Uniformity in Aerographic Records*

The Desirability of Universal Scientific Units

By Alexander McAdie, Abbott Lawrence Rotch Professor of Meteorology

PREVIOUS to the year 1910 no attempt had been made by meteorologists, so far as known, to publish atmospheric pressures in any other units than inches and millimetres. Temperatures were expressed in the Fahrenheit and Centigrade scales.

In 1908 the writer suggested a method of expressing pressure in percentages or permillages of some generally accepted value; and that for temperature, some other scale than the Fahrenheit should be adopted. In the Monthly Weather Review for August, 1908, these views were given publicity. Some further suggestions were officially considered by a Board which in June, 1910, reported among other things that "it did not appear that the subject had been formally reported on heretofore." The Board further expressed its opposition "to the substitution of the Absolute scale in general meteorological publications for existing scales" although it recognized that the C. G. S. system of units was peculiarly suited for the publication of aerological observations. There appeared to be some confusion of ideas regarding the use of the new units for it was stated that "if the new pressure scale of megadynes be employed the simple number 760 entering into the fundamental definition of temperature must give place to a number like 1013.303 milli-megadynes." The Board also expressed itself as opposed to discarding the Fahrenheit scale "until it was certain that world wide uniformity would be directly brought about by such a course."

The argument in favor of the adoption of scientific units was, however, received with favor in foreign countries, and gradually the reform made headway until now (January, 1917) all of the great meteorological services of the world recognize the desirability of using the new units; and many of them publish pressures in millibars or kilobars and temperatures in degrees Absolute Centigrade. A concise statement of the progress of the movement for the adoption of scientific units may be found in H.A. 73, 90-95.

Pressure.—The term millibar was unfortunately used by Bjerknes in his "Dynamic Meteorology and Hydrography." He defined the *bar* as a megadyne atmosphere, seemingly unaware of a prior use of the word by Richards and others in its proper sense. The term millibar "mb." as used by many meteorologists should be replaced by the more appropriate notation kilobar "kb." The *bar* then is best defined as the force which will produce in one gram an acceleration of one centimetre per second. Unless this definition be accepted, the basic unit in all meteorological tabulations will be a microbar. The bar is equal to 2.93506×10^{-4} mercury inches, or 7.50076×10^{-4} mercury millimetres. Since a kilogram will exert a force of 981,000 dynes, the bar is approximately equivalent to .00102 grams, and the kilobar approximately equivalent to 1.02 grams. One millimetre of pure mercury at a temperature of 1000 N. in latitude 45° will have a force equivalent of 1.3332 kilobars. One hundredth inch of mercury an equivalent of 0.3386 kilobar. At Blue Hill Observatory pressures have been expressed in kilobars in all summaries since 1914. The mean annual pressure for the period of 31 years is 992.6 kilobars and reduced to sea level 1016 kilobars. The highest pressure recorded in this period was 1047 kilobars reduced to sea level and the lowest 964.6; the absolute range being 82.4 kilobars.

There seems to be no practical difficulty in expressing pressure in units of this nature and no valid scientific reason against its general adoption.

Temperature.—Since 1914 temperature has been expressed at many observatories in degrees Absolute Centigrade. The use of the Fahrenheit scale is now restricted to a few communities and in scientific work it has practically outlived its usefulness. Some meteorologists, however, object to the use of the Absolute or Centigrade scale on the ground that the scale division, even when read to tenths, is too large a quantity for meteorological purposes.

To meet this objection and for other reasons the writer has suggested a new scale to be known as the New Absolute, or briefly New. The zero of the new scale is the same as that of the Absolute, approximately 491° below the temperature of melting ice under a pressure of 1000 kilobars on the Fahrenheit scale; and 273.02° below the same point on the Centigrade scale. On the new scale this temperature of melting ice is marked 1000. No degree sign is employed inasmuch as this symbol is reserved for angular measurement. The use of the degree symbol can well be abandoned as there is no scientific basis for its usage or retention.

Since we have no available method of expressing on a comprehensive scale the gain or loss of heat in units

N. it may be taken as 4.219 Joules and at 1100 N. as 4.176 Joules. The mean small calorie may be defined as above, i. e., the quantity of heat that will raise the temperature of one gram of water 3.666 degrees. The specific heat of water at 1084 N. will have the value of one calorie or its dynamic equivalent 4.18 Joules. For dry air at constant pressure the specific heat will be 0.2417 and at constant volume 0.1715. The ratio of specific heat, commonly designated "k," will be 1.409. The specific heat of water vapor at constant pressure remains 0.4652 and at constant volume 0.340. The ratio, sometimes designated by "k₁" is 1.368.

There seems, then, to be no great difficulty in the application of the New Absolute scale. In addition to the reasons which have been given above in favor of its general adoption, it may be further urged that the New scale offers the following advantages:

1. The abolition of all minus signs. In some countries surface temperatures do not fall below the zero

of the Centigrade or Fahrenheit scale, but over a considerable portion of the globe winter temperatures necessitate the use of minus signs. These are to some degree confusing and liable to misinterpretation. It is advisable that use of the minus sign be restricted. Over the entire globe, upper air temperatures are below the zero of both the old scales. Even over the equator at an elevation of four kilometres it becomes necessary to employ negative values. As temperatures readings of -90° C. have been recorded, there is quite a large range in which it is necessary to use the minus sign. In all modern balloon work the old scales have been abandoned and temperatures are given on the Absolute scale, both for theoretical reasons and to do away with the minus sign.

2. There is an advantage in recognizing the grand division of *warm* and *cold* as expressed by the values 1000 and 1100. Thus all temperatures below 1000 are known to be cold or below the freezing point of water; and all temperatures above 1100 are immediately recognized as warm since that temperature corresponds to so-called summer heat (81° F.).

3. In compiling data the New scale makes for greater accuracy without sacrificing definiteness, as in the use of the Absolute scale. There is also a marked saving in time and in the space required for presentation of data. As an illustration of the economy of labor and space, attention is called to the table of monthly and annual temperatures covering a period of 31 years at Blue Hill Observatory. There appears to be a saving of about 40 per cent. in favor of the New scale.

4. The New scale makes for clearer conception of the magnitude of temperature changes. While it does not describe in any way the inner kinetic energy of molecules and as it seems to be somewhat more suitable for application in problems bearing on the thermodynamics of the atmosphere and the kinetic theory in general. It can be used in the two fundamental laws of thermodynamics that of conservation of energy and of increase of expenditure in a non-conservative system; and in fact wherever the absolute temperature is used, since it is itself based on an absolute value.

Vapor Pressure and Humidity.—At Blue Hill it has been found practicable to express these conditions in the new units and for several years in the summaries, the mean values of vapor pressure have been given in kilobars. The temperature of saturation or dew-point is not as a rule published. If the relative humidity or percentage of saturation is desired and the new Absolute scale is used, it will be necessary to re-adjust the values of the Glaisher factor *A* as employed in the formula

$$t - d = A (t - t')$$

At 1000N. the Glaisher multiplier is 3.32	
1010	2.7
1020	2.3
1030	2.2

COMPARISON OF THE THERMOMETER SCALES

Fahr.	New	Fahr.	New	Fahr.	New	Fahr.	New	F. C. ABSOLUTE NEW			
-40 = 853		0 = 935		40 = 1016		80 = 1098		140	60	20	
-39 55		1 37		41 18		81 1100		130	30	10	
-38 57		2 39		42 20		82 2		120	30	0	
-37 59		3 41		43 22		83 4		110	30	0	
-36 61		4 43		44 24		84 6		100	40	0	
-35 63		5 45		45 27		85 8		90	30	0	
-34 65		6 47		46 29		86 10		80	30	0	
-33 67		7 49		47 31		87 12		70	30	0	
-32 69		8 51		48 33		88 14		60	30	0	
-31 72		9 53		49 35		89 16		50	20	0	
-30 74		10 55		50 37		90 18		40	20	0	
-29 76		11 57		51 39		91 20		30	10	0	
-28 78		12 59		52 41		92 22		20	30	0	
-27 80		13 61		53 43		93 24		10	10	0	
-26 82		14 63		54 45		94 26		0	0	0	
-25 84		15 65		55 47		95 28		20	10	0	
-24 86		16 67		56 49		96 30		10	10	0	
-23 88		17 70		57 51		97 32		0	20	0	
-22 90		18 72		58 53		98 35		10	20	0	
-21 92		19 74		59 55		99 37		20	30	0	
-20 94		20 76		60 57		100 39		30	30	0	
-19 96		21 78		61 59		101 41		40	40	0	
-18 98		22 80		62 61		102 43		50	40	0	
-17 100		23 82		63 63		103 45		60	40	0	
-16 2		24 84		64 65		104 47		70	30	0	
-15 4		25 86		65 67		105 49		80	30	0	
-14 6		26 88		66 69		106 51		90	60	0	
-13 8		27 90		67 72		107 53		100	60	0	
-12 10		28 92		68 74		108 55		110	70	0	
-11 12		29 94		69 76		109 57		120	70	0	
-10 14		30 96		70 78		110 59		130	80	0	
-9 16		31 98		71 80		111 61		140	90	0	
-8 18		32 1000		72 82		112 63		150	100	0	
-7 20		33 2		73 84		113 65		160	110	0	
-6 22		34 4		74 86		114 67		170	120	0	
-5 24		35 6		75 88		115 69		180	130	0	
-4 26		36 8		76 90		116 71		190	140	0	
-3 28		37 10		77 92		117 73		200	150	0	
-2 31		38 12		78 94		118 75		210	160	0	
-1 33		39 14		79 96		119 77		220	170	0	

of molecular motion, we must continue to use the mercurial thermometer and utilize as an approximate measure of temperature, the variation in the expansion of mercury and glass. There has been no material improvement in thermometer scales since Linnaeus reversed the order of the Celsius marking. There have been some scales such for example as De l'Isle's scale, mentioned in the computer's handbook M. O. 223, page 10, in which the boiling point was marked zero and the freezing point 150; also scales in which temperatures were measured above and below a so-called temperate or median value.

In measuring the quantity of heat received some such device as a pyrheliometer must be employed. In C. G. S. units if we use the New scale, the gram calorie becomes the quantity of heat that will raise the temperature of a gram of pure water under standard conditions 3.6663 degrees. The value of the gram calorie will vary slightly for different temperatures. At 1000

*Annals of the Astronomical Observatory of Harvard College. Vol. 83, part 1.

1040	2.1
1050	2.0
1060	1.9
1070	1.8
1080	1.7
1090	1.7
1100	1.6

For example, if the dry bulb reading is 1020 and the wet bulb 1010, the dew-point is 997 and the relative humidity 61%.

The mean annual vapor pressure at Blue Hill is 9.3 kilobars and the ratio of this to the air pressure is .0097. The mean annual percentage of saturation is 74.

If any of the revisions of Regnault's formula as used in Europe be adopted and the general expression for the force of the vapor pressure be of the form

$$e'' = e' - A (t - t')p$$

the value of A will vary with the velocity of flow of air over the evaporating surface, in this case, the wet bulb. In the effort to standardize wet-bulb readings and obtain a fixed flow of air or standard circulation or ventilation, the Assmann aspiration psychrometer or some form of sling or whirled psychrometer is generally used, although percentages of saturation or relative humidities as given by hair hygrometers and extensively used, are not thus corrected. It may be noted that from the standpoint of the climatologist, the unventilated reading is preferable to the forced circulation value, since this last represents a fictitious value and conveys an erroneous impression of the sensible temperature. With a wind of 2 metres per second a fairly serviceable value of the constant A in the formula given above is .000656. The product of this and the standard pressure of 1000 kilobars is roughly .66. When the new Absolute scale of temperature is employed, this product is roughly .18. For example if the dry bulb reading is 1020 and the wet bulb 1010, then the value of the vapor pressure e' at the wet bulb temperature is 7.39 kbs. and subtracting 1.8 we have for the vapor pressure e'' at the dew-point temperature 5.59 kbs. The ratio of this to the vapor pressure e at the dry bulb temperature is

$$5.59/8.97 \text{ or } 62 \text{ per cent.}$$

All the constants used in all formulas are probably too high if the velocity of the wind is great and again when there is a great difference between the readings of the dry and wet thermometers. Furthermore for temperatures near and below 1000 N, that is when the wet bulb (and care must be taken at such times to free the dry thermometer also from any deposit) is covered with ice an allowance must be made for difference in the saturation pressure of water vapor and ice; also for any latent heat of fusion. Supercooling below the freezing point sometimes occurs.

Wind Velocities and Directions.—Many observatories publish data for these values in metres per second and in degrees of azimuth. This practice has been followed at Blue Hill for some years. No corrections for change in density have ever been applied here or elsewhere, so far as known. Beginning January 1, 1917, a record is kept of *hours suitable (or safe) for aviation* counting as such those having an average velocity not less than 10 metres per second and no variation equalling 50 per cent. in a period of five minutes.

Precipitation.—There is no longer any reason for expressing rainfall in decimal parts of an inch. At most observatories rainfall is now both measured and expressed in millimetres and snowfall in centimetres. This has been the practice at Blue Hill for many years.

Rainy Days.—The use of the value .01 inch as the quantity determining a rainy day should be abandoned and the amount 1 millimetre adopted in its place.

It is interesting to notice that Dr. G. C. Simpson in a discussion of the Rainfall of India, 1914, embracing three thousand stations calls a rainy day one on which 2.54 millimetres falls, or 0.1 inch.

The "Duct" Keel in Sea-Going Steamers

UNDER the somewhat indefinite title of "Improvements in the Construction of Ships," Mr. E. F. Spanner, R.C.N.C., submitted a paper at the opening meeting of the present session of the Institution of Engineers and Shipbuilders in Scotland, on October 22nd, which has so intimate a bearing on questions of great present-day importance—*e. g.*, the maintenance of a ship's floatability after severe damage—that a short summary will be acceptable. The paper was primarily, if not wholly, concerned with propounding the idea, not for the first time proposed, of providing a central, or mid-line duct, along the lower portion of a vessel, for the purpose of dealing with fluid distributed in different compartments along its length. One proposed form of this idea provided for a central pipe running through the vessel, above the inner bottom, but the author briefly

dismissed this, as the objections attaching to the existence of a pipe of very large cross section in the holds, piercing the water-tight bulkheads, and having numerous branches, were well recognised.

The development of the central duct idea is considered to offer such advantages as regards safety, economy, etc., as should insure it a welcome from those interested in the construction and running of sea-going vessels of the passenger and large cargo types. The author's proposal is to provide the mid-line fore and aft duct by dispensing with the ordinary centre vertical or keel plate in the double bottom, and substituting two such verticals to form a relatively narrow box-keel running the length of the vessel, and having an uninterrupted passage through it from one end to the other, but with vertical doors or valves at specified intervals dividing the duct into sections, and with side valves into each water ballast section of the vessels double bottom, all of which can be operated by pressure, led in pipes within the duct, and operated, if need be, from the engine room.

The author first dealt exhaustively with the form of this duct-keel, and its structural relationship with, and strength effects on, the hull of a vessel, both in service and when docking, etc. He then treated fully of its adaptability and utility to the purposes of water ballast and oil fuel carrying in the double bottom compartments, and especially emphasised the important service it is calculated to render in emergency for trimming purposes, as between compartment and compartment, to secure and maintain float-ability in damaged vessels, after the manner made familiar to naval architects and shipowners by Messrs. Brunton Brothers. He briefly described the Brunton system, and remarked that it was thoroughly sound in conception and undoubtedly destined to be widely adopted when some of the practical difficulties were overcome.

Having touched upon most of the principal features of the duct form of keel construction—which the author said had recently been patented by him, jointly with Mr. J. H. Silley, he finished up a paper of great detail by summarising the advantages claimed for the duct keel vessel. The form of keel proposed was such as to increase the strength of the vessel against longitudinal strains and against strains due to docking or grounding. The duct provided a permanent connection between the pumping plant and the double bottom, and such hold compartments as was desired, enabling water or oil to be pumped into or out of these compartments without the necessity of fitting long leads of suction and filling pipes; also in the case of oil avoiding the necessity of fitting more than a small amount of heating pipe. With the duct fitted there was no need for the piercing of the water-tight bulkheads with numerous holes for the suction and filling pipes. Owing to the manner in which communication was arranged between duct and adjacent compartments, there was no danger of any portion of the vessel being flooded by the entry of water through the duct, unless such flooding was desired by the ship's officers. As the duct keel involved practically no addition to the structural weight of vessel, an amount of dead-weight represented by the weight of suction and delivery pipes, joints, bulkhead pieces, valves, strainers, etc., dispensed with, was available for cargo carrying, as was also the space saved by the absence from holds of any ballast or fuel pipes, and of the dunnage necessary for protecting them. The duct would be available, if desired, for arranging of leads of suction and delivery pipes from the pumps to the fresh water tanks, or reserve feed water tanks, so avoiding the necessity of piercing bulkheads to accommodate these leads. The cost of working the form of duct keel described as an integral part of the double bottom of vessels will be inappreciable, the saving in fitting and maintenance of piping considered, and it renders the carrying out of the Brunton system more eminently practicable. The author desiderated the fullest attention being drawn to any practical difficulties in the way of the application of the idea. It was desired to establish the soundness or otherwise of the idea as early as possible. In the present circumstances, when heavy demands were being made on the time and energies of all interested in the maintenance of our maritime efficiency, it was essential that impracticable schemes should receive an early quietus. On the other hand, it was reasonable to hope that a welcome would be extended to any idea which offered a sound prospect of success.—*The Marine Engineer.*

The Time to Cut Walnut

DR. ROBERT T. MORRIS, of New York City, a well-known authority, in a recent letter to *American Forestry*, says:

"No doubt the United States Department of Agricul-

ture has taken into consideration the proper time for cutting black walnut trees reported by the Boy Scouts. The matter, however, is one which concerns us so deeply that I may be allowed to impress the point that these trees so far as possible should be cut between the months of September and April. If the trees are cut at other times of the year the root dies. It is a very important matter to leave living roots which will reproduce the trees rapidly. It is not only a question of future timber supply but the nut growers are at the present time making special effort to locate black walnut trees bearing particularly thin-shelled and well flavored black walnuts with good cleavage.

"The black walnut is destined to play a large part in our agricultural economics, both as a timber tree and as a source of important food supply. For that reason special effort should be made to avoid summer cutting."

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