opinion, possible to prevent the blocking up of streams in the winter time by the use of reasonable amounts of energy in the form of heat.

The usual effect of frazil on hydraulic power plants is to block up the racks, tie up the gate mechanism, and reduce the output of the water wheels or shut them down altogether.

It is common practice among hydraulic power operators to await the action of the sun for relief from the above conditions.

To quote from my own experience alone in regard to the amount of trouble caused by frazil, it may be mentioned that I have seen frazil silence the hum and bustle of the grist mill, the saw mill, and the pulp and paper mill; I have seen waterworks pumping systems frozen up so that they could not supply a single drop of water for domestic or fire purposes; I have seen electric cars left standing in the streets until the lubricant was frozen solid in the journals; I have seen and heard electric generators speeding up and up as the load curve dropped towards midnight, until it seemed providential that they did not fly to pieces—while the increasing speed frightened the users of motors to such an extent that they added to the danger at the power plants by shutting them off, and I have also on occasions too numerous to enumerate seen the solid flange-like appearance of the spiders of generators gradually changing as they slowed up and finally stood still altogether, like the inert spokes of a barrow's wheel which had been deserted by its propeller. This last sight I was often obliged to view by the light of a coal oil lantern, althought upwards of 10,000 kw. of generating apparatus were within a stone's throw of the viewpoint. Those who were responsible for the supply of water to the turbines remarked as they gazed at the silent machinery: "The river will be frozen over before morning and there won't be any more trouble this winter." After the ice was removed from the penstock fires were built around the wheel cases or brine was used for the purpose of loosening the gates. Some who had steam at hand used it for the purpose of loosening the gates after the ice had been hewn out of the penstocks. While frazil is immersed it remains soft and mushy, but when exposed to temperatures below freezing point it immediately becomes solid.

The first trouble which frazil usually causes at a hydraulic plant is to clog up the openings in the rack or screen. This may to a great extent be alleviated by the use of a motor-driven rake. The more usual practice is for men to use hand rakes, but as their best efforts are so often futile something better is required where the continuous operation of services is a necessity.

When the racks are kept open by raking the frazil passes through and forms like adhesive plaster around the gates and gate mechanism, thus preventing speed regulation. If the run of frazil continues long enough it shuts the wheels down altogether.

Anchor ice makes trouble for the hydraulic plant in another manner. When the sun is shining anchor ice rises from the bottom of the stream where it has been formed, bringing with it loose rocks, etc., and is carried by the current into the forebay of the plant. Here it is held against the rack by the pressure of the water, and while it is not adhesive or very cohesive at such times, if it is not broken up by raking and passed through it will stop the flow of water. Floating anchor ice seems to be frazil with its tentacles short off or turned in—in this condition it has no sticky propensities.

As there are a great variety of hydraulic plants in the Ottawa district, and as none of them up to two years ago were free from ice difficulties, this proved to be a good place to study the ice question. I had frequently noticed that one plant invariably held out longer than any of the others against the onslaughts of frazil, although waterwheels of the same size and type were operating near by. The plant in question was protected by wooden racks which, although they would clog up with frazil as quickly as those which were made of iron, were more easily cleaned. The fact that iron was the better conductor of heat and that the temperature of the iron racks below the water was likely reduced by the cold air chilling the tops of the bars were reasons advanced by the writer in explanation of the difference in susceptibility to frazil between these iron and wood racks. The effect of cold air on other parts of the hydraulic equipments, in particular upon the draft tubes and penstocks, was also noted. Waterwheels which had their tail races enclosed so that the cold air could not sweep in were more slowly affected by frazil than others not so protected. Waterwheels set in wooden penstocks were more immune from frazil attacks than those set up in concrete chambers, if the concrete were exposed to the action of the atmosphere.

For a number of years I had observations made and data collected regarding weather conditions in the hope of being forewarned of the approach of frazil. However, it was not until we added the records of water temperature variations to the other data that we really knew when to expect frazil. We found when the sun was not shining, when the wind was blowing from the northwest, and when the temperature of the water was being lowered to the freezing point, frazil was being formed. It was further observed that so long as cold weather continued and the temperature of the water remained at the freezing point, practically no further frazil difficulty was likely to occur, no matter how low the temperature of the air became, but if the temperature of the water rose above the freezing point as the result of a thaw a recurrence of the frazil trouble would certainly be experienced again upon the approach of cold weather.

An ordinary thermometer, which had a scale with divisions of one-sixteenth of an inch to a degree, was used for the measurements which we made, and it was found that the temperature of the water usually remained exactly at the freezing point from the beginning to the end of the winter.

"Ice Formation and Precise Temperature Measurements" was the title of a paper presented by its author, Dr. Howard T. Barnes, at a meeting of the American Society of Mechanical Engineers, which was held at New York in the spring of 1905. With the aid of the Callendar thermometer, which is capable of indicating with accuracy variations as small as one ten-thousandth of a degree, Dr. Barnes had found that changes of the temperature of the water in the Lachine Rapids during cold winter weather actually did take place, and that when these changes amounted to only a few thousandths of one degree they were accompanied by "tremendous physical effects." While the temperature of the air had varied from 28 degrees above to 40 degrees below the freezing point, during many of Dr. Barnes' tests, he found that the temperature of the water never varied as much as one one-hundredth of a degree! If the temperature of the water fell ever so little below the freezing point frazil formed rapidly in great quantities, while if the water's temperature was raised a fraction of a degree above the freezing point huge masses of anchor ice arose from the bed of the river.

From the data contained in Dr. Barnes' paper and from our own observations and experiences I became convinced that by applying a moderate amount of heat to the racks and other parts of hydraulic equipments which are subject to the attacks of frazil, the difficulties caused by the latter could be obviated. With this end in view experiments were carried out which proved beyond doubt that this theory was correct.

When solid ice is formed upon a piece of metal—or in a mould, as in artificial ice-making—the bond between the ice and the metal is as close a union as the imagination can conceive. The ice grows on the metal, and it is practically impossible to separate them so long as the temperature of the metal remains at or below the freezing point. However, the application of a small amount of heat in the form of hot water or steam to the metal—or to the mould, as in ice-making—results in a severance of the bond, and a separation of the ice and metal is effected with ease. The freezing point is the flux that creates the bond between metal and frazil.

As an illustration of the lack of sympathy with my frazil combating proposals, and the skepticism which prevailed amongst hydraulic power people to whom I presented them, one institution which suffered greatly from frazil refused to carry out some simple experiments, although they had a steam plant within 50 feet of their racks and waterwheels.

A hydraulic engineer, who has designed a great many Canadian power plants, expressed the opinion that a reason-