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Example 1 (Centigrade Chart—Low Range)

Suppose a psychrometer reads 20° C on the dry bulb
on the wet bulb when the total (barometric) pressure is 6
To find the pressure of water vapor, place a straightedge
intersects the "Observed Dry Bulb Minus Wet Bulb, C"
20−8=12. Adjust it so that it intersects the "Barometer,
scale at 60, and note the intersection with the "Sea Level
lent Dry Bulb Minus Wet Bulb, C" scale (9.5). Hol
straightedge at this point, swing it so that it intersects the
nearly vertical) "Wet Bulb, C" scale at 8, and read the
of water vapor (3.30) on the "Humidity, mm Hg" scal
right. A computation from the psychrometric formula gi
mm Hg for this value.

In obtaining the pressure of water vapor when t
bulb temperature is below freezing, on either the
heit or centigrade low-range chart, the scale marke
Bulb" is employed if the psychrometer was us
either subcooled water or a frozen wick. Howe
more accurate results can be obtained with an ic
thermometer, using the "Ice Bulb" scale (to the
the "Wet Bulb" scale).

Determining Relative Humidity

To determine the relative humidity, place a strai
so that it intersects the "Humidity mm (or in.) H
at the value of the pressure of water vapor, and in
the (diagonal) "Dry Bulb" scale at the value of
bulb temperature. The relative humidity is give
point of intersection with the inner left scale.

Example 2 (Centigrade Chart—Low Range)

Continuing the example started above, hold the straight
at the value 3.30 on the "Humidity, mm Hg", and swing
it intersects the (diagonal) "Dry Bulb, C" scale at 20. B
ing this line to the vertical "Relative Humidity, Perce
(inner left), the relative humidity is found (18.8%). Con
gives 18.87% for the psychrometric data given originally.

Determining Dewpoint

To obtain the dewpoint, determine the pressure
vapor as in the first example. Connect this poin
"Humidity, mm (or in.) Hg" scale by straighte
100% relative humidity and read the dewpoint
"Wet Bulb" scale.

Example 3 (Centigrade Chart—Low Range)

Continuing with the data of example 1, connect 3.3
"Humidity, mm Hg" scale by straightedge with 100 on t
tive Humidity, Percent" scale. The intersection of the str
with the "Wet Bulb, C" scale (−4.35 C) gives the de

U. S. DEPARTMENT OF COMME
Daniel C. Roper, Secretary
NATIONAL BUREAU OF STANDAR
Lyman J. Briggs, Director

PSYCHROMETRIC

These charts were developed for use in the of humidity from psychrometric observatio ranging from ⅛ to 10 atmospheres. Their tended to any other pressure by either o described hereinafter. The charts are rig tations of the psychrometric formula, the f the Fahrenheit charts being that of Profe which has become conventional and which United States Weather Bureau (2). This

$$e=e'-0.000367\ P(t-t')\left(1+\frac{t'-}{15}\right.$$

in which t and t' are the temperatures of th bulb thermometers, in degrees Fahrenheit, metric pressure at the psychrometer, in inc e' is the saturation vapor pressure of wat mercury at the temperature t'; and e is water vapor in the atmosphere, or atmosp in inches of mercury. The centigrade char a formula of the same type

$$e=e'-0.000652\ P(t-t')\ (1+0.0$$

in which P, e', and e are expressed in milli cury, and t and t' in degrees centigrade. T has been taken to modify the constants u mula in the light of recent data (3, 4), whi to be more accurate. Hence the values in mula above are used rather than the valu correspond to those used in the first formu

EXAMPLE 1 (Centigrade Chart—Low Range)

Suppose a psychrometer reads 20° C on the dry bulb and 8° C on the wet bulb when the total (barometric) pressure is 60 cm Hg. To find the pressure of water vapor, place a straightedge so that it intersects the "Observed Dry Bulb Minus Wet Bulb, C" scale at 20—8=12. Adjust it so that it intersects the "Barometer, cm Hg" scale at 60, and note the intersection with the "Sea Level Equivalent Dry Bulb Minus Wet Bulb, C" scale (9.5). Holding the straightedge at this point, swing it so that it intersects the (central, nearly vertical) "Wet Bulb, C" scale at 8, and read the pressure of water vapor (3.30) on the "Humidity, mm Hg" scale at the right. A computation from the psychrometric formula gives 3.312 mm Hg for this value.

In obtaining the pressure of water vapor when the wet-bulb temperature is below freezing, on either the Fahrenheit or centigrade low-range chart, the scale marked "Wet Bulb" is employed if the psyebrometer was used with either subcooled water or a frozen wick. However (4), more accurate results can be obtained with an ice-coated thermometer, using the "Ice Bulb" scale (to the right of the "Wet Bulb" scale).

Determining Relative Humidity

To determine the relative humidity, place a straightedge so that it intersects the "Humidity mm (or in.) Hg" scale at the value of the pressure of water vapor, and intersects the (diagonal) "Dry Bulb" scale at the value of the dry-bulb temperature. The relative humidity is given at the point of intersection with the inner left scale.

EXAMPLE 2 (Centigrade Chart—Low Range)

Continuing the example started above, hold the straightedge fixed at the value 3.30 on the "Humidity, mm Hg", and swing it so that it intersects the (diagonal) "Dry Bulb, C" scale at 20. By extending this line to the vertical "Relative Humidity, Percent" scale (inner left), the relative humidity is found (18.8%). Computation gives 18.87% for the psychrometric data given originally.

Determining Dewpoint

To obtain the dewpoint, determine the pressure of water vapor as in the first example. Connect this point on the "Humidity, mm (or in.) Hg" scale by straightedge with 100% relative humidity and read the dewpoint on the "Wet Bulb" scale.

EXAMPLE 3 (Centigrade Chart—Low Range)

Continuing with the data of example 1, connect 3.30 on the "Humidity, mm Hg" scale by straightedge with 100 on the "Relative Humidity, Percent" scale. The intersection of the straightedge with the "Wet Bulb, C" scale (−4.35 C) gives the dewpoint in terms of supercooled water; that with the "Ice Bulb, C" scale (−3.85 C) gives the dewpoint relative to ice. Computed values are −4.37 C and −3.85 C.

ADDITIONAL USES OF THE CHARTS

Approximate Determinations: Error Involved

Numerous other uses for these charts will suggest themselves to those familiar with psyehrometric work. For example, when working at pressures near one atmosphere, the chart can be used to determine humidity approximately by neglecting the "Observed Dry Bulb Minus Wet Bulb" and the pressure scales. This amounts to assuming that the observed dry bulb minus wet hulh is equal to the sea-level equivalent dry hulh minus wet bulh, and proceeding accordingly.

EXAMPLE 4 (Centigrade Chart—Low Range)

A psychrometer reads 20° C dry on the bulb and 8° C on the wet bulb when the barometer reads 74.35 cm Hg. The humidity can be obtained approximately by neglecting the pressure correction, and using the observed wet-bulb depression as the sea-level equivalent depression. Place a straightedge on the "Sea Level Equivalent Dry Bulb Minus Wet Bulb, C" scale at 20—8=12, and adjust so it intersects the "Wet Bulb, C" scale at 8. The approximate humidity is read on the "Humidity, mm Hg" scale as 2.05 mm Hg. Computation gives the value 2.050 for a 76 cm Hg pressure (as is assumed in this approximate method) and 2.180 for the actual pressure of 74.35 cm Hg.

Thus this approximation introduced a departure from the formula of 0.13 mm Hg into the result. Note that such a departure results from the use of all psychrometric charts which do not include a correction for barometric pressure.

A useful guide as to when the above approximation can safely be used is

$$\text{Departure, mm Hg} = \frac{(t-t')\ (P-760)}{1533}$$

or the rule can be used, that the departure in the humidity will not exceed 0.1 mm Hg when the product of the wet-bulb depression by the difference between the observed barometric pressure in cm Hg and 76 does not exceed 15.

Similarly, for the Fahrenheit charts,

$$\text{Departure, in. Hg} = \frac{(t-t')\ (P-30)}{2725}$$

and the departure in the humidity will not exceed 0.01 in. Hg if the wet-bulb depression times the difference between the observed barometric pressure, in. Hg, and 30 does not exceed 27.

The above formulas are exact only when the wet-bulb temperature is 0° C or 32° F; however, they are sufficiently close for practical purposes over the working range of temperature.

Determining Pressure of Water Vapor from Relative Humidity

The use of these charts for the determination of the (saturation) vapor pressure of water at any temperature is too obvious to require an example. This determination is made by setting a straightedge on 100% relative humidity and on the required temperature on the wet-bulb (or dry-bulb) scale, and reading the vapor pressure of water on the humidity scale at the right.

It is also obvious that by reversing the procedure for finding the relative humidity when the dry-bulb temperature and the pressure of water vapor are given, the latter can be found for any given relative humidity.

EXAMPLE 5 (Centigrade Chart—Low Range)

When the dry-bulb temperature is 20° C and the relative humidity is 40%, what is the pressure of water vapor? Place a straightedge so that it connects 40 on the "Relative Humidity, Percent" scale with 20 on the (diagonal) "Dry Bulb, C" scale, and read the pressure of water vapor (7.02 mm Hg) on the "Humidity, mm Hg" scale. Computation gives 7.019 mm Hg.

Determining Temperatures for a Controlled Humidity

A problem which arises frequently is that of maintaining a desired relative or absolute humidity at a given dry-bulb temperature, the humidity to be indicated by a psychrometer. To find from the formula what wet-bulb reading corresponds to the required humidity involves tedious approximations, or double interpolation in tables. This value can be found from these charts quite simply. If a certain relative humidity is required, determine as in the above example the corresponding pressure of water vapor. Keeping the straightedge fixed on this value, swing it until the sum of the values on the "Wet Bulb" and "Sea Level Equivalent Dry Bulb Minus Wet Bulb" scales equals the given dry-bulb temperature. The value indicated by the intersection of the straightedge and the "Wet Bulb" scales is the required wet-bulb reading if operation is to be at sea-level pressure. For other pressures, the operation is slightly more complicated, but can be done by reversing the procedure used in example 1.

A similar problem is that of bringing a given atmosphere to a desired relative humidity by altering its dry-bulb temperature. To determine the desired dry-bulb temperature, connect by straightedge the point on the "Humidity, mm (or in.) Hg" scale representing the pressure of water vapor present with the point representing the desired relative humidity on the "Relative Humidity, Percent" scale. The required dry-bulb temperature is given by the intersection of the straightedge with the "Dry Bulb" scale.

EXAMPLE 6 (Centigrade Chart—Low Range)

It is desired to bring the atmosphere for which psychrometric data are given in example 1 to 50% relative humidity. To determine what dry-bulb temperature will accomplish this, connect 3.30 on the "Humidity, mm Hg" scale with 50 on the "Relative Humidity, Percent" scale. The required dry-bulb temperature, indicated by the intersection of the straightedge with the "Dry Bulb, C" scale, is 5.2° C. By computation the value 5.20° C is obtained.

Determining Precision Required

Another use of these charts is in determining the precision requisite in the psychrometric data to give a desired precision in the result. This can be done most readily by successively assuming a given error, say one unit in the reading, in each of the data, and finding the resulting change in the final value. From the changes so found, the requisite precision is apparent.

EXAMPLE 7 (Centigrade Chart—Low Range)

A psychrometer reads 24° C on the dry bulb and 8° C on the wet bulb when the pressure is 57 cm Hg. Using these values, the pressure of water vapor is found to be 2.05 mm Hg. By assuming separately the values 25° C on the dry bulb, 9° C on the wet bulb, and 58 cm Hg, the following sequence of values is found.

Dry, C	Wet, C	Pressure, cm Hg	Humidity, mm Hg	
			Chart	Formula
24	8	57	2.05	2.050
25	8	57	1.66	1.676
24	9	57	2.96	2.984
24	8	58	1.93	1.945

From these values, the effect of an error of one unit in each reading, and its reciprocal function, the precision requisite to obtaining a final value of desired precision, are obtained, as given below.

Unit error in	Error in final value, mm Hg	Precision for 1% relative humidity precision in result	Precision for 0.1 mm Hg precision in result
Dry bulb	0.39	0.58 C	0.26 C
Wet bulb	0.91	0.22 C	0.10 C
Pressure	0.12	1.86 cm Hg	0.83 cm Hg

Use of the Charts at Other Pressures

These charts can be used at pressures other than those marked on the pressure scale by either of two expedients. Since the pressure scale operates to multiply the observed wet-bulb depression by the ratio of observed pressure to standard pressure, to obtain the "sea-level equivalent" wet-bulb depression, this operation can be performed by computation instead of graphically.

The second alternative is to multiply the scale (absolute) values of the pressure scale by a suitable factor, and multiply the scale values of the "Observed Wet Bulb Minus Dry Bulb" scale by the reciprocal of that factor. The operation of finding the sea-level equivalent wet-bulb depression is then carried out graphically as usual. Note that one pressure scale is in terms of gage pressure, not absolute pressure and this method consequently cannot be used on it.

the chart can be used to determine humidity approximately by neglecting the "Observed Dry Bulb Minus Wet Bulb" and the pressure scales. This amounts to assuming that the observed dry bulb minus wet bulb is equal to the sea-level equivalent dry bulb minus wet bulb, and proceeding accordingly.

EXAMPLE 4 (Centigrade Chart—Low Range)

A psychrometer reads 20° C dry on the bulb and 8° C on the wet bulb when the barometer reads 74.35 cm Hg. The humidity can be obtained approximately by neglecting the pressure correction, and using the observed wet-bulb depression as the sea-level equivalent depression. Place a straightedge on the "Sea Level Equivalent Dry Bulb Minus Wet Bulb, C" scale at 20−8=12, and adjust so it intersects the "Wet Bulb, C" scale at 8. The approximate humidity is read on the "Humidity, mm Hg" scale as 2.05 mm Hg. Computation gives the value 2.050 for a 76 cm Hg pressure (as is assumed in this approximate method) and 2.180 for the actual pressure of 74.35 cm Hg.

Thus this approximation introduced a departure from the formula of 0.13 mm Hg into the result. Note that such a departure results from the use of all psychrometric charts which do not include a correction for barometric pressure.

A useful guide as to when the above approximation can safely be used is

$$\text{Departure, mm Hg} = \frac{(t-t')\ (P-760)}{1533}$$

or the rule can be used, that the departure in the humidity will not exceed 0.1 mm Hg when the product of the wet-bulb depression by the difference between the observed barometric pressure in cm Hg and 76 does not exceed 15.

Similarly, for the Fahrenheit charts,

$$\text{Departure, in. Hg} = \frac{(t-t')\ (P-30)}{2725}$$

and the departure in the humidity will not exceed 0.01 in. Hg if the wet-bulb depression times the difference between the observed barometric pressure, in. Hg, and 30 does not exceed 27.

The above formulas are exact only when the wet-bulb temperature is 0° C or 32° F; however, they are sufficiently close for practical purposes over the working range of temperature.

Determining Pressure of Water Vapor from Relative

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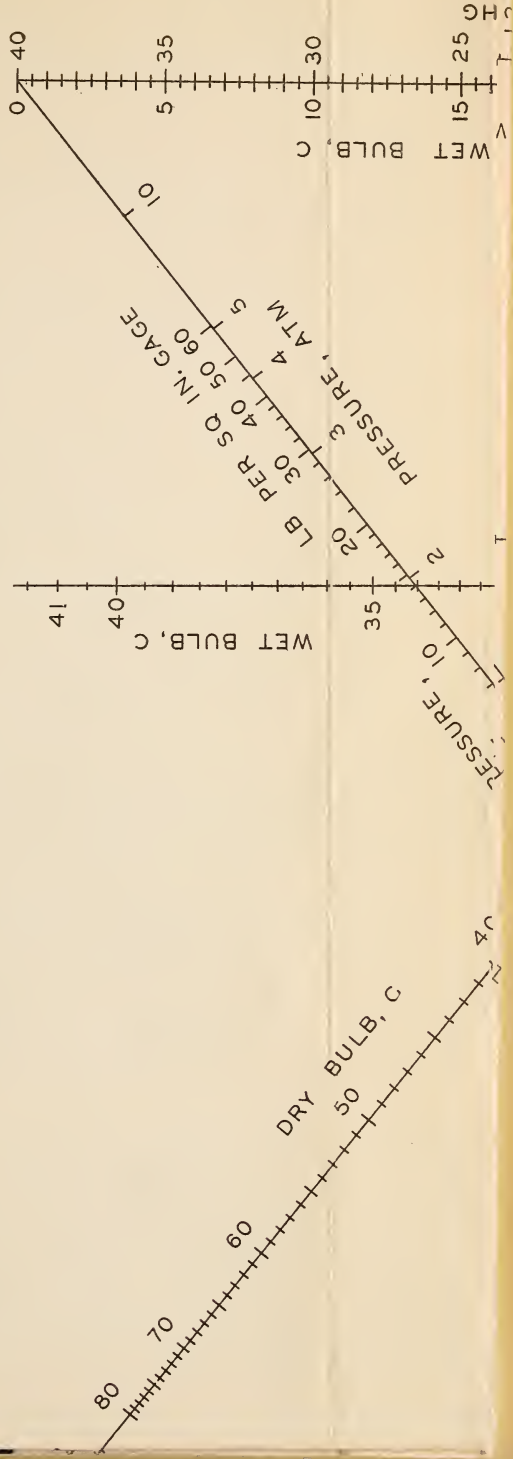
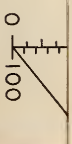




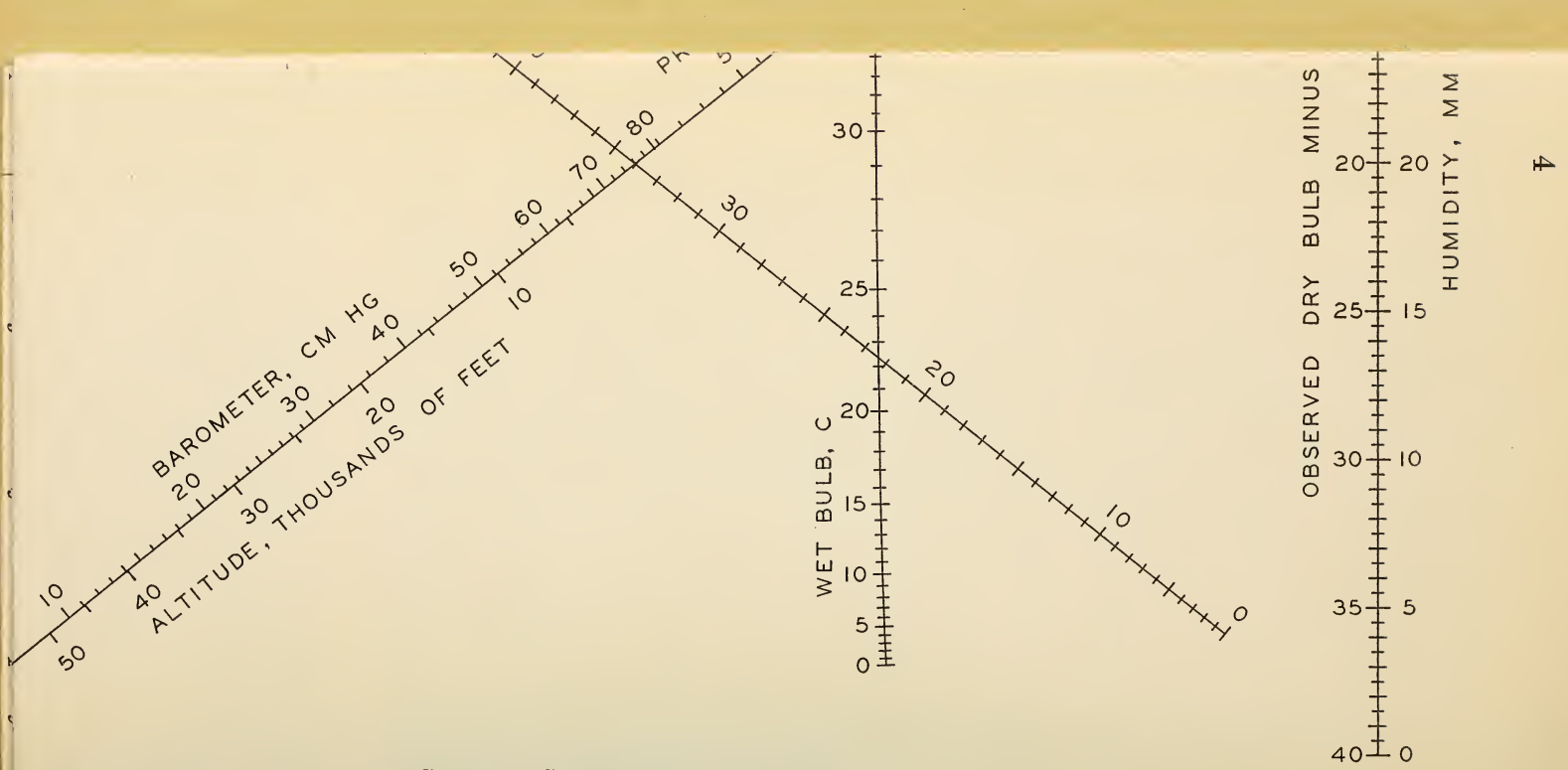
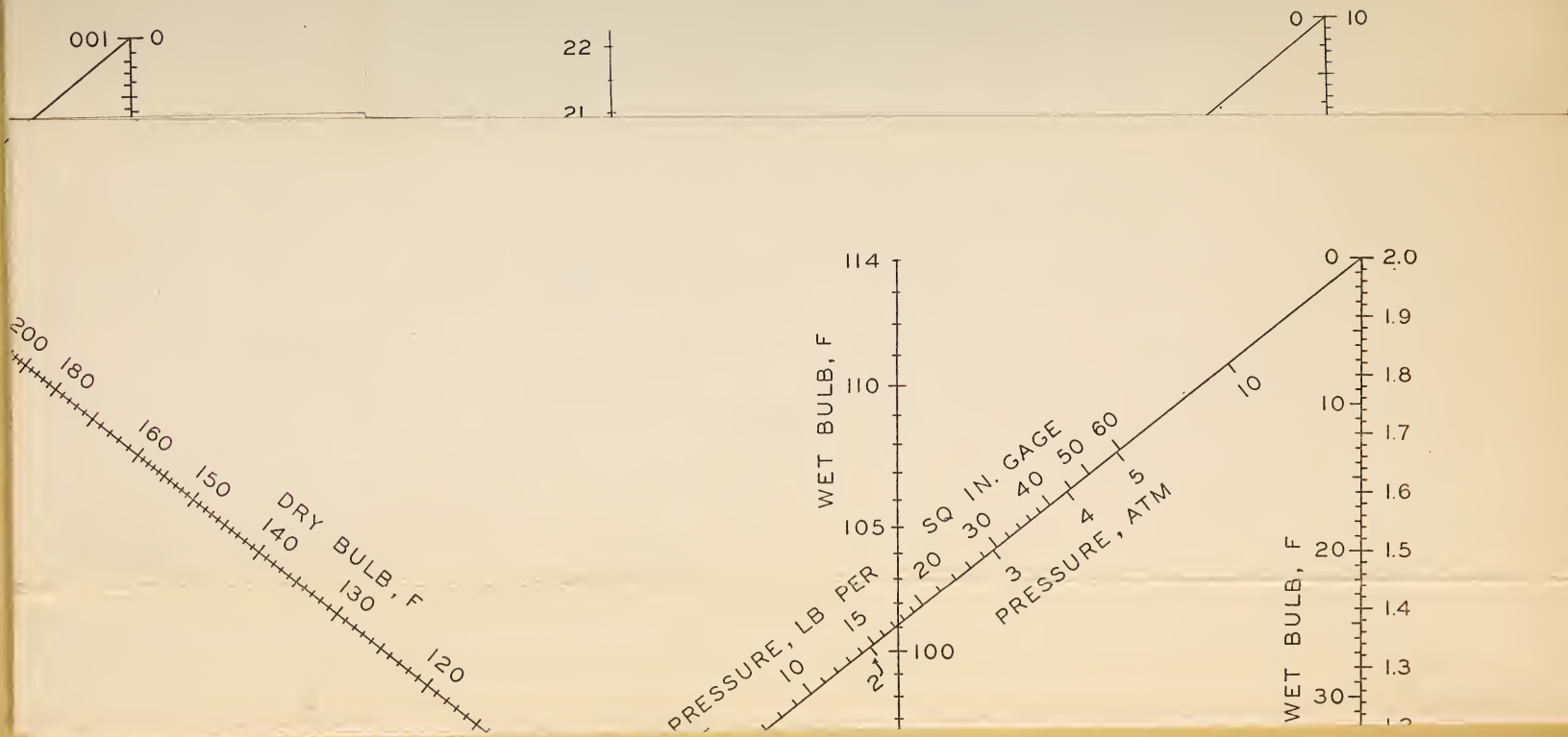


CHART 1.—*Centigrade chart—high range.*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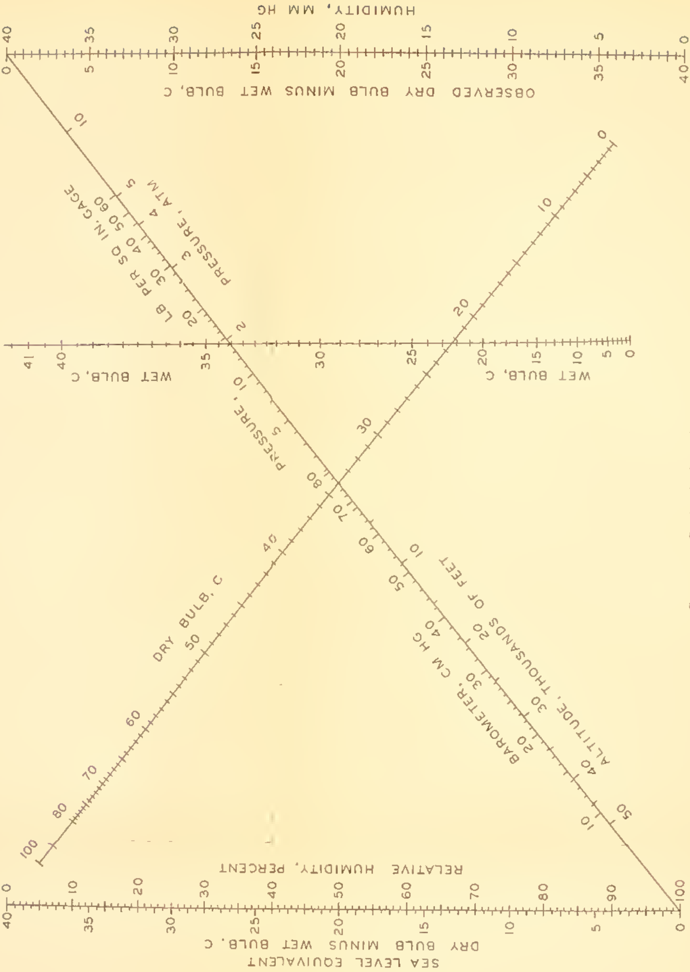

CHART 1.—*Centigrade chart—high range*

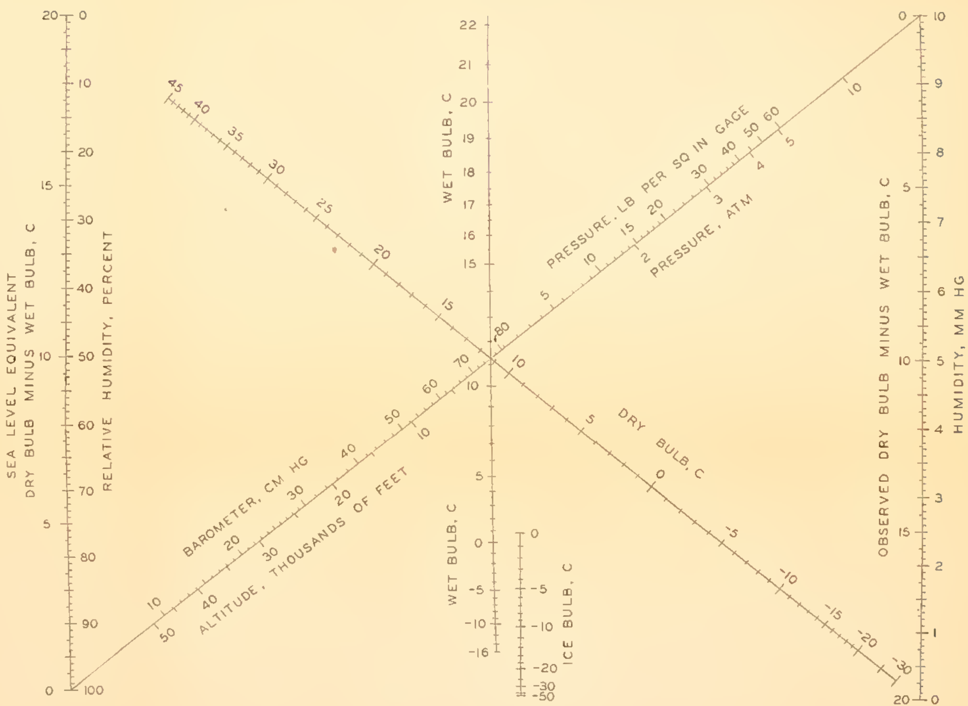

CHART 2.—*Centigrade chart—low range.*

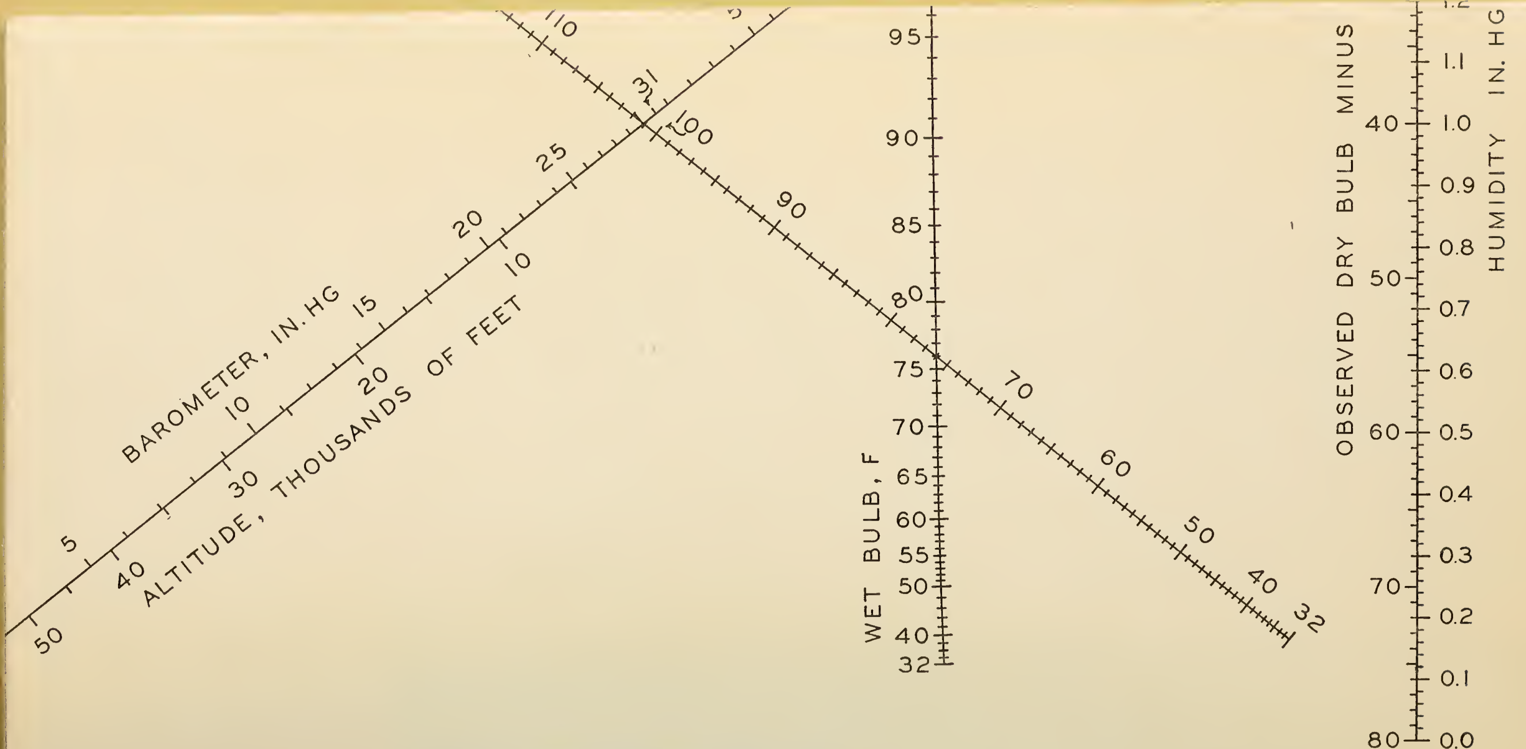

CHART 3.—*Fahrenheit chart—high range.*

EXAMPLE 8 (Centigrade Chart—Low Range)

A psychrometer operating at a pressure of 6 atmospl
15° C on the dry bulb and 13° C on the wet bulb. T
humidity, multiply the numbers on the atmosphere pre
by 2, and divide those on the "Observed Dry Bulb M
Bulb" scale by 2. Proceeding as usual, the "Sea Level
Dry Bulb Minus Wet Bulb, C" value is found to be 12.
humidity 5.22 mm Hg. Computed values are 12.00 and

This procedure can also be applied to the gage
scale, provided 14.7 ($n-1$), (where n=factor by
merics on gage pressure scale are multiplied) is su
from the observed pressure in entering the revised
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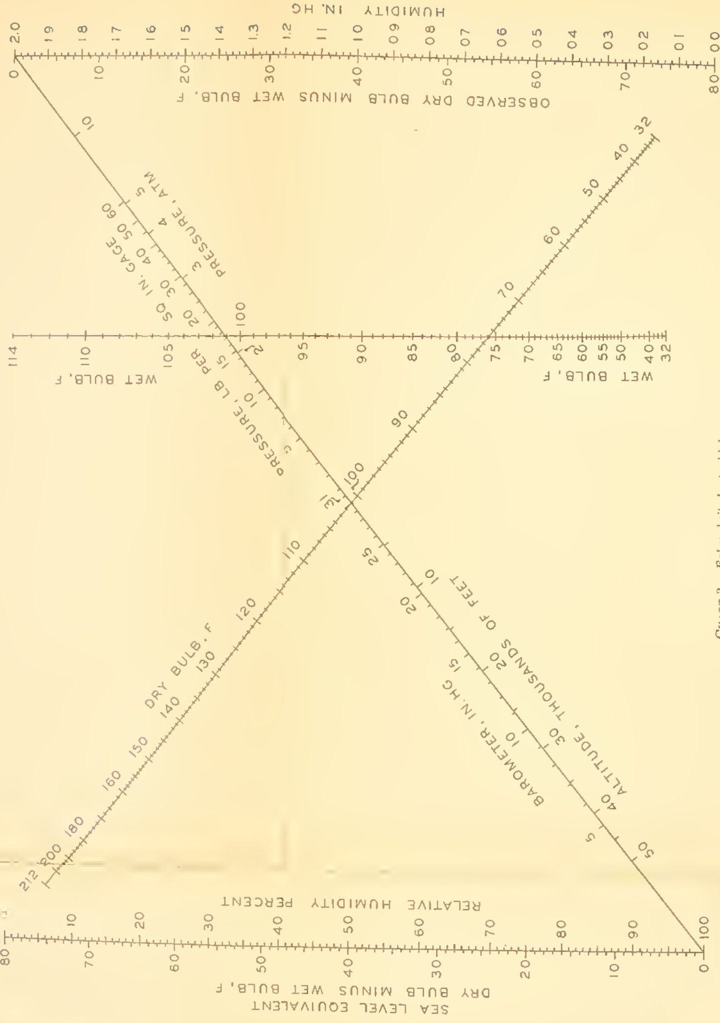

CHART 3.—*Fahrenheit chart—high range.*

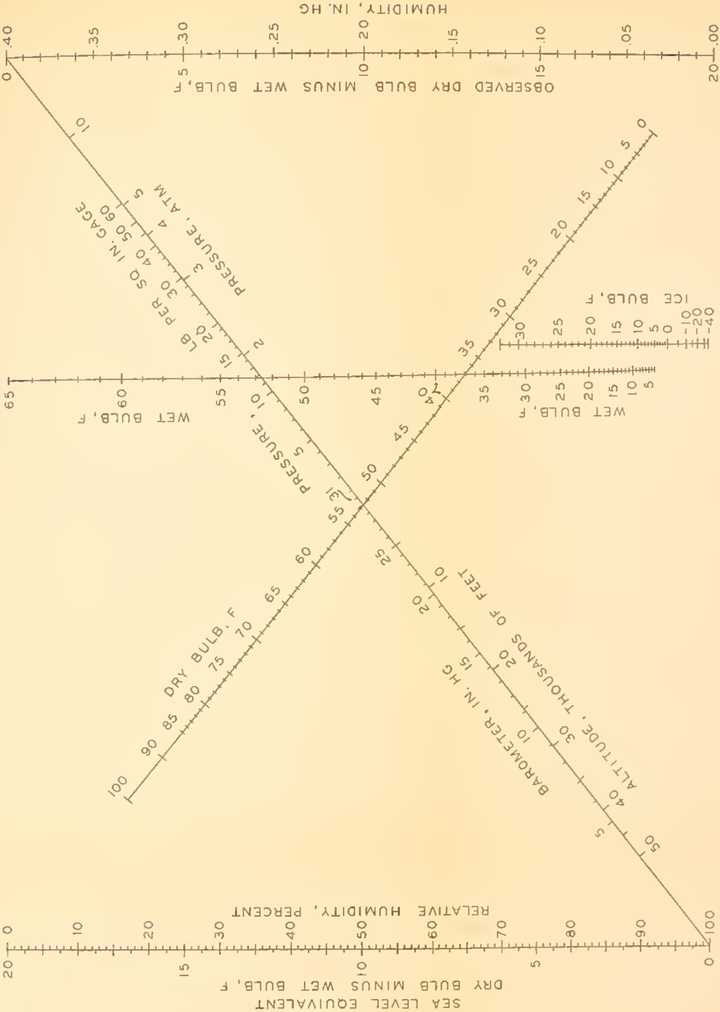

CHART 4.—*Fahrenheit chart—low range.*

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REFERENCES

(1) Report of the Chief Signal Officer, War Department, 1886, appendix 24, pages 233–259.

(2) Psychrometric Tables, WB no. 235, 10 cents.

(3) Feuchtigkeitsmessung, by Dr. Hermann Bongards.

(4) Journal of the Washington Academy of Sciences, March 15, 1933, pages 121–134.

(5) Centimeter-inch paper scales for convenient use with these charts are available from many manufacturers of drafting and scientific supplies.

EXAMPLE 8 (Centigrade Chart—Low Range)

A psychrometer operating at a pressure of 6 atmospheres reads 15° C on the dry bulb and 13° C on the wet bulb. To find the humidity, multiply the numbers on the atmosphere pressure scale by 2, and divide those on the "Observed Dry Bulb Minus Wet Bulb" scale by 2. Proceeding as usual, the "Sea Level Equivalent Dry Bulb Minus Wet Bulb, C" value is found to be 12.00 and the humidity 5.22 mm Hg. Computed values are 12.00 and 5.210.

This procedure can also be applied to the gage pressure scale, provided 14.7 $(n-1)$, (where n=factor by which numerics on gage pressure scale are multiplied) is subtracted from the observed pressure in entering the revised pressure scale.

REFERENCES

(1) Report of the Chief Signal Officer, War Department, 1886, appendix 24, pages 233–259

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