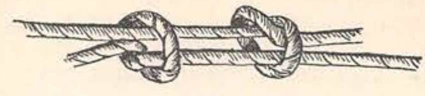
AN OVERHAND KNOT.



THE BEST KNOT.

SCIENTIFIC KITE-FLYING.

WITH SPECIAL REFERENCE TO THE BLUE HILL EXPERIMENTS.

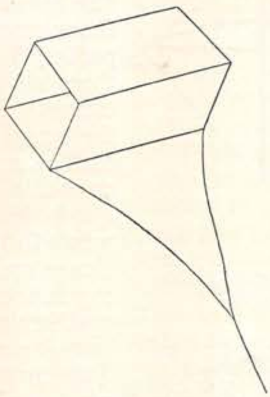
MOST persons, when asked for their mental picture of the wind, describe it as a horizontal stratum of air practically uniform in velocity. In reality neither of these characteristics is a part of the description of the wind. Investigations into the internal movements of the air currents, made by Professor S. P. Langley in America and by others abroad, have shown conclusively that the wind is made up of innumerable commingling and conflicting currents, much like the multitude of scarcely perceptible wavelets which unite to make up a huge billow. These component currents move in various directions, vertically as well as horizontally, and with velocities quite their own. The constant variation in velocities may be detected by any one who will watch a cup-anemometer whirling in a gale of wind. A little patience will soon detect the cups at a full stop for an appreciable period, while the gale whistles by. Meteorological instruments have detected distinct upward and downward movements in ordinary winds, and some of those who are investigating bird flight and the vast subject of aëronautics are convinced that the soaring power of a bird is due to its instinctive recognition of these upward currents, and to its ability instantly to make use of them in order to secure or retain altitude. Much in the same way as billows move in one general direction, a given wind usually follows a uniform course; but if it meets a terrestrial obstruction, it is at once retarded at some points, and a mingling of forces results. A hill obstructs the wind much as a dam retards water. The current in the stream is more rapid on the surface than at the point of contact with the dam. In the same way, the anemometer on a mountain-top may indicate a certain velocity, while the clouds above, moving in the same wind, will be observed to be moving much faster.

Considering the eagerness with which scientists are pursuing the fleeting testimony of nature's atmospheric vagaries, and the fact that this field of study lies directly over our heads, almost within reach, it is a matter of surprise for most readers to be told that until kites were resorted to there was no adequate means for getting records of the conditions even a few hundred feet above any chosen locality, whereas at the present time records above one and a half miles are frequent. If we take our instruments to the mountain-peak, we find there disturbing conditions due to the fact that we are still on the earth. If we ascend in a balloon, we are borne along with the wind, and while facts are obtained at different heights, they are from points far apart horizontally. The captive balloon has thus far afforded the only means for local use, but it is obvious that the expense of maintaining such a service is beyond average resources, to say nothing of the element of personal danger, and the important fact that captive balloons cannot be used if there is much wind, nor ascend very high under the most favorable conditions. To be deprived of studying the air because moderate wind-velocities forbid would be to lose the privilege of analyzing conditions which may be most desired.

In order that weather predictions may be made with greater certainty, it is necessary that the atmospheric conditions above may be frequently investigated, perhaps several times a day, and the results compared. If this be done in concert at several points far apart, the results will of course be of greater value, and the coming changes over a larger territory can be far more accurately predicted.

So it comes about that the toy which has amused the Chinese and the Coreans through countless dynasties (for the origin is in tradition), and which the Japanese adopted just as they did Chinese art, has come to be a scientific instrument of unique value. Kite-flying is generally associated with a fair wind in an open field in the summer; but as meteorologists use kites, a snow-storm, a freezing temperature, or a gale of thirty to forty miles an hour, does not deter the work in the least. It has again happened that amateurs have pointed the way for scientists. In the face of scientific deductions from known facts, it has been demonstrated that light kites can be constructed.

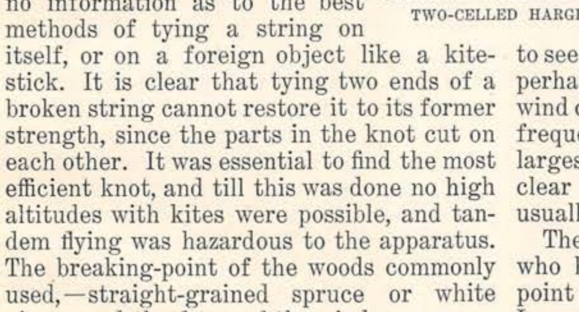
that will resist the pressure of great wind-velocities and at the same time lift considerable weights. In this practical demonstration amateurs have been foremost. The best knowledge on the subject a few years ago, when kites were first taken up seriously, was so deficient as to be virtually useless. Many of the materials used in kite construction had not been tested at all, and others had never been tried under conditions similar to those in which the strain was to occur. No one knew the breaking-point of different kinds of string, or what kind was on the whole best when compared weight for weight or by diameters. The manufacturers had never had occasion to make such tests. The safety of the whole apparatus in use depends upon the original strength of the string or wire used, and upon the knots in making connections. The literature of kites gave no information as to the best methods of tying a string on itself, or on a foreign object like a kite-stick. It is clear that tying two ends of a broken string cannot restore it to its former strength, since the parts in the knot cut on each other. It was essential to find the most efficient knot, and till this was done no high altitudes with kites were possible, and tandem flying was hazardous to the apparatus. The breaking-point of the woods commonly used,—straight-grained spruce or white pine,—and the force of the wind per square foot on a flat surface at right angles to the wind, were of course well known; but these and all other facts accessible two years ago pointed to the conclusion that kites would probably never be sent up more than 3000 to 4000 feet, and that no kite could be made strong enough in proportion to its weight to fly in winds varying from ten to forty miles an hour. The absence of data much needed in order to proceed on scientific lines in devising kite forms was due to the fact that the kite had always been considered a toy, and but for the development of tailless kites it would doubtless still be so regarded. The moment the weight and resistance of the tail may be safely discarded, the kite is able to lift so much more, and self-recording instruments may be attached; but any kite that can lift only itself is obviously useless in meteorology.



JAPANESE PROTOTYPE OF THE TWO-CELLED HARGRAVE.

Almost every man remembers kite-flying as one of the delights of his youth; but few, if any, have until very recently experienced the unique sensation of flying a kite up into the clouds. It is thrilling, indeed, to watch a kite disappear in the mist, to remain there sometimes half an hour; and still more so, in flying several kites on one string, to see some above and others below the cloud, perhaps facing in various directions as the wind currents in different strata vary. Very frequently, in trying for high altitudes, the largest kites used are lost to sight in the clear sky, and to avoid this the leaders are usually painted black.

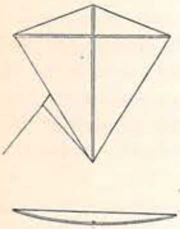
The motives which have actuated those who have studied kites from the amateur point of view have differed largely. Mr. Lawrence Hargrave of New South Wales, who invented the cellular or «box» kites, was in search of soaring-machines, and perhaps leaned toward aëronautics. It is interesting to note that the Japanese prototype of the box kite is made of but one cell flown on edge, as shown above. Mr. Hargrave tried some single-celled forms flown with flat surfaces toward the wind. Mr. W. A. Eddy, to whose enthusiasm we owe the resurrection and adoption of the Malay kite, and who has most generously aided others, including the writer, was in search of means to lift his leading kite high into the air, and his experiments have been to some extent meteorological. Many others in this country, and a few in England, have given serious attention to kites on account of their interest in one of these two subjects. Nearly everything has been done by rule of thumb. «Try it and see,» has been the reëchoed advice of those who were sup-



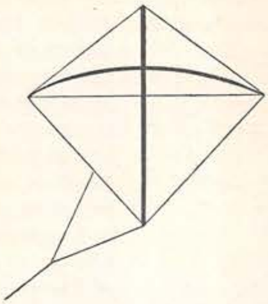
DRAWN BY WILL H. DRAKE.

A NINE-FOOT MALAY KITE WITH REEL, AND A HARGRAVE KITE.

posed to know. Science had recorded the fact that the pressure upon any rigid plane inclined toward the wind was greater at the top and diminished toward the bottom, because the top meets the wind first and



AN AMERICAN MALAY KITE.



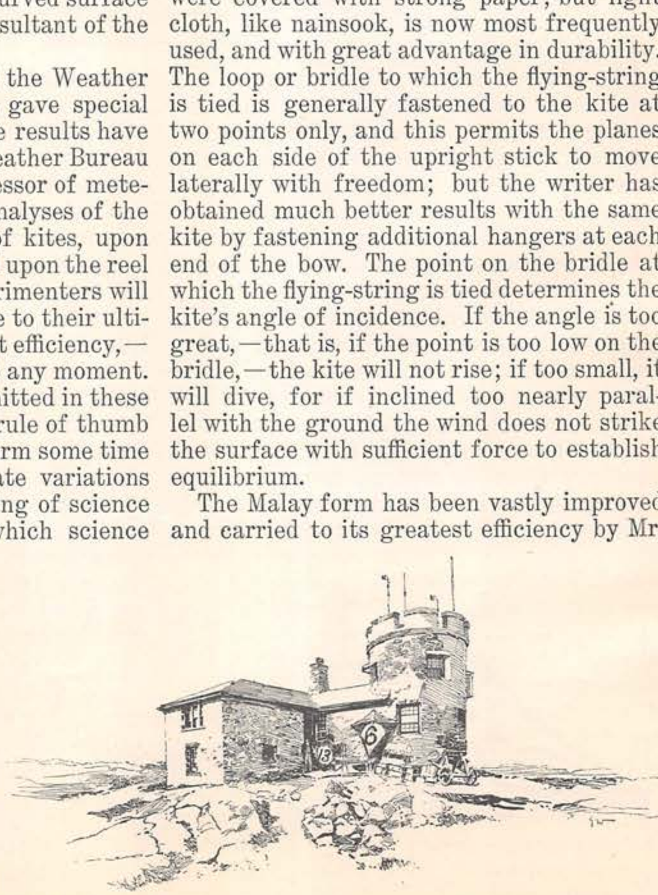
A JAPANESE MALAY KITE.

starts the flow of air downward; but no calculations had been made public on the action of the wind on a flexible curved surface like a Malay kite, so that the resultant of the forces was not known.

During the summer of 1896 the Weather Bureau at Washington, D. C., gave special attention to kite trials, and the results have been reported in full in the « Weather Bureau Review » by C. F. Marvin, professor of meteorology. To these exhaustive analyses of the forces acting upon all sorts of kites, upon the string at various points, and upon the reel at the ground, the future experimenters will refer with confidence as a guide to their ultimate goal, — the kite of greatest efficiency, — and as a measure of success at any moment. Nothing seems to have been omitted in these analyses. It appears that the rule of thumb found the most efficient kite form some time ago, and none of the elaborate variations since constructed under the wing of science have been an improvement, which science now comes forward to substantiate with elaborate and indisputable formulæ.

The two forms in use, the Malay and the Hargrave or cellular, are widely different. Both are tailless, and while the latter is by far the more efficient, the former, on account of its extreme lightness per unit of area, will doubtless be used for a long time to come in tandem flights in conjunction with the cellular. The construction of the Malay is best seen in the rear view given on this page. It is found as frequently in the kite literature of Japan as any other type. The only change from the Japanese form is in shortening the distance from the top to the cross-stick. Except for this improvement, the kite is identical with the one which the Japanese, Chinese, and Malays have always flown. This kite owes its buoyancy to the fact that the sections below the cross-stick are so proportioned as to balance under wind pressure those above, provided the bridle is tied on correctly; while the planes on each side of the upright stick, containing the same total surface, must balance each other, unless the cross-stick bends unevenly, in which case the kite is driven over to the weak side and may refuse to fly. It is found that unless the lower planes are made somewhat loosely, so as to bag in the wind, the kite will not remain in equilibrium without a tail. On the other hand, there is a serious loss of buoyancy and « lift » if the cover is too loose. Formerly these kites were covered with strong paper; but light cloth, like nainsook, is now most frequently used, and with great advantage in durability. The loop or bridle to which the flying-string is tied is generally fastened to the kite at two points only, and this permits the planes on each side of the upright stick to move laterally with freedom; but the writer has obtained much better results with the same kite by fastening additional hangers at each end of the bow. The point on the bridle at which the flying-string is tied determines the kite's angle of incidence. If the angle is too great, — that is, if the point is too low on the bridle, — the kite will not rise; if too small, it will dive, for if inclined too nearly parallel with the ground the wind does not strike the surface with sufficient force to establish equilibrium.

The Malay form has been vastly improved and carried to its greatest efficiency by Mr.



DRAWN BY GEORGE WRIGHT.

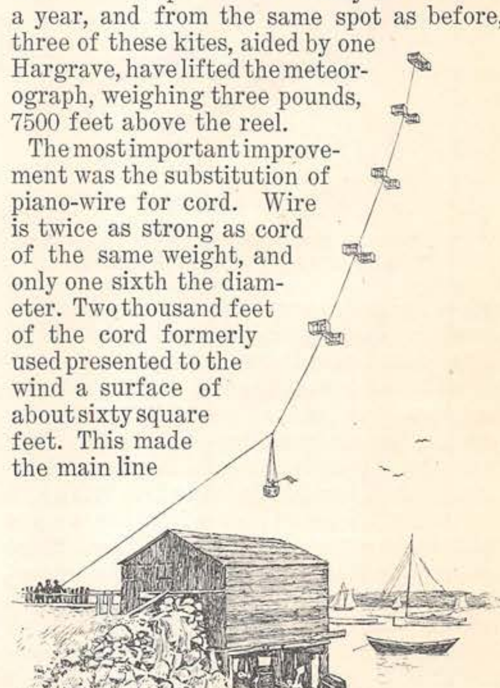
THE OBSERVATORY AT BLUE HILL, MILTON, MASSACHUSETTS.

DRAWN BY WILL H. DRAKE.

THE LATEST FORM OF CELLULAR KITE INVENTED BY MR. CLAYTON.

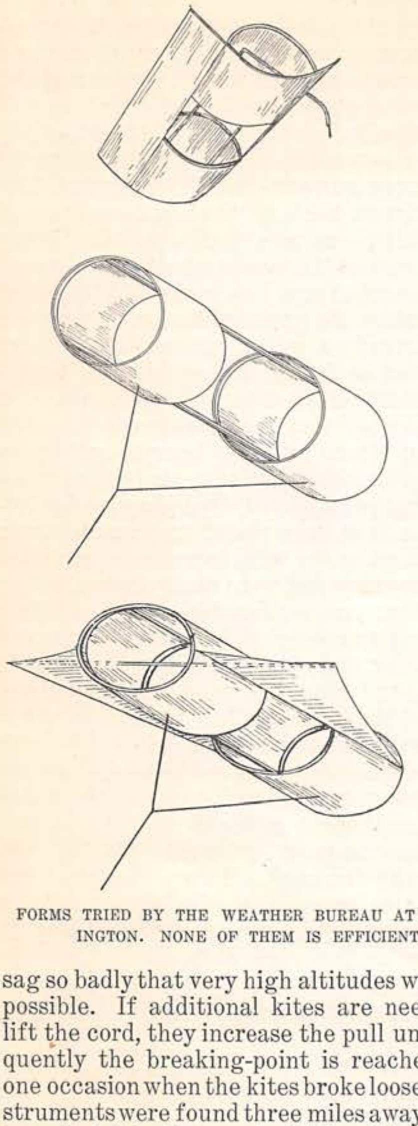
Fergusson and Mr. Clayton, the observers at Blue Hill Observatory, Milton, near Boston, Massachusetts, who, assisted by Mr. Sweetland, have been giving a large portion of their time to ascensions with kites during the last two years. To them belongs the credit not only of having carried their meteorograph quite half a mile higher than any one else by means of kites, but the honor of being the first to collect a mass of data from repeated ascents above a mile. The storms of winter have been no obstacle, and the rain-clouds of summer have been compelled to submit their records. Previous to 1894 occasional attempts had been made to attain great elevations, but the limit reached was only about 1500 feet. During August, 1895, trials with Malay kites were repeatedly made at Blue Hill, and the best altitude was about 1900 feet. This attempt was so much more successful than any previous one that it was considered at the moment satisfactory; but calm discussion of the facts was both discouraging and inspiring. Nine Malays, made by Mr. W. A. Eddy, who was present to instruct, were used. Three were nine feet tall, three six feet, one seven feet, and two five feet. The total area of flying-surface was, therefore, about two hundred and twenty square feet. The wind increased gradually from fifteen up to thirty miles per hour, during which the paper covers of some of the kites were blown to pieces. The greatest pull on the string at any one time was one hundred and fifteen pounds, and the best angle obtained by the leading kite 31°. Considering the force of the wind and the lifting-area exposed, the result was puny; but encouragement came from the fact that this attempt disclosed the great weakness of Malay kites—namely, flexibility. The theory had been that the bending back of the cross-stick would expose less surface to the wind, and so allow the gusts to pass by, making the kite virtually a self-regulator. This theory is correct as far as it goes, but the degree of flexibility cannot be regulated. When it is considered that the pressure of the wind blowing fifteen miles an hour is quite nine times as much as that of a wind of five miles an hour, the futility of depending on flexibility alone is at once plain. In practice it was found that as the wind increased these kites lost buoyancy and were finally driven to the ground, or were rendered incapable of lifting anything whatever. The force at Blue Hill has so far improved the Malay that within a year, and from the same spot as before, three of these kites, aided by one Hargrave, have lifted the meteorograph, weighing three pounds, 7500 feet above the reel.

The most important improvement was the substitution of piano-wire for cord. Wire is twice as strong as cord of the same weight, and only one sixth the diameter. Two thousand feet of the cord formerly used presented to the wind a surface of about sixty square feet. This made the main line

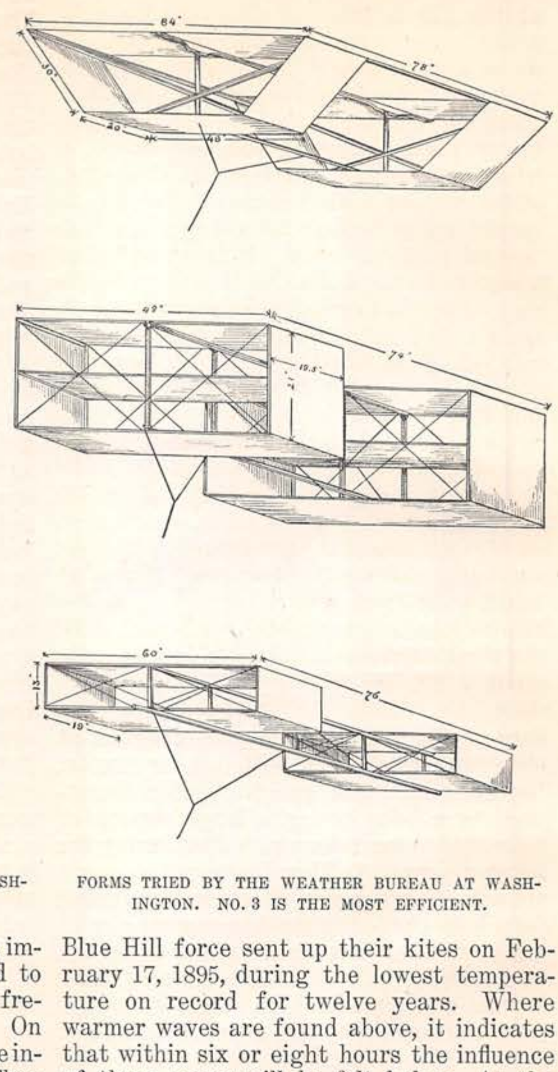


DRAWN BY WILL H. DRAKE.

FIVE HARGRAVE KITES LIFTING A BASKET CONTAINING A MAN.



FORMS TRIED BY THE WEATHER BUREAU AT WASHINGTON. NONE OF THEM IS EFFICIENT.



FORMS TRIED BY THE WEATHER BUREAU AT WASHINGTON. NO. 3 IS THE MOST EFFICIENT.

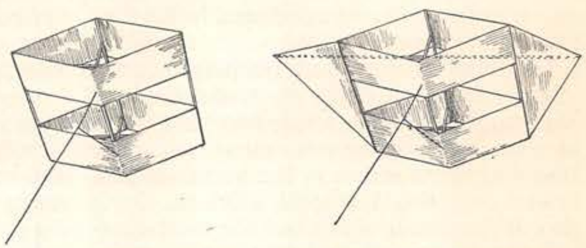
sag so badly that very high altitudes were impossible. If additional kites are needed to lift the cord, they increase the pull until frequently the breaking-point is reached. On one occasion when the kites broke loose the instruments were found three miles away. They travelled this distance in falling fifteen hundred feet. The pull of a large kite flying in a gale of forty miles an hour is from five to eight pounds per square foot of kite surface. Some of the Blue Hill kites have forty feet of surface, and when three are on the same main line the task of holding the «team» is no light one. A black kite in a driving snowstorm is a picturesque spectacle; and as it fades from sight there is something uncanny about the violent, jerky pulls on the cord, which appears to lead off into nowhere. The kites are often covered with frost when they return from the clouds in winter. Ordinarily a cold day would not be chosen by the amateur for kite-flying; but the scientist wants facts, and under all conditions. The Blue Hill force sent up their kites on February 17, 1895, during the lowest temperature on record for twelve years. Where warmer waves are found above, it indicates that within six or eight hours the influence of these waves will be felt below. As the kites ascend the wind-velocity increases and usually bears off to the right, showing a uniform curve in the direction of the wind. This does not always occur, but more frequently in south and westerly winds than in others. At Blue Hill the sea breeze is from the east, and it has been found, by sending kites up until they meet another current and face about, that these sea breezes are seldom more than twelve hundred feet thick. Clouds from which rain is falling, or about to fall, are often less than one thousand feet up.

The cumuli which boil up rapidly on a summer day are not so easily reached. The formation of one of these clouds may often be seen. It resembles a puff of steam shot into the blue ether, and this puff instantly begins to grow and boil like its kind. Several times at Blue Hill the kites have been caught under a newly born cumulus, and carried speedily up to a great height, showing that there is a strong upward current under the cloud. These currents seem to exist under all cumuli, but are particularly noticeable under the spot where a cloud has just formed. The night offers the best conditions for kite ascensions, for the upper current flows with the steadiness of a mighty river. It is possible that a lantern on the leader could be seen with a night-glass; but even if the apparatus be entirely out of sight the elevation may be calculated. Professor Marvin of the Weather Bureau has published a formula by which this may be done when the length of wire out, the tension, and the inclination at the reel are known.

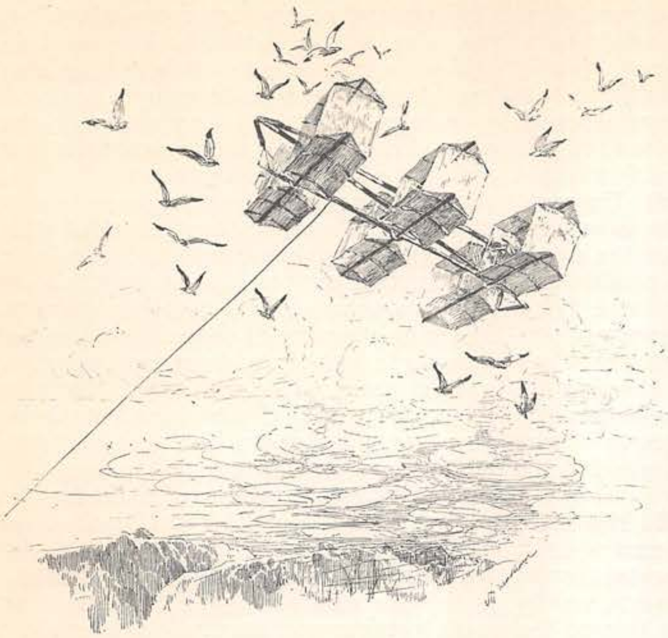
What is wanted in a scientific kite is the maximum of lift and the minimum of drift. By «lift» is meant the force directed upward vertically (the vertical component), and by «drift» the force which tends to send the kite to leeward (horizontal component). Of the three forces acting on the kite so as to produce lift and drift, gravity alone is constant. The pull on the string and the pressure of the wind on the kite surface, the other two forces, are variable; and as the former is the result of the latter, it is not properly a force in itself. Therefore, it follows that wind pressure is the only force which differs from time to time as conditions change. The problem in kite-flying, therefore, is so to construct the supporting plane or planes, and so to arrange the point of tying on the string, as to enable the kite to adjust itself quickly to changes, however violent, in the direction as well as in the force of the wind. In winds of twenty miles an hour gusts of from thirty to thirty-five miles frequently occur. On the water squalls are avoided by taking in sail; but even if a kite could be furled when aloft, it would be necessary to accomplish this at a moment's notice, since gusts approaching upon kites far up in the air are invisible from below. The apparatus would therefore have to be automatic, and may yet be invented.

It is seen that the wings of a bird when soaring bend upward slightly, forming a dihedral angle; and until Mr. Hargrave published the proportions and drawings of his cellular kites, with which, using several tandem, he lifted himself about fifteen feet (and could of course have exceeded this), it was always thought that no kite could fly without a tail unless its two lateral surfaces were made so as to form such an angle, or to be capable of making one when met by the wind. This is true of single-plane kites, but multiplane forms introduce new possibilities. Any kite becomes efficient in proportion as flexibility in the surface can be avoided without disturbing the equilibrium. The cellular construction permits bracing of parts so as to present to the wind reasonably rigid planes. The truss structure of the cells enables the inventor to use very light wood and fine wire, and the tension on the cloth covering is never on the bias, so that all stretching is uniform. Moreover, the force of the wind seems to stiffen the whole structure and to compel all the parts to work together. A still further advantage is obtained by curving the supporting surfaces fore and aft, so that the wind strikes a slightly convex plane, just as in the case of a bird's wings. Actual tests made by tying weights on cellular kites show that those with planes curved in this way are much the better lifters, and for the same reason they fly in much lighter winds. Even the simplest cellular kites lift much more than Malays of the same area; and as the pleasure in flying kites, as well as the scientific profit, depends considerably on the pull and lift, they are far the best for ordinary use.

At first sight it is not easy to understand why these forms fly at all, for they violate all past ideas of kites. The explanation is, however, simple. The side planes act as fins to keep the kite in the wind. The rear cell acts as a rudder, and actually lifts about one third as much as the front cell when both are of the same area. This depends, however, on the distance between the front and rear cells, which must be great enough to allow the wind to escape freely, after it has deflected from the front cell, without interfering with the current acting on the rear cell. It was found in yachting that cutting the old-fash-



TWO FORMS USED AT THE WEATHER BUREAU AT WASHINGTON. BOTH WERE FAIRLY EFFICIENT.



DRAWN BY HENRY SANDHAM.

THE «LADDER KITE» INVENTED BY MR. OCTAVE CHANUTE.

The wings are fastened to a central frame made like a pair of «lazy-tongs» so as to produce various transformations and changes in the position and angle of incidence of the wings. This kite flies very steadily, pulls very hard when arranged as shown in this illustration, and very little (while sustaining the same weight) when adjusted so as to resemble a step-ladder. It is the prototype of a gliding-machine recently constructed by Mr. Chanute.

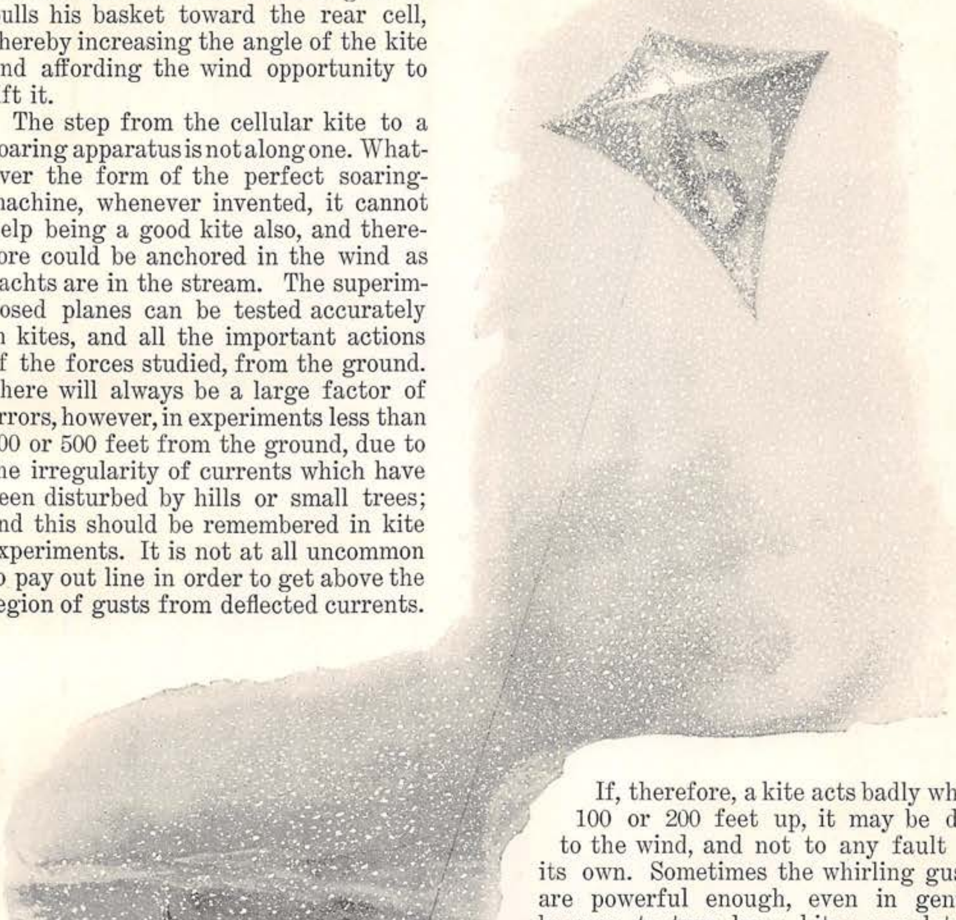
ioned big jib up into two or three small ones resulted in more power, because the wind was enabled to escape out of the way after it had done its work, and to permit a fresh current to impinge. The same law holds good in cellular kites, with the additional factor that equilibrium depends on it.

The Weather Bureau at Washington tried a large number of different arrangements of cells, varying in number and shape; but it was found at last that the two-celled rectangular kite, such as is shown in the accompanying illustrations, was the most efficient. It is also the easiest to make and the most durable. No diamond-shaped kite can be made without cutting the cloth or paper on the bias. This means that the edges will stretch and the proportions alter. A Malay which flew with perfect success in a heavy wind to-day may fail utterly to-morrow, unless thoroughly overhauled to remedy some imperceptible change in dimensions. The cellular kite, on the other hand, needs very little attention, and can be depended on to fly day after day. A tandem team of these kites may be safely counted upon to reach a higher elevation than any other combination, for the reason that they can be connected back to back and therefore pull in one direction. Malays cannot be so joined, but are put on in loops, and are often pulling at a disadvantage.

The possible use of kites in time of war, either for photographing the surrounding country at night, for signaling by kites illuminated by electricity, or for lifting observers into the air, is attracting the attention of inventors. For photographing the cellular is by far the better, because the camera may be attached to the kite-frame instead of being hung below. It is much steadier than the Malay under any conditions, and its position may be changed through a considerable arc by hauling taut on either of the two light strings which may be tied for the purpose to the lower front corners; while the angle of incidence, or inclination to the horizon, may be altered very much, for a few moments at a time, by pulling on both light strings at the same time. This regulates the field of the camera fairly well. As for raising men into the air, no one who has ever felt the lifting-force of a cellular kite containing twenty-five square feet, in a wind of twenty-five miles an hour, can have any doubt of it. The small model is already at hand, and it only remains to plan a kite large enough for the purpose. Naturally the details of construction would have to be entirely changed, because of the well-known law that the weight of solids varies as the cube of the dimensions, while the strength varies as the square.

The observation kite shown in the illustration on page 74 has several new features, one of the most important being the extended side planes which, while adding much to the lifting-power, prevent the kite from tipping sidewise, and convert it into a parachute the moment it breaks loose or is cut adrift. The observer in the basket has complete control of further ascent or descent without the assistance of those on the ground; for, by pulling on the supporting guy which leads forward, the observer's weight is brought forward, and causes the kite to assume a more horizontal position. It therefore spills the supporting wind and sinks slowly. If the observer wishes to mount higher he pulls his basket toward the rear cell, thereby increasing the angle of the kite and affording the wind opportunity to lift it.

The step from the cellular kite to a soaring apparatus is not a long one. Whatever the form of the perfect soaring-machine, whenever invented, it cannot help being a good kite also, and therefore could be anchored in the wind as yachts are in the stream. The superimposed planes can be tested accurately in kites, and all the important actions of the forces studied, from the ground. There will always be a large factor of errors, however, in experiments less than 400 or 500 feet from the ground, due to the irregularity of currents which have been disturbed by hills or small trees; and this should be remembered in kite experiments. It is not at all uncommon to pay out line in order to get above the region of gusts from deflected currents.

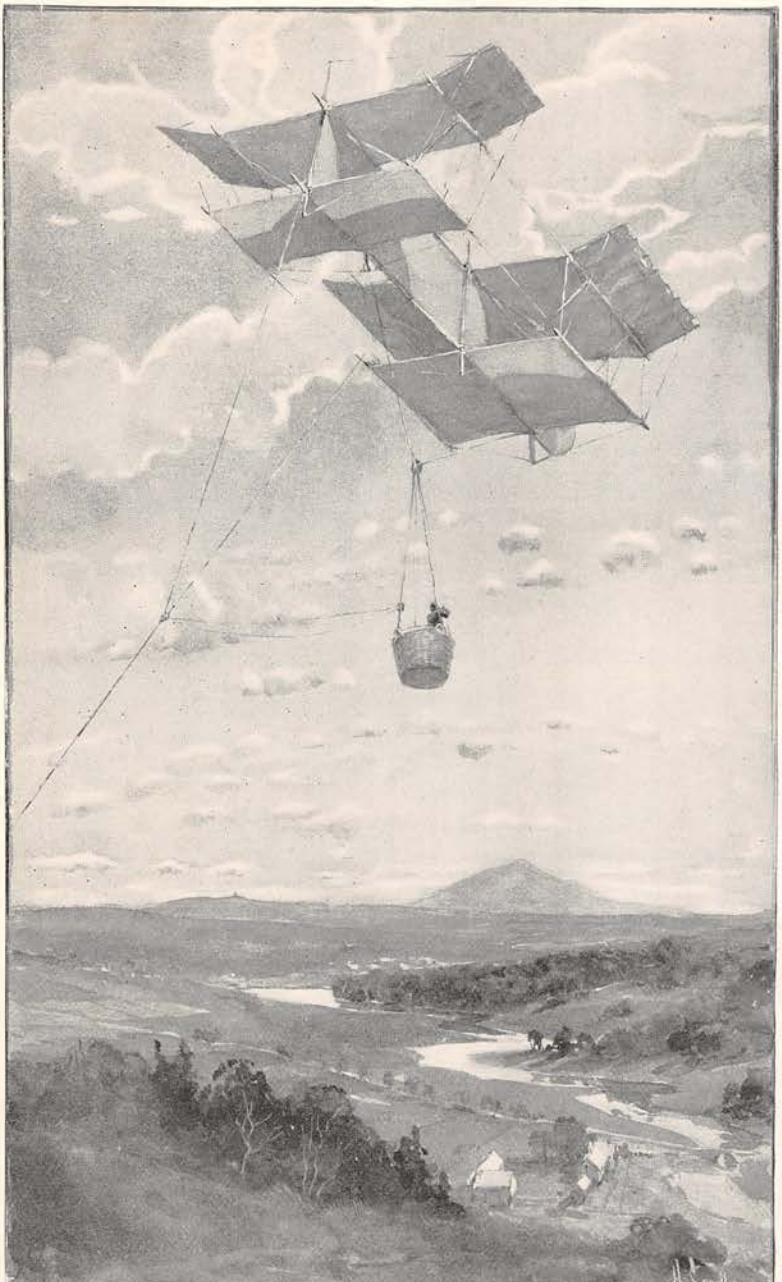


DRAWN BY HENRY SANDHAM.

FLYING A MALAY KITE IN A SNOW-STORM.

If, therefore, a kite acts badly when 100 or 200 feet up, it may be due to the wind, and not to any fault of its own. Sometimes the whirling gusts are powerful enough, even in gentle breezes, to turn large kites completely over and instantly restore them to their equilibrium. These gusts are, of course, invisible, and their existence near the earth in moderate breezes, under which conditions men must practise soaring, and under which the testing of aëroplanes is most convenient, becomes an element of great danger in the one case and exasperation in the other. It is trying, indeed, to spend several days in making a kite, and then to have a gust wreck it instantly, throwing all one's knowledge under suspicion because the real cause of the disaster cannot be known.

Much remains to be done before the ideal kite is found, and in searching for it the newly interested experimenter is quite as likely to be the discoverer as any one; for the best-known dimensions of various forms are given to the world, as well as tables of resistance, and the weight per square foot of different materials,

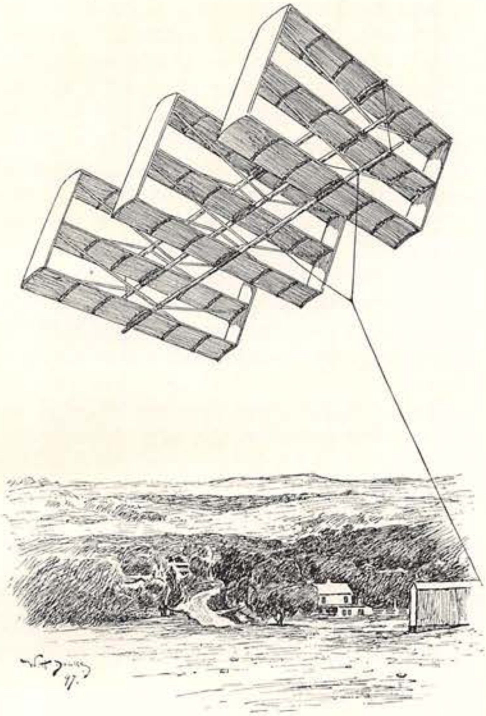


DRAWN BY HENRY SANDHAM.

OBSERVATION KITE DESIGNED BY J. B. MILLET.

In this kite the central vertical plane acts at once as a keel and as a backbone. In order to make the efficiency of the rear aëroplanes equal to the front ones, they are made nearly twice as large. The tendency of the kite is to assume a horizontal position, since the bridle-cord or wire runs loose through a block where the flying-rope is attached. Therefore, so long as the observer in the basket can at will place his weight as nearly under the rear or front cells as he chooses, he can control the ascent or descent of the kite. For, if he allows the basket to swing forward, the kite assumes a horizontal position and sinks to the ground; if he pulls the basket aft, the kite must rise. The inclined planes not only add much to the lifting-power, but convert the kite into a perfect parachute in case it breaks away or is cut adrift. This has been demonstrated by experiment with heavy weights.

and the best methods of handling kites in various winds. Well-recorded failures are often of more value than marked successes. It is necessary to know by trial under what wind pressure a given form will collapse, and at what point; and many variations in dimensions must be tried before we are sure of the best. It is clear that the kite which takes the best angle—that is, flies nearest the zenith—gives the most promise, provided it maintains its position as the wind increases. A kite which lifts ten pounds and flies at an angle of 20° is of no use in meteorology, for it could never obtain a high elevation or assist other kites to do so. The angular elevation of an unweighted kite ought to be from 50° to 60° under the best conditions, and will frequently run up to 70° or 80° for a short time. The relation that the weight of the kite bears to the force of the wind will indicate what may be expected of the kite without trial. If the pressure of the wind is only two or three times the weight of the kite, only a low



DRAWN BY WILL H. DRAKE.

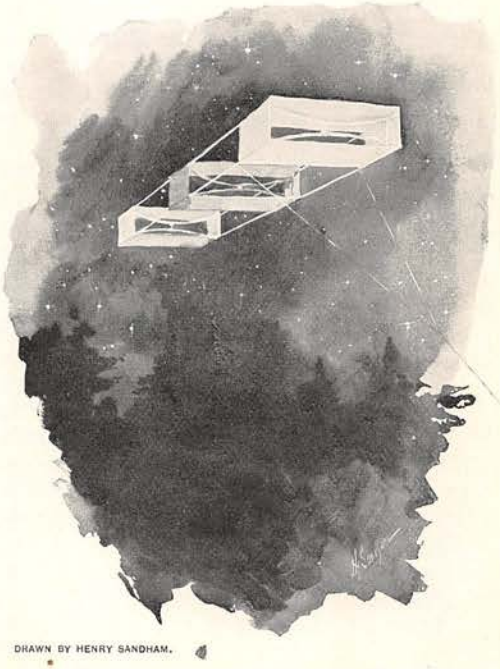
« LADDER KITE » INVENTED BY J. B. MILLET.

The aëroplanes are all curved fore and aft, and in the illustration are inclined at an angle of about ten degrees. In other words, the front edges are lifted so as to catch the wind better. This angle may be changed at will. The aëroplanes are placed so that each one gets the full and unbroken force of the wind. The spaces between the aëroplanes have been calculated with reference to the width and thickness of the aëroplanes so as to allow plenty of room for the wind to escape freely after it has done its work.

angle is possible. For high elevations the wind must be strong enough to produce a pressure from five to seven times the weight of the kite.

The highest ascent ever made with kites occurred on October 8, 1896, when the Blue Hill meteorograph was sent up to a height of 8740 feet above the hill, or 9375 feet above sea-level. Nine kites (seven Malays and two Hargraves), having a total area of nearly one hundred and seventy square feet, were used to lift the instrument and the three miles of piano-wire to which the kites were attached. About twelve hours were spent in making the ascent and descent, although between 11 A. M. and 1 P. M. the wire was wound in until the meteorograph was at a height of 600 feet, in order to remove a defective kite (a Malay). From this point the ascent was completed in less than ten hours.

The rise in humidity at 2 P. M. shows when the instrument entered the cloud, and its emergence is also indicated by the fall in humidity between 3 and 4 P. M. When the kites were drawn in, the instrument again entered a cloud (about 5:30 P. M.), and for the next hour and a half the whole apparatus remained stationary. The marked fall in humidity at 7 P. M. shows clearly when the weather cleared. When the meteorograph was at its highest point the recorded temperature was 20.2° F., at which time the temperature at the observatory was 46.2° F. The pull on the wire varied from thirty to one hundred pounds, and for several hours, when the kites were at the highest elevation, the pull was from sixty to one hundred pounds. The windlass used was wound in by hand, and the entire work was done by Messrs. Clayton, Fergusson, and Sweetland. Not the least difficult portion of the work is winding in the wire. Two miles seem a long distance when there is a pull of fifty pounds. Then the kites have to be taken off the main line as they come in, and landed safely. This takes both strength and skill. During the ascent one observer is detailed to take the angle of the leading kite (near which the meteorograph is fastened) at regular intervals, at the same time recording in the field-book the time, the



DRAWN BY HENRY SANDHAM.

TRIPLE-CELLED KITE ARRANGED WITH DIFFERENT-COLORED ELECTRIC LIGHTS IN EACH CELL.

They are connected with the ground through the flying-wire, and any one of them may be illumined at will, thus enabling signals to be exchanged at night. Designed by J. B. Millet.

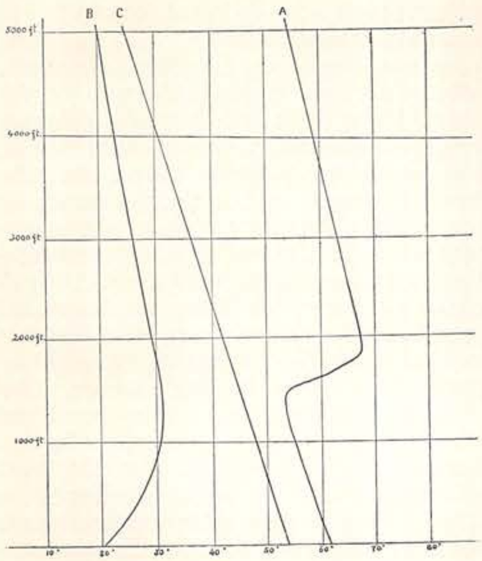


DIAGRAM OF PLOTTED CURVES.

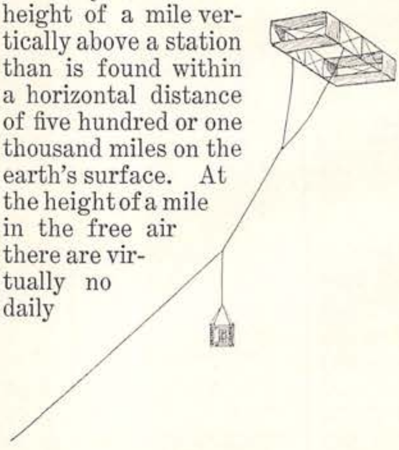
number of feet out, and the number, size, and kind of kites on the line. Whenever a kite is added to the «team,» the size, kind, and distance from the one ahead is carefully noted, as well as the minute when the added kite started. The total pull on the wire must be watched, and special care used to avoid electric shocks, for very frequently it is necessary to ground the wire. After the kites are 3000 feet up, sparks appear even in clear weather, and are particularly troublesome in snow-storms.

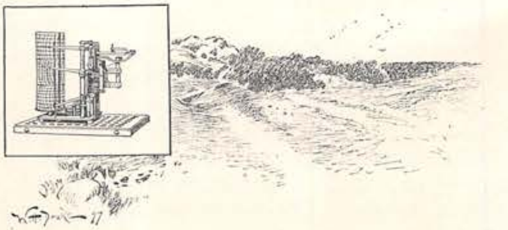
From the records of ascents the following facts appear: As a rule, the temperature of the air falls as the recording instrument ascends. Warm and cold waves are felt in the upper air many hours earlier than at a station on the ground beneath, which gives us a basis for prediction. If a recording instrument is sent up before the warm wave is felt on the ground, it enters the warm wave at some point above, when the temperature suddenly rises a few degrees, and then falls slowly with farther ascent. These changes are illustrated in the diagram above by the line marked A. In this diagram the lines running vertically upward from the figures at the bottom show the temperatures, and the figures at the left show the height in feet. The condition shown by the curve A is a very common one in the atmosphere, and whenever found indicates warmer weather soon.

The fall of temperature illustrated by the line C in the diagram precedes and continues during cold waves. In this case the instrument records a very rapid fall of temperature as it ascends. After the cold wave passes over and a southeast storm begins to set in, the change of temperature with height shown by the curve B is found. In this case the temperature rises rapidly as the instrument ascends, until at a height of from 1000 to 2000 feet it becomes stationary, and then, with farther ascent of the instrument, begins to fall. But in such cases it may be warmer at the height of a mile than at the earth's surface. The part of the curve where the temperature is stationary is generally found cloudy, and in some cases the cloud extends entirely to the earth's surface as a dense fog.

After a warm wave has set in, and in ordinary fair weather, the fall of temperature during the day is in a straight line like that shown by C, but is very much slower, the average fall being 4° in a thousand feet in ordinary weather. At night the change of temperature with height resembles very much that of the curve B, being coldest in the lowest places, as in valleys or hollows, and warmest at a height of a few hundred feet above the ground.

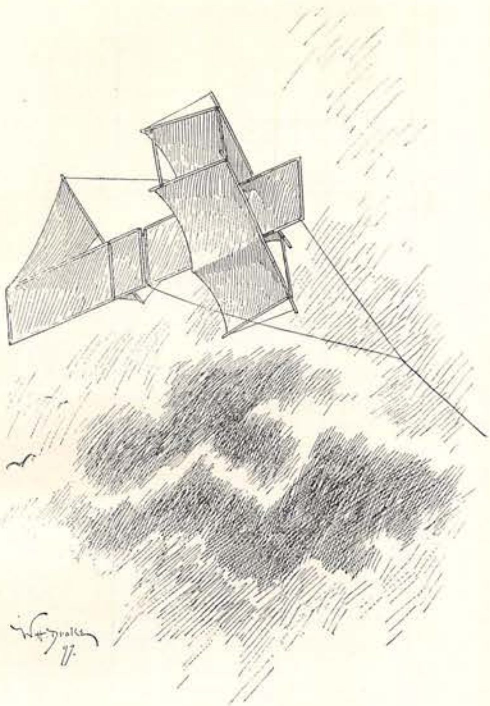
A greater difference of weather conditions is usually found at the height of a mile vertically above a station than is found within a horizontal distance of five hundred or one thousand miles on the earth's surface. At the height of a mile in the free air there are virtually no daily





DRAWN BY WILL H. DRAKE.

METHOD OF ATTACHING METEOROGRAPH.



DRAWN BY WILL H. DRAKE.

TRIPLE-PLANE CELLULAR KITE INVENTED BY C. F. LAMSON.

changes of temperature. The kite observations indicate that the average temperature of the night is less than a degree colder than the day temperature. Virtually the only changes which occur at this height are those due to the passage of warm and cold waves. The daily changes of humidity are, however, very marked. The days are very damp, the air being frequently saturated with moisture, while the nights during fair weather are very dry, so that the air rivals in dryness that at the ground over the driest desert. This daily change of humidity is the reverse of that found at the ground, where the days are dry and the nights damp.

At the height of a mile the wind-velocity averages four times as great as that found at the ground, and gales of one hundred miles an hour are not uncommon. (Clouds have been observed moving at the rate of one hundred and seventy-four miles an hour.) The air is not infrequently serenely clear, while the earth below is enveloped in clouds.

The facts already collected by the observations with kites at Blue Hill will serve to modify some of the opinions now expressed in text-books, and it is hoped will aid in solving some of the difficulties in the way of more accurate weather forecasting. The successive chiefs of the Weather Bureau have each expressed the opinion that observations in the upper air are the main reliance of more accurate weather forecasting in the future. The lifting of recording instruments to great elevations by means of kites at the Blue Hill Observatory has shown for the first time that frequent observations at altitudes exceeding a mile, and probably exceeding two miles, are possible. The highest ascent was but little short of two miles, and with improved appliances there is little doubt that ascents to this altitude will be frequent. Greater heights are entirely possible if mechanical skill becomes interested enough to work out the desiderata now formulated by science. It is no longer sufficient to make and wreck kites in order to learn what to avoid. Only those imperfections which are most prominent can be discovered in this way. Analysis of the forces acting on the kite, and of the kite's movements, will lead to a development along the lines of scientific accuracy. Without such assistance the minute details will elude the inventor, and we are even now at a point where no details can be ignored. A sunken yacht may serve again as a model, but a distorted or broken kite may not, unless the cause of the wreck is understood. Fragile as the best kites are, they are seldom broken by the wind alone. They should not be expected to withstand violent contact with the earth or trees, but should be built to resist wind pressure only.

The air above us is as yet unconquered, although much of the mystery which surrounds its unseen motions has been dispelled. The resistless and merciless force of its currents in violent action constantly reminds man of the utter uselessness of undertaking its entire subjection; and it is because that fact is recognized that one finds peculiar and almost vindictive pleasure in occasionally winning a victory in the combat between scientific ingenuity and the invisible forces which tantalize and defy us.

J. B. Millet.