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Investigations on the Design of Floats to Control Milk Meters

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To reduce the influence of variable density of milk on the accuracy of volumetric milk meters, equipped with floats, the amount of air in the milk at float level was measured and the effect of geometry and specific gravity of floats on the accuracy of two volumetric milk meters was estimated.

The influence of milk density on meter operation was lower when the float was placed in a measuring chamber after separation of air and milk in an inlet chamber. Best results were obtained using a float with a specific gravity of 0·724 g/cm^3.

A float with a long vertical axis, a cone-shaped upper portion and a specific gravity close to 0·5 g/cm^3 was least affected by variable density of the fluid when operating in unseparated air and milk.

1. Introduction

Floats are commonly used for various purposes in the dairy industry and in milking equipment. Typical applications to be found in patents include the control of devices for deaeration of milk in milk receiving systems of tanker lorries (Gronke,[1] Schwarte[2]) or level detection in liquid traps to protect vacuum pumps in milking installations (Ford[3]). Floats are also used to control the quantity of washing liquid in cleaning units of pipeline milking systems (Bucker[4]) or to separate milk and air and to stabilize the vacuum level in a milking claw (Olander[5]). Many proposals have been made for applications of floats in milk meters.

Reuschenbach and Scholtysik[6] described the use of a float as a transducer to measure milk level. The output signal was proportional to milk flow and the yield was to be calculated by integration of milk flow over time.

Several applications are described which use a float to count discrete quantities of milk by generating a control signal at one or more preset levels (Kiestra and Icking,[7] Schletter,[8] Kummer[9]). In general, magnets incorporated into the floats are chosen to activate appropriate galvanic switches or semiconductor devices. Some authors also refer to problems caused by air contained in milk. Delepierre[10] made the milk flow along the inner surface of a cylindrical receiver to separate the air. Montalescot[11] proposed a combination of a separate deaeration chamber and a measuring chamber and valves to control milk flow. A float was to be used to indicate milk level and to actuate the valves. A two chamber system has also been described by Landwehr and Jahoda.[12] In the lower chamber a magnetic float controlled a switch to drive the counting unit. A second chamber above the measuring chamber was designed to remove air from the milk.

Practically no literature exists on the design of floats for milk meters. However, Reuschenbach[13] proposed the use of a plunger with variable diameter to convert the level of milk in a metering chamber into a linear signal for milk flow.

Most floats installed in milk meters are not specifically designed for application in

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aerated milk. Their specific gravity ranges from 0·5 to 0·84 g/cm^3. Light floats operate reliably even with incompletely separated milk and air, but the bias of meters may then be affected by the amount of air in the milk. Meters equipped with heavy floats tend to be more precise, but measurements may become unreliable with high proportions of air.

In experiments with two milk meters the influence of design of milk meters, of floats and of the variable density of milk on accuracy were analysed.

2. Materials and methods

Both milk meters were designed for volumetric measurement of milk yield. The top of milk meter A (*Fig. 1*) is equipped with a tangential inlet for the milk (a). To some extent air and milk are separated immediately when milk flows down the walls of the milk meter in a thin film. At the bottom of the device milk is collected for further deaeration. This quantity of milk is 1·5 kg and for milk yield recording, quantities of milk exceeding 1·5 kg are removed by a rotating device with multiple measuring chambers (d, f). They are supplied with milk by an orifice in the bottom plate of the milk meter and discharge into the milk outlet (g) at a different location in the bottom plate. The operation of this device is controlled by a float (b) which by a built in magnet closes a reed contact when the milk rises above a preset level. The milk yield is calculated according to the number of portions removed by the rotating measuring chambers.

To evaluate the amount of air in the milk at float level, samples were taken by an experimental device (c, e) close to the surface of the milk while a cow was being milked.

This equipment was installed in a milking parlour and connected to a regular milking unit with an air inlet of 8 l/min into the claw. To obtain as much froth as possible, samples were taken at high flow rates just before full milk flow ended. The period of

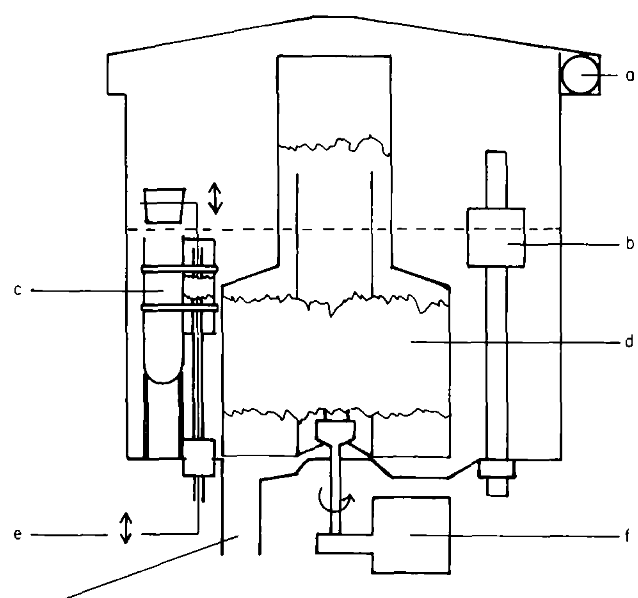

Fig. 1. Experimental installation to take samples at the float level of milk meter A. (a, milk inlet; b, float; c, sample container; d, rotating metering device; e, manipulator to open sample container; f, drive unit for metering device; g, milk outlet)

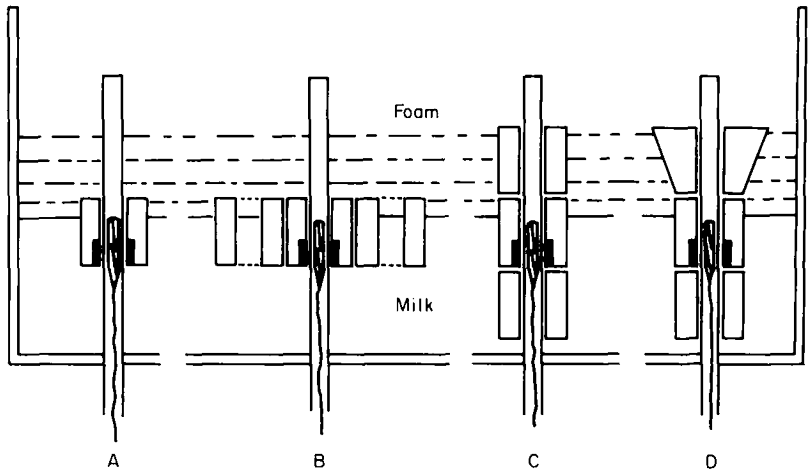

Fig. 2. Floats used with milk meter A

maximum milk flow was identified from flow characteristics recorded prior to the experiment.

The milk yield and the yield indicated by the milk meter were recorded and the bias of the meter was calculated by the difference between the milk yield indicated by a balance and that indicated by the display of the milk meter, as a percentage of the balance value. The amount of milk obtained from the sample container (c) was weighed.

To evaluate the influence of float geometry on the performance of milk meter A, the original square shaped float (A) with a specific gravity of 0·55 g/cm^3 was compared with experimental devices, assembled by connecting three original floats in different ways as shown in *Fig. 2.* At first, a device with a short vertical axis (B) was formed by joining floats horizontally, then the elements were stacked vertically (C) and finally the top module, above the level of deaerated milk, was formed into an inverted cone to compensate for decreasing specific gravity in upper levels of the froth (D).

Milk meter B (*Fig. 3*) is similar to the device described by Landwehr and Jahoda.[12] It is equipped with a single measuring chamber. Milk first enters a chamber (a), which is directly connected to the milking pipeline, to evacuate air coming with the milk from the milking unit. The measuring chamber (c) is located beneath chamber (a) and is separated by a disk valve (b), operated by atmospheric air which is used to evacuate the measuring chamber. A float (e) in the measuring chamber is used to control the milk level corresponding to 300 g of milk. When this level is reached the sensing device activates a solenoid valve (g) which allows atmospheric air to enter the measuring chamber. The air first lifts the disk valve to close the milk inlet. Then the rising pressure opens an elastic valve (f) at the base of the measuring chamber and milk is pushed into the milk line. Air flow is stopped after a predetermined time and the disk valve opens the milk inlet as soon as the pressure in the measuring chamber is back to normal vacuum.

The original float weighed 22·03 g and was 26·4 mm high with diameter 38·7 mm, corresponding to a volume of 25 cm^3. The resulting specific gravity was 0·841 g/cm^3. Several irregular measurements were observed due to excessive foam in the measuring chamber left from previously milked cows. Therefore several floats with identical shapes but lower specific gravity were tested.

For the experiment a milking claw was used with an air inlet of 8 l/min. Manual stimulation was completed by mechanical stimulation, provided by a pulsator working at

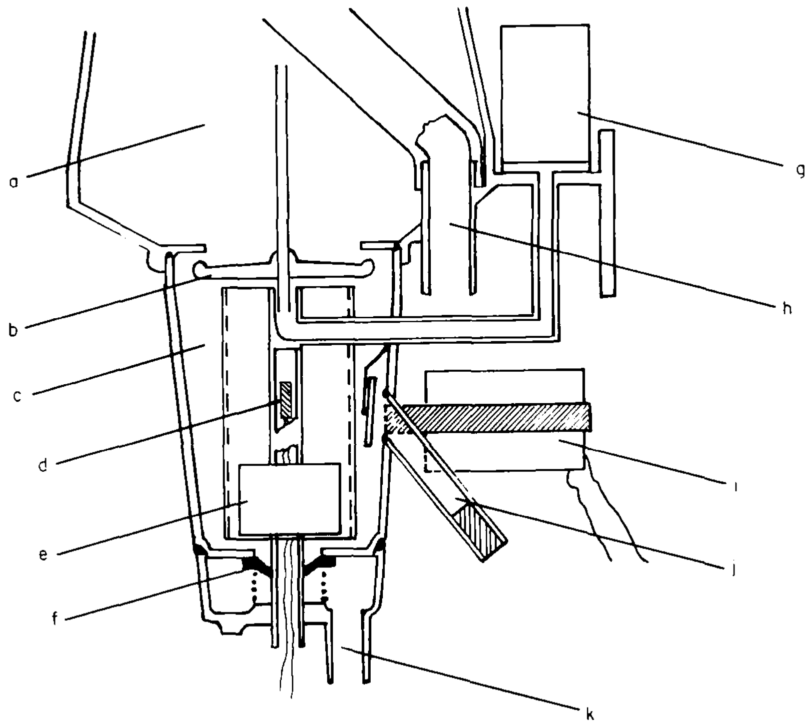

Fig. 3. Experimental design of milk meter B. (a, deaeration chamber; b, disk valve; c, measuring chamber; d, level sensor; e, float; f, outlet valve; g, valve to control evacuation of measuring chamber; h, milk inlet; i, solenoid to operate cover of sample container; j, sample container; k milk outlet)

150 cycles/min for 40 s. Normal milk flow started immediately the device switched to regular pulsation.

In a further trial the foam level in the inlet chamber of milk meter B was measured in steps of 2·5 cm by marks on the transparent case immediately after the period of full milk flow was terminated. Records were taken for each milking of the total yield and the quantity of milk displayed by the milk meter. Owing to the working cycle of the milk meter it was impossible to obtain clearly readable records of the milk flow. Therefore this parameter was replaced by the amount of milk obtained within the first minute of regular milking.

In the last experiment a tube (j) was fixed to the outside wall of the measuring chamber close to the maximum milk level to obtain samples from the milk/air mixture. The cover of the orifice was operated by a solenoid (i). The location of the sampling device was exposed to turbulence when the milk meter was working, so precautions were taken to keep the sample intact as soon as it was taken. Therefore, at the beginning of each milking the milk meter was bypassed and milk directly entered the collecting jar. So it was also possible to obtain an undisturbed record of milk flow. At the moment of peak flow the operation of the milk meter was started by closing the bypass valve and, as soon as the flow was stable, a sample was taken. Then the bypass valve was opened again and the operation of the milk meter was stopped. The sample was evacuated by a syringe. Since the milk meter was not operating continuously it was impossible to check its accuracy in this part of the experiment.

3. Results

The capacity of the sampling device in milk meter A was 3·63 g of water. The specific gravity of milk is about 1·03 g/cm^3, so the capacity corresponded to 3·75 g of milk (Table 1). Since various amounts of air were included in the milk at the level where the sample was taken, the weights of samples ranged from 0·83 g to 3·75 g. They represented 22·1% to 100% of the maximum sample weight and corresponded to specific gravities from 0·4 g/cm^3 to 1·03 g/cm^3 or proportions of air between 78% and 0%. When the original float (*Fig. 2A*) was installed the average weight of samples was 3·48 g (Table 2). When the float with large diameter (*Fig. 2B*) was installed, the samples weighed on average 3·52 g. When tall floats with small diameter and cylindrical top (*Fig. 2C*) or conical top (*Fig. 2D*) were chosen the average weight of samples ranged from 2·76 to 2·89 g. Owing to their shape the floats A and B in general floated in milk with a density corresponding closely to their specific gravity. Therefore the weight of the milk samples taken with these floats varied less than the weight of samples taken with the floats C and D which covered a wider spectrum of milk layers with different specific gravities. The averages of sample weights, related to different floats, did not differ significantly.

The positions of the magnets to control the reed switch to operate the metering rotor (*Fig. 1d*) in the experimental floats (*Fig. 2B,C,D*) did not coincide with the position of the magnet in the original float (*Fig. 2A*). Since it was impossible to adjust the position of the reed switch to suit each float, the biases of the milk meter, which were found with the experimental floats, represented systematic proportional errors (*Figs 4–8*). The bias of the milk meter therefore could not be used to evaluate differences between the floats. In regular operation, adjustment of the level detector should be no problem.

The influence of the floats on the accuracy of milk meter A was evaluated by calculation of standard deviations of the bias and by the regression of the bias on sample weight.

With the original float (*Fig. 2A*) a standard deviation of ±1·6% was obtained (Table 3).

Table 1
Capacity of the experimental sampling device in milk meter A

Medium	*Repetitions*	$\bar{x}$	*sd*	*Unit*
Water	11	3·63	0·06	g
Deaerated milk	10	3·75	0·03	g
Deaerated milk	10	3·65	0·07	ml

Table 2
Weights of samples obtained by installing different floats in milk meter A

Type of float	*Repetitions*	$\bar{x}$, *g*	*sd, g*	*Minimum, g*	*Maximum, g*
Original (A)	19	3·48	0·27	2·80	3·67
Large diameter, flat (B)	23	3·52	0·32	2·58	3·74
Small diameter, high, cylindrical top (C)	22	2·76	0·68	1·48	3·64
Small diameter, high, 30° cone on top (D)	13	2·80	0·86	1·55	3·75
Small diameter, high, 6° cone on top (D)	23	2·89	0·68	0·83	3·58

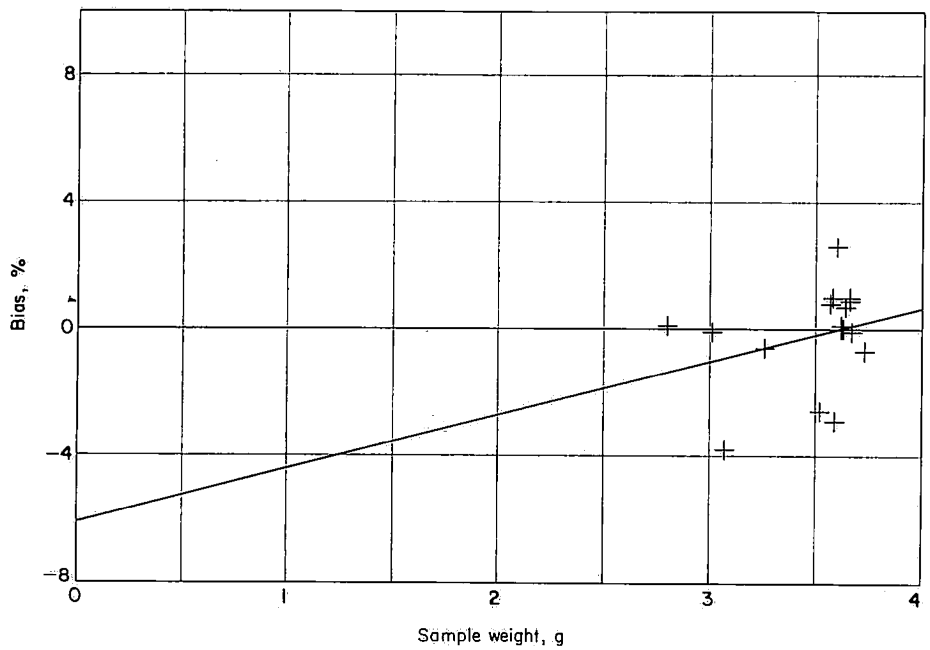

Fig. 4. Regression of bias of milk meter A with respect to the weight of the sample at float level with the float A

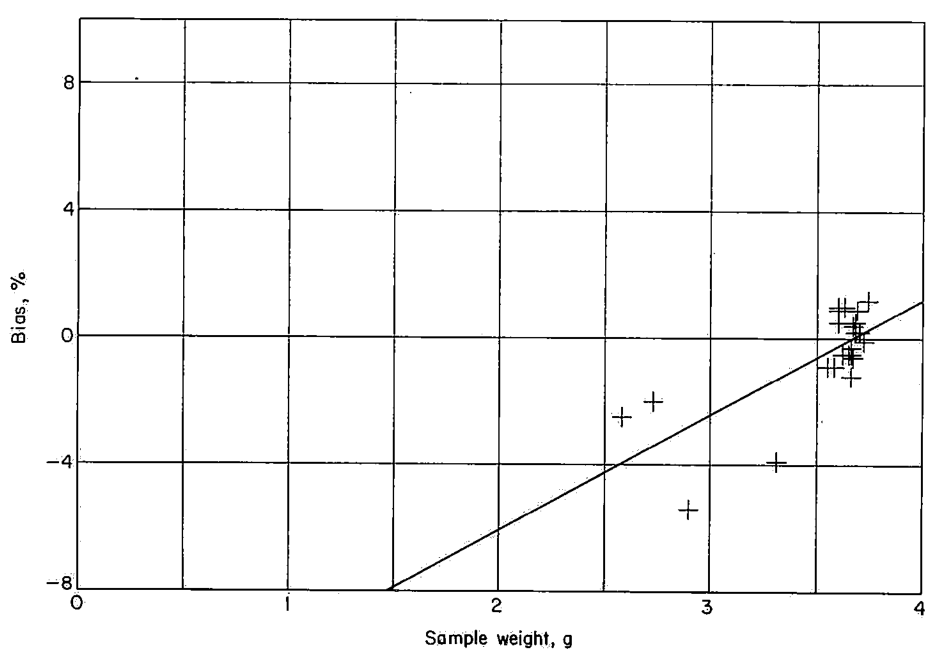

Fig. 5. Regression of bias of milk meter A with respect to the weight of the sample at float level with the float B

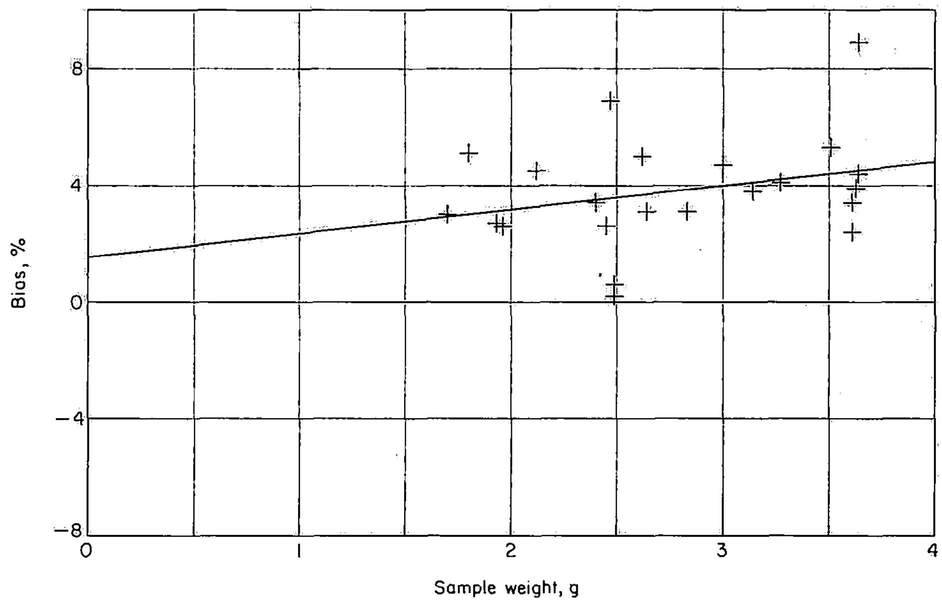

Fig. 6. Regression of bias of milk meter A with respect to the weight of the sample at float level with the float C

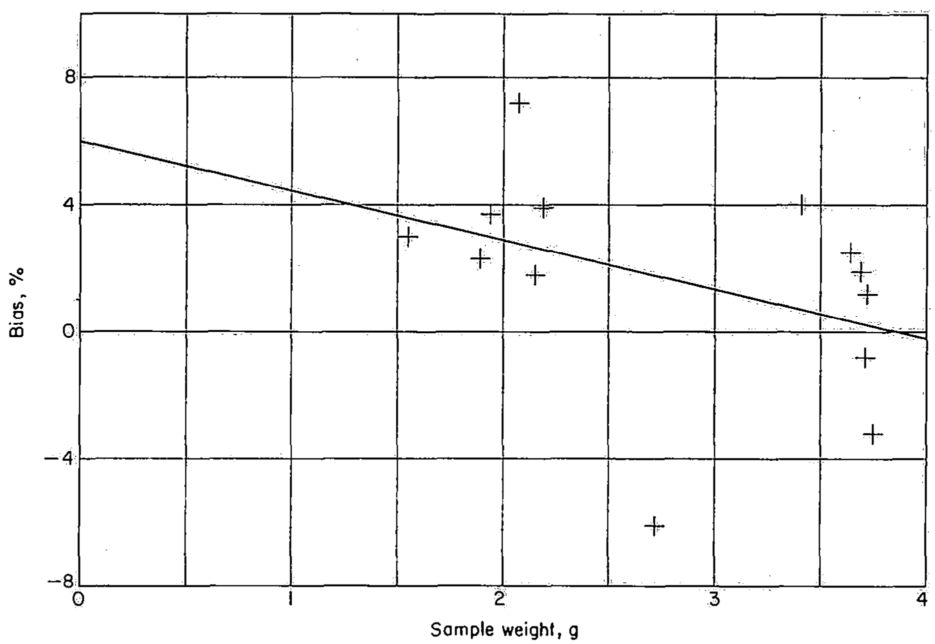

Fig. 7. Regression of bias of milk meter A with respect to the weight of the sample at float level with float D (angle 30°)

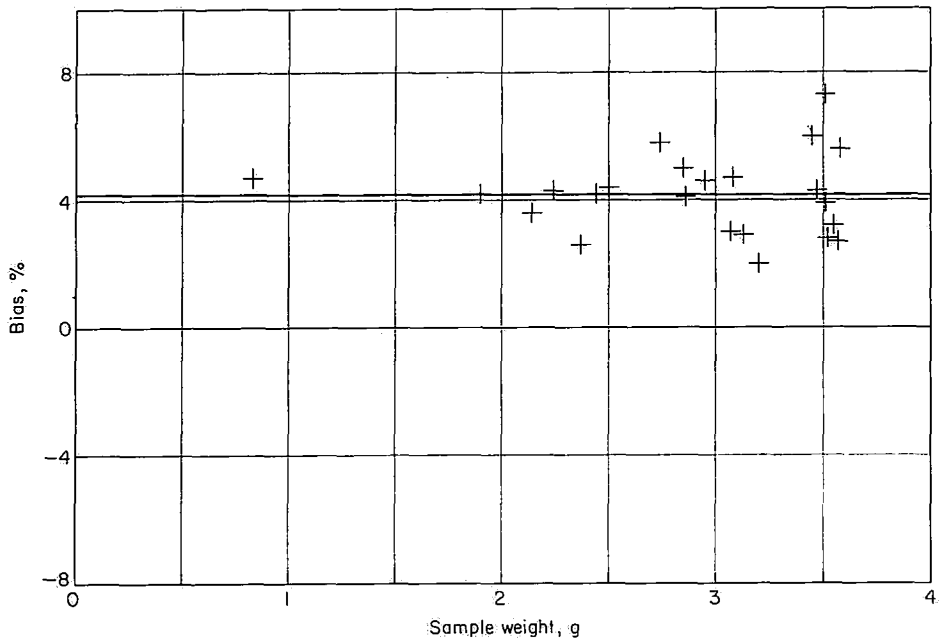

Fig. 8. Regression of bias of milk meter A with respect to the weight of the sample at float level with float D, (angle 6°)

Similar values were found with the flat float with short vertical axis B and with the float formed by three vertically arranged elements C. When the float D with a 30° cone on top was installed a standard deviation of ±3·4% was found, almost twice the standard deviation that was obtained with the original float. A standard deviation of only ±1·0% was found with the float D with a cone angle of 6°.

The correlation coefficients and the regressions of the bias on the size of samples were more suitable to indicate the interactions between float geometry and performance of the milk meter (Table 4, *Figs 4–8*)). For the original float A a regression coefficient of 1·7% of bias/g of sample was found (*Fig. 4*). The maximum of 3·6% of bias/g of sample was found for the flat float B (*Fig. 5*). Both figures corresponded to low meter readings for low sample weight. With the cylindrical float C, the regression between sample weight and bias was still positive (*Fig. 6*). The float D with a cone angle of 30° at its top portion caused high meter readings at low sample weight (*Fig. 7*). A coefficient of regression of

Table 3

Influence of floats on the accuracy of milk meter A

Type of float	*Repetitions*	*Bias, %* $\bar{x}$	*Bias, %* *sd*
Original (A)	19	−0·2	1·6
Large diameter, flat (B)	23	−0·6	1·6
Small diameter, high, cylindrical top (C)	22	3·8	1·9
Small diameter, high, 30° cone on top (D)	13	1·7	3·4
Small diameter, high, 6° cone on top (D)	23	4·2	1·0

Table 4
Influence of floats on interactions between bias of milk meter A and weight of milk samples

Type of float	Bias/sample weight r,	Coeff. of regression, bias %/sample weight g
Original, (A)	0·29	1·7
Large diameter, flat (B)	0·73	3·6
Small diameter, high, cylindrical top (C)	0·26	0·7
Small diameter, high, 30° cone on top (D)	−0·39	−1·6
Small diameter, high 6° cone on top (D)	0·00	0·0

0% of bias/g of sample resulted from float D when the top was formed into a cone with an angle of 6° (*Fig. 8*).

For milk meter B, with the original float and with a float weighing 18·6 g, equal to a specific gravity of 0·744 g/cm^3, the bias exceeded the limit of 2% set for official application (Table 5). The regressions of bias on milk yield, as expected, depended clearly on the specific gravity of the float. The least interaction was calculated for a float weighing 18·1 g, corresponding to a specific gravity of 0·724 g/cm^3.

In the next experiment an average milk yield of 12·96 kg (with 4·09% fat) was obtained of which 2·82 kg of the total yield was milked within the first minute. The bias was −4·30% (Table 6). The average height of foam on top of the milk in the inlet chamber of the milk meter was 6·75 cm.

Afterwards, 56 cows with an average peak flow of 2·98 kg/min were milked. The nominal capacity of the experimental sample container was 5·68 g of milk. The average weight of samples taken in the experiment was 5·32 g, corresponding to 93·67% of the

Table 5
Influence of specific weight of float on accuracy of milk meter B

Specific gravity, g/cm^3	Repetitions, n	Bias $\bar{x}$, %	Bias sd, %	Regression constant, g	Coeff., (bias/yield) g/kg
0·841	19	−9·20	3·83	339	−120·8
0·744	17	−2·98	1·50	−320	−3·2
0·732	19	−1·72	1·19	−397	−18·8
0·724	21	−1·91	1·54	−201	−1·5
0·704	19	−1·30	1·66	−528	+33·1
0·660	17	1·04	1·79	−375	+48·5

Table 6
Results of the second experiment with milk meter B

Parameter	Repetitions	$\bar{x}$	sd	Unit
Yield	53	12·96	3·85	kg
Fat	53	4·09	0·80	%
Milk 1st min	53	2·82	1·11	kg
Foam	53	6·75	3·77	cm
Bias	53	−4·30	1·50	%

Table 7

Results of the third experiment with milk meter B

Parameter	*Repetitions*	$\bar{x}$	*sd*	*Unit*
Peak flow	56	2·98	0·90	kg/min
Milk in sample	56	5·32	0·18	g

Table 8

Correlations between parameters in the second and third experiments with milk meter B

Parameters	*Coefficient of correlation*
Milk 1st min/foam	0·86
Fat/foam	−0·03
Milk 1st min/bias	0·73
Fat/bias	−0·02
Foam/bias	0·58
Peak flow/milk in sample	−0·38

possible quantity (Table 7). The smallest sample was 4·40 g, corresponding to 77·5% of the total capacity, the largest sample was 5·54 g, corresponding to 97·5% of the total capacity.

Correlations were calculated to evaluate interactions between milk obtained in the first minute, fat, foam and bias of the milk meter and between the peak flow and the amount of milk in the experimental sample (Table 8).

The correlations of fat with foam in the inlet chamber and with the bias of the milk meter were practically zero. All other correlations proved to be significant. Positive correlations were found between the amount of milk in the first minute and foam and bias and between foam and bias. Peak flow and the amount of milk in the experimental sample were negatively correlated.

These results indicate, that the accuracy of milk meter B was also affected by the interaction of air in the milk and weight of the float, especially at higher flow rates. The amount of air in the milk, collected in the measuring chamber, however, was lower than in samples taken in the inlet chamber of milk meter A.

4. Conclusions

According to these results, floats with a long vertical axis can improve accuracy of milk meters in spite of variable milk density before separation of milk and air. Floats with continuously increasing diameters of the upper parts which reach into the layer of froth on top of deaerated milk, compensate for the lower density of the milk/air mixture in that region. However, a conical top may not be necessary when the milk/air mixture does not stay long enough in the metering device to form layers of variable density. This is typical for milk meters with the float placed in a single measuring chamber containing the total volume of milk counted per measuring cycle.

For reliable operation, even when large amounts of air are present in milk, the specific gravity of floats operating in the inlet part of milk meters should not exceed 0·5 g/cm^3.

In a measuring chamber, supplied with milk from a separated inlet chamber, less variation of specific gravity of milk will occur. There it is possible to use heavier floats with less sophisticated design and still maintain the accuracy required for approval of milk meters. In the experiment it was possible to avoid erratic operation of the milk meter due to foam accumulated in the measuring chamber at the end of a milking procedure, by reducing the specific gravity of floats to less than 0·75 g/cm^3.

References

[1] **Gronke, H.** Durchflussmessanlage (Milk metering equipment). German Federal Republic Patent Application, DE 34 18 446 A1, 1985

[2] **Schwarte, H. P.** Vorrichtung zum Fördern, Entlüften und Messen von Milch (Device for conveying, deaerating and metering milk). German Federal Republic Patent Application, DE 33 36 890 A1, 1985

[3] **Ford, W. R.** Vacuum operated milking apparatus. UK Patent Application, GB 2 119 217 A, 1983

[4] **Bucker, H.** Einspülkasten für die automatische Dosierung eines Spülmittels (A device for automatic metering of washing liquids). German Federal Republic Patent, DE 34 533 C1, 1985

[5] **Olander, K. E.** Valve for a milk claw. UK Patent Application, 2 084 699 A, 1982

[6] **Reuschenbach, H.; Scholtysik, B.**; Durchflussgerät (Continuous flow meter). German Federal Republic Patent Application, 2 447 261, 1976

[7] **Kiestra, P. P.; Icking, C.** Milchmengenmessgerät und Verfahren zum Messen der von einer Kuh im Zuge des Melkens abgegebenen Gesamtmilchmenge (Milk meter and method for measuring the total milk yield produced by a cow while being milked). European Patent Application, 42 120, 1981

[8] **Schletter, P.** Milchmengenmessgerät (Milk meter). German Federal Republic Patent Application, 2 810 376, 1979

[9] **Kummer, J.** Milk meter measuring the weight of the quantity of milk issued by a cow, and device for taking samples adapted for use with said milk meter. European Patent Application, EP 0 052 396 A2, 1982

[10] **Delepierre, F.** Method for continuously measuring the production of liquid from a liquid-gas mixture and meter for carrying out said method. European Patent Application, EP 0 185 190 A1, 1986

[11] **Montalescot, J. B.** Compteur de liquide (Meter for liquids). European Patent Application, 23 449, 1981

[12] **Landwehr, F.; Jahoda, D.** Milchmengenmess- und/oder Milchflussüberwachungseinrichtung und Verfahren zum Messen der von einer Kuh während eines Melkvorganges abgegebenen Milchmenge bzw. zum Überwachen des Milchflusses während des Melkvorganges unter Verwendung der Vorrichtung (Milk measuring and milk flow sensing device and method for measuring the milk yield produced by a cow while being milked or for monitoring milk flow during milking by using the device). European Patent Application, EP 0 134 836 A1, 1985

[13] **Reuschenbach, H.** Pneumatische Verfahren der Durchflußmessung, Unterdruckregelung und Pulsmodulation an milchflußgesteurten Melkanlagen. (Pneumatic methods for measurement of flow rates, regulation of vacuum and modulation of pulsation in milking installations controlled by milk flow.) Diss. TU München, 1977