on canals running across country where means cannot be taken to mitigate or eliminate ice difficulties.

Ice troubles come under two heads: namely, those causing damage to the outer portion of the development, such as erosion of river banks, floods, damage to dams and other structures, back water, etc.; and secondly, those which cause trouble to hydraulic equipment, such as blocking of racks, wheel chambers and wheels.

To provide against these troubles great care should be exercised in selecting the site and in the design of the head and tail-race channel. If the development makes use only of a portion of the flow of a river, and if swift water results in the river not being ice-covered, care must be taken to ascertain the prevailing wind conditions. With open water above the plant, frazil and anchor ice will be formed, and if the prevailing wind is toward the intake channel, large quantities of frazil will be forced into the canal, even if the water outside of the power canal has a velocity of from five to eight feet per second and almost at right angles to the canal.

### Locating the Plant

This trouble could often be greatly reduced by properly locating the development. Power canals that are narrow and deep are preferable to those that are wide and shallow, but in any case the average velocity at the entrance should be very low.

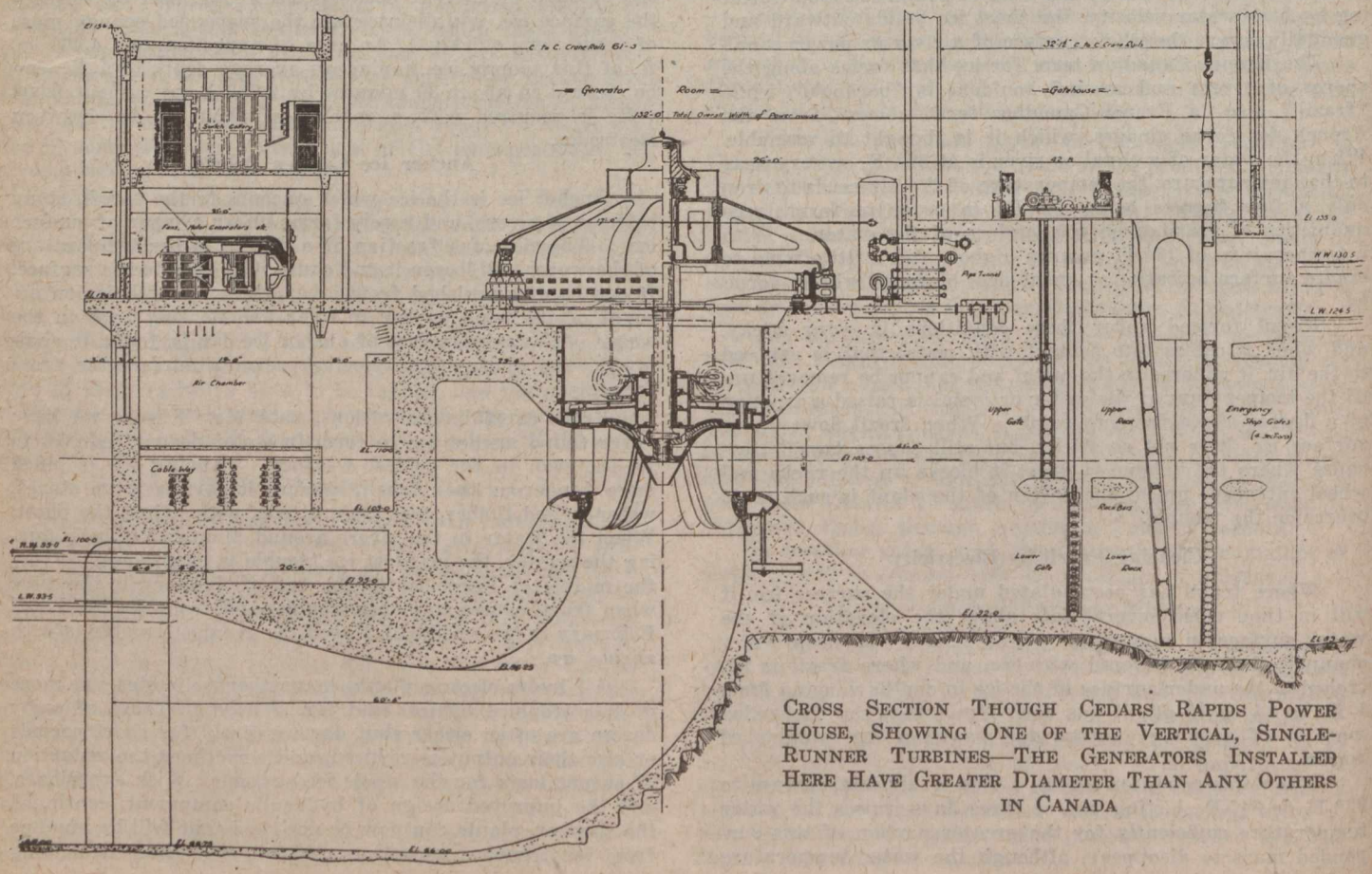
A survey of river conditions above the entrance to the canal should be made to ascertain the presence of reefs, boulders or other obstructions; because, with open water conditions, these will become coated with anchor ice so as possibly to divert the water from the entrance of the power canal sufficiently to lower the head several feet. Another source of ice trouble that should be guarded against is the lowering of the water level in the power canal due to temporary blockage of the river above the plant, caused by ice dams in the upper water during extreme cold weather. This is likely to affect seriously the plant's operation.

It is believed by many that if a large pond can be created by constructing a power canal, ice troubles can be reduced to a minimum. This is not true, said Mr. Wilson. In the case of large developments of the low or medium head class, with surface velocities of one to one and a half feet per second in the power canal or head-race, it is usually assumed that surface ice will form as soon as the water temperature reaches freezing point and the air somewhere between zero and 20° F. This condition may suit the formation of surface ice in some but not in all cases, and not with conditions that exist on the St. Lawrence. Sheet ice forms in the shallow waters and bays along the shore. When the wind breaks up its formation, and frazil is formed at the same time, the whole mass moves down, and with the aid of the wind enters the power canal, coating the whole surface with a conglomerate mass in a very short time.

The surface of the canal having been coated, sheet ice is deflected down the main channel, but the frazil continues to gather under the surface ice at the entrance to the canal, forming an underhung dam, which is serious, and unless properly handled would ultimately shut the plant down. Mr. Wilson showed a diagram prepared from actual measurements of such an underhung dam, where approximately 60% of the cross section of the power canal was closed by surface ice and the underhanging frazil that clung to it.

### Trouble from Back Water

When rapids exist below the plant, a suitable wing dam protecting the tail race discharge should be constructed to prevent trouble from back water caused by anchor ice forming in the main channel. If the development involves damming a whole river with the power house and overflow dam, a large pond is created, backing the water up stream for a considerable distance. With a development of this sort, at times a light surface ice will undoubtedly form on the pond. But if there are rapids up the river which have not been drowned out, considerable trouble will be experienced, as frazil and anchor ice will form and float down under the surface ice on the pond, clinging to its under-side and forming an underhanging dam. The free water area will be contracted and land above the plant will be flooded and there will be considerable damage and also reduction in the capacity of the plant. If the water backed up by the under-




CROSS SECTION THOUGH CEDARS RAPIDS POWER HOUSE, SHOWING ONE OF THE VERTICAL, SINGLE-RUNNER TURBINES—THE GENERATORS INSTALLED HERE HAVE GREATER DIAMETER THAN ANY OTHERS IN CANADA