SAN FRANCISCO WATER SUPPLY.

THE GREATEST MUNICIPAL SYSTEM OF ARTIFICIAL STORAGE IN THE WORLD.

In the memory of living men, drinking water has sold in the streets of San Francisco at a dollar a bucket. This was derived from wells situated where now the Palace Hotel stands. Later, individual enterprise erected pumping works in the northern portion of the city, drawing from Point Lobos Creek, a streamlet forming a boundary of the military reservation known as the Presidio. This water was forced into reservoirs with elevations of 140 and 300 feet, and from thence distributed over the city in pipes. The supply was limited.

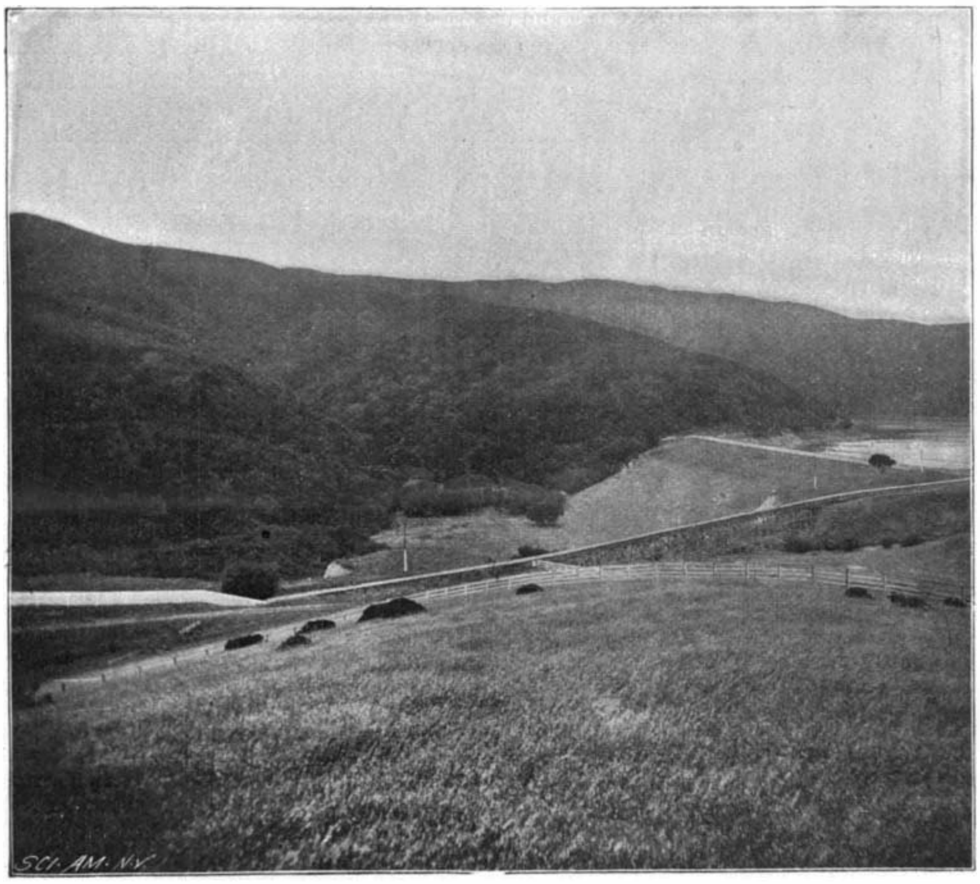
To-day no city in the world surpasses San Francisco in the abundance and purity of its water supply; but this result has not been achieved without an expenditure of nearly $30,000,000 in money. The obstacles met with and successfully overcome were almost insurmountable; for Nature, though granting every other advantage that the site of a great maritime capital required, gave neither natural reservoirs nor living streams whence supplies of water for a populous community might be drawn.

In one respect only were the engineers assisted by the natural features of the country—the ranges of mountains that traverse the peninsula upon which San Francisco is located provided admirable sites for artificial storage lakes. By the erection of massive dams across their outlets vast artificial stores of water were laid up, from which supplies might be drawn in the event of prolonged droughts and during the intervals when no rain falls whatever.

Within the boundaries of San Francisco and the country immediately adjoining, all sources of water supply combined would not naturally furnish a city of 30,000 inhabitants. The problem so successfully solved provides water in ample quantities for a city of, prospectively, 1,000,000 inhabitants, without natural resources of its own, and dependent upon the rainfall of but six months of the year. How this great feat has been accomplished is one of the engineering triumphs of the century. Nothing in municipal supply is to be found to compare with it on the globe. London, Manchester, Liverpool, Glasgow, Philadelphia, Boston, and New York, all cities which have spent vast sums in obtaining an adequate water supply, would suffer severely were a six months' drought to afflict their watersheds. San Francisco, on the contrary, with its system of great artificial lakes, could face a drought of twenty-four or even thirty-six months with entire equanimity without curtailing its normal consumption of 750,000,000 gallons a month. If the great cities named were compelled to provide a two years' supply by artificial storage, assuming it were possible to do so, their investment, on this account, would be multiplied many times and their charges, therefore, would have to be proportionately increased. Geographically, San Francisco occupies the head of a peninsula about fifty miles in extreme length and less than twenty-five in average breadth. The superficial area of the city is about that of Manhattan Island, and it is capable of supporting an equally large population. Unlike Manhattan Island, the contour of San Francisco is extremely irregular, rising from sea level to an elevation of 900 feet. Its surface is covered with hills of various height, divided by valleys, and to secure a practicable grade for its streets an immense amount of leveling has been necessary. As the city increases in population the higher elevations are becoming built up and water has to be afforded. Eventually the highest elevations will be covered with dwellings. Irregular as the surface of the city is, every foot of the area will ultimately become habitable. At present the population is about 325,000.

Within the city limits ten high distributing reservoirs have been constructed. The most elevated is at Clarendon Heights, 600 feet above the tide. The others are Lake Honda, 377 feet; Clay Street Hill, 375 feet; Halliday Hills, 375 feet; Russian Hill, 306 feet; Potnero Heights, 300 feet; College Hill, 210 feet; University Mound, 175 feet; Francisco Street, 139 feet; and Industrial School, 300 feet; with an aggregate capacity of about 200,000,000 gallons, available at all times for any emergency. The city is divided into four water districts, according to elevation. From 0 to 139 feet is the first, and 250 feet, 375 feet, and 600 feet are the limits of the other districts.

It is this high distributing system that affords San Francisco such ample protection from great conflagrations, even though 90 per cent of the buildings are frame, built less solidly than Eastern dwellings on account of the almost frostless climate The water flows from these reservoirs by gravity at a pressure of from 40 to 70 pounds per square inch at the hydrants, and the larger number of incipient fires are extinguished by means of private facilities made possible by this heavy pressure. In San Francisco there are in all 363 miles of pipes laid in the streets, from 3 to 44 inches in diameter, with 3,581 hydrants. At the present time there are 41,022 rate payers, increasing yearly about 1,000. The daily consumption of water is 25,000,000 gallons. The important functions performed by the great reservoirs of the San Francisco water supply system will be better understood if the peculiar conditions, meteorological and climatic, that prevail in the latitude of San Francisco be explained. The seasons are divided into "wet" and "dry," the former extending from October until May, during which all the rains of the year are precipitated. These rains are always moderate, never torrential, a fall of 1·5 inches in twenty-four hours being considered "heavy." During the whole twelve months there is an average of not more than 60 rainy days. In the season of 1897–98 there were only 36 days of rain. From May to October is the "dry" season, in which practically there is no rainfall whatever. From a record of 50 years the average annual fall is 25·54 inches. In 1889–90 the unprecedented amount of 52·27 inches was recorded; in 1897–98, but 10·07 inches. The lowest on record was in 1850–51—7·40 inches.



LAKE SAN ANDREAS; SAN FRANCISCO WATER SUPPLY.

Pilarcitos Lake was the first constructed by the company. It is situated in San Mateo County, 17½ miles from the city. Its elevation is 696 feet and it is inclosed by a stone dam 95 feet in height. Its storage capacity is 1,050 million gallons and it discharges into Lake Honda, within the city limits, through a 30-inch conduit, 32 miles in length, 2,500 feet of which is through a tunnel.

San Andreas Lake is 15 miles from the city at an elevation of 452 feet. Its dam is 95 feet high and built of stone. The storage capacity is 6,200 million gallons.

NUMBER OF "RAINY DAYS" IN SAN FRANCISCO DURING PAST TEN YEARS.

	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898
January	6	21	3	7	8	12	13	12	5	7
February	6	9	12	9	9	13	5	3	15	8
March	11	13	10	13	13	8	6	13	13	4
April	7	5	8	7	6	6	3	13	3	1
May	7	4	4	7	2	6	6	5	1	4
June	....	2	1	....	1	4	....	....	1	1
July	....	1	1	....	....	....	1	....	....	....
August	....	....	....	....	....	....	....	2	....	1
September	....	1	3	....	2	1	3	3	....	....
October	13	....	1	5	2	5	2	3	5	....
November	7	....	3	7	11	1	5	8	5	....
December	25	5	10	11	12	22	8	11	6	....
Total	82	61	56	66	66	78	52	73	54	23

Crystal Springs Lake is 23 miles from the city and is the largest of the entire group. It is formed by the great stone dam 145 feet in height, which is to be raised an additional 30 feet, which will increase the present storage capacity of 19,000 million gallons to 29,000 million. The elevation is 350 feet.

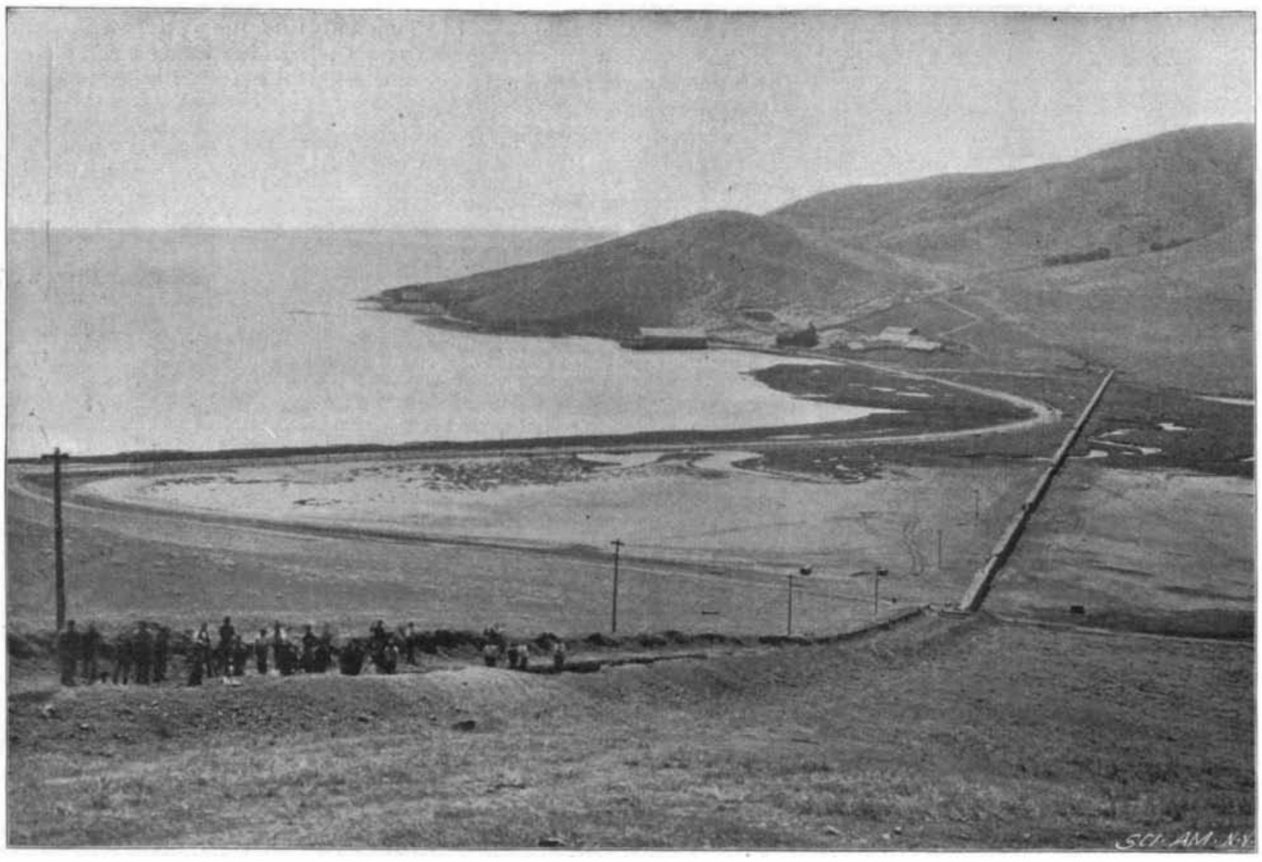
Portula Lake is 26 miles from the city, near Menlo Park. Its stone dam is 120 feet high and stores 3,000 million gallons.

The total storage capacity of these four artificial lakes is 29,250 million gallons. In addition to the sites occupied by these immense bodies of water, and to insure against any pollution of the supplies, the company has acquired by purchase the entire control of their watersheds, from which nearly every habitation has been banished. The land thus acquired amounts to many thousands of acres.

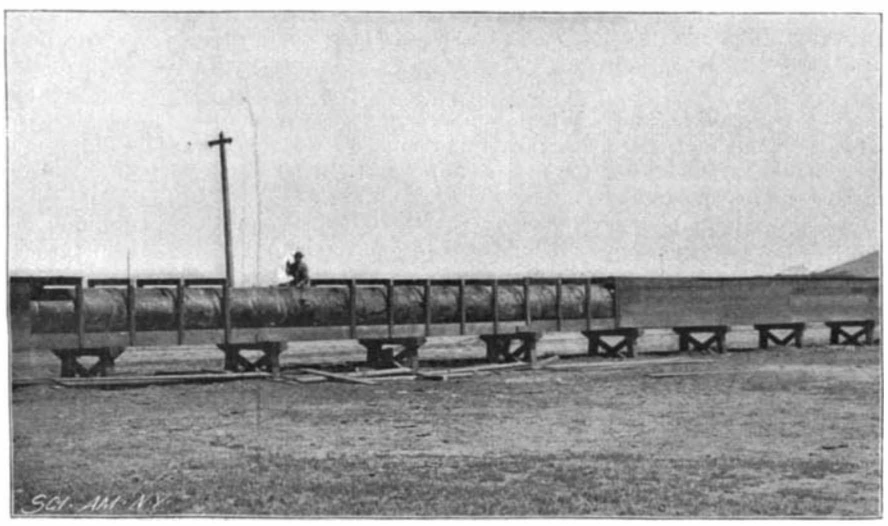
The only natural reservoir on the whole peninsula is Lake Merced, once

BLASTING IN HARD GROUND; FROM AN INSTANTANEOUS PHOTOGRAPH.

an arm of the sea, situated within the limits of San Francisco, and at its lowest depression. The outlet, through which the tide used to flow, has been closed; the lake water has become fresh and is now a valuable source of supply. It has a superficial area of several hundred acres and affords storage for 2,700 million gallons of water of the best quality. Three million five hundred thousand gallons can be drawn from it daily without diminishing the volume of the lake. A fine pumping plant, with a capacity of 7,000,000 gallons every twenty-four hours, forces the water to an elevation of 430 feet, supplying one of the larger high distributing reservoirs. In order to keep the lake free from surface pollution, the company has acquired 3,000 acres immediately surrounding it, and otherwise controls its entire watershed of 8 square miles. At times, however, when rains are unusually copious, floods of surface waters have poured into the lake down Ocean View and Coloma cañons and temporarily rendered the waters unfit for domestic use; but within the past year a settling reservoir has been constructed at the southerly end, with a brick conduit leading therefrom to and through the ridges oceanward by a brick tunnel, discharging into the ocean and carrying

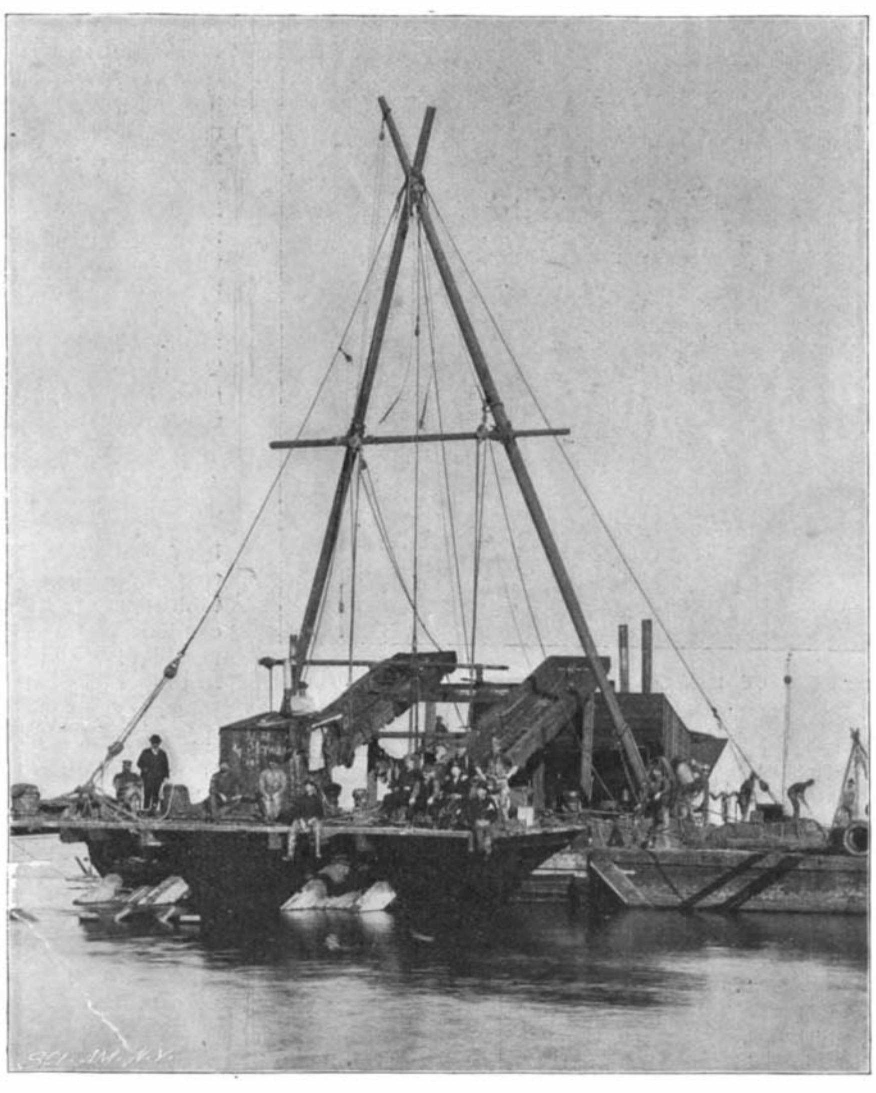


PIPE-LINE ACROSS MARSH, CARRIED ON TRESTLES.

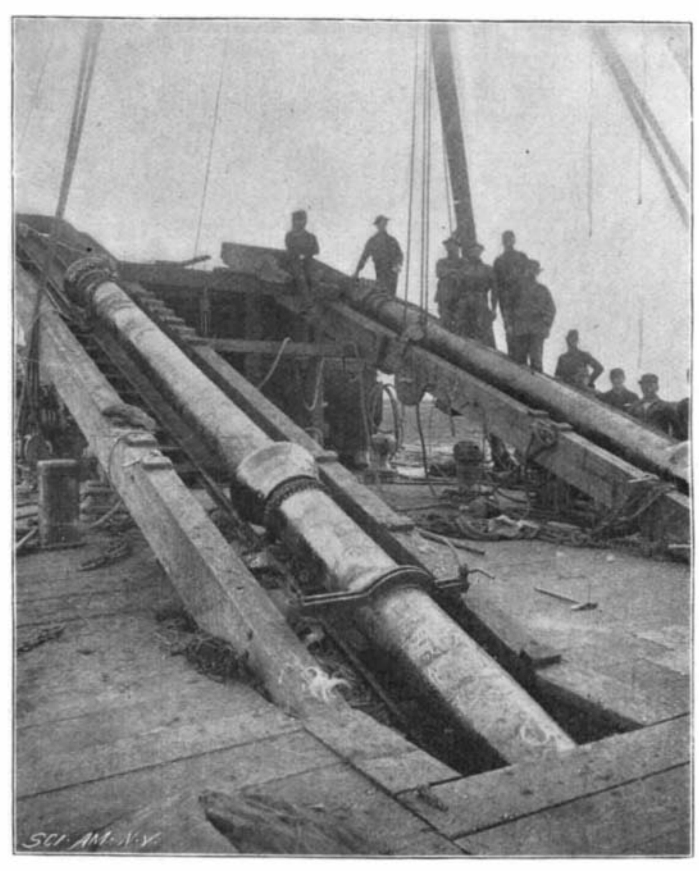


METHOD OF CARRYING PIPE ON TRESTLES.

DIGGING PIPE-DITCH WITH PLOW AND MULES NEAR SAN MATEO.



VIEW OF THE PIPE-LAYING BARGE.



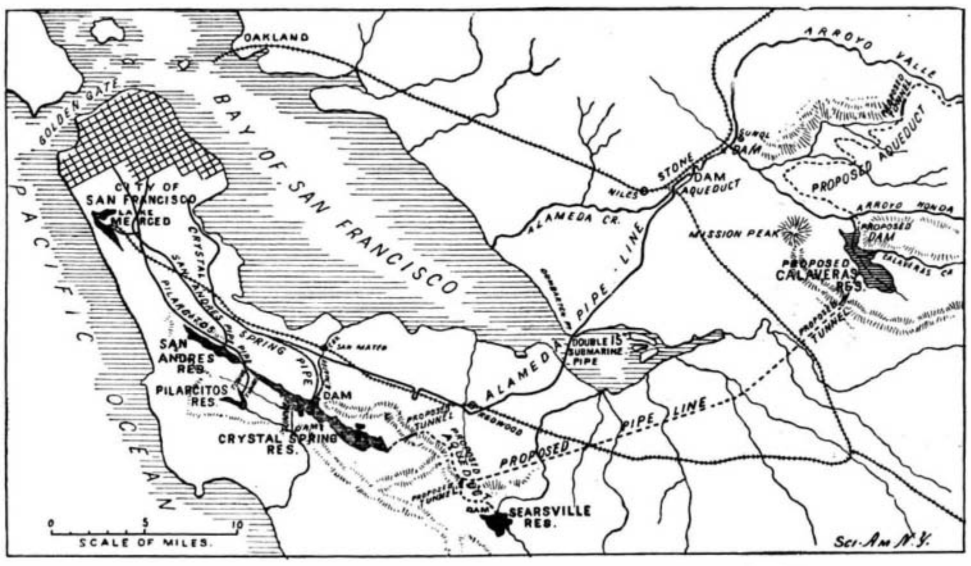
END VIEW OF BARGE, SHOWING LAUNCHING CHUTES FOR LAYING PIPES BELOW THE WATER.

away all polluted waters. From other neighboring cañons a redwood flume conveys the floods to the settling reservoirs. This provision keeps the lake waters pure, no matter how violent the floods may be.

With the store of Lake Merced added to the other reservoirs, an aggregate of 31,950 million gallons is available, or sufficient supply to furnish San Francisco, at its present rate of consumption, for at least three years.

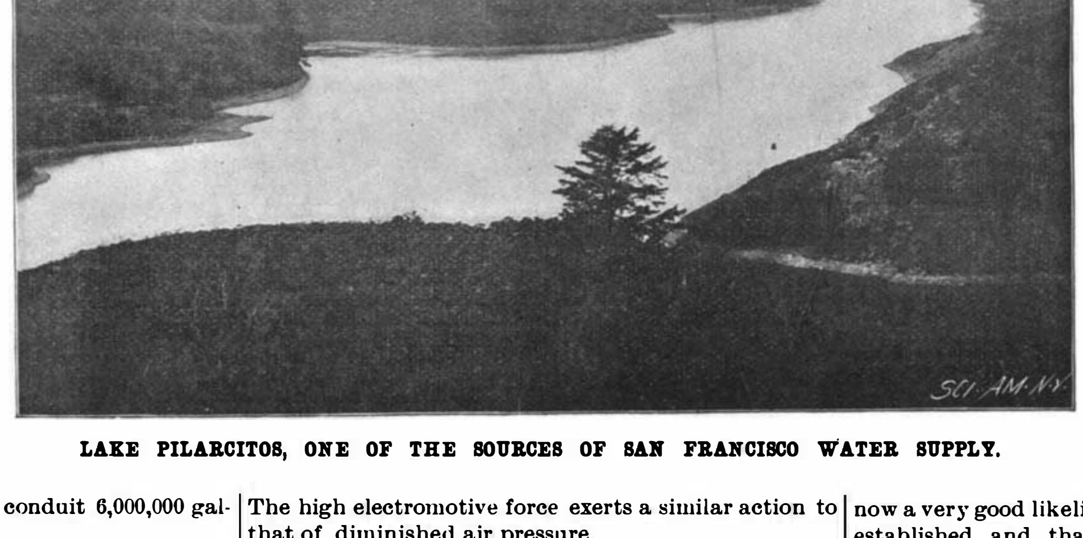
Twenty-five years ago the water company began to realize that no policy of extension ought to be adopted that did not adequately provide for all future eventualities.

To supply a city of the size that San Francisco is destined to assume with water was manifestly beyond the power of the limited watershed of the peninsula to accomplish; consequently, a tract of land, with all the water rights, reservoir sites and adjacent lands, was obtained on the east side of the Bay of San Francisco, and added to the resources of the company. It extends from Mount Diabolo on the north to Mount Hamilton on the south, and embraces an area of 700 square miles in three counties. On Calaveras Creek the site of a gigantic artificial lake has been selected, and a great stone dam, much higher than the one at Crystal Springs, will in the not distant future be erected. This great lake will submerge the entire Calaveras Valley and contain 100,000 million gallons of water. This tract is separated from the peninsula by the Bay of San Francisco.



MAP SHOWING THE RESERVOIRS AND PIPE-LINES OF THE SAN FRANCISCO WATER SUPPLY.

It was not until 1887 that water from the Calaveras tract was utilized for supplying San Francisco. In that year a stone dam was erected across Alameda Creek, near the city of Niles. The distance from this dam to the pumping works at Belmont, on the west side of the bay, is about 29 miles, and it cost $1,750,000 to make the connection, which required 146,000 feet of 36-inch and 13,000 feet of 16-inch iron pipe. The larger pipe was laid on land, 19,000 feet being laid on piles. There was, besides, a deep slough, 300 feet wide, and the bay, 6,500 feet wide and 60 feet deep, to span. Below water, double pipes, of 16 inches in diameter, were substituted for the 36-inch. The operation of laying the small pipes across the bay was highly ingenious, and has been but rarely employed in this country. Engineers were greatly interested at the time and anticipated failure, but time has proved it a success.



LAKE PILARCITOS, ONE OF THE SOURCES OF SAN FRANCISCO WATER SUPPLY.

A working barge 40 × 100 feet was fitted up especially for this work. Two heavy inclined chutes or aprons, fourteen feet from center to center, were built on the stern end, so swung on an axle on the barges as to admit of the angle being quickly changed to suit varying depth of water. Tracks, extending some ten feet under water, were fastened to the chutes for the pipes to slide down.

Erected on the barge, and straddling both chutes, was a large pair of shear legs 100 feet high so arranged that pipes could be taken from the lighters alongside and dropped into either chute. The pipes were connected with ball and socket joints. The entire conduit was constructed and placed in position by the Risdon Iron Works, of San Francisco, from plans prepared by Hermann Schussler, chief engineer of the Spring Valley Water Company. Through this conduit 6,000,000 gallons are received daily.

Transmission of Power Through the Air Without Wires.

BY PROF. JOHN TROWBRIDGE.

Mr. Tesla has recently patented a method of transmitting power through the air without the use of wires. This method consists in producing a very great difference of potential between a high point in the atmosphere, reached by a wire connected to a balloon, and a distant point on a balloon, which in turn is connected through a stepdown transformer with the earth. A stepup transformer produces the high potential at the sending station, or at the first balloon, and the difference of potential thus created produces a current of conduction through the rarefied air to the second balloon and thence through the stepdown transformer to earth. Mr. Tesla relies upon the good conductivity of rarefied air to high electromotive force.

Some recent experiments I have made with high electromotive force are interesting in regard to the suggestion of Mr. Tesla, and are in continuation of those I described in the SCIENTIFIC AMERICAN for January 15, 1898. At that time my apparatus was capable of producing one million two hundred thousand volts. It now can produce three million.

Up to the point of one million and a half volts, the length of the electrical discharge in air appears to be closely proportional to the electromotive force. When this voltage is exceeded, the length of the spark no longer increases in proportion to this force, for instance, and electromotive force of approximately three million volts produces a spark of about seven feet in length, when it should excite one at least ten feet long. The reason of this diminution is readily seen when the operation of my apparatus is examined in the dark.

From both terminals and from the conductors to those terminals there is a luminous brush discharge to the walls and floor of the room. The main portion of the discharge is, so to speak, shunted through the air, which breaks down with facility at such high voltages.

The high electromotive force exerts a similar action to that of diminished air pressure.

In the case of rarefied air, one sees the luminous area of discharge on the positive terminal extend farther and farther from the point of the terminal, thus indicating that there is an increased flow through the rarefied air. In ordinary atmospheric air the same increase of electrical conductivity takes place under the action of great electromotive force. When discharges produced by one million volts or more are excited between terminals six feet apart, in tubes filled with water, the tubes are speedily burst, and when the phenomenon is carefully examined, it is perceived that the disruptive sparks occur on the surface of the water inside the tubes which vaporize the water and thus lead to an explosion. The layer of air conducts more readily than the water. The same phenomenon can be shown by interposing a conductor made of plumbago and infusorial earth, making a resistance of about 10,000 ohms between the terminals of the apparatus. A spark passes over the surface of such a conductor through the air, if the length of such a conductor does not exceed ten or twelve inches.

I found also that the spark preferred to jump through five centimeters of air to passing through a thousand ohms of a copper sulphate solution. Thus the air evidently breaks down with increasing readiness when the electromotive force is increased beyond a certain limit.

One of the most striking experiments in this connection can be performed by coating a board with a thin layer of plumbago, which is polished upon the surface in such a manner as to make a resistance of about 1,000 ohms between broad terminal bands of copper. When a discharge under a difference of potential of 1,000,000 volts passes between the terminal bands, the entire surface of the conductor becomes luminous.

When my new apparatus was first set up, the coated surfaces of the Leyden jars were not more than a foot from the floor. On account of the great loss due to electrostatic induction, I determined to have the entire apparatus lifted three feet from the floor. A certain portion of the loss was thus obviated, but when discharge takes place, sparks an inch long can be drawn from the neighboring brick walls, and the entire room seems to be filled with brush discharges.

I believe, therefore, that beyond one million volts, the length of the spark is no longer proportional to the voltage, and that this departure from proportionality is due to the initial resistance of the neighboring air becoming less and less. In order to get the full effect of the voltage of my machine, I believe that it should be placed thirty or forty feet above the earth and at a distance from neighboring masses. The apparent length of lightning discharges at low altitudes is therefore no criterion of the voltage which produces these discharges; for there must be great leakage, which necessitates an excess of electromotive force to produce the discharge. On the other hand, the discharges in higher regions of the atmosphere are much lengthened on account of the increased conductivity of the medium.

In view of the experiments which I have described, I am led to believe that ordinary atmospheric air under very high voltage acts like a fairly good conductor, and I can conceive of such a high electromotive force that the initial resistance of air might not be more than the resistance of metals. The loss of electrical energy in producing difference of potential of three million volts at a distance of ten feet from the terminals of my machine is very great, and in employing such high voltages Mr. Tesla could only obviate great loss by lifting his entire generating apparatus far above the surface of the earth.

A COMMITTEE appointed by the English government to consider the matter of establishing a national physical laboratory has reported, making recommendations as to the scope of the proposed work. There seems to be now a very good likelihood that the laboratory will be established and that it will, when in operation, be directed by a governing council appointed by the Royal Society. It is thought, further, that it will be located near Kew, where much valuable work has already been done in the way of standardizing thermometers, barometers, watches, nautical instruments, etc. The new laboratory will take up the line of physical work which would naturally come before such a bureau.

IT is announced that a first-class meteorological observatory is to be built on the Zugspitze, the highest mountain in Germany. The altitude is stated to be nearly 3,000 meters.