of the operator; labels are all affixed uniformly; that is, at equal height from, and with lower edge parallel to, bottom of bottle, or if slanting labels are used, the slant on all labels is of the same angle.

CAPPING.

Although but a slight expense for each bottle, a cap of tin foil greatly adds to the finished appearance of the package. It has a further advantage, in that it protects the lip of the bottle from dirt or other matter settling on it after the bottle has stood in an upright position for some time. As this dirt is not removed by the drawing of a cork or the removing of a seal, it sometimes happens that it is washed into the glass while pouring out the contents of the bottle.

STORAGE AND DELIVERY.

The proper storage of bottled beer is of as great importance as any of the manipulations to produce it.

Light. Beer contained in white or clear glass bottles should never be exposed to direct light as it will quickly deteriorate in flavor and brilliancy.

Patent stopper or unsteamed beer should be stored cold, that is, the same as beer in kegs.

Pasteurized beer, on the other hand, should not be stored too cold, but preferably at ordinary room temperatures.

Corks.—Bottles closed with corks should not be stored in an upright position, but lying upon their sides so that the corks will be moistened by the beer and prevented from drying out, which would permit the escape of gas.

PIPE LINES.

In larger breweries the filling from barrels, which entails the troublesome operations of taking care of the packages—filling, cleaning, pitching, stamping, etc.—is being replaced by filling from government casks, connected by pipe line from the chip casks directly.

Here the casks or tanks, placed in a separate refrigerated room under the bottle shop, are filled and gauged under control of a government inspector.

This system has the advantage of rapidity—saving the repeated tapping of barrels—also a more uniform delivery, besides a saving of labor in the general handling of the beer. (See "Legal Relations.")

FIGURING IN THE BREWERY.

(Temperatures in this chapter are given in degrees Reaumur only because calculations are simpler than with Fahrenheit degrees, and the Reaumur thermometer is more generally employed for these purposes in American breweries.)

CALCULATING THE YIELD OF EXTRACT OF BREWING MATERIALS.

By "yield of extract," or "yield" simply, is meant the number of pounds of extract which is obtained from 100 pounds of a material used in brewing.

The yield is, therefore, always given in per cent. Thus, if we say the yield of a malt is 64 per cent, or a malt yields 64 per cent of extract, we mean that we obtain 64 pounds of extract from 100 pounds of malt.

In order to calculate the yield of extract of a material we should know:

1. Balling (B.), i. e., the saccharometer (Balling) indication of the wort in the cellar or in the kettle at 14° R.
2. Specific gravity (Sp. G.) of the wort.
3. Bbls., i. e., the number of barrels of wort in the cellar or in the kettle.
4. Materials, i. e., the amount of material used, in pounds.

In order to find the number of pounds of extract obtained from 100 pounds of material, i. e., to calculate the yield, we must first figure out how many pounds of extract were obtained altogether from the total materials used, i. e., how many pounds of extract are contained in the total wort. This is done as follows:

FIGURING EXTRACT IN TOTAL WORT.

The weight of a barrel of water at cellar temperature (4° R.) is 258.5 pounds. The weight of a barrel of wort of a certain Balling indication is 258.5 × sp. g.

Since the Balling indication of a wort (B.) shows how many pounds of extract are contained in 100 pounds of wort, it follows that

$$\text{Extract in 1 bbl. wort} = \frac{258.5 \times \text{sp. g.} \times \text{B.}}{100}.$$

Hence

$$\text{Total extract in wort} = \frac{258.5 \times \text{sp. g.} \times \text{B.} \times \text{bbls.}}{100}.$$

This being the extract obtained from the total materials, the extract from 100 pounds, or the

$$\text{Yield} = \frac{258.5 \times \text{sp. g.} \times \text{B.} \times \text{bbls.}}{\text{Total materials}}.$$

Example 1.—6,600 pounds malt yield 120 barrels wort in cellar at 13 per cent B.; sp. g. 1.053. What is the yield of the malt?

Solution.—

$$\text{Yield} = \frac{258.5 \times 1.053 \times 13 \times 120}{6600}.$$

$$= \frac{424632}{6600}$$

$$= 64.3.$$

Answer.—Yield = 64.3 per cent.

A table of Specific Gravity and Balling will be found in "The Brewers' Chemical Laboratory," and one for reducing Balling indications to pounds of extract per barrel on the next page.

CALCULATIONS ACCORDING TO R. WAHL.

ABRIDGED CALCULATION OF YIELD BY WAHL'S FORMULA.

To calculate the yield by the above method involves consulting a table for the specific gravity and a tedious multiplication by that figure. Both of these inconveniences are avoided by using Wahl's formula. Wahl found that if the Balling indication of a wort is added to 259—which is sufficiently accurate for the weight of a barrel of water at cellar temperature—the result will be the weight

BALLING READING IN POUNDS OF EXTRACT PER BARREL.

Balling's Saccharometer, Per Cent.	Pounds Extract Per Barrel.	Balling's Saccharometer, Per Cent.	Pounds Extract Per Barrel.	Balling's Saccharometer, Per Cent.	Pounds Extract Per Barrel.	Balling's Saccharometer, Per Cent.	Pound Extracts Per Barrel.
1.00	2.60	6.8	18.06	12.6	34.25	18.4	51.19
1.1	2.85	6.9	18.33	12.7	34.52	18.5	51.48
1.2	3.12	**7.0**	18.60	12.8	34.81	18.6	51.78
1.3	3.38	7.1	18.88	12.9	35.10	18.7	52.08
1.4	3.63	7.2	19.15	**13.0**	35.38	18.8	52.39
1.5	3.90	7.3	19.42	13.1	35.67	18.9	52.68
1.6	4.16	7.4	19.70	13.2	35.96	**19.0**	52.98
1.7	4.42	7.5	19.97	13.3	36.25	19.1	53.29
1.8	4.68	7.6	20.25	13.4	36.53	19.2	53.59
1.9	4.94	7.7	20.52	13.5	36.82	19.3	53.90
2.0	5.21	7.8	20.79	13.6	37.11	19.4	54.20
2.1	5.47	7.9	21.07	13.7	37.39	19.5	54.49
2.2	5.74	**8.0**	21.35	13.8	37.68	19.6	54.80
2.3	6.00	8.1	21.72	13.9	37.97	19.7	55.10
2.4	6.26	8.2	21.90	**14.0**	38.26	19.8	55.40
2.5	6.58	8.3	22.17	14.1	38.55	19.9	55.70
2.6	6.79	8.4	22.48	14.2	38.84	**20.0**	56.00
2.7	7.05	8.5	22.73	14.3	39.13	20.1	56.30
2.8	7.32	8.6	23.00	14.4	39.41	20.2	56.61
2.9	7.58	8.7	23.28	14.5	39.70	20.3	56.91
3 0	7.85	8.8	23.56	14.6	40.00	20.4	57.21
3.1	8.11	8.9	23.83	14.7	40.28	20.5	57.52
3.2	8.38	**9.0**	24.11	14.8	40.57	20.6	57.82
3.3	8.64	9.1	24.39	14.9	40.87	20.7	58.13
3.4	8.91	9.2	24.67	**15.0**	41.15	20.8	58.43
3.5	9.17	9.3	24.94	15.1	41.45	20.9	58.74
3.6	9.44	9.4	25.22	15.2	41.73	**21.0**	59.04
3.7	9.70	9.5	25.50	15.3	42.03	21.1	59.35
3.8	9.97	9.6	25.78	15.4	42.32	21.2	59.66
3.9	10.24	9.7	26.06	15.5	42.61	21.3	59.96
4 0	10.50	9.8	26.33	15.6	42.91	21.4	60.27
4.1	10.77	9.9	26.61	15.7	43.20	21.5	60.57
4.2	11.04	**10.0**	26.89	15.8	43.49	21.6	60.88
4.3	11.31	10.1	27.18	15.9	43.78	21.7	61.19
4.4	11.57	10.2	27.46	**16.0**	44.08	21.8	61.49
4.5	11.84	10.3	27.73	16.1	44.37	21.9	61.80
4.6	12.11	10.4	28.01	16.2	44.66	**22.0**	62.11
4.7	12.38	10.5	28.29	16.3	44.96	22.1	62.42
4.8	12.64	10.6	28.58	16.4	45.25	22.2	62.73
4.9	12.91	10.7	28.86	16.5	45.55	22.3	63.04
5.0	13.18	10.8	29.14	16.6	45.84	22.4	63.35
5.1	13.45	10.9	29.42	16.7	46.13	22.5	63.65
5.2	13.72	**11.0**	29.70	16.8	46.43	22.6	63.96
5.3	14.00	11.1	30.00	16.9	46.72	22.7	64.27
5.4	14.26	11.2	30.27	**17 0**	47.02	22.8	64.58
5.5	14.53	11.3	30.45	17.1	47.32	22.9	64.89
5.6	14.80	11.4	30.83	17.2	47.61	**23.0**	65.20
5.7	15.07	11.5	31.10	17.3	47.91	23.1	65.50
5.8	15.34	11.6	[illegible]	17.4	48.21	23.2	65.82
5.9	15.61	11.7	31.68	17.5	48.50	23.3	66.14
6.0	15.88	11.8	31.87	17.6	48.80	23.4	66.45
6.1	16.15	11.9	32.13	17.7	49.10	23.5	66.76
6.2	16.42	**12.0**	32.53	17.8	49.40	23.6	67.08
6.3	16.69	12.1	32.83	17.9	49.69	23.7	67.38
6.4	16.97	12.2	33.10	**18 0**	50.00	23.8	67.70
6.5	17.25	12.3	33.39	18.1	50.29	23.9	68.01
6.6	17.51	12.4	33.67	18.2	50.78	**24.0**	68.32
6.7	17.78	12.5	33.95	18.3	51.08		

of a barrel of wort of the given Balling indication. Wahl's formula reads as follows:

$$\text{Yield} = \frac{(259 + \text{B.}) \times \text{B.} \times \text{bbls.}}{\text{materials}}.$$

By this abridged formula the following values can be calculated:

1. Weight of 1 bbl. wort = 259 + B.
2. Lbs. extract in 1 bbl. wort $= \frac{(259 + \text{B}) \times \text{B}}{100}$.
3. Lbs. total extract in total wort $= \frac{(259 + \text{B}) \times \text{B} \times \text{bbls.}}{100}$.
4. Yield as above.

Example 2.—Same as in 1; 6,600 pounds of material give 120 barrels of wort in cellar at 13 per cent Balling. What is the yield?

Solution.—

$$\text{Yield} = \frac{(259 + 13) \times 13 \times 120}{6600}.$$

$$= \frac{424320}{6600}$$

$$= 64.3.$$

Answer.—Yield = 64.3 per cent, or, the same result as above.

CALCULATING YIELD FOR TWO DIFFERENT MATERIALS.

If two different materials are used together (malt and raw cereals), the total yield of mixed materials, or the average yield, is calculated the same as above. But if it is desired to find the yield of one of the two materials, for instance, the raw cereal, it is necessary to know the yield of the other, for instance, the malt. If an approximate value is sufficient for the purpose in hand, the average yield of a malt of the quality in question is taken. To be accurate, it is better to take the yield obtained in a pure malt brewing.

Example 1.—A brewing with 3,500 pounds of malt and 1,900 pounds of raw cereals, gives 95 barrels of wort in the cellar at 14 per cent Balling. The yield of the malt in a pure malt brewing was 63 per cent. What is the yield of the raw cereal?

Solution.—First figure out the total extract from the total material:

$$\text{Total extract} = \frac{(259 + 14) \times 14 \times 95}{100}.$$

$$= 3630.9 = 3631.$$

We have, therefore, 3631 pounds extract from the total material.

Next, calculate the extract from the malt:

100 lbs. malt yield = 63 lbs. extract.
3500 lbs. malt yield ? lbs. extract.

$$\frac{3500 \times 63}{100} = 2205.$$

We have, therefore, 2205 pounds malt extract.

Deducting the malt extract from the total extract, gives the extract from the raw cereal:

3631 lbs. total extract.
2205 lbs. malt extract.

1426 lbs. raw cereal extract.

This amount of extract was obtained from 1900 lbs. raw cereal, hence

1900 lbs. raw cereal yield 1426 lbs. extract.
100 lbs. raw cereal yield ? lbs. extract.

$$\frac{1426 \times 100}{1900} = 75.$$

Answer.—Yield of extract from raw cereal = 75 per cent.

Example 2.—6500 pounds of material, consisting of 60 per cent malt and 40 per cent grits, give 130 barrels of wort in the cellar at 12.5 per cent Balling. The malt yield is 63 per cent. What is the yield of the grits?

There are two ways of solving this example.

Solution 1.—First calculate the number of pounds of malt and grits used, respectively.

100 lbs. materials contain 60 lbs. malt.
6500 lbs. materials contain ? lbs. malt.

$$\frac{6500 \times 60}{100} = 3900 \text{ lbs. malt.}$$

6500 lbs. total materials
less 3900 lbs. malt

gives 2600 lbs. grits.

Calculate as above:

$$\text{Total extract} = \frac{(259 + 12.5) \times 12.5 \times 130}{100}$$
$$= \frac{3393.75 \times 130}{100}$$
$$= \frac{441187}{100}$$
$$= 4411.9, \text{ or } 4412.$$

100 lbs. malt yield 63 lbs. extract.
3900 lbs. malt yield ? lbs. extract.

$$\frac{3900 \times 63}{100} = 2457 \text{ lbs. malt extract.}$$

4412 lbs. total extract
subtract 2457 lbs. malt extract

leaves 1955 lbs. grits extract from 2600 lbs. grits.

2600 lbs. grits yield 1955 lbs. extract.
100 lbs. grits yield ? lbs. extract.

$$\frac{1955 \times 100}{2600} = 75.2.$$

Answer.—Yield of grits = 75.2 per cent.

Solution 2.—Calculate the average yield of the mixed materials:

$$\text{Yield of mixed materials} = \frac{(259 + 12.5) \times 12.5 \times 130}{6500}$$
$$= \frac{441187}{6500}$$
$$= 67.8.$$

The average yield is 67.8 per cent, i. e., 100 lbs. mixed materials yield 67.8 lbs. extract; 100 lbs. mixed materials consist of 60 lbs. malt and 40 lbs. grits. Deduct the extract of 60 lbs. malt

from 67.8 lbs. extract, and the result will be the extract of 40 lbs. grits:

100 lbs. malt yield 63 lbs. extract.
60 lbs. malt yield ? lbs. extract.

$$\frac{63 \times 60}{100} = 37.8 \text{ lbs. malt extract.}$$

67.8 lbs. extract from 60 lbs. malt and 40 lbs. grits
less 37.8 lbs. extract from 60 lbs. malt alone

gives 30.0 lbs. extract from 40 lbs. grits.

40 lbs. grits yield 30 lbs. extract.
100 lbs. grits yield ? lbs. extract.

$$\frac{30 \times 100}{40} = 75.$$

Answer.—Grits yield = 75 per cent.

CALCULATING YIELD IN THE KETTLE.

For many purposes it is desirable to calculate the yield from the material by the total amount of wort in the kettle and the Balling indication of such wort.

Since the wort in the kettle is at a boil, the figure 259 for the weight of a barrel of water at cellar temperature cannot be used, but the weight of a barrel of boiling water must be taken, which is approximately 246 lbs. For calculating the yield of extract in the kettle, Wahl's formula, therefore, takes this appearance:

$$\text{Yield} = \frac{(246 + B) \times B \times \text{bbls.}}{\text{materials}}.$$

Example.—8800 pounds of material is used, from which 200 barrels of wort in the kettle of 12 per cent Balling is obtained. What is the yield of extract?

Solution.—

$$\text{Yield} = \frac{(246 + 12) \times 12 \times 200}{8800}$$
$$= \frac{619200}{8800}$$
$$= 70.36.$$

Answer.—Yield = 70.36 per cent.

CALCULATING CONCENTRATION OF WORT IN KETTLE.

On leaving the mash-tun and running into the kettle the wort shows a certain per cent Balling, which is considerably below that required when the wort leaves the kettle. In order to concentrate the wort to the required density a certain amount of water must be drawn off by evaporation in boiling.

The question is, how much should be evaporated, or how much should the wort be boiled down?

The answer is found by the following formula:

$$\left.\begin{array}{l}\text{Bbls. wort}\\ \text{after boiling}\end{array}\right\} = \frac{\text{Bbls. of wort before boil.} \times \text{Balling before boil.}}{\text{Balling after boiling}}$$

Example.—A sample of wort from the kettle after being cooled to 14° R. shows 12 per cent Balling. It is required to have a wort of 13 per cent Balling, when running from kettle. How much should the wort be boiled down in the kettle, the total amount of wort on hand being 320 barrels?

Solution.—Bbls. wort after boiling $= \frac{320 \times 12}{13} = 295.4$, consequently the 320 barrels of wort must be boiled down to 295.4 barrels.

$$320 - 295.4 = 24.6.$$

Answer.—Amount of water to be evaporated = 24.6 barrels.

CALCULATING THE MATERIALS.

If the question is, how many pounds of material are required to produce a given number of barrels of wort of a certain Balling indication, the yield of the material should be known. The formula for this calculation is as follows:

$$\text{Materials in lbs.} = \frac{(259 + B) \times B \times \text{bbls.}}{\text{Yield.}}$$

MALT.

Example 1.—How many pounds of malt will be required for a brewing of 150 barrels in the cellar at 13.8 per cent Balling, the malt yield being 64 per cent?

Solution.—

$$\text{Materials} = \frac{(259 + 13.8) \times 13.8 \times 150}{64}$$

$$= \frac{564696}{64}$$

$$= 8823$$

Answer.—Required: 8823 lbs. malt.

MALT AND RAW CEREALS.

Example 2.—How many pounds of malt and how many pounds of grits are required for 300 barrels in the cellar at 12.5 per cent Balling, using 65 per cent of malt and 35 per cent of grits, the yield of malt being 64 per cent, of grits 75 per cent?

Solution.—

1. Calculate the average yield:

100 lbs. malt yield 64 lbs. extract.
65 lbs. malt yield ? lbs. extract.

$$\frac{64 \times 65}{100} = 41.6 \text{ lbs. malt extract.}$$

100 lbs. grits yield 75 lbs. extract.
35 lbs. grits yield ? lbs. extract.

$$\frac{75 \times 35}{100} = 26.2 \text{ lbs. grits extract.}$$

65 lbs. malt yield 41.6 lbs. extract.
35 lbs. grits yield 26.2 lbs. extract.

100 lbs. mixed yield 67.8 lbs. extract.

Answer.—Average yield = 67.8 per cent.

2. Calculate the total materials:

$$\text{Total material} = \frac{(259 + B) \times B \times \text{Bbls.}}{\text{Yield}}$$

$$= \frac{(259 + 12.5) \times 12.5 \times 300}{67.8}$$

$$= \frac{1018I2.5}{67.8}$$

$$= 15016.$$

Total materials required = 15016 lbs.

MATERIALS USED TO PRODUCE ONE BARREL OF WORT OF DIFFERENT GRAVITIES IN THE CELLAR. MALT RECKONED AT 64 PER CENT, YIELD OF ADJUNCTS AS PER HEADING.

Per Cent Balling of Wort.	Extract in 1 Barrel of Wort, Lbs.	Malt Employed, Lbs.	Yield of Adjunct: 75%.						Yield of Adjunct: 80%.						Yield of Adjunct: 90%.					
			75% Malt.		66⅔% Malt.		60% Malt.		75% Malt.		66⅔% Malt.		60% Malt.		75% Malt.		66⅔% Malt.		60% Malt.	
			Malt Lbs.	Adjt Lbs.	Malt Lbs.	Adjt Lbs.	Malt Lbs.	Adjt Lbs.	Malt Lbs.	Adjt Lbs.	Malt Lbs.	Adjt Lbs.	Malt Lbs.	Adjt Lbs.	Malt Lbs.	Adjt Lbs.	Malt Lbs.	Adjt Lbs.	Malt Lbs.	Adjt Lbs.
10.00	26.90	42.03	30.23	10.07	26.50	13.25	23.60	15.73	29.67	9.89	25.87	12.93	22.93	15.28	28.62	9.54	24.67	12.34	21.69	14.46
10.50	28.30	44.22	31.80	10.60	27.88	13.94	24.82	16.55	31.21	10.41	27.21	13.61	24.12	16.08	30.10	10.04	25.95	12.98	22.82	15.21
11.00	29.70	46.40	33.38	11.12	29.25	14.63	26.05	17.37	32.76	10.92	28.56	14.28	25.31	16.88	31.60	10.53	27.23	13.62	23.95	15.96
11.25	30.41	47.51	34.17	11.39	29.95	14.98	26.68	17.78	33.54	11.18	29.24	14.62	25.92	17.28	32.35	10.78	27.89	13.94	24.52	16.34
11.50	31.11	48.60	34.96	11.65	30.65	15.32	27.29	18.19	34.31	11.44	29.91	14.96	26.51	17.68	33.10	11.03	28.53	14.26	25.09	16.73
11.75	31.82	49.71	35.75	11.92	31.34	15.67	27.91	18.61	35.09	11.70	30.60	15.30	27.12	18.08	33.85	11.28	29.18	14.59	25.66	17.10
12.00	32.52	50.81	36.54	12.18	32.03	16.02	28.52	19.02	35.86	11.96	31.27	15.64	27.71	18.48	34.60	11.53	29.83	14.92	26.23	17.48
12.25	33.23	51.92	37.34	12.45	32.73	16.37	29.15	19.43	36.65	12.22	31.95	15.98	28.32	18.88	35.35	11.78	30.49	15.24	26.80	17.86
12.50	33.94	53.03	38.14	12.71	33.43	16.72	29.77	19.85	37.43	12.48	32.63	16.32	28.93	19.28	36.10	12.04	31.13	15.57	27.37	18.25
12.75	34.65	54.14	38.93	12.98	34.13	17.07	30.39	20.26	38.21	12.74	33.32	16.66	29.53	19.69	36.86	12.29	31.79	15.89	27.95	18.63
13.00	35.36	55.25	39.73	13.24	34.83	17.42	31.01	20.68	39.00	13.00	34.00	17.00	30.14	20.09	37.62	12.54	32.44	16.22	28.52	19.01
13.25	36.07	56.36	40.53	13.51	35.53	17.77	31.64	21.09	39.78	13.26	34.68	17.34	30.74	20.49	38.37	12.79	33.09	16.55	29.09	19.40
13.50	36.79	57.39	41.34	13.78	36.23	18.12	32.27	21.51	40.57	13.53	35.37	17.69	31.35	20.90	39.13	13.05	33.75	16.88	29.67	19.78
13.75	37.50	58.60	42.14	14.04	36.93	18.47	32.89	21.93	41.35	13.79	36.05	18.03	31.96	21.30	39.89	13.30	34.41	17.20	30.24	20.16
14.00	38.22	59.72	42.95	14.31	37.65	18.82	33.52	22.35	42.15	14.05	36.75	18.37	32.57	21.71	40.66	13.55	35.07	17.53	30.82	20.55
14.25	38.94	60.85	43.76	14.58	38.35	19.18	34.15	22.77	42.94	14.32	37.44	18.72	33.18	22.12	41.42	13.81	35.73	17.86	31.40	20.94
14.50	39.66	61.97	44.57	14.85	39.06	19.53	34.78	23.19	43.74	14.58	38.13	19.07	33.80	22.53	42.19	14.06	36.39	18.19	31.99	21.32
14.75	40.38	63.09	45.38	15.12	39.77	19.89	35.42	23.61	44.53	14.85	38.83	19.41	34.41	22.94	42.95	14.32	37.05	18.52	32.56	21.71
15.00	41.11	64.23	46.19	15.40	40.50	20.25	36.06	24.04	45.34	15.11	39.53	19.76	35.03	23.36	43.73	14.58	37.71	18.86	33.16	22.10
15.50	42.55	66.48	47.81	15.94	41.92	20.96	37.33	24.88	46.93	15.64	40.91	20.46	36.26	24.18	45.26	15.09	39.03	19.52	34.32	22.88
16.00	44.00	68.75	49.44	16.48	43.33	21.67	38.60	25.73	48.52	16.18	42.31	21.15	37.50	25.00	46.81	15.60	40.37	20.18	35.49	23.66
16.50	45.46	71.03	51.08	17.03	44.77	22.39	39.88	26.58	50.14	16.71	43.71	21.86	38.74	25.83	48.36	16.12	41.71	20.85	36.67	24.44
17.00	46.92	73.32	52.73	17.57	46.21	23.11	41.15	27.44	51.75	17.25	45.11	22.56	39.99	26.66	49.91	16.64	43.05	21.52	37.84	25.23
17.50	48.39	75.61	54.38	18.12	47.67	23.83	42.44	28.30	53.37	17.79	46.53	23.26	41.24	27.50	51.48	17.16	44.39	22.20	39.02	26.02
18.00	49.86	77.91	56.03	18.67	49.12	24.56	43.73	29.16	54.99	18.33	47.94	23.97	42.49	28.33	53.05	17.68	45.75	22.87	40.21	26.81

3. Calculate the pounds of malt and grits.

100 lbs. materials contain 65 lbs. malt.
15016 lbs. materials contain ? lbs. malt.

$$\frac{15016 \times 65}{100} = 9760 \text{ lbs. malt.}$$

15016 lbs. total materials.
9760 lbs. malt.

5256 lbs. grits.

Answer.—Required: 9750 lbs. malt and 5256 lbs. grits.

CALCULATING THE COST.

To calculate the cost of a barrel of wort (in cellar) as far as the required material is concerned, the following values must be known:

1. Saccharometer indication of the wort in cellar.
2. Percentage of each material of the total.
3. Yields of the materials.
4. Cost of the materials.

This calculation will be illustrated by the following:

Example.—A wort of 13.5 per cent Balling in the cellar is to be prepared from 60 per cent malt, 40 per cent rice, and 1.5 lbs. hops per barrel. What is the cost of the materials per barrel at the following prices: Malt 58 cents per bushel of 33 lbs., rice 210 cents per 100 lbs., and hops 18.5 cents per pound. Yield of the malt 64 per cent, of the rice 78 per cent?

Solution.—Find the amount of materials required for a barrel of wort, as above.

Calculation of average yield:

100 lbs. malt yield 64 lbs. extract.
60 lbs. malt yield ? lbs. extract.

$$\frac{60 \times 64}{100} = 38.4 \text{ lbs. malt extract.}$$

100 lbs. rice yield 78 lbs. extract.
40 lbs. rice yield ? lbs. extract.

$$\frac{78 \times 40}{100} = 31.2 \text{ rice extract.}$$

60 lbs. malt yield 38.4 lbs. extract.
40 lbs. rice yield 31.2 lbs. extract.

100 lbs. mixed yield 69.6 lbs. extract.

Calculation of total materials:

$$\text{Total materials for one barrel} = \frac{(259 + 13.5) \times 13.5}{69.6} = \frac{3678.75}{69.6} = 52.9.$$

Total materials required 52.9 lbs. of which 60 per cent malt and 40 per cent rice.

In 100 lbs. materials 60 lbs. malt.
In 52.9 lbs. materials ? lbs. malt.

$$\frac{52.9 \times 60}{100} = 31.74 \text{ lbs. malt.}$$

52.9 lbs. total materials
less 31.7 lbs. malt

gives 21.2 lbs. rice.

The materials required for a barrel of wort, therefore, are:

31.7 lbs. malt.
21.2 lbs. rice.
1.5 lbs. hops.

The cost of these materials is found in the following manner:

1. Malt.

33 lbs. malt cost 58 cents.
31.7 lbs. malt cost ? cents.

$$\frac{31.7 \times 58}{33} = 55.7.$$

Cost of malt = 55.7 cents.

2. Rice.

100 lbs. rice cost 210 cents.
21.2 lbs. rice cost ? cents.

$$\frac{21.2 \times 210}{100} = 44.5.$$

Cost of rice = 44.5 cents.

3. Hops.

1 lb. hops cost 18.5 cents.
1.5 lbs. hops cost ? cents.

$$18.5 \times 1.5 = 27.7.$$

Cost of hops = 27.7 cents.

In conclusion

the malt cost	55.7 cents.
the rice cost	44.5 cents.
the hops cost	27.7 cents.
Total materials cost	127.9 cents.

Answer.—The cost of the materials per barrel of wort amounts to $1.27.

FIGURING COST OF ONE BARREL OF BEER.

If we want to find the cost of material used in producing a barrel of beer ready for delivery we must add to the cost of a barrel of wort as figured above the cost of the beer lost between starting tub and racking bench. (See "Losses from Malt Mill to Racking Bench.")

Example.—If 100 barrels of wort in starting tub equal 95 barrels marketable beer (loss 5 per cent), and the cost of the material for the production of one barrel of wort is $1.27 what would be the cost of a barrel of beer?

Solution.—If 95 barrels of beer are obtained from 100 barrels of wort it takes $\frac{100}{95} = 1.05$ barrel of wort to obtain one barrel of beer.

Since one barrel of wort costs $1.27, 1.05 barrels of wort cost $1.05 \times 1.27 = \$1.33$.

Answer.—Cost of material for one barrel of beer $1.33.

CALCULATING THE MATERIALS ACCORDING TO M. SCHWARZ.

In figuring out the amounts of malt and adjuncts required for a brewing, the percentage of yield of extract from the various materials should be first determined. Average values for yields are given in the following tables:

1 bu. uncleaned malt = 34 lbs.
1 bu. cleaned malt = 33 lbs.

1 bu. cleaned malt yields........	21	pounds of extract
100 lbs. cleaned malt yields.........	63.6	pounds of extract
100 lbs. corn (fine) yields..........	76	pounds of extract
100 lbs. flakes yields...............	78	pounds of extract
100 lbs. rice yields.................	82	pounds of extract
100 lbs. glucose or grape sugar yields	79	pounds of extract
100 lbs. anhydrous grape sugar yields	97	pounds of extract
100 lbs. cane sugar yields..........	100	pounds of extract

One bushel of malt is replaced by

27.63 lbs. corn.
26.92 lbs. flakes.
25.61 lbs. rice.
26.58 lbs. glucose or grape sugar.
21.6 lbs. anhydrous grape sugar.
21.0 lbs. cane sugar.

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100 lbs. corn takes the place of..........	3.62 bu. malt.
100 lbs. flakes takes the place of........	3.7 bu. malt.
100 lbs. rice takes the place of..........	3.9 bu. malt.
100 lbs. glucose or grape sugar takes the place of	3.8 bu. malt.
100 lbs. anhydrous grape sugar takes the place of	4.62 bu. malt.
100 lbs. cane sugar takes the place of....	4.76 bu. malt.

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100 lbs. corn takes the place of....	119.5 lbs. cleaned malt.
100 lbs. flakes takes the place of....	122.6 lbs. cleaned malt.
100 lbs. rice takes the place of....	128.9 lbs. cleaned malt.
100 lbs. glucose or grape sugar takes the place of................	124.2 lbs. cleaned malt.
100 lbs. anhydrous grape sugar takes the place of.................	152.5 lbs. cleaned malt.
100 lbs. cane sugar takes the place of	157.2 lbs. cleaned malt.
10 gal. syrup takes the place of..	147 lbs. cleaned malt.

Inserting the respective values from the above tables in the formulas given below, the amount of materials for a brewing can be readily calculated.

ALL MALT.

The question is: How many bushels of malt are required in order to obtain a certain number of barrels of wort of a given percentage of extract, either in the kettle or in the fermenter?

Let B = the bushels of malt to be found,
W = the barrels of wort,
p = percentage of extract in the wort,
F = a factor which is equal 125 for wort in the kettle and 133 for wort in the fermenter, taking an average malt yield of 60 per cent. Should the yield not be 60 per cent, deduct 2 from the factor F for each per cent above 60, and add 2 to the factor F for each per cent below 60.

The formula then is:

$$B = \frac{W \times p \times F}{1000}.$$

Example 1.—How many bushels of malt are required to get 165 barrels of wort of 12.8 per cent extract in the fermenting cellar, the malt yield being 60 per cent?

Solution.—

$$W = 165,\ F = 133,\ p = 12.8.$$

$$B = \frac{165 \times 12.8 \times 133}{1000} = \frac{280896}{1000} = 280.9.$$

Answer.—The required amount of malt is 280.9, or nearly 281 bushels.

Example 2.—How many bushels of malt are required to get in the kettle 200 barrels of wort of 13 per cent Balling, the malt yield being 62 per cent?

Solution.—

$$W = 200,\ p = 13,\ F = 125 - (2 \times 2) = 121.$$

$$B = \frac{200 \times 13 \times 121}{1000} = \frac{314600}{1000} = 314.6.$$

Answer.—The required amount of malt is 314.6 bushels.

MALT AND ADJUNCTS.

If adjuncts are to be used with malt, calculate first the amount of malt that would be required if the brewing were to be made of all malt, after which replace the desired portion of the figure for malt by the adjunct that is to be used, inserting the values given in the tables above.

Example 1a.—Taking Example 1, above, under "All Malt," and saying that 30 per cent of the materials is to be replaced by flakes, what amounts of malt and flakes would be required?

Solution.—Total materials if malt alone was to be used would be 280.9 bushels, as calculated above. Of this amount 30 per cent is:

$$\frac{280.9 \times 30}{100} = 84.3 \text{ bushels (approximately).}$$

This amount is to be replaced with flakes. One bushel of malt is replaced by 26.92 pounds of flakes. Hence, multiply 26.92 by 84.3.

$$26.92 \times 84.3 = 2269.3$$

The amount of flakes to be taken is 2,269.3, or in round numbers 2,270 pounds. The quantity of malt is to be reduced 30 per cent.

Hence,

$$280.9 - 84.3 = 196.6$$

is the amount of malt to be used.

Answer.—2,270 pounds of flakes and 196.6 bushels of malt is the required amount of materials.

Example 1b.—Still taking Example 1 (above), under "All Malt," and saying 20 per cent of the malt is to be replaced by corn grits and 20 per cent by grape sugar. What amounts of malt, grits and grape sugar are required?

Solution.—The required amount of malt, if an all-malt brewing was intended, as calculated above, would be 280.9. Of this amount 40 per cent is:

$$\frac{280.9 \times 40}{100} = 112.4 \text{ (approximately).}$$

Half of this amount = 56.2 bushels is to be replaced by corn grits, and the other half by grape sugar. There remains malt

$$280.9 - 112.4 = 168.5 \text{ bu.}$$

One bushel of malt is replaced by 27.63 pounds of corn. Hence, the amount of corn required is

$$27.63 \times 56.2 = 1553 \text{ lbs.}$$

in round numbers.

One bushel of malt is replaced by 26.58 pounds of grape sugar.

Hence, the amount of grape sugar required is

$$56.2 \times 26.58 = 1494 \text{ lbs.}$$

in round numbers.

Answer.—The required amount of materials is 168.5 bushels of malt, 1,553 pounds of grits and 1,494 pounds of grape sugar.

MATERIALS ADDED IN KETTLE.

Where grape sugar, glucose or other adjuncts are used, which are directly soluble and are added in the kettle, another formula may be used.

The question here is, what amount of glucose, syrup or sugar of any kind, of known yield, should be added in the kettle in order to raise the percentage of extract in a given number of barrels of wort to a certain figure?

Let W = the barrels of wort,
p = the percentage of extract in the wort,
q = the required percentage of extract,
p_1 = the percentage of extract of the adjunct,
F = a constant factor = 250,
G = the required amount of the adjunct in pounds.

The formula then is:

$$G = \frac{(F \times W) \times (q - p)}{p_1 - q}.$$

Example.—How many pounds of glucose of 80 per cent extract are required in order to raise the percentage of extract in 210 barrels of wort from 13.2 to 14.4?

Solution.—

$$W = 210,\ p = 13.2,\ q = 14.4,\ F = 250,\ p_1 = 80.$$

$$G = \frac{(250 \times 210) \times (14.4 - 13.2)}{80 - 14.4} = \frac{52500 \times 1.2}{65.6}.$$

$$= \frac{63000}{65.6} = 960.$$

Answer.—The required amount of glucose is 960 pounds.

YIELD CALCULATIONS ACCORDING TO M. SCHWARZ.

CALCULATING YIELD FROM WORT IN FERMENTER.

Taking a wort of 13 per cent extract, which is the original density for most beers in the United States, whereby the specific gravity becomes a constant factor, the following formula is deemed accurate enough for practical purposes:

Let W = barrels of wort in fermenters,
p = saccharometer reading of such wort.
B = total materials expressed in bushels of malt,
Y = the yield.

The formula then is:

$$Y = \frac{W \times p \times 8}{B}.$$

Example.—500 bushels of malt yield 288 barrels of wort in fermenters at 13.5 per cent Balling. What is the yield?

Solution.—

$$W = 288,\ p = 13.5,\ B = 500.$$

$$Y = \frac{288 \times 13.5 \times 8}{500} = \frac{31104}{500} = 62.2.$$

Answer.—The yield is 62.2 per cent.

CALCULATING YIELD FROM WORT IN KETTLE AFTER BOILING.

The amount of wort which leaves the kettle differs from that which reaches the fermenters, since in passing from the kettle to the fermenter the volume of the wort shrinks on an average 10 per cent, while the density increases by the evaporation of water, causing an increase of 4 per cent in extract. If it is desired to calculate the yield from the amount of wort in the kettle after boiling, the formula given for calculating the yield from the amount of wort in the fermenter can be used with this modification that the specific gravity factor 8 is changed to 7.5.

Let W = barrels of hot wort in the kettle,
p = Balling reading at 14° R.,
B = total materials calculated in bushels of malt,
Y = the required yield of extract.

The formula then is:

$$Y = \frac{W \times p \times 7.5}{B}.$$

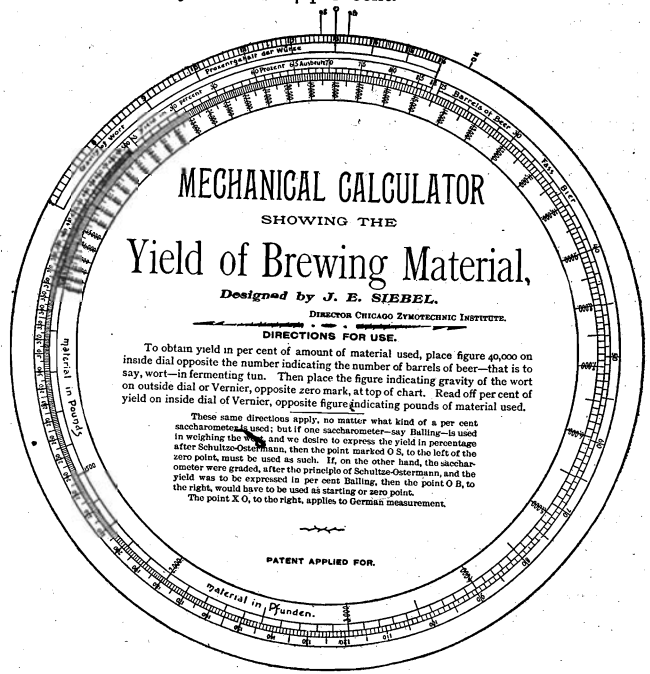
Example.—Taking the example given for calculating yield from amount of wort in fermenter, as above, there is obtained the following:

Solution.—Taking into consideration the contraction of the volume of wort from kettle to fermenter, the amount of wort of 13 per cent in the kettle, according to the above figures, is 320 barrels. Hence,

$$W = 320,\ p = 13,\ B = 500.$$

$$Y = \frac{320 \times 13 \times 7.5}{500} = \frac{31200}{500} = 62.4.$$

Answer.—The yield is 62.4 per cent.



MECHANICAL YIELD CALCULATOR BY J. E. SIEBEL.

A device for calculating the yield mechanically has been invented by J. E. Siebel, and is shown in the accompanying illustration. It is of a size to allow the printed matter on its dial to be read with ease, the illustration being considerably reduced in size.

The inside dial bearing the legend, "pounds of material," can be turned around the center, and the Vernier or segment of a circle, showing on one division gravity of wort and on another yield in per cent, can also be turned around partially. The dial showing the number of barrels of beer, or rather wort, remains stationary. The dials comprise a range of material from 1,000 to 40,000 pounds, and from 20 to 800 barrels of wort. The gravities shown on this diagram include the degrees 7 to 16, and the yields from 45 to 88 per cents, but the range of these figures may be enlarged, if desirable, on the same principle. It will be observed that in using this device it is immaterial what kind of saccharometer is used to determine the gravity of the wort, as it gives the percentage of yield always in the same denomination corresponding to that of the saccharometer. Moreover, the instrument is equally applicable if different weights and measures are used to indicate quantities of wort and raw material if the zero or starting point on the margin is shifted to a position which can be readily determined. Thus in using the point XO a little to the right of the zero point, as such, the instrument gives correct indications of yield if German pounds are used for material and hectoliters for barrels. In other words, by shifting the zero point to a point readily ascertainable in any given case, the apparatus may be adapted to any system of measurement, number of gallons per barrel, etc.

HEAT CALCULATIONS ACCORDING TO M. HENIUS.

THE BREWER'S HEAT UNIT.

For practical purposes when making calculations in the brewery we do not employ the heat unit as given in the chapter on Physics. A heat unit, as understood for the purpose of practical figuring in the brewery, is the amount of heat required to raise the temperature of one barrel of water one degree Réaumur.

The heat required to raise the temperature of larger quantities of water of a given temperature is governed by the weight of the water and the number of degrees by which the temperature is to be raised, but is independent of the original temperature of the water. In other words, in order to raise one barrel of water from 0° R. to 10° R., an equal amount of heat (= 10 heat-units) is required as to raise one barrel of water from 15° R. to 25° R., the rise being 10° in each case, and each degree requiring one heat-unit per barrel of water. Likewise, in order to raise five barrels of water of 20° R. to 80° R., five times as much heat is

required as to raise one barrel water from 20° to 80°, viz., $5 \times 60 = 300$ heat-units.

To heat 1 bbl. water from 0° R. to 1° R. or by 1°, requires	1 h. u.
To heat 1 bbl. water from 0° R. to 10° R. or by 10°, requires	10 h. u.
To heat 1 bbl. water from 35° R. to 50° R. or by 15°, requires	15 h. u.
To heat 2 bbls. water from 35° R. to 50° R. or by 15°, requires	2x15=30 h. u.
To heat 50 bbls. water from 15° R. to 80° R. or by 65°, requires	50x65=3250 h. u.

The amount of heat contained in a given quantity of water depends upon the weight of the water and its temperature. Thus, one barrel of water of 50° R. contains 50 heat-units, 20 barrels water of 50° contain $20 \times 50 = 1000$ heat-units.

Remark: The temperature of boiling water and boiling mash is taken at 78° R. in all subsequent calculations, since the water loses about 2° R. during its passage through the pipes.

CALCULATIONS WHERE WATER ONLY IS USED.

TO FIND TEMPERATURE OF MIXTURE OF WATER.

Example 1.—75 bbls. of water of 15° R. is mixed with 50 bbls. water of 70° R. What is the temperature of the mixture?

Solution.—

75 bbls. water of 15° contains $75 \times 15 = 1125$ heat-units.
50 bbls. water of 70° contains $50 \times 70 = 3500$ heat-units.

125 bbls. mixed water contains 4625 heat-units.

One barrel mixed water, then, contains the 125th part of the total heat of 4625 units.

$$4625 \div 125 = 37,$$

or 37 heat-units. Water possessing 37 heat-units per barrel has a temperature of 37°, hence:

Answer.—Temperature of the mixed water = 37° R.

TO FIND TEMPERATURE OF COLD WATER.

Example 2.—By mixing 20 barrels of boiling water with 12 barrels of cold water, the temperature of the mixture is 54° R. What was the temperature of the cold water?

Solution.—

12 bbls. water ? R.
20 bbls. water 78° R. contains $20 \times 78 = 1560$ heat-units.

32 bbls. mixed water of 54° contain $32 \times 54 = 1728$ heat-units.

From the total amount of heat of 1728 units, deduct the heat supplied by the boiling water = 1560 units. The remainder is the amount of heat that must be contained in the 12 bbls. cold water.

1728 heat-units = total amount of heat.
1560 heat-units = heat of boiling water.

168 heat-units = heat of cold water.

Dividing the amount of heat in the cold water by the number of barrels gives the temperature:

$$168 \div 12 = 14.$$

One barrel of cold water contains 14 heat-units, or

Answer.—Temperature of the cold water = 14° R.

TO FIND AMOUNT OF COLD WATER.

Example 3.—How many barrels of cold water of 15° R. are required in order to cool 30 barrels of water of 72° R. to 60° R.?

Solution.—In cooling the hot water from 72° to 60°, that is, by 12 degrees, each barrel of water gives up 12 heat-units, hence the 30 barrels of water give up 30 × 12 = 360 heat-units. This amount of heat serves to raise the temperature of the cold water from 15° to 60° to reach the final temperature of 60° in the mixed water. To raise the temperature as required from 15° to 60° = 45°, each barrel of cold water must receive an addition of 45 heat-units. There is a total of 360 heat-units available, which is given off by the hot water. It must be found how many barrels of cold water can be heated to 60° R., using 45 heat-units for each barrel.

One barrel cold water takes up 45 heat-units.
How many barrels cold water take up 360 heat-units?

$$360 \div 45 = 8 \text{ bbls.}$$

Answer.—8 barrels of cold water is required.

TO FIND AMOUNT OF BOILING WATER.

Example 4.—How many barrels of boiling water of 78° R. will be required to raise 20 barrels of water from 30° to 56°?

Solution 1.—To heat 20 barrels water from 30° to 56°, that is, by 26 degrees, requires 20 × 26 = 520 heat-units, which is taken from the boiling water. This water is thereby cooled from 78° to 56°, that is, by 22 degrees. Hence, each barrel of boiling water gives off 22 heat-units.

One barrel boiling water gives off 22 heat-units.
How many barrels boiling water give off 520 heat-units?

$$520 \div 22 = 23.6.$$

Answer.—It requires 23.6 bbls. of boiling water.

Solution 2 (Abridged).—Write the three temperatures in a column, beginning with the lowest and finishing with the highest. Take the difference between the first and the second temperatures, multiply it by the number of barrels, and divide the product by the difference between the second and third temperatures. The result is the required number of barrels of boiling water.

20 bbls. water

30° > 26
56°
78° > 22

$$\frac{26 \times 20}{22} = 23.6.$$

Answer.—23.6 barrels of boiling water.

TO FIND AMOUNTS OF COLD AND OF BOILING WATER.

Example 5.—How many barrels of cold water of 12° and how many barrels of boiling water are required to secure 35 barrels of 64°?

Solution (Abridged).—Write the three temperatures in a column as in Example 4, multiply the number of required barrels by the difference between the first and second temperatures, and divide by the difference between the first and third temperatures. This gives the barrels of hot water required. Deducting this number from the total amount of water gives the barrels of cold water.

35 bbls. water

12° > 52
64°
78° > 66

$$\frac{52 \times 35}{66} = 27.5.$$

35 bbls. total water of 64°.
27.5 bbls. boiling water of 78°.

7.5 bbls. cold water of 12°.

Answer.—It requires 27.5 barrels of boiling water and 7.5 barrels of cold water.

CALCULATIONS WHERE MALT OR RAW CEREAL AND WATER ARE USED.

Whenever malt or cereals are to be mixed with water and it is desired to determine the temperatures of such mixtures (mashes) or find the required temperature of either of these materials it must be borne in mind that it takes less heat to raise the temperature of malt or cereals than it does to heat water. Taking water as a unit it requires only 0.4 of the heat used in heating water to raise the temperature of an equal weight of malt an equal number of degrees. The figure 0.4 is called the specific heat of malt. (See "Physics.") For specific heat calculations in the brewery it is convenient to take 1,000 pounds of malt as a basis and to express its heat capacity in barrels of water.

One barrel of water weighs 258.5 pounds, but results sufficiently accurate may be obtained by taking the figure 250 as the weight of one barrel, or 1,000 pounds for four barrels. In short:

250 pounds malt = 1 barrel of water in weight.
or 1000 pounds malt = 4 barrels of water in weight.

Since the specific heat of malt is 0.4, we have

1000 pounds malt = 4 barrels × 0.4 = 1.6 barrel of water, as to heat capacity.

In order, then, to find the heat capacity of a given quantity of malt or cereals calculate 1.6 barrel of water for each 1,000 pounds of malt or cereals, or divide the number of pounds of malt or cereals by 1000 and multiply by 1.6.

Example 1.—5400 lbs. malt of 18° R. is doughed-in with 50 bbls. water of 33° R. What is the temperature of the mash?

Solution.—

$$5400 \div 1000 = 5.4.$$
$$5.4 \times 1.6 = 8.64.$$

5400 lbs. malt correspond to 8.6 bbls. water as to heat capacity.

8.6 bbls. water of 18° contain 8.6 × 18 = 154.8 heat-units.
50 bbls. water of 33° contain 50 × 33 = 1650 heat-units.

58.6 bbls. mash contain 1804.8 heat-units.

$$1804.8 \div 58.6 = 30.8.$$

Answer.—Temperature of mash = 30.8° R.

CALCULATIONS AT THE MASH TUB.

TO FIND THE TEMPERATURE OF THE DOUGHING-IN WATER.

Example.—6500 pounds of malt of 15° R. is doughed-in with 60 barrels of water. The temperature of the mash is to be 30° R. What should be the temperature of the doughing-in water?

Solution.—

$$6500 \div 1000 = 6.5.$$
$$6.5 \times 1.6 = 10.4.$$

6500 lbs. malt correspond to 10.4 bbls. water as to heat capacity.

10.4 bbls. water of 15° R. contains 10.4 × 15 = 156 heat-units.
60 bbls. water of ? R.

70.4 bbls. mash of 30° R. contain 70.4 × 30 = 2112 heat-units.

From the total heat-units of the mash deduct the amount of heat supplied by the malt, and the result will be the heat contained in the water.

70.4 bbls. mash contains 2112 heat-units.
10.4 bbls. water (malt) contains 156 heat-units.

60 bbls. doughing-in water contains 1956 heat-units

$$1956 \div 60 = 32.6.$$

Answer.—Temperature of doughing-in water = 32.6° R.

TO FIND THE FINAL TEMPERATURE (TEMPERATURE OF THE TOTAL MASH).

Example.—Doughed-in in the mash tub, 8750 lbs. malt with 80 bbls. water. Temperature of malt mash = 32°. Doughed-in in rice cooker, 6500 lbs. grits and 1900 lbs. malt, with 84 bbls. water. What is the temperature of the total mash, after the cereal mash has been run into the malt mash?

Solution.—First find how many bbls. mash are contained in the mash tub and how many in the rice cooker:

1. Malt mash.

$$8750 \div 1000 = 8.75.$$
$$8.75 \times 1.6 = 14.0.$$

14 bbls. water (malt).
80 bbls. water.

94 bbls. malt mash.

2. Cereal mash.

6500 lbs. grits.
1900 lbs. malt.

8400 lbs. materials.

$8400 \div 1000 = 8.4.$

$8.4 \times 1.6 = 13.44.$

13.44 bbls. water (materials).
84. bbls. water.

97.4 bbls. cereal mash.

94 bbls. malt mash of 32° contains $94 \times 32 = 3008$ h. u.
97.4 bbls. cereal mash of 78° contains $97.4 \times 78 = 7597.2$ h. u.

191.4 bbls. total mash contains 10605.2 h. u.

$10605.2 \div 191.4 = 55.4.$

Answer.—Final temperature = 55.4° R.

TO FIND THE DOUGHING-IN TEMPERATURE (TEMPERATURE OF THE MALT MASH).

Example.—Doughed-in in the mash tub, 6800 lbs. malt with 62 bbls. water. In rice cooker 5200 lbs. grits and 1500 bbls. malt with 64 bbls. water. Final temperature, i. e., temperature of total mash to be 56°. What should be the temperature of the malt mash when the cereal mash is run in?

Solution.—First find the bbls. of malt mash and cereal mash, respectively.

1. Malt mash.

$6800 \div 1000 = 6.8$

$6.8 \times 1.6 = 10.88.$

10.88 bbls. water (malt).
62 bbls. water.

72.9 bbls. malt mash.

2. Cereal Mash.

5200 lbs. grits.
1500 lbs. malt.

6700 lbs. materials.

$6700 \div 1000 = 6.7.$

$6.7 \times 1.6 = 10.72.$

10.72 bbls. water (materials).
64 bbls. water.

74.7 bbls. cereal mash.

72.9 bbls. malt mash of ? degrees.
74.7 bbls. cereal mash of 78° contains $74.7 \times 78 = 5826.6$ h. u.

147.6 bbls. total mash of 56° contains $147.6 \times 56 = 8265.6$ h. u.

From the heat-units of the total mash deduct the heat-units of the cereal mash; leaves the heat-units contained in the malt mash.

8265.6 h. u. in total mash.
5826.6 h. u. in cereal mash.

2439.0 h. u. in malt mash.

$2439.0 \div 72.9 = 33.4.$

Answer.—Doughing-in temperature = 33.4° R.

TO FIND THE NUMBER OF BARRELS OF CEREAL MASH.

Example.—Doughed-in in mash tub 5400 lbs. malt with 54 bbls. water. Temperature of mash = 35° R. How many barrels of cereal mash of 78° R., or boiling water, are wanted in order to raise the malt mash to 58°?

$5400 \div 1000 = 5.4.$

$5.4 \times 1.6 = 8.64.$

8.64 bbls. water (malt).
54 bbls. water.

62.6 bbls. malt mash.

Proceed according to abridged solution of Example 4, "Calculation where water only is used":

62.6 bbls. mash.

35° → 23
58°
78° → 20

$$\frac{62.6 \times 23}{20} = 71.99.$$

Answer.—Required, 72 bbls. cereal mash.

TO FIND THE BARRELS OF THICK MASH.

Example.—Doughed-in in mash tub 10500 lbs. malt with 100 bbls. water. Temperature of mash = 30°. The mash is to be heated by a thick mash to 40°, by a second thick mash to 52°, and by a "lauter" mash to 60°. How many barrels are required of the first and second thick mashes and the lauter mash?

Solution.—

$$10500 \div 1000 = 10.5.$$
$$10.5 \times 1.6 = 16.8.$$

16.80 bbls. water (malt).
100 bbls. water.

116.8 bbls. malt mash.

Proceed as in Example 5, "Calculation when water only is used":

1. Thick mash.
116.8 bbls. malt mash.

30° — 10
40°
78° — 48

$$\frac{116.8 \times 10}{48} = 24.3.$$

To raise the mash to 40° R. requires 24.3 bbls. thick mash. The total mash then has a temperature of 40°.

2. Thick mash.
116.8 bbls. malt mash.

40 — 12
52
78 — 38

$$\frac{116.8 \times 12}{38} = 36.9.$$

To raise the mash to 52° requires 36.9 bbls. thick mash. Temperature of total mash = 52°.

3. "Lauter" mash.
116.8 bbls. mash.

52 — 8
60
78 — 26

$$\frac{116.8 \times 8}{26} = 35.9.$$

To raise the mash to 60° requires 35.9 bbls. lauter mash.

Answer.—

First thick mash = 24.3 bbls.
Second thick mash = 36.9 bbls.
"Lauter" mash = 35.9 bbls.

CALCULATIONS BY MEANS OF LATENT HEAT, ACCORDING TO M. HENIUS.

COOLING CAPACITY OF ICE.

If heat is applied to ice of 0° R. it melts and changes into ice-water. Though a large amount of heat is expended in melting the ice no rise in temperature is indicated by the thermometer as long as any ice is present. The heat so absorbed is called *latent heat.* It has been found that the amount of heat it takes to melt one pound of ice will raise the temperature of one pound of water from 0° R. to 63° R., or is equal to 63 heat-units. The cooling capacity of ice is, therefore, 63 heat-units. We may here also, as in the calculations with specific heat, take for our practical figuring one barrel of water (250 pounds) as the unit of weight, and a heat-unit will then be the amount of heat it takes to raise the temperature of one barrel of water one degree Réaumur.

MIXING ICE AND WATER.

To illustrate the difference between ice and ice-water as to cooling capacity, the following examples will suffice:

Example 1.—Ten barrels of water of 78° R. are to be mixed with 10 barrels of water of 0° R. What is the temperature of the mixture?

Solution.—

10 barrels of water of 78° contain 10 × 78 h. u. = 780 h. u.
10 barrels of water of 0° contain 10 × 0 h. u. = 0 h. u.

20 barrels of water contain 780 h. u.
or one barrel contains 780 heat-units ÷ 20 = 39 heat-units, hence:

Answer.—Temperature of the mixture is 39° R.

Example 2.—Ten barrels of water of 78° R. are to be mixed with 10 barrels of ice (250 pounds each) of 0° R. What is the temperature of the mixture?

Solution.—The 10 barrels of water contain 78 × 10 heat units = 780 heat units. The 10 barrels of ice absorb 10 × 63 heat units = 630 heat units and are then changed into 10 barrels of ice water of 0° R. The heat units so absorbed are taken from the 780 heat units of the hot water, and after melting all the ice there are left 780 — 630 = 150 heat units in the hot water.

10 barrels of water containing 150 heat units
10 barrels of water containing 0 heat units

20 barrels of water containing 150 heat units.

One barrel contains 150 ÷ 20 = 7.5 heat units.

Answer.—Temperature of the mixture is 7.5° R.

We see from the two examples that while 10 barrels of ice-water of 0° R. cools the water of 78° R. to 39° R. only, the same quantity of ice reduced the temperature to 7.5° R.

COOLING WATER BY ICE.

If ice is melted and the resulting ice-water of 0° R. is raised to a higher temperature, then the heat absorbed is the sum of the latent heat and the heat required to raise the temperature to the desired point.

Example 3.—We want to cool 10 barrels of water of 78° R. to 4° R. with ice. How many barrels of ice does it require?

Solution.—To cool 10 barrels from 78° R. to 4° takes (78 — 4) × 10 heat units = 740 heat units, which must be absorbed by the ice. Each barrel of ice, when melting, absorbs 63 heat units, and as the water should have a temperature of 4° R., the melted ice must absorb four more heat units in rising from 0° to 4° R., or in all 63 + 4 = 67 heat units. As 740 heat units must be absorbed it takes 740 ÷ 67 = 11 barrels ice to cool 10 barrels of water from 78° R. to 4° R.

Answer.—It requires 11 barrels of ice (250 pounds each).

From the data given above we may construct the following formula:

$$\text{Bbls. ice required (250 lbs. each)} = \frac{\text{No. bbls. water} \times (\text{high temp.} - \text{end temp.})}{\text{Cooling capacity of ice} + \text{end temperature}}$$

It being more practical to get the result in tons of ice (2,000 pounds) instead of barrels of ice, 1 ton = 8 barrels, we can, by multiplying the barrels of ice, the latent heat and the end temperature by 8, change the formula as follows:

$$\text{Tons of ice} = \frac{\text{Barrels of water} \times (\text{high temp.} - \text{end temp.})}{\text{Cooling capacity} \times 8 + (\text{end temp.} \times 8)},$$

or taking latent heat 63 × 8 = 504 as 500 and abbreviating still further we have

$$\text{Tons of ice} = \frac{\text{Barrels of water} \times (\text{high temp.} - \text{end temp.})}{500 + (8 \times \text{end temperature})}.$$

Example 4.—(Abridged Method.) Taking Example 3 as an illustration, we have:

Solution.—

Barrels = 10.
High temperature = 78° R.
End temperature = 4° R.

$$\text{Tons of ice} = \frac{10 \times (78 - 4)}{500 + (8 \times 4)} = \frac{10 \times 74}{500 + 32} = \frac{740}{532} = 1.39$$

Answer.—1.39 tons.

We found in Example 3 that we required 11 barrels of ice; as 8 barrels of ice = 1 ton of ice, we have 11 ÷ 8 = 1.38 tons, and in Example 4, using the formula, 1.39 tons, which proves that our formula answers all practical purposes.

COOLING WORT BY ICE.

If we have to cool wort by means of ice we may employ the formula for water without any changes, because the heat capacity of a barrel of wort is about the same as that of a barrel of water, as the following reflection will show: One barrel of ordinary cold wort of, say, 13 per cent Balling weighs 259 + 13 = 272 pounds and contains 35 pounds extract and 272 — 35 = 237 pounds of water. The 35 pounds of extract have a specific heat of 0.4 or a heat capacity of only 0.4 × 35 = 14 pounds of water. The heat capacity of a barrel of wort of 13 per cent Balling is, therefore, equal to 237 + 14 = 251 pounds of water.

Example 5.—131 barrels of wort is to be cooled by ice from 7° R. to 3° R.

Solution.—

Barrels = 131.
High temperature = 7° R.
End temperature = 3° R.

$$\text{Tons of ice} = \frac{131 \times (7 - 3)}{500 + (8 \times 3)} = \frac{131 \times 4}{500 + 24} = \frac{524}{524} = 1.$$

Answer.—We use 1 ton of ice to cool 131 barrels of wort from 7° R. to 3° R.

When figuring with hot wort, a barrel of which weighs less than a barrel of cold wort, the formula gives results sufficiently accurate for all practical purposes.

In all the calculations no account has been taken of the ice melted by outside heat.

LATENT HEAT OF STEAM.

If a pound of steam of 80° R. is forced into water of 0° R. and condensed, the heat thus given out will raise the temperature of 5.37 pounds of water from 0° R. to 80° R., which is equal to $80 \times 5.37 = 430$ heat units. This amount of heat will also be absorbed in changing one pound of water of 80° (just on the verge of boiling) into one pound of steam of the same temperature or 80°. This heat is called the latent heat of vaporization, and is very nearly seven times the amount of heat absorbed by melting ice. The latent heat of steam at different pressures varies from that of steam of 80° R., but the differences being slight are not considered in the following.

The calculations for heating water with steam are very similar to those for melting ice, as a few examples will show.

Example 1.—How many pounds of steam are needed to heat 10 barrels of water from 14° R. to 40° R.

Solution.—Ten barrels of water equal 10×250 or 2,500 pounds of water, which, when warmed from 14° R. to 40°, or 26° R., require $2{,}500 \times 26$, or 65,000 heat units. One pound of steam gives off in the form of latent heat, 430 heat units, and the water so formed when cooling from 80° R. to 40° R., the desired temperature, an additional 40 heat units or a total of $430 + 40 = 470$ heat units. As the water needs 65,000 heat units and each pound of steam supplies 470 heat units we require $65{,}000 \div 470 = 138.5$ pounds steam.

Answer.—138.5 pounds of steam.

The formula, then, for figuring the number of pounds of steam it requires to heat a certain number of barrels of water would be

$$\text{Lbs. of steam} = \frac{\text{Bbls. water} \times 250 \times (\text{end temp.} - \text{low temp.})}{\text{Latent heat of steam (430)} + 80 - \text{end temp.}}$$

$$= \frac{\text{Barrels} \times 250 \times (\text{end temp.} - \text{low temp.})}{510 - \text{end temp.}}.$$

Example 2.—How many pounds of steam does it take to heat 120 barrels of water from 10° R. to boiling, 80° R.?

Solution.—

Barrels = 120.
End temperature = 80° R.
Low temperature = 10° R.

$$\text{Lbs. steam} = \frac{120 \times 250 \times (80 - 10)}{510 - 80} = \frac{30000 \times 70}{430} = 4884.$$

Answer.—4884 pounds of steam.

If we take the power of evaporation of 1 pound of coal to be 8 pounds of water, it would take $\frac{4884}{8} = 610$ pounds of coal to heat 120 barrels of water from 10° R. to boiling.

CALCULATION OF ATTENUATION.

In the calculation of attenuation Balling's treatise on attenuation (attenuate = thinning, decreasing the amount of extract) was used as a basis, but in a modified and simplified form, so as to meet the requirements of the practical brewer, for whose purpose the results obtained, which, to some extent, differ from those obtained by an exact chemical analysis, are sufficiently accurate.

BALLING OF WORT AND APPARENT EXTRACT.

In a wort the saccharometer (see "Saccharometry") indicates the number of pounds of extract contained in 100 pounds of wort, the Balling of wort. After adding yeast to this wort fermentation sets in (sugar is split up into alcohol and carbonic acid gas) and the saccharometer indication decreases day by day until the fermentation comes to a stop. The indications of the instrument, however, no longer, as they did in the wort originally, correspond to the extract *really* contained in the fluid because the beer contains alcohol which, being specifically lighter than water, allows the saccharometer to sink lower than it would do in a fluid containing an equal amount of extract dissolved in water only instead of in a mixture of water and alcohol. In other words, the saccharometer apparently indicates the extract contained in the beer while in reality it shows less than is actually present. The saccharometer indication of a beer is, therefore, called apparent extract.

In the following the apparent extract will be designated as the "Balling of beer," which is identical with "saccharometer indication of beer," or "density of beer," while the "original density," "original gravity," "original wort," or "extract of wort" will be designated as "Balling of wort," which then means the number of pounds of extract contained in one hundred pounds of wort in the cellar.

REAL EXTRACT.

In order to find the actual amount of extract contained in beer by means of a saccharometer it is necessary for reasons given above to remove the alcohol by distillation, and then add water again until the original weight is restored. In the liquid so obtained, free from alcohol, the saccharometer will show the extract contained in the beer. This is called the "real extract."

If we know the extract contained in the original wort, "Balling of wort," and the extract (sugar) fermented, we can readily ascertain the extract of the beer by deducting the extract fermented from the "Balling of wort."

APPARENT ATTENUATION AND REAL ATTENUATION.

The difference between the Balling of wort and the Balling of beer is called the "apparent" attenuation. It is the decrease of the saccharometer indication during fermentation.

The difference between the Balling of wort at the time when fermentation began, and the extract in the beer, is called the "real" attenuation, because it shows the actual decrease of extract by fermentation and represents the amount of sugar that has been fermented.

CALCULATING ALCOHOL CONTENT.

Since the real attenuation represents approximately the fermented sugar, it serves as a basis from which to figure the amount of alcohol in the beer, the effect of fermentation being to split up the sugar into two almost equal parts, one of alcohol, the other of carbonic acid. The latter escapes almost wholly, whereas the alcohol remains in the beer. The amount of alcohol can be found, therefore, by dividing the real attenuation by two.

The alcohol can also be calculated from the apparent attenuation by multiplying the same by a given alcohol factor, which differs according to the original density of the wort. For an original density of 11 per cent Balling the alcohol factor is 0.417; for a wort of 14 per cent it is 0.423, average 0.42. Now, the Balling indication of nearly all worts lies between the figures given. For practical purposes sufficient accuracy is, therefore, obtained by using 0.42 as the alcohol factor.

The alcohol content of beer, accordingly, can be calculated in either of two ways:

1. by dividing the real attenuation by 2, or
2. by multiplying the apparent attenuation by 0.42.

And, vice versa, the two attenuations can be found from the alcohol content, that is,

1. the real attenuation by multiplying the alcohol content by 2, and
2. the apparent attenuation by dividing the alcohol content by 0.42.

ATTENUATION FORMULA.

Summarizing we have:

Saccharometer indication	= Balling	= B.
Original wort extract	= Balling of wort	= B. W.
Apparent extract	= Balling of beer	= B. B.
Balling of wort — Balling of beer	= Apparent attenuation	= A. A.
Apparent attenuation × 0.42	= Alcohol	= Al.
Alcohol × 2	= Real attenuation	= R. A.
Balling of wort — real attenuation	= Real extract in beer	= R. E.

Example 1.—A wort in the cellar weighs 13 B. After fermentation the saccharometer indicates 4 B. How much alcohol and extract does the beer contain? What is the real and what the apparent attenuation?

Solution.—

Balling of wort	= 13
Balling of beer	= 4
Apparent attenuation	= 9
	× 0.42
Alcohol	= 3.78
	× 2
Real attenuation	= 7.56
Balling of wort	= 13
Real attenuation	— 7.56
Real extract	= 5.44

Answer.—The beer contains 3.78 per cent alcohol and 5.44 per cent extract. The real attenuation is 7.56, the apparent attenuation, 9.

APPARENT AND REAL DEGREE OF ATTENUATION.

In comparing two beers as to their apparent or real attenuation it is obvious that satisfactory results cannot be obtained if we do not know the *percentage* of the *extract,* which apparently or really attenuated, and this we can only figure out if the Balling of wort is known.

The following will serve as an illustration:

The analyses of two beers gave these results:

	No. 1.	No. 2.
Balling of wort	13.5	15.00
Balling of beer	3.5	5.00
Apparent attenuation	10.00	10.00
Alcohol	4.2	4.2
Real attenuation	8.4	8.4
Real extract of beer	5.1	6.6

It will readily be seen from the above figures that if we were to judge the two beers as to their composition, and only knew either the apparent or the real attenuation, or both, we would be justified in calling these beers identical. That they, however, are different we learn by noting the Balling of wort, which is different in the two beers, but still we cannot form an opinion as to their attenuation (real or apparent) before we have found the percentage of the extract that really or apparently fermented. This can easily be calculated by dividing the real or apparent attenuation by the Balling of wort, and multiplying by 100. We thus convert the apparent, or real attenuation into per cent of apparently or really fermented extract, and the figures so obtained we may, for purposes of convenience, which will be readily understood, term "apparent degree of attenuation" and "real degree of attenuation."

The apparent degree of attenuation then shows how many out of a hundred parts of extract *apparently* fermented, the real degree of attenuation, how many parts out of one hundred parts *really* fermented.

$$\frac{\text{Apparent attenuation} \times 100}{\text{Balling of wort}} = \text{Apparent deg. of atten.} = \text{A. D. A.}$$

$$\frac{\text{Real attenuation} \times 100}{\text{Balling of wort}} = \text{Real degree of attenuation} = \text{R. D. A.}$$

Example.—Balling of wort is 14. Balling of beer from this wort is 4.5. What is the apparent degree of fermentation and what the real degree of fermentation?

Solution.—

B. W. (Balling of wort)	14
B. B. (Balling of beer)	4.5
A. A. (apparent attenuation)	9.5
Al. (alcohol)	$9.5 \times 0.42 = 4$
R. A. (real attenuation)	$4 \times 2 = 8$
R. E. (extract in beer)	$14 - 8 = 6$

$$\text{A. D. A.} = \frac{\text{A. A.} \times 100}{\text{B. W.}} = \frac{9.5 \times 100}{14} = 67.8.$$

$$\text{R. D. A.} = \frac{\text{R. A.} \times 100}{\text{B. W.}} = \frac{8 \times 100}{14} = 57.1.$$

Answer.—Apparent degree of attenuation = 67.8. Real degree of attenuation = 57.1.

SUGAR DEGREE.

The extract of wort consists of a number of substances, chief of which are sugars, then follow dextrins, malto-dextrins, albuminoids, mineral substances, hop extract, lactic acid, etc. It has been customary heretofore to express the relative amount of sugar in the extract in the form of ratio of sugar to the other substances (non-sugar), taking either 100 or 1 as the sugar basis, but as the figures so obtained are misleading, especially if 100 is taken as a unit, and consequently the percentage of sugar and the ratio of sugar are often confounded, we have adopted, in conformity with the terms real and apparent degree of attenuation, the term "sugar degree," which simply means the parts of reducing sugars (commonly called sugar) contained in 100 parts of extract.

$$\text{S. D. (sugar degree)} = \frac{\text{Sugar} \times 100}{\text{B. W.}}.$$

Example.—By analysis it was found that a wort contained 13 per cent of extract, 9 parts of which were reducing sugars. What is the sugar degree?

Solution.—In 13 parts of extract, 9 are sugar, how many parts in 100 will be sugar?

$$\frac{9 \times 100}{13} = \frac{900}{13} = 69.2.$$

Answer.—Sugar degree is 69.2.

RATIO OF SUGAR TO NON-SUGAR.

If it is desired to find the ratio of sugar to non-sugar proceed in the following manner:

Example.—In 13 parts of extract, 9 parts were sugar, consequently 13 — 9 = 4 parts were non-sugar.

Solution.—

9	:	4	=	100	:	?
Sugar		Non-sugar		Sugar		Non-sugar.

$$\frac{4 \times 100}{9} = \text{Non-sugar.}$$

$$44 = \text{Non-sugar.}$$

Answer.—Ratio of sugar to non-sugar 100 : 44, or, if the sugar unit is one, 1 : 0.44.

FIGURING IN ENGLISH BREWERIES.

One barrel (English) = 36 gal., 10 lbs. each = 360 lbs.
A quarter (English) = 8 bu., 42 lbs. each = 336 lbs.
A hundredweight (cwt.) = 112 lbs.
L = saccharometer indication according to Long's scale (see below).

GRAVITY.

By "Gravity" the English brewer understands either "Brewers' Pounds" or "Degree of Specific Gravity."

BREWERS' POUNDS AND LONG'S SCALE.

"Brewers' Pounds" expresses the number of pounds a barrel of wort weighs more than a barrel of water of 360 pounds at 60° F. If a barrel of wort weighs 375 pounds the wort will then be called a 15-pound wort (375 — 360 = 15). After fermentation, this beer would still be called a 15-pound beer. Long's saccharometer, which is in general use, indicates "Brewers' Pounds."

DEGREE OF SPECIFIC GRAVITY.

If we take 1,000 parts of water as a unit of weight and weigh an equal volume of wort (or beer) at the same temperature, then the relation between the weight so obtained and 1,000 gives us the specific gravity of the wort or beer.

It is not customary, however, to give the specific gravity of the wort or beer, but simply to use the figure in excess of 1,000 which is called the "degree of specific gravity."

Example.—If the specific gravity of a wort is 1,050, then we speak of the wort as a 50 gravity wort (1,050 — 1,000 = 50), or the degree of specific gravity of the wort is 50.

TO CONVERT DEGREES OF SPECIFIC GRAVITY INTO BREWERS' POUNDS.

From the above it will be readily seen that 1,000 holds the same relation to "degree of specific gravity" as 360 to "brewers' pounds" (or Long).

$$\frac{\text{Brewers' lbs.}}{\text{D. S. G.}} = \frac{360}{1{,}000} = \frac{0.36}{1} = 0.36.$$

Therefore, by multiplying the degrees of specific gravity by 0.36 we obtain the equivalent in brewers' pounds.

Example.—Degree of specific gravity of a wort is 60. State equivalent in brewers' pounds.

Solution.—

$$60 \times 0.36 = 21.6.$$

Answer.—Brewers' pounds = 21.6.

TO CONVERT BREWERS' POUNDS INTO DEGREES OF SPECIFIC GRAVITY.

By dividing the brewers' pounds by 0.36 we obtain the degree of specific gravity.

Example.—How many degrees specific gravity are 15 brewers' pounds?

Solution.—

$$\frac{15}{0.36} = 41.67.$$

Answer.—41.67 degrees specific gravity.

We may also multiply by 2.78 (1 ÷ 0.36 = 2.78). Taking above example we have 15 × 2.78 = 41.7.

SOLID EXTRACT PER BARREL.

The brewers' pounds per barrel shows us the excess weight of a barrel of wort as compared to a barrel of water, but gives us no information about the actual quantity of solid extract contained in a barrel of wort. In order to understand the relation between the brewers' pounds and the actual pounds of solid extract contained in a barrel of wort the following will serve as an illustration:

One barrel of water weighs 360 pounds. If we mix 35 gallons of water with one gallon of dry sugar, a gallon of water weighing 10 pounds and a gallon of sugar weighing 16 pounds we have

35 gals. of water, 10 lbs. each, weighs 350 lbs.
1 gal. of sugar, 16 lbs. each, weighs 16 lbs.

36 gallons of water and sugar weighs 366 lbs.

Brewers' pounds of this wort are 6 (366 — 360 = 6), while the barrel contains 16 pounds of solid extract; therefore, the ratio between the solids contained in the wort and the brewers' pounds is 16 to 6 or about 2.67. (The correct figure is 2.59, but 2.6 is generally employed.) This calculation is based upon the fact that cane sugar has the same sp. gr. as dry malt extract. As 1 brewers' pound = 2.6 pounds sugar (or extract) 1 pound of sugar = $\frac{1}{2.6}$ or 0.39 brewers' pounds, and a cwt. of sugar = 112 × 0.39 or 43.68 brewers' pounds, or 1 cwt. of dry cane sugar will yield 43 brewers' pounds. A glucose, although apparently dry, may have several per cent water and will consequently yield less than 43.

TO CONVERT BREWERS' POUNDS INTO SOLID EXTRACT PER BARREL.

Rule.—Multiply brewers' pounds by 2.6.

Example.—Brewers' pounds of a beer = 25; how many pounds of solid extract does the barrel contain?

Solution.—

$$25 \times 2.6 = 65.$$

Answer.—A barrel contains 65 pounds of solid extract.

TO CONVERT POUNDS OF SOLID EXTRACT INTO BALLING.

By multiplying brewers' pounds by 2.6 we find, as shown above, the number of pounds of solid extract contained in a barrel of wort. Knowing now the weight of a barrel of wort (360 + L) and the solid extract contained therein (L × 2.6) we can readily ascertain the pounds of solid extract contained in 100 parts of the wort, or the Balling indication as follows:

$$B = \frac{L \times 2.6 \times 100}{360 + L.} = \frac{260 \times L.}{360 + L.}.$$

Example.—What is the Balling of a 25 pound wort?

Solution.—

$$\frac{260 \times 25}{360 + 25} = \frac{6500}{385} = 16.9.$$

Answer.—16.9 Balling.

YIELD.

In England it is customary to express the yield in pounds extract per quarter of malt, which, of course, is entirely arbitrary and has nothing in common with the yield proper that expresses the number of pounds of solid extract obtained from 100 pounds of material. By multiplying the number of barrels of wort obtained in a brew by the gravity (Long) and dividing by the number of quarters used, we obtain the extract yielded per quarter of malt. If sugar is used the extract obtained from the sugar must first be deducted before division takes place.

$$\text{Brewers' extract yielded} = \frac{\text{barrels} \times \text{brewers' lbs. (Long)}}{\text{Number of quarters}}.$$

$$= \frac{\text{Bbls.} \times \text{L.}}{\text{Qrs.}}.$$

Rule.—Multiply number of barrels by brewers' pounds (Long) and divide by number of quarters.

Example 1.—100 barrels brewed at 20 pounds employing 23.5 quarters of malt; state the yield.

Solution.—

$$\frac{100 \times 20}{23.5} = 85.$$

Answer.—Yield per quarter 85.

Example 2.—300 barrels wort were brewed at 20 pounds from 57 quarters of malt and 30 cwt. of sugar (sugar yielding 35 extract per cwt.). State the yield.

Solution.—

$$\frac{(300 \times 20) - (30 \times 35)}{57} = \frac{6000 - 1050}{57} = 87.$$

Answer.—87 yield extract per quarter.

SOLID EXTRACT PER QUARTER.

The solid extract of a quarter can readily be found by multiplying the extract per quarter by 2.6 (this factor is approximately correct).

Rule.—Multiply extract per quarter by 2.6.

Example.—Brewers' extract per quarter = 87; how many pounds of solid extract does a quarter yield?

Solution.—

$$87 \times 2.6 = 226.2.$$

Answer.—One quarter yields 226.2 pounds of solid extract.

SOLID EXTRACT PER HUNDRED POUNDS, OR EXTRACT PER CENT.

Knowing the solid extract per quarter (336 pounds) we can readily find the solid extract obtained from 100 pounds (extract per cent) of malt by multiplying by 100 and dividing by 336, or dividing by 3.36 ($\frac{336}{100}$).

Rule.—Divide solid extract per quarter by 3.36.

Example.—Solid extract per quarter = 226.2; what is the extract per cent?

Solution.—

$$\frac{226.2}{3.36} = 67.3.$$

Answer.—Extract per cent = 67.3.

TO CONVERT BREWERS' EXTRACT PER QUARTER INTO EXTRACT PER CENT YIELDED.

By employing the two preceding rules we derive the following rule:

$$\text{Extract per cent} = \frac{\text{Lbs. per quarter} \times 2.6}{3.36}.$$

$$= \text{Lbs. per quarter} \times \frac{2.6}{3.36}.$$

$$= \text{Lbs. per quarter} \times 0.774$$

Rule.—Multiply pounds per quarter by 0.774.

Example.—Pounds per quarter 83.5. Find extract per cent.

Solution.—

$$83.5 \times 0.774 = 64.6.$$

Answer.—64.6 per cent extract.

TO FIND QUANTITIES OF MATERIALS TO BE USED.

The quantity of material to be used in a brew can be found by multiplying the number of barrels to be brewed by the desired gravity (pounds) and dividing by the extract yielded per quarter. If materials other than malt are to be employed the extract yielded by them should be deducted from the extract yielded by the malt before dividing by the extract per quarter of malt.

$$\text{Quarters} = \frac{\text{Barrels} \times \text{brewers' pounds (L.)}}{\text{Extract per quarter}}.$$

Example 1.—In producing 200 barrels of 18 pounds a malt is employed yielding 86 pounds extract per quarter. How many quarters of malt are required for the brew?

Solution.—

$$\frac{200 \times 18}{86} = 41.9.$$

Answer.—We employ 41.9 quarters of malt.

Example 2.—The same number of barrels of same strength as in Example 1 are to be brewed from malt and sugar, using 20 cwt. of glucose (yielding 36 pounds per cwt.). How much malt is required?

Solution.—

$$\frac{(200 \times 18) - (20 \times 36)}{86} = \frac{3600 - 720}{86} = 33.5$$

Answer.—We employ 33.5 quarters of malt.

SUMMARY.

In figuring according to English usage it should then be borne in mind that:

1. Brewers' pounds = excess of weight, in pounds, of a barrel of wort (or beer) over a barrel of water (360 pounds).
2. Pound beer or pound gravity or saccharometer indication according to Long = L. = brewers' pounds (see 1).
3. Specific gravity or degree of specific gravity = excess number over 1,000 (the unit of water).
4. Extract, or brewers' extract, per quarter, generally 80—90 pounds, is an arbitrary figure based upon the extract as indicated by the Long saccharometer.
5. Dry or solid extract = real extract contained in wort or beer.
6. Extract per cent = solid extract per 100 pounds of material.
7. Material = quarters of malt.
8. Final attenuation of a beer is the saccharometer indication of the beer according to Long.