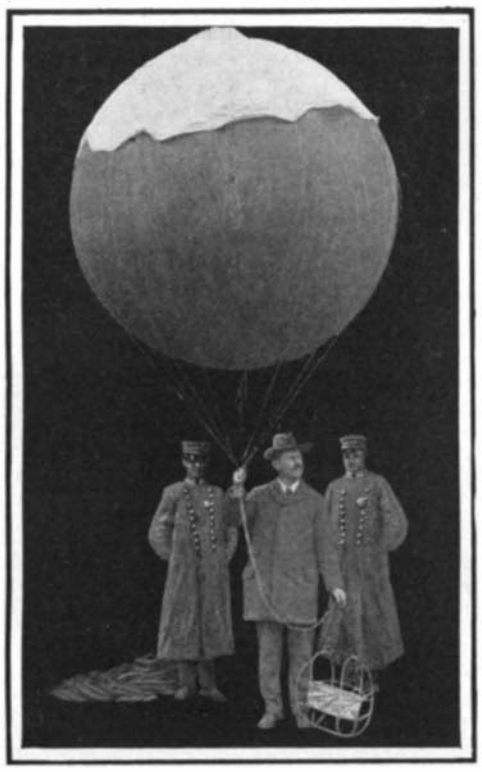
THE EXPLORATION OF THE UPPER AIR BY MEANS OF BALLONS SONDES.

BY S. P. FERGUSSON OF THE BLUE HILL METEOROLOGICAL OBSERVATORY STAFF.

In his "History and Practice of Aeronautics," published in 1850, John Wise quotes the following paragraph from an unnamed author:

"Much could be done, however, without great risk or material expense. Balloons from fifteen to thirty feet in diameter, and carrying registering thermometers



An Assmann ballon sonde ready for ascension. Mr. Clayton holding balloon and basket.

and barometers, might be capable of ascending alone to altitudes between eight and twelve miles. Dispatched from the centers of the great continent, they would not only determine the extreme gradations of cold, but indicate by their flight the direction of the regular and periodic winds which doubtless obtain in the highest regions of the atmosphere."

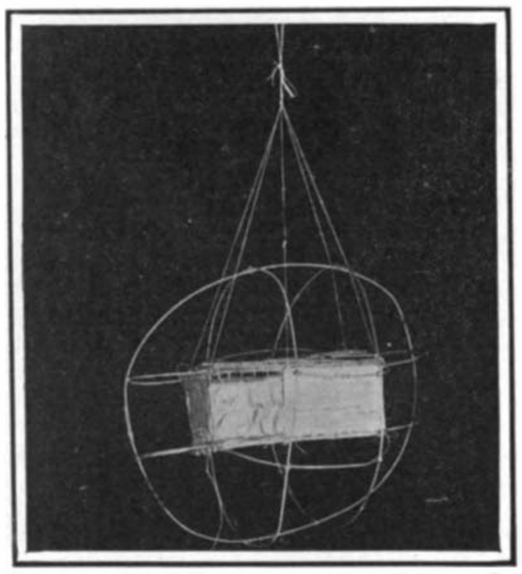
The above suggestion as to the use of balloons in meteorology, although written in the early days of balloons, was not fully realized until March 21, 1893, the date of epoch-making ascension of the balloon "L'Aerophile," conducted by Messrs. Hermite and Besançon of Paris. A very complete description of this experiment was published in L'Aerophile, Vol. 1, by W. de Fonvielle.

Until the first ascension of "L'Aerophile" the highest ascension on record was that of Glaisher and Coxwell in 1862. A height of 11,000 meters was claimed by Glaisher, but a careful analysis of his records indicates that the height probably did not exceed 9,000 meters. Hence, except for the data obtained from measurements of the heights and velocities of clouds, the atmosphere at heights exceeding 3,000 to 4,000 meters remained practically unexplored until within the past twelve years. At the present time, ascensions of the Assmann rubber balloons to heights of 20,000 meters are not unusual, and in a few instances the enormous height of 25,000 meters has been exceeded.

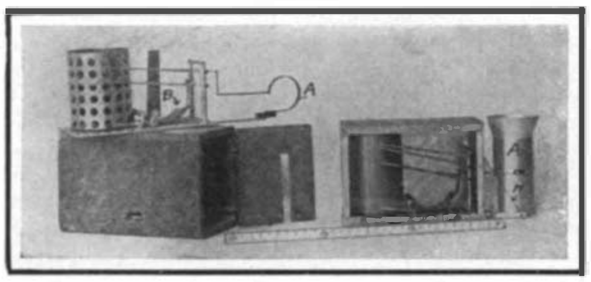
Experimenting with *ballons sondes*, as they were named by the French, is expensive, but was much more so at the beginning than at present. In order to reach a height where the atmosphere is one-half as dense as it is at sea level, a balloon should rise when half full of gas; to reach a point where the density of the air is one-fourth that at sea level, it should rise when one-fourth full. Therefore, to be able to reach very great heights, a balloon made of rigid materials, such as the silk, goldbeater's skin or paper employed in the earlier experiments, must be extremely light and of relatively large capacity, so that it may rise when only slightly inflated. Of the materials named, goldbeater's skin is the best, and silk has been found satisfactory, but both are very costly, consequently the number of ascensions between 1893 and 1897 was not large. In 1898 Teisserenc de Bort devised a simple and inexpensive paper balloon, by means of which he was enabled to make ascensions several times weekly for a number of years at a very moderate cost, the greater part of which was for labor and gas, the balloons being nearly as large as those employed in "manned" ascensions.

The most noteworthy improvement of the new method of sounding the air is the invention of Dr. Richard Assmann, director of the Royal Prussian Aeronautical Observatory. For the large balloons previously employed, some of which contained 500 cubic meters of gas, Dr. Assmann in 1901 substituted a much smaller one made of sheet rubber, which, when filled with hydrogen and sealed, rises until it is exploded by the internal expansion of the gas. The height at which rupture occurs depends almost wholly upon the quality of the rubber, but even under ordinary conditions the heights attained are much greater than can be reached by any other method. The balloons are made in several sizes, ranging from 1,200 to 2,000 millimeters in diameter, and when fully inflated will lift a light parachute and meteorograph and still exert a surplus lift of from one-half to two kilogrammes. The amount of gas required is insignificant—one to four cubic meters of hydrogen—and the entire work of making an ascension can be attended to by one man. The cost in Germany is about $12, $14, and $25 respectively for balloons 1,200, 1,500, and 2,000 millimeters in diameter. Ordinarily, the balloons cannot be used a second time, for in addition to the rupture by internal pressure, the rubber is easily torn by bushes, etc., after the descent. In the Blue Hill experiments one out of every four balloons could be used again, but the rubber was usually more porous than when new, and the heights reached were lower than those obtained by new balloons. Some of Dr. Assmann's balloons were provided with a valve, which was opened by the expansion of the balloon when it reached a height of 8,000 meters. By this means the balloons could be used repeatedly, and the cost of experimenting materially reduced. The superiority of the Assmann balloon, however, is in the excellent ventilation afforded the recording instrument. The rate of rise is rapid, from two to five meters a second, and is nearly uniform throughout the ascent.

The duration of an ascension is generally less than six hours for a paper balloon, and less than three hours for one of rubber. Instruments of the ordinary observatory pattern are entirely too sluggish to record accurately the rapid changes of temperature, etc., experienced during a high ascension of such brief dura



Basket containing instrument elevated by ballons sondes.



Baro-thermograph. A. Thermometric element. B. Bourdon tube barometer. Baro-hygro-thermograph. A. Thermometer screen. H. Hygrometer hair.

Recording apparatus employed in the Blue Hill experiments at St. Louis.

tion, and modifications have been found necessary in order to secure the requisite sensitiveness. Since the beginning the instruments most used have been of the well-known Richard pattern, except that instead of the alcohol-filled Bourdon tube, there is employed a metallic thermometer composed of two thin strips, one brass and the other steel, soldered together in the form of a circle. On account of the difference in expansion of the two metals, changes of temperature cause changes in the curvature of the element, which are recorded upon the clock drum. The barometer for recording the height is usually of the Bourdon-tube pattern, which is more nearly constant in action than the multiple-cell aneroid, though perhaps more liable to deteriorate. In some instances attempts have been made to record humidity by means of a hair hygrometer, but since this instrument is very sluggish at low temperatures, the records are only roughly approximate. Despite the rapid rate of ascent and descent, the heights recorded by most instruments are accurate within one per cent, and the temperatures within one degree Centigrade, ascending or descending. The clock cylinders are made to rotate once in an hour, giving a time scale

NOTICE!

Hydrogen Gas! Keep Away From Fire!

This Balloon was sent up from St. Louis, Mo., for the study of the upper air.

DO NOT OPEN BASKET OR DISTURB CONTENTS IN ANY MANNER. Please pack the BALLOON, CLOTH COVER AND BASKET in a Box or Barrel, and ship by Express, Collect, to one of the Addresses given below. A Reward of Two Dollars will be paid for this service.

If Found BEFORE NOVEMBER 4th, Return to	If Not Found until After NOVEMBER 4th Return to
S. P. FERGUSSON, Care the Aero Club, Kingshighway and Forest Park, ST. LOUIS, MO.	BLUE HILL OBSERVATORY, HYDE PARK, MASS.

Please Fill Out and Mail One of the Cards Inside this Envelope.

Notice on envelope secured to basket.

No. 274 *Sent up from St. Louis, Mo.,* MAY 10, 1906

(12th Ascension) *for the study of the upper air.*

Found at Eight miles east of Anna Ills

Date and Time Found May 11, 6 a.m.

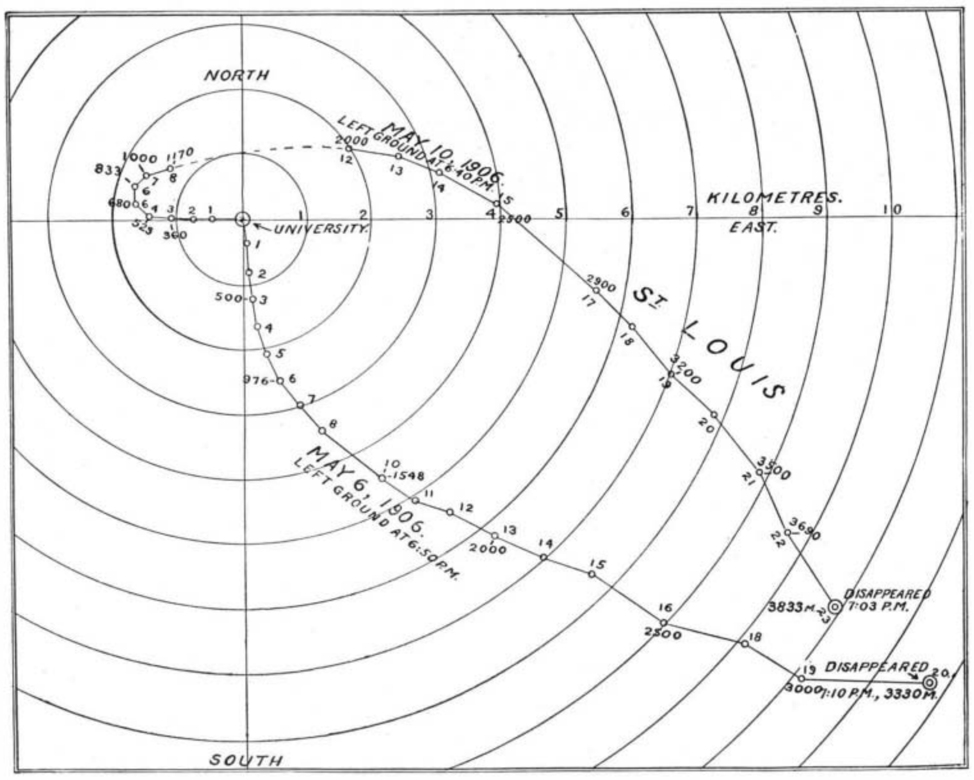
Name of Finder Joseph Toler

Address Anna, Ill.

If Found Before NOVEMBER 4th, return this *card.*

If Not Found until After NOVEMBER 4th, return the other *card.*

Card returned by finder of balloon sent up May 10th, 1906.



Courses of two ballons sondes liberated at Washington University, St. Lonis.

Small circles in the lines indicate times at which observations of altitude and azimuth were made. Figures show minutes elapsing since the balloon left the ground.

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of several millimeters a minute, so that readings can be made at least every 20 seconds during an ascension. There has been found no ink capable of withstanding the very low temperatures encountered in the upper air, and the ordinary ruled diagram cannot be used on these instruments. Instead there is employed a thin sheet of aluminium coated with lampblack, upon which the changes in pressure and temperature are traced by minute steel points secured to the recording styles. After the record is obtained, it is fixed by dipping the sheet into a solution of shellac. Since no ruled scales can be used, it is necessary to prepare for each instrument a separate calibration sheet or scale, upon which is marked the amount of displacement of each recording style when the instrument is subjected to definite changes of pressure, humidity, and temperature, measured by means of standard instruments. The pressure scale extends throughout the entire range of barometric pressure, and the range of temperature is usually from 30 deg. above to 80 deg. below zero Centigrade. This test or calibration is made to correspond as nearly as possible with the conditions experienced during an ascension, and in some instances the pressure and temperature are lowered or raised simultaneously. It is necessary to repeat these tests occasionally, in order to detect changes in the condition of the instruments. The operation of reading or measuring the records, when it is done thoroughly, is a very tedious one because of the very small values of the pressure scales. In some instances, at heights exceeding 15,000 meters, a change of height of 1,000 meters is indicated by a movement of the barometric style of less than 0.2 millimeter; hence the need of extreme care in measurement.

The outer casings of some instruments are made of cork, which prevents them from sinking when they fall into water; also, in the newer instruments of Teisserenc de Bort, the cases are of mica, so that every part may be inspected without opening them, and the curiosity of the finder satisfied without unnecessary risk.

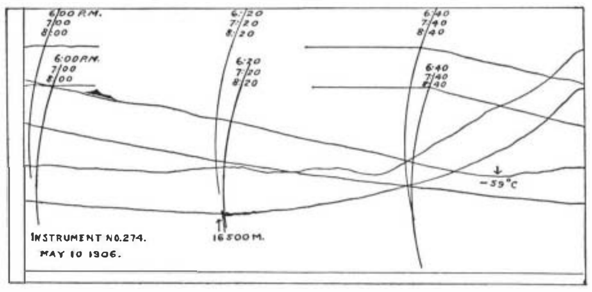
The instruments are secured within a light wicker framework surrounded with large elastic hoops or buffers, which prevent injury as the balloon descends. About the sides of this basket is wrapped a strip of silvered paper, which serves to protect the thermometer from direct sunlight, and by reflecting the light, attract the notice of a possible finder. Also, to secure identification, there is attached a waterproof envelope bearing instructions to the finder to return the balloon and basket unopened, and receive a reward for his trouble. Inside the envelope is a card on which are to be noted the time and place of descent, etc. The basket is suspended four or five meters below the balloon, the suspension cords being secured to a light cotton or silk parachute placed on top of the balloon. This parachute serves to retard the speed of descent after the balloon explodes. Sometimes, instead of a parachute, a smaller balloon only slightly inflated is employed, which does not explode, but after the descent floats a short distance above the basket, and thereby aids in its recovery. The total weight of the 1,500-millimeter balloon, recording instruments, basket and cotton parachute is about 2,450 grammes, or 2,200 grammes if silk parachute is employed. The capacity of this balloon is three cubic meters of hydrogen, having a lift of 3,000 grammes, or an excess over the weight lifted of 600 to 800 grammes. These data refer to the Assmann balloon and the recording instruments of Teisserenc de Bort, but will apply fairly well to apparatus employed by others.

In Europe, except England, more than 95 per cent of the *ballons sondes* liberated are returned; while in America, of 77 sent up at St. Louis, 71, or 92 per cent, have been found and returned.

The use of the *ballon sonde* has become very extensive in Europe, and in many places it has largely superseded the manned balloon in meteorological studies. Also, since the organization of the International Commission for Scientific Aeronautics, ascensions are being made, not only on predetermined days, but according to uniform methods.

The experiments with *ballons sondes* at St. Louis, the first of the kind undertaken in America, are due to the enterprise of Prof. A. L. Rotch, director of Blue Hill Observatory. In 1904 the Louisiana Purchase Exposition made a large appropriation in aid of aeronautics, and of this the sum of $1,300 was expended by the Department of Liberal Arts in the purchase of equipment and in the routine expense of the first experiments, which were conducted by the staff of Blue Hill Observatory. The first ascension occurred on September 15th, 1904; three others were made during that month, and ten others during the last days of the exposition in November. These were so successful that the work was continued in January, 1905, July, 1905, May, 1906, October and November, 1907, the greater part of the cost being paid from grants obtained by Prof. Rotch from the Hodgkins Fund, held by the Smithsonian Institution. The details of the work, including the management of the accessories and the discussion of the records, have been attended to by Mr. Clayton and myself. Since the close of the exposition the ascensions have been made at Washington University, St. Louis, except in October, 1907, when they were conducted at the grounds of the Aero Club of St. Louis, the authorities of the university and the Aero Club having very kindly given all possible assistance to the experimenters.

The results of the St. Louis ascensions show that the velocity of the upper air currents is much greater in America than in Europe. Of the 71 balloons returned, the average distance traveled was 160 kilometers, or at an average rate of at least 15 meters a second. The greatest distance traveled was 450 kilometers, at a mean velocity of 46 meters a second. Since the velocity of the wind at the ground was rarely more than 10 meters a second, it follows that in the higher regions of the air velocities of 60 meters a second may be expected at times. The increase of velocity with height is quite well illustrated in the plotted course of the balloons sent up on May 6th and 10th.

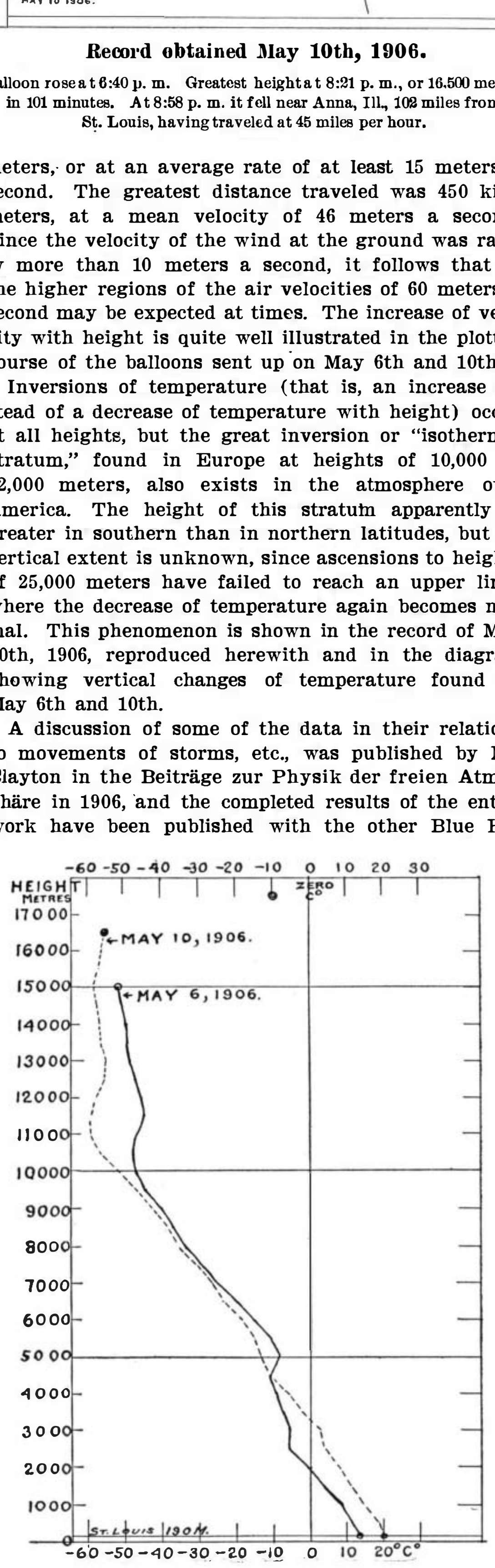


Record obtained May 10th, 1906.

Balloon rose at 6:40 p. m. Greatest height at 8:21 p. m., or 16.500 meters in 101 minutes. At 8:58 p. m. it fell near Anna, Ill., 102 miles from St. Louis, having traveled at 45 miles per hour.

Inversions of temperature (that is, an increase instead of a decrease of temperature with height) occur at all heights, but the great inversion or "isothermal stratum," found in Europe at heights of 10,000 to 12,000 meters, also exists in the atmosphere over America. The height of this stratum apparently is greater in southern than in northern latitudes, but its vertical extent is unknown, since ascensions to heights of 25,000 meters have failed to reach an upper limit where the decrease of temperature again becomes normal. This phenomenon is shown in the record of May 10th, 1906, reproduced herewith and in the diagram showing vertical changes of temperature found on May 6th and 10th.

A discussion of some of the data in their relations to movements of storms, etc., was published by Mr. Clayton in the Beiträge zur Physik der freien Atmosphäre in 1906, and the completed results of the entire work have been published with the other Blue Hill investigations in the Annals of the Astronomical Observatory of Harvard College.



Changes of temperature with change of height. Note beginning of "isothermal stratum" between 10,000 and 12,000 meters.

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Heretofore no experiments with *ballons sondes* have been undertaken near the Atlantic coast, for the reason that, even if the ascensions were made far enough inland to prevent loss of the equipment in the ocean, the probable loss, in the large areas covered by swamps, forests, and mountains in this region, would be much greater than in the region east of St. Louis. However, on May 7th and 8th, 1908, two ascensions were made at Pittsfield, Mass., by Prof. Rotch, director, and Mr. Clayton, meteorologist, of the Blue Hill Observatory, in order to test a method, proposed by Mr. Clayton, of limiting the duration of the ascensions, so that in all probability the instruments would fall before reaching the coast. This device consists of a mechanism controlled by a clock, whereby the balloon is released from the parachute at some predetermined time, the parachute and instrument falling to the earth before the balloon reaches its greatest height. By the use of two balloons it was expected that, with the resulting increase of lift, a maximum height exceeding 5,000 meters would be reached before the balloons drifted too far eastward. One balloon sent up on the 8th was found on the same day at Randolph Center, Vt., 177 kilometers N. N. E. from Pittsfield, but the instruments have not yet been reported, and at the present time it is impossible to reach a conclusion as to the practicability of the method or the suitability of the locality for experimenting. Further experiments are expected to yield more definite results.

Correspondence.

THE "REPUBLIC" DISASTER.

To the Editor of the SCIENTIFIC AMERICAN:

The writer, who is a constant reader of your paper, found your editorial "Lessons of the 'Republic' Disaster" very interesting and doubtless correct in its conclusions. At any rate the latter appear thus to a layman. He thinks, however, that you are not justified in assuming that the "Republic" was built on specifications of the White Star Company and "therefore represented the most approved methods of steamship construction."

He acknowledges the excellent reputation enjoyed by Harland & Wolff for marine work, but has no knowledge whether or not they build equally as well for one steamship company as another. One would suppose they would build according to specifications and charge accordingly. But the point he wishes to make is this: If not mistaken, the "Republic" (formerly the "Columbus") the "Canopic," and "Romanic" were built for the Dominion Line, and were bought from the latter by the White Star Company five or six or more years ago. At the time they were built they were perhaps not in the same class as the White Star ships launched about that time. They seem to have been rather what might be termed combination craft, provided with relatively large cargo and steerage capacity and of moderate power and speed. Built for general business between Boston and Europe and outside the intense competition existing in the New York service, it seems reasonable to conclude that there was not as much required in the way of speed, comfort and cost as in the case of the New York lines. The change of name and ownership added little to their strength and seaworthiness in case of accident.

W. G. PARSONS.

Cambridge, Mass., February 9th, 1909.

Death of Earzm von Jerzmanowski.

Herr Earzm J. von Jerzmanowski, who for many years lived in New York, where he was in the gas business, died on February 12th at Cracow, Austria.

Herr von Jerzmanowski was well known in this city as the introducer of the water process of making illuminating gas, now almost universally used throughout the United States.

After the Polish rebellion he had been exiled from Russian territory. He went to Paris and there took up scientific work under Prof. du Moty. His experiments carried him to the most advanced stages in the commercial application of natural and manufactured gas.

Herr von Jerzmanowski was appointed a captain in the French army during the Franco-Prussian war. He was stationed at Paris. The title of Count had been conferred on his father by Napoleon Bonaparte and fell to him by birth. In 1889 he was honored with the Cross of St. Sylvester by the Pope.

The Current Supplement.

An illustrated description of the new railroad bridge at Vancouver opens the current SUPPLEMENT, No. 1730. The extraordinary change that has taken place in recent years in the proportioning of screw propellers for turbine steamers is discussed from the engineering standpoint. The question of the amount of heat in steam under various operating conditions, the quantity of this heat available for transformation into work and the various relations of this heat quantity which produce condensation and superheating and other equally important changes in the steam content are treated by Joseph H. Hart. In commemoration of the centenary of Darwin's birth, Prof. David Starr Jordan writes a popular article on "Darwinism, Fifty Years After." The Life History of the White Ant is authoritatively set forth by Prof. K. Escherich. Dr. Robert Fuerstenau writes instructively on the mechanism of the human brain. Arthur W. Ewell explains the thermal production of ozone. A third installment of the treatise on aeronautic motors appears. Other articles worthy of mention are entitled "Glass Brick: A New Building Material"; "The New Reducing Agents Employed in Metallurgy"; "Reaction Propellers for Aeroplanes"; "Recent Progress with the X-rays," and "Earthquake Forecasts."