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Contents.

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TABLE OF CONTENTS OF

SCIENTIFIC AMERICAN SUPPLEMENT

No. 527

For the Week Ending February 6, 1886.

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STOPPAGE OF THE CLEVELAND WATER TUNNEL BY ICE SPICULES.

The system of running tunnels out to some distance under the surface of the water in our Western lakes, to gain a supply of pure water for cities on the shores thereof, has, in the main, proved highly successful. The single defect yet unsurmounted is the liability of these tunnels to become clogged with ice in cold weather, and thus cut off the water supply.

To the citizens of Cleveland, in whose memories the recollection of the great fires of sister cities is yet fresh and vivid, it must have been a starling announcement on the morning of January 14 that the water supply was entirely cut off by ice accumulation in the tunnel between the lake crib and the pumping station; that the principal industries of the city must be suspended, and its valuable property left, at least temporarily, to the mercy of circumstances should fires break out.

There ought never again to be a recurrence of such a danger and inconvenience to any town from the cause named. It can be wholly and cheaply prevented, as we shall proceed to point out; but first let us consider briefly the causes of the stoppage.

These are to be sought in well-ascertained principles of ice formation, under the condition that the application of the cold to the liquid to be frozen is made to the upper surface.

When a mass of still water having a temperature above 4° C., or 39° F., is exposed to a superimposed mass of air colder than the water, two surface actions for the removal of heat from the liquid unite their forces, to wit, convection and radiation.

The latter of these modes of heat change acts constantly, summer and winter, without any dependence upon the temperature of the air, except in so far as temperature affects the amount of water vapor held suspended in air. Air not being a radiating body, its action upon the upper surface of water can only effect heat change by convection, and this action will not be set up when either the air or the water is perfectly at rest, and the temperature of the air is higher than that of the water. The reason for this will be obvious when we reflect that the action called convection consists in the interchange of place of fluid molecules which are hotter with those that are colder; and that the colder molecules of water descend at all temperatures above that known as the temperature of maximum density, while the colder molecules of air descend, when free to move, at all temperatures yet known as naturally or artificially produced. It follows that when the upper surface of a still mass of water is in contact with a mass of superincumbent air, the warmer stratum of the water will be uppermost, and the colder stratum of the air will be that resting upon the water—a condition under which the motion needed for the action of convection is impossible.

But if the air be colder than the water, the lower stratum of air molecules derives heat from the upper stratum of water molecules; the former rises and the latter falls, and the action of convection at once begins.

This action continues (always provided there is no stirring of the mass by exterior forces) till the water reaches 4° C., or 39½° F., when a remarkable change takes place. The water molecules now expand, and their specific gravity becomes less; they now cease to descend, and begin to rise.

A stratum of water, having the temperature of 4° C., now forms at the upper surface of the water mass, and there remains. By contact with the colder air, this stratum quickly reaches the freezing point, and congeals into a film of ice. The action of convection between the air and the yet liquid water under the frozen film now wholly ceases, and all further transfer of heat from the liquid to the air must be by conduction through the ice. The action of convection between the air and the upper surface of the sheet of ice and transfer of heat from the water to the lower surface of the sheet of ice continue so long as any part of the water remains unfrozen; and not until the ice, after freezing, has cooled down to the temperature of the air will the heat transfer wholly cease. Radiation greatly assists the process. This is nature's method of manufacturing ice.

The upper film of ice, when it first begins to form on a still mass of water, will be found, when critically examined, to be a curious network of crystals, very slightly cohering at their angles or points. The slightest motion of the liquid breaks these connections, and sets the crystals free to move in obedience to any current that may be generated in the liquid. Now, if the liquid be kept constantly stirred, each stratum of crystals as it forms will be carried down ward, the temperature of the water will be reduced throughout its mass to the freezing point, and just as meal sprinkled on the surface of water can be stirred into the mass, so the continuously forming ice crystals commingle with the liquid portions, and the mass becomes (to use a common phrase) "mushy." Everywhere and anywhere where any obstruction to motion exists, the crystals, pausing in their course, immediately cohere to form ice masses themselves, also obstructive to motion, and at last large, granular, milky-looking masses of ice result. It hardly needs to be added that the conditions of ice formation on the Lakes must sometimes conform to what we have described.

Whenever the temperature of maximum density has been attained at their surfaces, and the action of winds and waves, assisted by a current into the mouths of the tunnels of the water supplies, becomes sufficiently intense to produce the "mushy" condition, the tunnels are sure to become obstructed, either partially or wholly. Strainers at the mouths of the tunnels, no matter how they may be constructed or arranged, cannot meet the difficulty; if fine enough to prevent the passage of the ice spicules, they inevitably become clogged.

It is evident that, if the mean temperature of the water entering the mouth of the tunnel be kept even a fraction of a degree above the freezing point, and if the ice particles be also melted as they enter, or just before they enter, no ice obstruction could even form in any part of the tunnels, these being by their situation protected from freezing.

We will briefly calculate the amount of heat required to effect this for a million of gallons, assuming 10 per cent as the proportion of ice in the water at the instant of inflow, which is probably considerably too high. For simplicity, we will consider the specific gravity of ice to be the same as that of the water, and the weight of a gallon of water to be eight pounds.

We shall then need to heat 900,000 gallons of water one-quarter of one degree, and melt 100,000 gallons of ice.

We shall need for the entire work $900{,}000 \times 8 \div 4 = 1{,}800{,}000$; $100{,}000 \times 142{\cdot}4 \times 8 = 113{,}920{,}000$.

Total (heat units) = 115,720,000.

Dividing this total by 966·5, the heat obtainable from one pound of steam, we get 119,710 pounds of steam required. With a boiler of good type, well housed, we can get a steam product of 10 pounds per pound of coal consumed, hence we have 11,971 pounds of coal required for the work, or, in round numbers, say 5½ tons. At $5 per ton this would cost $27.50, or 2¾ cents per each 1,000 gallons delivered.

Contrast this slight expense with the loss per hour to the city of Cleveland from the stoppage of her manifold industries, the risks entailed upon insured property and insurance writers, and the untold inconvenience and suffering in families.

The steam could be conveyed to and discharged into the water entering the mouth of a tunnel by insulated pipes from boilers located at the crib. The necessity for its use being for only a few days each winter, the steam could be supplied from the boilers of tugboats.

AMERICAN PRECIOUS STONES.

The recent volume on "The Mineral Resources of the United States," published by the Government, contains an interesting paper by Mr. George F. Kunz on the history and production of gem stones in America. For a country so otherwise richly endowed with mineral wealth as the United States, her product of precious stones is surprisingly small. The total value of gems mined in this country during 1884 amounted to but $82,975. Almost two-thirds of this sum was for minerals valuable only as cabinet specimens, and therefore not strictly to be classed under the head of gems. In addition, the value of the gold quartz withheld from reduction for use in jewelry and as specimens is calculated to be $140,000.

Though in point of quantity and value among the most insignificant of the entire list, the diamond, as the stone of all stones, naturally receives the first consideration. Probably the largest one ever found in this country is the Manchester diamond, which was unearthed by a laborer at Manchester, Va., about the middle of the century. The gem was not recognized at first, and by way of experiment was placed in an iron furnace at Richmond. After remaining at a red heat for two hours and twenty minutes, it was found to be unimpaired and brighter than before. When recognized, it was valued at $4,000. It passed through a number of hands, being cut at an expense of $1,500, and at one time $6,000 was loaned on it. The original weight was 23¾ carats. This was reduced by cutting to 11$\frac{11}{16}$ carats. As the stone is off-color, and imperfect, it is not worth to-day more than from $300 to $400. The gold regions of North Carolina have produced a number of small diamonds. Among the first discovered was a fine octohedron from Brindletown Creek, valued at $100. A number of stones, improperly classed as diamonds, proved on examination to be quartz pebbles or zircons. Another stone, of fine white color, found in a South Carolina placer claim, has a reputed value of $400.

Some of the finest American diamonds come from California, though their size is generally quite small. Professor Whitney states that the stone is found in fifteen or twenty different localities, the largest that has come under his notice having been discovered at French Corral. It weighed 7¼ carats. The most prolific locality has been at Cherokee Flats, Butte County, where the hydraulic operations have disclosed a number of diamonds of all colors, white, yel-