follows: President, George Fowler, Toronto; vice-president, W. F. Chapman, Brockville; registrar, W. G. Blackgrove, Toronto; treasurer, Chas. Moseley, Toronto. The board of examiners elected were: J. G. Bain, Toronto; Fred. Mitchell, London; W. F. Chapman, Brockville, and F. W. Donaldson, Toronto. A representative number of members were formed into a committee on legislation to follow up the recent efforts to secure a compulsory license law for engineers in this Province, and a sum of money was placed to the credit of the committee. The number of certificates now in force granted by the association is between 1,300 and 1,400, these being of three classes, first, second and third. Members were pleased to see the retiring president, J. G. Bain, present after his recovery from a serious accident, and he and the other retiring officers received a hearty vote of thanks for their work during the past year. The next place of meeting will be Hamilton.

FORMATION OF ANCHOR ICE AND PRECISE TEMPERATURE MEASUREMENTS.*

By DR. HOWARD T. BARNES, MCGILL UNIVERSITY, MONTREAL.

My attention was first directed to this very important problem by the Harbor Commissioners of Montreal in 1896. The Chief Engineer of the Harbor Commissioners, Mr. Kennedy, was a member of the Flood Commission to investigate the very serious floods that visited the city of Montreal from time to time, and he was appointed with other gentlemen to go into this question with a view of alleviating the disastrous effects. During the investigation of the Flood Commission efforts were made to study the slush ice, which is called in Canada frazil ice, and to connect the formation of this remarkable ice with the temperature changes in the water. A great many results were obtained showing that these temperatures varied a good deal. Calling for observations on this point many independent observers throughout the country took temperature readings during the winter time with instruments at hand and sent their results in to the Commission. The Commission also took a series of measurements of the temperature of the water and they thought they detected small differences of temperature during such times as the ice was most severe. But they were not sure of their results on account of the difficulties encountered in making the measurements. Other observers were not, however, so careful and they sent in results showing apparently that the temperature of the water varied from five to six degrees below the freezing point. Now, it was easy enough for the Commissioners to explain why these very low results were obtained when they received details in regard to the manner in which the measurements were carried out. Usually it was a mercury thermometer thrown in the water and held up in the air to read. Mr. Sproule, the assistant engineer of the Commission, devised a tin case for his thermometer in which he could entrap a small amount of the water and thereby have a longer time to read the thermometer after drawing it out of the water. The thermometers were not delicate enough, and as Mr. Sproule told me, when the question came up in 1896, that during the time of the Commission and later, it was impossible for him to say definitely that any deviations from the freezing point took place, his thermometer being graduated to degreees, and such variations that would occur beyond this point were not recorded. That is why the Commission came to McGill for more refined measurements. They wished, if possible, to connect the temperature of the water with the formation of frazil ice.

We devised then an instrument for doing this which depended on the change in the electrical resistance of platinum wire. Now such instruments have been made before, and have been exceedingly useful for all classes of temperature measurements; but we devised the most delicate differential thermometer that probably has ever been made. This thermometer had a degree which was eight inches long. It was possible to estimate by this means to the ten-thousandth part of a degree. Later I shall speak a little more about the practical details of the measurements.

My first object is to take up the problem of ice formation and so lead on to the measurements, and connect these measurements with the loss of heat from water which governs the formation of ice in the laboratory or in the actual conditions of nature, which problem is not an easy one. The varied conditions in which we meet river ice make it almost impossible to establish a definite set of rules by which we can say how much ice will be formed or what the ice will do. The weather itself varies from year to year and what conditions will hold one year will be entirely different the next. A long and continuous study of each problem of engineering should be made before anything definite can be said in regard to the effects of river ice.

Now I want first to run over the laws of heat, which I shall have to refer to, and I do this for the sake of clearness. I will do this very briefly, somewhat in the form of a review, but if we are to get a connected and scientific knowledge of the subject we must review first of all our elementary physical knowledge of heat transmission, for, after all, the problem is a problem of heat transmission. The extraction of heat from the water causes ice to form. How is this heat abstracted and how does water gain heat again?

Now the three recognized methods of transmission of heat are convection, conduction and radiation. This does not mean that we have three different kinds of heat, that one kind of heat is lost by conduction, one by convection, and one by radiation. It means three processes are operative.

The first method, convection, we may briefly define as the transmission of heat by the movement of matter itself. You have illustrations of this in the ocean currents and trade winds which are so important in tempering the earth's climate. It depends entirely on the fact that matter when heated expands and becomes less dense. Therefore, a heated portion of matter surrounded by cooler matter will be displaced by the cooler matter as a light object is displaced by water. So we have heated matter rising when surrounded by cooler matter. We have one exception to this in water at 4 degrees Cent. As an illustration of this showing the maximum density of water, we have twelve thermometers of equal bulbs containing equal weights of water. One bulb is placed at zero and the others in successive degrees to twelve. At four degrees we have the maximum density or the liquid occupying the least volume. Below that point to zero, water expands. Above that point, as high as we can go, water expands; hence we see that in the case of water the process of convection will cause a current of warmer water to rise until we get to four degrees, and then the reverse process will take place. Below four degrees, as the water becomes cool, the warmer layers sink to the bottom. Now, that has a very important influence, as we shall see presently in ice formation in lakes and quiet water.

The next process of heat transmission is conduction. By conduction we mean the transmission of heat from point to point in the body. Heat is a form of energy; it is a measure of the vibration of the molecules of a body. When the molecules at one point become warm or vibrate more energetically, these vibrations are conveyed to neighboring molecules.

Conduction only affects the ice problem in so far as it causes a thickening of the sheets of ice over a river or lake. We can measure the conduction, and we know it in definite units for ice and for water, and in any problem in which conduction enters we can calculate with a fair degree of exactness the rate at which ice will form; otherwise, conduction plays a very little part in river ice formation.

The next process is that of radiation, or the transmission of heat by ether waves. All bodies radiate energy by ether waves, which travel out in all directions in straight lines with a velocity of 187,000 miles a second. They are in fact merely a continuation of the ether waves which are capable of affecting the optic nerve, and which we call light, and we know some of these light waves possess heating qualities.

These waves extend for a long distance beyond the visible spectrum, and they are being investigated and the limit pushed further and further down. All light waves travel with the same velocity, and hence the length of the waves and the number of vibrations of the waves must vary correspondingly. The longer the wave the slower the vibration. Now we know that this is one fact that distinguishes the heat waves from the light waves. We can extend down for a long distance, almost to connect with the electrical waves which we are able to produce, but we have not yet bridged over a long gap which exists.

*A paper presented at the monthly reunion in New York City, in March, 1905, and at the Scranton meeting (June, 1905) of the American Society of Mechanical Engineers.