FRAZIL AND ANCHOR ICE*

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Until a very recent date it was generally believed that in Northern latitudes the operation or the stoppage of hydraulic power plants at the beginning of each winter was determined by the absence or the presence of Frazil or Anchor Ice.

Ten years ago—at the Niagara Falls convention of this Association in 1897—in a paper relating to the operation of hydro-electric plants, I ventured to offer some advice to those whose plants were subject to ice difficulties. The gist of this advice was to the effect that an auxiliary steam power station of similar capacity to the hydraulic plant affected by ice was a necessity if continuous uninterrupted service was desired. In other words, my opinion at that time was that if Frazil or Anchor Ice entered a power plant a shut-down must follow.

Three years ago at the Hamilton meeting, in reply to a query in the Question Box entitled, "How do you get rid of Anchor Ice?" I answered: "We do not get rid of it." This reply, however, was not published, although the editor knew it was absolutely true. From the year 1885, when electric lighting was begun at Ottawa, until two years ago, the annual experience had been that frazil had tied up or completely shut down the power plants every winter for periods varying from 15 to 40 hours. At the suggestion of the editor of the Question Box, I amplified my answer by stating that it was my opinion that if the exposed parts of the racks and draft tubes of hydraulic plants were protected from the action of cold air, many of the difficulties usually experienced would be eliminated. In support of this opinion, I pointed out that in the absence of the suggested protection the unimmersed parts of the hydraulic equipments became ice manufacturing plants by introducing into the already freezing water temperatures much below the freezing point.

To-day, by reason of the knowledge gained by study and experiment, I ask permission (1) to retract what I said ten years ago; (2) to reiterate the advice given three years ago; and, (3) to supplement that advice by stating that no hydraulic plant need now be tied up by frazil if the simple remedy of applying a moderate amount of heat to the vulnerable parts of the equipment be resorted to.

At the outset it may be well to direct attention to the precise meaning of the two terms "Frazil" and "Anchor Ice" as they are herein used. Many persons use these terms as synonyms and others describe almost everything in the form of ice as anchor ice. For an authority as to the correct use of the two terms I cannot do better than refer you to the notable work of Dr. Howard T. Barnes, entitled, "Ice Formation."† At page 109 of his remarkable book Dr. Barnes says: "The birth of frazil is in the water itself by surface cooling, through wind or rapid agitation and by radiation. . . The term anchor ice we shall use to designate all ice found attached to the bottom, irrespective of its nature of formation. . . Anchor ice may form "in situ" on the river bed, and may grow by attaching to itself frazil crystals brought down by currents, and (it may grow) by the process of radiation." On the same page an extract is given from the report of the Montreal Flood Commission, published in the year 1888, as follows:—"Frazil as distinguished from anchor ice is formed over the unfrozen surface. . . wherever there is sufficient current or wind to prevent the formation of bordage ice."

From the preceding paragraph it is evident that, while frazil and anchor ice may, upon inspection, prove to be identical in appearance and character, it is the surface-formed frazil that sticks to and interrupts the operation of hydraulic plants, while it is the bottom-grown anchor ice that attaches to itself frazil crystals and sometimes blocks the flow of streams, thus causing floods similar to those experienced at Montreal.

A review of the ice difficulties at Ottawa, Ontario, will, I believe, prove to be a fairly accurate description of those encountered in any northern latitude by the operators of hydraulic power plants. The Ottawa River, from Lake Deschenes to the Chaudiere Falls, which are situated between the cities of Ottawa and Hull, serves as a boundary line between Ontario and Quebec. Lake Deschenes is a large body of water unbroken by rapids, and it is navigable throughout its entire length. It empties into the Deschenes rapids, where there is available for power purposes a working head of 9½ feet. Adjoining these rapids, in Deschenes village, several hydraulic plants are in operation and these plants are all tied up by frazil as regularly as the winter season comes around, in spite of their supposedly ideal location—at the foot of a smooth lake. Of course, little or no difficulty from frazil is experienced after the lake is covered by surface ice.

About three miles below Deschenes rapids are the Remoux rapids, and about one mile lower down the river are the Little Chaudiere rapids. There are now no power plants at either of these latter rapids. Another mile further down stream are the Chaudiere Falls, where the power developments have been made from which Ottawa, Hull and the surrounding country secure most of the energy which is used for domestic, commercial, and industrial purposes. At the various plants heads from 22 to 33 feet are available under normal conditions. These figures represent normal working heads and not variations in head caused by the variations in the flow of water in the Ottawa River and its tributaries at different seasons. A dam prevents, or is intended to prevent, water from flowing over the falls when the river is low, and, consequently, frazil formed in the rapids above is guided into the power plants.

Up stream there is, in my opinion, an ideal place for producing frazil. The spray thrown up by the rapids is immediately crystallized in cold weather, while the whole body of water in the river becomes chilled, or "super-cooled," by the winds that sweep across the stream from the northwest. The resulting mass of ice crystals and freezing water is kneaded, in the rapids, from top to bottom, and from bottom to top, until the whole stream becomes at times a mass of frazil. On several occasions the rapids were almost completely blocked up in a single night, and the majority of the plants below were shut down for the greater part of two days. The blocking of the rapids is an exceptional event, as the frazil is usually carried by the current into the power plants.

In addition to the troubles caused by frazil, there is another with which the operators of northern hydraulic plants have to cope in the winter time. It is primarily due to a shortage of water. The surface ice continues to grow as winter advances, and the space between the surface ice and the bed of the stream becomes more and more clogged up with anchor ice and frazil; then when the river's level falls—as it invariably does after a couple of months of severe frost—the weighty surface ice descends upon the mass of mushy ice beneath it and packs the latter into such a solid mass that water cannot percolate through it. The falling of the river level each winter seems to be the natural result of the freezing up of the river's sources and the absence of surface drainage on account of the continued cold weather. The "area drained" is a factor which has perhaps most to do with determining how much power is available on any stream, but hydraulic engineers, when estimating such power, seem to lose sight of the fact that little or no drainage occurs during a great part of each winter in northern latitudes.

It is chiefly with frazil as it affects hydraulic power equipments that this article has to deal, but, by following the line of thought above indicated and by extending the method hereinafter described for combating frazil, it is, in my

*Paper read at the annual convention of the Canadian Electrical Association, Montreal.

†"Ice Formation," by Howard T. Barnes, M.A., D.Sc., F.R.S.C.: John Wiley & Sons, New York and London. In Canada, Renouf Publishing Company, 61 Union Avenue, Montreal.