ON THE METHOD OF TESTING MARINE METEOROLOGICAL INSTRUMENTS, RECENTLY INTRODUCED AT THE LIVERPOOL OBSERVATORY.

By John Hartnup, Esq., F.R.A.S.

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It will probably be remembered that in the year 1853 a conference of maritime nations was held at Brussels, on the subject of meteorology at sea. The report of this conference was laid before Parliament, and the result was a vote of money for the purchase of instruments and the discussion of observations, under the superintendence of the Board of Trade. Captain Fitz-Roy, of the Royal Navy, an officer well known for his zeal and great practical experience in these matters, was appointed to superintend this new department of marine meteorology. Arrangements were made, in accordance with the views of the Royal Society and the British Association for the Advancement of Science, for the supply of instruments properly tested. A committee called the Kew Committee was appointed for this purpose, and the Kew Observatory was at first fixed on as the sole place for testing these instruments. Arrangements were, however, subsequently made for testing barometers and thermometers at the Liverpool Observatory; and it is a brief description of these arrangements, together with a few examples, the results of our experiments during the past few months, that I venture to hope may not be found uninteresting to the Scientific Section of the Historic Society.

In the barometers now in general use by meteorologists, the diameters of the tubes are nearly equal throughout their whole length, and a provision is made for adjusting the mercury in the cistern to the zero point, previous to reading the height of the top of the column. The object of the latter arrangement, it is well known, is to avoid the necessity of applying a correction to the readings for the difference of capacity between the cistern

and the tube. At sea, barometers of this construction cannot be used. The tube of the marine barometer must be very much contracted to prevent the "pumping," and the motion of the ship would render it impracticable to adjust the mercury in the cistern to the zero point. In the barometer usually employed on shore, the index error is the same throughout the whole range of scale readings, if the instrument be properly made. In nearly all the barometers which have till recently been employed at sea, the index correction varies throughout the whole range of scale readings, in proportion to the difference of capacity between the cistern and the tube. To find the index correction for the first-named barometer, a comparison with a standard at any part of the scale at which the mercury may chance to be standing, is generally considered sufficient. To test the marine barometer is a work of much greater labour, since it is necessary to find the correction for scale readings for every half-inch or so throughout the range of atmospheric pressure to which it may be exposed, and it becomes necessary for us to have recourse to artificial means of changing the pressure of the atmosphere on the surface of the mercury in the cistern of the barometer. The first successful attempt to do this was, so far as I am aware, made at the Kew Observatory by Mr. Welsh. In December, 1854, I saw the apparatus for accomplishing this object, in operation at the observatory above named; and the apparatus which we now have at the Liverpool Observatory is of a similar description, with such improvements as were suggested by Mr. Welsh, from his experience at the Kew Observatory.

The barometers intended to be tested, together with a standard, are placed in an air-tight chamber, to which an air pump is applied, so that by partially exhausting the air, the standard can be made to read much lower than the lowest pressure to which marine barometers are likely to be exposed; and by compressing the air it can be made to read higher than the mercury ever stands at the level of the sea. The tube of the standard is contracted in a similar way to that of the marine barometer, but a provision is made for adjusting the mercury in its cistern to the zero point. Glass windows are inserted in the upper part of the air chamber, through which the scales of the barometers may be seen; but as the verniers cannot be moved in the usual way from outside the chamber, a provision is made for reading the height of the mercury independent of the verniers attached

to the scales of the respective barometers. At a distance of some five or six feet from the air-tight chamber a vertical scale is fixed. The divisions on this scale correspond exactly with those on the tube of the standard barometer. A vernier and telescope are made to slide on the scale by means of a rack and pinion. The telescope is armed with two horizontal wires, one fixed, and the other moveable by a micrometer screw, so that the difference between the height of the column of mercury and the nearest division on the scale of the standard, and also of all the other barometers placed by the side of it for comparison, can be measured either with the vertical scale and vernier or the micrometer wire. We therefore possess the means of testing barometers for index error in any part of the scale, through the whole range of atmospheric pressure to which they are likely to be exposed, and our usual practice is to test them at every half-inch from 27·5 to 31 inches.

Upwards of seventy barometers of various descriptions have already been tested in this way at the Liverpool Observatory, and the errors are often found to be so large that, independent of the necessity for finding the corrections in order that the readings of different instruments may be compared with each other, the advantage is of no small importance to captains, as we meet with some barometers which read half an inch and upwards too high, and others which read as much too low. In some cases those which are correct in one part of the scale are from half an inch to an inch wrong in other parts.

It is a very common fault, in the construction of the marine barometer now in general use, that the cistern is not large enough to hold the mercury which descends from the tube in a low atmospheric pressure. We have met with some in which the mercury would not descend lower than about 29 inches, from the above-named cause; and it must be evident to any one, that such barometers are calculated rather to mislead than to assist the judgment of the mariner.

The practice which has for so long been adopted of mounting the marine barometer in wood is very objectionable; and the instrument recently introduced agreeably to the recommendation of the Kew Committee, is greatly superior to any other description of marine barometer which we have tested, as regards the accuracy with which it indicates the pressure of

the atmosphere. A description of this barometer is given in the Report of the Kew Committee to the British Association for the Advancement of Science, by Mr. P. Adie, the maker of the instrument. The barometer now exhibited is one of Mr. Adie's, with the various improvements which have been effected since its first introduction. The diameter of the cistern is about an inch and a quarter, and that of the tube about a quarter of an inch. The scale, instead of being divided into inches in the usual way, is shortened in the proportion of about 0·04 of an inch for every inch. The object of shortening the scale is to save the trouble of applying the correction for difference of capacity between the cistern and the tube. The perfection with which this is done may be judged of from the fact that of the first twelve barometers tested at the Liverpool Observatory with the new apparatus, the index corrections in the two pressures of 28 and 31 inches in three of them were the same; two differed 0·001 of an inch, and for the remainder the differences ranged from 0·002 to 0·006 of an inch. The correction for capacity may therefore be considered sensibly perfect; and there can be no doubt whatever of the practicability of correcting for capacity the standard barometers ordinarily used on land in the same way, and thereby doing away with the necessity of adjusting the mercury in the cistern to the zero point before each reading. The twelve barometers above alluded to were first tested at the Kew Observatory, and then forwarded to the Liverpool Observatory by the railway. At Liverpool they were tested again, in order to see if any change had taken place from the shake of the railway carriages in a journey of upwards of 200 miles. In six of the twelve barometers the index errors were found to be the same at Liverpool as had been given at Kew. Three differed 0·001, two differed 0·002, and one differed 0·005 of an inch. I think it will be admitted that this is a degree of perfection highly creditable to Mr. Adie, the maker of the new marine barometer.

In order to stop the pumping of the mercury at sea, the tubes of these barometers are so contracted, that when first suspended, the mercury is about twenty minutes in falling from the top of the tube to its proper level. When used on shore, this contraction of the tube causes the marine barometer to be always a little behind an ordinary barometer, the tube of which is not contracted. The amount varies according to the rate at which the mercury is rising or falling, and I have found it to range from 0·00 to

0·02 of an inch. At sea it is thought that the motion of the ship causes the mercury to pass so much more rapidly through the contracted tube, that the readings will be sensibly the same as they would be if the tube was not contracted. For stationary purposes, the tube need not be contracted, and this barometer will then be found to be a very perfect instrument. I saw one at the Kew Observatory nearly two years ago, which was made by Mr. Adie; and I have been informed that M. Leverrier has recently adopted this method of construction for the barometers used at telegraph stations in France. The getting rid of the trouble of adjusting the mercury in the cistern to the zero point previous to each reading, and the very moderate price for which this barometer has been made, are recommendations so strong that they will probably soon lead to its general adoption.

The method of testing thermometers is so simple as scarcely to require an explanation. For the freezing point, the bulbs, and a considerable portion of the tubes of the thermometers, are immersed in pounded ice. For the higher temperatures, the thermometers are placed in a cylindrical glass vessel containing water of the required heat, and the scales of the thermometers intended to be tested, together with the standard with which they are to be compared, are read through the glass. In this way the scale readings may be tested at any required degree of temperature, and our usual practice is to test them at every ten degrees from 32° to 92° of Fahrenheit. For this range of 60° the makers who supply the Board of Trade are limited to 0·6 of a degree as the maximum error of scale reading; and so accurately are these thermometers made, that it has not been found necessary to reject more than a very few of them. This is a proof of the practicability of making cheap thermometers, adapted for all the requirements of the mariner, nearly as perfect as it is possible to read them.

With some opticians it is not unusual, when captains break their thermometers, to apply new tubes to the old scales; and we occasionally meet with thermometers which require corrections of four or five degrees and upwards, with contrary signs at the two extremes of temperature in which we test them. It can scarcely be supposed that the captain of any ship would trouble himself to take observations with such a thermometer if he knew its indications to be so erroneous; and we hope that the means now

afforded to the mariner to test his instruments, will soon lead to an improvement in their construction.

I do not know anything which is more likely to lead to a great improvement in navigation, than the encouragement which is now given by the Board of Trade to the intelligent mariner to keep, in a systematic manner, a record of the various meteorological and astronomical phenomena observed at sea. The captain who avails himself of every opportunity to ascertain the position of his ship and the error of his compass by astronomical observations, and who keeps his meteorological record in such a way as to enable him to trace those changes by which he is warned of the approach of an iceberg, or of a coming storm, must, on the average, conduct his ship from port to port quicker and in greater safety than he would do were he to neglect such observations.
