mechanical engineer—so that the engine, though of great length, can travel safely over curves. The engines on the L. & N.-W. consume over 3,000 tons of coal per day. In my next letter I shall speak further of this company's great shops at Crewe

For THE CANADIAN ENGINEER

FORMATION AND AGGLOMERATION OF FRAZIL AND ANCHOR ICE.

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In northern countries there is no subject which presents so many practical difficulties to the hydraulic engineer as the formation of frazil and anchor ice, and their subsequent agglomeration into masses. The relations of these phenomena to the temperature of the river water have been repeatedly under investigation, but while much valuable work has been done already, the observations have been of such a contradictory nature, especially as regards the temperature of the water, that very few practical suggestions have resulted. The purpose of the present paper is to endeavor to present to the readers of THE CANADIAN ENGINEER a simple and intelligible explanation of the appearance of frazil, based on a long series of experiments undertaken on the St. Lawrence River, to show the dependence of its formation on the temperature of the water.

Among those, in later years, who have taken the keenest interest in investigating the question of frazil is John Kennedy, who is the chief engineer of the Harbor Commissioners' Works, at Montreal, and it was through him that the writer's attention was first directed to the importance of the work. Mr. Kennedy bad long felt that some connection existed between the agglomeration of frazil ice and the temperature of the river water, but could not with the apparatus at his command satisfactorily demonstrate that such a relationship existed. Under his direction, as a member of the Montreal Flood Commission, temperatures of the river water during the winter were taken by W. J. Sproule, the assistant engineer, both under the surface ice and at Lachine in open water. Although great care was taken with the measurements, no definite variation from 32° F. could be detected even in the most severe weather. The measurements were taken with an instrument designed by Mr. Sproule, and consisted of a mercurial thermometer reading to tenths of a degree, enclosed in a tin case so that a quantity of the water to be measured was brought up and served as a protection against the colder air. By this means it was clearly shown that if any deviations from the freezing point took place, they must be less than can be measured on a thermometer reading only to tenths of a degree.

Mr. Kennedy, with the object of testing the matter more accurately by means of more delicate thermometers, consulted Prof. Callendar, of McGill University, in regard to carrying on the work by means of an electrical resistance thermometer. Prof. Callendar accordingly designed, and had constructed in the McDonald Physics Building, a thermometer capable of reading differences in temperature to the thousandth part of a degree centigrade. As the employment of this thermometer entailed considerable practice in the use of electrical measuring instruments, and Prof. Callendar was wholly occupied with the work of the session and had no spare time to devote to the observations, the writer undertook the measurements at Prof. Callendar's request.

An electrical resistance thermometer is really the only form of instrument suitable for measurements of this kind, not only because it measures with a far greater degree of refinement than can be looked for in a mercurial thermometer, but because it may be read from a sheltered place without withdrawing the stem from the water. Very little reliance can be placed on observations made on any temperature measuring instrument which has to be taken out of the water and read in an atmosphere cooled down far below freezing.

The thermometer used was of the differential type and consisted of two stems, each made of a similar coil of platinum wire. The coils were balanced against each other by the well-known Wheatstone's bridge method. The coils of wire were protected by small lead composition tubing, about eight inches long, which was soldered to longer and thicker compo-tubing containing the connecting leads. One end was made 100 feet long, to pass into the river, while the other end was made 10 feet long, for retention at a uniform temperature in a sheltered place.*

The temperature of the water was determined, not directly, but more accurately, as a small difference from a carefully prepared mixture of snow and water. Every possible error, due to changing temperature conditions, in the connecting leads and on the rest of the apparatus, was compensated for. The thermometer was so made as to have a scale of 8 inches to the degree and a vernier with lens reading to $\frac{1}{2000}$ of an inch. Under suitable laboratory conditions it was possible to measure to $\frac{1}{10000}$ part of a degree centigrade. In the present case, in spite of obvious difficulties in making refined electrical measurements in a light shanty unprotected from the wind, readings were accurate to $\frac{1}{1000}$ of a degree.

The method of making an observation consisted in immersing the two ends of the thermometer in a mixture of snow and water in the shanty, and obtaining a zero reading when both the ends were at 0° C. The shorter end was left in the mixture and the longer end passed out of the shanty into the river. Any difference in the temperature of the river from the mixture of snow and water in the shanty was immediately obtained. During the winter of 1895-96 the writer carried on the experiments for a considerable time on the river water, under the surface ice, opposite Montreal, and, during the winter of 1896-97, made a similar series of observations in open water at the Lachine Rapids. A shanty was provided at both places by the Harbor Commissioners, through the kindness of Mr. Kennedy, and served for the reception of the instruments and for making the measurements. A watchman was also procured to protect the instruments.

The results of the first series of experiments have been recently published in the "Transactions of the Royal Society of Canada," vol. ii., sec. iii., page 37, and those of the second series will, it is hoped, be published in the course of the year. In the first paper will be found, besides the results of the observations, a description of the instruments used in the investigation, and a brief discussion of some of the principal points brought out by previous observers.

The general results of the writer's experiments have

* The writer desires here to express his thanks to H. T. Pye, instrument maker in the McDonald Physics Building, for willing aid in renewing, at short notice, delicate portions of the apparatus which were broken through want of proper laboratory conditions.