegraphs reduce the number of errors in telegrams compared with the Morse key and sounder. Printing telegraphs eliminate a whole class of errors due to misreading of Morse signals. Also signals sent by a machine are of necessity more precise and accurate than hand signals can possibly be. It is for this reason, among others, that automatic transmission is now practically universal on ocean cables. It is an undoubted fact of experience, both in Great Britain, the United States, and other countries, that printing telegraphs, when in satisfactory working condition, reduce the percentage of errors very materially compared with the Morse key and sounder.

As an example of a Morse error the following may serve. A message was handed in at an office in Ireland: "Deliver Ten Pigs." This was mutilated in transmission into "Blister ten pigs." The Morse signals are identical, but the spacing differs, thus:



Complaint was made about the pork and mustard error, damages claimed, and sixpense, the cost of the telegram, was refunded by the Post Office.

Not only is long experience necessary for the quick detection of errors, but familiarity is also desirable with the traffic on particular circuits. Registered addresses are often peculiar, and slight mistakes on the part of the sending operator might cause a wrong delivery of a message. Experience on a circuit will detect such errors at once, as registered addresses occur frequently on particular circuits and become familiar to the receiving operator. Also the usual trade contractions must be known—for instance, "fmcht" for "fishmerchant." "Ystradyfodwg" is a real name, though it does not look right to the uninitiated. "Gwrwch," another Welsh town, is also correct, although its looks are against it. "Gablonzanderneisse" is obviously correct, and "Stcatherinesontario" and "Stmaloilleetvilaine" are quite right and count as one word each. Printing telegraphs occasionally become what the French called "derailed" for a few seconds, and a meaningless jumble of letters is printed. Fortunately this kind of error is recognizable after a little experience, as the "derailment" gives characteristic results with each kind of printing telegraph. Hence the only evil consequence is a little delay. Code and cipher messages are also a sore trial for the telegraph operator, but such messages come through, on the whole, more accurately on a good printing telegraph than with the Morse key and sounder.

The method of getting corrections and making inquiries is ingenious and brief. RQ is the British signal for an inquiry, and the following contractions are used:

A A = All after.
W A = Word after.
L W = Last word.
M M = Office of origin.

"What is the word after urgent in message No. 125" would be sent "125 W A urgent." If the last word is in doubt, the inquiry would be "125 L W." The sending operator also anticipates inquiry in regard to curious words by repeating them at the end of the message. This saves time.

(To be continued.)

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# Aeroplane Stability

By Arthur Holly Compton, Physics Laboratory, University of Wooster

When we remember that during the past year men have flown from almost dawn until dark, covering hundreds of miles without touching the ground, we realize that support in the air is no longer a troublesome problem; but when we look at the long list of fatalities that have occurred, we see great room for improvement before men will be able to use the air as safe highway. In considering these accidents, we find that they arise mostly from three causes: 1, Faulty construction; 2, undue recklessness, and 3, poor equilibrium. The first of these does not concern us at present, for it requires only a few years' experience before this fault will be overcome; and if an aviator wishes to deliberately turn his machine down at an angle of 45 degrees until it strikes the ground, we have no means of preventing him; but is it not possible to so construct the machine that with reasonable care the large proportion of accidents due to faulty balance may be prevented? It will be the purpose of this paper to determine the conditions on which the stability of aeroplanes depend, and to suggest some means whereby such stability may be automatically maintained under all possible conditions.

In order to understand the difficulty of this problem, we must first obtain some idea of the turbulence of the air. Even in the calmest weather the atmosphere is greatly disturbed. The sun shining on each dry field and on the roof of every house forms enormous bubbles of hot air, which rise up in great inverted whirlpools through the colder strata above. The winds are far from being regular currents of air. Like breakers on a seacoast, the wind strikes each tree and house and hill, glancing up hundreds of feet in whirling columns. One obtains an idea of the disturbed state of the atmosphere when one sees an aeroplane knocked up or down by a sudden gust of wind, 10, 20 or even 30 feet in a few seconds.

The problem of stability resolves itself into keeping the center of air pressure and the center of gravity in the same vertical line, while sailing through these rolling masses. The first experimenters tried to do this by shifting their weight while flying, but found it a difficult and at times impossible task. Otto Lilienthal, after making over a thousand successful glides in this manner, was finally overturned by the wind and killed. In 1901, however, the Wright brothers constructed a flyer on a new principle. Instead of shifting their weight to keep the machine balanced, they put a horizontal rudder in front, by which they could keep themselves from turning over frontward or backward, and twisted the tips of their wings to obtain lateral stability. With a little practice on this machine they could work it semi-automatically, like a bicycle.

The principle on which Wright's aeroplane works, that of operating stabilizing planes to counteract every variation of the position of the center of air pressure due to changes in the direction and velocity of the wind, is now used on every successful type of aeroplane. With the elevators and stabilizing planes made of moderate size and placed at the ordinary distance from the center of gravity, the balance of the aeroplane may be kept under perfect control in the most irregular winds, if the auxiliary surfaces are always set in the proper position. But when we remember that at times the birds themselves are knocked over by gusts of wind, and sometimes even fall to the ground before they can regain their equilibrium, is it surprising that sometimes the most experienced aviators should not be quick enough to set the rudders to meet every gust?

What, then, will happen if the aviator is attacked by "air-sickness" or becomes unconscious on account of too rapid rising or falling through the air? In order to avoid accidents from these causes it is necessary so to construct the aeroplane that it will be securely kept in the proper position, either by in-

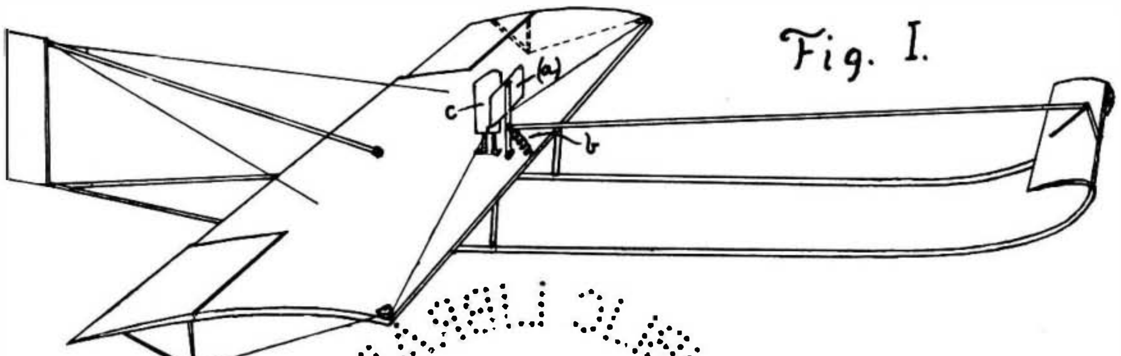


Fig. I.

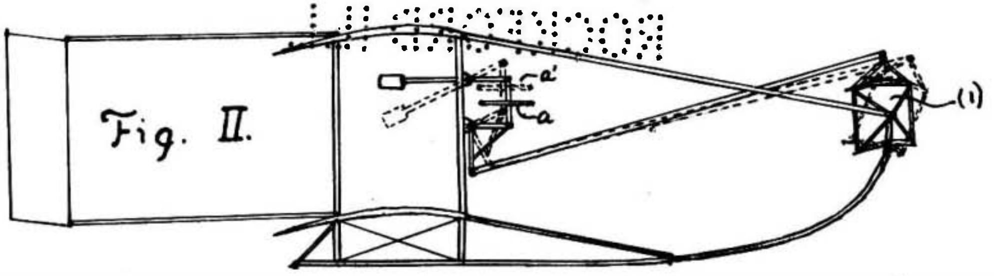


Fig. II.

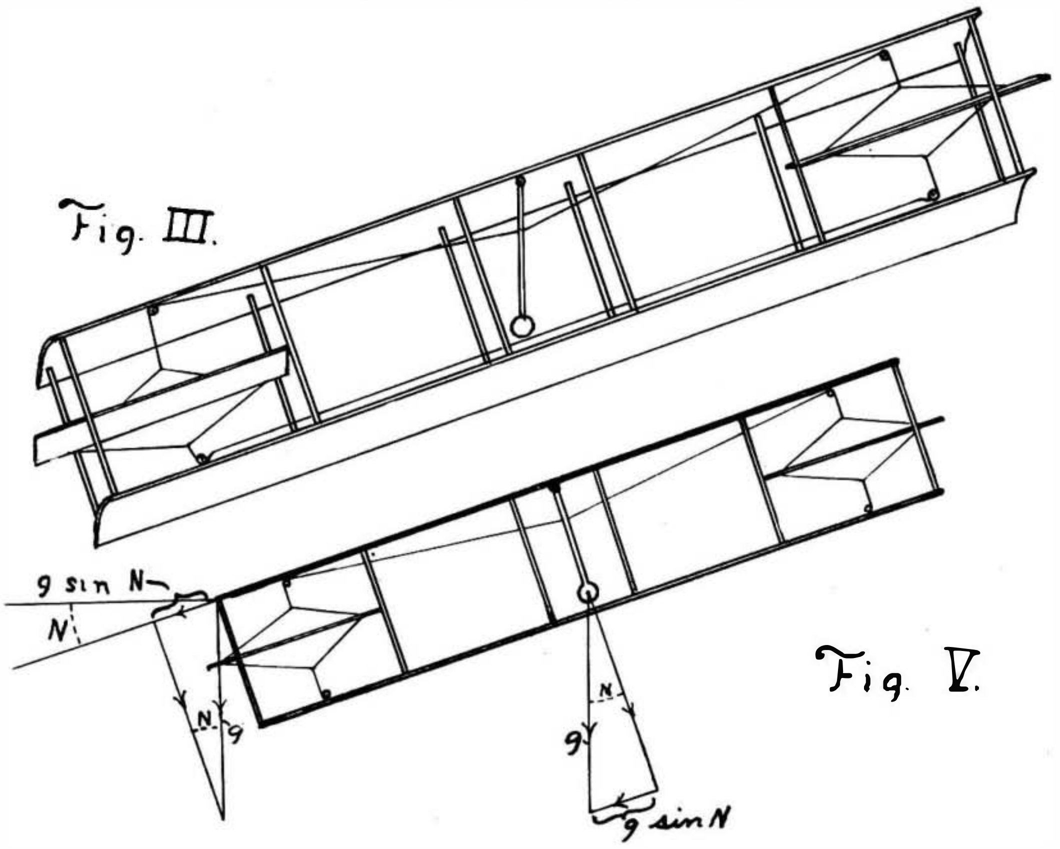


Fig. III.

Fig. V.

Fig. 1.—Automatic control by means of regulating planes. Fig. 2.—Form of control used by the Wright brothers. Figs. 3 and 5.—Diagram showing the fallacy of the pendulum control.

AUTOMATIC STABILIZERS FOR AEROPLANES

herent stability or by some controller which will automatically adjust the balancing surfaces.

The principle on which inherent fore-and-aft stability depends is comparatively simple. The center of gravity of the aeroplane is placed in front of the center of normal air pressure, and the forward planes are inclined upward at a greater angle to the line of flight than are the planes behind. If an aeroplane so adjusted be allowed to fall from a great height, since the center of gravity is in front of the center of normal air pressure, the front will turn down and the machine will dive toward the ground. Then, when it has gained sufficient speed, since the forward planes are turned upward, the front receives a proportionately greater air pressure and the machine rights itself. Whenever the aeroplane turns up in the air, its speed diminishes until the front again drops. In this manner its angle of flight through the air is kept constant.

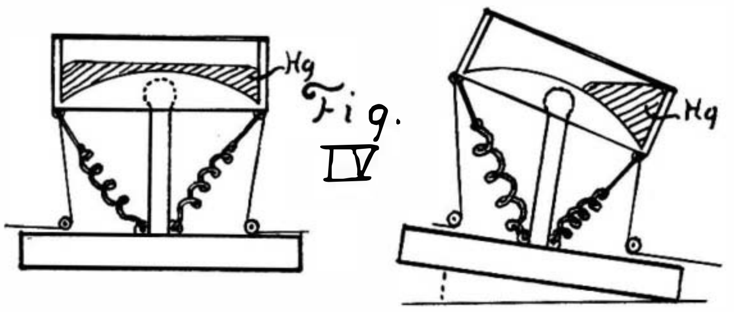
There are two different principles by which inherent lateral stability is secured. The first of these is simply to bend up the outer ends of the wings at a dihedral angle, or to use vertical surfaces with a low center of gravity. Both of these constructions give the same result: The air pressure on the lower side is increased, thus making this side rise. The other method is somewhat more complicated. In this case there must be a vertical plane at some distance behind the center of gravity. Now if the aeroplane tips to one side, it will slide sideways until the air catches the vertical plane in the rear and turns it head into the wind. The result is that, instead of upsetting, the aeroplane merely turns around. If there is a constant upsetting force, however, the radius of the turn becomes smaller and smaller, and unless corrected by the controlling planes, the machine strikes the ground banked at a steep angle. But this principle works fairly well even in high winds, and is used on nearly all successful aeroplanes.

However, though in this manner an aeroplane may be made to keep its balance in still air, when winds arise troubles arise with them. Since the stability of the machine depends upon the reaction of the air upon it when the force of gravity pulls it one way or the other, whenever it is struck by wind gusts the balance is disturbed. For instance, just as when the aeroplane flies too rapidly through the air it turns upward until its velocity becomes less, so if a wind strikes it in front its speed through the air is increased and the front turns up, while if the wind comes from behind its speed through the air is diminished and it heads toward the ground. If the wind gust is sharp and the aviator is flying low, he may strike the ground before equilibrium can be recovered. Indeed, it is supposed that this is the manner in which Moisant was killed last December. The writer has found by innumerable experiments with models of every description that in general the closer the centers of normal air pressure and gravity are to each other the less the longitudinal stability is influenced by variable air currents. It is almost impossible for a well-balanced aeroplane to be completely overturned while in the air, but it may be easily tipped to an angle which is very dangerous, especially when close to the ground.

This means of obtaining automatic equilibrium is the only one in common use to-day, but we have just noticed that although it works very well in calm air, when it is used in the air-whirls of every-day flying, it becomes a source of danger rather than safety. If every time the aviator comes within 50 feet of the ground he is in danger of finding too quickly the bosom of Mother Earth, it will require a great deal of persuasion to convince the thinking man that the aeroplane is a practical and safe means of transportation. We must therefore, if we wish to make the aeroplane practical, so construct it that it cannot be tipped at a steep angle except at the will of the operator.

As was noted above, the constructors of all good flying machines are careful to have ample power in their controlling surfaces to counteract any movement of the center of air pressure caused by variable wind currents. So if we are able in any manner to set the balancing planes to counteract these changes, we will have perfect equilibrium at all times in the most choppy wind gusts. The controllers which are used to regulate the supplementary surfaces in this manner may be divided into three different classes: 1. Those which depend for their balancing properties upon the action of the air when the position of the aeroplane is altered; 2, those which depend upon the action of gravity, such as pendulums, and 3, those which depend upon some other force than gravity and the reaction of the air to control the balancing planes. We shall take up each of these classes in detail, explaining its action, pointing out faults and merits.

The most simple form of controller which depends upon the reaction of the air is that in which the longitudinal stability is regulated by a plane which is struck by a wind from the front, and the lateral stability by a plane which is acted upon by air currents from either side, as shown in Fig. 1. In this diagram, when the aeroplane turns down, the increased speed through the air makes extra pressure on the wind-plane *a*, and, forcing it back, turns up the horizontal rudder. If it turns up, the air pressure diminishes, and the spring *b* brings the plane forward and turns the rudder down. If the aeroplane turns to one side, it slides down edgewise until there is sufficient wind pressure on the vertical surface *c* for it to adjust the ailerons so as to regain balance. The fault with this style of controller is, however, very evident. Since the position of the balancing planes depends entirely upon the wind striking the controller, whenever any wind gust strikes the machine its stability is greatly disturbed. It is, indeed, much more sensitive to the pitfalls of the air than the machine which secures stable equilibrium by means of fixed supplementary surfaces as described above. Thinking to eliminate this trouble with wind gusts, the Wright brothers invented a controller for longitudinal stability, which keeps the flyer soaring at a definite angle of incidence instead of at a constant velocity through the air. The principle of this controller is shown in Fig. 2, which, however, leaves out the rather complicated compressed air connections which set the horizontal rudder according to the position of the controller. The regulating plane *a* is placed parallel to the plane of flight, and is connected by levers and rods with the elevator *l*. Whenever the aeroplane turns up, the wind strikes the under side of the controlling plane and the rudder is directed down, or *vice versa*. The Wright brothers have used this apparatus on their flyer with some success, although oscillations occur, especially in windy weather; they say they cannot trust it as well as themselves. The reason for this is clear. It is affected by wind gusts in much the same manner as was the other controller, though not as strongly. Let us consider just one case in which this device endangers the aviator's life. Suppose a sudden gust of wind strike him from behind. Since the speed through the air is decreased, the aeroplane will drop down, increasing the angle of incidence. The air striking the wind-plane directs the rudder down, thus turning the machine toward the ground. If it is allowed to go far enough, the velocity will be increased so that the angle of incidence will again become normal, and the aeroplane will resume a horizontal position; but if it is only a few yards in the air, it will crash to the ground before it can regain its equilibrium. This one case is sufficient to show that the controller which is being considered is unsatisfactory.



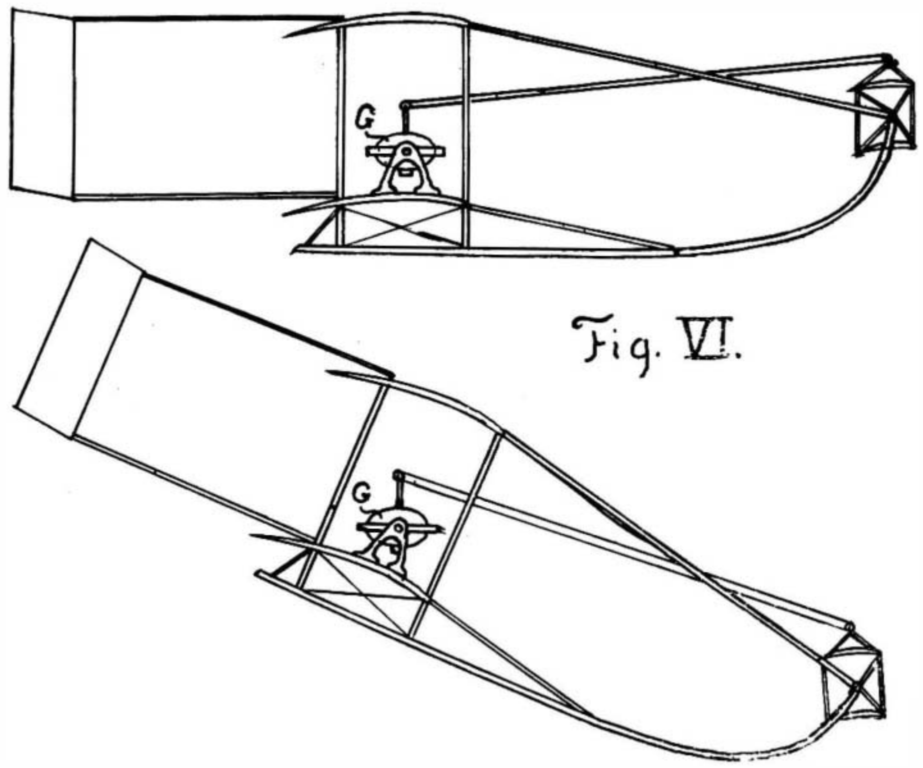


Fig. 4.—A mercury bath as a substitute for a pendulum. Fig. 6.—The gyroscope as used for automatically controlling the balancing planes.

AUTOMATIC CONTROLS FOR AEROPLANES.

We have shown, then, that the wind-plane cannot be used as a controller in either a horizontal or a vertical position. Let us now consider the pendulum in that capacity, as one of the class which depends upon gravity for its balancing powers. The intended action of this instrument, as shown in Fig. 3, is that when the aeroplane changes its position with respect to the direction of the force of gravity, the pendulum will remain vertical, and either by direct connections or by operating valves for compressed air, will set the balancing planes so as to re-establish equilibrium. One great difficulty with this device is that, when starting or stopping the machine, or when it is struck by wind gusts, the pendulum oscillates so violently that all stability is destroyed. But this difficulty is not insurmountable. These oscillations can be damped by friction or by a water basin, or a mercury level such as shown in Fig. 4 may be used in place of the pendulum. But even though these oscillations may thus be made negligible, the pendulum when used as a controller does not preserve a vertical position except by the reaction of the air upon the aeroplane, and therefore cannot be successfully so used. This fact is illustrated by Fig. 5. If the aeroplane is tipped at an angle *N* there is an acceleration due to gravity, tending to bring the pendulum back to a vertical position, which is evidently equal to $g \sin N$. But supposing the resistance of the aeroplane to motion in a horizontal plane to be zero, when tipped at an angle of *N* degrees its acceleration in the same direction is also $g \sin N$, the same as that of the pendulum This being the case, there is no force to change the latter's position with reference to the former. If, however, as is always the case, the aeroplane offers some resistance to motion in a horizontal direction, as its speed through the air under the influence of gravity is increased, the resistance will increase, and its acceleration will correspondingly diminish. The controller will then resume its perpendicular position, and by means of its connections adjust the balance of the flyer. But here we find our former difficulty: If it is only because of the air resistance that the controller works, it will be affected by wind currents. For instance, if a sharp gust of wind should strike the machine from one side, it would blow the wings over, while the pendulum, owing to its inertia, would tend to remain in its original position, and would therefore swing toward the wind, raising the aeroplane on that side.

When we have considered these different types of controllers, we are brought to the following conclusion, which, when understood, is almost self-evident. Since the same cause always produces the same result, if when the aeroplane is tipped to one side it is turned back to its proper level by the action of the air due to its change of velocity or angle of flight through the air in that direction, then when an equal change in angle of flight or speed through the air is caused by some wind gust striking the machine, the position of the aeroplane will be affected in a similar manner. That is to say, if the position of the controller depends, as it does in the cases considered, upon the action of the air when the machine is tilted from normal level, when a similar action of the air occurs from a wind gust, its stability is similarly affected. For instance, when a flyer in stable equilibrium turns upward, its speed through the air is diminished and the front drops to the proper level, but when a wind strikes it from behind, its speed through the air is likewise diminished, and the front will again drop, but this time away below the proper angle of flight. Therefore, since we find that the stability of all machines balanced in a manner similar to those above described must depend upon the machine's reaction with the air, no such system of automatic equilibrium can be depended upon to preserve perfect balance while the aeroplane sails through the currents and cross currents met in actual flight.

We find it essential, therefore, that the controller shall be sensitive, not to the force or direction of the wind which strikes the machine, but to some other force which will move the controller with respect to the aeroplane when its equilibrium is disturbed. The only such forces of which the writer knows are the force of the earth's magnetic field acting on a magnetic needle, and the gyroscopic force of a rapidly rotating wheel. The magnetic needle is usually employed merely to point north, but since the earth's magnetic field tends to make it dip downward at an angle of about 75 degrees to the horizon, and since this angle is almost constant in any locality, if the direction of flight is fixed, the magnet may be used to determine a horizontal position. This magnet may be made to operate the controlling planes by a system of electro-magnets and compressed air valves and pistons. Since both arms of the magnet have the same mass, neither gravity nor centrifugal force, due to oscillations of the aeroplane, would affect it in any way; but if vibrations should by any means be started, they would continue almost indefinitely and be transmitted to the flyer. Also in making turns, since the needle points down at 75 degrees instead of 90 degrees, there would be danger of losing balance. So, aside from its necessary frailness of construction, this instrument cannot make a suitable controller. It is therefore necessary for us to turn to the gyroscope to balance our flyer.

It is a well known property of the gyroscope that it tends to rotate continually in the same plane. If a force be made to act on the revolving wheel, its plane of rotation will be changed, but in a direction at right angles to the force, if the trunnions are frictionless. If by any means this precession at right angles to the force be increased, the gyroscopic action will overcome the turning force and move toward it. If, on the other hand, this precession be retarded, by friction or by any other means, the force will turn the gyroscope in the direction in which it acts. Gyroscopes constructed so that the precession is accelerated are the kind used to balance monorail cars. They are not adaptable to the aeroplane except when the latter is in unstable equilibrium with respect to gravity, and even then the controller would be affected by wind gusts. This would make flying very precarious in case the controller should get out of order.

When we consider a simpler form of gyroscope, however, that of a single wheel rotating in a horizontal plane, if, as is always the case, there is friction in the trunnions, the precession will be retarded and a force will be able to move the gyroscope slightly in the direction in which it is acting. Unless the friction is very great, the gyroscope will, however, strongly resist the forces whch act against it. The balancing action of this gyroscope is shown in Fig. 6. Since it resists any force to change its plane of rotation from the horizontal, the gyroscope by suitable connections keeps the balancing planes set so as to correct any tipping of the aeroplane. But since the trunnions are not frictionless, the forces required to operate the balancing planes would slowly turn the gyroscope from a horizontal plane. For this reason, if a gyroscope in neutral equilibrium with respect to gravity be used on an aeroplane, it will in time move far enough from normal position to dangerously tip the machine. In the same manner, if the gyroscope be set in unstable equilibrium, it will gradually move to a more stable position, upsetting the aeroplane with it. If, however, the gyroscope while rotating in a horizontal plane be in stable equilibrium, though its position may be slightly changed by the action of various forces, the force of gravity will be able slowly to bring it back to its original position, because of the friction of the supporting axes. We see then that this is the only condition in which the gyroscope can be relied upon to remain rotating in its orginal plane, and is the only condition in which it can be used to successfully balance an aeroplane.

When, however, a gyroscope in stable equilibrium is used, if it is affected by a force which changes its plane of rotation more than two or three degrees, the oscillations which it performs in returning to its original position disturbs the balance of the aeroplane quite perceptibly. Experimenters have found that these oscillations can be greatly diminished by the use of vanes in a water basin, but on a flying-machine the balancing planes answer very well the same purpose. If the gyroscope is connected directly to the balancing planes, as is shown in Fig. 6, it must be of comparatively great weight in order not to be disturbed by the forces acting upon it; but if instead of being connected directly to the auxiliary planes, it is used merely to open and close valves for compressed air to operate them, the forces acting on the gyroscope will be very small and the weight of the gyroscope may be greatly diminished. This controller is really a combination of a gyroscope and a pendulum, and is therefore slightly affected by wind currents. This disturbance is, however, insignificant, as long as the gyroscopic action is strong in comparison with the turning moment of the pendulum. A gyroscopic controller so constructed, with its plane of rotation regulated by gravity so that it is always kept constant, is capable, the writer believes, of setting the balancing planes so as to counteract every wind gust, and to keep its perfect balancing properties as long as the wheel is turning.

# The United States Reclamation Service

## Special Articles by the Engineers of the Projects

### THE INTERMOUNTAIN DISTRICT.

By R. F. Walter, Supervising Engineer.

The work of the Intermountain, sometimes known as the Central District of the Reclamation Service, covers a territory in which irrigation has been employed as a means of distributing moisture to grow crops since the earliest settlement by the pioneers, who, first attracted by the discovery of gold, in which all could not be successful, turned their attention to diverting the waters from the streams onto the barren land. So successful were they in this undertaking that agriculture soon became the chief resource of the territory, and quickly overshadowed the mining industry. Most of the builders have passed away; but the old canals constructed by the pioneers are still in use.

The original irrigation works were built merely to divert the flowing streams onto the parched lands; but the streams were so reduced in flow during the summer months, and there was so much water wasted during the spring months, that, after many years, some one suggested that the water going to waste might be run into reservoirs and stored for use after the streams had been reduced in flow, and also to make possible the extension of the irrigated area. The suggestions were considered at the time a huge joke, and the promoters called cranks. The building of reservoirs did not begin until about 1890, since which time thousands of storage basins have been put in use, and now on many of the streams no water escapes whatever, and the lower stretches of the river bed have become covered with trees and vegetation.

The work of the Reclamation Service in this district is scattered over the States of Colorado, Kansas, Nebraska, South Dakota, Oklahoma, and southern Wyoming, from an elevation of 2,500 feet above sea level to an elevation of over 10,000 feet, and from 38 degrees north latitude to 45 degrees, all in the neighborhood of the 105th meridian. The annual rainfall varies on the different projects from a normal of 6 or 8 inches to 16 inches, while in the mountains above the projects it may reach as high as 30 or 40 inches.

The crops produced are grain, alfalfa, potatoes, sugar beets, hay, and garden truck on all projects, while such fruit as apples, peaches, pears, and apricots are very extensively grown on the southerly projects, for which there is always an excellent market. The value of the irrigated lands under these projects ranges from $75 to $100 per acre in the northerly projects to $100 to $1,000 in the southern projects, much of the land having sold for $3 to $10 per acre before the projects were inaugurated.

Below is given a brief description of the most important projects in this district on which work is being done by the United States Reclamation Service, the larger engineering features connected with each having been fully discussed above.

*Uncompahgre Project, Colorado.*—In the Uncompahgre Valley, in Montrose and Delta Counties, in southwestern Colorado, there is a body of very fine land of some 150,000 acres. The Uncompahgre River, which has a limited run-off, nearly all of which comes during the spring months, was sufficient for but a small part of this area. This valley was settled in the early eighties, and a succession of crop failures followed; and as there was no chance to store the flood water in any considerable amount, the inhabitants began to look elsewhere for relief, and discovered that the elevation of the Gunnison River was such that the water of that stream, which has a large run-off, could, by carrying the same through a tunnel, be diverted to the lands in this valley. The cost of such an undertaking, however, was so great as to be absolutely impossible by private capital. The State of Colorado was importuned to relieve the situation, and after spending $25,000, turned the work over to the Reclamation Service in 1903, as it was too large an undertaking for them. The Reclamation Service has since completed this tunnel, which is six miles long, and it has been in use during the past two seasons. The old canals that have been turned over to the Government are being enlarged as fast as possible, and new canals and laterals built, so as to supply 140,000 acres with an assured water supply.

When fully developed the regular run-off of the Gunnison River will be augmented by the construction of a reservoir on Taylor River, which is a tributary of the same above the point of diversion. The reservoir will be built in the high mountains at an elevation of about 10,000 feet above sea level, and will be filled during the spring and winter with water that would otherwise go to waste. The water will be let out during July and August, as needed to keep up the full flow through the tunnel.

*Grand Valley Project, Colorado.*—This project is located in Mesa County in western Colorado; and while the lower lands in the valley have been irrigated since about 1883, the irrigation of the higher mesas has only been talked of on account of the engineering difficulties encountered.

The higher mesas generally include the best and most fertile lands, but are the most expensive and difficult to reach with water—hence they are the last in every valley to be reclaimed. This is no exception here, and a high-line canal to reach the same requires a large investment and many engineering difficulties have to be overcome. The canal which has been planned by the Reclamation Service will furnish water to some 60,000 acres of irrigable land, from the flow of the Grand River, which is one of the largest streams in the district. The canal, which will run for several miles through the canyon, will involve rough and difficult construction, requiring several miles of tunnel, besides lined sections and heavy rock cuts. The water will be diverted from the Grand River by a diverting dam, which must be constructed so as to stop most of the water during low flow, and pass immense floods during high periods.

There will be required an extensive canal and distribution system below the canyon in order to get the water to each farm. This work will proceed rapidly as soon as the legal questions which have been delaying progress are settled.

*North Platte Project, Wyoming and Nebraska.*—One of the chief water courses in the middle West is the North Platte River, heading in the high mountains of Colorado, and flowing through Wyoming and Nebraska on its way to the Missouri. Although its flow is large during the spring months, it goes practically dry during the later summer months, and is generally limited in flow after July 1st.

With the organization of the Reclamation Servic one of the first investigations made was looking towa the conservation of these waters and the saving them for use on the immense areas which the nat