THE LACTOMETER—ITS UTILITY AND RELIABILITY.

By CHARLES E. MUNSELL, Ph. D.*

After using the lactometer constantly for six years (1880 to 1885), an ex-milk inspector wishes to demonstrate its value, utility and reliability as a detector of adulteration, as well as to refute its alleged errors.

To obtain scientific accuracy with the lactometer, it is necessary to have an instrument which is absolutely correct, that is, exact from 90 to 110 degrees, and not over one degree in error at other points; and the examiner must be an expert, who uses all the precautions that would be needed in employing other sensitive instruments, for the lactometer is the most delicate hydrometer in ordinary use, each degree being less than one-twentieth of a degree Baumé, its modulus being the highest, $3548\frac{8}{19}$, while that of the Baumé scale is 149.

The compiler was extremely prejudiced against the lactometer when he commenced his inspections, for if analysis were useless, it would be unnecessary to employ a chemist as an inspector; therefore, for two years, no complaint was made by him unless the sample had been previously analyzed; afterwards the analysis was dispensed with unless the lactometer stood above 95 degrees, as in every case the analysis showed from three to ten per cent. more added water than the lactometric indication.

Whenever milk was found between 95 and 102 degrees, an attempt was made to discover its source, but in no instance was a cow found giving milk below 101 degrees; of course, in this search *strippers* (cows nearly dry) were avoided, as the small quantities of milk given by them would have but little influence

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on the specific gravity, when mixed with that of regular milkers in a forty quart can; the sale of the milk from a cow that is nearly dry should be prohibited, the same as that of a cow shortly after calving, on account of its liability to contain pus and to be otherwise contaminated.

The milk should be taken at the regular milking time, as it is very easy to obtain samples at irregular times which will have specific gravities as low as 1.0226 (78°); and the specific gravity immediately after milking and cooling is lessened by absorption of air.

If the cream has risen it is difficult to mix the sample again; and a sample taken from the top of a bottle or can is liable to contain an undue amount of fat.

Therefore, if the specific gravity of a cow's milk is below 1.029; either the milk is abnormal, that is, from a diseased cow, or from one which is nearly dry or has lately calved; or the sample tested is not a fair average of all the milk that could be obtained from the cow at her regular time of milking; or the sample has been tampered with; or is full of air; or the lactometer used is incorrect; or the temperature is above 60° Fahr.

When the New York City Board of Health commenced its crusade against the sale of adulterated milk in 1875, the citizens were paying over $10,000 daily for water sold as milk.

During 1875, $2,300; 1876, $2,900; 1877, $5,100; 1878, $1,736; and 1879, $527 were paid into the City Treasury as fines by milk dealers.

In 1880, a systematic store inspection was made throughout the city, which resulted in a reduction of the instances where the lactometric readings were below 100 degrees from one in three to less than one in twenty, the average for the year being eleven per cent., the average specific gravity in about one-fourth of the stores in the city being 1.0308 or 106 degrees; the fines for 1880 were $4,518.

In 1881, the store inspections were continued with weekly early morning inspections to examine the milk retailed from the wagons, and night inspections to test that brought to the city by the railroads and across the ferries; these night inspections showed

that dealers had ceased to deliver watered milk to the stores or consumers, or to receive it from the farmers, as the dealer was constantly watching the milk sent by the farmer in order to refuse payment for it if watered.

As the lactometer caused the detection of watered milk, the dealers formed a combination with the creameries for the sale of skimmed milk; during the Summer of 1881, these creameries were visited under the direction of the New York State Board of Health, and although no complaints were made against them directly, the dealers, whom they supplied, were watched and the milk was inspected at the ferries; from five to ten thousand quarts of skimmed milk were destroyed at each night inspection until the traffic was stopped and the dealers fined; these fines amounted to $11,657 in 1881; $9,058 in 1882; $2,265 in 1883; $3,101 in 1884; and $2,040 in 1885.

The total fines collected from dealers for the sale of adulterated milk from 1875 to 1885 amounted to $45,202; besides nearly fifty imprisonments for terms of from ten days to three months.

The combination of dealers and creamerymen resulted in a Milk Trust, known as the New York Milk Exchange, limited; nine of the thirteen original directors of this exchange have been arrested for selling adulterated milk, and aided by the best lawyers and most depraved chemists they hired a man to act as the defendant in a test case with regard to the lawfulness of the sale of skimmed milk; the trial resulted in his conviction at General Sessions and his payment of a fine of $150. This exchange has since succeeded in having the aforesaid defendant appointed as an expert on the New York State Dairy Commission, and the consequence is that the farmers can obtain no better price for milk containing over 3 per cent. of fat than these creameries do for partially skimmed milk.

The lactometer, or centesimal galactometer, was invented by Dinocourt; for descriptions of this and other lactometers, galactometers, lactodensimeters, milk testers, and milk weighers, see Dr. H. A. Mott's article in the *American Chemist*, April, 1877, Vol. VII., p. 369.

The compiler was only employed as an inspector, and as such was kept busy examining the milk sold by his proportion of the

2,000 milk dealers and 6,000 stores in New York City, and did not investigate methods of analyzing milk, but used the method of Wanklyn, as improved by Dr. Waller, and published in Cairn's Quantitative Analysis; what suggestions he would have made with regard to the analysis have been anticipated by Dr. W. H. Kent, and published in this journal (Vol. IX, p. 182, and Vol. X, p. 32.)

Lactometers as obtained from the maker should be tested at 60° Fahr.; this is done either by comparing with a standard lactometer which is known to be absolutely correct (this is the best method when only one instrument is to be examined), or by means of standard solutions; these solutions are made of salt or dilute sulphuric acid. A 3 per cent. solution of sodium chloride has a specific gravity of 1.0217 (75°); a 4 per cent. 1.029 (100°); and a 5 per cent. 1.036 (122°); these solutions, and others at 90° and 110°, should be tested with a specific gravity bottle at 60° Fahr.

With sulphuric acid a three per cent. solution has a specific gravity of 1.019 (66°); a four per cent, 1.0256 (88°); a five per-cent, 1.032 (111°).

The fault with the salt solutions is that they vary from evaporation; the dilute sulphuric acid solutions are more constant, still they should be tested occasionally.

It is necessary to allow the lactometer to descend into the milk slowly, as the milk which remains on the portion of the stem above the surface of the sample being tested, when the entire stem is dipped, would lower the reading about two degrees; the sample should not be shaken any more than is necessary to mix any cream which may have risen, as it will absorb air; and the foam on the surface should be removed, as it makes it difficult to read the scale.

When a cow is milked, it is necessary to take the entire quantity given at the regular time of milking, as the first portions of the milk contain the most casein and sugar, and the last the most cream; milk taken from a cow whose regular yield stands at over 105° will give milk standing below 80° if the cow is remilked shortly after her regular time; the milk should be allowed to

stand for some time after it is drawn from the cow, and cooled before testing, so that the air absorbed during milking will be allowed to escape.

For accurate tests the sample should be cooled (if above 60° Fahr.) by placing the bottle or cylinder in cold water or packing with ice; or if below 60° Fahr. by setting in warm water, rubbing the cylinder with the hand, or placing in a warm room. A difference in temperature of from 2½ to 3½ degrees Fahrenheit will cause a variation of one lactometric degree, different samples of milk having different coëfficients of expansion; 3 degrees is the usual average, and is approximately correct from 40° to 70° Fahr.

Beyond these temperatures its calculation is uncertain, particularly if the temperature is near freezing or so high that the milk is liable to sour; when once frozen, the constituents of the milk appear to separate, and after thawing the specific gravity is different.

When the contents of a can of milk are frozen, the water freezes first, pushing the cream and casein towards the center, in very cold weather forming an inner core of cream; while, after melting, the ice around the exterior has a specific gravity sometimes as low as 1.008; a common trick of milk dealers being to pour out the core, and then scrape out the ice, sometimes mixing it with snow or ice.

The consistence or thickness of milk can be easily determined by allowing it to run off of the lactometer and noting its appearance over the black background of the shot in the lower bulb; this consistence is an important test, as with the opacity due to the cream, the color and taste, the examiner, with some practice, will be able to determine within one-half of one per cent. how much fat the sample contains when below three per cent., and approximately above that amount; if the milk contains less than one-half of one per cent. of fat it has a mother of pearl opalescence, which can easily be seen even by lamplight, it also looks blue and tastes very sweet; if less than one per cent., the opal lustre is still apparent, the color blueish, and tastes sweetish; if under one and one-half per cent., the milk appears like glue, color neither blueish nor yellow, and tastes

flat; if below two per cent., it becomes more opaque, slightly yellow, and tastes more milky and not so sweet; above two and one-half per cent., it is opaque, yellow, and the cream can be tasted in proportion to the amount contained.

When the cows are kept confined in stables and fed on distillery swill, or are in an unhealthy condition and fed exclusively on decayed brewers' grains, the odor of the milk will betray the fact; but the odor of milk from cows fed on brewers' grains mixed with other feed is not characteristic, if the milk is thoroughly cooled immediately after milking, so as to remove the animal heat.

The principal complaint against the lactometer is that a person who never saw a sample of milk might be deceived by testing a liquid that had about the same specific gravity—a salted solution of white glue, for instance—if he made the test, as he might of an unknown substance, from a book description.

As it is necessary to add a solution of at least four per cent. of salt to milk in order not to reduce its specific gravity, it can always be detected by its brackish taste; and the addition of burnt sugar or annatto will not conceal the opalescence of skimmed milk or the thinness of watered milk.

The following formula for a compound for circumventing the lactometer was devised by the chemist, who was employed by the Hester street coalition of dishonest dealers:

(1) One gallon of water,

(3) Three ounces of sugar,

(1½) One and a half ounces of salt, and a little caramel;

This to be added to

(4) Four gallons of milk.

This gives a fluid which stands at 99 degrees on the lactometer at 60° Fahr., and shows on analysis:

Water, 89.06%; fat, 2.95%; casein and sugar, 6.80%; and salts, 1.19%; sodium chloride, 0.42%.

The salt can be easily detected by its brackish taste, and the dealer who offered it for sale did the State one month's service besides paying a fine.

Usually the addition of water alone was sufficient for milk adulterators of the olden time, as the easiest and most convenient;

they then ran the risk of detection, considering that the fine—if they were caught—had been paid many times by the consumer; now, the adulteration is mostly performed at creameries, where *crude* milk from the farmers is changed into *pure* milk for the city, by the addition of from twenty to fifty per cent. of skimmed milk.

Objection has been made to the use of the lactometer that it is unreliable, because, being an even scale hydrometer, the degrees are not accurately graduated; this error of construction is very small on account of the slight range of specific gravity which it records, the greatest error being at the 50 degree mark, where the error is .714 of one degree, or .026 of an inch on the regular size of lactometer, whose scale from 0° to 100° is $3\frac{3}{4}$ inches.

See Drs. Waller and Hathaway's paper on the Modulus of Hydrometers in the School of Mines Quarterly, Vol. VI., p. 153 (January, 1885).

To find the error of a lactometric degree from the true position of the same, according to the laws of graduation of hydrometers by the specific gravity.

V. = Volume of lactometer immersed when floating in water, that is, volume of water of the same weight as lactometer.

V_1, V_2, V_3, V_4, V_5, etc., V_{10} = Volumes of lactometer immersed when floating in solutions of gravities corresponding to 10°, 20°, 30°, 40°, 50°, etc., 100° respectively, assuming that $10^\circ = 1. + 10 \times 0.00029$; $20^\circ = 1. + 20 \times 0.00029$, etc.

l. = Length of stem from 0° to 100°.

r. = Area of cross section, assumed to be uniform throughout.

L. = Length of lactometer assuming it to be all stem; then

$$V = Lr. \qquad (1)$$

Now for a solution of gravity equal to 1.029; we have the volume of liquids of same weight as the lactometer V and V_{10}. These are to each other inversely as the specific gravities of the solutions, or

$$V : V_{10} = 1.029 : 1$$

$$V_{10} = \frac{1}{1.029} = V. \times 0.971817. \qquad (2)$$

Subtracting each member from V; $V - V_{10} = 0.028183\ V$ (3)

Or the stem of the lactometer between 0° and 100° is 0.028183 of the volume of the whole lactometer.

Then lr=volume of the stem between 0° and 100°, and lr=0.028183 Lr from (1), or dividing by r,

$l = 0.028183\ L$, or $L = \frac{1}{0.028183}l$. (4)

If the value of l is $3\frac{5}{8}$ (=3.625) inches,

L=128.623638 inches (or 10 feet $8\frac{5}{8}$ inches nearly).

If l is 20 centimeters, L=709.647659 centimeters.

If l is one meter, L=35.482383 meters.

For solution of gravity of 50°, specific gravity 1.0145. By the same reasoning which gives us equation (2), we obtain

$V : V_5 = 1.0145 : 1$;

$V_5 = V_{\frac{1}{1.0145}} = V \times 0.985707$. (5), and

$V - V_5 = 0.014293V = 0.014293Lr$. (6)

Volume of stem from 0° to 50°=$l_5 r = 0.014293Lr$, or dividing through by r

$l_5 = 0.014293L$ (7)

If the 50° mark is placed just half way between 0° and 100°; it is placed at $\frac{1}{2}$ l below the 0° mark or from equation (4) at $\frac{1}{2}$ l=0.014092L, then

$l_5 - \frac{1}{2}l = (0.014293 - 0.014092)L = 0.000201L$ (8)

or when placed half way between 0° and 100°, it is by that amount above its true position, the measurement being made from the 0° mark, and $l_5 > \frac{1}{2}l$.

Assuming the value for L obtained from (4), (8) gives;

$l_5 - \frac{1}{2}l = 0.259177$ inches (9)

$1° = \frac{1}{100}$ of $3.625 = 0.03625$ inch, and the 50° mark is out of place by $\frac{0.259177}{0.03625}° = \frac{3}{4}°$ nearly.

If L=709.647659 centimeters, $l_5 - \frac{1}{2}l = 0.142852$ centimeters

If L=35.482383 meters, $l_5 - \frac{1}{2}l = 0.714260$ centimeters.

For solutions of other gravities, corresponding to 10°, 20°, 30°, 40°, etc.=1.0029, 1.0058, 1.0087, 1.0116, etc.

$V : V_1 = 1.0029 : 1$; $V_{\frac{1}{1.0029}} = 0.997108V$

$V - V_1 = 0.002892V = 0.002892Lr = l_1 r$

dividing by r and substituting value of L

L=128.623638 inches; l_1=0.371981 inch, $\frac{1}{10}$ l=0.3625 inch; difference=0.009481 inch too high ($l_1 > \frac{1}{10}$ l)

L=709.647659 centimeters; difference=0.052017 centimeters

L=35.482383 meters; difference=0.260086 centimeters

For 90°=specific gravity of 1.0261 ;

$V : V_9 = 1.0261 : 1$; $V - V_9 = 0.25436V$,

$l_9 = 3.271680$ inches ; $\frac{9}{10}\, l = 3.2625$ inches,

difference=0.009180 inch too high ($l_9 > \frac{9}{10}\, l$)

For 1°=specific gravity of 1.00029 ;

$V - V_1 = 0.0000728V$; difference=0.0000103 inches too high.

For 99°=specific gravity of 1.02871 ;

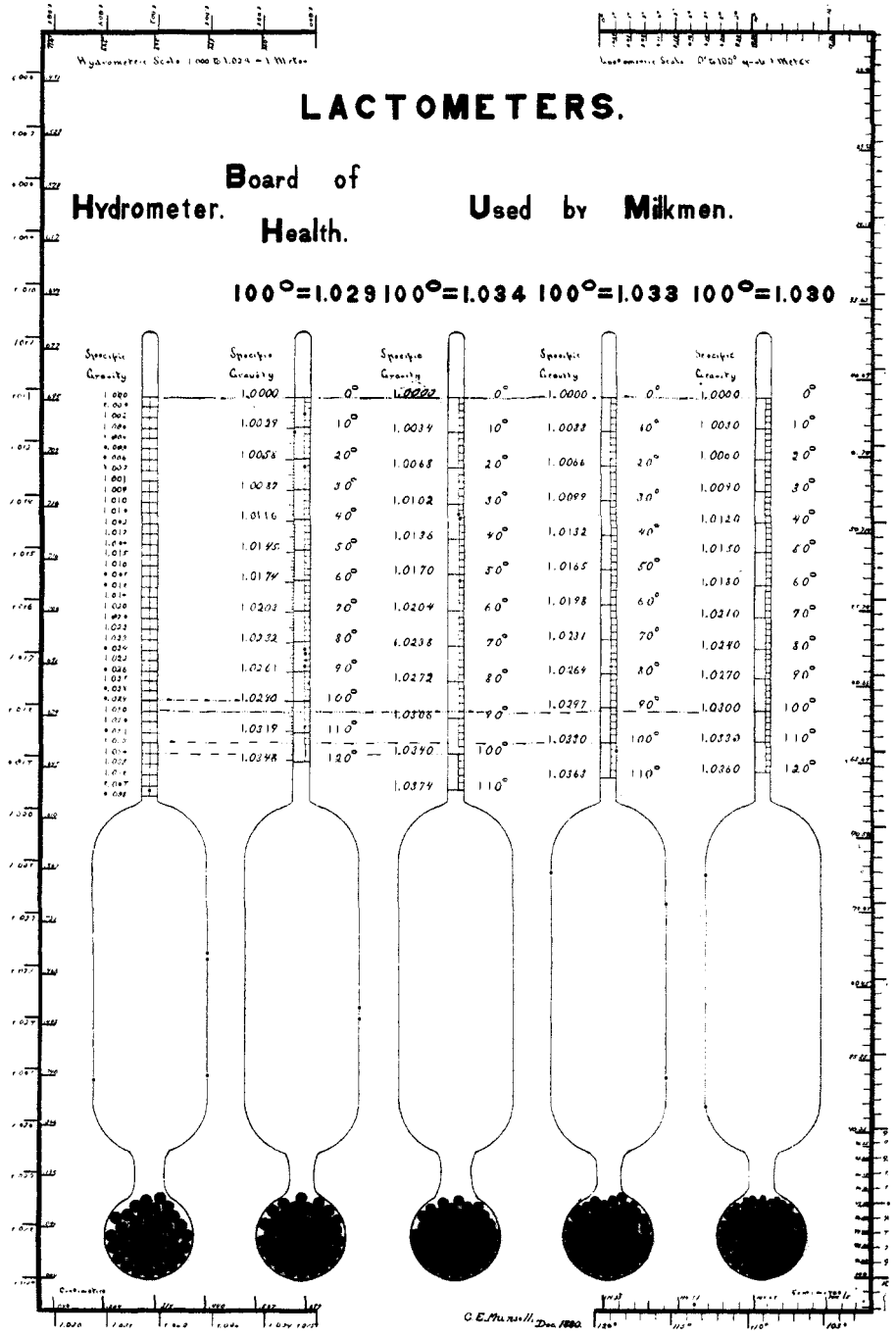
$l_{99} = 3.58974$ inches ; difference=0.00099 inches too high.

Table showing difference between actual positions and proper positions for marks indicating 10°, 20°, etc., respectively, measured from 0 mark.

Lactometric Degree.	Specific Gravity corresponding to degrees on the Lactometer.	Reciprocals of Specific Gravities.	Difference of Reciprocals and 1.000000.	Even Scale Reciprocal of 1.029 divided by 100, and multiplied by 10, 20, etc.	Error of Even Scale in decimals of the entire length of Lactometer	Error reduced to centimeters on a meter L = 35.482383 meters.
10°	1.0029	.997108	.002892	.002818	.000073	.260086
20°	1.0058	.994233	.005767	.005637	.000130	.461271
30°	1.0087	.991375	.008625	.008455	.000170	.603555
40°	1.0116	.988533	.011467	.011273	.000194	.687649
50°	1.0145	.985707	.014293	.014092	.000201	.714260
60°	1.0174	.982898	.017102	.016910	.000193	.683391
70°	1.0203	.980104	.019896	.019728	.000168	.596104
80°	1.0232	.977326	.022674	.022546	.000128	.452755
90°	1.0261	.974564	.025436	.025365	.000071	.253344
100°	1.0290	.971817	.028183	.028183	.000000	.000000
110°	1.0319	.969086	.030914	.031001	.000087	.309406
120°	1.0348	.966370	.033630	.033819	.000189	.672391

ERROR OF THE LACTOMETER FOR EACH DEGREE IN CENTIMETERS; DISTANCE FROM 0° TO 100° BEING ONE METER. LENGTH OF DEGREE AT 0° IS 1.028 CENTIMETERS, AT 100° .98 CENTIMETERS.

Degree.	Centimeters.	Degree.	Centimeters.	Degree.	Centimeters.	Degree.	Centimeters.
1	1.028	31	31.61	61	61.68	91	91.23
2	2.056	32	32.62	62	62.67	92	92.20
3	3.084	33	33.63	63	63.66	93	93.18
4	4.11	34	34.64	64	64.65	94	94.16
5	5.13	35	35.65	65	65.64	95	95.135
6	6.16	36	36.66	66	66.63	96	96.108
7	7.18	37	37.66	67	67.62	67	97.083
8	8.20	38	38.67	68	68.61	98	98.05
9	9.23	39	39.68	69	69.60	99	99.02
10	10.260	40	40.687	70	70.596	100	100.00
11	11.28	41	41.69	71	71.59	101	100.97
12	12.30	42	42.69	72	72.58	102	101.94
13	13.32	43	43.69	73	73.57	103	102.91
14	14.34	44	44.70	74	74.56	104	103.88
15	15.36	45	45.70	75	75.55	105	104.85
16	16.38	46	46.70	76	76.53	106	105.82
17	17.40	47	47.70	77	77.51	107	106.79
18	18.42	48	48.71	78	78.49	108	107.76
19	19.44	49	49.71	79	79.47	109	108.73
20	20.461	50	50.714	80	80.452	110	109.691
21	21.48	51	51.714	81	81.43	111	110.68
22	22.50	52	52.713	82	82.41	112	111.65
23	23.52	53	53.711	83	83.39	113	112.62
24	24.54	54	54.708	84	84.37	114	113.59
25	25.55	55	55.705	85	85.35	115	114.55
26	26.56	56	56.702	86	86.33	116	115.51
27	27.57	57	57.698	87	87.31	117	116.46
28	28.58	58	58.694	88	88.29	118	117.41
29	29.59	59	59.689	89	89.27	119	118.37
30	30.603	60	60.683	90	90.253	120	119.33


LACTOMETERS.
Hydrometer.
Board of Health.
Used by Milkmen.
100°=1.029
100°=1.034
100°=1.033
100°=1.030
Specific Gravity
1.0000
1.0039
1.0058
1.0087
1.0116
1.0145
1.0174
1.0203
1.0232
1.0261
1.0290
1.0319
1.0348
1.0000
1.0034
1.0068
1.0102
1.0136
1.0170
1.0204
1.0238
1.0272
1.0306
1.0340
1.0374
1.0000
1.0033
1.0066
1.0099
1.0132
1.0165
1.0198
1.0231
1.0264
1.0297
1.0330
1.0363
1.0000
1.0030
1.0060
1.0090
1.0120
1.0150
1.0180
1.0210
1.0240
1.0270
1.0300
1.0330
1.0360
0° 10° 20° 30° 40° 50° 60° 70° 80° 90° 100° 110° 120°
C. E. Munsell, Dec. 1880.

Lactometric Standings at 60° Fahr.—Omitting Samples of Skimmed Milk.

Lactometer.	1880.	1881.	1882.	1883.	1884.	1885.	Total.
47	---	---	---	1	1	---	2
62	---	1	---	---	---	---	1
65	---	---	---	---	1	---	1
66	---	1	---	---	---	---	1
71	---	1	---	---	---	---	1
72	1	---	---	---	---	---	1
74	---	---	1	---	---	---	1
75	---	---	---	---	1	---	1
76	1	---	---	---	---	1	2
78	---	---	---	---	1	---	1
79	1	---	---	---	---	---	1
80	1	1	---	1	---	---	3
81	1	1	---	---	---	1	3
82	---	2	1	---	---	1	4
83	1	---	2	---	---	1	4
84	2	---	---	---	2	---	4
85	4	1	---	1	2	---	8
86	2	---	---	2	1	---	5
87	2	---	2	1	---	---	5
88	9	1	1	---	---	1	12
89	2	1	2	4	3	---	12
90	9	1	3	---	2	---	15
91	6	---	2	3	1	---	12
92	10	4	4	---	1	---	19
93	2	3	5	2	3	1	16
94	15	6	3	4	6	3	37
95	10	5	14	9	6	3	47
96	22	3	13	14	15	10	77
97	20	6	18	13	25	24	106
98	25	13	18	17	24	21	118
99	21	6	32	14	30	34	137
100	64	43	37	19	34	22	219
101	66	20	47	36	35	35	239
102	67	37	90	51	59	50	354
103	61	56	97	76	68	48	406
104	80	61	125	51	94	85	496
105	87	75	143	92	117	118	632
106	102	108	141	130	201	160	842
107	116	91	177	159	169	214	926
108	122	114	161	145	237	210	989
109	126	111	158	149	208	255	1007
110	119	89	121	128	173	134	764
111	94	101	114	135	218	227	889
112	84	77	98	116	192	178	745
113	56	32	67	53	133	129	470
114	45	25	49	31	110	99	359
115	30	8	19	9	16	13	95
116	18	3	7	3	6	---	37
117	5	4	4	1	---	---	14
118	1	3	---	---	---	---	4
119	2	---	---	---	---	---	2
120	2	1	---	---	---	---	3
Total	1514	1116	1776	1470	2195	2078	10149
Average	106.12	107.06	106.26	107.12	107.71	107.97	107.12
No. below 100°	167	57	121	86	125	101	657
Percentage	11.0	5.1	6.7	5.8	5.7	4.8	6.4

Number Analysis.	Lactometer At 60° Fahr.	Specific Gravity At 60° Fahr.	Analysis.				Added Water.	Cream Removed.
			Water.	Fat.	Casein and Sugar.	Salts.		
189	62	1.0180	92.10	2.55	5.03	.32	40.7	15
188	66	1.0191	92.97	1.61	5.10	.32	39.8	46
171	71	1.0206	91.74	2.29	5.54	.43	33.7	24
13	72	1.0209	92.78	1.16	6.06	*	32.6	61
248	74	1.0215	91.42	1.70	6.47	.41	23.8	43
35	80	1.0232	91.31	1.31	6.76	*	24.8	56
88	80	1.0232	90.92	2.28	6.28	.52	24.4	24
173	81	1.0235	90.99	2.24	6.23	.54	25.0	25
349	81	1.0235	88.94	3.76	6.76	.54	19.0	--
192	82	1.0238	90.61	2.61	6.35	.43	25.0	13
193	82	1.0238	90.25	2.80	6.53	.42	23.0	7
8	84	1.0244	91.18	1.83	6.99	*	28.3	39
300	85	1.0247	90.07	2.71	7.22	*	19.8	10
330	85	1.0247	89.88	2.94	6.65	.53	21.0	2
9	86	1.0249	89.48	3.32	7.20	*	20.0	--
57	88	1.0255	90.94	1.84	7.22	*	19.8	38
20	88	1.0255	90.56	2.15	7.29	*	19.0	28
17	89	1.0258	88.79	3.75	7.45	*	17.2	--
327	90	1.0261	90.66	1.27	7.54	.53	10.5	57
27	--	-----	90.38	2.22	7.40	*	17.7	29
29	--	-----	89.74	2.73	7.53	*	16.3	9
16	--	-----	89.52	3.00	7.48	*	17.2	--
178	--	-----	89.37	2.74	7.29	.60	12.0	8
86	91	1.0264	90.08	2.39	6.95	.58	16.4	20
33	--	-----	89.96	2.57	7.47	*	17.0	14
14	--	-----	89.87	2.66	7.47	*	17.0	10
37	--	-----	89.78	2.78	7.44	*	16.3	7
12	92	1.0267	89.64	3.02	7.34	*	18.4	--
56	--	-----	89.20	2.98	7.82	*	13.1	--
31	93	1.0270	90.16	2.37	7.47	*	17.0	21
342	--	-----	89.77	2.57	7.07	.59	14.0	14
322	--	-----	89.60	2.62	7.22	.56	13.6	13

Other signs used in this table are as follows:

* Salts included with Casein and Sugar.

† Cow seen milked.

‡ Creamery milk.

§ Cows kept in Stables, and fed on Brewers' Grains.

Number Analysis.	Lactometer At 60° Fahr.	Specific Gravity At 60° Fahr.	Analysis.				Added Water.	Cream Removed.
			Water.	Fat.	Casein and Sugar.	Salts.		
308	94	1.0273	89.72	2.59	7.10	.59	14.6	14
343	..	.....	89.54	2.38	7.47	.61	10.2	20
64	..	.....	89.22	3.20	7.04	.54	15.8	..
23	..	.....	89.18	3.00	7.82	*	13.1	..
19	..	.....	89.15	3.10	7.75	*	18.4	..
344	..	.....	88.92	3.22	7.27	.59	12.7	..
321	..	.....	88.83	3.31	7.29	.57	12.7	..
32	..	.....	88.32	3.90	7.78	*	13.4	..
30	95	1.0276	89.22	2.83	7.95	*	11.5	6
348	..	.....	89.21	2.72	7.47	.60	10.3	9
169	..	.....	88.95	2.98	7.46	.61	10.3	..
22	..	.....	88.35	3.53	8.12	*	9.8	..
238	96	1.0278	91.04	1.37	6.98	.61	15.7	54
28	..	.....	89.80	2.41	7.79	*	13.4	20
351	..	.....	89.46	2.44	7.49	.61	10.0	19
346	..	.....	89.40	2.55	7.46	.59	10.6	15
345	..	.....	89.09	2.77	7.51	.64	9.5	7
185	..	.....	89.01	2.96	7.49	.55	10.7	1
18	..	.....	88.78	3.38	7.84	*	12.8	..
294	..	.....	88.64	3.16	7.61	.59	8.9	..
15	..	.....	88.51	3.66	7.83	*	12.7	..
316	..	.....	88.44	3.32	7.61	.63	8.5	..
328	97	1.0281	89.89	1.55	7.92	.64	5.2	48
164	..	.....	89.65	2.49	7.25	.61	12.7	17
317	..	.....	89.57	2.51	7.31	.61	12.0	16
352	..	.....	89.18	2.57	7.63	.62	8.3	21
65	..	.....	89.09	3.19	7.04	.68	14.2	..
293	..	.....	89.08	2.75	7.52	.65	9.2	8
223	..	.....	88.88	3.10	7.40	.62	10.9	..
58	..	.....	88.73	3.06	8.21	*	8.8	..
290	..	.....	88.26	3.36	7.75	.63	6.9	..
162	98	1.0284	89.71	1.82	7.81	.66	5.9	39
147	..	.....	89.55	2.33	7.65	.66	7.7	22
347	..	.....	89.41	2.48	7.50	.61	10.0	17
6	..	.....	89.21	2.25	8.54	*	5.1	25
254	..	.....	89.01	2.95	7.48	.56	10.7	2
240	99	1.0287	90.49	.99	7.88	.64	5.3	67

Number Analysis.	Lactometer At 60° Fahr.	Specific Gravity At 60° Fahr.	Analysis.				Added Water.	Cream Removed.
			Water.	Fat.	Casein and Sugar.	Salts.		
350	..	.....	89.06	2.50	7.83	.61	6.2	17
276	..	.....	88.81	2.67	7.91	.61	5.3	11
298	..	.....	88.49	3.19	7.69	.63	7.6	..
292	..	.....	88.18	3.26	7.95	.61	5.0	..
295	100	1.029	89.42	2.24	7.73	.61	7.3	25
163	..	.....	89.20	2.22	7.92	.66	4.7	26
89	..	.....	89.01	3.40	6.99	.60	15.7	..
247	..	.....	88.94	2.58	7.87	.61	5.8	14
1	..	.....	88.89	2.06	9.05	*	5.0	31
40	..	.....	88.65	3.02	8.33	*	7.5	..
146	..	.....	88.60	3.11	7.68	.61	7.9	..
251	..	.....	88.55	3.09	7.70	.66	7.1	..
208	100	1.029	88.32	3.47	7.60	.61	8.8	..
253	..	.....	88.19	3.23	7.96	.62	4.7	..
100	101	1.0293	88.76	2.78	7.78	.68	†	†
181	..	.....	90.66	1.30	7.41	.63	10.7	57
87	..	.....	89.61	2.18	7.58	.65	8.8	27
83	..	.....	89.14	2.76	7.46	.64	10.0	8
226	..	.....	89.05	2.65	7.70	.70	6.7	12
123	..	.....	88.89	2.92	7.55	.64	9.0	3
55	..	.....	88.80	2.85	8.35	*	7.2	5
299	..	.....	88.18	3.70	7.51	.61	9.8	..
209	102	1.0296	90.24	1.53	7.60	.63	8.3	49
245	..	.....	89.17	2.52	7.76	.55	7.6	16
297	..	.....	88.69	3.10	7.56	.65	8.8	..
246	..	.....	88.55	2.78	8.04	.63	3.7	7
211	..	.....	88.55	3.05	7.76	.64	6.7	..
331	..	.....	88.24	2.65	8.45	.66	§	..
176	103	1.0299	90.26	1.42	7.71	.61	7.6	53
212	..	.....	90.04	1.75	7.62	.59	8.8	42
228	..	.....	89.76	1.83	7.76	.67	5.2	39
36	..	.....	89.06	2.54	8.40	*	6.6	15
74	..	.....	88.15	3.06	8.13	.66	§	..
191	..	.....	87.16	3.74	8.45	.65	§	..
48	104	1.0302	88.54	2.77	8.69	*	†	†
99	..	.....	86.18	4.55	8.60	.67	†	†
72	..	.....	85.45	5.38	8.45	.72	†	†

Number Analysis.	Lactometer At 60° Fahr.	Specific Gravity At 60° Fahr.	Analysis.				Added Water.	Cream Removed.
			Water.	Fat.	Casein and Sugar.	Salts.		
150	104	1.0302	90.54	1.03	7.81	.62	6.3	66
210	..	.....	90.29	1.54	7.77	.60	7.0	48
239	..	.....	89.45	1.77	8.09	.69	2.5	41
318	..	.....	89.25	2.33	7.76	.66	6.5	22
244	..	.....	88.51	2.85	8.05	.59	4.0	5
341	..	.....	88.48	2.53	8.35	.65	?	16
332	..	.....	88.36	2.90	8.07	.67	2.9	3‡
154	..	.....	88.27	3.24	7.80	.69	5.7	..
155	105	1.0305	89.48	1.97	7.96	.59	5.0	34
38	..	.....	89.18	2.04	8.78	*	2.5	32
236	..	.....	88.84	2.82	7.74	.60	7.4	6
282	..	.....	88.68	2.74	8.01	.57	4.2	9
152	..	.....	88.63	2.46	8.38	.63	‡	18
184	..	.....	88.58	2.58	8.43	.61	?	14
233	..	.....	88.38	2.68	8.31	.63	?	10
148	..	.....	88.15	3.29	7.89	.67	4.9	..
304	106	1.0307	87.90	3.41	7.97	.72	†	†
180	..	.....	89.30	1.96	8.05	.69	2.9	35
277	..	.....	88.83	2.46	8.05	.66	3.1	18
230	..	.....	88.79	2.18	8.31	.68	‡	27
227	..	.....	88.37	2.69	8.14	.71	‡	10
101	107	1.0310	88.48	2.75	8.01	.76	†	†
302	..	.....	87.64	3.67	7.98	.71	†	†
93	..	.....	87.48	3.68	8.08	.76	†	†
94	..	.....	87.25	3.84	8.25	.70	†	†
53	..	.....	86.08	4.58	9.34	*	†	†
353	107	1.0310	91.39	1.50	6.51	.60	21.0	50
179	..	.....	90.01	1.31	8.06	.62	3.6	56
214	..	.....	89.38	2.02	7.96	.63	4.6	33
288	..	.....	89.19	2.47	7.72	.62	7.3	18
130	..	.....	89.16	2.22	7.93	.69	4.2	26
243	..	.....	89.00	2.14	8.15	.71	‡	29
123	..	.....	88.71	2.42	8.20	.67	‡	19
280	..	.....	88.52	2.86	8.02	.60	4.2	5
286	..	.....	88.48	3.03	7.88	.61	5.7	..
235	..	.....	88.26	2.36	8.70	.68	‡	21
291	..	.....	88.22	2.61	8.53	.68	‡	13

Number Analysis.	Lactometer At 60° Fahr.	Specific Gravity At 60° Fahr.	Analysis.				Added Water.	Cream Removed.
			Water.	Fat.	Casein and Sugar.	Salts.		
257	108	1.0313	87.65	3.20	8.47	.68	†	†
47	--	-----	87.56	3.16	9.28	*	†	†
95	--	-----	87.12	3.68	8.47	.73	†	†
46	--	-----	85.80	4.43	9.77	*	†	†
337	--	-----	87.72	3.07	8.53	.68	†	§
116	--	-----	89.59	1.71	7.99	.72	3.2	43
221	--	-----	89.58	1.79	8.00	.63	4.2	40
272	--	-----	89.45	1.92	7.98	.65	4.2	36
141	--	-----	89.26	2.03	8.02	.69	3.2	32
82	--	-----	88.55	2.21	8.55	.69	†	26
120	--	-----	88.43	2.60	8.25	.72	†	14
220	--	-----	88.40	2.79	8.18	.63	†	7
279	--	-----	88.26	2.67	8.40	.67	†	11
39	--	-----	88.19	2.39	9.42	*	†	20
103	--	-----	88.19	2.84	8.24	.73	†	5
283	--	-----	87.92	2.95	8.46	.76	†	2
102	109	1.0316	87.76	3.16	8.40	.68	†	†
96	---	-----	87.54	3.49	8.20	.77	†	†
303	---	-----	87.16	3.76	8.41	.67	†	†
97	---	-----	86.63	3.82	8.80	.75	†	†
156	---	-----	90.01	1.36	7.98	.65	4.2	55
90	---	-----	90.01	1.99	7.31	.69	11.2	34
118	---	-----	89.86	1.42	8.03	.69	3.2	51
142	---	-----	88.86	2.31	8.83	*	†	23
140	---	-----	88.69	2.64	8.00	.68	3.5	12
165	---	-----	88.64	2.61	8.06	.69	3.1	13
127	---	-----	88.19	2.67	8.44	.70	†	11
117	---	-----	88.13	2.76	8.40	.71	†	8
111	---	-----	88.00	2.82	8.45	.73	†	6
241	---	-----	87.84	2.89	8.54	.73	†	4
336	110	1.0319	87.85	2.72	8.76	.67	†	§
261	---	-----	84.99	5.14	9.13	.74	†	†
129	---	-----	90.17	1.22	7.91	.70	4.2	59
216	---	-----	89.04	2.09	8.24	.63	†	30
219	---	-----	88.91	2.14	8.25	.67	†	29
160	---	-----	88.06	2.23	9.01	.70	†	22
145	---	-----	88.00	2.88	8.47	.65	†	4

Number Analysis.	Lactometer At 60° Fahr.	Specific Gravity At 60° Fahr.	Analysis.				Added Water.	Cream Removed.
			Water.	Fat.	Casein and Sugar.	Salts.		
309	111	1.0322	87.96	3.10	8.24	.70	†	†
312	...	.....	87.93	2.89	8.53	.65	†	†
313	...	.....	87.59	3.45	8.29	.67	†	†
255	...	.....	87.58	2.99	8.85	.58	†	†
45	...	.....	87.08	3.63	9.29	*	†	†
59	...	.....	84.23	5.32	9.74	.71	†	†
71	...	.....	89.78	1.38	8.84	*	2.0	54
242	..	....	89.03	2.17	8.09	.71	2.3	27
232	..	.....	88.85	2.19	8.31	.65	†	27
285	..	.....	88.68	2.37	8.32	.63	†	21
229	..	.....	88.66	1.95	8.56	.70	†	35
151	..	.....	88.62	2.29	8.44	.65	†	24
5	..	.....	88.48	2.71	8.81	*	2.0	10
250	..	.....	88.21	2.96	8.23	.60	†	1
54	..	.....	87.90	2.78	9.32	*	†	7
168	..	.....	87.78	2.91	8.68	.63	§	§
98	112	1.0325	87.34	3.32	8.63	.71	†	†
60	..	.....	86.54	3.58	9.28	.60	†	†
52	..	.....	85.76	4.34	9.90	*	†	†
158	..	.....	91.25	.11	7.92	.72	4.0	96
132	..	.....	89.52	1.56	8.92	*	†	48
109	..	.....	89.47	1.68	8.16	.69	†	44
231	..	.....	89.04	1.67	8.59	.70	†	44
25	..	.....	88.71	2.31	8.98	*	†	23
21	..	.....	88.32	2.62	9.06	*	†	12
121	..	.....	88.27	2.54	8.46	.73	†	17
225	..	.....	87.87	2.58	8.88	.69	†	14
128	..	.....	87.78	2.93	8.58	.71	†	2
137	..	.....	87.72	2.96	9.32	*	†	1
75	..	.....	86.81	3.58	8.92	.69	§	§
167	..	.....	84.27	6.03	9.08	.62	§	§
306	113	1,0328	87.88	2.93	8.51	.67	†	†
311	..	.....	87.82	2.87	8.68	.62	†	†
259	..	.....	87.31	3.46	8.51	.72	†	†
310	..	.....	87.07	3.39	8.91	.63	†	†
215	..	.....	89.33	1.76	8.29	.62	‡	41
174	..	.....	88.82	1.75	8.74	.69	‡	42

Number Analysis.	Lactometer At 60° Fahr.	Specific Gravity At 60° Fahr.	Analysis.				Added Water.	Cream Removed.
			Water.	Fat.	Casein and Sugar.	Salts.		
115	..	.....	88.70	2.13	8.46	.71	†	29
77	..	.....	88.55	2.18	8.56	.71	†	27
319	..	.....	88.26	2.51	8.57	.66	†	16
133	..	.....	88.25	2.41	9.34	*	†	20
202	..	.....	88.24	2.60	9.16	*	†	13
80	..	.....	88.23	2.94	8.08	.75	†	2
144	..	.....	87.86	2.84	8.66	.64	†	5
49	114	1.0331	87.66	2.81	9.53	*	†	†
314	..	.....	87.50	3.01	8.76	.73	†	†
50	..	.....	87.47	3.01	9.52	*	†	†
305	..	.....	87.35	3.42	8.55	.68	†	†
44	..	.....	87.06	3.27	9.67	*	†	†
260	..	.....	86.55	3.88	8.91	.66	†	†
122	..	.....	90.48	.55	8.30	.67	†	82
84	..	.....	89.49	1.48	8.29	.74	†	51
78	..	.....	88.76	2.14	8.47	.63	†	29
85	..	.....	88.54	2.35	8.37	.74	†	22
269	..	.....	88.53	2.96	7.87	.64	5.5	1
287	..	.....	88.41	2.72	8.21	.65	†	9
270	..	.....	88.03	2.84	8.48	.65	†	5
131	114	1.0331	87.53	2.70	9.77	*	†	10
166	..	.....	86.08	3.96	9.24	.72	§	§
301	115	1.0334	88.36	2.74	8.19	.71	†	†
258	..	.....	86.83	3.71	8.77	.68	†	†
338	..	.....	86.69	3.18	9.47	.66	†	§
339	..	.....	86.12	3.64	9.59	.65	†	§
217	..	.....	90.26	.29	8.81	.65	†	90
262	..	.....	90.16	.92	8.27	.65	†	69
263	..	.....	88.55	2.21	8.56	.68	†	26
7	..	.....	87.81	2.60	9.59	*	†	13
105	116	1.0336	90.85	.27	8.14	.74	†	91
113	..	.....	89.58	1.18	8.52	.72	†	61
112	..	.....	89.21	1.36	8.71	.72	†	55
73	..	.....	88.97	1.64	8.69	.70	†	45
354	..	.....	88.81	1.36	9.17	.66	†	55
273	..	.....	88.61	1.86	8.84	.69	†	37
66	..	.....	88.54	1.99	9.47	*	†	34

Number Analysis.	Lactometer At 60° Fahr.	Specific Gravity At 60° Fahr.	Analysis.				Added Water.	Cream Removed.
			Water.	Fat.	Casein and Sugar.	Salts.		
76	..	.....	88.10	2.48	8.71	.71	†	17
264	..	.....	88.06	2.79	8.46	.69	†	7
79	..	.....	87.90	2.61	8.76	.73	†	13
307	117	1.0339	86.91	3.65	8.74	.70	†	†
256	..	.....	86.28	4.19	8.88	.65	†	†
119	..	.....	90.55	.06	8.70	.69	†	98
110	..	.....	89.86	.71	8.74	.69	†	76
159	118	1.0342	90.70	.08	8.50	.72	†	97
24	..	.....	90.69	.51	8.80	*	†	83
281	..	.....	90.23	.49	8.59	.69	†	84
34	..	.....	88.78	1.83	9.39	*	†	39
355	..	.....	88.23	1.94	9.17	.66	†	35
266	..	.....	88.12	2.54	8.61	.73	†	15
43	119	1.0345	86.87	3.29	9.84	*	†	†
26	..	.....	90.73	.18	9.09	*	†	94
218	..	.....	90.38	.06	8.89	.68	†	98
10	..	.....	88.62	1.87	9.51	*	†	38
224	..	.....	88.53	2.14	8.66	.70	†	29
92	..	.....	86.91	2.13	10.21	.75	†	29
356	121	1.0341	89.65	.26	9.47	.62	†	91
357	..	.....	89.46	.49	9.39	.66	†	84
265	126	1.0365	89.61	.55	9.11	.73	†	82

The percentages of water added and cream removed in the preceding analyses were calculated from the standards of the States of New York and New Jersey, namely, over 9 per cent. of solids, not fat, over 3 per cent. of fat, and less than 88 per cent. of water. For details with regard to the samples taken from cows which were seen milked, and the names of owners of some of the samples of adulterated milk, see Report on Fresh and Condensed Milk in the Fourth Annual Report (1883-4) of the New York State Board of Health.

In conclusion : The lactometer is an accurate instrument for taking the specific gravity of milk. The specific gravity of the entire quantity of milk given by a healthy cow at her regular time of milking is rarely, if ever, below 1.029. The specific gravity of pure milk increases with the quality, that is, with the decreased percentage of water ; while it decreases in proportion to the water added and increases with the cream removed, either or both adulterations being apparent to the senses of an expert. If the test is performed by an expert, it is impossible to tamper with a sample of milk, to the extent of commercial adulteration, without being detected by the specific gravity taken in connection with evidence of the senses.