# EXPERIMENTAL USE OF AIR BUBBLES FOR THE CONTROL OF SHEET ICE AT SAFE HARBOR

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The Safe Harbor dam is located approximately 40 miles above the mouth of the Susquehanna River which has its origin in New York and flows through the rugged and mountainous sections of northern, central, and southern Pennsylvania. This river from its earliest history has records of tremendous damage due to ice movements and statements have been made that "No river in the United States east of the Rocky Mountains is subject to greater movements of ice than the Susquehanna."

Since the Susquehanna has its source in the mountainous and also comparatively cold sections of Pennsylvania and New York, it can be visualized that a great amount of ice accumulates in the river during a cold winter. In addition to the ice covering of the river and feeder streams, the mountainous sections accumulate vast storages of snow and ice, which are potential conditions contributing to the movement of the ice. It is desirable to prevent ice from gorging or going aground as it moves through shallow sections toward the Safe Harbor dam, which is the first full gate type dam encountered below Harrisburg. (York Haven, just below Harrisburg, is a wing dam with free overflow from island to one shore.)

To assist in the breakup of the river ice, with consequent movement and run off, efforts are made to weaken the sheet by the use of numerous schemes. Many schemes have been tried such as cinders, sand, carbon black, salt and even ice-breaking tug boats. All of these have some shortcoming and their use has been temporarily abandoned, except on an experimental basis.

Knowing from experience that a properly designed bubbler system will prevent the formation of sheet ice, even in zero weather, an extended application of this proven principle was installed in the fall of 1949 at the spill-gates on the dam. The initial installation consisted of a 1000-foot length of 1½" and 1" galvanized steel pipe laid on the bottom of the pond (approximately 50 feet deep) – plastic pipe was also tried without success because it floated – and coupled to the air system through a 2" rubber hose. Graded orifices were installed every 20 feet of the pipe line, varying in drill size from number 35 to number 38. Air is supplied to this system from a 100-pound air header and the quantity is regulated by selecting the proper size orifice plate which will just pass sufficient air to supply all openings. For this experimental installation, a 9/32" orifice was sufficiently large and it is estimated that approximately 200 cubic feet of free air per minute is required to supply the demand.

In 1953 the initial installation was increased to 1500 feet and 2 more 1000-ft. lengths were installed perpendicular to the dam and 1 more 1000-ft. length was extended upriver from the skimmer wall entrance to the forebay in front of the plant. These air lines maintain a line of open water, even during long cold spells with open width varying somewhat with the severity of the weather. Even though the areas should close completely during a long cold period they will open *before* the river breakup occurs which is, after all, the objective. With these open or weakened lines it is hoped the foreward movement of the pack ice can be directed to the desired section of the spillway in the dam. These air lines maintain a line of open water about 2 feet wide.

When the Safe Harbor dam was built in 1930-31, a compressed air bubbler system was provided for each of 32 Stoney-type steel spill gates 36 feet high with a free opening of 48 feet. Initially only a limited number of these gates had electrically heated seals to prevent freezing, but experience has warranted the inclusion of all 32 gates which are now heated.

Briefly, the bubbler system consists of two flexible metal hoses at each gate connected to a 100 psi. header from the powerhouse compressed air system; the supply header forms one of the railing pipes of the spillway operating bridge. Just ahead of the shutoff valve to each hose is a 1/16" orifice which cuts down the quantity of air to each bubbler. Each outlet draws about 4 cfm. of free air. The original design provided a length of bent pipe to thread the metal hose through to hold the outlet about 10 ft. under the surface and 5 ft. upstream from the face of the gate. During summer or time of continued spilling the flexible hose can be withdrawn or disconnected entirely. Two experimental installations of rubber hose to a ½" pipe fastened to the upstream side of the gate are now in use instead of the metal hoses because some difficulty has been experienced with refrigeration at the discharge end (even though 10 ft. under water), forming a quantity of ice of sufficient size to cause the hose end to float to the water surface thereby discharging the air to the atmosphere. It is hoped that the rubber hose may reduce this tendency, and further, be less expensive.

No bubblers should be placed in the water until a skim of ice is formed over the pond and they should be removed prior to ice movements to prevent mechanical damage to the pipes or hoses. The hose at the gate end is provided with a quick coupler to permit raising the gate for spilling. Both types of bubbler installations have been effective in keeping ice from forming against the gates. They are of no use however when ice is pushed against the gate during general ice movement and should be removed, at least turned off, prior to an ice push. At this time the temperature is generally rising so danger of a gate freezing tight is past. If the ice push results in only a foot or so of pack the bubblers have been known to free themselves by their normal action of bringing up warmer water to the surface if the weather remains mild.

There has been evidence of warmer water being raised to the surface, but not until this year have actual measurements of this gradient been successful. Results of the present measurements show why our previous tests showed no gradient. The maximum gradient between the surface and 30 ft. depth at the spill-gates was only 0.020°C. This year was the first that a portable recorder of a high enough sensitivity was devised to show such small variations (full scale 10 inch chart is .75°C). These tests indicate that about twice this sensitivity will be required in further study to determine the effect of air temperature, river flow, sunlight and the exact depth of points of temperature change. Present tests indicate that the cold water is in the top inches and below 10 feet little change exists, but further tests are necessary to definitely establish the best depth of bubbler operation.

Other tests were made with a very light and sensitive resistance thermometer and wheatstone bridge and the river bottom silt where the river bubblers are imbedded was 0.60°C warmer than the river water only 7 ft. above. This test gives rise to further hope that a long air bubbler on the bottom of the river will draw heat from the silt too for assisting in breaking up the river ice. It would certainly be of interest to see how a bubbler like this would work in the more northerly locations and also what water temperature gradients are found at other rivers and dams after the water temperature is below the maximum density point of 4°C.

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