ON THE MANUFACTURE OF SUGAR IN BELGIUM.

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RAW MATERIAL.

The raw material from which sugar is made in Belgium is the Beet-root. This plant, which is indigenous to the south of Europe, in Spain, Portugal, &c., was imported into Belgium in the 16th century. It was only however in the last century that its cultivation became extensive; this was in consequence of the continental blockade, which made it necessary that Belgium should manufacture her own sugar, so as to replace that which had formerly come exclusively from the Colonies.

A good sugar beet-root does not exceed 1 kilogramme (2·2 lbs.) in weight, and in general weighs from 400 to 700 grammes. Beyond the latter figure, and without exception, the larger it becomes the less rich is it in sugar. The roots richest in sugar are always found of a weight between 400 and 500 grammes; below 400 grammes the quality becomes inferior; the weight is abnormal, and shows a tendency to disease, or the occurrence of some hindrance to the growth of the root. In general the purity of the juice goes hand in hand with its richness, the exceptions to this rule being rare. The best shape is that of an elongated pear, regular in form, not forked, and without lateral rootlets; the flesh is white, dense, opaque and brittle; the head is small, and rises but a short distance out of the ground. A fact confirmed by thousands of analyses is that, other conditions remaining the same, the white varieties are richer in sugar than the red; and similarly the elongated form is superior to the round form in this particular.

As to soil, beet-root will grow in any soil, but that which suits it the best is an earth of moderate consistency. The one condition which is indispensable for the success of all sugar-bearing roots is an earth which is deep and a sub-soil which is permeable to moisture, for they are eminently disposed to send out tap-roots.

It is usual in Belgium to make beet-root the first crop in the course of agriculture, so as to receive the first effect of the manure. The two-year course, beet-root and barley, is but little used; the four-year course, beet-root, barley, clover, barley, is perhaps the most common. At the Agricultural Institute in Gembloux the course is as follows—beet-root, barley, clover, barley, beet-root, barley. Sometimes a three-year course, beet-root, barley, clover, is used; but in this case the beet-root has a disadvantage in following the clover. Regular courses of this kind are only adhered to by good farmers.

The manures ordinarily employed for beet-root are the common refuse of the farm, assisted by chemical manures; the quantities depend often upon those which are at the disposal of the farmer. Good farmers ordinarily apply 30,000 or 40,000 or 50,000 kilogrammes to the hectare (12 to 20 tons per acre), together with 500 to 600 kilogrammes of artificial manure (4 to 5 cwt. per acre). Such manures generally contain 4 to 5 per cent. of assimilable nitric and ammoniacal compounds; 5 to 6 per cent. of assimilable phosphoric acid (mono-calcic or bi-calcic); and 6 to 8 per cent. of potash. This manure is quite sufficient both as to quantity and quality. To this is often added a certain quantity—10,000 to 20,000 kilogrammes per hectare, or 4 to 8 tons per acre—of scum, &c. from the sugar works themselves, which forms an excellent manure.

The farm manure is ploughed in in the ordinary way; the chemical manures are always applied in the spring, and buried less deep. They are scattered broadcast over the last harrowing but one, and covered in by the last. As we have said, the beet-root receives the first effects of the manure; as its vegetation is of short duration, it is indispensable, especially as regards quality, that the farm manures should be applied before the winter comes on, in order that their decomposition may be as advanced as possible.

Numerous experiments have shown the results of manuring to be as follows:—

I. A powerful manure, especially if slowly applied, augments the quantity to the disadvantage of the quality of the product, as to quantity of sugar and purity of juice.

II. Manures rich in nitrogen have a similar effect.

III. Manures containing potash, although they bring in an element which is harmful in the manufacture, are indispensable for the development of the sugar, as well as for the growth of the root.

IV. Phosphates have an excellent effect on the quality of the beet-root.

V. Lime appears to have a remarkable effect on the purity of the juice, as well as on its richness in sugar.

As to the preparation of the soil, good farmers after the harvest are accustomed to plough their land slightly, in preparation for beet-root. The object is to make the seeds of grass &c. germinate, in order that they may be destroyed at a later period. They then apply the manure, and plough again before the winter. This ploughing is especially useful for heavy soils, since, in addition to advancing the decomposition of the manure, it exposes the ground to the frost, so that it is broken up in a way that no mechanical means could ensure. Some days after ploughing afresh in the spring, the ground is harrowed and rolled alternately, until the soil is perfectly broken up, after which the sowing is done upon the last harrowing.

In Belgium sowing takes place about the second half of April. The young plants spring up about the beginning of May; and have thus nothing to fear from late frosts.

Good farmers experiment on their seed before sowing, in order to ascertain its germinating powers. Special germinators, of which that of Nobbe is most in use, are employed for the purpose, or mere earthenware pots filled with earth. The conditions indispensable to germination are air, warmth, and moisture; the most suitable temperature is from 59° to 72° Fahr. Good seed will give 80 to 90 per cent. of germinated grains within ten days. If the number falls below 70 per cent. the seed is of doubtful character, due either to damage or to adulteration.

Seed which has been thus tested is sown by means of sowing machines, of which that most in use is the spoon machine of Smyth.

The space between the rows is 35, 40, or 45 centimetres (14, 16, or 18 in.), and the depth of sowing 3 to 4 centimetres (1 to 1½ in.). In each row the plants are at distances of 25, 28, and 30 centimetres (10, 11, and 12 in.). During the sowing a labourer leads the horse by hand, a precaution necessary to get the lines straight and thereby render possible the operations to be subsequently performed by means of horses.

Experiments made at the Agricultural Institute of Gembloux give the following results:—

I. A distance of 40 centimetres (16 in.) between the lines, and 25 centimetres (10 in.) between the plants, is especially to be recommended, both as regards weight and richness in sugar of the crop.

II. By adopting these distances, in place of 45 centimetres (18 in.) and 30 centimetres (12 in.), which are most common in Belgium, and by selling his crop upon analysis, the farmer will obtain not only a larger return per acre, but will produce superior beet-root and do real justice to the industry he follows.

As to the quantity to be sown, it was formerly 15 kilogrammes per hectare (13 lbs. per acre); but at that time gaps were numerous in the sowing, and at present 20 to 25 kilogrammes (18 to 22 lb.) are employed. Theoretically this quantity is perhaps ten times too great; but the amount of seed thus spent is much more than recouped by the crop obtained.

A roller follows the sower and covers in the grain. As soon as the plants spring out of the soil, the farmer begins a series of hoeings, which succeed each other at intervals more or less short. The number cannot be determined beforehand, for in moist and hot years, when weeds grow apace, it is often necessary to begin a second hoeing before the first is ended. A horse-hoe is employed. The destruction of the weeds should be completed by repeated weedings, which should commence as soon as possible. The longer the delay the greater the growth of the weeds, and the greater the inconvenience of their removal.

These hoeings and weedings have a double aim, first the complete breaking up of the soil, secondly the destruction of the weeds.

We have seen that to avoid gaps more seed is sown than is required. This seed springs up thickly and in a continuous row, but as the roots are to be spaced 25 to 30 centimetres apart (10 to 12 in.), a clearing is necessary. This clearing is done roughly by hoes, and afterwards completed by hand; the latter is a delicate operation which requires much care. Children move over the field on their knees and pluck up the superfluous plants. They leave one at each 30 centimetres, trying always to preserve the finest plants. This operation should be carried out as soon as possible, for the superfluous plants act the part of weeds. They may also entangle their rootlets with those of the plants to be left, which produces disease and deformity in the latter.

The beet-root has a tendency to become an annual plant; hence every year some plants scattered over the field are seen to run to seed. These stalks must be removed, since the root becomes tough, and partially loses its sugar.

The beet-root becomes ripe about the end of October, but economical reasons require its being pulled from the 15th to the 30th September, so that all which cannot be worked up at once may be placed in silos. They are pulled by hand, the labourers drawing the roots from the earth and laying them on the ground. Others follow, pick up the roots, and cut off the top with a knife. The tops and leaves remain on the ground for manure. The roots, thus lopped and freed from the earth hanging about them, are placed upon wagons, which transport them to the sugar works.

The amount of the crop varies exceedingly, depending on the nature of the soil, of the seed, of the cultivation, of the weather, &c. On an average a crop of 40,000 kilogrammes per hectare (16 tons per acre) may be expected, with a richness in sugar varying from 9 to 11 per cent. Crops are frequently met with however of 60,000 to 70,000 or even 80,000 kilogrammes to the hectare (24, 28, and 32 tons per acre), but in such cases the richness of the sugar falls from 9 down to 7½ per cent.

To obtain seed, when it is desired to make sure of its quality, a certain quantity of roots, which are chosen as the finest, are preserved in silos or in cellars, and are carefully looked after. In the spring these roots are replanted, and they run to seed the same year.

Such roots should be chosen from those which are the richest in sugar; they will give seed suitable for reproducing beet-root of good quality, their properties being transmitted from one generation to another. This choice is not easy to make, for the richness must be judged of without destroying the root, inasmuch as it has to be replanted in order to give seed.

Many farmers choose their seeding roots by throwing them into a pan of water mixed with sea-salt, and raised to a density of about 1·05. Some of the roots swim, being less dense than the liquid, and these are rejected as ill suited for reproduction. The others sink; these are the best, and are preserved for seed. The principle in this method is that the densest roots are the richest in sugar. The principle is correct, but cannot be rigorously applied: there are numerous failures, chiefly due to the fact that the tops are not all cut at the same level, and that those roots which have more top have a tendency to float, although they may be of excellent quality.

Another process, more sure in its effects than the last, consists in analysing a part of the root, leaving it in a state in which it will still grow after being replanted. M. Vilmorin, the author of the process, uses for this purpose a probe like a cheese-taster, a small copper cup lined with silver, a rasp, a meter for density, a thermometer, and a gauge. By means of the probe he takes a cylinder of flesh from the centre of the beet-root. This is rasped up, pressed in a linen cloth, and the juice run into the gauge. The temperature and density of this juice are taken, and then by special tables an approximation can be made to the richness in sugar of the beet-root operated upon. The principle here is the same as in the previous method, namely that a denser juice is richer in sugar. It is however a long process, scarcely practicable on a large scale; its advantage is that it operates on the centre of the beet-root apart from its outside, but it is still only approximate on account of the dry constituents, which though free from sugar equally affect the measure of density. The beet-roots being thus chosen for seed, the hole left by the probe is filled up with clay, and the roots are preserved out of the reach of the frost until the spring, when they are replanted.

For the cultivation of the seed the land is made ready as for ordinary sowing. In April the selected roots are replanted at distances of 60, 80, or 100 centimetres from each other (24, 32, or 40 in.), and in lines. The field ought to be at a distance from any other field which contains other seeding plants, otherwise a mixture might take place to the damage of the beet-root. These plants become very strong, especially in good soil. Under the weight of the seed they are very apt to turn over, which is avoided by the use of supports. The seed is ripe in September. To gather it one ought not to wait until all the seeds are ripe, as the finest might thus be lost. The stalks are cut whilst the seed is still half ripe. They are tied up in bundles, and hung in a sheltered spot fully exposed to the air. With a space of one metre (40 in.) between the plants, the return will be 200 to 250 grammes (7 to 9 oz.) of seed per plant, or 2,000 kilogrammes per hectare (16 cwt. per acre).

Analysis of the Substances occurring in the Manufacture of Beet-root Sugar.

From the industrial point of view it is necessary to remember the following facts :—First, 100 kilogrammes of good beet-root contain approximately and in round numbers 95 kilos. of juice, and 5 kilos. of cellulose substance : secondly, these 95 kilos. of juice contain 10 kilos. of crystallisable sugar, 2 kilos. of solid matter not containing sugar, and 83 kilos. of water. In manufacturing, the point to be specially ascertained is the percentage of sugar, for on this depends the value of the beet-root. There is however another point of great importance, namely the purity of the juice; the latter depends on the less or greater quantity of matter free from sugar which is dissolved in the juice with the sugar itself.

The following is the process for ascertaining the percentage of sugar. The roots, properly washed, lopped, and dried, are scraped into pulp with a small special rasp; the pulp is squeezed in a special screw press, and the juice drawn off into a glass vessel. Into this juice is plunged a special hydrometer, which gives the total weight of matter, sugar or otherwise, which is dissolved in 100 grammes of the liquid. This figure, say 14, is noted. A hollow ball of glass, gauged to 100 to 110 cubic centimetres, is filled with this juice up to the 100 mark, and then 10 c.c. of sub-acetate of lead is added; the two are shaken up together and filtered. With the filtered liquid you fill a polarimeter about 200 mm. long, and polarise. Suppose that the polarimeter has the normal weight of 0·162 gramme per degree, and that the juice gives a polarisation of 69 degrees. Here it must be remembered that the figure 69 is below the true figure, because we have added to 100 c.c. of juice 10 c.c. of the qualifying liquid, sub-acetate of lead. The liquid has thus been diluted by one-tenth, and would have otherwise have polarised $69 + \frac{1}{10}$ of $69 = 75 \cdot 9$ degrees. It follows then that in 100 c.c. of the liquid there are $75 \cdot 9 \times 0 \cdot 162$ grammes of pure sugar, or 12·29 grammes. But as we know the total quantity of matter dissolved in 100 grammes, and not in 100 c.c., of the juice, we must determine the sugar thus contained in 100 grammes. By means of special tables we find that the figure 14 given by the hydrometer corresponds to a specific gravity of the juice equal to 1·057. Hence we have the following proportion. If 100 c.c. of juice weighing 105·7 grammes contain 12·29 grammes of sugar, the volume corresponding to 100 grammes will contain $\frac{1229}{105 \cdot 7} = 11 \cdot 63$ grammes of sugar per 100 grammes of juice. We now have as follows:

	Grammes.
Total solid matter in 100 gr. of juice (by the hydrometer) .	14
Pure sugar in 100 gr. of juice (by the polarimeter) . . .	11·63
Difference, or solid matter free from sugar	2·37

These two figures express the purity of the juice. For if in 14 parts of solid matter there are 11·63 of sugar, 100 parts of solid matter will give $\frac{1163}{14} = 83 \cdot 07$ per cent., as the "quotient of purity," that is the percentage of sugar contained in the whole of the solid matter in solution. In beet-root the purity generally varies between

75 and 90 per cent.; if it falls below 75 per cent. the beet-root is considered unsuitable for the manufacture of sugar.

In order to know the amount of sugar in the beet-root, we have only to remember that the root contains 95 per cent. of juice; hence, since 100 grammes of juice give 11·63 of sugar, 95 grammes of juice, or 100 grammes of beet-root, will give 11·05 of sugar.

The richness in sugar and the purity being the two essential qualities in beet-root juice, they have been united together in a single "standard of value:" this standard is merely the product of the two factors, namely the percentage by weight of sugar in the juice and the quotient of purity. In the example given this product will be $11 \cdot 63 \times 0 \cdot 8307 = 9 \cdot 66$. It is not common to make any further investigations, unless into the quantity of ash and glucose.

We may now pass on to the products of manufacture. The first to be considered is the Raw Juice (as obtained by pressing the pulp), which is nothing but the natural juice of the beet-root with the addition of a certain quantity of water, say 20 to 30 per cent. of the beet-root weight; the analysis of this juice is therefore identical with that of the beet-root juice already discussed. If when analysed it is already mixed with lime, it must be treated with acetic acid, before adding the clarifier, so as to neutralise the lime completely; otherwise this would falsify the reading of the polarimeter and give results below the truth.

In order to ascertain the progress of the juice towards purification, in the course of manufacture, analyses are made of the carbonated juice and filtered juice, as well as of the syrup before and after filtration. The juice is analysed as before, the small quantity of lime which it contains being previously neutralised. The investigation is merely into the purity of the juice, with the object of regulating the method of working.

With regard to the syrups, they are much richer than the juice, and contain more than 16·2 per cent. of sugar, a quantity which corresponds with 100 degrees of the polarimeter or with the top of its scale: hence it is impossible to operate on 100 c.c. of the syrup, as in the case of the raw juice. It is therefore usual to take 50 or 25 c.c. of this concentrated juice, and to add water enough to make it up to 100 c.c. When reading off, this dilution will be taken into account by doubling or quadrupling the reading of the polarimeter.

Next comes the "Boiled Mass" (masse cuite), Nos. 1, 2, and 3. In these products it is usual to analyse:—

1st. The crystallisable sugar.

2nd. The ash.

3rd. The water.

4th. The organic matter free from sugar.

From these data the quotient of purity of the boiled mass is calculated; sometimes the uncrystallisable sugar is also determined.

To determine the crystallisable sugar, let us suppose the normal weight of the polarimeter to be 16·2 grammes; in other words that 16·2 grammes of pure sugar dissolved in distilled water to the amount of 100 c.c. of sugar and water together, and polarised in a tube 200 mm. long, will make the instrument read 100 degrees. If we now take 16·2 grammes of the boiled mass, and dissolve them in water, making a total of 100 c.c., with the addition of some drops of sub-acetate of lead, and if we filter and polarise them, the liquid will give a figure corresponding to the percentage of sugar in the boiled mass, the other matters having no action on the polarimeter. The No. 1 mass generally gives from 80 to 84 per cent. by weight of crystallisable sugar.

To gauge the ash, 5 grammes of the mass are weighed in a platinum crucible, 10 drops of concentrated pure sulphuric acid are added, and the mixture is calcined in a muffle heated to a dull red heat. This gives a perfectly white ash, which is weighed. It must be remembered that the sulphuric acid has been added in order to transform into sulphates the alkaline carbonates which would have been difficult to burn. Experiment has proved that the ash thus treated weighs about one-tenth more than where no sulphuric acid has been added; hence after determining the weight of the ash 10 per cent. is subtracted in order to obtain the true ash, the gross quantity being called the sulphuric ash. Thus 0·300 gramme of sulphuric ash would give $0 \cdot 300 - 0 \cdot 030 = 0 \cdot 27$ gramme of true ash. As this ash corresponds to 5 grammes of the substance first weighed, it follows that in 100 grammes there will be $0 \cdot 27 \times 20 = 5 \cdot 4$ per cent. of ash. The boiled mass No. 1 generally contains 4·5 to 5·5 per cent., or 5 per cent. on the average.

To ascertain the water, 5 grammes of the substance are weighed and dried in a hot-air stove for several hours, at a heat of 100° to 105° Cent., until they lose weight no longer. The weight lost represents the water in 5 grammes of the substance, and must be multiplied by 20 to give the percentage. Generally there is 5 to 6 per cent. of water in the mass No. 1.

To ascertain the unknown organic matters no analyses are made; they are determined by the method of difference. Thus, suppose we have—

	Per cent.
Crystallisable sugar	83·00
Ash	5·00
Water	5·50
Organic matter will be	6·50
Total	100·00
The total amount of solid matter in solution being	94·50

With regard to the quotient of purity, it will be remembered that the purity is determined by the ratio of the sugar to the total amount of matter in solution. It now therefore becomes easy to determine this ratio. We have sugar = 83·00 per cent., total matter in solution (crystallisable sugar, ash, and organic matter) = 94·50 per cent.: hence the quotient of purity = $\frac{8300}{94 \cdot 50} = 87 \cdot 84$ per cent. The ordinary figure for mass No. 1 is 87 to 90 per cent.

The quantities indicated for taking samples need not of course be exactly as stated. They may be selected at convenience, and the percentages afterwards calculated.

The masses Nos. 2 and 3 are subjected to analysis in the same way as No. 1. They are naturally less rich and more impure than the latter. The approximate constitution will be as follows:—

Mass No. 2.	Per cent.	Mass No. 3.	Per cent.
Crystallisable sugar	67·00	Crystallisable sugar	58·00
Ash	10·50	Ash	14·00
Water	11·50	Water	12·00
Organic matter	11·00	Organic matter	16·00
Quotient of purity	75·76	Quotient of purity	65·91

The final molasses, left after the treatment of mass No. 3, are analysed in the same manner.

After the treatment of mass No. 2, it is no longer possible to discolour the liquid sufficiently by means of sub-acetate of lead alone; therefore, after taking a sample and dissolving it, some drops of sub-acetate of lead are added, and twice as many drops of solution of tannin in alcohol, the proportion of tannin being 20 per cent. The approximate figures for these final molasses are as follows:—

Density (by Baumé densimeter)	42·17
	Per cent.
Crystallisable sugar	47·17
Ash	13·17
Water	24·52
Organic matter, &c.	15·14
Quotient of purity	62·27.

We now proceed to the analysis of the sugar. In raw sugar it is usual to ascertain—

1st. The crystallisable sugar.
2nd. The uncrystallisable sugar.
3rd. The ash.
4th. The water.
5th. The organic matter free from sugar.

From the three first of these the commercial value of the sugar can be calculated.

To ascertain the quantity of crystallisable sugar contained in a raw sugar, a weight equal to the normal weight of the polarimeter is dissolved in a vessel gauged to 100 c.c., with the addition of a little water. To this are added 10 drops of sub-acetate of lead and 20 drops of tannin prepared as described above; the volume of 100 c.c. is made up with pure water. The clear juice is shaken up, filtered, and polarised. If it polarises 95 degrees, this indicates that it contains 95 per cent. of pure sugar, the remaining 5 per cent. being due to moisture, ash, and organic matter free from sugar.

There always exists in raw sugar a small quantity of uncrystallisable sugar: this is tested by means of a definite cupro-potassic solution. This liquid, which is blue, is completely discoloured when hot by a solution of uncrystallisable sugar. The same juice is employed as in polarising the crystallisable sugar. The amount of this juice which has been required to discolour a known quantity of the cupro-potassic solution, gives the percentage of the uncrystallisable sugar contained in the raw sugar.

The ash is ascertained by burning in a platinum crucible, heated in a muffle to a dark red, 5 grammes of sugar moistened with a few drops of pure sulphuric acid at 66 degrees. The ash resulting from the calcination is weighed, and one-tenth the weight subtracted; the remainder multiplied by 20 represents the percentage of ash.

The water is found by drying at 100° C., in a hot-air stove, 5 grammes of sugar; the loss in weight multiplied by 20 gives the percentage of moisture.

The organic substances are ascertained by the method of difference.

It is asserted by refiners that 1 kilogramme of ash prevents the crystallisation of 5 kilos of sugar in the refinery. This is an exaggeration, but it is sanctioned by usage, and has to be accepted by the manufacturer; so that the buyer everywhere pays only for the crystallisable sugar, diminished by five times the weight of the ash, and by the weight of the uncrystallisable sugar. The result thus produced is called the "titrage."

The usual composition of Belgian sugar is in round numbers as follows:—

	Sugar No 1.	Sugar No. 2.	Sugar No. 3.
Crystallisable	96·00	92·00	90·00
Uncrystallisable	0·05	0·10	0·15
Ash	1·10	2·50	2·80
Water	1·50	2·80	3·40
Unknown matter (by difference)	1·35	2·60	3·65
	100·00	100·00	100·00

Thus the "titrage," or the percentage paid for by the buyer, will be as follows:—

Sugar No. 1 . . . $96·00 - (0·05 + 1·10 \times 5) = 90·45$

Sugar No. 2 . . . $92·00 - (0·10 + 2·50 \times 5) = 79·40$

Sugar No. 3 . . . $90·00 - (0·15 + 2·80 \times 5) = 75·85$

For sugars Nos. 2 and 3 these figures vary greatly: they are sometimes higher for No. 3 than for No. 2.

The ordinary methods of buying beet-root have an essential influence on the saccharine qualities of the root supplied by the farmer. Beet-root may be bought on various principles, as follows.

(1) By simple weight, at so much per ton, without any consideration as to the richness. This gives the buyer no guarantee whatever as to the value of his raw material, and the farmer thinks of nothing but the largest possible yield per acre. In consequence it is almost certain that the manufacturer will receive poor root, overcharged with foreign matters. This method is rapidly disappearing.

(2) By the specific gravity of the juice. This is an improvement, but gives no certainty as to richness. The density of a juice is not due exclusively to its richness in sugar; it is largely influenced by the smaller or greater proportion of saline and organic matter contained in solution. On this basis a beet-root of a density of 1·05 would be paid for at a price of say 20 francs per 1000 kilos, and this would be increased or diminished by 0·4 franc for each tenth of a degree more or less, as indicated by the densimeter. The Union of Belgian Cultivators and Manufacturers formerly proposed the following prices:—4·50 francs for 1000 kilos and for 0° of the densimeter in September; 4·00 francs from the 1st of October to the 15th of November; 4·25 francs from the 15th of November to the 5th of December; and 4·50 francs from the 5th of December to the end of the season.

Five methods are employed by the manufacturer, to secure himself against poverty in sugar and impurity, in the beet-root furnished him by the two modes of purchase just explained. These are as follows:—

(*a*) Selection of his own seed.

(*b*) Fixing the number of plants per square metre.

(*c*) Forbidding the employment of certain manures largely charged with nitrogen.

(*d*) Forbidding the application of certain manures at certain periods in the year.

(*e*) Refusing beet-root which has been grown on waste land newly cleared.

(3) According to the richness in sugar. This is more rational, and suits at once the interests of the manufacturer and the farmer. The former pays according to the intrinsic value of what he gets; the latter, though raising a smaller crop, receives a better price; he gets the advantage of a reduced cost for transport, and a smaller quantity of fertilising matter subtracted from the soil. This latter quantity varies directly as the weight of beet-root produced, and inversely as the richness of the roots in sugar. It is generally assumed that 1000 kilogrammes of beet-root carry away with them 3·9 kilogrammes of potash, 1·6 of nitrogen, and 0·8 of phosphoric acid. On this system beet-root would be bought at 22 francs per 1000 kg. if containing 11 per cent. of sugar, and this price would be increased or diminished by 1½ to 2 francs for every 1 per cent. that the richness was above or below this amount. This is becoming the general method of buying.

(4) By the standard of value, which, as we have explained, means the product of the percentage of sugar in the juice multiplied by the quotient of purity. This is superior to all other methods, and gives the manufacturer all he can require. Being based both on the richness and the quotient of purity, it takes into account the relation between the saccharine value and the quantity of foreign matters, organic and inorganic, which accompany the juice. It is the combination of these two factors which constitutes the true element of industrial efficiency. On this system the price per 1000 kg. would be calculated at a certain number of francs per unit of standard of value. M. Péterman, director of the Agricultural Institution at Gembloux, proposes the following prices:—

In September, 2·65 francs per unit of standard of value.

From the 1st October to 15th November, 2·50 fr.

From the 15th November to 15th December, 2·60 fr.

From the 15th December to end of season, 2·70 fr.

This fourth method is as yet very little employed. Naturally, in all the examples given above the prices stated will vary according to the fluctuations of demand and supply, the price of sugar, of labour, &c.

There are two difficulties which prevent the last two methods from becoming general. These are (1) The means of arriving at an exact average sample; and (2) The objections of the farmer.

The first difficulty is not insurmountable. A sample may be taken, (*a*) on the field before carting, (*b*) on the wagons when being discharged, (*c*) on the samples used for fixing the tare. (See third paragraph below.)

The second obstacle is more difficult to overcome, being due to the farmer's mistrust, and in general to his ignorance, of the analytical processes employed.

OPERATIONS PRELIMINARY TO MANUFACTURE.

Whatever may be the mode of buying, the exact determination of the weight of beet-root is indispensable, since the price is per tonne net. For this purpose the wagons are drawn, first loaded and afterwards empty, over large 10-tonne weighing machines: the difference between the two weights gives the gross load.

To obtain the net weight, it is necessary to subtract the earth still adhering to the roots, and the injurious parts of the root itself. To do this, as each wagon is weighed, ten or twelve roots are taken off and weighed separately. They are then washed and brushed, the top cut off, together with the green part next to it, and the roots again weighed; the difference between the two weighings fixes the tare.

The Ensilage of the beet-root generally takes place at the works. It is only in exceptional cases and for special reasons that it is sometimes done on the fields, in cases when a road, open at all seasons, lies handy. The object of this ensilage is mainly to ensure that the work shall go on regularly during a given period, and to avoid any stoppages. That the silos may fulfil the proper conditions, the roots should be sheltered from the frost and from heating during winter, and should be removed from all drying action of the sun or wind before the frost begins. Formerly the silos were small holes dug in the ground, into which the beet-roots were thrust pell-mell and covered with earth. This system has altogether disappeared. The silos are now placed upon the ground, having a width of 2·50 to 3 metres (8 to 10 ft.), a height of

1·50 to 2 metres (5 to 6½ ft.), and a length as great as may be needed. There is a general tendency to diminish the number of silos by increasing the width to 10, 12, or 15 metres (30, 40, or 50 ft.), whilst preserving the same height. In this case however it is necessary to place at certain distances apart vertical shafts, in wood or iron, which allow of a circulation of cold air within the mass. These shafts rest on similar pipes laid upon the ground at the bottom of the silos, and placed end to end so as to form horizontal channels. The channels are from 1·50 to 2 metres apart, centre to centre (5 to 6½ ft.), and the shafts which terminate in them are at about the same distance. When the first frosts come on, the side walls of the silos are covered in with a layer of earth sufficient for the purpose. A proper thickness of straw or coarse hay is spread at the same time on the top. This on the one hand keeps off the frost, and on the other gives easy passage to the heat and moisture developed by the roots, which continue to ripen while in the heap.

The first operation of manufacture is to wash the beet-roots, in order to remove gravel, earth, and rootlets. The quantity of earth adhering depends chiefly upon the moisture of the soil at the moment of pulling, the character of the soil, and the shape of the roots. Good washing is of the utmost importance: it prevents the rapid wearing out of the teeth of the rasps, ensures the purity of the pulp to be given to the cattle, and prevents any change in the natural density of the juice, which is the basis of excise. The washing is generally done in two tanks placed one behind the other. The first serves to remove the mud, the second is the washer properly so-called. Each tank is formed of sheet iron, and is 3½ to 4 metres long, 1 metre wide, and 55 centimetres high (11 to 13 ft., 3 ft., and 2 ft.). They are filled to a certain height with water. In each turns a horizontal shaft, on which are fixed cast-iron bosses carrying wooden arms set spirally round them. The beet-root is thrown in at one end, and comes out at the other where the water enters. The speed is from 15 to 20 revolutions per minute. The mud and water are collected in large reservoirs, where the mud settles, forming a deposit which contains a great quantity of roots and rootlets, and forms an excellent manure.

The proportion of sugar is not reduced by the most prolonged washing.

After washing, the beet-roots are brought together by an elevator, which delivers them either upon the rasp or upon the cutter, according as the juice is to be extracted by hydraulic press, or by diffusion. Both systems are employed in Belgium. The diffusion process is the newer and begins to displace the other.

Extraction of Juice by Hydraulic Pressure.

The first operation is to rasp the roots, in order to break open the cells. The more of these there are opened the more complete will be the division of the pulp, and the greater the yield of juice. This yield may vary from 80 to 84 per cent. of the weight of the pure juice, or say 78 per cent. of the weight of the beet-root. From the elevator the roots fall into a hopper H, Fig. 1, Plate 30, which delivers them to the rasping drum D. Against this they are pressed forwards by two pushers P moving alternately in a horizontal direction. The forward movement of the pushers is slow and due to a cam C: the backward movement is rapid and caused by a counterweight W. The rasp is placed on a cast-iron bed-plate of great strength. The rasping drum D, Fig. 2, is composed of three discs cast upon long hollow bosses, which are keyed upon a horizontal wrought-iron shaft having a pulley at each end so as to be worked by a double belt. The diameter of the discs is 0·70 metre (28 in.), and the interval between them 0·32 metre (13 in.). These discs are grooved on their inside faces, with a circular groove close to the circumference; in these grooves are fixed longitudinal toothed strips or blades of iron or steel, Fig. 3, separated by wooden laths, and forming the cylindrical rasping surface of the drum. The teeth are 3 mm. apart (0·12 in.), and have a height of 4 mm. (0·16 in.). The two intervals formed by the three discs are thus filled up, and the whole then has the appearance of a drum in two lengths, from the surface of which project only the tips of the teeth, standing up above the laths and the discs. The rasp is covered by a sheet-iron casing to prevent the pulp from being thrown out. Its efficiency depends on the form and size of the teeth, on their width, on the area of the drum, on the speed of revolution, and on the speed and pressure of the pushers. The finest pulp is the best, but it requires most power. The speed and area of the rasp are the two elements which chiefly influence the quantity broken up. It is always better to augment the area and diminish the speed, as the pushers can then move more slowly, and the formation of a coarse pulp is avoided. In general a rasp running at 850 to 1000 revolutions, and having a total area of 140 sq. decimetres (15 sq. ft.), will rasp 120,000 to 140,000 kilogrammes of beet-root in the 24 hours, or 1000 kilogrammes per sq. decimetre of surface (9 tons per sq. ft.). The power is estimated at 1 HP. per 10,000 or 12,000 kilogrammes treated daily (10 to 12 tons). The loss of weight in rasping is about 1 per cent. of the weight of the beet-root. A certain quantity of water is always added, varying from 20 to 30 per cent. of the weight of the beet-root. The object is to dilute the juice, render it more liquid, and thus diminish its richness, and thereby the richness of the pulp produced. The quantity of water is determined so as to give the pressed juice a density of 1·04. The rasping is the process in which the greatest quantity of water enters into the manufacture. It is indispensable to make sure of its purity, as any salts which it contains would not only injure the yield but alter the density of the juice, which is the basis of excise, and that to the prejudice of the manufacturer. In works where the pulp first pressed is again diluted, to be pressed over again, the thin juice obtained by this second pressing is used at the rasp in place of water.

The next step is to press the pulp by hydraulic pressure to extract the juice. The plant for pressing is as follows:—

(1) Four sets of woollen sacks to receive the pulp. Their dimensions are 0·80 metre by 0·50 metre (32 by 20 in.), and their weight 300 to 400 grammes (0·7 to 0·9 lb.). After six hours' use each set is sent to be washed.

(2) Screens, either of solid sheet-iron, or made of iron strips crossing each other and riveted together. These screens exceed the dimensions of the sacks by some centimetres, and form metallic diaphragms.

(3) Two preparing tables, which can be turned about a vertical shaft. They are rectangular castings with a trough around the outside, so as to collect the juice which escapes during the formation of the preliminary heaps of sacks and screens.

(4) In many cases there are two preparing presses in place of the two preparing tables. These two presses are sufficient for six hydraulic presses, and serve to begin the work of pressure, getting rid of a part of the juice before the hydraulic presses are set to work, and thus allowing the latter to move more slowly, and to keep for a longer time at the maximum pressure. These preparing presses have rapid motion but a low pressure. They are worked by gearing, and so arranged as to be automatically thrown out of gear and reversed as soon as the pile has been pressed to half its original height.

(5) A number of hydraulic presses proportional to the work to be done, and an equal number of pumps. Generally six, eight, or ten presses go to a set. Six presses will treat on an average 100,000 kilogrammes of beet-root (100 tons) in the 24 hours. The moving table of the hydraulic press is fixed upon the ram, whilst the pressure head is united to the cylinder by four strong columns. Between the table and the head is placed the pile of sacks and screens. The motion of the plungers or pumps is given by means of rods worked by eccentrics on the main shaft. These plungers are continually working, but may be made to pump or not, as required, by closing or opening a discharge valve.

The mode of action is as follows. On leaving the rasp the pulp falls into a sheet-iron vat. Two conical and self-acting scoops lift the pulp from this, and discharge it into woollen sacks, which the workmen hold in their hands. The scoops give from 15 to 20 strokes per minute. The sack when full is placed on one half of the preparing table. Its contents are made even, the mouth closed up, and the whole covered by a screen, solid or open. A preliminary pile of sacks, separated by screens, is thus formed, rising to a height of 0·40 to 0·50 metre (16 to 20 in.). The table is then swung half way round; a second pile is formed on the other half, whilst the first half is taken off and deposited on the table of the hydraulic press.

The latter can be charged with 40 to 45 sacks and screens, giving a total height of 0·85 to 0·90 metre (34 to 36 in.). The weight of pulp per sack is from 2·75 to 3 kilogrammes (6 to 7 lbs.). The press being thus loaded, the discharge cock belonging to the pump of this press is closed, the plunger forces the water under the press ram, and the latter rises until the maximum pressure is attained. The ram then ceases to rise, the pressure of water acting automatically upon the parts of the pump through a train of levers, to prevent any further inflow of water. The maximum pressure is retained as long as is considered advisable, say from 7 to 8 minutes. The discharge cock is then opened, the water is allowed to escape, and the ram of the press slowly descends. The sacks and screens are now removed; the former go to the pulp store to be emptied, and the latter return to the preparing table. The pressure in these presses varies from 150 to 200 atmospheres: it is rarely greater than 180. With a ram of 0·30 metre diameter (12 in.), or 706 sq. centimetres area (113 sq. in.), the pressure transmitted is 127,080 kilogrammes (127 tons), or 31·77 kilogrammes per sq. centimetre of the sack pressed (452 lbs. per sq. in.).

The average yield of this process, taking account of the water added during rasping, is 20 to 25 per cent. in pulp, and 90 to 100 per cent. in juice at 1·04 density, reckoning the percentage upon the weight of the beet-root. In general 100 to 105 kilogrammes of beet-root are required to produce 100 litres of juice at 1·04 density.

The richness of the pulp in sugar is from 5·50 to 7·50 per cent. in weight, the moisture from 70 to 75 per cent. in weight. The pulp is used for feeding cattle, and is much esteemed by farmers. It is preserved in holes dug in the ground, where it is strongly rammed down. The part above the surface is made to slope from all sides, and is covered in with long straw and then with a layer of earth. The sugar contained in the pulp soon begins to ferment, and this action gives a wine-like smell to the whole mass and makes it very acceptable to cattle. The value of the pulp as food is considerable. The tables of Wolff give the following results:—The ratio of nitrogenous to non-nitrogenous matter is in the pulp 1 to 10·4; in the beet-root it is 1 to 15·7; giving a proportion of 1·50 to 1 in favour of the pulp. The money value is 2·95 fr. for the pulp, and 2·17 fr. for the beet-root; giving a proportion in favour of the pulp of 1·31 to 1. The value of the pulp as food may thus be taken as 50 per cent. more than that of beet-root.

EXTRACTION OF JUICE BY DIFFUSION.

The process of diffusion is the result of the actions known as *endosmosis* and *exosmosis*, as applied to the beet-root. These actions take place between any two liquids of different nature and density, when separated by a porous diaphragm. In the present case the liquids are pure water on one side, and on the other the beet-root juice enclosed in the cells, the walls of which are formed by vegetable membrane. To apply the process of diffusion, the roots are first cut up into slices called "cossettes," of suitable thickness, which are afterwards immersed in water. The result is that a current of *endosmosis* takes place in the water towards the juice in the cells, and a current of *exosmosis* in the juice towards the water. These currents go on cell by cell, and the effect does not come to an end until a state of equilibrium is produced between the contiguous layers of liquid. If at this moment the first water is removed and fresh water substituted, new currents begin, and a fresh quantity of sugar and of salts are extracted until another state of equilibrium results. Continuing in this way, the final result is to abstract completely the sugar and saline matter contained in the slices. On the other hand, if the water which was first in contact with the slices, and is thus already become a thin juice, is passed subsequently over slices less exhausted than the first, new currents will start, and go on until a new state of equilibrium is attained. As it advances in this way, the juice will continually increase in richness and density, encountering at each step slices less and less exhausted,—in other words more and more rich in sugar. The process going on at each instant and at any point of the diffusion battery is therefore the enriching of the juice on the one hand, and the impoverishing of the slices on the other.

The plant for this process is as follows, Figs. 11 and 12, Plates

32 and 33:—first, the root-cutter R; secondly, the diffusers D; thirdly, the heaters H; fourthly, the presses P for the slices.

The cutter, Fig. 4, Plate 31, is the machine which replaces the rasp, and divides the roots into the cossettes or slices. It is composed of a horizontal disc A, 1·40 metre in diameter ($4\frac{1}{2}$ ft.) having eight openings C, Fig. 5, to receive the knife-carriers, Figs. 6 to 8. These carriers are 0·40 metre long (16 in.), and carry two blades with a total cutting edge of 0·333 metre (13 in.). The disc A is fixed on a vertical shaft turned by gearing; it can be thrown out of gear so that the cutting is stopped. The cossettes fall into a sloping trough T beneath, which conducts them to the diffuser D, Fig. 4. The revolving disc A is covered by a cast-iron plate with three openings. On one of these is placed the hopper E by which the roots are introduced, and which should be high enough for the weight within it to press the beet-roots sufficiently hard against the cutting disc. The second opening is to allow of changing the knives; and the third to give access to a solid steel plate B, Fig. 8, fixed about 5 mm. (0·2 in.) above the knives, and serving to stop the beet-roots which would otherwise be carried round with the disc. This plate is called the "buttoir" or abutment. It also serves to stop the stones or other bodies which might otherwise be introduced into the cutter. The sloping spout into which the cut slices fall can be turned round its upper end, so as to be brought successively over each diffuser, without stopping the supply of the slices. Sometimes the slices fall into a chamber beneath the cutter, and are raked into the sloping spout by a scraper carried upon the bottom of the revolving vertical shaft.

The shape of the knives is very varied and even fantastic. Some have wavy edges or with sharp angles, some have a lozenge or roof shape &c. The Naprawill knives, Fig. 9, have a rectangular section, being formed of a cutting blade on which are a series of vertical projections, also having cutting edges. According to the distances between these projections will be the size of the cossettes, which are rectangular in shape. The Goller knives have a lozenge-shaped section, Fig. 10.

The ordinary dimensions for the cossettes are as follows:—Thickness, $1\frac{3}{4}$ to 2 millimetres (0·07 to 0·08 in.), or 3 to 4 millimetres (0·12 to 0·16 in.), for a width of 6 to 8 millimetres (0·24 to 0·32 in.); or thickness $1\frac{1}{2}$ millimetre (0·06 in.), for a width of 7 millimetres (0·28 in.); or thickness 2½ millimetres (0·10 in.) for a width of 4 millimetres (0·16 in.). The length varies according to the position of the beet-root at the moment it comes in contact with the knives.

The knives quickly become blunted, and generally have to be changed two or three times in the twenty-four hours. They are sharpened by the file or grindstone. The section of the cossettes ought to be clean and regular, without distortion or notches; otherwise the juice is less pure, is charged with waste pulp, and is likely to ferment.

The Diffusion Battery, Figs. 11 and 12, Plates 32 and 33, is generally composed of 10, 12, or 14 diffusers DD. They are placed either in a row, a semi-circle, or a complete circle. One 20-hectolitre diffuser (70 c. ft.) will receive a charge of 1000 to 1100 kilos (1·0 to 1·1 ton) of cossettes, and a battery of twelve diffusers will work 180,000 to 200,000 kilog. of beet-root in the twenty-four hours (188 to 200 tons). Each operation lasts from seven to eight minutes. The diffusers are cylindrical vessels with conical ends, varying in content from 15 to 25 hectolitres (50 to 90 cub. ft.). At the top is an opening for charging, covered by a lid; at the bottom is a side-door for emptying, with a false bottom sloping towards it, in order to facilitate the emptying when the door is opened. This false bottom is formed of pierced sheet-iron, and prevents the slices from being drawn into the pipes below, which carry off the juice. A similar perforated screen is placed at the top, to arrest the slices which rise on the top of the juice during the filling of the vessel with juice. There is an air cock, which is kept open all the time of the filling.

The heaters HH are cylindrical vessels 0·40 metre in diameter (16 in.), and 2 to 2½ metres in height (6½ to 8 ft.). Their ends are two perforated plates united by brass tubes; at the bottom they communicate with the diffuser behind them, and at the top with the diffuser in front. They thus serve as pipes communicating between two successive diffusers, and at the same time as heaters for the juice which traverses them. The juice passes inside the tubes, which are surrounded by steam. A thermometer placed in the upper or discharge pipe shows the temperature which the juice has attained in passing through the heater. There are three sets of pipes which surround the battery, one set for water, one for juice, one for steam. The set for water is in communication with an air pump, so that the water may be replaced by compressed air at any instant. By means of proper valves and cocks, these pipes may be put in communication with each of the diffusers at will. The passage of the juice from one diffuser to the next is produced by the pressure of water or of air. The water pressure is given by connecting the water pipes with a tank at a height of 10, 15, or 18 metres (33 to 60 ft.). The air pressure is only used if the water supply is insufficient; it varies from $\frac{3}{4}$ to 1 atmosphere.

The slice-presses are used to extract from the cossettes the excess of water which they contain. There are four systems in general use:—(*a*) Klusemann's; (*b*) Bergreen's; (*c*) Selwig and Lange's; (*d*) the Russian pump. But none of these bring the cossettes to a condition of dryness approaching that given to the pulp by the hydraulic press. The slice-presses are generally fed with slices by means of a bucket-chain elevator, E, Fig. 11, Plate 32, to the foot of which the slices are brought by a creeper from the pit the diffusers are emptied into.

(*a*) In Klusemann's press, Fig. 15, Plate 34, a vertical cone C of perforated sheet-iron, with its smaller diameter at top, runs at 50 to 60 revolutions per minute within a fixed cylindrical casing A, which is also made of perforated sheet-iron. By means of helical blades B on the revolving cone, the slices fed in at the open top of the cylindrical casing are drawn downwards, and become thereby compressed between the cone and the cylinder. The topmost blades have their front end bent upwards, so as to subdivide the material with a view to uniformity of feed. The water squeezed out through the holes in the cone and cylinder runs away from the bottom of the press. The pressure is varied by raising or lowering, within the annular orifice left between the bottom of the revolving cone and the cylinder, an annular conical plug P carried by adjusting screws, so as more or less to throttle the escape of the pressed material from the bottom of the cylinder. Three of these presses suffice for treating 200 tons of beet-root per 24 hours, each requiring $1\frac{1}{2}$ HP. to drive it. After compression the weight of the pressed material amounts to from 35 to 40 per cent. of the weight of the beet-root.

(*b*) Bergreen's press differs from the preceding merely in having no holes in the upper portion of its pressing cone; the perforations are only in the lower portion, which carries a continuous helical blade in place of a succession of shorter blades, like those studding its upper portion.

(*c*) Selwig and Lange's press, Figs. 13 and 14, Plate 33, has two cast-iron discs D of 57 in. diameter, revolving face to face at one revolution per minute and in the same direction, but having their axes slightly inclined from the horizontal in opposite ways, so as to leave the widest space between the edges of the discs at top and the narrowest at bottom. The faces of the discs are grooved and perforated, and are themselves covered with perforated sheet-iron E. The pulp fed in at the top or widest space becomes compressed between the discs as they carry it round to the narrowest space at bottom; and on the rising side it is thrown out by a scraper S, as they release it from their grip. At the bottom, where the heaviest pressure comes on, the discs are held up to their work by six conical pressing rollers R behind them. One of these presses is sufficient for working 200 tons of beet-root per 24 hours; the driving power required is about 2 HP.

(*d*) The Russian pump is properly speaking only a feeder for supplying one or other of the above presses with material slightly drained beforehand. It consists of a horizontal cylinder, in which works a piston. During the back stroke the cylinder receives a charge of slices from a hopper above; and in its forward stroke the piston pushes the material into a perforated pipe, through which some of the water drains off. The pipe leads to a press, where the required compression is effected.

At any given moment a diffusion battery will be found in the following condition. There will be one diffuser discharging its juice to the workshops, a second being emptied and then immediately refilled, a third receiving the water pressure. In all the other diffusers the juice is in process of circulation, all the valves being open. For example, let there be ten diffusers, Nos. 1 to 10. If No. 1 is discharging its juice to the workshop, No. 2 will be emptying during half the time of each operation, and filling with fresh cossettes during the other half. No. 3 will be receiving the water pressure; under this pressure the juice from No. 3 will pass to No. 4, that of No. 4 to No. 5, and so on up to No. 10, of which the contents are passing into No. 1. The contents of No. 1 will next pass into No. 2, which has just been filled with fresh cossettes; the juice enters No. 2 at the bottom and rises to the top, whereas in all the other diffusers the circulation goes on from top to bottom. When discharging in the next operation, the current in No. 2 will also be from top to bottom; and this reversal of the direction of motion, applied each time to the last diffuser charged, and to that only, is called "Meichage."

At this next operation then, No. 2 will send its juice to the works, No. 3 will be emptied and refilled, No. 4 will receive the water pressure; the juice will pass from 4 to 5, from 5 to 6, and so on to No. 10; from No. 10 to No. 1, and from No. 1 to No. 2; whilst No. 2 will afterwards produce the Meichage of No. 3, which has just been filled with fresh cossettes.

Thus the juice in passing from one diffuser to another continually meets with cossettes less and less exhausted, becomes thereby more and more enriched, and is finally drawn out of the last diffuser, which has just been charged with fresh cossettes. A density of about 1·04 is thus ensured to the juice. In passing from one diffuser to the next the juice traverses the heater between them.

The temperature of the juice varies from one diffuser to another, being given to it by the different heaters which it traverses. In the example here given the respective temperatures of the juice in each diffuser should be as follows:—

	Réaumur.	Fahrenheit.
In No. 1 which is discharging its juice	15°	66°
„ 2 which is being emptied, say	15°	66°
„ 3 which receives the water pressure	10° to 15°	55° to 66°
„ 4 where the juice is circulating	35° to 40°	111° to 122°
„ 5 „ „ „	50°	145°
„ 6 „ „ „	55° to 60°	156° to 167°
„ 7 „ „ „	55° to 60°	156° to 167°
„ 8 „ „ „	55° to 60°	156° to 167°
„ 9 „ „ „	35°	111°
„ 10 „ „ „	10°	55°

The juice as it leaves the diffusers is cooled to 15° R. = 66° F., although it has to be re-heated afterwards; because the excise allows no correction for excess of volume due to a temperature higher than 15° R., which is that at which the sample for excise is taken.

The yield by diffusion may be 90 to 95 per cent. of the juice contained by the beet-root. On an average it takes 90 to 95 kilos of beet-root to give a hectolitre of juice at 1·04 density (56 to 59 lbs. per cub. ft.). The quantity of cossettes left at the end is 35 to 40 per cent. of the weight of the beet-root, the amount depending much upon the presses employed and the degree of dryness of the slices. In the pressed cossettes the moisture may be taken at 88 to 90 per cent. of their weight. If, before being pressed, the cossettes are left to drain till their weight has fallen to 70 per cent. of the beet-root, the sugar they contain is from 0·30 to 0·60 per cent. of the beet-root, or from 0·43 to 0·86 per cent. of their own weight. The sugar contained in the discharged water is from 0·15 to 0·25 per cent. of the weight of the beet-root.

Péterman gives the following comparative analysis of the pulp from the hydraulic press and of the cossettes from the diffusion process, both being fresh:—

	Diffusion Process.	Pressing Process.
Water	89·91	72·48
Albumenoid matter	1·08	2·18
Fatty matter	0·08	0·30
Matter free from nitrogen	6·13	15·98
Mineral matter	0·72	3·27
Cellulose	2·08	5·79
Total	100·00	100·00

The comparison of these analyses shows that the residue from the diffusion process contains much more water and is much less rich in nutritious matter than that from the presses. A farmer therefore should not pay for cossettes containing 90 per cent. of water more than about half the price which he pays for the pulp from the hydraulic press.

Wolff gives as the ratio of the two residues as regards nutriment the following figures:—Ratio of albumenoid matter to matter free from nitrogen;—diffusion process 1 to 6·3, pressing process 1 to 10·4, (ratio of diffusion to pressing process 1·65 to 1). Money value;—

diffusion process 0·98 franc, pressing process 2·95 francs, (ratio of diffusion to pressing process 1 to 3).

Thus, when at the same degree of moisture, the cossettes give a food more rich and more nutritious than the pulp; and 100 tons of cossettes would give the same useful effect as 165 tons of the pulp from the pressure process.

The cossettes are preserved in silos like the pulp, but there is more difficulty in securing them against damage. This however may be accomplished by placing small drains at the bottom of the silos, so as to get rid of the water which runs from the cossettes under their own weight.

There are several new systems of continuous diffusers, but they are not as yet employed in Belgium.

The quantity of water employed in extracting the juice by hydraulic pressure is about equal to the weight of the beet-root. In the diffusion process the quantity of water employed is from $2\frac{1}{4}$ to $2\frac{1}{2}$ times the weight of the beet-root, when water alone is used; when compressed air is used, the water can be reduced about one half. The power required for working from 100 to 125 tons of beet-root per 24 hours is from 175 to 200 HP. The coal consumption is from $2\frac{1}{2}$ to $2\frac{3}{4}$ tons per ton of sugar produced.

Method of taking the Excise.

The mode employed by the Excise authorities to determine the quantity of sugar to be taxed is the following. The juice on leaving either the press or the diffuser is gauged by government officers before passing to the works. For this purpose it is run into tanks called measurers, previously gauged. Of these one is always being filled, one being emptied, and a third being cleaned. That which is being filled has its valves kept under lock and key, until the formalities relative to the taking of samples are accomplished. These consist in fixing precisely the point on the gauge corresponding to the level of the juice, and the taking of a sample to determine its density.

The law which regulates this sampling is as follows. At each measurer the charge in sugar is calculated at the rate of 1500 grammes for every 100 litres of juice, and for every degree of density on the densimeter above 100 degrees (the density of water), these figures being taken before the discharge and at a temperature of 15° R. = 66° F.; fractions below 0·1 of a degree on the densimeter are neglected. Then, to determine the quantity of sugar to be allowed for, the volume of the juice in the measurer is multiplied by the number of degrees and tenths, as shown by the densimeter, and the product by 1500 grammes. A fraction above $\frac{1}{2}$ is taken as 1. Thus for a measure of 20 hectolitres and a juice of 104 degrees density, the weight would be as follows: $20 \times 4 \times 1500 = 120$ kilog.

This would be the amount of sugar taxed, the tax being 45 fr. per 100 kilog. for raw native sugar. Thus the amount of duty for 20 hectolitres of juice at 104 density would be $1 \cdot 20 \times 45 = 54$ fr.

Beet-root juice has a great tendency to spoil. Immediately after rasping, its colour deepens, and rapid fermentation would soon begin. To prevent this, as soon as the Excise operations are finished, a dose of lime is added with all speed, sufficient to preserve and purify it. If the juice is extracted at the sugar works, the juice after being limed is sent direct from the measurers to the clarifying vats. If, on the contrary, the extraction takes place at the rasping works, the juice after being limed is pumped to the central works through an underground pipe. On leaving this pipe, the juice is run at the works into new measurers, at which there are other agents of the Excise continually stationed. Their duties are merely to ascertain the volume of the juice, in order to check the volume sent from the rasping works.

SEPARATE RASPING WORKS.

In Belgium there is only one establishment with separate rasping works: this is the central establishment at Wanze, near Statte, twenty miles south-west from Liége. It possesses thirteen sets of rasping plant, nine of which extract the juice by hydraulic pressure, and four by diffusion. Two distinct sets of pipes collect the juice, one of them serving six of the raspers, the other the remaining seven. No rasping takes place at the sugar works. These pipes are buried in the ground to 0·80 metre depth (32 in.); they are laid by the side of a road, following its windings and gradients. Their inside diameter is 0·125 metre (5 in.), whilst that of the pipes leading from each rasper to the main pipes is 0·09 metre ($3\frac{1}{2}$ in.). The main pipes have socket joints made with lead; they are of cast-iron, and are proved originally up to 15 atmospheres. The pressure within them varies according to their position from $\frac{1}{2}$ atmosphere to 10 and even 14 atmospheres. A pressure gauge in each rasping shop indicates the pressure within the pipes. Accidents by rupture of the pipes are very rare. They are made known by a depression of the gauges at the rasping shops, and by the exudation of the juice above the ground at the point of rupture. No stopping up of the pipes has ever taken place: this is prevented by flushing them for a long time with pure water before and after the season of manufacture. On the highest points of the line are placed air valves, to discharge the gases which collect there. These valves are opened daily by watchmen, who walk along the line for this purpose. On the lowest points are discharge valves, used chiefly for cleaning purposes. The juice flows through the pipes at an average speed of 2 kilometres per hour ($1\frac{1}{4}$ mile); it keeps perfectly fresh.

A telephone service unites part of the rasping shops with the central works. At the latter works the Wanze Company annually consume 100 to 115 million kilogrammes of beet-root (100,000 to 115,000 tons). The volume of juice treated each twenty-four hours is from 15,000 to 16,000 hectolitres (53,000 to 56,500 cub. ft.), corresponding to about 1,600,000 kilogrammes of beet-root (1600 tons). In 1882–3 the amount on which duty was paid was 6,500,000 kilogrammes (6500 tons), or one-twelfth of the total amount for Belgium. The distance, as the crow flies, from the central works to the different rasping works is as follows: for the first collecting main, 1730, 8650, 10,770, 20,770, 23,080, 28,080 metres; for the second, 6540, 7500, 12,115, 13,260, 17,115, 19,615, 21,923 metres. The total length of pipes is about 102 kilometres (64 miles).

DEFECATION.

The process of defecation is at once a clarifying and a purifying process, and is effected by lime. It is an operation on the perfection of which depends the purity of the juice and the yield in sugar. In its action on the juice the lime neutralises the organic acids, and forms with most of them, as well as with phosphoric acid, compounds which in great part are precipitated. It also decomposes the salts of potassium, sodium, and ammonia: the former of these remain in solution, the latter evaporates. Magnesia and oxides of iron and of manganese are carried off with the other precipitates, being enclosed in the albuminate of lime which is formed by the coagulation of albumen under the influence of heat. As to the other nitrogenous substances, they are partially decomposed and transformed into ammonia, the penetrating odour of which is observable during the whole operation. The result of defecation is that for a juice dark brown and almost black, containing an immense amount of organic matter in suspension, is substituted a juice perfectly clear, transparent, and of amber colour. To the eye the transformation is complete, but the purification is not so perfect as might be supposed. From a purity represented by 81 to 82 per cent. the juice has attained that of 87 to 88 per cent.

The lime is not added in the form of quicklime, but in the form of milk of lime at 20° on the Baumé densimeter. The lime milk is obtained by stirring quicklime in mixers, on the bottom of which are scrapers moved by machinery. Clear water is employed, only until a thick soup is formed; then, to economise steam, the density of 20° Baumé is obtained by adding thin juice derived either from the cleaning of the filters or from the second pressing of the scum. This thin juice would in any case have to be evaporated. The lime milk is then filtered to get rid of gravel and fragments. 22 to 23 kilos of quicklime produce one hectolitre of lime milk at 20° Baumé (14 lbs. per. cub. ft.). The quantity of lime for defecation cannot be exactly stated; it varies with the nature of the juice, its composition, the period of the year, &c. As a general rule $2\frac{1}{2}$ to 3 per cent. of the weight of the beet-root is sufficient in quicklime, or $12\frac{1}{2}$ to 15 per cent. in milk at 20° Baumé.

Two methods of defecation are employed in Belgium:

(1) *Defecation and Saturation.*—The defecation consists in treating the juice, heated to from 60° to 70° R. (167° to 190° Fahr.), with a

proportion of lime varying from 1 to 3 per cent. as a maximum; a scum of albuminate of lime is formed, gathers together, and floats on the top of the clear purified juice, which is drawn out from beneath and sent to be saturated. The operation of saturation has as its object to take away by an injection of carbonic acid the excess of lime still contained by the clear juice from the last process. The precipitate of carbonate of lime and organic matter is allowed gradually to settle at the bottom, and the clear juice on the top is drawn off for filtration.

(2) *Double Carbonatation.*—This is a method which is becoming almost universal. In the first carbonatation the juice is heated to from 60° to 70° R. = 167° to 190° Fahr.; lime to the amount of 1 to 2 per cent. is added by successive fractions, carbonic acid being injected after each addition. The injection of gas stops when the juice has reached a fixed point of alkalisation—generally 0·10 to 0·12 per cent. of the juice in volume, but varying according to the quality of the juice. The liquor first obtained is heated, allowed to settle, and the juice drawn off from the top for the second carbonatation. This is the same operation as the last, except that the addition of lime is reduced to 0·20 or 0·30 per cent. of quicklime, and that the neutralisation by a second injection of carbonic acid is pushed much further. Generally not more than 0·02 to 0·03 of alkalisation per cent. of the juice in volume is kept at the end, and some makers go on to absolute neutrality. The liquor is allowed to settle, and the clear juice passes to the filter.

The carbonatating vats are ranged in a row, Fig. 16, Plate 35, with the settling tanks immediately beneath them, a tank under each vat; all are about the same size, and nearly cubical in shape, each being of about 40 hectolitres capacity (140 cub. ft.) for works treating 100 to 120 tons of beet-root per 24 hours. Both vats and tanks are open at the top, Figs. 17 and 18, and the bottom slopes downwards to the front for drawing off the contents. In a row of six vats and six tanks, four pairs would be for the first carbonatation and two for the second. Inside each vat, Fig. 17, is a worm of three coils of steam-pipe for heating the juice; and in the centre of the vat a pipe with perforated branches radiating from it injects the carbonic acid gas into the liquid, which when ready is run off into the settling tank beneath. After settling here, Fig. 18, the clear juice is drawn off through a tap high enough from the bottom; and the sediment below the tap, consisting of scum and carbonate of lime, is run out through a plug in the bottom of the tank. The pipe supplying the carbonic acid gas to the vats is from 0·15 to 0·18 metre diameter (6 to 7 in.).

MANUFACTURE OF THE LIME AND CARBONIC ACID.

In consequence of the large quantity of lime and carbonic acid introduced into the juice, importance attaches to the purity of the raw material from which they are produced. This raw material consists of limestone and washed coke.

The qualities required in the limestone are the absence of clayey matter, of sulphate of lime, of ferric oxide, of bituminous substances, of sulphur, and above all of the alkaline salts of potassium and sodium. It is known that one unit of this latter prevents five units of sugar from crystallising. In general the yield of Belgian limestone in carbonic acid is from 42 to 43 per cent. of its weight.

The washed coke should be poor in sulphur, in volatile matter, and in ash, and should have a sufficient hardness.

Despite this selection of the raw material, the richness of the carbonic acid produced in practice never surpasses 35 per cent. of the pure gas, and only attains this figure in exceptional cases. For a furnace in first-rate working order the average richness of the gas is from 28 to 32 per cent. of carbonic acid, the remainder being composed of air, carbonic oxide, nitrogen &c.

The manufacture of the lime and carbonic acid takes place in upright furnaces communicating with each other, and having the form of a frustum of a cone. They are closed at the top by a cone, which is worked at the time of charging with a little hand-winch. At the lower part are four or six discharging holes partially closed, with coke fires between them. The fires however are considered useless, and are being gradually suppressed. The lime is extracted through the holes, and conducted to the mixers to be made into lime milk.

The carbonic acid is drawn off by a blowing machine belonging to the works, through a wrought-iron tube which leads from a circular passage constructed in the masonry of the upper part of the furnace; and from the blowing machine is delivered into the carbonating vats. In its passage from the furnace to the blower the gas should always traverse a water scrubber, entering at the bottom and then passing through three diaphragms one above the other, which are pierced with holes and produce a continual rain. In the blower a distributing slide-valve takes the place of flap-valves.

For 1000 kilog. of beet-root, there are required 5 to 6 kilog. of washed coke and about 40 kilog. of limestone.

Treatment of the Scum.

Under the name of "scum" is comprised the crust which swims on the clear liquid in the process of defecation, as well as the deposit resulting in the settling process which follows saturation or carbonatation. This scum contains so much more juice as the settling has been more difficult; and this juice has to be separated. For this purpose an apparatus called a filtering press is employed, Fig. 21, Plate 36. It is formed of a set of square cast-iron filter plates or frames A, Fig. 19, Plate 35, in which is cut on each face a series of vertical grooves, all uniting at bottom in a common horizontal channel, also cut within the plate itself. The grooves are covered with perforated sheet-iron, and this again by a hempen cloth, both being fixed to the plate. Generally each press has a dozen plates, supported between a pair of longitudinal side-bars B, and locked together face to face between a fixed end-plate D and a movable one E, the latter being tightened up by hand-screws. In the Daneck press, Fig. 21, Plate 36, there is interposed between each plate a square wood frame C, Fig. 20, Plate 35, of the same size as the plate, but entirely open within, so as to form a narrow chamber between each two consecutive plates. Through the top rim of each cast-iron plate and wood frame is bored a circular hole F, forming a continuous channel through the whole set of plates and frames when strung together in the press; from this channel is bored a smaller hole I into the body or chamber of each wood frame. The scum to be filtered, being delivered under pressure into the channel F, enters thence into each of the chambers between the filter plates;

the liquid passes through the filter cloth into the grooves in the plates, and runs off perfectly clear through a tap G at bottom of each plate; whilst the solids it contained, such as carbonate of lime &c., are retained by the filter cloth, and form a hard and nearly dry cake in the chamber of the wood frame. When the filtering is finished, the press is unlocked, the wood frames lifted out, cleared of cake, and replaced, and the press locked together again for the next filtering.

In the Trinks press the use of intermediate wood frames is dispensed with, the cast-iron plates being made with a projecting rim all round, which thus forms the cake-chamber between the adjacent plates. In this case the scum to be filtered enters through a central hole in each plate, instead of through the top rim.

In many cases the cakes are rinsed within the press itself before being taken out, which is done either by introducing water or by a jet of steam; for this purpose a separate hole J, Figs. 19 and 20, is provided in the Daneck press through each of the cast-iron plates and wood frames, and in the Trinks press through the top corner of each plate.

Despite the pressure it is subjected to, which with a juice-pump amounts to the boiler-pressure of 4 to 5 atmospheres, the scum still contains 3 to 4 per cent. by weight of sugar. Accordingly at the present day the scum is almost everywhere subjected to fresh treatment in hot water, followed by a second pressing. This yields a scum containing about 50 per cent. only of its original content of sugar, depending upon the volume of water employed; and also a thin juice, which is mixed with that from the first pressing and is passed with it to the second carbonatation. The impoverished scum is furnished as manure to farmers, who value it much: for such uses it has a value of 6 francs per 1000 kilog.

The proportion of scum formed is from 7 to 8 per cent. of the weight of the beet-root acted upon.

FILTRATION.

The diluted juice at 5° Baumé, as it is found after defecation, is submitted to a first filtration; a second filtration takes place with the same juice concentrated, that is to say, when it has become a syrup at 25° Baumé, and is leaving the evaporating pans—an operation which we shall describe hereafter. The filtering matter is animal charcoal, obtained by calcining in closed vessels fresh and hard bones crushed into grains of an average size of 5 mm. by 5 to 15 mm. (0·2 by 0·2 to 0·6 in.). Recently there has been much discussion as to the substitution for animal charcoal of a sort of gravel, specially prepared, with the addition of sulphuric acid so as to give a third defecation. Up to the present time this method of filtration has not gone beyond a few experiments, which are not very conclusive; and it has not succeeded in displacing animal charcoal, in spite of the high yield which it produces.

Some works manufacture charcoal themselves, as a *guarantee* of its quality; the greater number buy it. The charcoal chiefly acts by its surface, and therefore finer grains would be adopted, were it not for the slowness of the filtration which they produce. The action of the charcoal is chiefly to remove the lime left after saturation, the alkalis and their organic compounds, the greater part of the alkaline salts, the colouring matter, and the viscous substances. Its work is therefore to purify and to remove colour. The result is a rise in the quotient of purity of the juice, a loss of colour, a greater yield in sugar, and the obtaining of a product clearer, less brown, and less sticky. The filters employed are open or close. The former are low and wide—2·20 metres high by 1·20 metre in diameter (7¼ ft. by 4 ft.)—and work each by itself; the latter are high and narrow—4 to 5 metres high by 0·50 metre in diameter (13 to 16½ ft. by 1¾ ft.)—and work in series, the juice passing through several filters consecutively. The passage is produced by hydraulic pressure, due to the elevation of the tank filled with juice to be filtered. Open filters are the most common.

The system of filtration varies in different works. There are the three following methods:—

I. To filter first the syrups and then the juice in the same filter.

II. To filter the syrup and juice separately.

III. To filter the syrup alone, the juice going at once to the filter presses.

The first method is defective, since the warm and diluted juice may re-dissolve part of the matter given up by the syrup. The second is the more rational one. The third is doubtful, the action of the charcoal being less energetic on the concentrated juice than when diluted.

The duration of filtering depends, first, on the quantity of charcoal in use; secondly, on its quality; thirdly, on the quantity of juice to be filtered; fourthly, on the nature of the juice. In ordinary work the duration is from nine to twelve hours. It is fixed by a trial which determines the limit of time giving useful effect.

The quantity of charcoal employed varies almost without limit, being from 3 to 30 per cent. of the weight of the beet-root. The method of defecation largely influences the quantity of charcoal required. Generally the works which use the process of defecation and saturation require much more charcoal than those which work by double carbonatation, and where the purifying by lime is carried much further. The charcoal having served for filtration, and reached the limit of useful effect of which it is capable, should be revivified in order to recover the original properties which for the moment it has lost.

This revivification of the charcoal comprises first acidulation, secondly fermentation, thirdly washing, fourthly calcination.

Acidulation is with the object of dissolving the lime and carbonate of lime withdrawn from the juice, but without dissolving the carbonate of lime which makes an integral part of the charcoal itself. The proportion of this latter must therefore be known, and the amount of chlor-hydric acid calculated which is required to bring back the proportion in carbonate of lime to that of the fresh charcoal.

The fermentation usually employed is that by hot water. It serves to destroy the nitrogenous organic matter which has been separated by the filtration, and prevent it from being reduced to carbon by calcination, and from thus filling up the pores of the charcoal and so impairing its efficiency. It is carried out in masonry vats, and lasts from seven to eight days.

The washing is carried out first in a vat, by successive renewals of hot water, afterwards in special washers turning on trunnions, and having blades arranged in the inside in such a way as to lift up the charcoal and push it forwards in the opposite direction to a current of hot water. The charcoal is then submitted in a closed vessel to a pressure of steam, intended to get rid of its excess of water charged with organic matter, before it is delivered to the furnaces.

The revivification further includes drying and calcination. Drying is done on cast-iron plates or in kilns, heated by the waste flame from the furnaces. Calcination takes place in pipes, either of cast-iron or fire-clay, and composed of two parts. The upper one is heated directly by the flames to a temperature varying from dull red to cherry red; the lower is in the open air outside the furnace, and serves to cool the material without the contact of air. Every twenty minutes a discharge takes place, by means of slide valves which open and close the cooling pipes. On leaving the furnaces the charcoal is again submitted to treatment with steam, in order to get rid of the gas which it might still contain.

The charcoal has now become once more fit for filtration: the waste which it experiences in filtration and revivification is 4 to 5 per cent. of its weight. The waste consists, first of a powder sifted out of the charcoal when it leaves the calcining furnace, and secondly of mud deposited by settlement from the washing water.

The richness of this waste in phosphoric acid makes it an excellent manure, especially when transformed by sulphuric acid into super-phosphate. It is thus treated accordingly, either for the use of the works or else to be sold to the makers of chemical manures.

EVAPORATION OF THE JUICE.

This operation has for its object to concentrate the filtered juice at 5° Baumé, and transform it into syrup at 25° Baumé. It is carried out in what are called "double-action" concentrators when there are two vessels or boilers, and "triple-action" when there are three. The principle is the same under both systems, and is that of evaporation in a vacuum. We will take a triple-action system only.

The plant consists of three vertical vessels, Fig. 23, Plate 37, each formed of a group of vertical tubes in the lower part H, a cylinder with glass windows to it in the centre, and a dome-shaped covering at the top. The tubes are made of tinned brass and are fixed above and below to two plates of metal; the juice to be evaporated passes down through the inside of the tubes, which are surrounded by steam in a chamber H; their length is usually 1·80 m. (6 ft.).

The three vessels communicate with each other as follows:—the dome of the first communicates by a large pipe J with the tube chamber of the second, the dome of the second with the tube chamber of the third, and the dome of the third with a condenser K acting by injection of cold water.

From this arrangement it results that the admission of steam at A directly to the tubes of the first vessel produces a boiling of the juice within that vessel; the vapour thus produced warms the second, and the vapour produced in the second warms the third, whilst the vapour from the third passes to the condenser.

The condensing water, the condensed vapour, and the air are drawn off by an air-pump L worked with metal or india-rubber flap valves. In many cases a re-heater E, also tubular, is placed between the third vessel and the condenser: this effects the utilisation of part of the heat carried over by the vapour to be condensed, reduces the quantity of injection water, and so diminishes the work of the air-pump. The steam admitted directly and once for all to the first vessel is thus enabled to produce three successive effects, whence the name of triple action.

The steam employed is the exhaust steam from the various engines of the works; its temperature at $1\frac{1}{4}$ atmospheres is 106° to 108° Cent. (223° to 227° Fahr.). In consequence the ebullition would stop at the second vessel if a certain degree of vacuum did not exist in the two latter vessels; this produces a difference of temperature, between that of the steam and that of the boiling liquid in these vessels, sufficient to continue the ebullition. This vacuum, which is thus indispensable, is obtained in the third vessel by the direct action of the condenser, and in the second through the tubes in the third, which act as a surface condenser for the vapour from the second vessel. The group of tubes in the second acts equally as a surface condenser for the vapour from the first. The tubes of the second and third vessel also communicate by small pipes with the water condenser.

When at full work, the vacuum in each vessel is as follows:—

	First Vessel.	Second Vessel.	Third Vessel.
Vacuum in inches of mercury .	3 to 5	12 to 15	18 to 21
Corresponding temperatures of boiling . . .	97° to 95° C. 207° to 203° F.	85° to 80° C. 185° to 176° F.	74° to 66° C. 165° to 151° F
Difference of temperature between the steam or vapour and the boiling liquid .	10° to 12° C. 18° to 22° F.	12° to 15° C. 22° to 27° F.	11° to 14° C. 20° to 25° F
Total difference between the steam entering the first vessel and the boiling vapour leaving the third	——	——	107–70 = 37° C. 225–158 = 67° F.

These vacuums are kept up by the rapid condensation of the vapour, and their degree depends only on the ratio between the speed of condensation and the production of vapour. In consequence of the differences in vacuum within the three vessels there results a difference in pressure, the highest internal pressure corresponding with the lowest vacuum. Hence under these pressures, and without any other operation than the opening of the valves, the juice from the first vessel passes into the second, and the juice from the second into the third, through pipes C communicating from the bottom of each vessel to the space above the tubes in the next. Thus there is in ordinary working a continuous circulation of the juice, provided the valves in the pipes between the vessels are properly regulated. From the bottom of the third vessel is drawn off at D the concentrated syrup at 25° Baumé.

The efficiency depends first on the heating surface, secondly on the total difference of temperature between the boiling liquid and the steam. The larger the heating surface, and the greater the difference of temperature, the larger is the quantity of heat given up by the steam and absorbed by the juice. Thus, to attain from a given plant a higher efficiency, without altering the heating surface, it is sufficient to raise the temperature of the steam at its entry, or to diminish the temperature of ebullition in the last vessel by employing a larger quantity of condensing water.

The evaporative power of this plant is from 22 to 25 kilog. of water per square metre per hour (4·51 to 5·12 lbs. per sq. ft.); or 6·5 to 7·5 hectolitres of juice per square metre per 24 hours (2·13 to 2·46 cub. ft. per sq. ft.). If we take the heating surface in the first vessel as unity, that in the second should be 1·25 to 1·50, and that in the third 1·50 to 1·75. For working 100 to 120 tons of beetroot per 24 hours, provision should be made for evaporating 1250 hectolitres of juice (4400 cub. ft.) in the same time.

The advantages of the triple-action evaporators are as follows:—(1) the quantity of condensing water may be reduced, in consequence of the repeated use of the steam and vapour; (2) the working is continuous and rapid; (3) the products are withdrawn from the injurious influence of the air; (4) the juice is enabled to boil at temperatures so much the lower as the richness in sugar is greater; (5) they are very economical in fuel, because the evaporation goes on in a vacuum.

BOILING.

This operation has for its object the concentration of the syrup, now at 25° Baumé, and its transformation into a "masse cuite" or Boiled Mass.

The boiling apparatus or vacuum pan, Fig. 22, Plate 36, is composed of three parts; first, a hemispherical bottom B of cast-iron, provided at its centre with a circular hole H for emptying, which is closed by a sliding door; secondly, the middle part, composed of a cylinder C provided with glass windows G, so that the boiling may be observed inside; thirdly, the upper part D, formed of a dome-shaped cover, which communicates by a large pipe P with a cold-water injection condenser J. The water injected, the vapour condensed, and the air are withdrawn as in the triple-action evaporators by an air-pump. Between the condenser and the dome is a catch-chamber K, intended to retain the froth, the syrup, and the crystals themselves, which are sometimes carried over by too violent ebullition.

The apparatus is heated by steam at high pressure, generally

$4\frac{1}{2}$ to 5 atmospheres. This steam circulates in three or four worms W inside the boiler, placed one above the other, from 0·30 to 0·40 metre apart (12 to 16 in.), and of dimensions proportionate to the capacity of the plant.

As in the triple-action evaporators, the boiling goes on in a vacuum; the degree adopted in practice varies from 17 to 24 inches of mercury, according to the stage of the operation. The corresponding temperatures of ebullition are 76° and 55° Cent. (169° and 131° F.) To regulate the vacuum, the man in charge has only to manage the steam cock on the one hand, and the cock for the cold-water injection into the condenser on the other.

The efficiency of this plant varies, first with the difference of temperature between the syrup to be boiled and the heating steam; secondly, with the heating surface of the worms. The temperature of the steam at 5 atmospheres is 152° Cent. = 306° F.; the mean temperature of the syrup when boiling, corresponding to a vacuum of from 17 to 24 inches, is 60° Cent. = 140° F.; the difference is thus 92° Cent. = 166° F. With a pressure thus diminished and with so great a total difference between the temperature of the juice and that of the steam, it is easy to conceive how rapidly the evaporation goes on. It attains the figure of 60 to 75 kilog. of water per square metre of heating surface per hour (12 to 15 lbs. per sq. ft.), or 1·50 to 1·65 hectolitres of syrup (5·30 to 5·83 cub. ft.).

The boiling process may be divided into four stages:—(1) evaporation of the syrup up to the crystallising point; (2) formation of crystals; (3) accretion of crystals; (4) final drying or compression.

(1) The crystallisation is obtained by the evaporation, up to the "string test," of a volume of juice representing about two-fifths that of the crystals left. The string test consists in simply placing a drop of liquid between the thumb and forefinger, which are then separated more or less. The test is reached when wide separation of the fingers gives a delicate thread which breaks, and of which the upper end presents at its lower extremity a small hook neatly formed. There are what are called light hooks and strong hooks; the latter correspond to more intense concentration, and are employed in the

crystallisation of impure and viscous sugar. This latter test corresponds practically to a density of 42½ to 43° Baumé.

(2) The formation of the crystals is due to the state of super-saturation in which the syrup exists at the crystallising point. It is indicated by the formation of an immense number of small grains of sugar. This is the moment when the foreman has to attend to the formation of crystals regular in shape, sufficiently large, hard, and well formed. This is achieved by pumping in additional charges of syrup in amounts exactly equal to each other, and at intervals more or less long.

(3) The accretion of the crystals once formed is produced by a continuous pumping in of syrup, so as to maintain the mass in a proper state of fluidity. As it evaporates, this syrup gives up its sugar, which settles upon the crystals already formed and increases their size, according to the laws of crystallisation. The introduction of the syrup should be carefully watched. If the quantity is too great, the crystals are re-dissolved; if it is too small, the mass returns rapidly to the state of super-saturation, small crystals are formed afresh, and the final product is irregular. Small or large crystals may be produced at will, following the principle that slow crystallisation gives large and regular crystals, and rapid crystallisation gives small and irregular crystals. The grains will be large if the boiling goes on slowly, if large charges of syrup are added at long intervals, and if the syrup is diluted. They will be small on the contrary if the boiling is rapid, if the additions of syrup are frequent and small, and if the syrup is concentrated.

(4) The crystals are dried to the degree required by ceasing to supply the syrup, and introducing only a thin current of steam. The point at which to stop is of great importance. If you stop too soon, many crystals will remain dissolved in the syrup and the yield will suffer accordingly; if you stop too late, the crystals are found glued in a mass, and difficult to separate. The degree of drying varies with the purity of the product; the more impure, the less it should be dried. When the crystallisation is over, the valve at the bottom of the pan is opened, and the contents drawn out into vats called coolers or crystallisers, which are maintained as near as possible at a temperature of 20° to 25° Cent. (68° to 77° F.).

The duration of the process is from eight to ten hours. The quantity of crystals obtained per 1000 kilog. of beet-root depends first on the quality of the beet-root; secondly, on its state of preservation; thirdly, on the degree to which the crystals are dried; fourthly, on the perfection of the process. Generally the volume varies from 0·600 to 0·675 hectolitre per 1000 kilog. of beet-root (2·12 to 2·38 cub. ft. per ton); the weight of a hectolitre is 138 to 142 kilog. (86 to 89 lbs. per cub. ft.). The yield of No. 1 sugar is from 85 to 95 kilog. to the hectolitre of No. 1 crystals (53 to 59 lbs. per cub. ft.).

CENTRIFUGAL SEPARATION.

The object of this process is to separate the grains of sugar from the syrup which contains them, the mixture forming what we have called the "boiled mass." It is performed by means of centrifugal machines, in which a vertical shaft, running in a fixed bearing at the top and on a pivot at the bottom, carries a drum 0·75 metre in diameter and 0·30 metre in height (30 in. and 12 in.); the circumference of the drum is lined inside with a cloth, or a sheet of iron pierced with holes sufficiently small to retain all the little crystals of sugar. In general the shaft receives its motion from the top by friction cones, and has a speed of 1,000 to 1,200 revolutions per minute; in exceptional cases the motion is given from below. Under the action of the centrifugal force the boiled mass is spread out upon the cloth or perforated plate, and the syrup passes out through the holes, whilst the grains of sugar remain behind, forming a layer which can be purified by simple rotation, until a sugar is obtained of any desired richness and quality. Sometimes however clarification by means of water or steam is employed. By this means a sugar is obtained, the grains of which are perfectly white and dry, and of great richness. This sugar may be sold at once, and may even compete with refined sugar. Two machines are enough to work 80,000 or 100,000 kilog. (80 to 100 tons) of beet-root in the twenty-four hours; in each operation from 30 to 40 kilog. of boiled mass (66 to 88 lbs.) are charged into each machine, and produce 25 to 35 kilog. of sugar (55 to 77 lbs.). Each operation lasts eight to ten minutes.

From the boiled mass No. 1 we thus obtain by the centrifugal process a sugar also called No. 1, and a first waste syrup.

This syrup is boiled over again under a vacuum of 18 to 22 inches, is concentrated to the crystalline point by the test of the strong hook, and crystallised in vats of from 60 to 70 hectolitres (210 to 250 cub. ft.), placed in chambers kept at a temperature of 30° to 35° Cent. (86° to 95° F.). These hot chambers are called "*emplis.*" The mass thus obtained is called boiled mass No. 2. It must be remarked that no formation of grains takes place in the boiling in this process: the syrup is not sufficiently pure. The crystallisation takes place in the hot chamber, after a time which is longer as the crystalline mass is more impure, and generally is about four weeks. At the end of this time the centrifugal process is carried out, and a sugar is obtained called No. 2, together with a second waste syrup. This sugar No. 2 is browner and more impure than No. 1. The second waste syrup is again boiled, concentrated under the same degree of vacuum and to the same test point as the first, and crystallised in "*emplis*" heated to from 40° to 45° Cent. (104° to 113° F.).

In consequence of the growing impurity of the product, the slowness of the crystallisation increases, and whilst four weeks are sufficient to crystallise the mass No. 2, five to six months are required to finish the process in the mass No. 3. Then by the centrifugal action a sugar called No. 3 is obtained, yet browner and more impure than No. 2; and also a third waste syrup which is called Molasses.

This molasses forms a final residue in the make of sugar; it is a product which despite its richness in saccharine matter, amounting to 40 or 50 per cent. in weight, cannot give crystallised sugar by fresh boiling. In Belgium it is sold to Belgian or foreign distillers to make alcohol. Its commercial value is from 9 to 15 francs per 100 kilogrammes at 42° Baumé. The proportion of molasses varies from 2·5 to 3·5 per cent. of the weight of the beet-root.

Many processes have been proposed to extract sugar from molasses. That of osmosis is the only one applied in Belgium, and only by about half the works. The cause which prevents its becoming general is simply the supplemental duty of 6 per cent. on the total make of the season, which is exacted by the Excise.

Osmosis of Molasses.

This process consists in applying the principles of endosmosis and exosmosis to molasses. The liquids to be treated consist of water on the one side and molasses on the other, separated by a sheet of parchment paper. A current of endosmosis takes place from the water towards the molasses, and a current of exosmosis in the opposite direction. The object of osmosis is to carry off the salts diffused through the mass. In particular it takes off the greater part of the salts of potassium and sodium, and thus restores a certain quantity of sugar which these substances had rendered non-separable.

The Osmogene, or apparatus used, Figs. 24 and 25, Plate 38, is composed of a series of 51 wooden cases, Figs. 26 and 27, about 1·15 metre long, 1·00 metre wide, and 0·66 metre high (46 in. × 40 in. × 26 in.), the wood being 15 millimetres thick (0·6 in.). There are different types of construction. They are placed next to one another, side by side, with a sheet of parchment paper between each, and the whole bolted tightly together: thus there are formed a series of chambers filled alternately with molasses and water. In the compartments of the even numbers, Fig. 25, there is an ascending current of molasses heated to 60° to 75° C. (140° to 167° F.), and in the compartments of the odd numbers a descending current of water at 75° to 80° C. (167° to 176° F.). The analysis by osmosis takes place through the membranes; part of the water enters into the molasses, and part of the salts of potassium and sodium passes into the water, as well as a certain quantity of sugar, which is also soluble in the water. The water thus charged with salts and sugar is called water of exosmosis.

The effect of osmosis will be greater as the molasses leave the osmogene in a more diluted condition, in consequence of a more prolonged contact with the water, and of a larger volume of water having passed through in proportion to the quantity of molasses. The molasses may leave at 20°, 18°, 15° or even 12° Baumé. The effect of osmosis is measured by the increase in the saline coefficient of the molasses which has been treated, compared with that which has still to be treated. The higher this coefficient has been raised, the greater will have been the improvement and the larger the quantity of sugar recovered. The saline coefficient is found by dividing the percentage of sugar by the percentage of ash. To be satisfactory the increase ought to be at least 2, but with the condition that the saline coefficient in the water of exosmosis does not exceed 1, that is to say that in this water the content of sugar and of salt should never pass the ratio of 1 of sugar to 1 of salt.

In an osmogene about six times more water passes than molasses, and each apparatus will produce 7 to 8 hectolitres of boiled mass per 24 hours (25 to 28 cub. ft.).

According to the nature of the molasses, the employment of osmosis allows the formation of boiled masses numbered 4, 5, 6, and even 7, the osmosis of course being performed afresh after each. A time however will come when the concentration of the organic matter and of other matters incapable of diffusion is so great that the point of crystallisation cannot be attained, and then all further crystallisation becomes impossible.

It is estimated that 1 kilogramme of saline matter expelled will restore 3·5 kilog. of sugar. The loss in osmosis varies from 15 to 20 per cent. of the weight of the molasses treated, and the yield of sugar varies from 20 to 25 kilog. per hectolitre of boiled mass produced ($12\frac{1}{2}$ to $15\frac{1}{2}$ lbs. per cub. ft.). The employment of the process will depend upon the proportion existing between the value of sugar and that of molasses.

Osmosis, if well managed, will eliminate as much as 50 per cent. of the saline matter; and this, assuming a coefficient of 3·5, would give, for a molasses containing 13·17 per cent. of ash, 23 per cent. of sugar regenerated, supposing that this could all be separated by a single crystallisation. In general 100 kilog. of molasses, after thorough osmosis from 43° to 13° Baumé, will give 20 kilog. of sugar with a loss of 50 kilog. in molasses; and 50 kilog. of molasses in a normal condition will remain. Some works have begun to concentrate their water of exosmosis to 42° Baumé, and then sell it. This may be considered as the first step towards "osmosis à outrance," as already used to some extent in France. This comprises simple osmosis, concentration of the water of exosmosis, crystallisation of the salts, and re-osmosis of the new molasses thus obtained. The yield in salts thus recovered to agriculture (a mixture of nitrates and alkaline chlorides) may reach 3 per cent. of the amount of molasses first subjected to osmosis.

TABLE OF ANALYSES SHOWING THE COMPOSITION OF THE JUICE AND OF ITS PRODUCTS IN THE DIFFERENT STAGES OF THE MANUFACTURE.

	Density.	Sugar per cent. In volume of juice.	Sugar per cent. In weight of juice.	Sugar per cent. In weight of beet-root.	Quotient of purity.	Standard of value.	Alkaline matter.
	Baumé.	per cent.	per cent.	per cent.			grammes.
Beetroot (mean of 1500 analyses)	1·0537	11·49	10·90	10·35	82·70	9·02	
Juice not limed	1·0400	8·51	8·18	. . .	81·80	. . .	
Juice limed	1·0456	7·65	7·32	. . .	64·98	. . .	0·91 % of juice by volume
Juice of the first carbonatation	1·0331	7·39	7·16	. . .	87·04	. . .	0·1180 % of juice by volume
Juice of the second carbonatation	1·0323	7·38	7·15	. . .	88·60	. . .	0·0280 % of juice by volume
Juice filtered through animal charcoal	1·0311	7·25	7·03	. . .	89·73	. . .	0·0240 % of juice by volume
Syrup before filtration	1·2105	48·91	40·34	. . .	87·02	. . .	0·1040 % of juice by volume
Syrup after filtration	1·2005	46·09	38·40	. . .	87·32	. . .	0·0930 % of juice by volume

	Density.	Crystallisable.	Ash.	Water.	Organic matter.	Quotient of purity.	Yield of boiled mass per 1000 kilos of beet-root.	Yield of sugar per hectolitre of boiled mass.	Ordinary limits of yield per hectolitre according to the quality of beet-root.
	Baumé.	per cent.	per cent.	per cent.	per cent.		hectolitres.	kilos.	kilos.
Boiled mass No. 1	—	82·22	5·14	6·43	6·21	87·87	0·59	88·60	86 to 91·75
Boiled mass No. 2	—	66·32	10·35	12·64	10·69	76·00	0·26	44·10	40 to 52·00
Boiled mass No. 3	—	58·45	13·65	13·08	14·82	67·25	0·17	15·42	15 to 30·00
Molasses	42·10	46·34	13·14	20·40	20·12	58·22	26 kilos		

	Crystallisable.	Ash.	Water.	Organic matter.	Standard of value.	Yield per 100 kilos of beet-root.	Ordinary limits of yield per 100 kilos of beet-root according to the quality of the beet-root.
	per cent.	per cent.	per cent.	per cent.		kilos.	kilos.
Sugar No. 1	96·01	1·22	1·525	1·245	89·91	5·227	5 to 6
Sugar No. 2	91·04	3·00	3·06	2·90	76·04	1·146	0·90 to 1·35
Sugar No. 3	90·87	3·13	3·05	2·95	75·22	0·262	0·20 to 0·35
						6·635	6·10 to 7·70

ANALYSES OF BY-PRODUCTS.

Pulp from the hydraulic press.

Moisture	from 70	to 75	% by weight.
Sugar	from 5·50	to 7·50	% by weight.
Quotient of purity in the juice		72	

Pressed Pulp from the diffusion process.

Moisture	from 88 to 90 % of weight of pulp.

Unpressed Pulp from the diffusion process, representing about 70 per cent. of the weight of the beet-root.

Sugar	from 0·43 to 0·85 % of weight of pulp.
Water contained	from 0·15 to 0·25 % of weight of beet-root.

Scum from the first pressing.

Sugar	from 3 to 4·5 %

Scum from the second pressing.

Sugar	from 1·50 to 1·80 %
Moisture	from 41·50 to 43·50 %

Juice from the second pressing.

Sugar per cent. in volume	3·00
Quotient of purity	79·00

Fermented Scum for manure.

Moisture		36·100
Solid Matter	Nitrogen	0·347
	Phosphoric acid	0·914
	Potash	0·153
	Lime	30·065
	Organic matter non-nitrogenous	30·919
	Matter not examined	1·502
Total		100·000

Waste from animal charcoal.

In dust	Water	3·14 %
	Phosphoric acid in a state of tri-calcic phosphate	33·38 %
Mud deposited	Water	20·74 %
	Phosphoric acid in a state of tri-calcic phosphate	21·68 %

ANALYSIS OF OSMOSIS.

	Density Baumé.	Crystallisable Sugar.	Ash.	Saline Coefficient.
Molasses before osmosis	42·14	44·08	11·02	4·00
Molasses after osmosis	17·00	21·17	3·33	6·35

This shows an improvement in saline coefficient to the extent of 2·35. The water of exosmosis shows crystallisable sugar 0·75, ash 0·76; or one of sugar to one of ash.

Mode of Valuing Sugar.

Sugar is sold according to its richness. To obtain the figure of value which regulates the sale, the figure for ash is multiplied by 5, the figure for uncrystallisable sugar is added, and the total of the saccharimeter figure is subtracted. In selling raw native sugar, four kinds are distinguished; (1) sugars taken on a basis of 88°, in which the figure of value is 85° minimum and 92° maximum, inclusive; (2) sugars taken on a basis of 85°, in which the figure of value is 82° minimum and 86° maximum, inclusive; (3) sugars taken on a basis of 75°, in which the figure of value is 70° minimum and 82° maximum, inclusive; (4) sugars taken on a basis below 72°.

The degrees and fractions of degrees above or below the basis of value are calculated as follows:—1·25 francs per degree for sugars of basis 88° and 85°; 0·30 franc per degree for the sugar of basis 75°. If it should be stipulated that the seller may deliver sugar above 92° or below 70°, each degree is calculated as follows:—Above 92° at 1 franc; below 70° at 0·90 franc.

Sugars may be sold either for exportation or for home use. On exported sugar a drawback is allowed by the Excise, which is fixed as follows:—For native raw sugar not moistened, 45 francs per 100 kilog. for No. 11 and above (this is the first class, on which the whole of the duty is returned); and 40·91 francs per 100 kilog. for sugars No. 8 to No. 11 exclusive (this is the second class, on which only a partial return is given). The numbers 11 and 8 indicate merely varieties of shade, the colour corresponding to types which are designated by these numbers.

The quantity exported, and on which the drawback is paid, cannot in any case exceed the quantity taken by the Excise. Any excess over the quantity so taken must then be sold for home consumption; but in the latter case the amount of the tax is still added to the selling price of the goods. Thus the buyer has to reimburse the manufacturer for a tax which he has not paid, so constituting a bounty to the latter.

A sugar on which the drawback is payable, that is to say, which comes within the limits of the Excise, may equally be sold for home consumption. In this case the manufacturer is still reimbursed by the buyer for the taxes which are comprised in the selling price, but he remains debtor for these taxes to the State.

The customs charged on raw sugar from abroad correspond to the drawback on the native sugar exported of the same class, as follows:—

		Fr. per 100 kilog.
Foreign raw sugar	below No. 7	34·26
	from No. 7 to No. 10 exclusive . . .	40·91
	from No. 10 to No. 15 „ . . .	45·00
	from No. 15 to No. 18 „ . . .	48·07

The paper may be terminated by some statistics on the subject.

		Hectares.		Acres.
The area under cultivation for beet-root . .	In 1846 was	2,121	=	5,241.
	In 1866 „	18,000	=	44,480.
	In 1882 „	35,000	=	86,490.

The last figure is calculated on the assumption of a return of 40,000 kilog. per hectare (16 tons per acre), and an excise of 5·75 kilog. per 100 kilog. of beet-root.

The sugar works which were in action during the season of 1882–3 were as follows: — 98 with hydraulic presses, 2 with continuous presses, 42 with the diffusion process; and 1 work with separate rasping mills, having 9 rasping mills with hydraulic presses and 4 with the diffusion process.

The Excise quantity of raw sugar for the season 1882–3 was 80,408,809 kilog. (80,400 tons). Of this 6,483,466 kilog. (6,480 tons) belong to the central works.

The statistics of raw sugar are as follows:—

	1880–81. Kilog.	1881–82. Kilog.	1882–83. Kilog.
Total make . .	68,626,000	73,136,000	80,000,000 (probable)
Total exported .	——	63,833,000	——
Total imported .	——	22,289,614	——

The statistics for refined sugar are as follows:—In 1881–82 the quantity exported was 11,475,874 kilog., and the quantity imported 5,629,727 kilog. The average consumption during the three seasons 1879–80, 1880–81, 1881–82, was 21,223,909 kilog.: the population being 5,600,000, this gives 3·79 kilog. per head (8·34 lbs.). This figure would reach about 5·25 kilog. per head (11·55 lbs.), if account were taken of the various products which escape the notice of the excise, but which all go into consumption.

Rasping Apparatus.

Fig. 1. *General Elevation.*

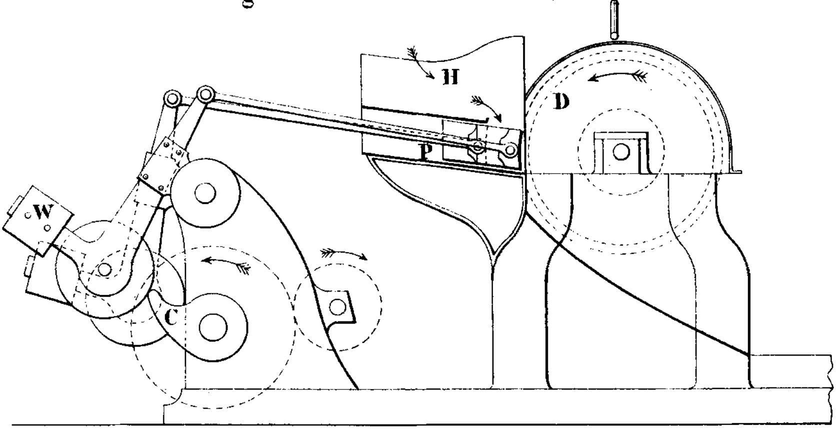


Fig. 2. *Longitudinal Section of Rasping Drum.*
Scale 1 to 10.

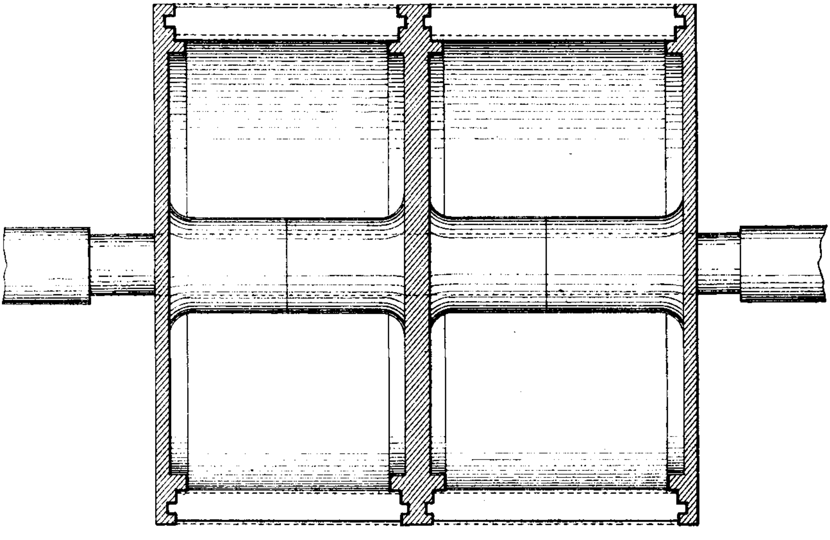
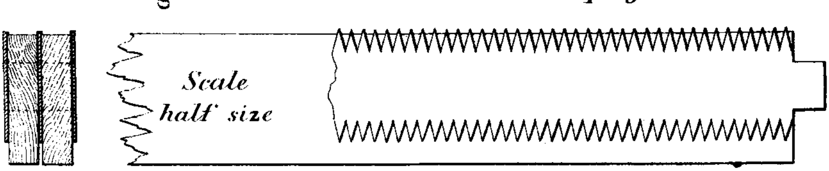


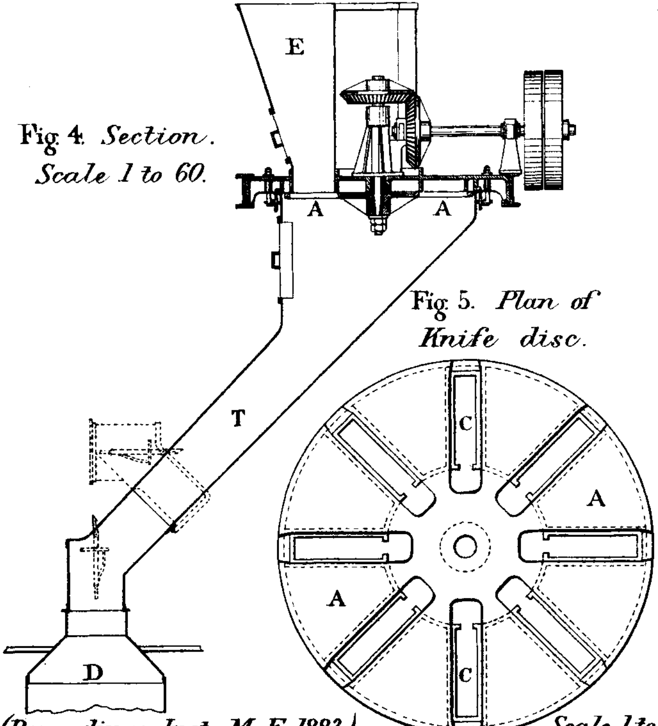
Fig. 3. *Details of Laths and Rasping Blades.*



Cutter for Cossettes.

Fig 4. *Section.*
Scale 1 to 60.

Fig 5. *Plan of Knife disc.*



(Proceedings Inst. M. E. 1883.)

Scale 1 to 30.

Fig. 10. *Goller Knife.*

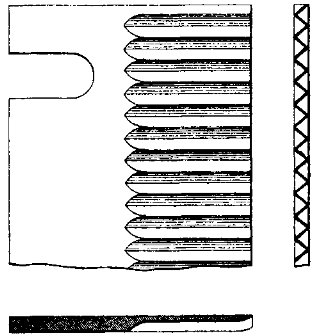
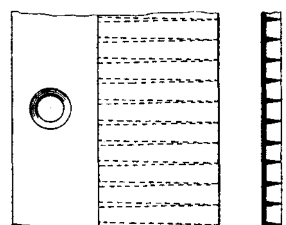


Fig. 9.
Naprawill Knife.



Knife Carrier.

Fig. 6. *Plan.*

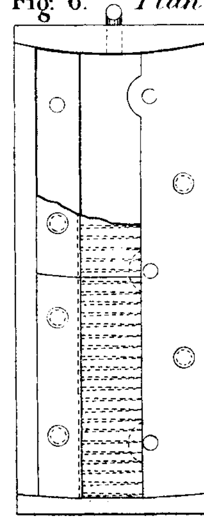


Fig. 7.
Section.

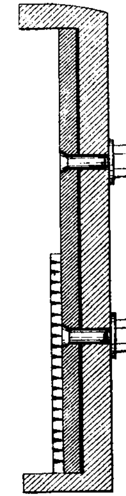
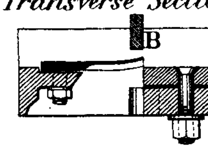


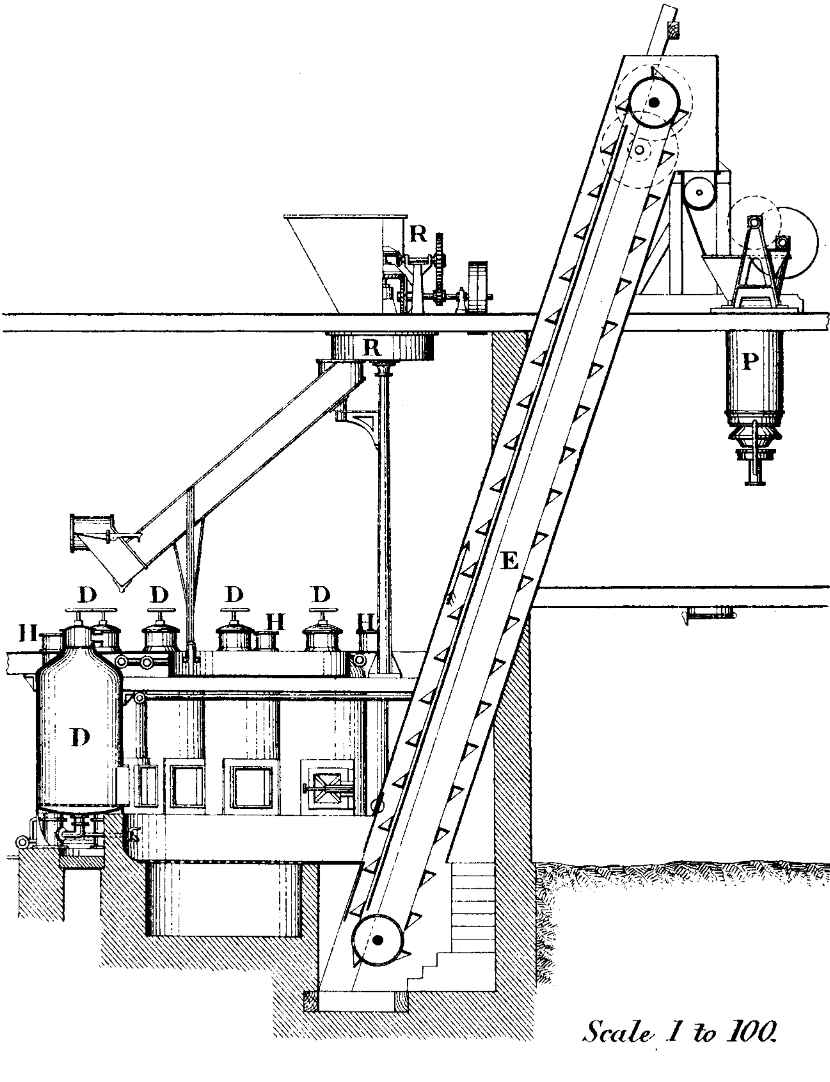
Fig. 8.
Transverse Section.



Scale 1 to 5.

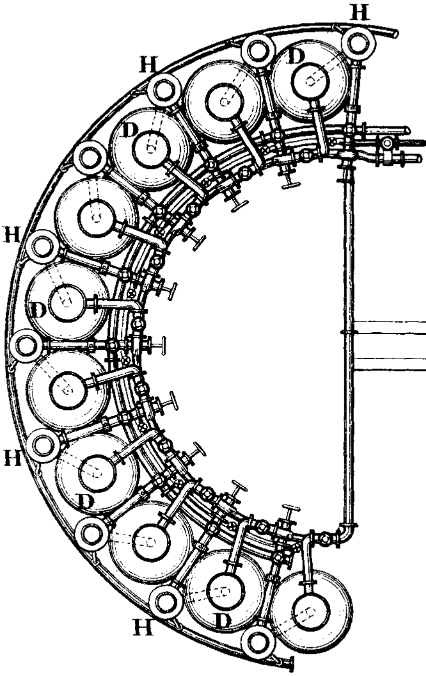
Plate 31.

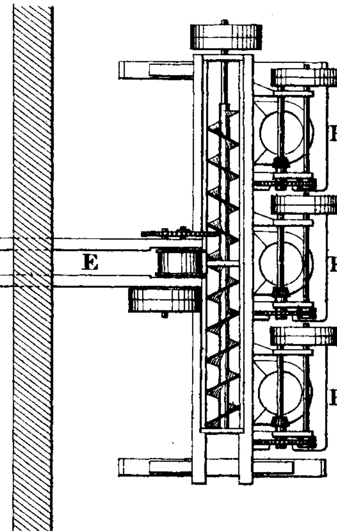
Fig. 11. *General Elevation of Diffusion Battery with Klusemann Press.*



Scale 1 to 100.

Fig. 12. *Plan of Diffusion Battery.*





Scale 1 to 100.

Selwig and Lange Press.

Fig. 13.

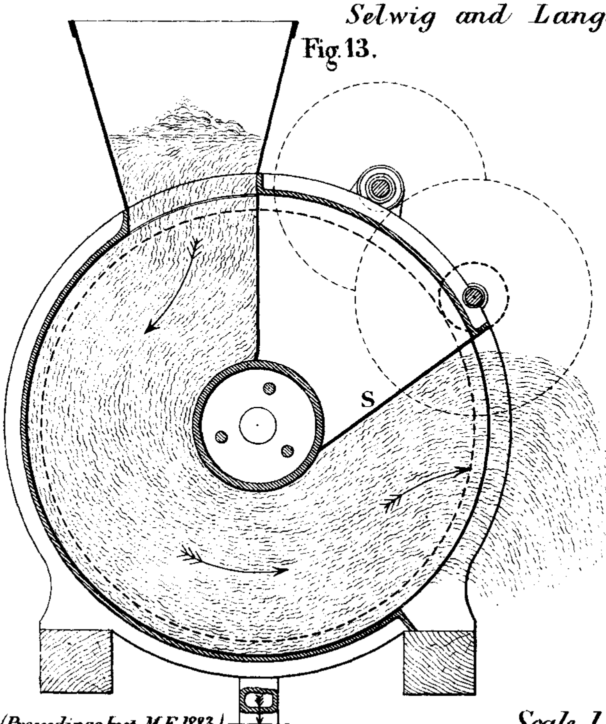
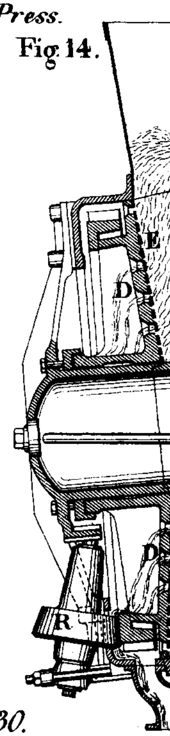
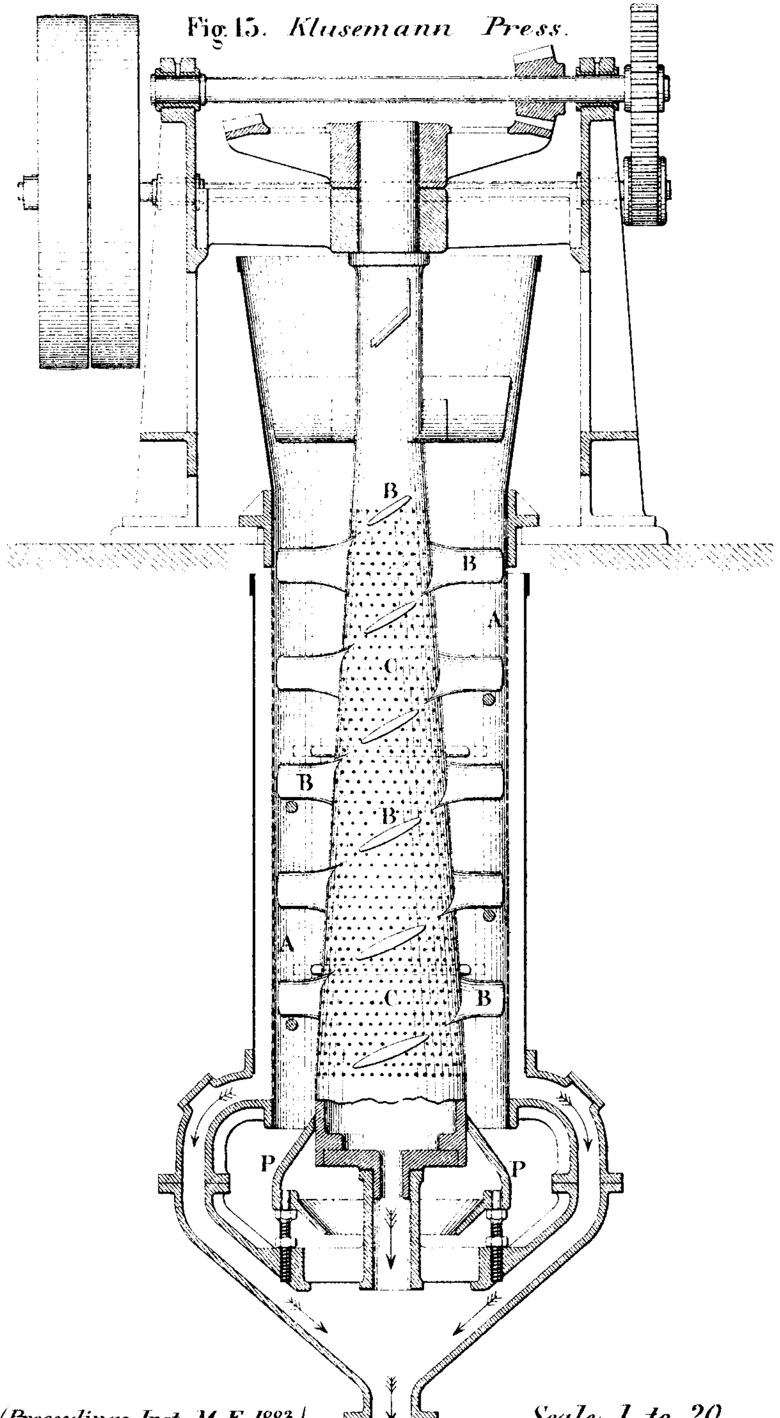


Fig. 14.



Scale 1 to 30.

Fig. 15. *Klusemann Press.*



(Proceedings Inst. M. E. 1883.) *Scale 1 to 20.*

Fig. 16. *Diagram of Carbonatation Plant.*

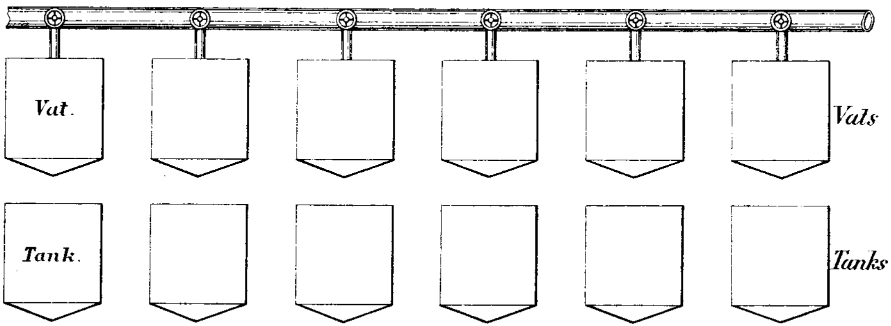


Fig. 17. *Carbonatation Vat.*

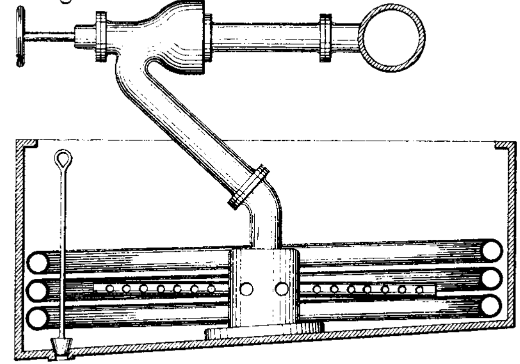


Fig. 19.

Plate for Filtering Press.

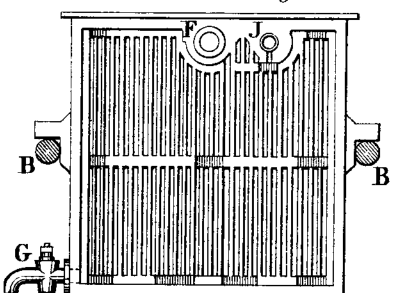


Fig. 20.

Open Frame for Filtering Press.

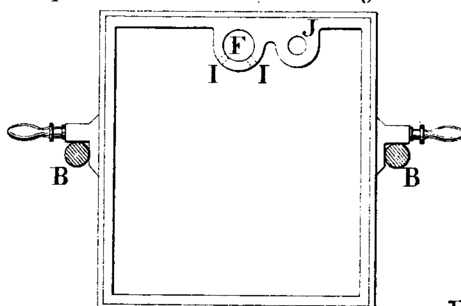
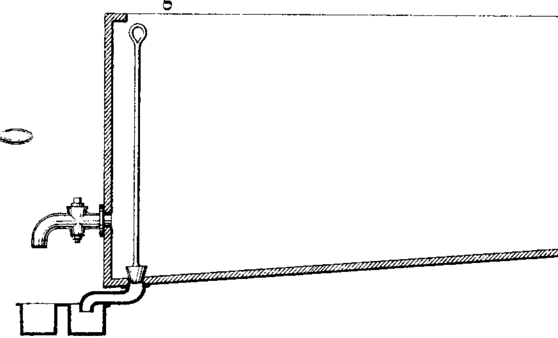


Fig. 18. *Carbonatation Tank.*



(Proceedings Inst. M.E. 1883.)

Fig. 21. *Section and Side View of Filtering Press.*

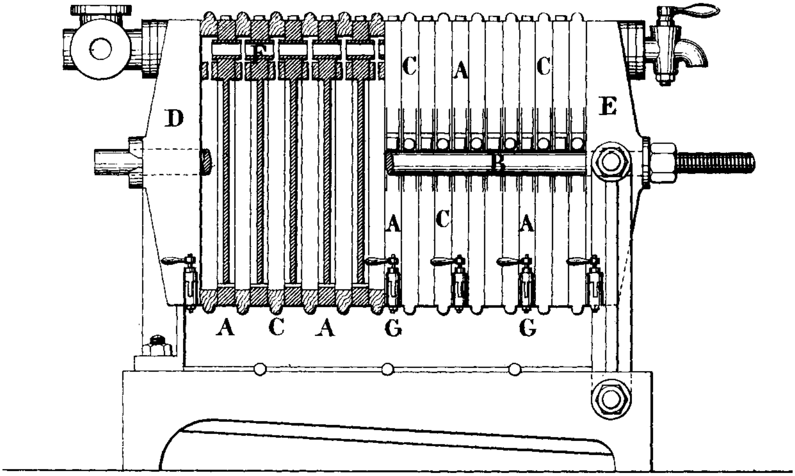


Fig. 22. *Elevation of Sugar Boiler.*

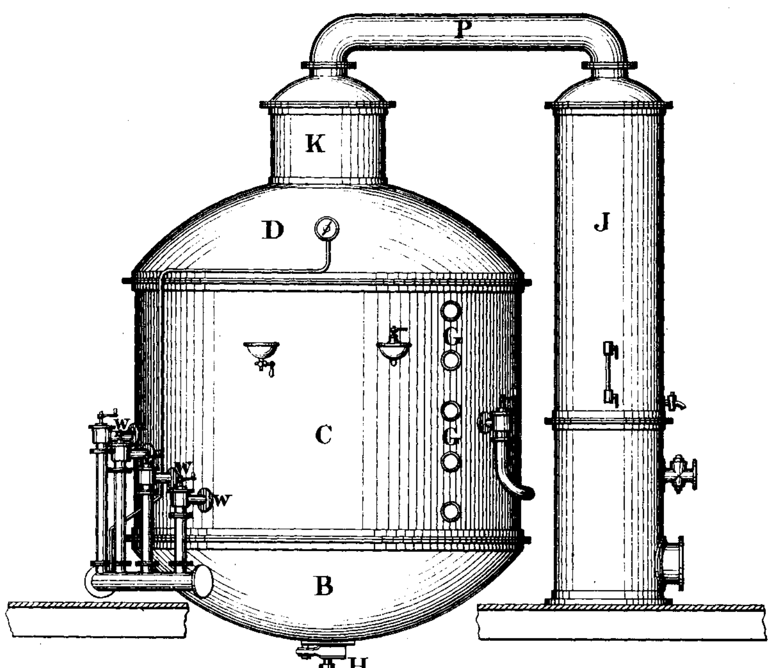
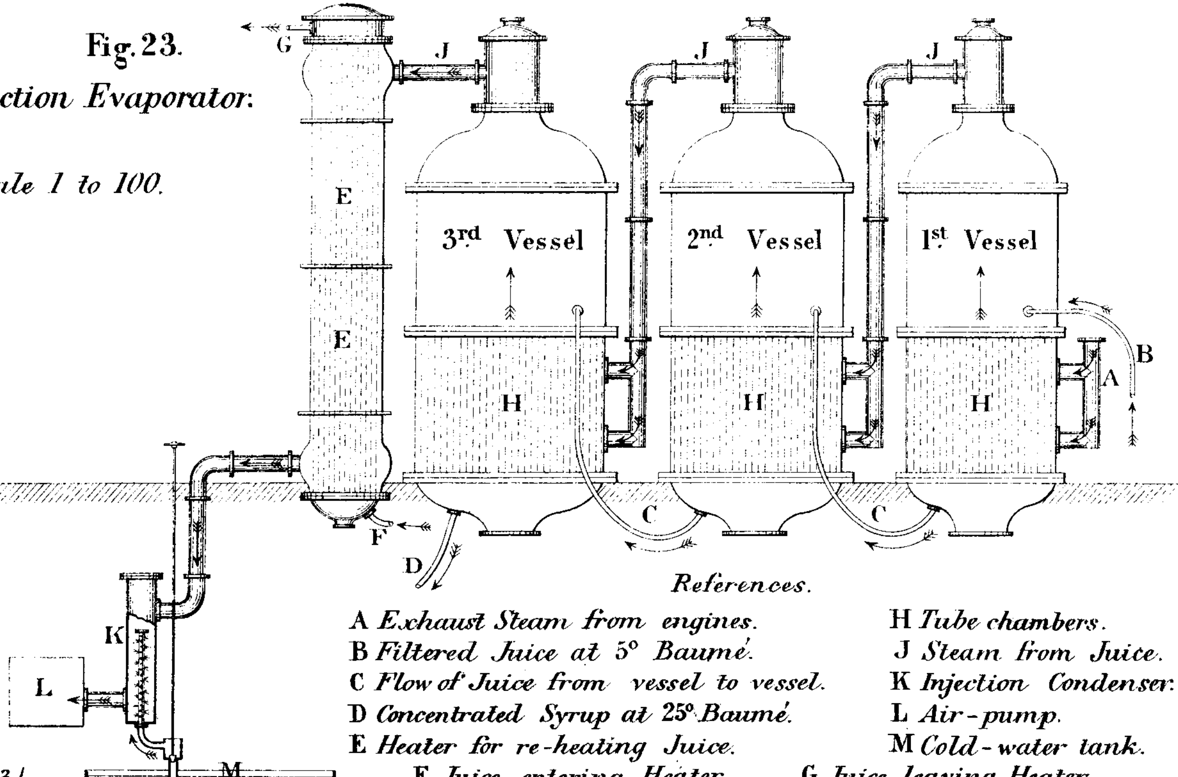


Fig. 23.

Triple-action Evaporator:

Scale 1 to 100.



References.

A *Exhaust Steam from engines.*
B *Filtered Juice at 5° Baumé.*
C *Flow of Juice from vessel to vessel.*
D *Concentrated Syrup at 25° Baumé.*
E *Heater for re-heating Juice.*
F *Juice entering Heater.*
G *Juice leaving Heater.*
H *Tube chambers.*
J *Steam from Juice.*
K *Injection Condenser.*
L *Air-pump.*
M *Cold-water tank.*

(Proceedings Inst. M. E. 1883.)

BEET-ROOT SUGAR. *Plate 38.*

Osmogene for Molasses.

Fig. 24. *End View.*

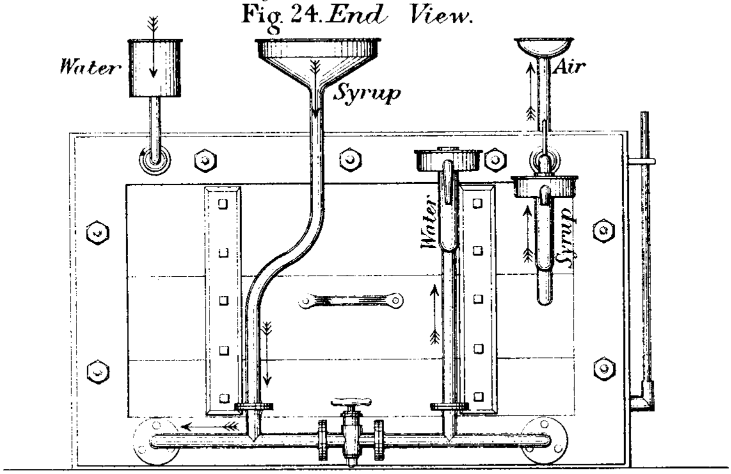


Fig. 25. *Side View and Section.*

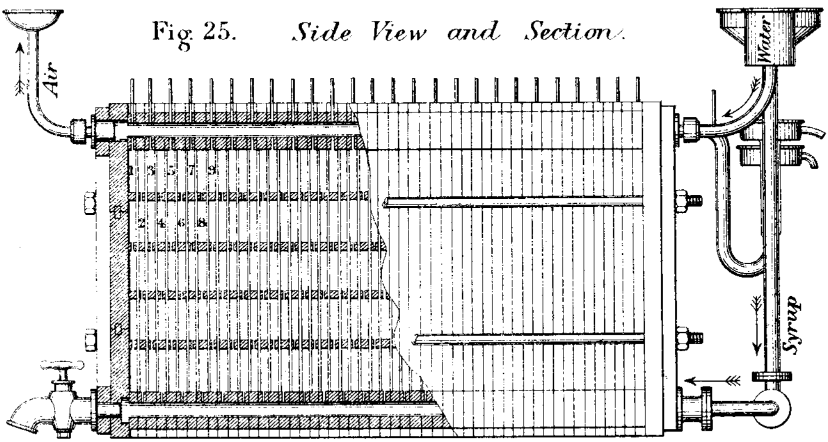


Fig. 26. *Elevation of Frame.*

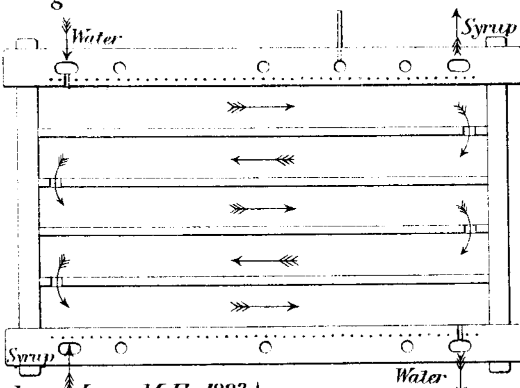
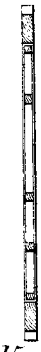


Fig. 27.
Section.



(Proceedings Inst. M.E. 1883.)

Scale 1 to 15.