LIQUID AIR.

BY PROF. W. C. PECKHAM.

There are three essentially different methods of measuring low temperatures, all of which are applicable to any temperatures and equally reliable at any temperatures excepting very high ones, at which the instruments would melt. These will be described in the order of their development.

1. The Air or Hydrogen Thermometer.—This is based on the fact that all gases expand and contract at the same rate by heating and cooling. This rate is $\frac{1}{273}$ per degree Centigrade. Now if a cooling of one degree causes a gas to shrink $\frac{1}{273}$ in volume, it follows that a cooling of 273° would cause a gas to shrink to 0 volume and it would disappear. All heat would be gone from it; 273° C. below zero is therefore the absolute zero, at which there would be no heat, and all molecular motion would cease. Of course this temperature cannot be reached by cooling a gas, since it will turn into a liquid long before all heat is removed from it; but so long as a gas remains a gas, it obeys this law of volume and may be used for thermometric purposes.

Air is the best gas for this use. since it can be most easily procured, and does not liquefy till an extremely low degree is reached.

The air thermometer is considered the most reliable and accurate thermometer for scientific work. Hydrogen may be used in place of air for the lowest temperatures attained, since its point of liquefaction is only 32° above absolute zero, the lowest of any known substance, except possibly fluorine, while air liquefies at 82° of absolute temperature, or 50° C. above hydrogen.

2. The Thermoelectric Couple.—Here an electric current is produced by the difference in the temperature of the junctions of two dissimilar metals, and the current is proportional to this difference of temperature. The thermopile is used with a galvanometer, and the deflection of its magnetic needle is graduated by comparison with a standard thermometer, so that the effect of a difference of 1°, 10°, etc., upon the instrument is known. This is the method used by Prof. Dewar. In his lectures the thermoelectric couple was tested at 0° C. with ice. Its face was then dipped into liquid air, when it indicated —191° C. Upon applying it to the ice it returned to the 0 point again.

3. The Platinum Thermometer.—It has long been known that the electrical resistance of all pure metals is increased by heating and reduced by cooling. In this respect they differ from alloys and from carbon, the latter of which has its resistance reduced by heating.

A chart of the principal metals prepared from the measurements of Profs. Fleming and Dewar is here reproduced, Fig. 1.

The temperatures from 100° C. to 190° C. are given below, that is, from the temperature of boiling water to that of liquid air. The specific resistances are on the right. It will be noticed that the lines of all the metals given converge toward the absolute zero, from which it is inferred that all pure metals would be perfect conductors at —273° C. It will also be seen that the lines of platinum, aluminum, gold, silver and copper are very nearly straight, from which we infer that the specific electrical resistance of these metals bears a constant ratio to the absolute temperature, or the temperature above absolute zero. The lines of all these, except platinum, slope so slowly that they are not suitable for thermometric uses. That of platinum varies much more rapidly, and a coil of platinum wire may be used to measure temperature. This is calibrated by comparison with the thermopile and air thermometer at known temperatures, and it can then be employed for measurements. The method of its use is simple. It is cooled to the temperature to be determined and its resistance at that temperature is measured. Some record these degrees as "platinum degrees," so that if the relation of a platinum degree to a Centigrade degree should in the future be determined to a higher degree of accuracy, results recorded in platinum degrees would still be easily transformed into Centigrade degrees.

In the use of each of these instruments the measurements are tested through the range which is known, and it is then relied upon through a further range, below this, by a process of extrapolation, that is, its scale is assumed to be unchanged to a certain extent. The agreement of the results obtained by the various methods of measurement is the best possible reason for believing them to be substantially correct.

In addition to the experiments described in a recent issue of the SCIENTIFIC AMERICAN, certain tests were made in a lecture since given by the writer in Adelphi College. By means of a dynamometer the tensile strength of an iron wire was measured. At 58° F. it broke with 15 lb. At —312° F. it sustained a strain of 22 lb.—an increase of 50 per cent. This leads to the curious conclusion that, as the world grows cold, cohesion will become stronger, and that rocks and metals on the moon are at present much harder than similar materials upon the earth.

Alcohol 98 per cent pure was quietly frozen in a glass tube in a tumbler of liquid air. On melting it was found that the frozen mass softened throughout and returned to a liquid by first becoming of a jellylike consistency, then very viscid and last sirupy before it became limpid. This would seem to indicate that alcohol resembles iron, glass, wax and similar substances in having no definite melting point, in distinction from substances like ice, which retains its hardness in the interior and melts from the exterior at a definite temperature. The latest data for alcohol are that it is sirupy at —129° C. and stiffens at —130·5° C. (Beilstein). Mr. Benoliel, instructor in electricity in Adelphi College, made several tests before the audience. One of these was to demonstrate the greatly reduced resistance of copper at the temperature of liquid air. A coil of copper wire was fastened to the top of a box into which

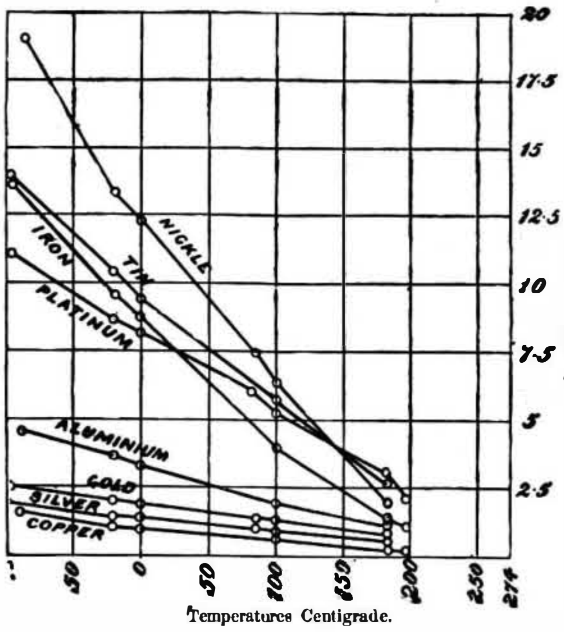

Fig. 1.—ELECTRICAL RESISTANCE OF METALS AT LOW TEMPERATURES.

liquid air was poured and its resistance was measured as it was cooled. It was shown that the resistance was very greatly reduced by cooling.

In another experiment a pair of platinum plates were immersed in liquid oxygen which was contained in a tube surrounded by a Crookes vacuum, Fig. 2. This had been made for the occasion from a design by the writer, with a straight tube 1¼ inches in diameter and 7 inches deep, covered by an outer tube, so that there was a space one inch wide around the tube. This proved to be a much better form than the ordinary bulb, since it presented much less surface to the air from which evaporation could take place, and thus preserved the liquid oxygen from all boiling. The platinum plates were placed in the liquid oxygen one

Fig. 2.—TUBE SURROUNDED BY CROOKES' VACUUM.

centimeter apart. The resistance of the liquid between the plates was found to be much greater than if it had been pure water, thus proving that liquid oxygen, though a magnetic substance, is still an insulator. Prof. Dewar concluded from experiments with an induction coil that its resistance would be about five times that of air, but in this experiment the actual resistance was shown to the audience.

Doubtless the tests which can now be made at extremely low temperatures by the agency of liquid air at atmospheric pressure will cause a revision of some of the data at present received as correct.

Electrical News and Notes.

The Longest Telephone Line in the World.—By the first of June next there will be completed a telephone system from San Diego, Cal., to Nelson, B. C., a distance of 2,225 miles. This will make a line about twice as long as the longest line now in use—that from Boston to Chicago by the way of New York.

The names telephone and microphone are older than the instruments now designated thereby. As far back as 1827, Wheatstone gave the name of microphone to an apparatus invented by him, to render weak sounds audible, and in 1845 a kind of steam whistle or trumpet which had the purpose of giving roaring signals in foggy weather was called telephone by Captain John Taylor, while Sudre used the same name in 1854 for a system of musical telephony.

The number of German towns and cities having electric railways was: 3, in 1891; 5, in 1892; 11, in 1893; 20, in 1894; 34, in 1895; 42, in August, 1896. At the end of 1897 the number was about 80. The overhead trolley is used most; three lines have a mixed overhead and underground system, two have overhead conductors combined with storage batteries, and two have the current supplied by accumulators only.—Oesterreichische Monatschrift für den Oeffentlichen Baudienst.

M. Charles Bos, in the Rappel (Paris, France), publishes as the result of a visit to Hamburg, Germany, a comparison between that city and the French capital. He finds Paris distinctly inferior in the matter of public conveyances and lighting, and says, "I would say to my countrymen: Awake! shake off your apathy, if you do not want France to count as little in Europe in twenty years as Spain does now." M. Bos is a member of the municipal council of Paris, and his warning should be heeded.—Revue Internationale de l'Electricité.

The Conductivity of Lightning Rods.—Some interesting experiments bearing on the conductivity of lightning conductors have been carried out by Prof. Koch, says Industries and Iron. He formed a chain several yards long with links of iron oxide, and placed it in circuit with two accumulator cells and a galvanometer. The chain was in a room thirty yards from the galvanometer. When a spark was discharged in the vicinity of the chain, the deviation of the galvanometer showed that the resistance of the circuit was reduced to one thousandth of its normal value, and in a second experiment the resistance fell to one ten-thousandth of the normal. Prof. Koch concludes from these experiments that they may afford an explanation why lightning conductors with poor conductivity are nevertheless effective in thunder storms. The oscillations produced provoke an enormous reduction of resistance at the proper instant to facilitate the flow of current through the conductor.

Telephone Statistics of Europe.—In no department of industry is Germany more active than in electrical appliances, says a United States consul in the Consular Reports. To our people, certainly the equal of any nation in this line, the following statistics will prove interesting. The list leaves out Norway, Denmark, Finland, Great Britain, and Portugal, because these people put down no answers to the cards of inquiry. Turkey and Greece have no telephones.

Country.	Number of lines.	Instruments.	Inhabitants to each telephone.
Sweden	293	42.354	115
Switzerland	295	23.446	129
Luxemburg	57	1,356	160
Germany	534	131,577	397
Holland	31	7.9 0	615
Belgium	15	9,400	682
France	407	31.681	1,216
Austria	124	18.950	1,318
Spain	48	10.810	1,597
Hungary	36	8.458	2,168
Italy	54	11,815	2,629
Russia	53	16,050	6,988
Bulgaria	5	243	13,616
Roumania	6	337	16,042

Submarine Cables.—The number of submarine cables throughout the world is 1,459, of which, however, 1,141 are coast and river cables belonging to governments, and of comparatively small strategic value. The total length of cable is 162,928 miles, says The English Engineer. Of this mileage companies own 143,024, and of the companies themselves 76 per cent are managed in London. France commands twelve cables of 2,033 nautical miles in European waters and thirty-three cables of 26,356 miles in colonial waters; while Germany controls eleven cables of 3,040 nautical miles in European waters and three cables of 470 miles in colonial waters. In time of war it has always been the practice for messages to pass without question through neutral states. For instance, during the recent war, telegrams between Turkey and Greece were forwarded by way of Austria, though direct communication was suspended. In the Chinese war there was no interruption of the telegraphic service with China and Japan. But in the event of war with France or Germany, 28,389 miles of cable in the case of France and 3,510 miles in the case of Germany would be deducted from the mileage control of England.