

Density hydrometers for use in milk —

Part 2: Methods

Confirmed
November 2011

Co-operating organizations

The Dairying Industry Standards Committee, under whose supervision this British Standard was prepared, consists of representatives from the following Government departments and scientific and industrial organizations:

- Agricultural Research Council
- British Dairy Farmers' Association*
- Central Milk Distributive Committee*
- Chemical Society
- Dairy Engineers' Association
- Dairy and Ice Cream Equipment Association
- Department of Agriculture for Scotland
- D.S.I.R.—Laboratory of the Government Chemist*
- Hannah Dairy Research Institute*
- Milk Marketing Board*
- Ministry of Agriculture, Fisheries and Food*
- Ministry of Health
- National Association of Creamery Proprietors and Wholesale Dairymen*
- National Farmers' Union
- National Institute for Research in Dairying*
- National Physical Laboratory (D.S.I.R.)
- Office of the High Commissioner for Australia*
- Office of the High Commissioner for Canada
- Office of the High Commissioner for New Zealand*
- Office of the High Commissioners for the Union of South Africa
- Royal Society for the Promotion of Health
- Scottish Milk Marketing Board*
- Scottish Milk Trade Federation
- Society for Analytical Chemistry*
- Society of Chemical Industry
- Society of Dairy Technology

The Government departments, and scientific and industrial organizations marked with an asterisk in the above list, together with the following, were directly represented on the committees entrusted with the preparation of this standard:

- Association of British and Dominion Condensed Milk Manufacturers
- British Food Manufacturing Industries Research Association
- Coated Paper and Board Makers' Association
- Department of Agriculture for Canada
- Government of Northern Ireland (Ministry of Agriculture)
- Ice Cream Alliance Ltd.
- London Provision Exchange
- University of Reading

This British Standard, having been approved by the Dairying Industry Standards Committee and endorsed by the Chairman of the Chemical Divisional Council, was published under the authority of the General Council on 31 December 1959

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Foreword

This standard makes reference to the following British Standards:

BS 696, *Gerber method for the determination of fat in milk and milk products*.

BS 1741, *Methods for the chemical analysis of liquid milk*.

Part 2 of this British Standard, published under the authority of the Dairying Industry Standards Committee, specifies two procedures for determining the density of milk so that it can be measured either with the milk fat wholly in the solid state or wholly in the liquid state, and provides tables relating the known fat content and measured density of a milk with its solids-not-fat (S.N.F.) content.

The density of milk held at 20 °C or less after leaving the cow slowly increases to a maximum (Recknagel phenomenon), due mainly to the gradual solidification of the fat. The density of a milk will therefore vary with the duration and temperature of storage. This variation can be overcome by ensuring that the fat is either completely in the liquid state or completely in the solid state.

This British Standard was first published in 1937 and revised in 1955. It had as its theoretical basis the equation established in 1895 by H. Droop Richmond which relates the total solids content of milk to fat content and specific gravity (measured at 15.5 °C with the fat in the solid state). In these editions the prescribed hydrometers gave the density of milk with the fat in the liquid state in grammes (mass) per millilitre at 20 °C. Richmond's formula was modified to allow for substitution of density at 20 °C for specific gravity at 15.5 °C. No allowance was made for the change in state of the fat, although the density of a milk is less when the fat is in the liquid state than when in the solid state. This omission was deliberate since it was known that when Richmond's formula is applied to density readings obtained with the fat in the solid state it gives higher figures for total solids than those obtained by modern gravimetric methods¹⁾. However, subsequent investigations showed that the use of the modified formula with the fat in the liquid state over-compensates for the high figures obtained by Richmond's method and usually gives lower results for total solids than those obtained gravimetrically. Other investigations have been carried out in which the density was determined with fat in the solid state.

An amendment to BS 734 was published in 1957 which took into account the results of these investigations and also the reduction in the capacity of the milk pipette specified in BS 696 and used in the determination of the fat content of milk²⁾. The present edition of this standard incorporates the amendment and hence provides two formulae (Appendix A), one for use when the fat is solid and one for use when the fat is liquid. These formulae result in total solids values that are, on average, in close agreement with those obtained by gravimetric methods.

As in the previous editions of this standard, hydrometers of three sizes are provided to meet the need of the dairy industry to deal with samples of differing volume. The construction of the Nos. 2 and 2A hydrometers, a size in common use, has been altered to make them more robust. The hydrometers are used in cylinders of which details are given in Appendix A of Part 1 of this standard. Recent observations have indicated the desirability of providing greater clearance between the side of the cylinders and the bulb of the hydrometers, and this has been done by increasing the internal diameter of the cylinders.

The basis of calibration of the hydrometers adopted in 1937, namely density in grammes (mass) per millilitre at 20 °C in a liquid with a surface tension of 46 dyn/cm, has become established in the dairy industry and is retained in this standard. The value 46 dyn/cm is an average for the surface tension at 20 °C of freshly formed surfaces of milk, i.e. the surface obtained by pouring milk into a vessel until some has overflowed. The surface tension of such milk surfaces may vary by about ± 4 dyn/cm from the mean value of 46 dyn/cm. If the milk is not allowed to overflow, the surface has a slightly lower and more variable surface tension.

¹⁾ BS 1741, "Methods for the chemical analysis of liquid milk".

²⁾ BS 696, "Gerber method for the determination of fat in milk and milk products".

An important innovation in this standard is that the hydrometers are calibrated to be read at the top of the milk meniscus and not at the level of the milk surface. It is essential that the hydrometers should comply with the specifications set out in Part 1 of this standard. The accuracy of the calibration of the hydrometers should be tested by comparison with hydrometers tested at the National Physical Laboratory, as described in Appendix B.

It should be stressed that methods employing hydrometers for the determination of the total solids content of milk, although having the advantage of speed, yield results less accurate than gravimetric methods. The accuracy of the value of the total solids content calculated from the equations is dependent on the density of the fat and of the density of the S.N.F. Only when these densities approximate to the average values implicit in the equations will the results be in close agreement with those obtained gravimetrically; it is known that these densities may vary appreciably in milk from individual cows and to a lesser extent even in bulked milks.

As it is usual to express the composition of milk in terms of fat and S.N.F. content, this standard provides tables relating fat content and density to S.N.F. content and not to total solids content.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 22, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

Part 2 of this British Standard specifies procedures for determining the density of milk with the fat either wholly in the liquid state or wholly in the solid state and provides tables relating the known fat content and measured density to percentage of S.N.F. in the milk under test.

Of the hydrometers specified in Part 1 of this standard the Nos. 1 and 1A hydrometers are the most accurate; 225 ml (8 fl. oz) of milk is ample for these hydrometers. The Nos. 2 and 2A hydrometers can be used with 150 ml (5 fl. oz) of milk while the Nos. 3 and 3A hydrometers may be used with as little as 90 ml (3 fl. oz) of milk but the use of such a small sample should be avoided whenever possible.

2 Determination of density

The density of milk may be determined with the milk fat wholly in the liquid state or wholly in the solid state by the procedures set out below.

Method 1. Milk with fat in liquid state. The milk is warmed to a temperature of 40–45 °C and maintained within this range for 5 minutes, during which time the contents of the bottle are adequately mixed. Care must be taken to avoid the formation of air bubbles or froth when mixing the sample. The sample is then water-cooled to 20 ± 2 °C and held within this range until the density reading is taken. The sample must not be so held for more than 1 hour. The reading is then taken according to the following procedure:

The sample bottle is gently inverted two or three times. The milk is then poured down the side of the cylinder so as to avoid the formation of air bubbles. Sufficient milk must be poured into the cylinder to ensure that some overflows when the hydrometer is inserted. The hydrometer, held by the top of the stem, is inserted in the sample and released when approximately in its position of equilibrium thus avoiding wetting more than a very short length, of the stem above the milk surface. As soon as the hydrometer is at rest, the scale reading corresponding to the top of the meniscus of the milk is noted. The eye must be level with the top of the meniscus when the reading is taken. The cylinder must be vertical and the bulb of the hydrometer must not touch the side. It is advisable to repeat the reading after depressing the hydrometer about 3 mm and allowing it to come to rest.

The temperature of the milk is recorded immediately after taking the hydrometer reading.

Method 2. Milk with fat in solid state. The milk is cooled quickly to a temperature of 3–5 °C in chilled water and maintained within this range for at least 15 hours. The temperature of the sample is then raised to 18–20 °C in a water bath in any part of which the temperature must not exceed 21 °C at any time.

During this time the contents of the bottle are adequately mixed by rotary motion of the bottle followed by inversion at least six times. Care must be taken to avoid the formation of air bubbles or froth when mixing the sample. The density reading is then taken within 1 hour according to the procedure given under Method 1.

3 Corrections to observed hydrometer readings

When the observed hydrometer reading has been obtained it must be corrected before it can be used in the calculation of the S.N.F. content of the sample. Two corrections are necessary. The first is the correction (see Appendix B) for any scale error and the second is the correction (see Table 1) for the error introduced when the reading is made at a temperature other than 20 °C. The method of applying these corrections is shown in examples 1 and 2 of Clause 4.

Table 1 — Temperature corrections to hydrometer reading

Temperature (°C)	Fat in liquid state	Fat in solid state
22.0	+ 0.000 5	—
21.5	+ 0.000 4	—
21.0	+ 0.000 3	—
20.5	+ 0.000 1	—
20.0	0	0
19.5	− 0.000 1	− 0.000 1
19.0	− 0.000 3	− 0.000 3
18.5	− 0.000 4	− 0.000 4
18.0	− 0.000 5	− 0.000 5

NOTE These corrections apply to milk containing 4 per cent of fat but they can be used for all milks (0–10 per cent fat) as the maximum error that may be so introduced is only $\pm 0.000 1$ in the corrected hydrometer reading.

4 Determination of S.N.F. content

The corrected hydrometer reading is used in conjunction with the known fat content to obtain the S.N.F. content of the sample, either by substitution in the appropriate formula or from the appropriate table.

Fat in liquid state

Formula: Percentage (by weight) of S.N.F. = $0.25 D + 0.22 F + 0.72$

Table: Use Table 2

Fat in solid state

Formula: Percentage (by weight) of S.N.F. = $0.25 D + 0.22 F + 0.55$

Table: Use Table 3

F = percentage (by weight) of fat

D = (corrected hydrometer reading − 1) $\times 1\,000$

Example 1. Fat in liquid state.

Fat content 3.65 per cent

Observed hydrometer reading	1.0294 g/ml
Temperature of sample	18.5 °C
Correction for scale error	+ 0.0002 g/ml
Reading corrected for scale error	$1.0294 + 0.0002 = 1.0296$ g/ml
Correction for temperature from Table 1	− 0.0004 g/ml
Reading corrected for scale error and temperature	$1.0296 - 0.0004 = 1.0292$ g/ml

The part of Table 2 which includes the column headed 1.029 and the row opposite 3.65 per cent of fat is consulted. The S.N.F. figure corresponding to a density of 1.0292 g/ml and a fat content of 3.65 per cent is 8.82 per cent.

Example 2. Fat in solid state.

Fat content, 3.60 per cent

Observed hydrometer reading	1.0301 g/ml
Temperature of sample	19.5 °C
Correction for scale error	− 0.0003 g/ml
Reading corrected for scale error	$1.0301 - 0.0003 = 1.0298$ g/ml
Correction for temperature from Table 1	− 0.0001 g/ml
Reading corrected for scale error and temperature	$1.0298 - 0.0001 = 1.0297$ g/ml

The part of Table 3 which includes the column headed 1.029 and the row opposite 3.60 per cent of fat is consulted. The S.N.F. figure corresponding to a density of 1.0297 g/ml and a fat content of 3.60 per cent is 8.77 per cent (by interpolation).

Appendix A Derivation of the equations relating density and percentage of fat to percentage of solids-not-fat

The original equation of H. Droop Richmond which related specific gravity and percentage of fat to percentage of total solids was:

$$T = 0.25 G + 1.2 F + 0.14 \quad (1)$$

where T = percentage of total solids by weight in the milk,

$G = 1\,000 (S - 1)$ where S is the specific gravity 15.5/15.5 °C of the milk,

F = percentage of fat by weight in the milk.

From a knowledge of the coefficient of cubical expansion of milk and the density of water at 15.5 °C, the specific gravity 15.5/15.5 °C of a milk may be expressed in terms of its density in g/ml at 20 °C. If d is the density in g/ml at 20 °C it has been shown to an accuracy adequate for the purpose in view, that

$$S = d + 0.002\,05 + 0.000\,05 F \quad (2)$$

when the fat in the milk is in the liquid state. Substituting in (1) the value of S given by (2) we have:

$$T = 0.25 [1\,000 (d + 0.002\,05 + 0.000\,05 F - 1)] + 1.2 F + 0.14$$

$$\text{or } T = 0.25 [1\,000 (d - 1)] + 1.2125 F + 0.6525 \quad (3)$$

By writing D for $1\,000 (d - 1)$ equation (3) becomes:

$$T = 0.25 D + 1.2125 F + 0.6525 \quad (4)$$

which is in the same form as Richmond's equation (1).

A simplified version of this equation formed the basis of the calculation of percentage of S.N.F. in BS 734:1955, namely:

$$\text{S.N.F.} = T - F = 0.25 D + 0.21 F + 0.66 \quad (5)$$

the fat being in the liquid state.

A revision of equation (5) was made as the result of over two thousand determinations of total solids, using hydrometry and calculation by equation (5) as compared with the gravimetric technique of BS 1741³⁾.

Provided that the density is determined with the fat in the liquid state, and the percentage of fat is determined according to BS 696⁴⁾, the new equation, upon which Table 2 is based, is:

$$T = 0.25 D + 1.22 F + 0.72 \quad (6)$$

or $\text{S.N.F.} = T - F = 0.25 D + 0.22 F + 0.72$.

A similar investigation carried out on a large number of samples has resulted in the formulation of an alternative equation to (6), to apply when the fat is in the solid state. This equation (7) was used in compiling Table 3:

$$T = 0.25 D + 1.22 F + 0.55 \quad (7)$$

or $\text{S.N.F.} = T - F = 0.25 D + 0.22 F + 0.55$.

³⁾ BS 1741 "Methods for the chemical analysis of liquid milk".

⁴⁾ BS 696 "Gerber method for the determination of fat in milk and milk products".