Process Application Note

Anton Paar

# Fat Content Determination during Milk Standardization using Density

## 1. Introduction

Milk is a very complex food with over 100.000 different molecular species found.
There are many factors that affect the composition of raw milk such as breed, age and physical state of the cow and seasonal variations.
Therefore only an approximate milk composition of 87-88% water and 12-13% total solids can be given (references [1], [2]).
The total solids consist of approx. 4% fat and 9% solids-not-fat (SNF) (proteins, lactose, minerals, vitamins,... ).
Milk is an emulsion of milk fat globules in fat-free milk liquid (mainly water). There are up to 4,6 billions fat globules in one milliliter milk.

## 2. Density of milk

The density of raw milk varies between approx. 1.026 g/cm$^3$ and 1.034 g/cm$^3$ at 20°C [1].

Milk density is derived from the densities of its components, according to their content.
The following densities of milk components (at 20 °C) strongly influence the density of milk [1]:

- Water 0.998 g/cm$^3$
- Fat 0.931 g/cm$^3$
- Proteins 1.451 g/cm$^3$ (average)
- Lactose 1.545 g/cm$^3$ (average)
- Minerals 3.000 g/cm$^3$.

### 2.1. Influences on milk density

The density of milk and dairy products depends on:

- **Composition**
  The density of milk increases with increasing content of proteins, lactose or minerals and it decreases with increasing fat content.
  See table 1 on page 4.
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- **Temperature**
  The density of milk decreases, if the temperature increases.
  The higher the fat content of the milk, the bigger the density change with temperature. The reason is that the volume of fat changes much more with temperature than the volume of water.

- **"Temperature history" of the dairy product**
  Depending on the "temperature history" small differences in density are observed. These are caused by different solidified states of the milk fat.

### 2.2. Density measurement of milk

Since milk is a multi-component mixture and the density variations of raw milk are very high, it is not possible to determine the concentration of single milk components, like fat, directly from density measurement.
Yet the fat content of milk can be determined from the density difference between standardized milk and skim milk.

The **DPRn** on-line transducers by Anton Paar are used for the accurate determination and control of the milk fat content during milk standardization.

Density measurement with laboratory digital density meters by Anton Paar [3] is used for

- quality control of milk (watering or skimming)
- conversion of volume to weight
- calculation of total milk solids.

## 3. Measuring principle

The following figure illustrates the principle of density measurement used in the DPRn density transducers by Anton Paar.

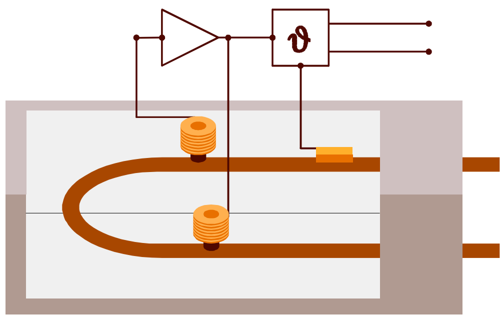

*Fig. 1: DPRn density transducer*

The U-tube, a mechanical oscillator system, is excited. It is kept oscillating at its resonant frequency by two coils and an electronic circuit.

Oscillation period and sample temperature are measured and transferred to a mPDS evaluation unit for data processing and control purposes.
The accuracy of DPRn density transducers typically amounts to ± 1 x $10^{-4}$ g/$cm^3$.

## 4. Typical installation sites

Dairy products must have a defined and constant composition.
During milk standardization the fat content of milk is adjusted to a legally defined value.

Figure 2 shows a simplified scheme of the milk standardization process.
In the first step the raw milk is skimmed in a centrifuge to obtain cream and skim milk.
The cream is again added to the skim milk to obtain a "standardized" fat content of e.g. 4.5 % fat.
The fat content of the standardized milk is determined by the density difference to skim milk upon addition of cream.

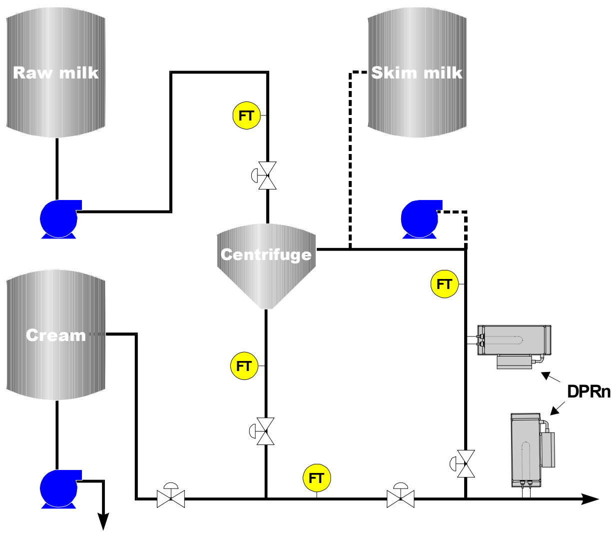


*Fig. 2 Scheme of the milk standardization process*

Density measurement can be performed with a DPRn transducer in combination with a mPDS 2000V3 evaluation unit.

The DPRn density transducer is mounted in a bypass to the main line.

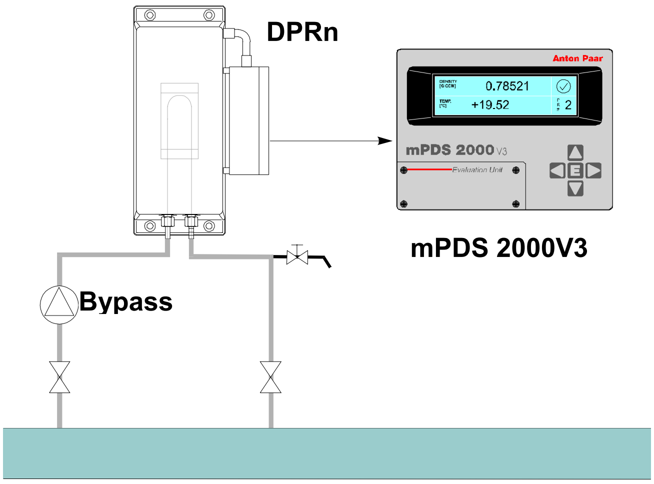


*Fig. 3: Bypass installation of the DPRn*

The mPDS 2000V3 uses the density difference between skim milk and standardized milk to determine the fat content.

There are two ways to determine the fat content of the standardized milk with DPRn transducers:

(1) The densities of skim milk and standardized milk are continuously measured with two DPRn transducers and mPDS 2000V3 evaluation units. The density result of skim milk is automatically transferred to the evaluation unit of the transducer for standardized milk and the fat content is determined from the density difference between skimmed and standardized milk.

(2) Only the density of standardized milk is continuously measured with one DPRn transducer and mPDS 2000V3 evaluation unit. The density of skim milk is determined before the production start:
- Skim milk is measured with the DPRn transducer later to be used for standardized milk and the density result is stored in the evaluation unit.
- The density of skim milk is determined in the laboratory and the result is manually entered in the evaluation unit.

Again the fat content is determined from the density difference between skimmed and standardized milk.

## 5. Measuring range

Temperature: 4 to 70 °C
Concentration: 0 to 40 % fat content

## 6. Measuring results - accuracy

Following parameters influence the measuring result:

- **Density** accuracy: 1 x $10^{-4}$ g/$cm^3$
  Corresponding variations in fat content concentration: 0.1 % fat content (typical).
  Repeatability: typically ± 0.01% fat content.
- **Temperature** influences are compensated by the built-in temperature measurement.

**Total error:**
Variations of all process conditions lead to a total error of 0.1 % fat content.

## 7. Benefits

- With the DPRn density transducers the fat content of the milk is **continuously monitored** during milk standardization and **milk quality is assured with high precision.**
- The precise control of the fat content in standardized milk is important for economic (fat is an expensive component of milk) and legal reasons (a fat content which is too low is considered to be customer deception).

## 8. DPRn 427S

With the new Stainless Steel housing cell more installation possibilities are open. Depending on the process situation the bypass can be created in the following way:

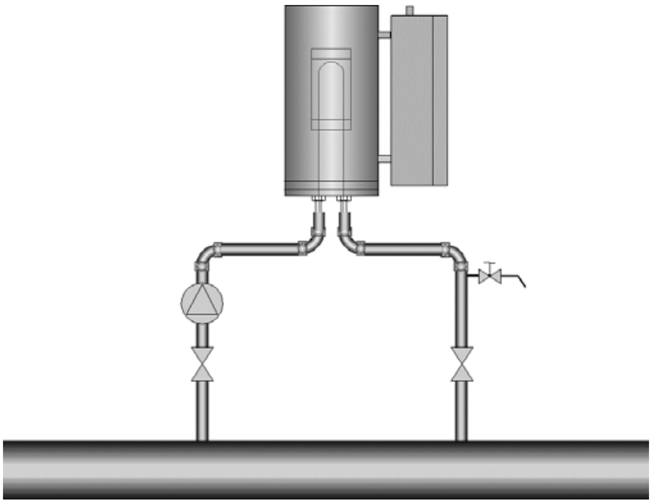

*Fig. 4 Classical bypass installation*

The system can be disconnected from the main line with the 2 installed valves.

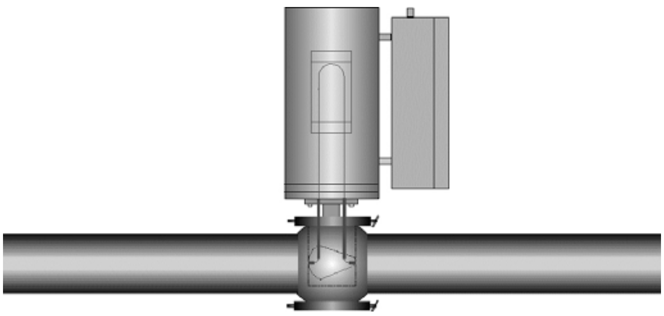

*Fig. 5 Bypass with In-line-fitting*

No pump is required; the flow speed in the main line have to be at lease 1 m/s.

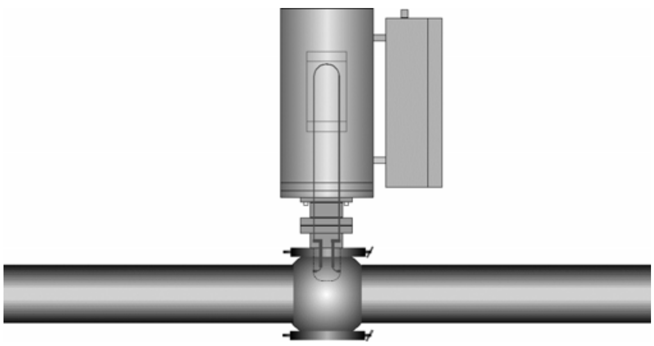

*Fig. 6 Bypass with pump*

The measurement is independent from the flow speed in the main line.

## 9. Summary

On-line density measurement with the Anton Paar transducers DPRn offers accurate determination and control of the milk fat content during milk standardization.

**Table 1:** Density of various dairy products as a function of fat and solids-not-fat (SNF) content [4].

| Product | Composition | | Density [g/cm³] at | | | |
|---|---|---|---|---|---|---|
| | Fat [%] | SNF [%] | 4.4 °C | 10 °C | 20 °C | 38.9 °C |
| Skim milk | 0.02<br>0.02 | 8.9<br>10.15 | 1.036<br>1.041 | 1.035<br>1.040 | 1.033<br>1.038 | 1.026<br>1.031 |
| Whole milk | 4.0<br>3.6<br>12.25<br>11.3 | 8.95<br>8.6<br>7.75<br>8.9 | 1.035<br>1.033<br>1.027<br>1.031 | 1.033<br>1.032<br>1.025<br>1.030 | 1.030<br>1.029<br>1.020<br>1.024 | 1.023<br>1.022<br>1.010<br>1.014 |
| Cream | 20.0<br>36.6 | 7.2<br>5.55 | 1.021<br>1.008 | 1.018<br>1.005 | 1.012<br>0.994 | 1.000<br>0.978 |

Temperature coefficients: whole milk 2.7 to 3.1 x $10^{-4}$ g/cm³/°C; skim milk 2.3 to 2.8 x $10^{-4}$ g/cm³/°C [5].

## 10. References

[1] "Chemie und Physik der Milch", A. Töpel, VEB Fachbuchverlag Leipzig, 2. Auflage, 1981
[2] "Milk and Dairy Products", Ullmann's Encyclopedia of Industrial Chemistry, 589
[3] Anton Paar Lab Application Note, "Density Measurement in Dairy Industry"
[4] Goff, H.D., Hill A.R., "Dairy Chemistry and Physics", Dairy Science and Technology Handbook, VCH Publishers, 1993, Vol.1
[5] "Einfluss der Temperatur auf die Dichte von Milch zwischen 15 °C und 25 °C", M. Rüegg, U. Moor, Schweiz.Milchw.Forschung, 1985, 14(3), 7

**B-R Controls Pty Ltd**
Unit 3, 95 Hunter Street
HORNSBY NSW 2077
Australia

Telephone: (+61) (02) 9476 2133
Facsimile: (+61) (02) 9476 2688
E-mail: mail@brcontrols.com.au
Website: www.brcontrols.com.au