ICE, AND ITS EFFECT ON HYDROELECTRIC OPERATIONS

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If one consults the Experts (and picks the same Expert as I did), he finds there are many varieties of ice: - slush, shale, sheet, frazil, anchor and agglomerate. Let's quickly define these varieties: - slush ice is simply a lot of snow in water that is not warm enough to melt it: shale ice is the thin beginnings of sheet ice, that forms along the shores and around rocks and continually breaks off and floats away; sheet ice is the variety that covers quiet waters, and eventually provides skating, or ice in the ice house, or headaches for the hydro-operating man; frazil ice is the kind that isn't there, almost, it is the tiny particles or slivers that form in supercooled turbulent or fast running waters, and floats along with the current looking for something cold to stick itself to; anchor ice is the glamour variety that freezes on the bottom of an open stream on a cold clear night, sometimes to a thickness that will float and move stones along the bottom; and agglomerate is a frozen mixture of all kinds.

From a practical viewpoint, for this discussion, we will confine ourselves to the sheet and the frazil ice. Formulae are available from which one can figure how much ice will form under different conditions but they are so complicated that I cannot even read them intelligently, much less explain them. So let's just mention a couple of answers that someone else has figured out. Sheet ice in Northern New York seldom exceeds two to two and one-half feet in thickness. Good, clear ice at - 8° F. has a crushing strength of some 30,000 lbs. per sq. inch. Frazil ice, under good generating conditions, forms at a rate equivalent to 1/2" of ice in 2-1/2 hours when the temperature is 0°. The St. Lawrence River in the open sections produces some 15 cu.ft. of frazil ice for every sq.ft. of open surface in the course of an average winter. Shallower streams produce more - up to 25 cu.ft. per sq.ft. (per winter). Quite a pile of ice.

Now, how do these things affect the operation of a hydro-electric station? Let us look at the various structures that make up a plant and briefly describe the headaches.

First, we have a dam, concrete or wood, solid or hollow. The dam creates a pool, reasonably quiet water, and eventually a covering of sheet ice. No trouble from that, unless one is the worrying type and starts thinking of the tremendous push which, theoretically, could develop from the ice sheet to the top of the dam. A modern dam has a crest shape which curves downward on the upstream side, usually ending with a face sloping downward at 45° to a depth of 2 to 3 or more feet. This sloping face puts the ice into shear instead of compression and the ice breaks and slides up and over. It also climbs up the banks around a normal pond where the grip of the ice sheet on the shores is not too good. But, on rare occasions, disaster can catch up to you. We once had a stone dam with a square top, and not too far away there was a road crossing the pond with good solid approaches and abutments. Ice pressure moved the top 3 feet of the dam some 2 feet downstream. This dam has been reconstructed. At another location we have a long, hollow concrete dam of the Ambursen design. Here we have plenty of sloping face, but with the thin, concrete sections, we find the sheet ice anchors itself exceptionally well, with a sort of fillet weld that goes down 6 - 8 feet along the face of the dam. For years we cut an open slot, upstream from the crest, to relieve the ice thrust, then an Operating Superintendent had an idea, bought several barrels of "Petrolatum", greased the top 10' of the dam and now the ice slides up and over with no trouble at all.

Frequently, on the top of a dam, there are flashboards. Sheet ice can be bothersome here in two ways. It will push the boards over, or it will freeze to the boards and on an increase in pond level, will lift the boards and allow heavy leakage of water under the boards. In several locations, we have solved this problem by fastening soil heating cable along the boards and applying enough heat to keep open water next to the boards. Four passes of soil heating cable, using 26.4 watts per foot of board, works very well - and is much cheaper than keeping an open slot cut in the sheet of ice. The only trouble is to successfully guess the time of the spring flood so that the boards and the soil heating cable can be saved for future use.

Another usual accessory to a dam is one or more floodgates, which, if you let them alone, are always frozen in tight when the proverbial January thaw occurs. If one could just rebuild them all in the light of present day knowledge, the headache would vanish, as they would have heated rubbing strips along the sides and would be housed in and heated to prevent freezing to the sheet ice in the pond or freezing to the piers. Since we are not blessed with modern design, we have progressed through the ice chopping era and the blow torch age, and are now using live steam generated with a portable flash boiler (oil fired-15 H.P. rating). We have also tried air bubbler systems for keeping gates operative, but with limited success, in that the airnozzles are so small that they easily clog from frost in the air supply, or corrode and close off with age.

Let's assume our hydro plant has a canal between the dam and intake. This structure can be a fair sized headache, depending on the method of plant operation in force. In our System, we are looking for maximum K.W.H. production from the water available, and, therefore each hydraulic unit is operated at its most efficient load point or it is shut down. When load is quickly picked up on a unit, the water in a canal will drop in surface elevation and, if there is an ice cover of 1 - 3 inches on the canal, the chances are the ice sheet will break up into small and large cakes and float on down to the intake where something has to be done about it. When load is dropped on a unit, a surge wave moves up the canal, breaking up more of the ice cover. Go through this sequence a few times per day and one can make chunks of ice all winter. The only answer to this problem is to "sweet talk" the load dispatching operators into allowing inefficient, steady load conditions for long enough to form an ice cover of 4 to 6 inches, or more, at which thickness the ice will hold together and rise or fall as a unit.

Next, we come to the intake of our plant, where we have at least 75% of our ice problems concentrated. In addition to the sheet ice which gets broken up in the canal and floats to the intake, we have, under certain weather and temperature conditions, frazil ice to contend with. Going back to our definitions, frazil ice forms in tiny particles and slivers in super-cooled, turbulent water and floats along throughout the entire cross-section of the stream. Thus, it will be found deep down in a stream as well as at the surface. It has no particular tendency to float but it does have a tendency to stick to anything cold, even to itself. So, as it moves away from the point of origin, it gradually forms into balls that look much like loose cotton floating in the water, the size of the ball depending on how fast it is being made at the open water spot, and how far it has floated. At one of our plants, where there is a waterfall 2 miles upstream from the intake, these balls of frazil ice have been described to me as being the size of basketballs. When these balls hit the racks, they stick right there, and, under ideal conditions for making frazil, it is no time at all before a plant is out of service due to a plugged intake.

The operating boys have various ways of combatting these troubles. For the floating ice, a side sluice of ample capacity is a necessity. I use the term "floating" rather loosely, for the current in front of intake racks is rapid enough to counteract the bouyancy of the ice and drag it down to considerable depths. The usual way of cleaning the racks is to open the side sluice, and close the plant down - quickly. The resulting back surge pushes the ice off the racks and, with no current, it floats to the top and out the side sluice. A simple procedure, if you don't have too many tons of ice to deal with. The frazil ice that catches on the racks doesn't respond to this washing treatment, it stays stuck. A well designed, rugged, mechanical rack rake will, in most instances, remove frazil ice as fast as it comes. Unfortunately, most of our plants are not equipped with mechanical rakes, so we have to shift to well designed and rugged manpower using hand rakes, which is really a tough job. Jarring the rack bars with a sledge hammer helps to remove ice - if one can get to them - but it is rather hard on the racks. We have used dynamite, but don't recommend it.

Some utilities have experimented with heated racks with some degree of success. It has been found that the heating of the rack bars to only a fraction of a degree above the water temperature will prevent frazil ice from sticking or freezing to the bars. The heating is done electrically by putting a low voltage, high amperage current through insulated sections of racks. Current use has approximated 5% of the plant output. The idea works swell as long as the flow of frazil ice is low or even moderate, but, when the ice is coming in balls that will not pass between the rack bars, the system falls down, because the heat applied is not capable of melting ice, only sufficient to keep it from sticking.

I am occasionally surprised at the misconception some folks have as to the ability of a power plant to melt its way out of ice troubles. Let's make a few quick figures - say we have a plant using 1,000 c.f.s. through a 100' head, that's, theoretically, 11,350 H.P., or 8,500 KW, and in one hour, 28,900,000 B.T.U.'s of heat; but, 1,000 c.f.s. x 62.5 lbs. x 3600 secs. = 225,000,000 lbs. of water to heat per hour; so, the rise in water temperature is 0.13 degrees. The whole plant output to raise the water 0.13 degrees, will not melt much ice.

Getting back to our intake, if the methods mentioned above are unsuccessful, and the trouble is frazil ice - and the demand for power is high enough, one avenue of escape is still open - remove the rack bars. This is hazardous, as a cake of sheet ice may break loose or some other debris may find its way down the pipeline and into the turbine. The best solution left is to join a big system, in which the loss of a plant or two is inconsequential and, therefore, you can shut down and wait for conditions to improve.

Going on down the line, suppose our plant has a pipeline. If it is of steel, we have little or no trouble. True, if the plant operates intermittently, in the off-load periods ice forms in a ring around the inside of the pipe, but the next on-load period usually wears it out. Occasionally, it may break loose and arrive at the turbines as thin sheet ice, but it is not heavy enough to do any damage. If the pipe is of wood construction, it will bear watching. Internally, we have no trouble, but outside, every little leak (and every wood pipe has hundreds of them) builds up a beautiful mound of ice. If the pipe is built on or partially in the ground, these mounds can just be admired and forgotten - unless the pipe has to be unwatered, in which case an axe is the best known method of relieving the external load. If the pipe is built on piers, one watches it a little closer and removes the extra ice load before the pipe fails as a beam.

At one of our plants, we have a particular 140' of 12' wood pipe which calls for special treatment. The pipe is running along the side of a river gorge and, at one point, crosses a gulley on a bridge. The rock under this bridge slopes very percipitously toward the river and, on the stream side, is some 40 feet below the bridge floor. The very minor leakage from the pipe drips over the edges of the floor and builds icicles down from the bridge and up from the ground until a solid wall is built up under both edges of the bridge. Our worry is that the whole mass of ice may take off down the slope with a resulting jar to the bridge which may be disastrous. Our treatment of this is unique. When the ice stalactites and stalagmites join up solid, we cut the bridge floor free, using a very narrow cut, then start and maintain fires in salamanders in the ice room under the bridge, and keep the bridge free for the rest of the winter.

Next we come to surge tanks, the safety valve for the pipeline. The rules say the top water surface must not be allowed to freeze over solid and anchor itself to the sides, and, if it is a differential tank, the port areas must be ice free. Most of our tanks are housed in and insulated, and within the housing, electrical space heaters are judiciously located. It is surprising how much ice gets by the intake racks, floats down the pipe and bobs up in the surge tank. This ice, plus any which may form on the top water surface, can be slowly melted with hot water, pumped to the top of the tank and directed in small 1/8" streams to the desired points. We inherited one plant with a surge tank that had no housing and no heat and it operated for years that way. It started life with a conical steel roof, but the slug of ice that floated in this tank, reacting to a few plant trip-offs, reconstructed the roof to a much battered mushroom contour. And we are lucky that that was all that happened.

Now we come to the powerhouse, and here we can end this discourse on a happy note - no trouble!