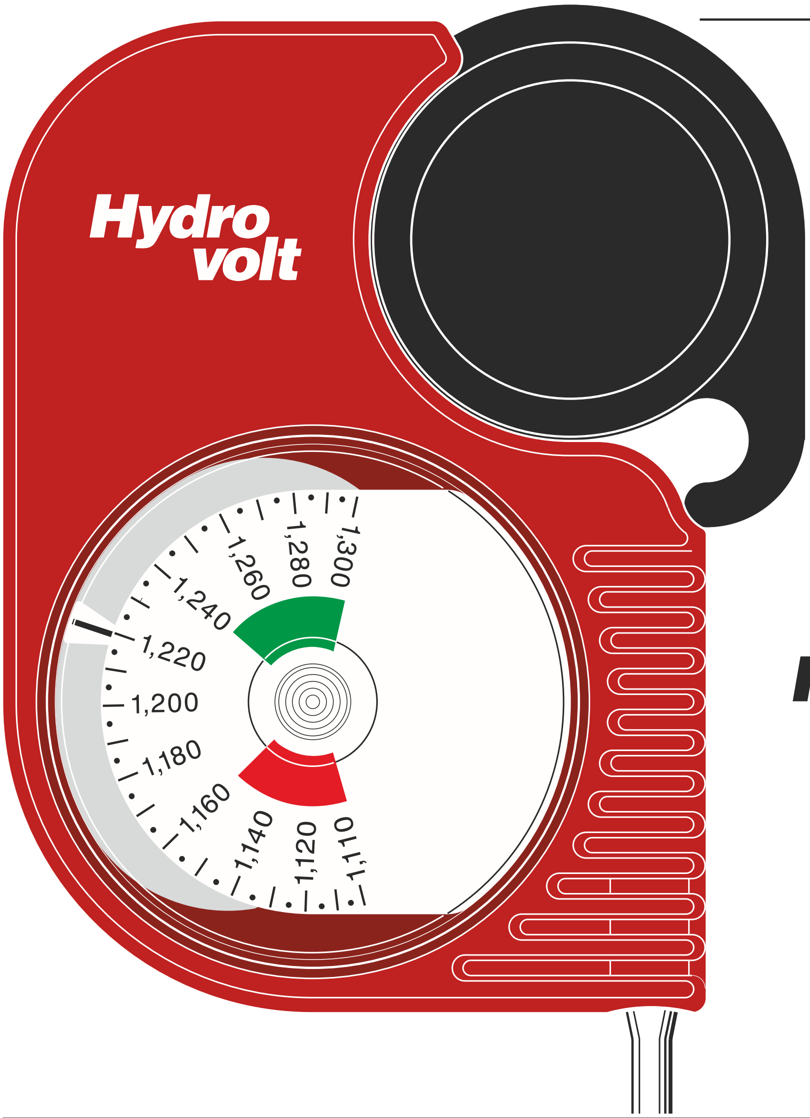

Hydro volt *Battery Tester*

The HYDROVOLT battery tester is a heavy-duty, chemical-resistant hydrometer which is direct-reading and accurate at all electolyte temperatures. Its advanced design incorporates important practical features which simplify battery service as never before:

- handy compact size for use with hard-to-get-at batteries
- large, easy-to-read scale with quick-check colored sectors
- readings independent of vertical positioning of instrument
- fast, bubble-free intake of fluid sample
- automatic air-lock prevents fluid loss and air bleed
- unexcelled temperature compensation and measuring accuracy
- sturdy, shock-resistant materials, noncorrosive throughout

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The HYDROVOLT battery tester uses a unique twinrotor system with two density-responsive elements, each of which contributes to the accurate measurement of battery-acid density. This makes it possible to place a large, easy-to-read scale in a compact housing of handy size for working in cramped quarters.

Each of these elements is made of two different plastic materials which have been selected on the basis of their thermal expansion coefficients in such a manner that their combination provides optimal temperature compensation [1]). The two elements are mutually corrective, thus avoiding temperature error over the entire density range. Both elements respond to the temperature of the fluid sample within seconds, and the reading they show always provides a reliable indication of battery charge.

Since the relative position of the two HYDROVOLT elements is independent of the position of the housing, the instrument need not be held vertically in order to obtain an accurate reading, nor does it require any kind of "artificial horizon" for providing reference to the vertical. When immersed in battery acid, the elements are practically weightless, i.e. they are not inhibited by friction, and therefore will accurately indicate density differences of less than 0.001 g/ml (with full temperature compensation, as described above).

Obviously, no type of hydrometer will provide accurate readings if its buoyancy is affected by adhering air bubbles, and this has been a serious practical disadvantage of such instruments so far. Therefore, in designing the HYDROVOLT system, a careful study was made of this problem, since a solution to it was mandatory if the unique advantages of the HYDROVOLT system were to be retained under conditions of actual use. These studies resulted in a new laminar-flow inlet duct which allows very rapid filling (as is necessary in practical use), but avoids the formation of air bubbles under all normal conditions [2]). Backflow, which often occurs in open hydrostatic systems, is no problem with the HYDROVOLT system, since once the instrument is filled, hydrostatic lock automatically prevents loss of fluid from, and intake of air into, the measuring chamber.

In practical use, no other hydrometer is more accurate than the HYDROVOLT system, not even relatively expensive optical battery testers [3]). At the same time, this instrument is extremely simple to use:

1. While holding the instrument more or less upright, press the bulb to fill the measuring chamber completely, and
2. Read off the battery-acid density shown by the indicator.

HYDROVOLT does the rest automatically!

In addition to the density, the HYDROVOLT scale also has colored sectors which give a quick indication of battery charge. Starter batteries are fully charged at an acid density of 1,280 and depending upon the type - fully discharged at an acid density of from 1,110 to 1,120. The relation between acid density and battery charge is approximately as follows:

Acid Density		Battery Charge in Percent	
1,120	=	0	
1,160	=	25	(End of the red sector)
1,200	=	50	
1,240	=	75	
1,280	=	100	(Beginning of the green sector)

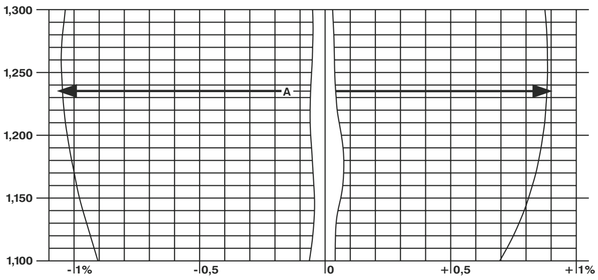
[1]) The densities (specific gravities) of liquids are temperature-dependent because of thermal expansion. It is absolutely necessary to correct such temperature errors if density measurements are to provide reliable information on battery charge.

[2]) If the charging voltage exceeds 2.4 volts per cell, the battery itself will produce gas bubbles in the electrolyte. In this case, the HYDROVOLT should be tapped a few times to remove such gas bubbles from the measuring elements and ensure an accurate reading.

[3]) This accuracy is based on the combination of twin rotors, proper design, and careful selection of materials. The accuracy of the HYDROVOLT system cannot be evaluated by comparing it with other battery testers, since the latter (e.g. glass hydrometers) are by nature relatively inaccurate. True liquid densities can be determined by hydrostatic weighing, or by differential pyknometry (using quartz pyknometers at extreme temperatures).

Calibration and Measurement Accuracy

The outstanding accuracy of the HYDROVOLT system is based in part on the quality of its temperature compensation compared with that of conventional glass hydrometers. The thermal expansion coefficient of glass is much less than that of the electrolyte, which means that a glass hydrometer cannot follow the change in acid density at various temperatures. If battery acid is assumed to have a temperature range of 10 to 45 °C (50 to 113 °F), the temperature errors within this range can be given precisely, since they result from the thermal expansions of the materials used in the measuring instrument. Here, the residual temperature error of HYDROVOLT is found to be only onetenth of that of a glass hydrometer. In the HYDROVOLT instrument, this error is negligible, since it remains less than 0.1% of the indicated density over the entire temperature range. The following diagram shows the exact values and, for comparison, the range of error "A" for glass hydrometers [4]).



The accuracy of the HYDROVOLT system is further based on the narrow tolerances of the injectionmolded parts. Glass laboratory hydrometers are accurate at their particular reference temperature, but the small hydrometers used in conventional battery testers have - in addition to temperature error - reading errors of up to 2% of the density. These errors result from variations in the size and weight of the component parts due to the manufacturing procedure. In addition, there are imponderable factors, such as the varying surface tension of the electrolyte and the weight of liquid droplets adhering to the spindle.

When assessing the accuracy of any measuring instrument, all possible sources of error must be taken into consideration. In this type of hydrometer, errors may result from:

1. Excessive tolerances in dimensions and materials during manufacture,
2. Temperature and friction effects during use,
3. Alterations in materials due to ageing.

By a careful choice of materials and strict quality controls, these errors can be reduced to a minimum in well-designed instruments. However, since no quantity-produced instrument, regardless of its cost, can be said to be absolutely free of error, it is customary to assess accuracy in terms of the standard deviation of the sum of all possible errors. The resulting tolerance field for HYDROVOLT testers is shown in the diagram (page 4). This diagram includes all temperature influences in the range from 10 to 45 °C (50 to 113 °F) [5]).

The diagram also presents the tolerance field "A" for conventional commercial battery testers made of glass. The height of this field shows that the readings given by instruments of this type may be so inaccurate that no reliable information on battery charge can be obtained.

The use of the HYDROVOLT system is by no means limited to the temperature range shown in the diagram. Even in the temperature range from -30 to +80 °C (-22 to +176 °F), the temperature error of HYDROVOLT is nowhere greater than 1% of the indicated density.

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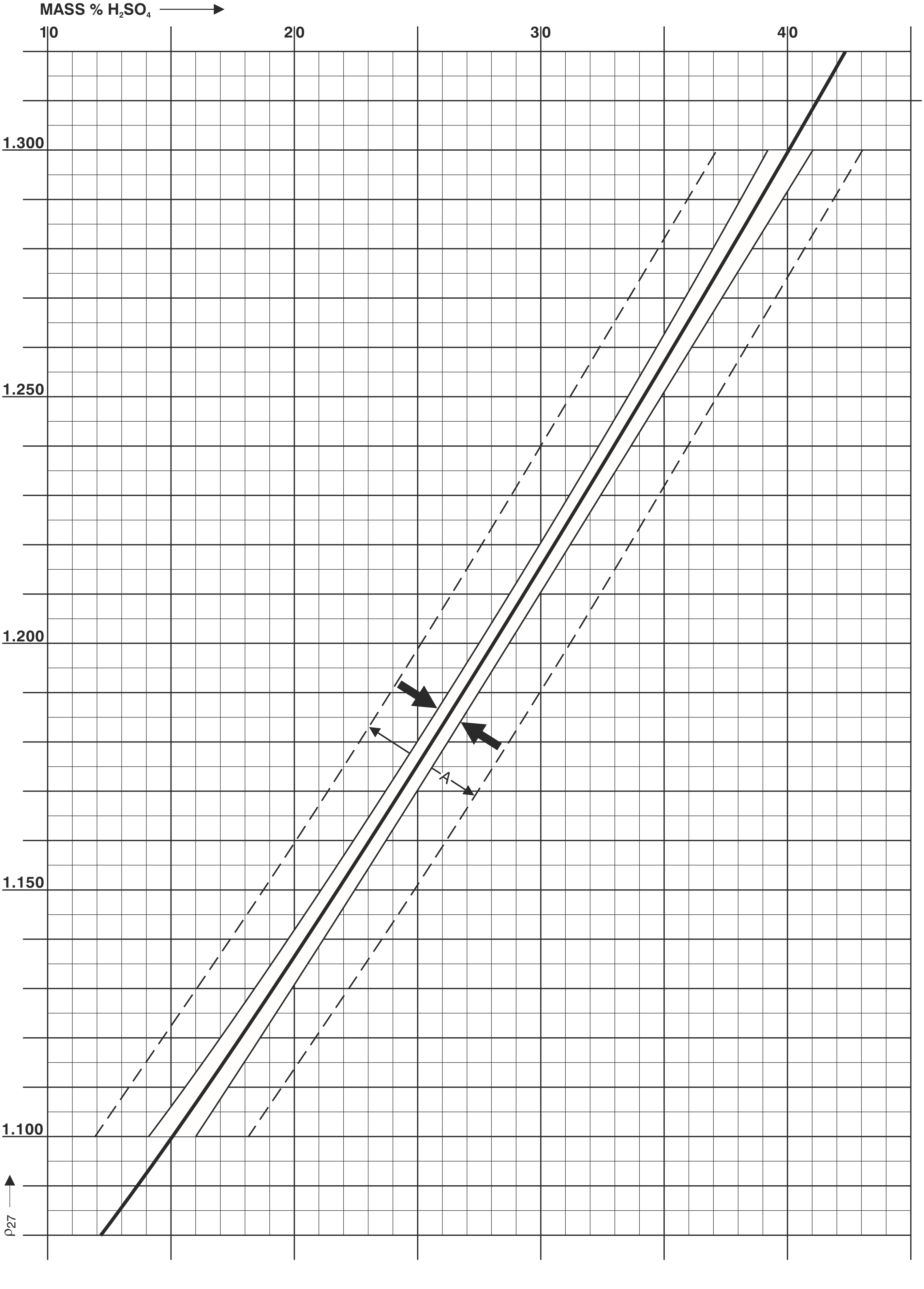
[4]) The considerable temperature errors of glass hydrometers can be corrected to a certain extent by using an additional thermometer and a correction table. However, the tolerances of this thermometer, and the uncertainties in interpolating the values in the table, make it impossible to make any general statement on the margin of error of such instruments.

[5]) Since the HYDROVOLT principle automatically corrects temperature influences (by cancelling the temperature error) and bases each measurement on the reference temperature, the diagram shows the values for this reference tempeTature.



Hydro volt

10 - 45 °C
50-115 °F