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# SUGAR HOUSE NOTES AND TABLES

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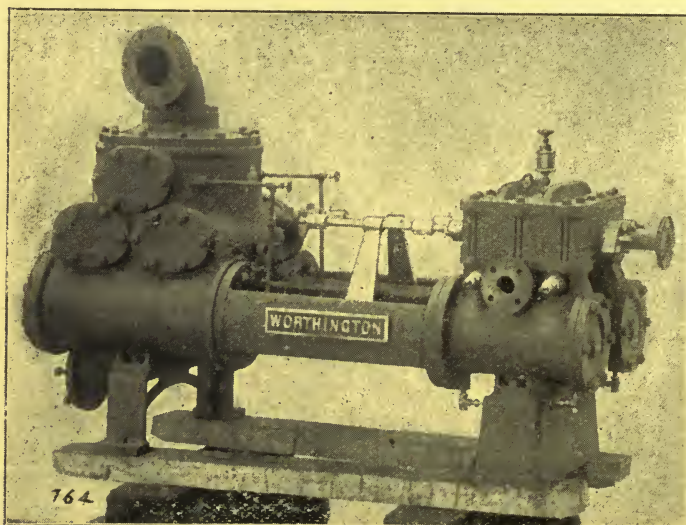
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**Sugar House**

**Notes and .**

**Tables . .**





# SUGAR HOUSE NOTES

AND

# TABLES.

A REFERENCE BOOK FOR PLANTERS, FACTORY  
MANAGERS, CHEMISTS, ENGINEERS, AND  
OTHERS EMPLOYED IN THE MANU-  
FACTURE OF CANE SUGAR.

BY

**NOËL DEERR.**



E. & F. N. SPON, Limited, 125 STRAND, LONDON.  
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## PREFACE.

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THE want, felt by the writer in his first experience of the cane sugar industry, of a book similar to the present one, is his only excuse for undertaking this compilation of notes and tables.

Although voluminous treatises on the manufacture of beet sugar have been written, the literature of the sugar cane is very scanty, and contains no work to compare with the numerous able treatises published by workers in the beet sugar industry. Of isolated information there are the various technical journals, such as "The Sugar Cane," and the publications of the Botanical Gardens and experimental stations established in nearly all sugar growing countries. In this respect the writer would like to pay a tribute of admiration to the excellent work that has been done by the skilled chemists and botanists at the various Java experimental stations.

In compiling this book, use has been made of nearly all the published works dealing with cane sugar (a list of which is given later); special mention should be made of "The Sugar Cane," the papers of Prinsen Geerligs, and the very useful handbooks of G. L. Spencer.

The writer would take this opportunity of expressing his admiration of the stubborn fight made by sugar cane planters in all parts of the world against a State-aided system of suppression, and to these men this little book is respectfully dedicated, in the hope that it may be of some assistance to those whom it is intended to serve.

Finally, no one is more aware than the writer of the many imperfections which must necessarily exist in a work of this sort ; he will be always pleased to accept suggestions or corrections from planters, manufacturers, or others interested in the cane sugar industry.

NOËL DEERR.

Albion, Berbice, British Guiana,

*January, 1900.*



# Sugar House Notes and Tables.



## ALBUMEN. ALBUMENOIDS.



COMPLEX nitrogenous bodies occurring in all vegetable juices ; they are partly precipitated by heat, acids, and alkalies redissolving with excess of either of the latter ; heated with excess of alkalies they are decomposed, giving chiefly amido-fatty acids.

## ANTISEPTICS.

Any body preventing putrefaction or fermentation ; those most commonly employed are Corrosive Sublimate one part in a thousand ; Sulphur Dioxide ; Calcium Bisulphite ; Chloride of Lime ; Boracic Acid and Soluble Borates ; Alkaline Fluorides (see under *Distillery*) ; Fresh Milk of Lime ; Carbolic Acid and its derivatives, known commercially as Aseptol, Solveol, Lysol, etc. ; Salicylic Acid recommended in the proportions of one pound to five thousand gallons of cane juice left overnight ; Antinonnen ; the last is a complex derivative of Carbolic Acid patented and prepared by the Baeyer Farbenfabrik, which, independently, has recently been highly recommended ; besides its antiseptic qualities it is largely used as a preventative of dry rot and the ravages of insects.

ATOMIC WEIGHTS.  
PARTIAL LIST (F. W. CLARKE).

NAME.	Atomic Weight.		NAME.	Atomic Weight.	
	Hydrogen=1	Oxygen=16.		Hydrogen=1	Oxygen=16.
Aluminium ..	26.91	27.11	Nitrogen ..	13.93	14.04
Barium ..	136.39	137.43	Oxygen ..	15.88	16.00
Calcium ..	39.76	40.07	Phosphorus ..	30.79	31.02
Carbon ..	11.92	12.01	Platinum ..	193.41	194.89
Chlorine ..	35.18	35.45	Potassium ..	38.82	39.11
Copper ..	63.12	63.60	Silicon ..	28.18	28.40
Fluorine ..	18.91	19.06	Silver ..	107.11	107.92
Hydrogen ..	1.00	1.008	Sodium ..	22.88	23.05
Iron ..	55.60	56.02	Strontium ..	86.95	87.61
Lead ..	205.36	206.92	Sulphur ..	31.83	32.07
Magnesium ..	24.10	24.28	Tin ..	118.15	119.05
Manganese ..	54.57	54.99	Zinc ..	64.91	65.41

AVAILABLE SUGAR.

The available sugar is the amount of sugar that can be extracted, expressed as a percentage on the sugar in the juice: the figure is entirely empirical, and depends not only on the purity but on the nature of the impurities, especially the glucose and ash, the quality of the lime, the skill in tempering and subsequent operations, particularly in the pan-boiling and the application or otherwise of crystallisation in motion. In no case should the recovery of first sugar fall below 70 per cent., and with pure juice and the best plant as much as 90 per cent. may be recovered in all sugars.

BALLING.

See Brix.

BEAUMÉ.

To convert Beaumé degrees to Density.

$$D = \frac{144.3}{144.3 - B} ; \quad B = \frac{144.3 (D - 1)}{D}$$

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## BOILERS.

In a sugar factory a type of boiler is to be chosen which has a large water capacity, so as to always have a provision of heat for unequal consumption of steam in the factory, and not large steam space. In a boiler internally fired there is a greater advantage from the radiation of the heat than with external firing. If a boiler that is fired internally is provided with a so-called combustion chamber, it promotes the easy mixing of

the developed gases and gives space and opportunity for combustion before they can cool on the sides of the boiler. Tube boilers with internal firing must absolutely have combustion chambers, so that the gases are not immediately cooled when they enter the tubes. (*Felinek.*)

1,000 square feet heating surface are required to every 600 pounds sugar per hour. (*Williams.*)

240 h.p. of steam are required to make one ton of sugar per hour. (*Lock.*)

A certain large firm of sugar engineers allow one boiler horse-power for every ten gallons of juice per hour; this allowance is sufficient for rich juice with double crushing and no maceration, but with poorer juices and with maceration processes a proportionate increase must be made.

Watts estimated the evaporation of one cubic foot of water per hour from  $212^{\circ}$  F. as giving one horse-power with the best engines of his time; this still remains a measure of the horse-power of a boiler, although as many as twelve engine horse-power may be obtained from one cubic foot of water evaporated per hour. Thurston estimates the water required per horse-power per hour with good engines as  $\frac{200}{\sqrt{P}}$ , P being the pressure in pounds per square inch, and with the best engines as only being  $\frac{150}{\sqrt{P}}$ .

Those in charge of boilers should attend to the following rules:—Get up steam gradually with cold water in not less than six hours; fire regularly, keeping the bars covered up to the bridge. Do not slack ashes in front of the boiler. Blow through the gauge glasses hourly, and test them before firing in the morning.

Test the safety valves daily to see they are free. In cases of shortness of water draw fires or smother with ashes, lower the dampers, relieve the weight on the safety valve, open the furnace doors, and turn on the reed. Do not empty a boiler with steam on, but allow to cool first. Clean out the boiler every two months. (*Abridged from the Manchester Steam Users Association's directions.*)

If  $S$  = the ultimate tensile strength of boiler plate in pounds per square inch,  $T$  = the thickness of the plate, and  $D$  = the diameter of the boiler in inches, then the bursting pressure is  $\frac{2TS}{D}$ ;  $S$  is about 43,000 pounds per square inch for ordinary boiler plates; for single riveted seams allow 50 per cent., and for double riveted seams 70 per cent. of the result. Lloyd's allow a factor of safety of 5, *i.e.*, a boiler to work at 100 lbs. pressure per square inch must be capable of standing a pressure of 500 lbs. before bursting.

Among other recipes, sal ammoniac, oak bark, molasses, pulped potatoes, soda crystals, heavy petroleum oils, an internal coating of tallow and blacklead, have been recommended for preventing boiler scale. The Manchester Steam Users' Association do not recommend their use.

Water tube boilers, as the Stirling, Climax, Babcock and Wilcox, are largely coming into use in sugar houses. They possess the following advantages over older types:—steam is raised more quickly, owing to larger heating surface; rapid circulation, lessening the deposit of sediment; well adapted for high pressures; explosions less disastrous; ease of transport, and facility of repair; on the other hand, steam rapidly falls; they are more

expensive in first cost, and more liable to accident.

For each boiler horse-power are required roughly one cubic foot water per hour, one square yard heating surface, one square foot fire grate area.

## TABLE OF THE DIMENSIONS OF BOILERS.

(FROM MOLESWORTH'S POCKET-BOOK.)

Pressures assumed at 5 atmospheres effective or 6 atmospheres actual.

NOMINAL HORSE POWER.	CORNISH BOILERS.				LANCASHIRE BOILERS.			
	Diameter of Shell: inches.	Diameter of Flue: inches.	Length of Boiler: feet.	Weight of Boiler: tons.	Diameter of Boiler: inches.	Diameter of Flues: inches.	Length of Boiler: feet.	Weight of Boiler: tons.
30	62·5	36·75	28	9·54	60·5	25	28·2	7·48
40	72·25	42·25	32·3	14·39	72	28·75	32·8	10·90
50	80·75	47·5	36	19·82	80·5	32·25	37·4	14·66
60	88·5	52	39·5	25·77	88·25	34·5	42	18·72

## BOILERS, TRIAL OF.

As the question of fuel is one of the most important with which the sugar manufacturer has to deal, trials of the boilers should be made from time to time: the two essential determinations to be made are the quantity of fuel burnt, and the water evaporated. To carry out the trial the megass must be weighed; this is best done by delivering the megass from the carrier into trucks which pass over a weighbridge before being discharged over the hopper; the floor space over the boiler under trial should be separated from the others by a movable partition. The estimation of the water fed into the boiler is most easily determined by employing an automatic meter, but in the absence of this accurate results

may be obtained by fitting up two rectangular tanks, A and B, to receive the feed water; these are connected to the feed pump by a pipe fitted with a two-way cock, so that either A or B can feed as desired; suppose A starts feeding; the depth of water in A is taken, and is say 37.5 inches: when A is nearly empty, the supply from A is cut off and B turned on; the depth of water in A is again taken, say 2.5 inches, showing that 35 inches of water have been fed into the boiler; then from the area of cross section of the tank the weight of water can be calculated (see under *Water*): the mean temperature of the feed water in each tank must be determined. In starting a trial the floor space is swept clean and a truck load of megass discharged, the operator at the same time signalling to the attendant at the feed water tanks to start feeding; at conclusion of the trial the last truck load is allowed to completely enter the hopper, the operator again signalling to the feed water attendant: the steam pressure at the boiler gauge should be taken at regular intervals, and the mean pressure used in calculating the results: these data give the essential particulars as regards evaporation per pound of fuel, but wherever possible more extended data should be obtained—the temperature, velocity, and analysis of the flue gases, the analysis of the megass and weight of ashes. The temperature of the flue gases is easiest obtained by a pyrometer, but in case this is not available either of the following schemes may be used. In a piece of iron or copper pipe, of about two pounds weight, drill a number of holes; place this on the end of a long rod, and insert



well into the flue through an aperture in the boiler wall, closing the aperture with a plug: the calorimeter may conveniently be constructed out of an iron saucepan or glass vessel of about two pints capacity, wrapped in asbestos or other non-conducting material, the whole being placed in a larger vessel such as a wooden nail keg; in the lid of the saucepan two holes are cut, one to serve for the insertion of the thermometer, and the other for a small wooden stirrer; the saucepan or other vessel is filled about three parts full with a weighed or measured quantity of water, the temperature of which is ascertained; after the iron or copper pipe has been for about an hour in the flue, it is removed and placed in the calorimeter as rapidly as possible: the water is stirred, and the temperature of the water now noted.

If  $t_f$  be the temperature of the flue gases,  $t_0$  the initial temperature, and  $t_1$  the final temperature of the water,  $w_1$  the weight of the iron or copper pipe,  $w_2$  the weight of the water,  $w_3$  the weight of the calorimeter,  $s_1$  the specific heat of the iron or copper pipe, and  $s_2$  that of the calorimeter, then

$$t_f = t_1 + \frac{(t_1 - t_0) (w_2 + w_3 s_2)}{w_1 s_1}$$

Specific Heat of iron = .1138; Specific Heat of copper = .0952; Specific Heat of glass = .185.

Another method consists in placing in the flue selections of bodies of melting point near to the flue temperature, and estimating the latter from their behaviour: only small quantities should be used, and they should remain for at least three hours; the

melting points of some bodies useful in this respect are given in degrees Fahrenheit.

Silver Nitrate 423; Tin 455; Mercuric Bromide 468; Bismuth 518; Mercuric Chloride 559; Sodium Chlorate 576; Sodium Nitrate 591; Cadmium 608; Lead 630; Potassium Nitrate 667.

The draught in the flues is obtained by connecting a U shaped tube, fixed on a board carrying a scale graduated in tenths of an inch, with an india-rubber tube to a tube let into the flue wall; the U tube is filled with water up to the zero mark on the scale, and the depression of the water in one limb is read off the scale. For the analysis of the flue gases, see under that heading.

In expressing the results of trials it is customary to attempt to account for all the heat units, represented by the combustion of the fuel (see under *Megass*), which will be divided between the heat actually used in the boiler, that carried away by the flue gases, that lost in radiation, and in unburnt fuel. The ratio of the heat used in the boiler to that represented by the combustion of the fuel is called the efficiency of the boiler. The heat used by the boiler is obtained thus: let  $t_1$  = mean temperature of the feed water in degrees Fahrenheit,  $w$  the weight of water evaporated in boiler in pounds,  $t_2$  the temperature of steam corresponding to the mean steam pressure (see table below); then total heat in British Thermal units from water at feed water temperature to steam at boiler pressure =  $w (1082.4 + .305 t_1) - w (t_2 - 32)$ . Example:—Feed water at 172° F.; Steam Pressure 75 pounds per square inch equivalent to 90

pounds absolute, corresponding to a temperature of  $320.2$ ; then heat required to evaporate one pound water =  $1082.4 + .305 \times 320.2 - (172 - 32) = 1040.0$  B.T.U.; in order that trials may be comparable it is convenient to express the evaporation as from and at  $212^\circ$  F.; at this temperature the evaporation of a pound of water requires  $966$  B.T.U., so that in the case quoted above the equivalent evaporation from and at  $212^\circ$  F. would be  $\frac{1040}{966} = 1.076$  times as great.

The amount of heat carried away in the flue gases is determined by calculating from the analysis of the flue gases combined with the theoretical amount required for combustion (see under *Megass*), the amount of air passing through the furnace; if  $c_1$  be the percentage of oxygen,  $c_2$  that of carbon dioxide,  $c_3$  that of carbon monoxide, then the multiple of the theoretical amount of air (A) is given by

$$A = \frac{c_1 + c_2 + .5 c_3}{c_2 + c_3};$$

using this quantity the amount of air passing per pound of fuel is obtained: to calculate the heat used, let  $t_1$  = the external temperature of the air,  $t_2$  the temperature of the flue gases,  $s$  the mean specific heat of flue gases,  $w$  = weight flue gases per pound fuel, then heat used =  $w s (t_2 - t_1)$ .

The remaining losses in radiation and unburnt fuel are usually calculated by difference;  $10\%$  to  $12\%$  is a usual figure for radiation, and  $5\%$  for losses in unburnt fuel.



## TABLE GIVING THEORETICAL DRAUGHT IN CHIMNEYS.

Flue gases at 552° F. ; External air at 62° F.

Height of Chimney : feet.	Draught Power : Inches of Water.	Theoretical Velocity : feet per second of Cold Air Entering.	Theoretical Velocity : feet per second of Hot Air at Exit.
80	·585	50·6	101·2
90	·657	53·7	107·4
100	·730	56·5	113·0
120	·876	62·0	124·0
150	1·095	69·3	138·6
175	1·277	74·8	149·6
200	1·460	80·5	160·0

(BOX.)

## TABLE GIVING THE PROPERTIES OF SATURATED STEAM.

Absolute Pressures : lbs. per sq. in.	Temperature of Steam, F°.	Total Heat from Water at 32° F.	Absolute Pressures : lbs. per sq. in.	Temperature of Steam, F°.	Total Heat from Water at 32° F.
1	102·1	1112·5	50	281·0	1167·1
2	126·3	1119·7	60	292·7	1170·7
5	162·3	1130·9	70	302·9	1173·8
10	193·3	1140·3	80	312·0	1176·5
14·70	212·0	1146·1	90	320·2	1179·1
20	228·0	1150·9	100	327·9	1181·4
25	240·1	1154·6	110	334·6	1183·5
30	250·4	1157·8	120	341·1	1185·4
35	259·3	1160·5	130	347·2	1187·3
40	267·3	1162·9	140	352·9	1189·0
45	274·4	1165·1			

## SPECIFIC HEATS OF GASES AT CONSTANT PRESSURE.

Air ·2379 ; Oxygen ·2182 ; Nitrogen ·2440 ; Carbon  
Dioxide ·2164 ; Carbon Monoxide ·2479 ; Water  
Vapour ·4750.

Below will be found details of a trial made by the  
writer.

# DATA OF BOILER TRIAL.

COMPOSITION OF MEGASS.		B.T.U. affor-Evaporation ded * by com-from and at bustion of one 212° F. per lb. of Megass. lb. of Megass.	
Parts per 100.			
Water ..	54.0	—	—
Sugar ..	5.8	403	.42
Glucose ..	.6	40	.04
Fibre ..	88.6	2879	2.98
Ash ..	.9	—	—
Allowing for Evaporation of contained Water, there are available 2,800 B.T.U. per lb. Megass equivalent to Evaporation from and at 212° F. of 2.90 lbs. of Water.			
FUEL.			
Pounds burnt ..	..	25298	
Pounds per minute ..	..	108.1	
EVAPORATION.			
Feed Water Temperature ..	169° F.		
Steam Pressure ..	80 lbs. per sq. in.		
Lbs. Water Evaporated, actual	53205.5		
Equivalent from and at 212° F.	57142.0		
Lbs. per minute, actual	227.4		
Equivalent from and at 212° F.	244.4		
Lbs. actual per lb. fuel	2.103		
Equivalent from and at 212° F.	2.256		
FLUE GASES.			
Oxygen ..	..	11.4 %	
Nitrogen ..	..	80.2 %	
Carbon Dioxide ..	..	8.4 %	
Carbon Monoxide ..	..	0.0 %	
Temperature ..	..	582° F.	
Draught ..	..	.73 inch of Water	
Velocity of Cold Air entering	56.5 feet per minute		
Velocity of Hot Gases leaving	113.0 " "		
Height of Chimney ..	156 feet		
Oxygen, multiple of theoretical	2.33		
External Temperature ..	84° F.		
MISCELLANEOUS.			
Type of Boiler ..	Stirling Water Tube		
Grate Area ..	33 square feet		
Heating Surface ..	3632 "		
Duration of Test ..	234 minutes		
Place ..	Albion, Berbice		
Date ..	Aug. 11th, 1898		
HEAT ACCOUNT.			
Total B.T.U. in Megass*	84,040,030		
Used in evaporating moisture ..	10,637,000		
Net available for Boiler	73,403,000		
Used in Boiler ..	55,199,000		
Per cent. of net available	75.20		
Lost in flue gases ..	12,892,000		
Per cent. of net available	17.49		
Lost in ashes, radiation, etc. † ..	9,372,000		
Per cent. of net available	7.31		
		* See under Megass.	
		† By difference.	

## BRITISH THERMAL UNIT.

The British Thermal Unit, generally written B.T.U., is the amount of heat required to raise one pound of water through one degree Fahrenheit.

## BRIX HYDROMETER.

The Brix hydrometer, when immersed in a solution of sugar, indicates directly the percentage of sugar in the solution ; when working with cane juices it is usual to call the degree Brix the per cent. of total solids ; this introduces an error, as the other bodies present do not affect the density in the same degree as sugar, hence the total solids as determined by the hydrometer are often called the apparent total solids as distinguished from the true total solids as determined by drying. In addition to the Brix instrument, determinations of the density of sugar solutions have been made by Chevalier, Maumené, Balling, and Niemann, all of which show slight variations tending to make the sugar hydrometer scale as confused as that of Beaumé with its hundred odd scales, none of which are correct. A redetermination of the density of sugar solutions between 80° F. and 90° F. is urgently needed.

## CANE, ANALYSIS OF.

*Wiley's Method.* Divide the cane into long strips and cut into small pieces ; mix well, weigh out 52,096 grams and place in a 300 c.c. pressure bottle ; add subacetate of lead to decided alkalinity ; fill the bottle with water to a little below the lowest mark, and heat one hour to 100° C. ; allow to cool, filter off 100 c.c.,

add some acetic acid, make up to 110 c.c. and polarise, allow 1 c.c. for each gram of woody fibre present; determine the glucose by Febhing's method after removal of lead; in determining the fibre, the U.S.A. experimental station at Magnolia recommend 20 grams of finely-shredded cane to be introduced into a beaker of 100 c.c. to 150 c.c. capacity, the top to be covered with linen, and the soluble matter to be removed by steeping the cane three times in cold, three times in warm, and ten times in hot water, pouring off the water through the linen cover: the fibre is dried initially in the beaker, and finally removed to a tared platinum basin and dried to constant weight.

Owing to the difficulty of obtaining a uniform sample of cane with so small a quantity, the writer prefers performing the analysis on a much larger quantity—say, one pound—soaking out the sugar in a large vessel such as a kerosene oil tin; for the fibre a similar quantity is taken and washed in running water in a basket of wire gauze, covered with linen to retain fine particles. The second method consists in passing strips of cane through a handmill, saturating the partially-exhausted megass with hot water, and again crushing till completely exhausted; the expressed juice and washings are weighed or measured, and then polarised.

The water is determined by drying the finely-shredded cane to constant weight at a temperature gradually increasing to 100° C., and the ash by incinerating the dried cane at a low red heat.

In sugar-house work it is usual to deduce the composition of the canes from the analysis of juice and

megass ; in mill work, where an average sample of canes cannot be obtained, this course is almost essential.

TABLE GIVING A COMPARISON OF  
DEGREES BRIX AND SPECIFIC  
GRAVITY AT 84° F.

$$\text{FORMULA: SPECIFIC GRAVITY} = \frac{272}{272 - B^{\circ}}$$

	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	1·0000	1·0004	1·0007	1·0011	1·0014	1·0017	1·0021	1·0024	1·0028	1·0032
1	1·0036	1·0039	1·0043	1·0047	1·0051	1·0054	1·0058	1·0062	1·0065	1·0070
2	1·0074	1·0077	1·0081	1·0085	1·0089	1·0092	1·0096	1·1000	1·1004	1·1008
3	1·0112	1·0115	1·0119	1·0123	1·0126	1·0130	1·0134	1·0138	1·0141	1·0145
4	1·0149	1·0152	1·0156	1·0160	1·0164	1·0167	1·0171	1·0175	1·0179	1·0183
5	1·0187	1·0191	1·0194	1·0198	1·0202	1·0205	1·0209	1·0213	1·0217	1·0221
6	1·0225	1·0229	1·0233	1·0237	1·0240	1·0244	1·0248	1·0252	1·0256	1·0260
7	1·0264	1·0268	1·0272	1·0275	1·0279	1·0283	1·0287	1·0291	1·0295	1·0299
8	1·0303	1·0307	1·0311	1·0314	1·0318	1·0322	1·0326	1·0330	1·0334	1·0338
9	1·0342	1·0346	1·0350	1·0354	1·0358	1·0362	1·0366	1·0370	1·0374	1·0378
10	1·0382	1·0386	1·0390	1·0394	1·0398	1·0402	1·0406	1·0410	1·0414	1·0418
11	1·0422	1·0426	1·0430	1·0434	1·0438	1·0442	1·0446	1·0450	1·0454	1·0458
12	1·0462	1·0466	1·0470	1·0474	1·0478	1·0482	1·0486	1·0490	1·0494	1·0498
13	1·0502	1·0506	1·0510	1·0514	1·0518	1·0522	1·0526	1·0530	1·0534	1·0538
14	1·0543	1·0547	1·0551	1·0555	1·0559	1·0563	1·0567	1·0571	1·0575	1·0579
15	1·0584	1·0588	1·0592	1·0596	1·0600	1·0604	1·0608	1·0612	1·0616	1·0621
16	1·0625	1·0629	1·0633	1·0637	1·0641	1·0646	1·0650	1·0654	1·0658	1·0662
17	1·0666	1·0671	1·0675	1·0679	1·0683	1·0687	1·0692	1·0696	1·0700	1·0707
18	1·0709	1·0713	1·0717	1·0721	1·0725	1·0730	1·0734	1·0738	1·0742	1·0747
19	1·0751	1·0755	1·0759	1·0764	1·0768	1·0772	1·0777	1·0781	1·0785	1·0789
20	1·0794	1·0798	1·0802	1·0806	1·0810	1·0815	1·0819	1·0823	1·0827	1·0831
21	1·0836	1·0840	1·0845	1·0849	1·0853	1·0858	1·0862	1·0867	1·0871	1·0876
22	1·0880	1·0884	1·0889	1·0893	1·0898	1·0902	1·0907	1·0911	1·0916	1·0920
23	1·0924	1·0928	1·0933	1·0938	1·0942	1·0947	1·0951	1·0955	1·0959	1·0963
24	1·0968	1·0972	1·0977	1·0981	1·0986	1·0990	1·0994	1·0999	1·1003	1·1007
25	1·1012	1·1016	1·1021	1·1025	1·1030	1·1034	1·1039	1·1043	1·1048	1·1052
26	1·1057	1·1061	1·1066	1·1070	1·1075	1·1079	1·1084	1·1089	1·1093	1·1098
27	1·1102	1·1107	1·1111	1·1115	1·1120	1·1124	1·1129	1·1133	1·1137	1·1142
28	1·1147	1·1151	1·1156	1·1160	1·1165	1·1169	1·1174	1·1178	1·1183	1·1188
29	1·1193	1·1198	1·1202	1·1207	1·1211	1·1216	1·1221	1·1225	1·1230	1·1234
30	1·1239	1·1244	1·1249	1·1253	1·1258	1·1262	1·1267	1·1272	1·1276	1·1281
31	1·1286	1·1290	1·1295	1·1300	1·1304	1·1309	1·1314	1·1319	1·1323	1·1328
32	1·1333	1·1337	1·1342	1·1347	1·1351	1·1356	1·1361	1·1366	1·1370	1·1375
33	1·1380	1·1384	1·1389	1·1394	1·1399	1·1404	1·1409	1·1413	1·1418	1·1423
34	1·1428	1·1432	1·1437	1·1442	1·1447	1·1452	1·1457	1·1461	1·1466	1·1471
35	1·1476	1·1481	1·1486	1·1491	1·1496	1·1501	1·1506	1·1511	1·1516	1·1521
36	1·1525	1·1530	1·1535	1·1540	1·1545	1·1550	1·1555	1·1560	1·1565	1·1570
37	1·1574	1·1579	1·1584	1·1589	1·1594	1·1599	1·1604	1·1609	1·1614	1·1619
38	1·1624	1·1629	1·1634	1·1639	1·1644	1·1649	1·1654	1·1659	1·1664	1·1669
39	1·1674	1·1679	1·1684	1·1689	1·1694	1·1699	1·1704	1·1709	1·1714	1·1719

	•0	•1	•2	•3	•4	•5	•6	•7	•8	•9
40	1.1724	1.1730	1.1735	1.1740	1.1745	1.1750	1.1755	1.1760	1.1765	1.1770
41	1.1775	1.1781	1.1786	1.1791	1.1796	1.1801	1.1806	1.1811	1.1816	1.1821
42	1.1826	1.1832	1.1837	1.1842	1.1847	1.1852	1.1857	1.1862	1.1867	1.1872
43	1.1878	1.1884	1.1889	1.1894	1.1899	1.1904	1.1909	1.1915	1.1920	1.1925
44	1.1930	1.1936	1.1941	1.1946	1.1951	1.1956	1.1961	1.1967	1.1972	1.1978
45	1.1982	1.1988	1.1993	1.1998	1.2004	1.2009	1.2014	1.2019	1.2025	1.2030
46	1.2035	1.2041	1.2046	1.2051	1.2057	1.2062	1.2068	1.2073	1.2079	1.2084
47	1.2089	1.2095	1.2100	1.2105	1.2111	1.2116	1.2122	1.2127	1.2133	1.2138
48	1.2143	1.2149	1.2154	1.2159	1.2165	1.2170	1.2176	1.2181	1.2187	1.2192
49	1.2197	1.2203	1.2208	1.2214	1.2219	1.2225	1.2230	1.2236	1.2241	1.2247
50	1.2252	1.2258	1.2263	1.2269	1.2274	1.2280	1.2285	1.2291	1.2296	1.2302
51	1.2307	1.2313	1.2319	1.2324	1.2330	1.2336	1.2341	1.2347	1.2352	1.2358
52	1.2363	1.2369	1.2374	1.2380	1.2386	1.2391	1.2397	1.2403	1.2408	1.2414
53	1.2420	1.2426	1.2431	1.2437	1.2443	1.2448	1.2454	1.2460	1.2465	1.2471
54	1.2477	1.2483	1.2488	1.2494	1.2500	1.2505	1.2511	1.2517	1.2522	1.2528
55	1.2534	1.2540	1.2546	1.2552	1.2557	1.2562	1.2568	1.2574	1.2580	1.2586
56	1.2592	1.2598	1.2604	1.2610	1.2616	1.2621	1.2627	1.2633	1.2639	1.2645
57	1.2651	1.2657	1.2663	1.2669	1.2675	1.2680	1.2686	1.2692	1.2698	1.2704
58	1.2710	1.2716	1.2722	1.2728	1.2734	1.2740	1.2746	1.2752	1.2758	1.2764
59	1.2770	1.2776	1.2782	1.2788	1.2794	1.2800	1.2806	1.2812	1.2818	1.2824
60	1.2830	1.2836	1.2842	1.2848	1.2854	1.2860	1.2866	1.2872	1.2878	1.2883
61	1.2891	1.2897	1.2903	1.2909	1.2915	1.2921	1.2927	1.2933	1.2940	1.2946
62	1.2952	1.2958	1.2964	1.2970	1.2977	1.2983	1.2989	1.2995	1.3002	1.3008
63	1.3014	1.3021	1.3027	1.3033	1.3039	1.3045	1.3052	1.3058	1.3064	1.3070
64	1.3076	1.3083	1.3089	1.3095	1.3102	1.3108	1.3115	1.3121	1.3128	1.3134
65	1.3140	1.3147	1.3153	1.3159	1.3166	1.3173	1.3179	1.3186	1.3192	1.3198
66	1.3204	1.3210	1.3217	1.3223	1.3230	1.3236	1.3243	1.3249	1.3256	1.3262
67	1.3268	1.3275	1.3281	1.3288	1.3294	1.3301	1.3307	1.3313	1.3320	1.3326
68	1.3333	1.3340	1.3346	1.3353	1.3359	1.3366	1.3373	1.3380	1.3386	1.3393
69	1.3399	1.3406	1.3413	1.3419	1.3426	1.3433	1.3440	1.3446	1.3453	1.3459
70	1.3465	1.3472	1.3478	1.3485	1.3492	1.3498	1.3505	1.3512	1.3518	1.3525
71	1.3532	1.3539	1.3546	1.3552	1.3559	1.3566	1.3573	1.3579	1.3586	1.3593
72	1.3600	1.3607	1.3613	1.3620	1.3627	1.3634	1.3640	1.3647	1.3654	1.3661
73	1.3668	1.3675	1.3682	1.3689	1.3695	1.3702	1.3709	1.3716	1.3723	1.3730
74	1.3737	1.3744	1.3751	1.3758	1.3765	1.3772	1.3779	1.3786	1.3793	1.3800
75	1.3807	1.3814	1.3821	1.3828	1.3835	1.3842	1.3849	1.3856	1.3863	1.3870
76	1.3878	1.3885	1.3892	1.3899	1.3906	1.3913	1.3920	1.3927	1.3935	1.3942
77	1.3949	1.3956	1.3963	1.3971	1.3978	1.3985	1.3992	1.3999	1.4007	1.4014
78	1.4021	1.4028	1.4036	1.4043	1.4050	1.4057	1.4065	1.4072	1.4079	1.4086
79	1.4093	1.4101	1.4108	1.4115	1.4123	1.4130	1.4138	1.4145	1.4152	1.4160
80	1.4167	1.4175	1.4182	1.4190	1.4197	1.4205	1.4212	1.4220	1.4227	1.4234
81	1.4241	1.4249	1.4256	1.4264	1.4271	1.4279	1.4287	1.4294	1.4302	1.4309
82	1.4316	1.4324	1.4331	1.4339	1.4346	1.4354	1.4361	1.4369	1.4376	1.4384
83	1.4391	1.4399	1.4406	1.4414	1.4422	1.4429	1.4437	1.4445	1.4452	1.4460
84	1.4468	1.4476	1.4483	1.4491	1.4499	1.4506	1.4514	1.4522	1.4529	1.4537
85	1.4545	1.4553	1.4560	1.4568	1.4576	1.4584	1.4592	1.4599	1.4607	1.4615
86	1.4623	1.4631	1.4638	1.4646	1.4654	1.4662	1.4670	1.4678	1.4686	1.4694
87	1.4702	1.4710	1.4718	1.4726	1.4734	1.4742	1.4750	1.4758	1.4766	1.4774
88	1.4782	1.4790	1.4798	1.4806	1.4814	1.4822	1.4831	1.4839	1.4847	1.4855
89	1.4863	1.4871	1.4879	1.4888	1.4896	1.4904	1.4912	1.4921	1.4929	1.4937
90	1.4945	1.4953	1.4962	1.4970	1.4978	1.4986	1.4995	1.5003	1.5011	1.5019
91	1.5027	1.5035	1.5043	1.5052	1.5060	1.5069	1.5077	1.5086	1.5094	1.5103
92	1.5111	1.5119	1.5128	1.5136	1.5145	1.5153	1.5162	1.5170	1.5179	1.5187
93	1.5195	1.5203	1.5212	1.5220	1.5229	1.5237	1.5246	1.5255	1.5263	1.5272
94	1.5281	1.5290	1.5298	1.5307	1.5315	1.5324	1.5333	1.5341	1.5350	1.5358
95	1.5367	1.5376	1.5385	1.5393	1.5402	1.5410	1.5419	1.5428	1.5435	1.5445
96	1.5454	1.5462	1.5471	1.5480	1.5489	1.5498	1.5507	1.5516	1.5525	1.5534

## CANES, ASH OF.

	TRINIDAD.				BERBICE.			DEMERARA.	GRENADA.	JAMAICA.		
	1	2	3	4	5	6	7	8	9	10	11	12
Silica ..	45·97	42·90	46·46	41·37	46·48	50·00	45·13	17·64	26·38	52·30	48·73	54·59
Phosphoric Acid	3·76	7·99	8·23	4·59	8·16	6·56	4·88	7·37	6·20	13·04	2·90	8·00
Sulphuric Acid	6·66	10·94	4·65	10·93	7·52	6·40	7·74	7·97	6·08	3·31	5·35	1·94
Lime ..	9·16	13·20	8·91	9·11	5·78	5·09	4·49	2·34	5·87	10·64	11·62	14·36
Magnesia ..	3·66	9·88	4·50	6·92	15·61	13·01	11·90	3·93	5·48	5·63	5·61	5·30
Potash ..	25·50	12·01	10·63	15·99	11·93	13·69	16·97	32·93	13·21	10·09	7·46	11·14
Soda ..		1·39			·57	1·33	1·64			·80		
Chloride of Potash	3·27		7·41	8·96				10·70	11·14		16·06	·84
Chloride of Soda	2·02	1·62	9·21	2·13	3·95	3·92	7·25	17·20	7·64	4·29	2·27	3·83

(STENHOUSE.)

Nos. 1-7 and 10-12, ripe canes with leaves; No. 8, no leaves; No. 9, few leaves.

## CANES, COMPOSITION OF.

Water, 69%-74%; Sugar, 10%-18%; Glucose, 3%-2%; Fibre, 9%-13%; Albumen and other Nitrogenous matter, 5%-12%; Ash, 3%-8%; Gums and other matter, 1%-3%. There are also present in very small quantities—citric acid, malic acid, pectic bodies, colouring matters, wax, and in diseased or damaged canes, acetic acid.

## CANES, DISEASES AND ENEMIES OF.

Of the larger pests of the planter, are rats, which on occasion do immense damage to young cultivation; they seem to be attracted by rice; on an estate in

Berbice some fields were planted with rice, with the result of an invasion of thousands of rats ; poison and extermination by dogs or mongooses are the remedies chiefly applied.

Of insects attacking the cane a great number have been described : chief amongst them is the moth borer, (*Diatraea Sacchari*), this attacks the living cane ; the shot borer beetle (*Xyleborus Perforans*), and the lady bird borer (*Sphenophorus Sacchari*), attack the dead cane only ; apart from the damage done by the moth borer itself, there exists the great danger of opening the way for attacks of the more serious fungus diseases. Bovell (West Indian Bulletin, No. 1) recommends all borer plants to be rejected, all plants to be soaked for twelve hours in a disinfecting solution, the systematic inspection of growing canes and their destruction where larvae are found, the burning of all dried or damaged canes after the fields have been cut, and the exposure of lanterns over molasses and water in places where the moth is known to be abundant.

The principal diseases of the cane that have been described are the Sereh, Red Smut, and Pineapple diseases in Java ; the Root and Rind fungus in the West Indies ; and the Gumming disease in Queensland, Mauritius, and Pernambuco. The Sereh disease, which is apparently confined to West Java, is characterised by the cane becoming stunted with short joints ; at the same time the eyes become enlarged and throw out shoots, giving the canes a bush-like appearance, whence the name (Sereh, lemon grass) : at a later stage gumming in the interior of the cane occurs, together with



the simultaneous presence of bacteria ; but in the opinion of the skilled botanists in Java who have investigated the disease, the bacteria are to be considered as the effect and not the cause of the disease ; over cultivation, over or unsuitable manuring, bad drainage, excessive ratooning, an insufficiency of silica have been suggested as the cause ; it is certain that ratoon is more liable than plant cane. Krüger recommends as a prophylactic measure that only the young upper joints, and not the older lower joints should be used for planting.

The Red Smut has been described by Went in the "Archief voor de Java Suikindustrie," 1893. According to him the interior of the cane alone is infected ; the fibre of the cane is covered with red blotches, on which appear white spots ; this serves to distinguish the disease from Sereh, which is characterised by a red stripe : the disease is due to a bacterium which Went calls *Colletotrichum Falcatum* ; he states that the bacterium is only capable of infecting a wounded cane or a very young one, and that originally it was a Saprophyte,<sup>1</sup> which from special causes has acquired the property of infecting a living cane.

The Pineapple disease, also described by Went, very rarely attacks other than cuttings : the cuttings are characterised by red or black patches ; canes grown from diseased cuttings soon die, and give off an odour of pineapples : the disease is due to a bacterium (*Thielopsis Ethaceticus*), and may be combated by covering the ends of the cuttings with an impermeable layer of tar.

<sup>1</sup>A Saprophyte is a bacterium living on dead animals or plants.

The Gummy disease of Queensland has been described by Cobb, and ascribed by him to the presence of a bacterium (*Bacillus Vasculorum*); the disease is very similar to Sereh, but characterised by the exudation of a clear yellow mucilage.

The fungus diseases of the West Indies are the Root and Rind fungus; most botanists think that they are different forms of the same fungus; to the Rind fungus, the name *Tricosphaeria Sacchari* has been applied; the Root fungus, following Masee, being identified with the *Colletotrichum Falcatum* of the Red Smut of Java, although this is denied by Went, who is of opinion that the *Tricosphaeria Sacchari* and the *Thielopsis Ethaceticus* may be identical. The Rind fungus is marked by reddish brown discoloured patches on the rind, the fibres underlying the rind being also red with white spots; later on a black fungus growth appears on the outside of the cane. When canes are attacked by the Root fungus the shoots wither and die, fresh ones are continually sent up which in turn die; the roots on examination will be found to be covered with small red spots. Bovell (*loc. cit.*) recommends that, when the disease has appeared, only canes of a fungus-resistant nature should be planted; that no plant should be taken from a stool with the appearance of the disease; that plants should be soaked in water containing disinfectants; that plants which fail to germinate should be destroyed; that so long as labourers can pass along the rows all infected canes should be removed and destroyed; that fields where the Root fungus has appeared should be planted for at least a year in

another crop, and not in another variety of cane ; that, after cutting, all rotten and diseased canes be destroyed. Among the fungus-resisting varieties he mentions Caledonian Queen, Rappoe, Naga B., Queensland Creole, White Transparent.

In addition to the facts stated above, Harrison has shown that canes heavily manured with ammonia are more liable to fungus than others. The points of greatest interest are the sequence of fungus disease on insect damage, and that in general well-drained, carefully-cultivated canes are less liable than others. For more detailed information see the papers by Krüger, Went, Wakker, etc., published at the several Java experiment stations. Barber, "Science Progress," July, 1897; Masee, "Annals of Botany," December, 1893; "The Kew Bulletins"; Cobb, "Agricultural Gazette of New South Wales," December, 1893.

### CANE, IMPROVEMENTS IN.

Harrison (Address to the Agricultural Society of British Guiana, S.C. 337) indicates the methods to be adopted.

- (a) By examination of varieties obtained from other countries.
- (b) By "bud variation."
- (c) By "grafting."
- (d) By selection of tops for planting from canes of high saccharine strength.
- (e) By raising new varieties by means of the seed of the cane.

With regard to *a*, he concludes that every sugar-cane

region is peculiarly adapted to the culture of one or other variety of the cane, the causes of which science cannot accurately determine; that we shall be led to false conclusions if we judge of the qualities of a variety of the cane suited to a certain district by the qualities shown when transplanted into conditions of inferior culture; that the sugar cane, like a number of other vegetables, is improved by continuous careful cultivation; that it is not always advantageous, and it may be imprudent, to replace on a larger scale in a given locality a good variety of cane, by another variety of cane which gives good results in another region.

With regard to *b*, he is of opinion that bud variation is so rare as not to be feasible in practice.

Regarding *c*, he quotes the Imperial Agricultural Institute of Brazil as concluding that the real grafting of the cane does not exist; Barber, however, controverts this view.

Respecting *d*, Edson, of Louisiana, states that by planting tops of rich canes, canes of high saccharine content are obtained, and in this he is supported by Thistleton Dyer; but Harrison, on the other hand, quotes reports from the Barbados experimental station:—

	BOURBON.	WHITE TRANSPARENT.	RED RIBBON.	PURPLE TRANSPARENT.
	Per cent. of Sugar.	Per cent. of Sugar.	Per cent. of Sugar.	Per cent. of Sugar.
Canes from rich parents	13'04	15'07	13'75	14'36
Canes from poor parents	13'67	14'75	14'85	14'29

As a means of improving the cane he is in favour of method *e*, which is being systematically pursued in British Guiana, Barbados, Java, Mauritius, Martinique,

Queensland, Singapore ; (in Demerara, canes have been grown with as high a sugar content as 20 per cent., and one of these transplanted to Louisiana preserved its characteristics) ; he states that saccharine richness of the parent is no guide to richness in the progeny ; that with self-coloured canes seedlings resemble the parent, but that with ribbon canes great variation occurs ; that the red ribbon and white transparent are most hopeful, but that the general tendency of seedlings is towards deterioration. He indicates the points to be aimed at as :—

1. High saccharine strength.
2. Heavy yields per acre, due to heavy tillering or large individual size.
3. Resistent power to attacks of insects and concomitant fungus.
4. Upright habit of growth.
5. Absence of tendency of eyes to springing.
6. Resistent power to attacks of cane rust.
7. Light colour of stem and consequent light colour of juice, which results in easier clarification during the manufacture of yellow crystals.

Went and Geerligs conclude from experiments made in Java :—

1. That the sugar cane is strongly subject to variation.
2. That the variation of all characteristics is considerable.
3. That European methods of plant improvement are applicable to the cane.

4. That it is probable that the characteristics of seedlings will be inherited in cuttings, and they recommend that large quantities of seed be sown ; that care be taken to prevent crossing ; that seedlings which approach the wild cane be destroyed, and that at a later stage attention be paid to outward characteristics.

### CANE, MANURING OF.

Scard, as the result of an extended series of experiments on the Colonial Company's Estates in British Guiana, concluded :—

1. That lime used by itself gives a small pecuniary gain.
2. That lime associated with manures gives an increase sufficient to pay for itself, only when used with larger (2 cwt.) quantities of soluble nitrogen, as sulphate of ammonia.
3. That of nitrogenous manures, sulphate of ammonia, at the rate of 2 cwt. per acre, gives the best results.
4. That ground mineral phosphate appears to give an increased yield compared to superphosphate.
5. That guanos, especially in conjunction with lime, fall far short of soluble nitrogen in beneficial influence.
6. That an increase of phosphoric acid over the

minimum employed (168 lbs. per acre) fails to give satisfactory pecuniary results.

7. That neither lime nor manures produce any perceptible difference in the purity of the juice, but only affect the weight of cane.

Dr. Morris states :—

1. That manuring with mineral manures alone is useless, as the cane cannot assimilate nitrogen from the air.
2. That the application of readily available nitrogen to mineral manures produces largely increased yields, but that dressings of over 3 cwt. ammonia manures per acre largely decreases the purity and richness of the juices.
3. That, under the climatic influences at Dodd's Reformatory in Barbados during the seasons 1885, '86, '87, nitrate of soda was inferior to sulphate of ammonia.
4. That an excess of superphosphate over 75 lbs. per acre does not produce a corresponding yield, and may even be deleterious.
5. That the presence of potash in rather high relative proportions in manures tends to increase the percentage of sugar.
6. That the presence of an excess of potash has no harmful effect on the purity of the juice.

Harrison and Bovell, in a series of experiments at Dodd's Reformatory in Barbados, found that increased applications of sulphate of ammonia did not pay for the

extra expenditure ; that nitrate of soda was very inferior to sulphate of ammonia ; that farmyard manure gave the biggest crop, and also the heaviest loss due to expenses in application ; and that the most economical manure was Oblendorff's early cane manure and dissolved Peruvian Guano. They recommended the manuring of the young cane with suitable manure, such canes standing a subsequent drought better ; and that afterwards phosphates and potash should be applied, the latter, only if not applied with earlier manurings, and that the manures should not be applied in one dressing but in two or three applications.

Harrison, in a paper read before the Royal Agricultural Society of British Guiana, 1897, concludes as a *résumé* of recent work on sugar cane manuring :—

1. That the yield is governed by the amount of readily available nitrogen, either naturally present or added as manures.
2. When applied in quantities containing not more than 40 to 50 lbs. nitrogen per acre, sulphate of ammonia and nitrate of soda are equally effective as manures on the majority of soils, but that when the unit of nitrogen is of equal money value that it is more economical to supply the former. Dried blood and similar organic manures, in which the nitrogen only slowly becomes available, are distinctly inferior sources.
3. Under ordinary conditions of soil and climate



and the usual range of prices for sugar, it is not advisable to supply more than 2 cwt. of sulphate of ammonia or  $2\frac{3}{4}$  cwt. nitrate of soda per acre.

4. If circumstances arise in which it is desirable to obtain the maximum yield per acre by the application of more than 50 lbs. nitrogen per acre, sulphate of ammonia should always be used.
5. Practically, on all soils, manurings with nitrogen require to be supplemented by phosphoric acid. The most effective form appears to be superphosphate of lime and slag phosphate meal. Mineral phosphates are of distinctly lower value, and are not effective unless applied in quantities far in excess in value of those required for either superphosphate or slag phosphate meal; as a rule phosphates should only be applied to plant canes, their action on ratoons being limited.
6. On some soils the application of potash salts, in quantities from 60 to 160 lbs. sulphate of potash per acre, results in greatly increasing the effectiveness of nitrogenous manuring; soils containing less than  $\cdot 01\%$  potash soluble in  $1\%$  citric acid solution, will as a rule respond favourably to this treatment, while those containing between  $\cdot 01\%$  and  $\cdot 02\%$  may or may not be favourably affected.

## CANE, VARIETIES OF.

Harrison and Jenman (S.C. 273) class the varieties of the cane under their outward characteristics into five classes:—(a) Yellow-green or green canes, often blotched with red; (b) white, vinous and brown tinged canes; (c) grey or pink tinged canes; (d) ribbon canes; (e) claret or purple canes.

Under *a* are included amongst others the Bourbon, Jamaica Elephant, Singapore, Lakona, Barbados native, China, Honolulu; under *b*, the Burke, Salangore, and Tamarind; under *c*, the Elephant and White Transparent; under *d*, the red, green, and violet Ribbon canes, the Drard, Grande Savanne, Po-a-ole; under *e*, the Boisronge, the Purple Transparent, Mani and Governor Lees. The following names are synonymous:—

*Bourbon.* Labania, Otaheite, Bamboo II., China II., Colony II., Cuban II., Louzier, Portier.

*Barbados Native.* West Indian Creole.

*Meligrei.* Bamboo I. and III., Demerara.

*Salangore.* White Mauritius.

*White Transparent.* Caledonian Queen, Mamuri, Rappoe, Hope, Cheribon, Light Java.

*Red Ribbon.* Seete, Striped Singapore.

*Po-a-ole.* Jamaica, Barbados Purple Mauritius, Giant Claret.

*Mani.* Norman.

*Purple Transparent.* Black Java, Purple Mauritius, Queensland Creole, Meera.

*Boisronge.* Bouronappa.

*Chrystallina.* Rose Bamboo, Blue Cane, Light Purple.

## CANE, YIELD OF.

Sixty tons of cane to the acre may be taken as an exceptionally high yield, 40 tons being above the average. Taking the sweetest canes as carrying 18% sugar, as much as 10 tons sugar per acre might be looked for. In Demerara, Mauritius, Queensland, Natal, Louisiana, West Indies, the return of commercial sugar per acre is, year in and year out, rather under 2 tons; from 3 to 4 tons is a common return in Java, and similar crops have been reported from Peru; in Hawaii the average return is much higher. In a letter received by the writer from Dr. Maxwell, the chief chemist of the Hawaiian Sugar Planters Association, the latter mentions an estate there which obtained a return of 10.5 (short) tons per acre of sugar at 100. These figures are not strictly comparable, the ton and acre varying in different countries, and, in addition, the time to maturity and number of crops from one planting should be taken into account; for instance, in Demerara, where the return is low, four or five crops are obtained in as many years from one planting; whereas in Java canes are not allowed to ratoon, and in Hawaii canes do not reach maturity till two years; it is an open question still, whether high returns are actually economical.

## CAMEL.

Caramel is the name given to the decomposition products obtained on subjecting sugar to a temperature of 180° C. and upwards. Gelis states that at 180° C. the body formed is  $C_{12}H_{18}O_9$ ; this is soluble, deliquescent, and bitter. At 190° C. more water is lost; the product

consisting of a mixture of caramélène  $C_{12}H_{16}O_8$ , and caramélène  $C_{12}H_{12}O_6$ . Of these the first is soluble in water, and the latter insoluble; both are soluble in 85% alcohol; above  $190^{\circ}C$ . caramélène is formed insoluble in water and alkalies.

When caramel is used for colouring rum, two points have to be considered; the caramel should reduce the strength of the rum as little as possible and give to the rum a sugary flavour. To obtain the latter effect the molasses or sugar syrup used for turning colour should not be burnt too far, but in this case the strength is very much reduced; to obtain a low obscuration the writer has found the following scheme of use:—

In an iron pot of about 200 gallons capacity, 40 to 50 gallons of molasses are placed, and water added till of density 1.25; instead of molasses a syrup of sugar and water of the same density may be used. A brick oven is built under the pot and a brisk fire kept up; the molasses or sugar syrup must be kept in continual movement, preferably by a mechanical stirrer; the sugar solution rapidly darkens, and in about 60 to 90 minutes is quite black; the usual test to show if the caramel is sufficiently burnt is to remove a portion on a stick, and after cooling to break the caramel with the finger; the caramel should be quite brittle. Another test is to drop a globule of colour into water, the floating of the globule being an indication that the caramel is sufficiently burnt; when either of these tests obtains the caramel will colour rum reasonably well, but to obtain a low obscuration (*q.v.*) the burning must be continued longer. The test the writer employs, is that

no caramel should run off a stick plunged into the mass and quickly withdrawn, but should solidify before any can fall off; if the burning be continued but a very little beyond this point, the whole mass becomes charred; when the point at which the caramel is sufficiently burnt is decided, the fire is drawn and sufficient water added to permit of easy carriage into the rum store; the treatment in the store has an effect on the obscuration. If the caramel be used to colour rum directly after cooling, a high obscuration will result, but if to the colour strong spirit at 60 to 70 O.P. be added, and the colour solution allowed to settle, the clear colour drawn off and spirit again added and the process repeated, finally a colour is obtained which gives a barely appreciable obscuration; this process is too lengthy to carry out in practice. The writer has found by experience that a well burnt colour, mixed with an equal bulk of 60 O.P. spirit, allowed to settle, and the clear colour used, will give a fully-coloured rum with apparent strength as shown by the Sikes hydrometer, only from one to two proof degrees less than the actual.

Various patented preparations are on the market; these consist largely of organic dyes; they colour rum with a minimum obscuration but spoil the flavour, and do not preserve their colour for any time; their use in excess is not advisable, but where difficulty with obscuration is experienced they may with advantage be used mixed with caramel colour. The writer has used logwood for the same purpose, without detracting from the quality of the rum.

## CARBONATATION.

The carbonatation process has only recently been applied to cane sugar manufacture, and its success is due chiefly to the efforts of Winter and Geerligns in Java, in which country the process is rapidly gaining ground, all recently erected factories adopting this scheme. The principle of the process is the use of a large quantity of lime giving a very complete clarification and easy filtration, and subsequent removal of the lime as carbonate by the passage of a current of carbon dioxide. The action of the lime is to destroy the glucose, giving rise to saccharic and glucinic acids; in practice two schemes are employed, single and double carbonatation. In the single process the whole of the excess of lime is removed by carbon dioxide in one operation; the juice is then heated to  $90^{\circ}$  C. and filtered, the amount of lime used being regulated by the filtration. In the double carbonatation process, carbon dioxide is passed in to the juice at a temperature not exceeding  $60^{\circ}$  C., until about .05 % lime remains; the juice is then filtered, the filtered juice saturated with carbon dioxide, boiled to break up bicarbonates, and filtered. As in the single process, the quantity of lime used is regulated by the filtration. Geerligns (S.C. 334) explains the process. At temperatures near the boiling point the action of lime on glucose is to form saccharic and glucinic acid; if, however, the temperature does not rise above  $60^{\circ}$  C., saccharic and lactic acids are chiefly formed, and only small quantities of glucinic acid, and the glucinate of lime which results being insoluble at  $60^{\circ}$  C. in an alkaline medium is, in the double process, removed in the scums,

but remains in the juice in the single process. It is claimed for these processes that clarification is more complete, that it is easy to control, that there is no necessity to temper the juice, that filtration is easy; that they are suited for impure juices, that the extraction is high, that, especially on soils poor in lime, the scums are a valuable manure, and, in the case of the double process, a very high-class sugar is made. On the other hand, the destruction of glucose entails loss in rum, the initial cost in limekiln, filters, saturation tanks, and carbon dioxide pumps is very great, and current expenses in lime and fuel are much increased. Owing to various causes (*v. Molasses*) the percentage of sugar in molasses is very high, but this disadvantage is more than counterbalanced by the less quantity of molasses obtained. Below are given analyses by Geerligs of juices treated by carbonatation.

	Brix.	Sugar %.	Glucose %.	Pectine.	Glucose per 100 Sugar.	Purity.
Mill Juice ..	18.4	15.72	0.92	0.634	5.9	85.6
Clarified by Defecation }	18.6	15.99	0.95	0.292	5.9	86.1
Clarified by Carbonatation }	16.9	14.65	0.44	0.142	3.0	86.7

### CENTRIFUGALS.

The centrifugal machines in general use in modern factories are practically all now of the overhead driven suspended type, and of these the principal forms are the Weston and Hepworth machines. The Weston centrifugal consists essentially of a steel spindle sus-

pended from the framing by means of a top nut and washer ; this spindle passes through an elastic buffer, thus giving it a certain freedom of motion and permitting an unevenly-loaded basket to find its own centre of gyration ; the lower end of this spindle carries a revolving bearing to which is attached an outer spindle which carries the pulley supplying motive power ; the basket is attached to the outer spindle ; the outer casing is stationary. In the Hepworth type the outer casing is suspended from the framework by a ball and socket joint ; this latter is securely fastened to a bracket, from which pass diagonally downwards three rods which are bolted to the outer casing ; the bracket also carries the bearings of the spindle to which is attached the revolving basket ; the lower bearing of this spindle is carried by the outer casing ; the outer casing is attached by elastic bands to brackets on the flooring, by means of which it is prevented from revolving, but allowed a certain freedom of movement.

Both types of machines are independent of heavy foundations, and as the load is free to find its own centre of gyration but little strain is placed on any part, and no power is lost in restraining the basket into a fixed centre. The size of basket most in favour on plantations is one from 30 to 36 inches in diameter, driven at a circumferential speed of 10,000 feet per minute, or about 1,200 revolutions per minute. Too great care cannot be taken with centrifugals—the pressure at full load at full speed is as great as 120 lbs. per square inch, and as the load is intermittent a greater factor of safety must be allowed than for a dead load ;



owing to wet sugar being acid the tendency to corrosion is great, and consequently the machines must be kept scrupulously clean, and after each grinding taken down and carefully examined.

## PARTICULARS OF CENTRIFUGALS.

(POTT AND CASSELS.)

Diameter of Basket in inches.	PER EACH MACHINE.					
	Output of Sugar per Hour in Pounds.		Indicated Horse-power.	Speed in revolutions per minute.	Capacity in Cubic feet.	
	Refinery.	Plantation.			Nett.	Gross.
24	1568	1255	2	1500	2½	4
30	2800	2240	2½	1200	4½	7
36	3080	2464	4½	1000	5½	10
42	3360	2688	6	850	6½	16
48	4368	3495	7½	750	11½	24
54	4704	3763	8	700	13½	32
60	5226	4181	9	600	14½	39
66	5680	4544	10	550	15½	47

The power stated in the above table is what is necessary for each machine up to four; where five or more machines are worked in series, deduct 15%.

## PARTICULARS OF CENTRIFUGALS.

(WATSON AND LAIDLAW.)

Diameter of Basket in inches.	NUMBER OF MACHINES TO BE DRIVEN.											Sugar cured on estate per day of 10 hours, per machine.	
	1	2	4	6	8	10	12	14	16	18	20		
	INDICATED HORSE-POWER.											First.	Second.
30	3·7	7·5	13·7	20·0	26·0	31·5	37·5	43·7	50·0	58·0	66·0	Tons.	Tons.
36	5·0	10·0	18·0	26·5	34·5	41·0	49·5	57·7	67·5	77·5		10·00	7·50
42	6·0	12·0	22·0	32·0	42·0	50·0	60·0	72·0	84·0			11·00	8·25
48	7·5	15·0	27·0	40·0	52·0	62·0	77·0	92·0				12·00	9·00
54	8·5	17·0	33·0	46·0	57·0	70·0	87·0					13·00	9·75
60	10·0	20·0	36·0	53·0	71·0	91·0						14·00	10·50
												16·00	12·00

When Pug Mills or Mixers are used with centrifugals add 15% to horse-power given above.

## CHIMNEYS.

If  $a$  = area of fire-grate in square feet,  $F$  = quantity of coal consumed per hour,  $H$  = indicated horse-power of engines,  $A$  = area of chimney at top in square inches, then

$$A = \frac{15F}{\sqrt{h}} = \frac{100H}{\sqrt{h}} = \frac{180a}{\sqrt{h}}$$

The diameter at base should be from  $\frac{1}{10}$  to  $\frac{1}{12}$  the height, and the batter about 3 inches to the foot.

TABLE GIVING THE POWER OF CHIMNEYS TO BOILERS. (BOX.)

Size at Top: inside.	40 Feet.		60 Feet.		80 Feet.		100 Feet.		120 Feet.		150 Feet.	
	Round	Square	Round.	Square.	Round.	Square.	Round.	Square.	Round.	Square.	Round	Square
ft. ins.	H.P.	H.P.	H.P.	H.P.	H.P.	H.P.						
1:6	16·6	21·0	19·5	24·8	21·7	27·5						
1:9	23·6	30·0	27·9	34·2	31·1	40·0						
2:0	31·9	41·0	37·3	47·5	42·3	53·8	46·7	58·2				
2:3			49·4	62·8	55·3	70·4	60·0	76·4	63·8	81·2		
2:6			65·3	83·1	70·4	90·0	76·5	97·4	81·0	103	85·0	108
2:9			75	100	88	112	94·9	121	101	128	106	135
3:0			94	123	106	135	114	145	123	157	130	165
3:6					150	191	143	207	175	223	186	237
4:0					202	257	220	280	235	300	252	321
5:0							360	458	388	494	415	528
6:0									577	734	615	783

## CLARIFICATION.

The object of clarification is to remove from the juice all bodies other than sugar, and to obtain a juice permitting of easy filtration and working in the pans and centrifugals; the agents universally employed for this purpose are heat and lime. The effect of an increased temperature is to coagulate a portion of the albumenoids and to expel volatile acids, besides facilitating filtration. The action of lime is to precipitate a further portion of albumenoid matter, to precipitate the phosphoric acid

and all mineral bases except alkalies, and when used in excess at higher temperatures to decompose the glucose (see under *Carbonatation*); all these bodies, along with suspended dirt, fibre, wax, are removed in filtration.

The lime is usually applied as a cream standing at about 20 Brix, the quantity required being determined under three methods:—

1. The raw juice is tested in the laboratory, and from the result the amount of lime required per clarifier is obtained; when working on these lines tests should be made hourly, and oftener if there is reason to suppose the canes are of uneven quality.

2. To a clarifier half full of juice an amount of lime, approximately that which experience has shown to be necessary, is added, and the reaction of the limed juice to litmus papers observed; according to the indication, more or less lime is added when the clarifier is full; proceeding in this way, the required amount of lime is soon found.

3. Instead of using litmus papers the limed juice is filtered into a test tube, and to the clear filtrate a drop of a solution of lime in sugar is added; the formation of a precipitate indicates the necessity for more lime, no precipitate occurring with an overlimed or exactly tempered juice.

These three methods do not give consonant results, for a juice limed so far as to be alkaline to litmus papers will give a further precipitation on the addition of more lime, precipitation being only complete in the presence of a considerable excess of lime; plenolphthalein is often

recommended as a more suitable indicator than litmus ; juice just alkaline to litmus, however, does not give an alkaline reaction to plenolphthalein. The alkaline reaction with plenolphthalein appears very close to the third method given above ; in general practice it is customary to lime so that the juice is just alkaline to litmus, but perhaps the best control is to use no more lime than will give a juice permitting of easy filtration (see under *Molasses*).

Other bodies which are largely used are sulphur dioxide and phosphoric acid ; the former is obtained by burning roll sulphur in brick ovens, whence the gaseous dioxide is led into the juice either before or after the addition of lime ; its action is to precipitate a portion of the albumenoids, to decolourise the juice, and to break up organic lime salts ; the best way of applying sulphur is to allow the juice to flow down perforated trays contained inside a tall box, at the bottom of which the sulphur dioxide enters ; in practice, when using sulphur in this way, the proportions of lime and sulphur are so regulated that an almost neutral juice is obtained, a good clarification being judged by a rapidly settling precipitate in a clear pale amber coloured liquid.

Phosphoric acid is used to remove an excess of lime as insoluble phosphate, the precipitate of phosphate of lime carrying down a certain proportion of organic matter ; if, however, an excess of phosphoric acid be used the precipitate redissolves, due to the formation of a soluble superphosphate.

The other agents which have been proposed may be classed :—

1. Sulphurous acid and soluble sulphites.
2. Phosphoric acid and soluble phosphates.
3. Oxidising bodies, *e.g.*, ozone, chlorine.
4. Baryta, strontia, and their salts.
5. Salts of iron, aluminium, zinc, lead, tin.
6. Tannin, oxalic acid, blood, alcohol, eucalyptus, etc.
7. Combinations of the above, added with a view to produce a precipitate in the juice and mechanically to carry down impurities; in all, upwards of three hundred preparations, rational and irrational; of these the use of sulphites, phosphates, baryta, strontia, lead, alum, oxalic acid, and tannin have been, or are used to a limited extent; the expense or poisonous attributes of the agents limiting their general use.

### CONTROL OF FACTORY.

A modern factory should, from the mill up to the distillery, be conducted as a huge chemical experiment, and efforts made to account for every pound of sugar entering the factory; to do this all products must be systematically weighed or measured, and carefully sampled for analysis; neglect in either of these particulars will vitiate the whole control. The following notes will be of help in guiding those responsible for the estimation of yield and losses:—

1. *Weight of canes.* In factories where the canes are weighed no difficulty is experienced, the only precautions necessary being a check on the scales and native operator; but in factories which do not admit of direct measurement of the canes, this figure

must be obtained from the weights of the juice and megass.

2. *Sugar in canes.* In mill work it is practically impossible to obtain a general sample of the canes, so that the composition of the canes is best calculated from the analysis and measurements of the juice and megass; in diffusion work samples for analysis may be taken from the diffusor cells, and stored in an air-tight vessel until sufficient have accumulated for analysis.

3. *Megass and crushed chips.* These should be weighed, and must be so where the canes are not; no difficulty arises in sampling so long as samples are not kept for too long. Geerligs advises intermittent heat sterilisation, the megass being enclosed in an air-tight box as a means of preserving samples over a lengthy period, or for shorter periods (three or four hours) the presence of a few drops of formaldehyde solution.

4. *Waste water.* This should be measured, either by a meter or in tanks.

5. *Juice.* The density, weight, or volume may be obtained automatically by any of the apparatus which have been devised; the forms most in use are those of Langen giving the density, of Baldwin giving the weight, and of Horsin Déon giving the volume; automatic scales similar to those used in bagging sugar are also employed; all these devices have the reputation of becoming choked by megass fibres, so that measurement in the clarifiers is usually resorted to. Where these are symmetrical their volume can readily be obtained by calculation, but where they are bulged or

warped they must be calibrated by filling with a known quantity of water ; their capacity should be calculated to one inch of the top, and care taken that they are filled to this level ; errors are unavoidable with this method, and a more accurate measurement would be obtained by allowing the juice to flow over from clarifier to clarifier successively. Where the clarifiers are contiguous, this can be done by cutting slots in the common sides of the clarifiers, each slot being at a little lower level than the preceding one, or when each clarifier is separate by connecting them similarly with overflow pipes. As the juice, in general, enters the clarifiers at an elevated temperature, a correction must be allowed for expansion ; taking the volume of a 15 % solution of sugar at 84° F. as 1.000, the volume at 180° F. is 1.0216, at 185° F. is 1.0285, at 190° F. is 1.0303, at 195° F. is 1.0327, at 200° F. is 1.0345. Samples should be taken from each clarifier and stored with the addition of one part corrosive sublimate per 10,000, which will prevent fermentation for at least twenty-four hours, and the analysis performed on the day's collection of samples ; instead of using the analysis of the clarifier juice to obtain the amount of sugar, the analysis of the raw mill juice may be used, but in this case an allowance must be made for evaporation. Let  $B_1$  = degrees Brix of mill juice,  $B_2$  = degrees Brix of clarifier juice ; then, percentage evaporation by weight in terms of original juice is  $\frac{100 (B_2 - B_1)}{B_2}$  ; in sampling mill juice a sample taken hourly, or oftener if there is cause to suspect much variation in the canes, will suffice. The volume of juice from the different mills is some-

times required and may be obtained :—Let  $B_1$  = degrees Brix of first mill juice,  $B_2$  = degrees Brix of second mill juice,  $X$  = volume of juice from second mill,  $B_3$  = degrees Brix of mixed juices ; then  $X = \frac{100 B_3}{B_1 + B_2}$  in terms per cent. of juice from first mill. To determine the added water used in maceration or diffusion a meter should be employed, but in its absence the quantity may be determined thus :—Let  $B_1$  = degrees Brix of first mill, so that  $A B_1$  = degrees Brix of mixed juices when not employing maceration,  $X$  = added water per cent. on original juice ; then  $X = \frac{A B_1 - B_2}{A B_1}$ .

6. *Scum cake*. This is best weighed on the trucks used for its removal, or in the absence of this convenience, the average weight of a cake may be obtained by weighing a large number, and a tally kept of the presses filled.

7. *Syrup* is best measured automatically, or else in the receiving tanks ; in sampling, samples should be taken from each tank.

8. *Massequite*, wherever possible, should be weighed ; where the massequite is received in trucks or wagons running on rails, this becomes an easy matter ; but in the absence of a weighbridge, measurements of the volume must be made ; for accuracy, care must be exercised that the trucks are always filled to the same level, and, a tally being kept, the volume over a week's work is determined. To obtain the density, some authorities recommend the weighing of a cubic foot of massequite contained in a wooden box, but the writer has never been able to obtain consistent results in this way. A second method for obtaining the density



consists in taking the degree Brix of a weight of massecuite dissolved in an equal weight of water, the density corresponding to twice this degree Brix being taken as that of the massecuite ; this method the writer can recommend as giving concordant results. Where crystallisers are employed, the weight and volume of the massecuite cannot be directly obtained ; they may be estimated, however, by working back from the weights of sugar and molasses, after allowance has been made for water used in washing in the centrifugals. The control of the massecuite requires the knowledge of the amount of fine grain passing through the centrifugal meshes ; this point is referred to under analysis of massecuite ; since the composition of the massecuite varies in different parts of the pan, attention should be paid to this in sampling.

9. *Molasses* may, of course, be weighed, but an estimation by volume is sufficiently accurate, the density being determined as given under massecuite ; in some houses it is customary to estimate them from the volume of the second massecuite, allowing 8 % for evaporation.

10. *Distillery*. For the control of the distillery are required the number of gallons of wash set up together with the percentages of sugar and glucose when just set up ; sufficient accuracy is obtained by direct measurement in the fermenting vats ; the rum may be measured in an automatic meter, and checked by the record in the butts from day to day ; when filled off for shipment weighing gives an easier and better measurement than gauging.

11. *Inversion* losses are estimated by calculating the amount of glucose present in the various stages of manufacture in excess of that present originally in the juice. For example:—glucose in 100 tons juice, 2223 lbs.; glucose in massecuite from 100 tons juice, 2236 lbs.; glucose in scum cake from 100 tons juice, 20 lbs.; hence, sugar inverted per 100 tons juice =  $\frac{2236 + 20 - 2223}{1.0526} = 31.35$  lbs. (1 lb. sugar on inversion giving 1.0526 lbs. glucose). In the carbonatation process, where the glucose is in great part destroyed, it is impossible to estimate inversion losses in the earlier stages of manufacture, though calculations may be made for losses in inversion in after products.

12. *Entrainment* losses are almost impossible to estimate directly, and may be obtained by difference after accounting for all other yields and losses.

No hard and fast rules can be laid down for sugar house control; the estimation of yield and losses must be left to the skill and ingenuity of the chemist in charge, who should alone be responsible for the actual manufacture; a weekly return should be made out, a specimen of which is given, which can be varied to suit the requirements of different factories.

## ACREAGE.

Hours at Work.	Acres Ground.	Tons of Cane.	Tons per Acre.	Tons of Sugar per Acre.

## CANES.

Sugar in Canes: tons.	Glucose in Canes: tons.	Sugar %.	Glucose %.	Ash %.	Fibre %.	Water %.

## JUICE.

Normal Juice : tons.	Juice % on Canes.	Tons of Sugar.	Tons of Glucose.	Sugar % on Sugar in Canes.	Density.

Total Solids %.	Sugar %.	Glucose %.	Ash %.	Sugar : Glucose.	Purity.

## MEGASS.

Tons.	Tons of Sugar.	Sugar % on Sugar in Canes.	Sugar %.

Glucose %.	Ash %.	Fibre %.	Water %.

## SCUM DIRT.

Tons.	Tons of Sugar.	Sugar % on Sugar in Canes.	Sugar % on Sugar in Juice.	Sugar %.	Glucose %.	Water %.

## SYRUP.

Tons.	Tons of Sugar.	Sugar % on Sugar in Canes.	Sugar % on Sugar in Juice.

Density.	Sugar %.	Glucose %.	Sugar : Glucose.	Purity.

## MASSECUTE I.

Tons.	Tons of Sugar as Crystals.	Tons of Sugar in Solution.	Total tons of Sugar.	Sugar % on Sugar in Canes	Sugar % on Sugar in Juice.

Crystallised Sugar %.	Dissolved Sugar %.	Glucose %.	Ash %.	Sugar : Glucose.	Purity.

## SUGAR I.

Tons: gross.	Tons: net.	Per cent. on Canes: gross.	Per cent. on Massecuite: gross.	Sugar % on Sugar in Canes: gross.	Sugar % on sugar in Canes: net.

Sugar % on Sugar in Juice: gross.	Sugar % on Sugar in Juice: net.	Sugar %.	Glucose %.	Ash %.	Water %.

## MOLASSES I.

Tons.	Tons of Sugar.	Sugar % on Sugar in Canes.	Sugar % on Sugar in Juice.	Density.	Sugar %.

Glucose %.	Water %.	Ash %.	Purity.	Alkalinity of Ash, as $K_2O$ %.	Glucose: Alkalinity of Ash.

## MASSECUITE II. CURED.

Tons.	Crystallised Sugar %.	Dissolved Sugar %.

## MASSECUITE II. ESTIMATED FOR CURRENT WEEK.

Tons.	Sugar %.	Glucose %.	Purity.	Tons of Sugar.

## SUGAR II. CURED.

Tons: gross.	Tons: net.	Percentage on Massecuite II.	Sugar %.	Glucose %.	Ash %.	Water %.

## SUGAR II. ESTIMATED FOR CURRENT WEEK.

Tons: gross.	Tons: net.	Per cent. on Canes: gross.	Sugar % on Sugar in Canes gross.	Sugar % on Sugar in Canes: net.	Sugar % on Sugar in Juice: gross.	Sugar % on Sugar in Juice: gross

## MOLASSES II. MADE.

Tons.	Tons of Sugar.	Sugar %.	Glucose %.	Water %.	Ash %.	Density.

## MOLASSES II. ESTIMATED TO BE MADE.

Tons.	Tons of Sugar.	Sugar % on Sugar in Canes.	Sugar % on Sugar in Juice.

## DISTILLERY.

Tons of Molasses used.	Gallons of Wash set up.	Gallons of Wash distilled.	Sugar in Wash %.	Glucose in Wash %.

Total Sugars % as Glucose.	Tons of Sugars in Wash distilled.	Gallons of Spirit made.	Strength of Spirit.	Gallons of Spirit made at Proof.

Attenuation of Wash.	Proof Spirit % by analysis.	Proof Spirit % by attenuation.	Per cent. of Proof Spirit recovered.	Lbs. of Sugars as Glucose per gall. of Proof Spirit.

## COST OF PRODUCTION.

The cost of production varies with the return per acre, the price of labour, the feasibility of mechanical cultivation, the capability of the factory, the necessity for forced drainage or irrigation, etc., etc.

In Queensland, 1897-98, cost of a ton of sugar varied between £6 8s. 10½d. and £9 4s. 7d., canes being sold to the factory at 14s. 7d. per ton.

At Daria Sanieh, Egypt, 1897, cost of a ton of sugar was £9 11s. 0½d., canes being bought at 13s. 7d. per ton.

In Louisiana, the cost of manufacture per ton of cane is estimated at \$2.67, leaving, in 1894, \$3.08 to cover cost of cane.



Below are given detailed figures for a large estate in Demerara :—

Crop, 3,852 tons ; all sugars being 2·43 tons per acre, with 80,000 gallons of rum.

Item.	Cost per Acre.			Cost per Ton.		
	£	s	d.	£	s.	d.
Salaries .. .. .	2	5	2	0	18	3
Labour .. .. .	10	8	6	4	5	9
Manures .. .. .	1	2	9	0	9	4
Packages .. .. .	1	16	9	0	14	3
Fuel (including drainage) ..	1	4	2	0	9	9
Transport .. .. .	1	0	1	0	8	4
Machinery and New Works	1	2	3	0	9	3
Immigration .. .. .	0	3	10	0	1	7
Insurance .. .. .	0	1	7	0	0	8
Hospital .. .. .	0	9	1	0	3	9
Interest .. .. .	0	3	2	0	1	4
Sundries .. .. .	0	17	1	0	7	0
Total ..	£21	17	6	£8	18	9

The following figures, from a Demerara factory making about 350 tons per week of 150 hours, are not given to show what should be done, but rather how labour can be saved.

Employment.	No. of Hands per Shift.	Total Earnings per Week for both Shifts.		
		£	s.	d.
Throwing Canes .. .. .	28	18	16	4
Docking and Baling Punts ..	4	2	6	0
Strainers, Cush Cush, etc. ..	6	3	9	0
Mill Attendants .. .. .	6	4	12	0
Megass loft, Firemen .. .. .	27	16	12	6
Engineers and Engine-drivers	15	11	8	0
Curing Sugar (one shift) ..	25	10	8	4
Triple and Pan Boilers .. ..	12	6	12	3
Porters (one shift) .. .. .	25	8	6	9
Distillery .. .. .	7	5	17	7
Clarifiers and Fitters .. .. .	15	6	5	0
Watchmen .. .. .	7	1	12	6
Carpenters .. .. .	6	4	18	9
Sundries .. .. .	8	3	7	5
Total		£104	12	5
		(or 5/9 per ton)		

By adopting automatically fired furnaces, mechanical discharge of canes, juice filters instead of skimming in open vessels, hydraulic apparatus to move massecuite, at least 50 hands per shift would be dispensed with, a money saving in a week of from £35 to £40.

The following are figures for a Java estate ("Deutsche Zuckerindustrie," 1889, S. 1509).

CULTIVATION.	Dollars per Acre.	Dollars per metric ton (2,206 lbs.)	MANUFACTURE.	Dollars per Acre.	Dollars per metric ton (2,206 lbs.)
Staff, Household, etc.	7.70	3.77	Staff, Household, etc.	3.65	1.78
New Plants.. ..	3.13	1.53	Cane Carrier .. ..	0.80	0.39
After Plants .. ..	1.48	0.72	Extraction of Juice	0.83	0.41
Weeding .. ..	9.53	4.67	Clarification .. ..	0.80	0.39
Manuring .. ..	0.94	0.46	Boiling .. ..	0.36	0.18
Ploughing .. ..	2.66	1.30	Centrifugals.. ..	0.90	0.44
Drilling .. ..	0.83	0.41	Packing .. ..	0.27	0.13
Draining .. ..	2.30	1.13	Coal Boilers .. ..	0.84	0.41
Trashing .. ..	0.58	0.28	Megass Boilers .. ..	0.33	0.16
Cane Cutting .. ..	2.15	1.05	Watchmen .. ..	0.59	0.29
Loading .. ..	2.26	1.11	Engineers .. ..	0.64	0.31
Watchmen .. ..	0.19	0.09	Sundries .. ..	0.42	0.21
Manures .. ..	4.33	2.12	Smiths, Masons, etc.	1.78	0.87
Tools .. ..	0.70	0.34	Transport to Steamer	2.75	1.34
Labour Supply .. ..	1.73	0.85	General Stores .. ..	1.33	0.65
Hospital .. ..	1.64	0.80	Oil .. ..	0.40	0.20
Taxes, Insurance ..	2.34	1.15	Acids and Lime .. ..	1.28	0.63
<b>Total</b> .. ..	<b>44.49</b>	<b>21.78</b>	Lighting .. ..	0.08	0.04
			Filters .. ..	0.30	0.14
			Packages .. ..	2.20	1.08
			Machinery .. ..	2.43	1.19
			Coal.. ..	4.75	2.32
			Labour Supply .. ..	0.23	0.11
			Taxes, Insurance ..	2.54	1.25
			Hospital .. ..	0.30	0.14
			Sundries .. ..	1.43	0.70
			Freight .. ..	15.22	7.46
			Commission .. ..	7.61	3.73
			<b>Total</b> .. ..	<b>55.06</b>	<b>26.95</b>
<b>TRANSPORT.</b>	<b>Dollars per Acre.</b>	<b>Dollars per metric ton (2,206 lbs.)</b>			
Superintendence ..	0.37	0.18			
Wages .. ..	3.21	1.57			
Maintenance .. ..	4.90	2.39			
Coal and Fodder ..	3.97	1.95			
Wagons, Horses ..	4.57	2.23			
Roads, Railway ..	1.31	0.64			
Taxes .. ..	0.94	0.47			
<b>Total</b> .. ..	<b>19.27</b>	<b>9.43</b>			

Grand total per acre, 118.32; per ton, 58.16; and deducting value of molasses net per acre, 112.27; per ton, 54.95.

## CRYSTALLISATION IN MOVEMENT.

This process, which was originally conceived many years ago, and abandoned through its principles not being understood, has lately been very extensively adopted in both raw and refined sugar manufactories. Our information concerning its application to cane sugar manufacture depends largely on the researches of Geerligs. This investigator has shown that the actual amount of sugar, *separating as crystals*, from first massecuite is very nearly always about 65 %, the massecuite holding from 8 % to 9 % of water. When working with very pure juices, say of purity 85 and upwards, nearly all this sugar crystallises out in a form which can be readily recovered in the centrifugals ; but with impure juices, especially such as contain a large proportion of glucose (8 % and over), it is found that the recovery at the centrifugals is very low ; the reason of this is that a supersaturated solution of sugar is formed in the pan, and this sugar in supersaturated solution separates as solid very slowly, and, owing to the viscosity of the molasses preventing free movement of the particles of sugar, does not deposit on the crystals already formed, but separates as new crystals forming " false grain " ; this false grain, in addition to being totally lost in curing, chokes the web of the basket and entails the use of much water in covering, leading to a further loss of sugar ; in the crystallisation in motion process, after striking, the massecuite is kept in motion till cool, with the result that the sugar deposited from supersaturated solution, and that deposited as the result of a fall of temperature forms on the crystals already present,



leading to a high recovery in the centrifugals. The most generally used method of working is as follows:—The pan is filled about three-fifths full, and then hot molasses from a former operation—saturated at the ordinary temperature—are drawn in; the fine grain already in the pan is dissolved; the whole is boiled close and struck out into crystallisers and stirred till cold, and then cured; the quantity of molasses drawn in are calculated to bring the purity of the whole strike to about 70; as a general rule, molasses are drawn in until the centrifugalled molasses have a purity under 40, although purities of little over 30 have been obtained; when the quotient is reduced so far, a small further yield may be obtained in low grade sugar, or the molasses may be sent to the distillery; if the massequite on striking becomes very stiff and viscous, diluted molasses may be drawn into the crystalliser; points of practical importance are that the molasses must be drawn in hot, the crystalliser must be warmed before receiving a charge, and that the blades must be in motion before massequite enters; neglect of the first two precautions causes a formation of false grain; and of the third may lead to fracture of the blades. The following analyses by Geerligs illustrate the points mentioned.

COOLED.	MASSEQUITE.				MOLASSES DRAINED OUT.				
	Sugar.	Glucose	Ash.	Purity.	Sugar.	Glucose	Ash.	Water.	Purity.
At rest ..	74·1	11·07	1·54	81·44	32·9	28·59	3·11	25·37	42·86
„ ..	78·9	8·99	1·16	85·32	33·7	28·12	3·65	24·50	44·63
„ ..	79·0	8·47	1·15	85·72	32·9	27·52	3·72	26·12	44·67
In motion ..	77·0	9·62	2·51	83·45	35·3	26·54	6·70	22·94	46·40

COOLED.	Sugar Crystallised.	Amount of Crystals obtained on Curing.	Loss of Crystals on Curing, per 100 Sugar.
At rest .. ..	61·62	51·51	16·40
" .. ..	68·22	58·81	13·79
" .. ..	69·09	55·28	19·88
In motion.. ..	64	64	

In addition to the extra return in sugar, nearly all of which is first sugar, must be put the saving in labour and the cleanliness of the process; the capital expenditure for massecuite cooling houses is saved, as well as the expense and inconvenience of putting the factory about, after the crop is taken off, to cure off the low grade sugars, as these are totally suppressed.

Crystallisation in movement has also been applied to low grade massecuites boiled string proof with very favourable results; in this case the after massecuites can be cured from 60 to 72 hours after boiling, a slightly higher yield being obtained; as the boiling in of molasses tends to darken the sugar, detracting from the value of consumption sugars, this method should be adopted in those houses which specialise in this product. The mechanical processes for the crystallisation may be classed under two heads—those employing closed and those using open vessels; the closed system is the more expensive in first cost, but it has the advantage that the crystallisers may be placed where convenient, the massecuite being carried to the centrifugals by means of compressed air; in the open type the crystallisers have to be placed directly over the centrifugals discharging into them by means of a sluice.

It must be remembered that it is only with impure

juices that this process gives the best results; pure juices do not tend to form supersaturated solutions, and not being viscous on cooling, allow the separating sugar to deposit on the crystals already formed. Results approximating to those obtained by crystallisers may be obtained by *very* skilful pan boiling, but such skill is rare; on an estate with which the writer is acquainted, and which possesses a peculiarly skilful pan boiler, the return from massecuite averages 62% to 63%; an estate close by working very similar juice, but the pans being boiled by a native of average capability, only recovering from 56% to 58%. Appliances to obtain similar results to those described above have been attempted; chief amongst them are Dr. Winter's pan, which towards completion of boiling allows air in a fine state of division to enter the pan, agitating the massecuite and causing solution of fine grain; and Aitken and McNeil's pan, where constant agitation of the massecuite is obtained by a continually moving coil.

### DEMING PROCESS.

In this process the juice is raised in closed vessels to a temperature of 240° F., the time at which the juice remains at this temperature being only a few seconds; leaving these vessels the superheated juice meets cold juice on its way to the superheater, parting with a proportion of its heat and raising the temperature of the cold juice. The apparatus is provided with an arrangement of baffle plates for removing the scums, dispensing with the trouble of skimming in open vessels; among the points claimed for this process are a large increase

in purity, easy filtration, saving in labour, great economy in steam, and consumption of waste heat. The juice is limed before it is superheated, and a very possible source of danger is the effect of a small excess of lime at the high temperature. The following figures dealing with the process have been published by Beeson (S.C. 330):—

Juice.	Total Solids.	Sucrose.	Solids not Sugar.	Purity.	Glucose.
{ Diffusion .. .. .	14.9	11.22	1.69	75.3	1.99
{ Ordinary Clarification ..	14.9	12.04	0.83	80.9	2.03
{ Deming Clarification ..	14.9	11.58	1.29	77.7	2.03
{ Diffusion .. .. .	14.9	11.78	1.11	79.1	2.01
{ Ordinary Clarification ..	14.9	11.65	1.21	78.2	2.04
{ Deming Clarification ..	14.9	10.85	2.06	72.8	1.99

Juice.	Glucose ratio.	Total Proteids.	Albu- menoids.	Amides.	Alcoholic Precipitate.
{ Diffusion .. .. .	17.7	.248	.0617	.1863	.105
{ Ordinary Clarification ..	16.9	.205	.0416	.1634	.202
{ Deming Clarification ..	17.5	.208	.0434	.1646	.171
{ Diffusion .. .. .	17.1	.215	.0733	.1417	.246
{ Ordinary Clarification ..	17.5	.201	.0538	.1472	.386
{ Deming Clarification ..	18.3	.202	.0447	.1574	.297

Edson, experimenting at Calumet, Louisiana, on the rapidity of filtration for juices treated by the Deming process to filter more rapidly than others.

Temperature of Clarification.	215° F.	230° F.	246° F.	260° F.
Filtration started at ..	3-45	3-45	3-45	3-45
Juice freed from mud at	4-15	4-5	3-56	3-56
Time of Filtration ..	30 min.	20 min.	11 min.	11 min.
Using Juice heated to 260° F. as a unit, the time of Filtration was )	2-75	1-82	1-00	1-00

## DEFECATION.

See *Clarification*.

## DIFFUSION.

The diffusion process, which has obtained universally in beet factories, has only been very partially adopted in cane factories ; the chief reason against its adoption being the contingent deterioration of the megass as fuel, combined with the high price of the latter in tropical countries, considerations which do not apply to beet factories. As worked at present, diffusion will extract from the cane from 95 % to 97 % of the sugar actually present, with the addition of from 20 % to 30 % of added water on the weight of the cane ; compared with mill work, the advantages are the higher extraction and purer juice, counterbalanced by greater initial cost of machinery, greater expense in labour and in consumption of steam to evaporate the added water, and inferiority in the mechanical nature and water content of the resulting fuel ; the added water in maceration processes seldom exceeds 20‰, and then only with exceptionally rich canes, and this added water can be controlled according to the nature of the cane, a proceeding not feasible with diffusion work.

A comparison of mill and diffusion work from a financial standpoint comprises so many points, that a hard and fast statement is impossible ; on the score of capital expenditure the balance is probably in favour of a crushing plant, and decidedly so in the case of an absolutely new installation, where a mill to crush the exhausted chips would be required in addition to the

diffusion plant—the extra labour dependent in the case of diffusion on the greater volume of juice worked up is of little moment, but of much greater importance is the deterioration in the value of diffusion megass as fuel; although in mill and diffusion work the fibre available for combustion is the same, in the latter case it is so finely divided that mechanically it is very unsuited, the difference between the two is comparable to the difference between well-screened coal and slack. In tropical countries, where coal often costs 30/- per ton at the furnace mouth, this point is of supreme importance. A comparison of various types of mill and diffusion work is appended, but no attempt is made to estimate the *net* financial gains. In general, it is now accepted that the most economical method of extraction is powerful mill work combined with a moderate maceration, but perhaps in countries as Natal, Louisiana, where coal is fairly cheap, diffusion might give better results.

TABLE GIVING A COMPARISON OF MILL AND DIFFUSION WORK.

	A.		B.	
	Double Crushing. No dilution.		Double Crushing. 8% to 12% dilution.	
Sugar in juice per 100 tons sugar in canes	80	82.5	85	87.5
Corresponding Output in all sugars	72	74.25	76.5	78.75
Gross Value at 12/- per cwt.	£364	£391	£918	£945
Less for Labour, Packages, etc., at 12/- per ton		£1 - 1 - 0	£2 - 2 - 0	£3 - 3 - 0
Gross Value of Increased Output over A.		£25 - 19 - 0	£52 - 18 - 0	£77 - 17 - 0

	C. Treble Crushing. 12% to 20% dilution.		D. Diffusion. 20% to 30% dilution.	
Sugar in juice per 100 tons sugar in canes	90	92.5	95	97.5
Corresponding Output in all sugars	81	83.25	85.5	87.75
Gross Value at 12/- per cwt.	£972	£999	£1,026	£1,053
Less for Labour, Packages, etc., at 12/- per ton	£4 - 4 - 0	£5 - 5 - 0	£6 - 6 - 0	£7 - 7 - 0
Gross Value of Increased Output over A.	£103 - 16 - 0	£129 - 15 - 0	£155 - 14 - 0	£218 - 13 - 0

The following concise explanation of the working of a diffusion battery is taken from Spencer's "Handbook for Sugar Manufacturers"—

"The first duty of the head battery man is to see that all joints are tight, that the various signal bells are in place, and that all mechanical details essential to good working have received attention. For convenience of reference we will suppose cell No. 4 is the first to be filled with chips. Fill cell No. 1 with water; when this cell is filled turn the water into No. 2, passing it through two heaters; fill No. 3 in the same manner, heating the water to about 203° F. (95° C.). This assures an abundant supply of water for the first round of the battery. Fill cell No. 4 with cane chips; pass the hot water up through heater No. 3, and down through heater No. 4, and into cell No. 4 at the bottom, driving the air out of this cell through the vent in the cover. It must be understood that the supply of cold water in No. 1 is replenished as fast as drawn upon, through the water valve of this cell. When cell No. 4 is filled, as indicated by the juice flowing through the air vent, close this vent and the

valve communicating with the bottom of the cell by way of the juice main, and admit the water at the top of the cell. This operation is termed in this article 'establishing the pressure at the top of the cell.' By this time No. 5 should be filled with chips. Draw the juice from cell No. 4 up through its heater and into No. 5 at the bottom, venting the air as before. It will be observed that the juice passes through two heaters each time before reaching the fresh cane chips. When cell No. 5 is filled with juice, establish the pressure at the top as before. These operations are repeated until six or seven cells are filled with chips. It is now time to make the first draw of diffusion juice. For example, let us draw from No. 11. Having filled this cell in the same manner as the preceding ones, the next manipulation—the pressure being already established at the top—is to open the valve connecting the juice main with the measuring tank, and draw a charge. Having drawn the requisite amount of juice, and having closed the tank valve, open that connecting heater No. 12 with the juice main, and fill cell No. 12 as usual, this cell having previously received its charge of chips. When cell No. 12 is filled, draw another charge of juice as before. Continue in this manner drawing a charge of juice from each cell of fresh chips. When cell No. 14 is reached, discharge the water from Nos. 1, 2, 3 through the waste valves, the valve connecting No. 1 with the water main having been closed, and also that connecting caloriser No. 4 with the top of cell No. 5; connect cell No. 5 directly with the water main. Cell No. 4 is now out of the circuit, and the first round of



the battery is completed. If compressed air were employed in forcing the circulation, as is usual, each time a cell of juice is drawn (except the first round of the battery), No. 4 will have very little water left in it. The next operation is to open the air vent on No. 4 for the escape of the compressed air, or if water pressure is used, to admit the air to the cell and permit the water to escape through the waste valve. The door at the bottom of the cell must now be opened, and the exhausted chips discharged into a car or carrier. The workman on duty below, before latching the door, should rapidly pass his hand, protected by a cloth, about that part of the bottom which comes in contact with the hydraulic joint, to remove adhering chips, which might cause a leak.

“The first round of the battery having been completed, the regular routine commences. Two cells should always remain open, one filling and one being prepared for fresh chips. Each time a cell is filled with fresh chips and juice, a charge must be drawn and a cell of exhausted chips rejected. In regular work it is usual to designate the cell first in the series, *i.e.*, the one which receives the water direct from the supply tank, No. 1, and that from which the juice is drawn No. 10 or No. 12, according to the number of cells composing the battery. In the above description of battery routine nothing was said in regard to the temperature to which the juice should be heated. The following table shows the temperature at which the United States Government experiments were conducted in work at Magnolia plantation, season of 1888-1889.

Lower temperatures with very thin chips would probably give a purer juice, yielding more readily to subsequent processes of manufacture.

Cell No.	1	(2, 3, 4, 5, 6, 7)	8	9	10	11	12
Temp. F.°	140°	158°-176°	203°	203°	203°	185°	160°

“In order to obtain a maximum extraction and at the same time a juice of maximum density, it is necessary that the temperature of the cells, 9, 10, 11, be kept as high as is possible. The hotter the water entering the cells containing the fresh chips the better the extraction in this cell, and consequently the less work for the subsequent portions of thin juice which enters this cell. It is a well known fact, that the greater the difference in the densities of the thin juice bathing the chips and the heavier juice contained in them, the more rapidly the diffusion will take place. Advantage is taken of this fact in requiring the last cell in the series to do as much work as possible.”

*Quantity of juice to draw per 100 lbs. of cane chips.*  
 With a constant percentage of sucrose in the normal juice, a uniform draw and a perfectly regular extraction, the dilution, and consequently the per cent. sucrose in the diffusion juice, will vary considerably. This variation is due to the variable juice content of the cane. In ordinary seasons in Louisiana, the per cent. juice in plant cane will average about 91, and in stubble (ratoons) 89; consequently, if we draw the same amount of juice, when diffusing plant cane as we do with stubble, the dilution will be lower and the analysis of the two juices will vary, even though the normal juices contain the same per cents. of sucrose. It is

safe to commence working with a dilution of about 23%, estimating on an average about 90% of juice in the cane. If the extraction is satisfactory, but the density of the diffusion juice too low, the cane contains less than 90% of juice, and the draw should be decreased until a satisfactory density is obtained. With thin chips and regular work the draw may be reduced to 18%, but it is not safe to go below this limit, except when there is a careful chemical control to promptly detect and remedy a poor extraction. With the best multiple effect evaporation it is economical to burn more coal to evaporate additional water, rather than leave two or three-tenths per cent. sucrose in the chips which might have been obtained by a little higher dilution.

The following table, designed for preliminary work, gives the dilution for different quantities of juice drawn. Table showing the apparent dilution of the normal juice corresponding to different quantities of juice drawn. This table is based on an assumed juice content in the cane of 90%, and of an average density of 16° Brix.

Apparent Dilution.	Diffusion juice drawn per 100 lbs. cane.			Apparent Dilution.	Diffusion juice drawn per 100 lbs. cane.		
	Weight: lbs.	Gallons.	Litres.		Weight: lbs.	Gallons.	Litres.
PER CENT.				PER CENT.			
10	99.0	11.2	42.3	21	108.9	12.4	46.9
11	99.9	11.3	42.7	22	109.8	12.5	47.2
12	100.8	11.4	43.1	23	110.7	12.6	47.6
13	101.7	11.5	43.5	24	111.6	12.7	48.0
14	102.6	11.6	43.8	25	112.5	12.8	48.4
15	103.5	11.7	44.2	26	113.4	12.9	48.8
16	104.4	11.8	44.6	27	114.3	13.0	49.1
17	105.3	11.9	45.0	28	115.2	13.1	49.5
18	106.2	12.0	45.3	29	116.1	13.2	49.9
19	107.1	12.2	46.1	30	117.0	13.4	50.6
20	108.0	12.3	46.5				

Llewellyn Jones gives the temperature of the different cells as under : No. 1, 75° C.-80° C. ; No. 2, 80° C.-85° C. ; No. 3, 85° C.-90° C. ; No. 4, 95° C.-100° C. ; Nos. 5-9, 100° C. ; No. 10, 90° C. ; No. 11, 85° C. ; and estimates the consumption of steam as : establishing and maintaining juice at 212°F. 40 % ; evaporation of juice, 38 % ; molasses sugar, 5 % ; the various engines, 17 %.

*Dimensions of Diffusion Batteries (Spencer).*

1. Battery of 165 tons capacity, in 23 working hours ; one cell every seven minutes :—

Diameter of cell (diffuser), 44 in. ; length (net)  
6 ft. 2 in.

Juice and water mains, 4 in. diameter.

Heaters, 25 square feet heating surface.

Net volume of cell (cane space), 65 cubic feet.

Air compressor, 100 cubic feet.

Measuring tank, 30 cubic feet volume (net).

Steam supply pipe (assuming 75 lbs. pressure),  
2 in. diameter.

2. Battery of 190 tons, in 23 working hours ; one cell every seven minutes :—

Diameter of cell, 40 in. ; length (net), 8 ft. 2 in.

Net volume of cell (cane space), 75 cubic feet.

Heaters, 30 square feet heating surface.

Juice and water mains, 4 in. diameter.

Air compressor, cylinder 9 in. diameter, 12 in.  
stroke.

Air reservoir, 120 cubic feet.

Measuring tank, 35 cubic feet.

Steam supply (assuming 75 lbs. pressure), 2 in.  
diameter.

3. Battery of 275 tons capacity, in 23 working hours ; one cell every seven minutes :—

Diameter of cell, 44 in. ; length (net), 10 ft. 2 in.

Net volume of cell (cane space), 107 cubic feet.

Heaters, 43 square feet.

Water and juice mains, 5 in. diameter.

Air compressor, 12 in. diameter, 12 in. stroke.

Air reservoir, 175 cubic feet.

Measuring tank, 50 cubic feet.

### DILUTION.

The apparent dilution is the amount of water added to the normal juice to increase its volume to that of the diffusion juice. This is expressed in percentage terms of the normal juice. The actual dilution is the proportion of water added to the normal juice to reduce its percentage of sugar to that of the diffusion juice ; hence the actual dilution represents the evaporation necessary, per cent. normal juice, to remove the added water. In calculating the dilution, we take the sum of the percentages of sucrose and glucose in order to diminish the errors liable to result from inversion. In figuring coal consumption, all statements should be based on the actual dilution. The nearer we approach a perfect extraction, the nearer the apparent dilution approaches the actual. (*Spencer.*)

### DISTILLERY.

The fermenting vats should be placed in a well-lighted, well-ventilated loft, and all pipes and gutters

should be arranged so as to give access for easy cleaning; before starting, and after finishing operations, all pipes, vats, etc., should be cleansed with an antiseptic wash; milk of lime, with subsequent removal by dilute sulphuric acid is frequently employed, but more satisfactory results would be obtained by the use of more energetic antiseptics, such as alkaline fluorides; the parts of the fermenting loft not actually in contact with the wash may be kept free of harmful organisms by the use of antinonnen. In setting up wash, Scard advises a density of 1.063, and the addition of one gallon sulphuric acid and 10 lbs. sulphate of ammonia per 1,000 gallons of wash. The object of the sulphuric acid is to prevent bacterial action, and of the ammonia to supply food to the yeast.

In the fermentation two distinct processes happen: the alcoholic fermentation under the influence of yeast, and a secondary fermentation under the influence of bacteria giving rise to organic acids and fusel oils. In European distilleries it is quite general to prepare yeasts free from bacteria, and to obtain cultures which experience has shown possess the property of giving some peculiar flavour to the spirit; but in rum distilleries lamentable disregard of these methods is shown, the fermentation being nearly always left to chance.

To calculate the proportions of molasses and water to set up wash at a given density, let  $N$  = number of gallons of wash,  $n$  = number of gallons of molasses,  $d_1$  = density of the wash,  $d_2$  = density of the molasses, then

$$n = \frac{N (d_1 - 1)}{d_2 - 1}$$

To calculate percentage of proof spirit (by volume) from "attenuation." Let  $d_1$  = original density, and  $d_2$  = final density of wash; then, Proof spirit % =  $212 (d_1 - d_2)$ .

*Capacity of Vats and Stills.* For every 100 tons of sugar made per week, about 6,000-7,000 gallons of molasses result, which, when set up at a density of 1.063, will occupy about 42,000 gallons; so that a factory making 100 tons per week will make about 7,000 gallons of wash per day, and as at least 48 hours are required for fermentation, a minimum capacity of fermenting vats of 14,000 gallons are required; at least 25% in excess of this is desirable. In a working day of 15 to 16 hours a pot still will make six charges, and must therefore be capable of taking as its charge one-sixth of the wash set up in that time. The total capacity of the still vat should be at least twice its normal charge.

*Continuous Still, Coffey type.* In this type of still the wash is pumped through a pipe to a height of about 30 feet, and descends within the same pipe now arranged in a series of horizontal U bends, the pipe being enclosed in an upright vessel called the rectifier; leaving the rectifier, the wash is carried in a continuation of the same pipe to the top of a second upright vessel of similar size to the rectifier called the analyser, where it is discharged, and flows down a series of trays and empties itself at the bottom of this vessel; at the bottom of the analyser, steam at about 5 to 10 lbs. pressure is admitted, and passing upwards through perforations in the trays causes all the alcohol and some water to

vapourise; the alcohol and water vapours are carried off from the top of the analyser by a pipe called the vapour pipe to the bottom of the rectifier, whence the vapours pass upwards and outside the U bends of the wash pipe, and in doing so give up their heat to the cold wash descending and become condensed; in the lower portions of the rectifier are condensed the watery vapour, the fusel oils, and the small quantities of organic acids present; these constitute the hot feints, and, as they contain a proportion of spirit, are continually drawn off by a pump and lifted to the top of the analyser, where they mix with the wash and are re-distilled. In the upper portion of the rectifier the spirit proper collects on trays, and is carried off by a pipe to the refrigerator. The methyl alcohol and aldehydes do not condense in the rectifier, but are carried off by a pipe leading from the top of the rectifier, and called the cold feints pipe; they are stored till of sufficient quantity, mixed with lime, allowed to stand for 24 hours, then mixed with the wash and re-distilled; owing to their volatility they cannot be pumped directly to the top of the analyser.

In using these stills, neither more nor less wash than that for which the still was designed should be worked up, and the supply of steam and wash to each other should be carefully adjusted; too much steam results in the wash boiling over from the analyser into the rectifier, besides carrying over an undue proportion of watery vapour, increasing the quantity of hot feints, and giving a weak spirit; too little steam, on the other hand, imperfectly exhausts the wash. The proportions



of wash and steam may be regulated by the wash cock or steam cock, preferably by the former. The temperature at which the spirit is collected should be from  $140^{\circ}$  F. to  $160^{\circ}$  F., and only experience will show at what particular temperature the still will work best. The wash entering the analyser should be at a temperature of  $190^{\circ}$  F. to  $200^{\circ}$  F., the cold feints coming off at  $100^{\circ}$  F. to  $110^{\circ}$  F.; if the cold feints be collected at a temperature lower than this, methyl alcohol and aldehydes will remain in the spirit, with consequent deterioration to its quality.

*Distillation, Heat necessary for.* The latent heat of evaporation of alcohol is 457 B.T.U. per lb., and the specific heat is  $\cdot622$ ; the heat necessary to raise a mixture of alcohol and water to the boiling point, and to evaporate a proportion of alcohol and water, can then be obtained, and the dimensions of a still calculated from analogy to a steam boiler. The Coffey type of still, owing to its regenerative design, is more economical than older forms.

*Distillery, Miscellaneous data for.*

One pound glucose could at most give 1.269 pounds proof spirit, or  $\cdot1396$  gallon at  $84^{\circ}$  F.

One pound sugar could at most give 1.276 pounds proof spirit, or  $\cdot1414$  gallon at  $84^{\circ}$  F.

One gallon proof spirit at  $84^{\circ}$  F. could be made from 7.17 pounds glucose or 7.07 pounds cane sugar.

One pound cane sugar on inversion gives 1.0526 pounds glucose.

In general practice from 10 to 13 pounds glucose are required to make one gallon proof spirit.

Density of proof spirit at 84° F., .9091.

### DRAINAGE.

One inch of rain per acre is a little more than 100 tons water per acre; one inch falling in twenty-four hours is roughly 11.5 tons, or 2,600 gallons per acre per minute; taking the maximum rainfall as eight inches per twenty-four hours, the capacity of draining engines for an estate of 1,000 acres should be 100 tons, or 21,000 gallons per minute, so as to take off in twenty-four hours the maximum rainfall.

### DUTCH STANDARD.

Sugars are prepared yearly by certain firms in Holland, numbered from 6 to 20, and remain the standard for the U.S. Customs for that year; No. 6 is a dark, low-grade sugar, No. 20 almost white.

### ERHMANITE PROCESS.

The Erhmanite process consisted essentially of liming the raw juice to excess, and subsequently removing the lime by means of phosphoric acid.

### ESTIMATES.

The following figures are of recent date, and are intended to serve as a rough guide only in figuring out approximate cost of new plant; unskilled labour

earned from 1s. to 1s. 6d. per diem, artisans earning

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*Clarifiers and Defecators.* Seven cast iron clarifiers, without heating coils, each to hold 700 gallons, £550; four cast iron defecators, with copper steam coils, calendar, two way cocks, etc., each holding 800 gallons, £600. Erection of loft for above—labour, £110; materials, £320.

*Filter Press Plant.* Six presses, with plates, 24 in. square, 30 plates to a press. Presses with fittings, £492. Erection—labour, £10; materials, £25.

*Mill: Six Roller.* Rollers 36 in. × 72 in. Horizontal engines; stroke, 48 in.; diameter of cylinder, 24 in. Mill, engine, and gearing, £7,300. Erection, including excavation of foundations, etc.—labour, £580; materials,

In general practice from 10 to 13 pounds glucose are required

*[Substitute for the paragraph on p. 70.]*

## DRAINAGE.

One inch of rain per acre is a little more than 100 tons of water per acre; one inch of rain falling in twenty-four hours is roughly .07 ton per acre per minute; taking the maximum rainfall as eight inches per twenty-four hours, the capacity of draining-engines for an estate of 1000 acres should be 560 tons per minute, so as to take off in twenty-four hours the maximum rainfall.

Standard for the U.S. Customs for that year; No. 6 is a dark, low-grade sugar, No. 20 almost white.

## ERHMANITE PROCESS.

The Erhmanite process consisted essentially of liming the raw juice to excess, and subsequently removing the lime by means of phosphoric acid.

## ESTIMATES.

The following figures are of recent date, and are intended to serve as a rough guide only in figuring out approximate cost of new plant; unskilled labour

earned from 1s. to 1s. 6d. per diem, artisans earning from 2s. to 4s. per diem.

*Boiler Multitubular*, 10 ft.  $\times$  7 ft., 1,100 square feet heating surface, with mountings complete, £260. Erection—labour, £45; materials, £105.

*Boiler Stirling Water Tube*, 3,600 square feet heating surface, with mountings complete, £880. Erection—labour, £145; materials, £330.

*Centrifugal Plant*. Six 30 in. centrifugals and framing, £730; pug mill, £200; platform elevator, £180; dumping machine, £180; engine, £175; turn-table, belts, pulleys, etc., £60; waggons to hold one ton, £5 each. Erection—labour, £25; materials, £30.

*Chimney, Brick*, 152 ft.  $\times$  7 ft.  $\times$  7 ft. Materials, £1,800; labour, £500.

*Chimney, Iron*, 80 ft., 3 ft. 6 in. diameter, £270. Erection, £18.

*Clarifiers and Defecators*. Seven cast iron clarifiers, without heating coils, each to hold 700 gallons, £550; four cast iron defecators, with copper steam coils, calendar, two way cocks, etc., each holding 800 gallons, £600. Erection of loft for above—labour, £110; materials, £320.

*Filter Press Plant*. Six presses, with plates, 24 in. square, 30 plates to a press. Presses with fittings, £492. Erection—labour, £10; materials, £25.

*Mill: Six Roller*. Rollers 36 in.  $\times$  72 in. Horizontal engines; stroke, 48 in.; diameter of cylinder, 24 in. Mill, engine, and gearing, £7,300. Erection, including excavation of foundations, etc.—labour, £580; materials,

£1030. Mill house for above—labour, £220; materials, £490.

*Triple effect.* Standard type; 4,000 square feet heating surface; triple, £2,800. Pump, 24 in. stroke; diameter of air cylinder, 30 in.; £630. Erection—labour, £170; materials, £70.

*Still: Coffey.* To take 1,000 gallons of wash per hour. Still, complete, with wash and feint pumps, £1,700. Erection, including still house—labour, £105; materials, £290.

*Vacuum Pan.* Cast iron body, 9 ft. inside diameter, 12 ft. deep, holding 390 cubic feet green sugar. Pan, with fittings, condenser, etc., £1,180. Pump, 24 in. stroke; air cylinder, 26 in. diameter, £540. Erection—labour, £88; materials, £45.

## EVAPORATION.

The earliest improvement on evaporation over open fires was the introduction of steam-heated pans, followed by the Wetzels, Aspinalls, and other similar devices; all these consisted essentially of an open pan containing the liquid under evaporation, in which revolved steam-heated coils or discs, so arranged that half the coil or disc was immersed in the liquid; the effect of this was to expose a large surface to evaporation. Box ("Treatise on Heat") states that the evaporation of 1 lb. water from, and at 212° F., with external air at 52° F., requires 1186 B.T.U., 4.32 lbs. water being evaporated per square foot heating surface, the loss in radiation being 60 B.T.U. The air carrying off 160 B.T.U. per lb. water evaporated.

In 1865 Fryer introduced the concretor ; in this the thin juice flows over a series of trays placed over a flue, the whole being built on a slight incline. The flue is about 40 ft. long, and the juice traverses a distance in a zigzag path of about 200 ft. ; reaching the end at about a density of 25 Beaumé, it flows into a revolving cylindrical vessel, in the interior of which are fitted scroll-shaped plates, so that as the cylinder revolves a large surface is exposed to evaporation ; at the same time a current of hot air is blown through ; after twenty minutes' treatment in the cylinder, the thickened juice sets quite solid on cooling, and is ready for shipment to refineries. This process has been largely used, and is still to some extent in use.

Evaporation is now nearly always performed in multiple evaporators ; these depend on the phenomenon that the boiling point of a liquid falls, as the pressure under which ebullition occurs falls, and that the vapour coming off at a certain temperature, when condensed at a lower temperature, parts with a portion of the heat it contains (latent heat) ; all multiple effect apparatuses consist of a series of vessels, so arranged that the pressure in each vessel successively falls, so that vapour passing from one vessel to the next is capable of giving up a certain amount of heat and causing liquid contained in that vessel to boil. Each vessel of a multiple effect consists of two portions : a steam chamber called the calandria, and the main body of the vessel containing the liquid under evaporation ; the calandria of each vessel is connected by a steam pipe with the main body of the immediately preceding vessel, so that vapour

arising from the liquid boiling in the latter passes into the calandria of the former. The differences in pressure in the different bodies is effected by connecting the last body to a vacuum pump, creating a high vacuum in that vessel, so that the liquid there contained will boil at a low temperature; the calandria of this vessel acts as a surface condenser to vapour coming off from the vessel connected to it, creating a partial vacuum in that vessel; to the calandria of the vessel first in series, live steam at about 5 to 10 lbs. pressure per square inch is admitted, this supplying the source of steam.

Multiple effect apparatuses fall into two classes: those conforming to the original design of Rillieux, referred to as the "Standard," and the film evaporators such as those of Yaryan and Lillie. The "Standard" consists of two, three, or four vertical cylindrical vessels, in each of which are placed two tube plates, one near the middle and one near the bottom. The space between these tube plates forms the calandria into which steam or vapour is admitted, the liquid itself being contained within the tubes and above and below the tube plates. The liquid passes from one vessel to the next under the influence of different pressures, the circulation being generally aided by a small pump; the concentrated liquid is removed from the last vessel by a tail pump, conveniently worked off the main vacuum pump. The water of condensation in the calandrias frequently circulates from calandria to calandria, being drawn off the last body by a pump and used for feeding the boilers; owing, however, to the water of condensation containing ammoniacal bodies and small traces of



sugar, carried over in entrainment, this water is apt to corrode the boilers ; and in many houses it is customary to so use only the water of condensation from the first body.

The objections to the "Standard" type, which it is the object of the film evaporators to overcome, are the excessive weight of the apparatus, and the large body of liquid under concentration at one time, entailing consequent long exposure to a high temperature. In the Yaryan effect the liquor is pumped with great velocity through a number of tubes, outside of which is the heating surface ; in its passage through these it is partly converted to vapour ; emerging from the tubes the partly concentrated liquor impinges with great velocity upon a baffle plate, being converted by the impact into minute spray exposing a large surface to evaporation, and helping the disentanglement of the vapour. The process is then repeated in a second vessel, and so on ; the time during which the liquid is under treatment is about four or five minutes ; the rapid movement is said to prevent scaling, and it is claimed that the economical use of a large number of effects is possible with this form than with any other system.

The Lillie evaporator differs from any other, in that the liquid under evaporation circulates on the exterior of the tubes forming the calandria, the steam being contained in the interior of the tubes. The apparatus consists essentially of three or four horizontal cylindrical bodies, each body containing a number of horizontal tubes set in tube plates, the plates being near either

end of the body; steam is admitted to the interior of the tubes, the liquid under evaporation entering at the top of the vessel, and flowing downwards over the tubes in a fine shower. Circulation of the liquid is effected by means of centrifugal pumps, these being of sufficient power to carry the concentrated liquid out against atmospheric pressure; the apparatus is so constructed that the order in which the vessels are worked may be reversed; this feature is stated to be very useful in equalising the deposit of scale. A very important point in connection with this apparatus is that it is capable of enlargement, up to 100 %, so as to meet an increased output.

In the "Standard" type of evaporators it is very usual for makers to increase the heating surface from vessel to vessel, very often in the ratio of 4 : 5 : 6 : both Horsin Déon and Jelinek condemn this practice, and show that the most economical results are obtained when each vessel does an equal amount of evaporation, when the difference of temperatures are the same between the successive bodies, and the heating surfaces are practically the same in each body.

In general, the evaporation per square foot in a single effect is about 12 lbs. water per hour, in a double 8, in a triple 6, and in a quadruple 4. The evaporation of 6 lbs. of water is approximately equivalent to the concentration of one gallon of juice from 10° to 25° Beaumé, so that a triple must have as many square feet heating surface as there are gallons of juice per hour. The evaporation per lb. of steam supplied in a single effect will lie between .85 and .90 lb., in a double effect from

1·85 to 1·95, in a triple effect from 2·70 to 2·85, in a quadruple from 3·60 to 3·80, always assuming that the heating surface is clean.

To obtain good results in working a multiple evaporator, it must be fed regularly, the liquid must not rise above the surface of the tube plates, the tubes must be kept clean and free from scale, and the condensed steam regularly drawn off. Owing to the hardness of the scale, difficulty is often experienced in its removal; the scale may be softened by boiling with at 10% to 20% solution of hydrochloric acid, or where the scale chiefly consists of silica, by a 10% solution of caustic soda; when acid has been used to soften the scale, a light must not be brought near the apparatus until it has been open for a considerable time, as, due to the action of the acid on the metal, hydrogen gas is evolved which, on mixture with air, forms a violently explosive combination. The chief points in connection with the design of multiple evaporators are:—

1. *Rapid circulation of the liquid under treatment.*

The more quickly this takes place the greater is the passage of heat from the heating vapour to the evaporating liquid, so that the evaporation per square foot of heating surface is increased. Horsin Déon estimates that, with clean heating surfaces of brass 1 mm. thick, per 1° C. difference of temperature and per 1 square metre, 3 kilograms of vapour are condensed per hour with the best practice; this, reduced to English measures, gives a condensation of ·25 lb. per square foot, per hour, per 1° F. difference of temperature, with brass heating surface  $\frac{1}{8}$  in. thick.

2. *Size of vapour pipes.* Horsin Déon says that the velocity should not be more than 30 metres, or, say 90 feet per second. When the volume of vapour given off from a body is known the area of the pipe can be calculated.

3. *Size of juice pipes.* Following Horsin Déon, the velocity of the juice should not exceed 3 metres, or about 9 ft. per second.

4. *Injection water.* Jelinek gives the quantity of injection water as from 20 to 40 times the quantity of vapour to be condensed; but this is with regard to European practice, where the temperature of the condensed water lies between 32° F. and 70° F.; in the tropics, where the injection water is at a temperature of 80° F. to 85° F., at least 50 times as much water must be used as there is vapour to be condensed.

5. *Condenser.* Jelinek, commenting on condensers, states that often they are too small, and recommends that their volume should be from 1.5 to 2 times the volume of the air pump; as the efficiency of a multiple effect depends very largely on the vacuum in the last vessel, this point is of great importance.

In papers dealing with multiple evaporators, most writers assume that the fall in temperature from vessel to vessel is the same, and base their calculations on this assumption; observations of a multiple effect actually working show that the differences are irregular, and up to the present no explanation of this phenomenon has been given; the nearer the differences in temperature approach equality the more efficient will the apparatus be. In general, a

difference in temperature from body to body of 15° C. or 25° F. gives good results. Taking the temperature of the last body as 140° F., this difference would, in a triple, give the temperature of the first body as 190° F., and in a quadruple as 215° F. necessity boiling under pressure; it is this high temperature boiling that makes many authorities prefer triple to quadruple evaporation.

In the table below is given a comparison of the heat required for the evaporation, up to first massecuite of the juice resulting from different types of canes and extractions. The specific heat of the solids have been taken as of sugar (= .301); to raise one ton of water to 212° F. from 84° F., 300,000 B.T.U. are assumed necessary; to evaporate in open vessels, 2,700,000 B.T.U. per ton; in a triple, 815,000 B.T.U. per ton; in a quadruple, 640,000 B.T.U. per ton; and in the pans, 2,500,000 B.T.U. per ton of water removed.

For more detailed information, Horsin Déon's or Jelinek's treatises should be consulted; those parts of these works dealing with evaporation are incorporated in Foster's "Evaporation on the Multiple System."

Analyses of the scale from a triple, by H. Pellet, are appended:—

	First Body.	Second Body.	Third Body.
Water and Organic Matter	29.80	26.70	18.60
Silica.. .. .	0.40	23.40	69.80
Iron and Illumina.. ..	3.80	9.98	2.80
Lime .. .. .	46.30	25.80	0.80
Magnesia .. .. .	1.36	0.81	1.08
Phosphoric Acid .. ..	17.10	11.70	Trace
Sulphuric Acid .. ..	0.00	0.00	Trace
Copper .. .. .	Trace	Trace	Trace
Undetermined .. ..	1.24	1.61	0.92

TABLE GIVING THE UNITS OF HEAT REQUIRED FOR EVAPORATION  
 TO MASSECUTE I. OF THE JUICE RESULTING FROM 100 TONS  
 OF CANE UNDER VARIOUS TREATMENTS.

TYPE OF EXTRACTION.	CANES.			JUICE WORKED UP.				To raise juice to 212° F. from 84° F. B.T.U. × 10 <sup>6</sup> .	To concentrate through 1.5° open pans. B.T.U. × 10 <sup>6</sup> .	To concentrate to 55° Brix in triple, after cleaning juice in open pans. B.T.U. × 10 <sup>6</sup> .	To concentrate to 55° Brix in quadruple, after cleaning juice in open pans. B.T.U. × 10 <sup>6</sup> .	To concentrate to 55° Brix in triple, without cleaning juice in open pans. B.T.U. × 10 <sup>6</sup> .	To concentrate to 55° Brix in quadruple, without cleaning in open pans. B.T.U. × 10 <sup>6</sup> .	To concentrate syrup to Masseccule at 96° Brix. B.T.U. × 10 <sup>6</sup> .	Total for triple concentration and cleaning in open pans. B.T.U. × 10 <sup>6</sup> .	Total for quadruple concentration and no cleaning in open pans. B.T.U. × 10 <sup>6</sup> .
	Sugar %.	Water %.	Fibre %.	Tons.	Solids.	Water.	Degree Brix.									
Single Crushing	12	72	13	62	11.0	51.0	17.7	16.3	14.3	29.9	23.5	34.3	26.9	21.0	81.6	64.2
	15	70.5	12	63	12.8	50.2	20.3	16.2	12.7	28.5	22.4	32.4	25.4	24.5	81.9	66.1
	18	69	11	64	14.6	49.4	22.8	16.1	11.3	27.1	21.3	30.5	23.7	28.0	82.5	67.8
Dry Double Crushing	12	72	13	70	12.3	57.7	17.7	18.4	15.9	34.0	26.7	38.8	30.5	23.7	92.0	72.6
	15	70.5	12	71	14.4	56.6	20.3	18.3	14.3	32.2	25.3	36.5	28.7	27.5	92.3	74.5
	18	69	11	72	16.4	55.6	22.8	18.2	12.9	30.5	23.9	35.1	26.9	31.5	93.1	76.6
Double Crushing with 10% dilution	12	72	13	79.3	12.9	66.4	16.2	21.1	19.7	39.8	31.1	45.6	35.8	24.5	104.1	81.4
	15	70.5	12	80.5	15.1	65.4	18.7	21.0	17.3	38.2	29.9	43.0	34.0	28.7	105.2	83.7
	18	69	11	81.6	17.2	64.4	21.1	20.9	16.1	36.4	28.5	41.1	32.3	32.7	106.1	85.9
Treble Crushing with 20% dilution	12	72	13	89.1	14.0	75.1	15.7	23.8	22.9	44.9	35.3	51.9	40.8	26.5	117.9	91.3
	15	70.5	12	90.5	16.3	74.2	18.0	23.7	20.5	42.7	34.2	49.6	39.0	31.0	118.5	93.7
	18	69	11	92.0	18.6	73.4	20.2	23.7	18.4	41.7	32.9	47.4	37.3	35.5	119.3	96.2

TABLE GIVING THE TEMPERATURE OF STEAM AT PRESSURES LESS THAN ONE ATMOSPHERE (=29.92 INCHES OF MERCURY).

Pressure in inches of Mercury.	Inches of Vacuum.	Temperature of Steam, F°.	Pressure in inches of Mercury.	Inches of Vacuum.	Temperature of Steam, F°.
29.9	0.0	212°	10.8	19.1	165°
26.0	3.9	205°	9.6	20.3	160°
23.5	6.4	200°	8.5	21.4	155°
21.1	8.8	195°	7.5	22.4	150°
19.0	10.9	190°	6.7	23.2	145°
17.1	12.8	185°	5.9	24.0	140°
15.3	14.6	180°	5.1	24.8	135°
13.7	15.2	175°	4.5	25.4	130°
12.2	17.7	170°	3.9	26.0	125°

TABLE GIVING DATA CONCERNING TRIPLE EFFECTS.

(STEWART.)

Capacity in Litres.	Capacity in Gallons.	Heating Surface Square Metres.	Heating Surface Square feet.	Air Pump. Bore: inches.	Air Pump. Stroke: inches
100,000	22,000	100	1,076	15 $\frac{3}{8}$	24
125,000	27,500	125	1,346	17 $\frac{1}{2}$	24
150,000	33,000	150	1,615	15 $\frac{7}{8}$	26
175,000	38,500	175	1,884	20 $\frac{3}{8}$	26
200,000	44,000	200	2,153	21 $\frac{3}{4}$	26
225,000	49,500	225	2,422	23	30
250,000	55,000	250	2,691	23 $\frac{3}{4}$	30
275,000	60,500	275	2,960	24 $\frac{1}{2}$	30
300,000	66,500	300	3,229	25 $\frac{1}{2}$	36
325,000	71,500	325	3,498	26 $\frac{5}{8}$	36
350,000	77,000	350	3,768	27 $\frac{5}{8}$	36
375,000	82,500	375	4,037	28 $\frac{1}{2}$	36
400,000	88,000	400	4,300	29 $\frac{1}{2}$	36
425,000	93,500	425	4,575	30 $\frac{3}{8}$	42
450,000	99,000	450	4,846	31 $\frac{1}{2}$	42
475,000	104,000	475	5,113	32 $\frac{1}{8}$	42
500,000	110,000	500	5,382	33	42

TABLE GIVING THE PERCENTAGES BY WEIGHT, PER CENT ON ORIGINAL JUICE EVAPORATED BETWEEN DIFFERENT DEGREES BRIX OR BEAUMÉ.

Final Density : Degrees Brix.	INITIAL DENSITY : DEGREES BRIX IN UPPER, DEGREES BEAUMÉ IN LOWER LINE.															25 14.1
	10 5.7	11 6.2	12 6.8	13 7.4	14 7.9	15 8.5	16 9.0	17 9.6	18 10.1	19 10.7	20 11.3	21 11.8	22 12.4	23 13.0	24 13.5	
35	71.43	68.57	65.71	62.86	60.00	57.14	54.29	51.43	48.57	45.71	42.86	40.00	37.15	34.29	31.43	28.57
36	72.33	69.45	66.68	63.90	61.11	58.33	55.56	52.78	50.00	47.23	44.45	41.67	38.90	36.12	33.34	30.56
37	73.00	70.27	67.57	64.86	62.16	59.46	56.75	54.05	51.35	48.65	45.95	43.23	40.53	37.83	35.13	32.42
38	73.70	71.07	68.44	65.81	63.17	60.52	57.89	55.26	52.63	50.00	47.37	44.74	42.11	39.48	36.85	34.22
39	74.36	71.79	69.23	66.66	64.10	61.54	58.97	56.41	53.81	51.28	48.72	46.16	43.60	41.08	38.47	35.90
40	75.00	72.50	70.00	67.50	65.00	62.50	60.00	57.50	55.00	52.50	50.00	47.50	45.00	42.50	40.00	37.50
41	75.61	73.17	70.73	68.29	65.84	63.41	60.97	58.53	56.09	53.66	51.22	48.78	46.34	43.90	41.46	39.02
42	76.19	73.81	71.43	69.06	66.67	64.29	61.91	59.53	57.17	54.76	52.38	50.00	47.62	45.24	42.86	40.48
43	76.74	74.42	72.09	69.76	67.44	65.12	62.79	60.46	58.14	55.81	53.48	51.16	48.84	46.51	44.19	41.86
44	77.35	75.08	73.80	71.53	68.25	65.98	63.70	61.43	59.15	56.88	54.60	52.32	50.05	47.78	45.50	43.13
45	77.78	75.55	73.83	71.11	68.89	66.67	64.44	62.22	60.00	57.89	55.55	53.33	51.11	48.89	46.67	44.44
46	78.26	76.08	73.92	71.74	69.57	67.39	65.22	63.04	60.94	58.77	56.52	54.35	52.17	50.00	47.83	45.64
47	78.72	76.59	74.47	72.34	70.21	68.09	65.96	63.83	61.70	59.57	57.44	55.32	53.19	51.06	48.93	46.81
48	79.17	77.08	75.00	72.92	70.83	68.75	66.67	64.58	62.50	60.42	58.33	56.25	54.17	52.08	50.00	47.92
49	79.59	77.55	75.56	73.47	71.43	69.32	67.35	65.30	63.26	61.22	59.18	57.15	55.11	53.07	51.02	48.98
50	80.00	78.00	76.00	74.00	72.00	70.00	68.00	66.00	64.00	62.00	60.00	58.00	56.00	54.00	52.00	50.00
51	80.39	78.43	76.47	74.51	72.55	70.59	68.62	66.66	64.70	62.75	60.78	58.82	56.86	54.90	52.94	50.98
52	80.77	78.84	76.92	75.00	73.07	71.15	69.23	67.31	65.38	63.46	61.54	59.61	57.69	55.77	53.85	51.92
53	81.13	79.26	77.36	75.46	73.58	71.61	69.81	67.92	66.03	64.15	62.25	60.37	58.49	56.60	54.71	52.83
54	81.49	79.64	77.78	75.93	74.08	72.23	70.38	68.52	66.67	64.82	62.97	61.12	59.26	57.41	55.56	53.71
55	81.82	80.00	78.18	76.36	74.54	72.72	70.91	69.09	67.27	65.45	63.63	61.81	59.99	58.18	56.36	54.54
56	82.14	80.36	78.57	76.79	75.00	73.21	71.43	69.64	67.86	66.07	64.29	62.50	60.71	58.93	57.14	55.36
57	82.45	80.70	78.95	77.19	75.43	73.68	71.93	70.17	68.42	66.66	64.91	63.13	61.38	59.63	57.88	56.13
58	82.75	81.03	79.30	77.58	75.86	74.13	72.41	70.68	68.96	67.24	65.51	63.79	62.06	60.34	58.62	56.89
59	83.04	81.35	79.66	77.97	76.27	74.58	72.88	71.18	69.49	67.80	66.10	64.41	62.72	61.02	59.32	57.63
60	83.33	81.67	80.00	78.33	76.67	75.00	73.33	71.67	70.00	68.33	66.67	65.00	63.33	61.67	60.00	58.33

PER CENTS. BY WEIGHT ON ORIGINAL WEIGHT, EVAPORATED BETWEEN THE DENSITIES.



## FERMENTATION.

(See also *Distillery*.)

In many books dealing with the manufacture of sugar, fermentation processes are briefly grouped under four heads—alcoholic fermentation, acetous fermentation, viscous fermentation, and putrid fermentation; in general, fermentation may be defined as any process taking place under the influence of micro-organisms. In addition to the alcoholic fermentation, the change of most interest to the sugar maker is the *acetic* fermentation; cane juice, if exposed to the air, rapidly turns sour, due to the formation of acetic acid; with rapid working this fermentation should never occur, but if cane juice be allowed to settle in the crevices of the mill, etc., acetic fermentation arises and seriously corrodes the iron work; this can easily be avoided by systematically washing the mill with thin milk of lime; neglect of this precaution has, in the writer's experience, led to the fracture of the gudgeon of a roller; the rusting of the shells of the centrifugals is also due to this cause.

The viscous fermentation is occasioned chiefly by an organism, *Leuconostoc Mesenterioides*. This bacterium occurs in all tropical countries, and finds a suitable habitat in molasses and after-massecuite products, which it converts into a slimy mucinous mass with large loss of sugar; this organism has also been identified as the cause of choking of pipes, blocking the passage with gelatinous masses; the remedy is disinfection with a one per cent. solution of ammonium fluoride, if there is reason to suppose the massecuities

are seriously infected. Herzfeld and Pultow, working on beet molasses, recommend the same remedy.

Occasionally a spontaneous combustion of molasses occurs, which may be due to heat developed by bacterial agency. Crawley ("Jour. Amer. Chem. Soc." XIX. 238), mentions such a case occurring in Hawaii.

The foaming of massecuites stored in tanks has often been ascribed to the escape of the decomposition products of bacteria; others, however, think it due to the spontaneous decomposition of the glucinic acid, formed by the action of lime on glucose.

### FILTER PRESSES.

The loss of sugar in the old Taylor bag filters amounts to as much as two or three per cent. of the juice, a loss reduced to one half to one per cent. with presses of modern construction; with bag filters the scums weigh from three to four per cent. on the juice, and contain from sixty to sixty-five per cent. water, and from ten to twelve per cent. of sugar; with good presses the weight of scums per cent. on juice is from one-and-a-half to two per cent., the percentage of water lying between forty and fifty, that of sugar between three and eight.

When making high-class sugars it is unadvisable to wash the scums too far, the last washings being very dark coloured. When rum fetches a good price, it is often economical to send the skimmings to the distillery, as these materially assist the fermentation. Sometimes the scums are very slimy and resist filtration; in such cases the use of more lime in the

clarification will often remedy this defect, or where it is inadvisable to use more lime, the addition of oxalic acid to the scums followed by a second application of lime, producing a precipitate of calcium oxalate which, mixing with the scums and reducing their "sliminess," will be found beneficial.

TABLE OF FILTERING AREAS REQUIRED.

Tons of Cane per Hour.	Filtering Area: Square feet.	Tons of Cane per Hour.	Filtering Area: Square feet.
3	125—150	40	800—1,000
6	200—250	50	1,000—1,300
9	300—350	60	1,200—1,500
12	400—475	70	1,400—1,700
15	500—575	80	1,500—1,900
20	650—800	90	1,700—2,100
25	700—850	100	2,000—2,500
30	750—900		

TABLE OF THE DIMENSIONS, ETC., OF FILTER PRESSES.

Size of Plates in inches..	21 × 21	21 × 21	21 × 21	24 × 24	24 × 24	24 × 24
Number of Plates ..	20	25	30	20	25	30
Effective Filtering Area: } square feet	70	90	105	105	130	160
Capacity of Press in } Gallons	18·5	23	28	27·5	34·5	41·5
Space required for each } Press: feet	11 × 3·5	13 × 3·5	15 × 3·5	11 × 4	13 × 4	16 × 4

Size of Plates in inches..	27 × 27	27 × 27	27 × 27	30 × 30	30 × 30	30 × 30
Number of Plates ..	20	25	30	20	25	30
Effective Filtering Area: } square feet	125	150	185	155	190	230
Capacity of Press in } Gallons	32	40	48	40	50	60
Space required for each } Press: feet	12 × 4·5	14 × 4·5	16 × 4·5	12 × 5	14 × 5	17 × 5

## FILTER PRESS CAKE, ANALYSIS OF.

*Water.* Dry about .25 gram to constant weight in platinum capsule.

*Sugar.* Weigh out about 20 grams, heat to a thick cream and transfer to a 100 c.c. flask; add a few drops acetate of lead, filter and polarise in as long a tube as possible; if no allowance be made for the volume of insoluble matter, the reading will be too high. The amount of water actually present may be obtained by measuring from a burette the water required to make up to 100 c.c. in addition to that already present in the cake. In sugar house work this correction may be determined once and for all from a series of experiments, provided that the cake shows no large variation; 20 grams of good, well-pressed cake give insoluble matter rather under 5 c.c. in volume.

If saccharates are present in the cake, these must be decomposed either by a passage of a current of carbon dioxide as recommended by Stammer, or by the addition of acetic acid to faint acidity as recommended by Sidersky. Saccharates need only be looked for when large quantities of lime are used in clarification, as in the carbonatation process.

*Glucose.* The glucose is so small that its determination is usually attended with inconvenience; where this quantity is required it is better to determine the total glucose after inversion, and to calculate the glucose originally present from the polarisation.

FILTER PRESS CAKE, COMPOSITION OF.  
(PRINSEN GEERLIGS.)

	Defecation Process.	Single Carbonatation.	Double Carbonatation: First Saturation.	Double Carbonatation: Second Saturation.
Water .. ..	69·72			
Sugar .. ..	10·20	3·90	10·10	8·10
Glucose .. ..	·71		·38	
Wax .. ..	4·12	3·43	2·48	
Albumen .. ..	1·80	2·55	2·72	
Fibre .. ..		3·08	6·10	·50
Organic Acids .. ..		1·94	2·12	4·20
Gums .. ..		1·11	1·20	
Phosphate of Lime..	2·92			
Silica .. ..	·37	8·48	1·85	·64
Iron and Alumina ..	1·40	2·41	4·66	·51
Magnesia .. ..	·22			·10
Sand and Clay .. ..	2·82	2·48	4·37	
Calcium Carbonate..		67·94	61·94	85·01
Magnesian Carbonate		1·80	1·21	
Phosphoric Acid ..		·71	·87	·12
Undetermined .. ..	5·35	·17		·82

### FLUE GASES.

(See also *Boiler Trial*.)

In the analysis of flue gases the following solutions are required:—

1. Caustic potash of density 60° Brix, for carbon dioxide.

2. 25 grams pyrogallol dissolved in 50 c.c. hot water, and mixed with 100 c.c. caustic potash of density 50° Brix, for oxygen.

3. Cuprous chloride in hydrochloric acid. Dissolve 35 grams cupric chloride in 200 c.c. hydrochloric acid of specific gravity 1·20, add a quantity of copper turnings or foil and preserve in a stoppered bottle for 48 hours, with occasional shaking; then add 120 c.c. of water, for carbon monoxide.

The flue gases are most conveniently collected by a

double syphon aspirator, consisting of two Winchester quart bottles connected by tubing, so that by raising or lowering either the water level in the other may be raised or lowered, either expelling air or sucking in flue gases. The gases are best collected over a layer of oil; in collecting the gases, care must be taken to draw out the air from the pipe leading into the flue, before samples are taken for analysis. In factories where the flue gas analysis forms a regular part of the routine, it is convenient to lead a pipe from the flue to the laboratory, and to use a form of Orsat's apparatus; but where these analyses are only occasionally made, the less expensive Hempel bulbs are sufficient. Various types of instruments for rapid work are obtainable from dealers, and these will be found convenient where expedition is more desirable than accuracy.

## FUEL.

Substance.	Comparative Value.	Substance.	Comparative Value.
Irish Anthracite ..	1·088	Petroleum .. ..	·555
Patent Fuel .. ..	1·016	Dried Peat .. ..	·500
Welsh Coal .. ..	1·000	Oak .. .. ..	·500
Coke .. .. ..	·995	Sun-dried Megass ..	·333
Newcastle Coal ..	·885	Cotton Stalks .. ..	·333
French Coal .. ..	·884	Straw .. .. ..	·283
Lancashire Coal ..	·877	Pine .. .. ..	·276
Yorkshire Coal ..	·837	Wet Megass .. ..	·180
Lignite .. .. ..	·736		

The value of a fuel may be calculated from Welter's rule:—The heat of combustion of an organic compound is the sum of the heats of combustion of its constituents, after removing so much hydrogen as will go to form

water; *e.g.*, the composition of glucose is Carbon 40.0%, Hydrogen 6.7%, Oxygen 53.3%. The heat of combustion of 1 lb. of carbon is 14,500 B.T.U., and of 1 lb. of hydrogen, 62,535; in glucose, the hydrogen and oxygen being present in the proportions necessary to form water, no heat is allowed for the hydrogen, so that the combustion of 1 lb. of glucose gives  $14500 \times .4$  B.T.U. = 5800 B.T.U.; by direct experiment, Stohmann gives this figure as 5427 B.T.U. The air required for the combustion of 1 lb. of carbon is 12.03 lbs., equal to 165 cubic feet of air at 84° F.

### GLUCOSE.

Glucose is otherwise known as dextrose, grape sugar, glycose, and occurs in nearly all vegetable juices; specific gravity, 1.386; specific rotation,  $[\alpha]_D = +52.7$ ,  $[\alpha]_J = +58.6$ ; composition,  $CH_2OH [CHOH]_4 CHO$ : Carbon, 40.0%; Hydrogen, 6.67%; Oxygen, 53.33%; Molecular Weight, 180. It is prepared by dissolving 350 grams pure cane sugar in 1000 c.c. of 90% alcohol mixed with 40 c.c. strong hydrochloric acid. The solution is kept at 50° C. for two hours, allowed to cool, and crystallisation promoted by stirring or by adding a crystal of glucose; after two days the crystals are collected and purified by repeated crystallisations from 80% alcohol. With lime, baryta, and strontia, glucose forms salt-like bodies called glucosates, which are decomposed by carbon dioxide; with certain salts glucose forms molecular compounds of great interest in the formation of molasses (*q.v.*). The body or bodies occurring in the sugar cane and returned in analysis as

glucose is *not* the body described above, but in all probability consists of varying proportions of dextrose (or glucose proper) and levulose; in sound, ripe canes probably no levulose is present, but in damaged canes and in after products this body appears as a result of inversion. Earlier investigators stated the "glucose" to be inactive; but Wehne, Herzfeld and Geerligs state that its rotatory power is either positive, negative, or vanishing, dependent on the varying quantities of dextrose and levulose.

### GLUCOSE, DETERMINATION OF.

Solutions of a cupric salt in alkaline solution, when warmed with glucose, are reduced; approximately, five molecules of cupric salt are reduced by one molecule of glucose; so that .34645 gram crystallised copper sulphate ( $CUSO_4 \cdot 5H_2O$ ) are reduced by .05 gram glucose. The methods in use are either gravimetric or volumetric, and to be comparable must always be conducted under the same conditions; as regards concentration of both glucose and copper solutions, the reducing power of glucose varying slightly under different conditions.

(a) *Direct Gravimetric Methods.* Solutions required: 34.639 grams copper sulphate in 500 c.c. water; 173 grams sodium potassium tartrate, and 100 c.c. caustic soda solution 40% by volume in 500 c.c.

With materials containing 1% or less of glucose, in the presence of a large excess of sugar, dissolve 20 grams in water, add lead acetate, precipitate the excess of



lead by sodium sulphate or carbonate, make up to 100 c.c. and filter; mix 25 c.c. of each of the solutions given above, add 50 c.c. of the solution under analysis, and boil for two minutes; the precipitated cuprous oxide may be collected on a tared asbestos filter, and dried at a gentle heat in a current of hydrogen until it is completely reduced to metallic copper, or it may be collected in a Gooch filter, dissolved in nitric acid, and determined electrolytically. Instead of weighing the reduced copper, it may be determined volumetrically; in Sidersky's methods, the reduced copper after washing is dissolved in 25 c.c. normal sulphuric acid, with the addition of a few crystals of potassium chlorate, and the excess of acid determined by titration with half normal ammonia; in the presence of free ammonia the copper solution becomes deep blue, being faint green before the ammonia is in excess. The usual methods for the determination of copper as the permanganate process, or Haen's iodometric method, are applicable.

Reigler recommends Haen's iodometric process to be applied to determine the excess of cupric salt remaining unreduced. The percentage of glucose, whichever method is used to determine the weight of copper, is obtained from Herzfeld's table (*q.v.*).

When more than 1% of glucose is present, 20 grams are made up as before to 100 c.c., and the approximate percentage of glucose determined by a preliminary experiment, and the solution diluted until not more than .2 gram glucose are present in 100 c.c.; the determination is then made as above, Meissl and Hiller's table being used:—

HERZFELD'S TABLE FOR INVERT SUGAR  
IN MATERIALS CONTAINING LESS  
THAN ONE PER CENT.

Copper reduced by 10 grams of material.	Invert Sugar.	Copper reduced by 10 grams of material.	Invert Sugar.	Copper reduced by 10 grams of material.	Invert Sugar.
MILLIGRAMS.	PER CENT.	MILLIGRAMS.	PER CENT.	MILLIGRAMS.	PER CENT.
50	·05	120	·40	185	·76
55	·07	125	·43	190	·79
60	·09	130	·45	195	·82
65	·11	135	·48	200	·85
70	·14	140	·51	205	·88
75	·16	145	·53	210	·90
80	·19	150	·56	215	·93
85	·21	155	·59	220	·96
90	·24	160	·62	225	·99
95	·27	165	·65	230	1·02
100	·30	170	·68	235	1·05
105	·32	175	·71	240	1·07
110	·35	180	·74	245	1·10
115	·38				

MEISSL & HILLER'S TABLE FOR INVERT  
SUGAR IN MATERIALS CONTAINING  
MORE THAN ONE PER CENT.

Ratio of Sucrose to Invert Sugar = R : I.	Approximate Absolute Weight of Invert Sugar = Z.						
	200 Mgrs.	175 Mgrs.	150 Mgrs.	125 Mgrs.	100 Mgrs.	75 Mgrs.	50 Mgrs.
	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT	PER CENT
0 : 100	56·4	55·4	54·5	53·8	53·2	53·0	53 0
10 : 90	56·3	55·3	54·4	53·8	53·2	52·9	52·9
20 : 80	56·2	55·2	54·3	53·7	53·2	52·7	52·7
30 : 70	56·1	55·1	54·2	53·7	53·2	52·6	52·6
40 : 60	55·9	55·0	54·1	53·6	53·1	52·5	52·4
50 : 50	55·7	54·9	54·0	53·5	53·1	52·3	52·2
60 : 40	55·6	54·7	53·8	53·2	52·8	52·1	51·9
70 : 30	55·5	54·5	53·5	52·9	52·5	51·9	51·6
80 : 20	55·4	54·3	53·3	52·7	52·2	51·7	51·3
90 : 10	54·6	53·6	53·1	52·6	52·1	51·6	51·2
100 : 9	54·1	53·6	52·6	52·1	51·6	51·2	50·7
92 : 8	53·6	53·1	52·1	51·6	51·2	50·7	50·3
93 : 7	53·6	53·1	52·1	51·2	50·7	50·3	49·8
94 : 6	53·6	52·6	51·6	50·7	50·3	49·8	48·9
95 : 5	52·6	52·1	51·2	50·3	49·4	48·9	48·5
96 : 4	52·1	51·2	50·7	49·8	48·9	47·7	46·9
97 : 3	50·7	50·3	49·8	48·9	47·7	46·2	45·1
98 : 2	49·9	48·9	48·5	47·3	45·8	43·3	40·0
99 : 1	47·7	47·7	46·5	45·1	43·3	41·2	38·1

Let  $C$  = weight of copper obtained,  $P$  = polarisation of the sample,  $W$  = weight of material in the 50 c.c. used in the analysis,  $F$  = the factor obtained from the table for the conversion of copper to invert sugar,  $\frac{C}{2}$  = approximate absolute weight of invert sugar =  $Z$ ,  $\frac{Z \times 100}{W}$  = approximate percentage of invert sugar =  $y$ ,  $\frac{100P}{P+y}$  =  $R$  relative number for sucrose,  $100 - R = I$  relative number for invert sugar =  $w$ ,  $\frac{C \cdot F}{W}$  = percentage of invert sugar.

The factor  $F$  used in the calculation is obtained from where the vertical column  $Z$  meets the horizontal column  $R : I$ . Example :—Approximate weight of invert sugar = 129 mgrms., and  $R : I = 96.3 : 4.2$ . The nearest values in the table to these are  $Z = 125$ ,  $R : I = 96 : 4$ ; where these meet we find the value  $49.8 = F$ , which is used in the calculation.

*Volumetric Methods.* 1. *Fehling's Process.* Solutions required:—34.639 copper sulphate in 1000 c.c.; 187 grams sodium potassium tartrate and 78 grams caustic soda in 1000 c.c. Mix equal volumes of these immediately before use; 20 c.c. of the mixed solution are reduced by .05 gram glucose. The glucose solution must not contain more than .05 gram in 10 c.c., and, if lead has been used in clarification, it must be removed by a small excess of carbonate or sulphate of sodium; the analysis is carried out as follows:—20 c.c. of the mixed copper and alkaline solutions are placed in a large test tube or small flask, and heated to boiling; a quantity of glucose solution, a little less than that which previous experience has shown to be necessary, is run in and the boiling continued for two

minutes ; the glucose solution is then added, in quantities of 1 c.c., until the blue colour is discharged. The experiment is then repeated, now adding at one time nearly all the glucose necessary as shown by the preliminary experiment, and then drop by drop ; as the final disappearance of the blue colour is difficult of observation owing to the suspended precipitate, it is advisable to proceed thus: remove a drop of the copper solution on the end of a glass rod and place on filter paper ; the copper precipitate remains in the centre of the wet paper ; drop some dilute potassium ferrocyanide solution acidified with acetic acid on the paper ; in the presence of copper the meeting place of the two drops is shown by a brown colouration.

2. *Pavy's Method.* Solution required :—8·3134 grams copper sulphate, 45 grams sodium potassium tartrate, 20 grams caustic soda, 300 c.c. liquid ammonia ·880, made up to 1000 c.c. ; 50 c.c. of this solution are reduced by ·05 gram glucose.

In this method the reduced cuprous oxide is held in solution by the ammonia, the end of the reaction being indicated by the complete disappearance of a blue colour. The determination is made as follows:—The apparatus consists of a flask holding about 150 c.c., into the neck of which is fitted a rubber stopper carrying three tubes, one of which communicates with a reservoir of ammonia by a rubber tube carrying a screw clamp ; a second communicates with a burette containing the glucose solution, the flow of which is controlled by a screw clamp ; the third serves to carry

away and condense under water the escaping fumes of ammonia; the whole apparatus is supported by suitable holders; 50 c.c. of Pavy's solution are placed in the flask and boiled, ammonia being allowed to drip slowly into the flask. As soon as the air is expelled, indicated by the almost complete absorption of the escaping bubbles, the glucose solution is slowly added and continued until the blue colour is discharged; the last few drops should be allowed to flow very slowly. The addition of ammonia must be continued throughout the experiment, as, notwithstanding the partial expulsion of air on boiling, the reduced copper oxide reoxidises, the experiment should be made as expeditiously as compatible with accuracy. Peska (S.C. 311) recommends the copper solution to be covered with a layer of pure paraffin oil .5 c.m. thick, and the experiment to be carried out at a temperature of 80° C. to 85° C., and dispenses with the continued addition of ammonia; he advises the quantity of ammonia used in preparing the solution to be 160 c.c., of 25 % liquid ammonia per 3.464 grams copper sulphate.

The determination of glucose is beset with considerable difficulty, and exact results are only obtainable by the gravimetric methods. The laboratories of very few tropical sugar houses are provided with the means of making these determinations, and where they are feasible the time required for their execution would keep the chemist (where one is employed) engaged in doing nothing else. Results obtained by Fehling's or Pavy's method, when conducted under similar conditions, give comparable results, and serve the purpose

of showing what inversion has taken place. Since the reducing power of dextrose and levulose is not exactly the same, and in cane sugar work we are dealing with a mixture of the two in variant proportions, attempts to obtain extreme accuracy, based on tables constructed from experiments made with pure cane sugar, are necessarily spurious. In preparing the copper solution for volumetric work, it is well to standardise them against a solution of invert sugar, as crystals of copper sulphate are apt to effloresce.

The following table of the reciprocals of numbers from 10 to 30, will be of use in calculations relating to the volumetric estimation of glucose.

### RECIPROCAL OF NUMBERS FROM 10 TO 30.

	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
10	·1000	·0990	·0980	·0971	·0962	·0953	·0943	·0935	·0926	·0917
11	·0909	·0901	·0893	·0885	·0877	·0869	·0862	·0855	·0847	·0840
12	·0833	·0826	·0820	·0813	·0806	·0800	·0794	·0787	·0781	·0775
13	·0769	·0763	·0757	·0752	·0746	·0741	·0735	·0730	·0725	·0719
14	·0714	·0709	·0704	·0699	·0694	·0690	·0685	·0680	·0676	·0671
15	·0667	·0662	·0658	·0654	·0649	·0645	·0641	·0637	·0633	·0629
16	·0625	·0621	·0617	·0613	·0610	·0603	·0602	·0599	·0595	·0592
17	·0588	·0585	·0581	·0578	·0575	·0571	·0568	·0565	·0562	·0559
18	·0556	·0552	·0549	·0546	·0543	·0540	·0538	·0535	·0532	·0529
19	·0526	·0523	·0521	·0518	·0515	·0513	·0510	·0508	·0505	·0502
20	·0500	·0497	·0495	·0493	·0490	·0488	·0485	·0483	·0481	·0478
21	·0476	·0474	·0472	·0469	·0467	·0465	·0463	·0461	·0459	·0457
22	·0454	·0452	·0450	·0448	·0446	·0444	·0442	·0440	·0438	·0437
23	·0435	·0433	·0431	·0429	·0427	·0425	·0424	·0422	·0420	·0418
24	·0417	·0415	·0413	·0411	·0409	·0408	·0406	·0405	·0403	·0402
25	·0400	·0398	·0397	·0395	·0394	·0392	·0391	·0389	·0388	·0386
26	·0385	·0383	·0381	·0380	·0379	·0377	·0376	·0374	·0373	·0372
27	·0370	·0369	·0368	·0366	·0365	·0364	·0362	·0361	·0360	·0358
28	·0357	·0356	·0355	·0353	·0352	·0351	·0350	·0348	·0347	·0346
29	·0345	·0344	·0342	·0341	·0340	·0339	·0338	·0337	·0335	·0334

The mixture of dextrose and levulose occurring in sugar house products is nearly always returned as

glucose, but where the proportions of dextrose and levulose are required separately the following schemes may be adopted:—

1. The rotation of dextrose in sugar grades is  $+ 80^\circ$  in a transition tint instrument, the normal weight of which is 26.048 grams; in the same scale the rotation of levulose is  $- 140^\circ$ . The rotation of a solution of 26.048 grams sugar in 100 c.c. is, after inversion,  $- 29$ .

Let  $a$  = percentage of sugar (obtained by Clerget's method),  $b$  = sum of percentages of dextrose and levulose,  $c$  = reading after inversion referred to normal weight dissolved in 100 c.c.,  $x$  = percentage of dextrose,  $y$  = percentage of levulose; then, at  $27^\circ \text{C.}$ ,

$$\begin{aligned} \cdot 8 x - 1 \cdot 4 y - \cdot 29 a &= c \\ x + y &= b. \end{aligned}$$

2. Weichmann gives the following scheme:—

(1) Make a solution of the substance under examination of arbitrary density =  $B^\circ$  Brix, then  $\frac{1000}{B^\circ}$  = number of grams which contain one gram of dry substance.

(2) Weigh out of the solution a quantity equal to 10 grams dry substance and polarise at  $20^\circ \text{C.}$ , and correct the reading to a 100 m.m. tube.

(3) Determine the reducing sugars before and after inversion, and from the result calculate the sugar.

If in (2) a sugar polariscope taking 26.048 grams as normal weight is used, the readings must be multiplied by  $\cdot 346$  to reduce to circular scale degrees  $[\alpha]_D$ .

Let  $a$  = sugar,  $b$  = reducing sugars,  $x$  = dextrose,  $y$  = levulose,  $s$  = specific rotation of sugar  $\div 100$ ,  $d$  = specific rotation of dextrose  $\div 100$ ,  $l$  = specific rotation of levu-

lose  $\div 100$ ,  $p$  = the polarisation of the sample in circular degrees obtained in (2). Then :—

$$a s + x d - y l = p, \text{ and } x + y = b.$$

For the values of  $s$ ,  $d$ ,  $y$ , see under *Sugar*.

Levulose may also be determined by making use of the large variation in optical activity shown by that substance under the influence of a change of temperature, dextrose and saccharose only undergoing a small change. The solution of sugars is polarised as usual in a tube, round which ice water circulates. The temperature at which the observation is made is accurately determined; a second observation at an increased temperature is made; if  $P$  and  $P'$  be the readings at temperatures  $C$  and  $C'$  made in a 20 c.m. tube, then the number of grams of levulose per 100 c.c. is given by the formula

$$\frac{(P - P') 100}{(C' - C) 1.277}.$$

Recently invertase, the enzyme of yeast, has been used instead of acid for inverting cane sugar for analysis. This is prepared as follows: one part of yeast and ten parts of water are boiled together and filtered; the filtrate contains the invertase (see Ling, "Int. Sugar Jour.," No. III.).

Complex mixtures of sugars do not enter into the routine of the tropical sugar house analyst; but the following table, extracted from Allen's "Commercial Analysis," giving the behaviour of sugars after treatment with invertase and acids will be useful; full information for the analysis of such mixtures is contained in the work quoted above.



		Dextrose.	Levulose.	Lactose.	Maltose.	Saccharose	Dextrin.	Gallisin
Original .. ..	Reducing power	100	100	67.8	62			45.6
After treatment with invertase		100	100	67.8	62	105.3		45.6
After inversion with acid		100	100	97.7	105.3	105.3	111.1	
Original .. ..	[ $\alpha$ ] <sub>D</sub>	+ 52.7	- 98.8	+ 55.8	+ 139.2	+ 66.5	+ 198	+ 84
After treatment with invertase		+ 52.7	- 98.8	+ 55.8	+ 139.2	- 24.3	+ 198?	+ 84
After inversion with acid		+ 52.7	- 98.8	+ 71.0	+ 55.0	- 24.3	+ 58.5	

## GUMS.

The gums are amorphous bodies of composition  $[C_6 H_{10} O_5]_n$ ; they are precipitated by alcohol and with water from sticky masses. The gums in sugar work are nearly all removed in the clarification, and consequently offer little trouble to subsequent manufacture of sugar.

## HEAT.

See under *Boiler, Steam.*

## HORSE-POWER.

A horse-power is the energy required to raise 33,000 lbs. one foot in one second; to develop this amount of energy per hour, the evaporation of one cubic foot of water per hour was formerly required, and this quantity still remains a measure of boiler horse-power, though as many as ten actual horse-power have been obtained from the evaporation of one cubic foot of water. To calculate the horse-power of an engine, let  $P$  be the mean pressure on the cylinder in lbs. per square inch,  $L$  the length of stroke in feet,  $A$  the area of the piston in square inches,  $N$  the number of revolutions per minute; then  $H.P. = \frac{2 P L A N}{33000}$ .

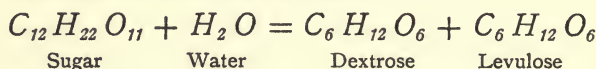
One American horse-power is equal to one-half an English horse-power, and one French horse-power to .9863 English horse-power.

### HYDROMETER.

See *Beaumé, Brix, Twaddle.*

### INVERSION.

Cane sugar when heated with acids, is rapidly converted into equal quantities of dextrose and levulose, the mixture of the two being called invert sugar; the process obtains under the equation



one part of cane sugar giving 1.053 parts of invert sugar.

The rate of inversion varies with the concentration of the acid, with the temperature, and with the nature of the acid; the coefficient of inversion is a number giving the relative invertive power of different acids referred to hydrochloric acid as a standard. Spohr states that for each rise in temperature of 10° C., the amount of sugar inverted in the same time increases 3.36 times.

TABLE GIVING THE COEFFICIENTS OF INVERSION OF DIFFERENT ACIDS AT 65° C.

Acid.	Coefficient of Inversion.	Acid.	Coefficient of Inversion.
Hydrochloric ..	100	Citric.. ..	1.72
Nitric .. ..	100	Acetic .. ..	.400
Sulphuric .. ..	53.6	Tartaric {	Probably a little greater than for Citric
Oxalic .. ..	18.57	Sulphurous ..	
Phosphoric ..	6.21	Boracic {	Not determined, but probably very low
Malic .. ..	1.27		
Succinic .. ..	.545		

Besides acids, the salts of the heavy metals, *e.g.*, Zinc Sulphate, Ferric Chloride, are capable of inverting sugar; but as these do not occur in sugar house work, this is of no interest. It was stated by Pellet, a statement frequently met with, that glucose had the power of inverting sugar. Gunning and Durin did not find this effect. Geerligs (S.C. 311), who went into the subject very fully, found

1. That glucose, in the absence of salts, did not invert sugar.

2. That in the presence of salts the quantity of sugar inverted increases as the glucose increases.

3. That the sugar inverted is greatest in the presence of salts containing a strong acid.

4. That the combined effect of glucose and organic salts is small.

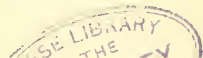
5. That the effect of glucose and inorganic salts is diminished by the simultaneous presence of organic salts.

### INVERT SUGAR.

Dissolve 2.375 grams pure cane sugar in 50 c.c. water, add 5 c.c. strong hydrochloric acid and allow to stand for 24 hours, or gradually raise the temperature to 70° C.; keep at this temperature for seven minutes, and cool rapidly. Neutralise with caustic soda, and make up to 1000 c.c.; 20 c.c. of this solution contain .05 gram invert sugar, and should reduce exactly 10 c.c. of Fehling's solution (.3464 gram copper sulphate).

### JUICE, ANALYSIS OF.

*Density.* Pour the sample into a cylinder provided



with a cock about two inches from the bottom ; allow the dirt to settle and the air bubbles to rise, which may take from five to twenty minutes ; when settled, draw off into a hydrometer cylinder, and take the density with a Brix spindle graduated in tenths of a degree.

*Sugar.* Fill a flask graduated at 100 c.c. and 110 c.c. up to the 100 c.c. mark, so that the lower edge of the meniscus is on a level with the 100 c.c. graduation mark ; add 6 or 7 c.c. of basic acetate of lead, make up to 110 c.c. and filter, rejecting the first few drops. The filtrate is best collected in a tall, narrow vessel, the funnel resting directly on the rim of the vessel receiving the filtrate ; polarise at once, using either a 220 c.m. tube or a 200 c.m. tube, and adding 10% to the reading ; if  $n$  be the normal weight for the polariscope used,  $w$  the reading in the 200 c.m. tube, then  $\frac{n}{100} w =$  lbs. of sugar per gallon. Instead of measuring the juice by volume, the normal weight for the polariscope may be weighed out, clarified with lead acetate, and made up to 100 c.c. ; the reading will now give directly the percentage of sugar in the juice. Spencer's pipettes, graduated to deliver two or three times the normal weight at different temperatures, are very convenient for this determination.

Owing to the volume of the lead precipitate an error is introduced ; this may be corrected by Schribler's method. Polarise as described above ; dilute 100 c.c. of juice to 220 c.c., clarifying as usual with lead acetate, and polarise ; take twice the second reading from the first, multiply the remainder by 2.2 and subtract the result from the original reading, giving the correct

result. In Sach's method for determining the volume of the lead precipitate, the precipitate from 100 c.c. of juice is washed by decantation till free from sugar, and transferred to a 100 c.c. flask; the normal weight of a pure sugar of known polarisation is then dissolved in the same flask in the presence of the lead precipitate, and polarised; from the reading the volume of the lead precipitate can be calculated at once. Where no great variation in the purity of the juice happens, it is convenient to determine from previous experiments a correction for subsequent use.

*Glucose.* Remove 20 c.c. of the clarified juice, add a sufficient quantity of sulphate or carbonate of sodium to precipitate the lead, dilute so that 10 c.c. to 20 c.c. will contain .05 gram glucose, and determine by one of the methods described under glucose.

*Total Solids.* The degree Brix is usually taken as representing the percentage of total solids; where extreme accuracy is desired, 10 c.c. of the juice must be dried to constant weight. The drying is best performed at a low temperature in a vacuum oven, but in the absence of this the drying must be continued for a long time at a temperature of 105°C.; the drying is materially accelerated by the addition of some clean dry sand or broken pumice stone.

*Purity.* The purity, *i.e.*, the percentage of sugar to total solids, is obtained by calculation from the sugar percentage and degree Brix, or in special cases from the total solids as determined by drying.

*Pectine.* The bodies insoluble in alcohol are summarised under the name of pectine; to determine, pour

20 c.c. of juice into a large excess of 80 % alcohol, collect on a weighed filter, wash with 80 % alcohol, dry at 100° C., and weigh.

*Acidity.* Titrate 20 c.c. of juice with decinormal caustic soda, using plenolphthalein as an indicator; the determination is not exact, due to the colour of the juice masking the end reaction.

*Alkalinity* (for Carbonatation process). For juices resulting from the first carbonatation, titrate with a solution of sulphuric acid, of strength such that 1 c.c. will neutralise .02 gram lime as  $Ca O$ ; for second saturation juices use a solution one-fifth this strength; plenolphthalein should be used as an indicator.

Where the amount of lime is required with exactitude, treat 100 c.c. of juice with ammonia, filter if a precipitate form, add ammonium oxalate, boil, allow to stand for twelve hours; filter, wash, and weigh as calcium carbonate or sulphate.

To determine the alkalinity, due to sodium and potassium hydrates, formed by the action of lime on alkaline salts, Pellet's method is used:—The total alkalinity is determined as above, and then 50 c.c. of juice is mixed with an equal volume of strong alcohol; the lime is precipitated as saccharate, and the residual alkalinity determined in the filtrate.

*Viscosity.* The viscosity of the juices are very conveniently referred to a standard arbitrarily fixed; a convenient one is the viscosity of a solution of pure sugar of density, 1.0500. The juices should be diluted to this density for comparison (see under *Oils*).

*Ash.* Evaporate 20 c.c. to dryness in a tared

platinum basin, and ignite at a low red heat ; it is often customary to char with sulphuric acid before ignition, and to deduct 10% from the result to allow for conversion of carbonates to sulphates.

### LABORATORY.

Where attempt is made to keep a systematic control of the factory, a special office should be built for laboratory work ; the laboratory should be conveniently near to the factory, but so far removed from the mill that the balance is not affected by the vibrations ; the balance may very suitably be placed on a brick pillar built for the purpose. The laboratory should be well lighted and ventilated, a supply of rain water laid on, a lead sink provided, together with a sufficiency of shelves and cupboards ; a part should be partitioned off to serve as a polariscope room (*q.v.*). The following list of apparatus and chemicals are necessary where any systematic control is attempted, those absolutely essential for the simplest control being indicated by italics. The prices quoted are only approximate.

*Polariscope* (from £20).

*Polariscope Tubes*, 100 *m.m.*, 200 *m.m.*, 400 *m.m.* long (from 13s.).

*German Silver Basin*, for weighing sugars, etc. (from 15s.).

*Chemical Balance*, sensible to  $\frac{1}{8}$  mgram. (from £8).

*Set of Weights*, 100 grams to 1 mgram. (from 15s.)

Hand Centrifugal Machine (from £5).

Hand Filter Press (from £6).

Microscope, magnifying up to 500 diameters (from £10).

Ice Machine (from £15).

*Two Sets Brix Hydrometers*, graduated in  $\frac{1}{10}$  of a degree (from £2 5s.).

Still, for estimating alcohol in wash (from £3 10s.)

Lovibond's Tintometer, for colour of rum (from £5).

*Sykes' Hydrometer* (from £6).

Drying Oven (from 10s.).

Orsat Muencke's Gas Analysis Apparatus (from £3 10s.); *or*

Set of Hempel Bulbs and Gas Burette (from £1 10s.); *or*

Bunte's Gas Burette (from 15s.).

Pyrometer (from £5).

Schleibler's Calcimeter, for carbonation process (from £2 5s.)

Oil Blast Lamp (from £1).

Two Platinum Basins, 6 oz. capacity.

Three Platinum Capsules, 1 oz. capacity.

*Six each Flasks*, graduated 50 and 55 c.c. and 100 and 110 c.c. (1s. each).

*Three Burettes*, graduated in tenths of a c.c. (5s. each).

*Two each Flasks*, graduated 250 c.c., 500 c.c., 1000 c.c. (2s. to 3s. each).

*Three each Pipettes*, graduated 20 c.c., 50 c.c., 100 c.c. (1s. each).

*Six Hydrometer Immersion Tubes*, 12" × 1" (1s. each).

*Six each Flasks*, 3 oz., 6 oz., 12 oz. capacity (from 6d. to 1s. each).

*Twelve Funnels*, 4 in. diameter (from 6d. each).



Six each Beakers, 4 oz., 6 oz., 12 oz., 20 oz. capacity (from 3d. to 1s. each).

*Glass and India-rubber Tubing, Burette Stands, Funnel Holders, Spirit Lamp, etc.*

Six each Evaporating Basin, 6 oz., 10 oz., 20 oz. capacity (from 1s. each).

Two Hydrometers, for obscuration, graduated from 1·0000 to 10100 to read to ·0002 (10s. each).

Two Thermometers, graduated from 0° C. to 120° C. (5s. each).

A stock of the following chemicals are also necessary:—Sulphuric acid, nitric acid, *hydrochloric acid*, *acetic acid*, oxalic acid, *copper sulphate*, *caustic soda*, caustic potash, *potassium tartrate*, *sodium sulphate*, *sodium carbonate*, sodium chloride, sodium phosphate, pure cane sugar,  $\alpha$ -naphthol, thymol, cobalt nitrate, *potassium ferrocyanide*, *lead acetate basic*, *ammonia* ·880, *litmus*, plenolphthalein, corallin, alcohol, ether, cupric chloride, pyrogallic acid, alum, potassium permanganate, bone charcoal, glass wool, *mercuric chloride*, methylated spirit, paraffin wax.

## LIME, ANALYSIS OF.

*Free Lime.* Make about 10 grams of lime to a thick cream with water, and add an excess of a syrup of sugar of density 30° to 40° Brix; agitate for a few minutes, filter, wash the filter with a solution of sugar, make up to 1000 c.c., and determine the free lime in the filtrate with decinormal acid.

1 c.c. decinormal acid = ·0028 grams lime as *Ca O*.

*Total Lime.* Slake about 1 gram with water, and add

50 c.c. normal sulphuric or hydrochloric acid; determine the excess of acid by titration with decinormal alkali.

Degener Lunge method : Slake some lime with water, add a few drops phenacetoline and titrate with decinormal hydrochloric acid until the yellow colour changes to red; this change marks the neutralisation of the free lime. Continue the titration until the red colour changes to golden yellow; this change marks the final combination of the unburnt lime with the acid.

The above analyses are all that are usually required in sugar house work, but in factories using the carbonation process, and employing large quantities of lime, complete analyses are called for, for which larger works must be consulted. For rapid work the following method after Sundström may be used:—

1. Dissolve 1 gram in 25 c.c. normal hydrochloric acid; heat to boiling, and determine the excess of acid by titration with caustic soda, using methyl orange as an indicator; this gives the c.c. of normal acid required to neutralise the carbonates of lime and magnesia.

2. Dissolve 1 gram in 5 c.c. hydrochloric acid; filter and wash; dry, ignite and weigh the insoluble residue, giving the dirt, sand, etc.; evaporate the filtrate to dryness, take up with hot water, filter, wash, dry, ignite and weigh as  $SiO_2$ .

3. In the filtrate from 2 precipitate the iron and alumina by a small excess of ammonia.

4. Precipitate the lime in the filtrate from 3 as oxalate, and weigh as carbonate or sulphate.

5. Calculate from the result obtained from 4 the c.c.

of acid required to neutralise the calcium carbonate; this, taken from that found in 1, gives the c.c. required to neutralise the magnesium carbonate.

### LIME, CHOICE OF.

The lime used in the factory should be as pure as possible; the impurities met with are sand, clay, etc., which are removed in the filter; silica, magnesium carbonate, calcium sulphate, iron and alumina. Magnesium salts and calcium sulphate are objectionable as giving rise to scaling in the evaporators; the presence of iron gives rise to the formation of a flocculent mass of ferropectine, clogging the filters; this is also often due to an undue proportion of soluble silica.

In factories using the carbonatation process analyses of the lime-kiln gases should be systematically made; any notable proportion of carbon monoxide indicates a deficiency of air in the kiln. The carbon dioxide usually varies from 25% to 30%; a fall in the proportion of carbon dioxide and consequent rise in the percentages of nitrogen and oxygen indicates a too free access of air or a leakage in the pipes.

For the action of lime on cane juice see under *Carbonatation* and *Clarification*.

### LOSSES IN MANUFACTURE.

The losses which occur are in the megass, the filter cake, in inversion, in centrifuging, and in the final molasses; houses which make rum partly recover the inversion and molasses losses in the distillery.

With single crushing in a modern three-roller mill

the loss in megass is from 25% to 30% of sugar in canes; with double crushing from 17% to 20%; with double crushing and 10% dilution from 12% to 15%; with treble crushing and 20% dilution from 7% to 12%; the least loss occurs with diffusion, amount to from 3% to 6%.

With presses of modern construction the filter cake should not carry away more than .5% of sugar in cane; with bag filters a loss of 2% is common.

The loss in inversion is with careful working very small, but with negligent work, especially when making yellow crystals for direct consumption, may become serious; in general work, the chief loss in inversion occurs in the cooling of the after massecuites; where crystallisation in motion is applied to after products, this loss is reduced to a minimum. In a Demerara factory with which the writer was connected, the loss in inversion between the mill and first massecuite was, when making yellow crystals, 6.2% of sugar in juice falling to 1.6% when refining crystals were made; exact figures dealing with inversion losses do not seem to have been published. With careful work the loss may be reduced to as low as 2% on sugar in canes rising to as high as 10% with negligent control. Losses in the centrifugals occur chiefly from fine grain, formed in careless pan boiling, passing through the centrifugal mesh; this loss is in part recovered in after boiling, and may be reduced to a minimum by the adoption of crystallisation in motion.

The exhausted molasses contain from 20% to 40% sugar, and weigh about 2% on the canes, indicating a

loss of from 4% to 12% of sugar in canes; this loss depends very largely on the presence of organic potassium salts, as well as on the purity of the juice.

The sum total of losses seldom if ever falls below 15% of sugar in canes, and the majority of factories show a loss of at least 25%.

Examples of modern practice are appended, the losses, except where otherwise stated, being expressed on sugar in canes.

Kealia, Hawaii, 1889-90. Diffusion plant, dilution 27.9% on canes. Loss in megass, 8.96%. Loss in manufacture, 9.80%.

Sprecklesville, Hawaii, 1889-90. Double crushing with maceration, 9.6% on cane. Loss in megass, 15.69%. Loss in manufacture, 10.90%.

Ewa, Hawaii, 1895. Treble crushing with maceration, 7.91% on normal juice. Loss in megass, 7.51%. Loss in press cake, 1.07%. Loss in molasses, 4.98%. Undetermined, 3.31%. 1898—Loss in megass, 6.50%. Dilution on normal juice, 21.65%.

Daria Sanieh, Egypt, 1896. First sugar, 9.23% on cane; second sugar, .81%; third sugar, .19%; final molasses, 2.30%.

Sempel Wadak, Java, 1897. Crystallisation in movement plant. Loss in press cake, .63% of sugar in juice. Loss in molasses, 5.92%. Unknown losses, 5.40%.

The following figures are given by Stade (I. S. J. No. 3) for a beet factory using diffusion, treble clarification, and crystallisation in movement process:—

Acres in cultivation (about) 10.825.

Yield per acre (about) 14·4 metric tons.

Tons saccharose per 100 tons beets, 15·07.

Tons first sugar 88% renderment per 100 tons saccharose in beets, 82·31.

Tons sugar II. and III., per 100 tons saccharose in beets, 12·42.

Tons sugar II. and III., per 100 tons sugar I., 15·10.

Tons sugar I., II., III., per 100 tons beet, 14·28.

Total tons sugar I., II., III., per 100 tons saccharose in beet, 94·82.\*

Tons beet to one ton sugar, 7.

Tons final molasses per 100 tons beet, 2.

### MACERATION.

The various schemes for maceration fall under two heads:—those in which the added water is allowed to fall on the megass in the shape of a number of jets, and those in which the crushed cane is passed through a trough filled with hot water. The former system is the one generally employed. When macerating, it is important, in order to obtain good results, that the added water should be allowed sufficient time to dilute and thoroughly mix with the juice in the partially crushed cane; this result can be obtained by placing the successive mills a reasonable distance apart. In Russel and Risien's original scheme the mills were placed 30 feet apart, but often no more than 10 feet separate the mills, with the result that the added water is expressed without it diluting the juice.

When two mills are employed it is customary to use

\*If the sugars polarised 90%, this is equivalent to an extraction of 85% saccharose on saccharose in beets.

from 5% to 10% added water; from 8% to 20% on the normal juice being used with three mills; in some instances the diluted juice coming from the third mill is partly used to macerate the megass coming from the first mill.

The advantage of the process lies in the increased yield of sugar, against which has to be put increased expenditure in labour, initial cost and fuel; generally the added water is so controlled that the megass just affords sufficient fuel for working the factory; compared with diffusion, less sugar is obtained, except in extreme cases, but maceration has the advantage in giving a mechanically better fuel, and in that the added water is capable of being regulated according to the nature of the canes.

In the Perichon system, recently tried at the Daria Sanieh, Egypt, the crushed megass is washed in wagons on the way to the boilers; the same water is used nine times—the fresh megass being washed with water that has already passed over eight lots of megass. After complete lixiviation the megass is crushed for fuel; the lixivated juice contained about 5% to 6% sugar, the normal juice about 12%, and the waste waters from .3% to .8%.

### MANURES.

In the following notes are given the approximate composition of the manures most commonly met with, and short notes on their action; for more complete information see Aikmann's "Manures, and the Principles of Manuring."

*Dissolved Peruvian Guano.* Organic matter, 40% to 50% (containing Nitrogen, 5% to 8%); soluble phosphate of lime, 10% to 15%; insoluble phosphate of lime, 3% to 5%; potash, 3% to 8%.

This manure, containing all the more important elements of plant food, is extremely economical in application; it is generally stated to be more efficacious on clayey than on sandy soils. The dissolved guano most frequently met with is Ohlendorff's, and of this Dr. Voelcker stated that it was the most powerful, best prepared and intrinsically valuable manure with which he had met.

*Bone Manure.* Organic matter, 30% to 35% (containing nitrogen 4% to 6%); phosphate of lime, 40% to 50%; carbonate of lime, 5% to 7%; alkaline salts, 3% to 5%. The manure is usually sold as half-inch, quarter-inch, or bone meal; it is slow in action, and as such is said to produce a permanent improvement in the land.

*Mineral Phosphates.* Phosphoric acid, 25% to 35%; lime, 35% to 50%. The ground mineral phosphate of commerce is prepared from naturally occurring deposits in Canada, Norway, South Carolina, etc. The phosphates are present in an insoluble form, and when applied as such have a very slow action; hence they as well as bone manures are often treated with sulphuric acid, the action of which is to render the phosphates soluble; such phosphates on storing have a tendency to change into a sparingly soluble form known as reverted phosphate. Authorities differ greatly as to the value of reverted phosphate, some even considering it more valuable than superphosphate; reverted



phosphate has the advantage of being less easily washed out of the soil.

*Thomas Slag, Basic Cinder, Phosphate Meal.* Lime, 40% to 50%; magnesia, 5% to 6%; ferrous oxide, 10% to 15%; ferric oxide, 2% to 10%; manganous oxide, 3% to 4%; alumina, 1% to 3%; phosphoric acid, 14% to 20%. This manure, a by-product of the Thomas-Gilchrist steel process, is of comparatively recent introduction; the lime is present partly free, and partly combined with phosphoric acid; the phosphates are very soluble in water containing carbonic acid, and in the waters from peaty soils. The state of division of the slag has a great bearing on its efficacy, and the manure should be bought under a guarantee of fineness. Owing to the presence of the free lime, it must never be used immediately in connection with sulphate of ammonia or other ammonia salts.

*Nitrate of Soda.* The pure body contains 16.5% nitrogen, and as commercially sold is about 96% pure. The manure is extremely soluble, and is accordingly very rapid in action and liable to be carried away in drainage; to obviate this it is best applied in fractional dressings. Experiments made on the continent show that this manure tends to increase the albumenoids in the sugar beet, sulphate of ammonia tending to increase the sugar content.

*Sulphate of Ammonia.* The pure body contains 21.2% nitrogen, and as sold contains from 8% to 10% of impurities; it is generally conceded to be superior to nitrate of soda for the sugar cane (see *Cane, Manuring of*). Both this and nitrate of soda are often

applied to the young cane to give it a healthy start.

*Kainit* contains from 12% to 15% of potash as sulphate, and is superior to carnallite, which contains potash as chloride.

*Gypsum*, when pure, contains 32.56% lime, and 46.31% sulphuric acid; although formerly largely used as a source of lime, it is now rapidly being discarded.

Among other manures may be mentioned *Fish Guanos*, *Blood Manures*, *Shoddy*; all these are slow acting nitrogenous manures, which have in the tropics met with comparatively small use.

*Manures Produced on Estate.* Considered as an agricultural system, a sugar estate is in the peculiarly happy position of removing for the market none of the constituents of plant food, provided that the molasses are not sold off the estate; by systematically replacing on the soil the megass ashes, the filter cake, and the distillery refuse, there is no reason why the productiveness of a plantation should not remain the same over very lengthy periods, without any extraneous manures being applied; and, in the case where large quantities of lime and phosphoric acid are used in manufacture, the application of the filter cake should result in continual amelioration of the soil. From published analyses of the ash of the cane (*q.v.*), 1,000 tons of cane carry off from the soil from 500 to 2,000 lbs. phosphoric acid, from 500 to 1,700 lbs. sulphuric acid, from 400 to 2,400 lbs. lime, from 2,000 to 6,000 lbs. potash, and from 1,600 to 3,000 lbs. nitrogen. On an estate in British Guiana, the writer estimated that the filter mud contained, per 1,000 tons

cane, 350 lbs. lime, 140 lbs. phosphoric acid, 40 lbs. sulphuric acid, and 150 lbs. nitrogen; that the megass ash contained 450 lbs. phosphoric acid, 100 lbs. lime, 400 lbs. sulphuric acid, 300 lbs. potash, and that 80 lbs. nitrogen were lost in combustion, per 1,000 tons cane; that the distillery refuse estimated over the same amount of cane contained 500 lbs. lime, 150 lbs. phosphoric acid, 3,000 lbs. potash, 1,600 lbs. sulphuric acid, and 1,300 lbs. nitrogen; there were used in the boiling house and distillery, per 1,000 tons cane, about 500 lbs. lime, 400 lbs. sulphate of ammonia, and 700 lbs. sulphuric acid, but no phosphoric acid. These figures must not be taken as general; the distribution of the manurial constituents will not only vary with the methods of working, but the quality and composition of such is entirely dependent upon the composition of the soil.

### MASSECUITE, ANALYSIS OF.

#### *Density and Total Solids.*

Dissolve about 200 grams of massecuite in an equal weight of water, and observe the degree Brix of the solution; the degree Brix of the original massecuite is approximately twice that of the solution; where greater accuracy is required the total solids must be determined by drying.

*Purity.* Make a solution of the massecuite approximately of the same density as that of the juice from which it was boiled, and treat as described under *Juice, Analysis of.*

*Total Sugar.* In general work it is customary to

return as the percentage of sugar that obtained from the direct reading (see under *Sugar*), without allowing either for the error introduced by the volume of the lead precipitate or for the presence of reducing sugars; these two errors tend to correct each other, so that the direct reading may often give results very little incorrect; results thoroughly reliable can only be obtained by Clerget's methods, or by determination of the glucose before and after inversion; unfortunately, with low-grade products the material after inversion is so dark coloured, that a confident reading can very seldom be obtained, and the accurate determination of glucose is too lengthy a process to be employed in sugar house control—for these reasons the direct reading is usually employed.

*Crystallised Sugar: Vivien's Method.* Place in a funnel fitted with a perforated filtering cone, about 200 grams of massecuite; connect the funnel to a filter pump, and wash the massecuite with a saturated solution of pure sugar until all the molasses are removed; transfer the crystals to a basin, mix and weigh; dry about 10 grams and determine the loss in weight. At the average temperature in the tropics one part of water dissolves 2.15 parts sugar, so that the loss of weight on drying multiplied by 3.15 gives the amount of sugar liquor adhering to the crystals: subtracting this from the weight of wet crystals, the weight of crystals in the massecuite is obtained.

*Dupont's Method.* Heat the massecuite on the water bath to about 85° C., and centrifugal in a small hand machine, the basket of which is covered with flannel;

dry the sugar as completely as possible, polarise the molasses, and calculate the percentage of crystallised sugar from the formula  $x = \frac{a-p'}{p-p'}$ ; where  $x$  = weight of crystallised sugar in one part of massecuite,  $a$  = percentage of sugar in crystals,  $p'$  = percentage of sugar in molasses; this method is applicable to control work on a large scale, provided no water is used in the curing, and that the molasses are filtered through flannel before analysis so as to remove fine grain.

*Glucose.* Determine by one of the methods given under *Glucose*.

*Ash.* Carbonise about 2 grams at a low, red heat, gradually increasing to bright redness.

*Alkalinity: Buisson's Method.* Place 25 c.c. of a solution of the material under analysis in a glass-stoppered flask; add 10 c.c. of ether containing a little corallin, and titrate with decinormal acid; after each addition of acid shake the flask, and allow the ether to rise to the surface; an excess of acid is denoted by the ethereal solution turning yellow.

In the absence of these reagents the colour of the massecuite solution, which is dark brown in alkaline and light yellow in acid solution, may be employed to give approximate results.

## MEGASS, ANALYSIS OF.

The analysis of megass presents considerable difficulty. In the first place it is extremely difficult to obtain an even sample for analysis, and secondly, supposing that a uniform sample is collected, to ensure that, when the analysis is performed, the megass is in

the same condition as when it leaves the mill. Megass very rapidly absorbs or loses moisture, dependent on the state of the atmosphere, and the sugar is very liable to invert and undergo fermentation. Geerligs has shown that megass may be preserved for several hours in the presence of formaldehyde, and for lengthy periods when submitted to intermittent sterilisation in air-tight vessels. Another difficulty lies in the impracticability of obtaining any but a small reading in the polarisation of an aqueous extract. To obviate this difficulty a polariscope tube, one half or even one metre long, may be used, but very few tropical sugar houses are provided with a polariscope capable of accommodating a tube of this length. The writer has used the following scheme for several years, and obtained consistent results.

*Sampling.* The megass is taken hourly as it leaves the mill, rapidly torn into small pieces with the hand, and stored in an air-tight vessel, into which a few drops of formaldehyde are introduced. After five or six samples have been taken the whole is mixed, sub-sampled, and the subsample cut into small pieces.

*Water.* About 2 lbs. of the subsample are weighed out into a basket of wire gauze, and dried to constant weight; an oven built in the flue, and provided with a damper for regulating the temperature, is very convenient. At first the temperature should not exceed 160° F., being finally raised to 230° F.; a balance turning with .005 lb. is of sufficient accuracy.

*Sugar.* About 1 lb. of megass is weighed into a large vessel, as a kerosene oil tin, and macerated with about half a gallon of water, or say two litres; the maceration

may be effected with the hand, without introducing sensible error; the complete diffusion of the soluble matter is complete in a very short time. The water present may be determined by weight after the percentage of fibre, or by volume when the added water and the percentage of moisture is known. To 100 c.c. of the extract a few drops of lead acetate are added, made up to 110 c.c., filtered and polarised; with a 20 c.m. tube and megass carrying 5% sugar, a reading of about  $4^{\circ}$  is obtained in the transition tint instrument. The glucose is determined, as usual, after removal of lead. A convenient check to the polariscope figure may be obtained by obtaining the density of the aqueous extract with a hydrometer reading to  $\cdot 0001$ , and calculating from that the total solids, and assuming the purity of the extract is the same as the juice. Instead of polarising, some chemists prefer to invert the aqueous extract, and determine the total glucose, and from this figure calculate out the proportions of sugar and glucose on the assumption that their ratio is the same as in the juice.

*Fibre.* Wash about a pound in a running stream of cold water, until the drainings after inversion do not reduce Fehling's solution; the washing is best done in a wire gauze basket, covered with linen so as to catch fine particles; after washing with water, the water may be removed by a washing with spirit in the rum store, the spirit being returned to the still; in either case the fibre is squeezed and dried to constant weight in an oven; the drying will take seldom less than 48 hours' exposure to a temperature of  $220^{\circ}$  F. to  $230^{\circ}$  F.

## MEGASS, THERMAL VALUE OF.

The combustible bodies present in megass are the fibre, sugar, glucose, and details of other organic bodies. According to Stohlmann, the combustion of 1 lb. of cellulose (fibre) affords 7461 B.T.U.; of 1 lb. of sugar, 6959 B.T.U.; and of 1 lb. of glucose, 6646 B.T.U.; so that from these data the thermal value of a megass can be calculated from the analysis; for example, a megass of composition—water 51%, fibre 42%, sugar 5.5%, glucose .5%, other solids 1%, will give on combustion per pound the following heat value  $(.42 \times 7461) + (.055 \times 6959) + (.005 \times 6646) = 3549$  B.T.U., and, allowing 1050 B.T.U. for the evaporation of each pound of water, a net value of 3014 B.T.U. per pound. It is often stated that a double dry crushed megass has a higher calorific value than a single crushed; a calculation on the lines given above indicates the reverse, the extra sugar in the single crushed megass being more than sufficient to evaporate the concomitant water.

A second method for the estimation of the thermal value of megass lies in the application of the antiquated and incorrect Welter's rule, which states that the heat of combustion of an organic compound is the heat of combustion of its elements, after the removal of so much hydrogen as will go to form water with oxygen already present in the compound; in the case of cellulose, sugar, and glucose, the hydrogen and oxygen being present in the same proportions as in water, do not enter into the calculation; cellulose containing 49.4%, sugar 42.1%, glucose 40.0% carbon, the megass of analysis



quoted above will contain 23·2% carbon. One pound carbon affords on complete combustion 14400 B.T.U., so that on the above argument the thermal value of the megass is per pound  $14400 \times \cdot 232 = 3341$  B.T.U., and allowing for the evaporation of the contained water, 2806 B.T.U., a difference of 208 B.T.U. per pound from that obtained from Stohlmann's experiments. In determining the efficiency of boilers, the calculation of the thermal value of megass is of unique importance. In the table below have been calculated the thermal values of megass from 100 tons of cane, from Stohlmann's data for different types of cane and extraction.

TABLE GIVING A COMPARISON OF THE THERMAL VALUES OF DIFFERENT TYPES OF MEGASS.

TYPE OF CRUSHING.	CANES.				MEGASS PER 100 TONS OF CANE.				Gross Thermal Value of Megass, per 100 tons of Cane, B.T.U. $\times 10^6$ .	Net Thermal Value of Megass, per 100 tons of Cane, after evaporation of water. B.T.U. $\times 10^6$ .	Absolute maximum water evaporated, per 100 tons Cane, from and at 212° F. Lbs. $\times 10^3$ .	
	Sugar %.	Glucose %.	Water %.	Fibre %.	Tons.	Tons of Sugar.	Tons of Glucose.	Tons of Water.				Tons of Fibre.
Single ..	12	1·25	72	13	38	3·2	·3	21	13	277	228	236
	15	1	70·5	12	37	4·1	·3	20·3	12	267	219	227
	18	·75	69	11	36	4·9	·2	19·6	11	258	211	218
Dry Double..	12	1·25	72	13	30	2·2	·2	14·3	13	252	218	226
	15	1	70·5	12	29	2·7	·2	13·9	12	243	210	217
	18	·75	69	11	28	3·2	·2	13·4	11	233	202	208
Double with 10% dilution	12	1·25	72	13	29·4	1·7	·2	14·3	13	246	212	220
	15	1	70·5	12	28·3	2·2	·1	13·9	12	235	202	209
	18	·75	69	11	29·2	2·5	·1	13·4	11	225	194	200
Treble with 20% dilution	12	1·25	72	13	28·3	·8	·1	14·3	13	232	199	206
	15	1	70·5	12	27·1	1·1	·1	13·9	12	218	186	193
	18	·75	69	11	25·8	1·3	·1	13·4	11	204	174	180

## MEGASS, PRODUCTS OF COMBUSTION OF.

Each pound of carbon requires a theoretical minimum of 12.03 lbs. of air, or 165 cubic feet at 84° F.; in megass and similar fuels the hydrogen present is considered as uniting with the oxygen when present in the fuel, and these in megass being present in the same proportions as in water the hydrogen drops out of the calculation; the gases, after a perfect combustion per pound of carbon, consists of 3.67 lbs. carbon dioxide and 9.36 lbs. nitrogen, the volume remaining unaltered. In practice, it is found that the best results are obtained when about twice this quantity of air is admitted; taking the temperature of the flue gases as 580° F., the volume of flue gases will be about 150 cubic feet per pound of megass, and with good combustion should contain from 10% to 12% oxygen, from 8% to 10% carbon dioxide, from 75% to 80% nitrogen, and no carbon monoxide.

## MENSURATION, MEASURES, WEIGHTS, &amp;c.

Area of rectangle: Product of length and breadth.

Area of parallelogram: Product of length and perpendicular distance between other two sides.

Area of triangle: Product of base and half the perpendicular height.

Area of any figure: Divide into suitable parts and find the area of each separately.

Area of circle:  $\cdot 7854$  (Diameter)<sup>2</sup>.

Content of rectangular tank: Product of length, breadth, and depth.

Content of cylinder of diameter  $D$  and height  $H$  :  
 $\cdot 7854 D^2 H$ .

Content of cone of diameter  $D$  and height  $H$  :  
 $\cdot 2618 D^2 H$ .

Content of sphere of diameter  $D$  :  $\cdot 5236 D^3$ .

Content of cap of sphere, diameter of base of cap  $D$ ,  
height of cap  $H$  :  $\cdot 5236 H (H^2 + \cdot 75 D^2)$ .

One cubic foot water at  $84^\circ$  F. weighs  $62\cdot 15$  lbs.

One cubic foot is  $6\cdot 232$  gallons.

One gallon is  $\cdot 1604$  cubic foot.

$1\cdot 802$  cubic foot at  $84^\circ$  F. weighs 1 cwt.

One gallon water at  $84^\circ$  F. weighs  $9\cdot 97$  lbs.

One U.S. gallon of water weighs  $8\cdot 33$  lbs.

One litre =  $\cdot 220$  gallon =  $\cdot 264$  U.S. gallon =  $\cdot 0353$   
cubic foot.

One metre =  $39\frac{3}{8}$  inches.

One kilogram =  $2\cdot 205$  lbs.

One metric ton =  $2205$  lbs. =  $19\cdot 8$  cwt. =  $\cdot 984$  ton.

One short ton =  $2000$  lbs.

One cantar (Egypt) =  $98\frac{1}{4}$  lbs.

One picul (East Indies) varies from 133 to 136

## MEGASS, PRODUCTS OF COMBUSTION OF.

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## MENSURATION, MEASURES, WEIGHTS, &amp;c.

*Erratum, p. 125.*

Sixth line from bottom,

*for* One arroba (Cuba) = 35 lbs.

*read* One arroba (Cuba) = 25.35 lbs.

Content of cylinder of diameter  $D$  and height  $H$  :  
 $\cdot 7854 D^2 H$ .

Content of cone of diameter  $D$  and height  $H$  :  
 $\cdot 2618 D^2 H$ .

Content of sphere of diameter  $D$  :  $\cdot 5236 D^3$ .

Content of cap of sphere, diameter of base of cap  $D$ ,  
height of cap  $H$  :  $\cdot 5236 H (H^2 + \cdot 75 D^2)$ .

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One metric ton =  $2205$  lbs. =  $19\cdot 8$  cwt. =  $\cdot 984$  ton.

One short ton =  $2000$  lbs.

One cantar (Egypt) =  $98\frac{1}{4}$  lbs.

One picul (East Indies) varies from  $133$  to  $136$   
lbs.

One quintal (South America) varies from  $100$  to  
 $112$  lbs.

One maund (India) =  $82$  lbs.

One arroba (Cuba) =  $35$  lbs.

One hogshead =  $16$  cwt.

One hectare (metric acre) =  $2\cdot 471$  acres.

Piculs per hectare = tons per acre  $\div 41\cdot 7$ .

Metric tons per hectare = tons per acre  $\div 2\cdot 51$ .

Hogsheads per acre = tons per acre  $\div 1\cdot 25$ .

## MILLS.

The mills almost generally in use now are either two or three rollers, the favourite type in recently erected mills being three three-rollers arranged tandem fashion, with maceration between each pair. Three-roller mills are almost universally used for the first crushing and generally for the second and third, but some engineers prefer two rollers on the ground that the power absorbed in the trash turner is saved, and that strains are more evenly distributed ; a serious objection to two rollers is that the rollers cannot be set close, else the mill will refuse the feed.

Of four-roller mills, those which have obtained most vogue are the De Mornay and Le Blanc. The De Mornay mill consists of two main rollers and two smaller supplementary rollers, so arranged that the cane passes between the front main roller and front supplementary roller, the front main roller and second supplementary roller, and thence between the two main rollers.

The Le Blanc mill consists of a main central roller, round the periphery of which are placed three other rollers ; the cane passes between each of these and the main central roller, and so is crushed three times ; two trash turners are required. In this mill there seems a danger of an excessive amount of reabsorption.

Of five-roller mills, Thomson and Black's is most often met with ; in this the side frames are extended, so as to receive a pair of rollers which give a preliminary crushing to the cane, preparing it for the subsequent crushing by the three rollers ; a very similar effect is produced by the use of cane breakers, such as

Krajewski's, which consists of a pair of heavily-grooved rollers ; the adoption of such a cane breaker increases the capacity of the mill as well as the extraction, and diminishes the risk of accident.

Considerable difference of opinion exists as to the proper speed at which mills should be worked ; formerly, a peripheral speed of 15 ft. per minute was considered great ; but, now, speeds of 20 to 25 ft. are common, recent practice inclining to the opinion that a high speed and light feed give better results than a heavy feed and slow speed.

Of the more recent improvements to crushing machinery may be mentioned the Riley Pusher, for feeding the crushed cane to the second or third mill ; it consists essentially of a strong iron or steel bar extending the length of the roller, and placed below the feeding table and above the bottom roll ; a series of V shaped teeth are cut in the bar ; a to-and-fro motion is communicated to the bar by means of a spur and pinion and lever gear, which may be conveniently worked off the main cane engine ; the toothed bar catches the megass and forces it into the mill ; this device, besides saving labour, secures a regular and even feed to the second mill. The toggle gear of Mirlees and Watson consists essentially of a combination of knuckle or toggle levers, the tops of which press against the nuts of the cover bolts, and the bottoms against the cap of the roller journal. Under normal conditions the top roller rests on its bearings, but under very heavy pressure it lifts the caps that are controlled by the toggle gear, until the upward pressure

is balanced. It is claimed for this contrivance that a uniform pressure is maintained between wide limits of feed, and that the liability to breakage is greatly reduced.

The following are examples of recent practice in mill work:—

1. Albion, Berbice, British Guiana. Two mills set tandem: first mill, three-roller, 32" × 72" (feeding roll 24½" × 72"); second mill, three-roller, 36" × 76"; hydraulic attachment to back roll of second mill. Speed: first mill, 13·6 ft. per minute; second mill, 15·1 ft. per minute; 30 to 35 tons cane crushed per hour. Cane engine: horizontal, slide valve, non-condensing; cylinder, 24" diameter, stroke, 48"; revolutions, 42-44 per minute; steam pressure, 80 lbs. per square inch; extraction per cent on cane, 68-72.

2. Caffery, Louisiana. One three-roller, 72" × 32"; one two-roller, 75" × 48"; one two-roller, 78" × 60"; cane carrier, 569" wide by 180 ft. long. Hydraulic to all mills of capacity 225, 450, 900 tons respectively.

3. Ewa, Hawaii, "Cora" nine-roller plant. Rollers, 78" × 34", of hard cast iron, with 16" iron shafts. Hydraulic to top roll of each mill, 355, 365, 400 tons respectively. Setting first mill, front  $\frac{5}{8}$ ", back  $\frac{1}{16}$ "; second mill, front  $\frac{3}{16}$ ", back, close; third mill, front  $\frac{1}{16}$ ", back, close. Surface speed of rollers, 20, 22, 24 ft. per minute respectively. Cane engine cylinder, 24" × 48"; steam pressure, 70 to 75 lbs. per square inch; cane crushed, about 31 long tons per hour.

Steele (S.C. 275) gives particulars of a number of



mills in Demerara, from which the following figures are extracted:—

ESTATE.	Diameter of Top Roller in inches.	Length of Top Roller in inches.	Speed of Roller, feet per minute.	Diameter of Cylinder in inches.	Stroke of Cylinder in inches.	Revolutions per minute.	Revolutions of Engine to one of Mill.	Actual I.H.P.	Gallons of Juice per hour.	I.H.P. per Gallons of Juice per minute.
La Jalousie ..	28	60	17·07	20	42	40	17·17	60·9	1,340	2·53
Skeldon ..	30	60	19	23	48	39	16·08	77·9	1,860	2·79
Vitvulgt ..	32	72	16·58	24	48	32	16·17	93	1,950	3·08
Non Pareil ..	34	78	16·25	35 60	condensing 60	28	14·18	111	2,736	2·21
Bel Air ..	48	84	14·07			30	60	28	25	206·7

### PARTICULARS OF MILLS: AMERICAN PRACTICE. (SQUIER.)

Diameter of Roller: inches.	Length of Roller: inches.	Diameter of Shaft: inches.	Weight: Pounds.	Tons of Cane per 12 hours.	Gallons of Juice per 12 hours: 135 gallons to ton of Cane.	Tons of Sugar per 12 hours: 130 lbs. Sugar to ton of Cane.	Horse Power required.
24	42	9½	5,000	120	16,200	9	35
24	48	10	6,500	150	20,250	11½	45
26	54	10½	6,800	180	24,300	13½	55
26	60	11	7,350	200	27,000	15	70
28	66	11½	8,940	240	32,400	18	80
28	72	12	9,700	300	40,500	22½	100
30	54	11	7,900	200	27,000	15	70
30	60	11½	8,850	220	29,700	16½	75
30	66	12	9,750	240	32,400	18	80
30	72	13	10,500	260	35,100	19½	90
34	60	12½	9,800	250	33,750	18½	85
34	66	13½	11,200	270	36,450	20	90
34	72	14½	12,000	300	40,500	22½	100
34	78	15	13,260	320	43,200	24½	125
36	78	16	15,120	365	49,275	27½	150

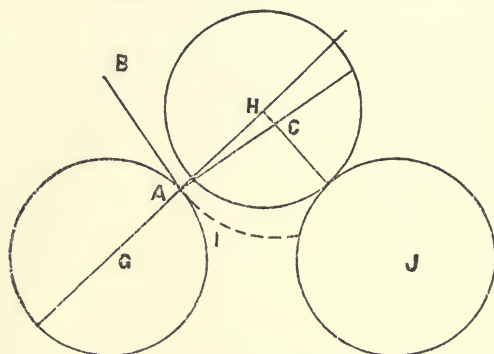
### FORMULA AND TABLE FOR ADJUSTING THE MEGASS TURNER

FOR THREE-ROLLER MILLS HAVING ROLLERS OF 26 TO 32 INCHES DIAMETER.

(GEERLIGS.)

When the position of the rollers has been settled so that they will crush the quantity of cane correspond-

ing with the capacity of the factory, the proper adjusting of the trash turner may be determined, which should properly be curved in a logarithmic spiral, for which may be substituted the arc of a circle owing to the relatively small length of the trash turner. The con-



struction of this is made by the following table, in which  $R$  = radius of the circle of which the trash turner is an arc,  $S$  = distance between head and feed rollers,  $D$  = diameter of the rollers, angle  $\alpha$  = constant angle of the spiral.

In the table the greatest angles concur with the lowest values for  $S$ , and the lowest figures for  $R$  with the lowest for  $S$ .

FOR A DISTANCE S OF 2 TO 4 INCHES.				
Diameter of Rollers in inches.	Diameter of Rollers in millimetres.	Angle $\alpha$ .	R Inches.	R Millimeters.
26	660	83°—81°	13 $\frac{1}{8}$ —13 $\frac{1}{8}$	345—352
27	686	83°—81°	14 $\frac{3}{8}$ —14 $\frac{6}{8}$	360—365
28	712	83° 30'—81° 30'	14 $\frac{1}{8}$ —14 $\frac{1}{8}$	370—378
29	738	83° 30'—81° 30'	15 $\frac{3}{8}$ —15 $\frac{6}{8}$	385—392
30	762	84°—82°	15 $\frac{1}{8}$ —15 $\frac{1}{8}$	395—404
31	788	84°—82°	16 $\frac{3}{8}$ —16 $\frac{6}{8}$	409—416
32	814	84° 30'—85°	16 $\frac{1}{8}$ —17	423—430

The construction is effected as follows:—Draw the

exact position of the rollers to scale, join the centres of the head and feed rollers, draw the angle  $\alpha$  (generally  $83^\circ$ ) beginning at the point  $A$ , causing angle  $HAB$  to be  $83^\circ$ ; now draw  $AC$  perpendicular to  $AB$ , and  $HC$  perpendicular to  $AC$ , when  $C$  will be the centre of the circle having radius  $AC = R$ , of which the trash turner is an arc.

### PARTICULARS OF MILLS: ENGLISH PRACTICE.

Size of Rollers: Inches.	Diameter of Cylinder: inches.	Length of Stroke: inches.	CANE CRUSHED PER HOUR: TONS.			GALLONS OF JUICE PER HOUR.			FIRST SUGAR PER HOUR: POUNDS.		
			Single Crushing.	Double Crushing with 10% dilution.	Treble Crushing with 20% dilution.	Single Crushing.	Double Crushing with 10% dilution.	Treble Crushing with 20% dilution.	Single Crushing.	Double Crushing with 10% dilution.	Treble Crushing with 20% dilution.
18 x 30	9	24	2.5	3.25	4	340	540	785	425	650	880
20 x 36	10	28	3.5	4.25	5	470	710	980	595	850	1,100
22 x 42	12	32	4	5	6	540	830	1,180	680	1,000	1,320
24 x 48	14	36	5	6.25	7.5	670	1,040	1,470	850	1,250	1,650
26 x 54	16	42	6	8.5	9	810	1,410	1,760	1,020	1,700	1,980
28 x 60	18	42	8	10	12	1,080	1,660	2,350	1,360	2,000	2,640
30 x 66	20	42	12	15	18	1,620	2,490	3,530	2,020	3,000	2,960
32 x 72	22	44	16	20	24	2,160	3,320	4,710	2,740	4,000	5,290
34 x 78	24	46	20	25	30	2,700	4,150	5,880	3,400	5,000	6,610
36 x 84	26	48	25	32	38	3,400	5,300	7,450	4,250	6,400	8,370
38 x 84	28	48	33	42	50	4,450	6,960	9,800	5,610	8,400	11,000
42 x 84	32	48	35	45	55	4,720	7,460	10,800	5,950	9,000	12,100
48 x 84	32	48	38	48	60	5,130	7,960	11,800	6,400	9,600	13,200

In calculating the above table, canes are supposed to hold 14% sugar, single crushing to give 75%, double crushing and 10% dilution 85%, treble crushing and 20% dilution 93% of sugar in canes; the extraction of first sugar is assumed 75% of sugar in juice, and the gallons given are the actual, and are not reduced to normal juice.

### MOLASSES, ANALYSIS OF.

The analysis of the molasses is performed as described under massecuite; the errors in the con-

ventional methods of analysis are greatest of all in the molasses—the final product of the boiling house—so that, when time and opportunity permit, analyses should be made by Clerget's method or by determination of the glucose before or after inversion. In general the percentage of sugar found by direct polarisation is too low; this is in part counteracted by the volume of the lead precipitate making the reading too high. A very complete discussion of the analysis of low grade molasses is given by Geerligs (S.C. 284).

### MOLASSES, COMPOSITION OF.

No definite figures can be given for the composition of molasses; first molasses from defecation process generally contain under 50% sugar, those from carbonatation processes containing as much as 60%; in general, in all saturated molasses the sum total of sugars lies between 55% and 60%.

	Sugar.	Glucose.	Ash.	Water.	Alkalinity of Ash, as $K_2O$ .	Glucose: Ash.	Glucose: Alkalinity.	Sugar per 100 Water.
First Molasses.	59·20	7·29	6·07	25·12	1·13	1·22	6·40	235·6
	50·20	15·14	4·35	25·31	1·30	3·48	11·47	198·3
	42·90	19·93	3·00	28·93	·34	6·64	23·45	148·6
	33·70	28·12	3·65	24·50	1·01	7·70	27·30	145·7
After Molasses.	47·90	17·44	7·00	16·45	3·85	2·49	4·53	291·1
	39·90	18·50	7·00	24·40	3·24	2·64	5·11	163·5
	34·11	28·60	5·30	23·46	3·05	5·40	9·50	144·5
	30·90	27·47	6·37	24·14	2·63	4·31	10·40	128·0
Worked out Molasses.	22·42	34·50	3·30	26·07	1·10	10·46	31·30	86·0
	43·70	15·80	6·50	17·10	2·75	2·43	5·70	255·6
	38·40	21·00	5·41	27·90	2·72	3·88	7·70	138·3
	32·40	23·00	5·20	28·60	2·25	4·42	10·20	113·3
	23·94	40·00	5·30	18·00	2·78	7·55	15·00	133·0

Besides the sugar, glucose, ash, and water given in the table abstracted from analysis by Geerligs (S.C. 312),

that investigator found in exhausted molasses from 8.3 % to 22.9 % of dextrose, from 5.6 % to 16.5 % levulose, from 1.95 % to 6.25 % soluble ash, .99 % to 5.30 % insoluble ash; the ash containing potassium carbonate .74 to 3.51 %, potassium sulphate .15 % to 3.37 %, potassium chloride 0.0 % to 2.30 %, sodium chloride .06 % to .59 %, calcium carbonate .40 % to 3.80 %, calcium sulphate 0.0 % to .52 %, calcium phosphate .05 % to .83 %, magnesium carbonate .05 % to 1.75 %, silica 0.0 % to .241 %, free acid as acetic 0.0 % to .54 %, pectine .68 % to 2.5 %, malic, saccharic and succinic acids 1.30 % to 3.99 %, glucinic acid 0.0 % to 6.28 %; but no citric or lactic acid, dextran, dextrin, or galactan.

Of saccharic acid, which had previously been described by Winter under the name of cannic acid, he says that its formula is  $C_{14}H_{18}O_{14}$ ; that it is hexabasic, that the ammonium, potassium, sodium, strontium, magnesium, zinc, copper, platinum and gold salts are soluble; and that the barium, iron, aluminium and lead salts are insoluble. Of the other two acids present in large relative proportions—metapectic and glucinic acid—both give insoluble or sparingly soluble barium salts; metapectic acid dissolves in water to a gumming mass; glucinic acid on evaporation decomposes, giving off acetic acid and carbon dioxide; and Geerligs suggests that in this decomposition lies the explanation of the frothing or scum fermentation of molasses and after massecurites.

### MOLASSES, FORMATION OF.

The chief factor in the formation of molasses was formerly considered to be the viscosity of the syrups

preventing free movement of the sugar molecules ; this theory fitted in with the observed fact that in beet molasses the sugar content was greater than corresponded with the water content, but in cane molasses the reverse happens ; in addition to this, Geerligs (S.C. 284) has shown that the same amount of sugar crystallises out on cooling from warm saturated solutions whether large amounts of glucose be present, thus increasing the viscosity, as from solutions of sugar in the complete absence of other bodies ; this theory, known as the mechanical theory of the formation of molasses, now has but few adherents.

Among earlier investigators, Marschall ("Zeit : fur Ruben") showed that the citrate, acetate, carbonate and butyrate of potassium increased the solubility of sugar in water. Gunning believed the formation of molasses to be due to the formation of potassium saccharates ; and he, together with Pellet and Flourens, ascribed to glucose the property of preventing the crystallisation of sugar. Degener, on the other hand, declared that glucose of itself had no molasses forming effect. The whole subject has been very ably reviewed and investigated by Geerligs (S.C. 284-292 ; 311-313), who has shown that the presence of organic potassium salts prevents the crystallisation of sugar, but that no fixed rule can be laid down dependent on the amount of potassium salt present, and that this molasses forming effect is diminished by the simultaneous presence of glucose ; this phenomenon he explains on the assumption that the potassium salt forms with sugar a molecular compound, and that in the presence of

glucose the potassium salt unites with the glucose in preference to the sugar. He further shows that, contrary to what has been stated and often repeated, glucose of itself does not invert sugar; but in the presence of inorganic alkaline salts, as nitrates, chlorides, sulphates, and of ammonium salts generally, sugar is inverted under the influence of glucose. This inversion takes place to a less degree in the presence of apoglucينات,\* and is inappreciable when alkaline acetates and other salts of weak acids only are present. Further experiments made by Geerligs show that, of those salts present in molasses, the sugar precipitating effect of the calcium salts is greatest, of the sodium salts least, the potassium salts being intermediate; but that owing to molasses containing sodium salts being less viscid than when containing calcium salts, the replacement of the latter by sodium salts may often be advisable.

The causes tending to the formation of molasses may be summed up:—

1. The presence of non-sugar requiring water for its removal, such water carrying away sugar.
2. The formation of molecular compounds consisting of sugar and organic potassium salts.
3. Inversion under the influence of acids, as when working with phosphoric acid, and under the influence of glucose and inorganic salts.
4. An excess of lime acting on the glucose and giving rise to organic salts, which then act as in 2 and 3.
5. Viscosity of syrups resulting in the formation of

\* The decomposition products formed by the action of lime on glucose.

fine grain, which passes through the centrifugal mesh.

6. Viscosity of syrups requiring a large amount of water for curing.

7. Careless pan boiling, resulting in fine grain.

As tending to prevent the formation of molasses, Geerligs indicates, but does not recommend, the use of baryta, inclining more to the carbonatation process ; and when the usual defecation process is employed, he advises :—

1. Use as little lime as possible in defecation, but, of course, enough to get a good clarification.

2. Prevent by rapid working and cleanliness every source of acidity, because if the juices get sour they require fresh quantities of lime to neutralise the acid, and therefore fresh quantities of salts are produced.

3. If any excess of lime has been used, remove it by the use of phosphoric or sulphurous acid, which decompose some of the organic acids and precipitate the lime.

4. Extract the salts from the after product *massecuites* by putting the latter under water.

Geerligs (*loc : cit :*) shows that the ratio of glucose to alkalinity of ash calculated as  $K_2O$ , very approximately measures the solubility of the sugar in the molasses in water ; this relation is well shown in the analyses given above, and this ratio may very well be made use of in determining the advisability of reboiling after molasses.

## OBSCURATION.

(See also under *Caramel.*)

The obscuration of a spirit is the difference between the actual proof strength and the apparent proof



strength as determined by the alcoholometer; thus spirit showing 40·0 over proof by the alcoholometer, and of actual strength 43·1 over proof, is said to have an obscuration of 3·1. The obscuration is best determined by Tabaire's method :—

1. Take the apparent strength by the hydrometer.
2. Evaporate about 200 c.c. on a water bath till all the alcohol is removed; take up the residue with water, and make up to the volume of spirit taken.
3. Take the density of the solution of the residue either by the pycnometer or by a hydrometer graduated to read to ·0001. It is absolutely essential that all measurements are made at that temperature at which the instruments are graduated.

Calculation : Let  $x$  = specific gravity of the obscured spirit, and  $d$  = specific gravity of the residue dissolved in water ; then  $\frac{x}{d}$  = original gravity of the spirit.

Example : Coloured rum stands 21·0° Sikes, at 84° F. indicating an apparent strength of 40·6 O.P. ; the specific gravity corresponding to 21·0° Sikes is ·8512. The residue dissolved in water at 84° F. is of density 1·0040 ; then original gravity of the spirit =  $\frac{·8512}{1·0040} = ·8478$ . The Sikes indication corresponding to a specific gravity of ·8478 is 19·0°, indicating a spirit 42·8 O.P. ; hence the obscuration is 42·8 - 40·6 = 2·2.

An older formula for use with this method gives  $x - d$  = original gravity of the spirit.

In the following table are calculated obscurations from the observed density of the residue dissolved in water, the standards adopted for the calculation being a spirit of strength 40·6 O.P. (= 21·0° Sikes) at a tem-

perature of 84° F.; the table is applicable to spirits varying considerably from these adopted standards.

### OBSCURATION TABLE.

Density of dissolved residue.	Obscuration	Density of dissolved residue.	Obscuration	Density of dissolved residue.	Obscuration
1·0000	0·0	1·0026	1·4	1·0052	2·8
1·0002	0·2	1·0028	1·5	1·0054	2·9
1·0004	0·3	1·0030	1·7	1·0056	3·0
1·0006	0·4	1·0032	1·8	1·0058	3·1
1·0008	0·5	1·0034	1·9	1·0060	3·1
1·0010	0·6	1·0036	2·0	1·0062	3·2
1·0012	0·7	1·0038	2·1	1·0064	3·3
1·0014	0·8	1·0040	2·2	1·0066	3·4
1·0016	0·9	1·0042	2·3	1·0068	3·5
1·0018	1·0	1·0044	2·4	1·0070	3·6
1·0020	1·1	1·0046	2·5	1·0072	3·7
1·0022	1·2	1·0048	2·6	1·0074	3·7
1·0024	1·3	1·0050	2·7	1·0076	3·8
				1·0078	3·9

### OILS.

In a large factory using considerable amounts of oil, tests of the oils supplied should occasionally be made; the complete examination requires complicated apparatus, but the following simple tests can be made.

*Viscosity.* In the absence of a specially-constructed viscosimeter an instrument may be improvised: a pipette of 100 c.c. or 50 c.c. capacity is selected, with orifice so large that when filled with oil and held vertically the oil will be emptied in about 500 seconds; two marks are made on the pipette, one on the upper and one on the lower portion of the stem; the pipette is filled with the oil under examination, and placed in an exactly vertical position in a burette holder; this is easily effected by means of a plumb line and spirit level; during the operation of adjusting the pipette to

a vertical position, the oil is kept from flowing out by closing the upper end by a rubber tube and a pinch cock; when the pipette is adjusted the pinch cock is opened, and the time taken for the oil to flow out between the two marks is taken by a stop watch; with very little practice consecutive experiments can be made, consistent to two-fifths of a second. In comparing results it is customary to refer results to a standard, and for this purpose pure rape seed oil is commonly used; the apparatus being standardised with this oil under the conditions under which the other oils are tested. If  $n_1$  be the number of seconds required for the flow of the standard oil,  $n_2$  for the oil under trial,  $s_1$  be the specific gravity of the standard oil,  $s_2$  that of the oil under trial,  $v_1$  and  $v_2$  the viscosities of the standard oil and of that under trial respectively, then

$$v_2 = v_1 \frac{n_2 s_2}{n_1 s_1}.$$

All experiments must be made at one constant temperature. Another method consists in ascertaining the time taken for a drop of oil to flow down an inclined plane of glass or polished metal.

*Acidity.* Shake a portion of the oil with hot distilled water; and after the two layers have separated, test the water with litmus or other indicator.

*Adulteration.* The presence of an adulterant can be detected by comparing the specific gravity of the suspected oil with that of a sample of undoubted purity; except in very extreme cases a determination by the hydrometer is not sufficiently accurate, so that the specific gravity must be obtained by weighing in a

specific gravity bottle. The presence of a vegetable oil in a mineral oil may be detected by heating to 100° C. about two grams of the oil with about 25 c.c. of alcoholic potash solution ; the potash is determined before and after experiment by titration with standard acid ; if the amount of potash found after treatment is less than that originally present, it is an indication of the presence of vegetable oils, due to the saponification of the latter by the potash. For more detailed information see Allen's "Commercial Analysis."

### OSMOSIS.

A solution of any soluble body in water, when separated from a weaker or stronger solution by a porous membrane, tends to mix with the latter until the concentrations of the two are the same ; this phenomenon is known as osmosis, and has been applied to effect a separation of the salts in molasses from the sugar with the object of increasing the yield in crystallised sugar. The apparatus, called an osmogene, used for this purpose, consists of a series of parchment membranes held in position by wooden frames ; alternate compartments are filled, one with molasses and one with water ; it is found that the salts present in the molasses in great part pass into the water together with some of the sugar, and that the purity of the osmosed molasses is increased ; however, consequent upon the necessary dilution, the loss of sugar in the osmosis, the length of time required for the process, the increased yield does not in general pay for increased expenditure, and the process is now but

little used ; an application of osmosis is, however, found in covering massecuites set to cool in tanks with a foot or so of water, when a partial osmosis takes place resulting in an increased yield (see under *Molasses*).

### PATENTS AND SPECIAL PROCESSES.

The number of patents that have been taken out for improvements in sugar manufacture is legion, and no attempt is made here to give an even partial list ; some of historic interest are, however, here noted. A fairly complete list will be found in Spon's "Encyclopædia" (Art. Sugar).

H. Newton (1848) dried and pulverised the cane to facilitate extraction of the sugar. Gaddesen (1845), Fletcher (1862), Wyatt (1871), and several others introduced evaporators consisting essentially of revolving discs or coils heated internally with steam, so placed that the lower half of the disc was immersed in the liquid, and on rotation drew out and exposed to the air a thin film ; these had an extensive use, and are to a small extent still employed. Fryer (1865, 1877) introduced his concretor (see *Evaporation*). The vacuum pan and the filter press were both introduced by Howard early in the nineteenth century, and have both retained to a large extent their original form. Very recent improvements in the former are the moving coil of Aitken and McNeill, and Winter's patent to introduce air into the pan at a late period so as, by thorough mixing of the massequite, to dissolve up fine grain. Rillieux invented multiple evaporation in vacuo in 1830. The first apparatuses were indifferently constructed,

and proved a failure; they were worked in Louisiana successfully about 1850, introduced into Java in 1872, and into the West Indies a little later; strangely enough, the continental beet factors were slow at first to adopt them. The most important recent improvements have been Chapman's system of circulation by means of syphons (1888), the film evaporators of Yaryan (1880) and of Lillie (1888), and Watson's and Robertson's evaporators, where the cross section of the tubes carrying the liquid decreases proportionally to the volume of the same.

Char has practically no use now in cane sugar factories; many artificial substitutes, such as lignite, gravel, charred peat, have been patented; recently Soxhlet has used diatomaceous earth on the surface of filter clothes with, it is said, considerable success. Bag filters were introduced by Cleland in 1824, and filtration into a vacuum has been patented by Nash (1854) and Cowen (1863). The centrifugal machine was originally conceived by Hardman in 1843, and applied successfully in France by Dubeunfaut a few years later. The forms devised by Weston and Hepworth (see *Centrifugal*) are now generally used; recent inventions have for their object a continual feed and discharge. The greatest improvement of recent years is the application of an old idea, crystallisation in movement (*q.v.*).

Of chemicals may be mentioned blood (Fordyce, 1772); alum, lime, and chalk (Howard, 1813); sulphurous acid, introduced probably first by Tcery; sulphurous acid to remove lead (Scoffern, 1847);

tannin, oxalic acid, and gallic acid for a similar purpose (Galloway, 1863); phosphoric acid to remove lime (Oxland, 1851), also the basis of the Erhmanite process; (oxalic acid has been used for a similar purpose). Lime and carbonic acid (Possóz, 1859); bleaching powder (Herepath, 1862); ozone (Beanes, 1866). Of processes of greater interest that have been worked on an extended scale, may be cited Duncan and Newland's process, in which the potash salts are removed by the addition of sulphate of aluminium, forming a slightly soluble potash alum, which is recovered; oxalic acid has also been proposed for use in a similar way, taking advantage of the slightly soluble potassium oxalate. In beet factories, Steffen's and Schleiber's lime and strontia processes are largely employed; in these insoluble saccharates of lime or strontia are formed, separated from the mother liquor by filtration, and decomposed by the action of carbonic acid gas; the large amounts of invert sugar present in cane molasses are said to form an insuperable obstacle to their use. The trend of recent invention is towards complete suppression of low products, either by application of crystallisation in motion processes, or by very complete clarifications as in the Ranson process, where this is effected by alternate oxidation and reduction by means of hydrogen peroxide and hydrosulphurous acid.

### POLARISCOPE.

Ordinary light is supposed to be the effect on the eye of vibrations of the ether, these vibrations taking place in all directions; by certain optical devices these vibra-

tions may be confined to one plane, and such light is called polarised light; the plane in which the vibrations occur being called the plane of polarisation; polarised light differs from ordinary light in that, when passed through certain bodies, *e.g.*, quartz, cane sugar, the plane of polarisation is rotated; bodies which possess this property are called optically active, and instruments for measuring this activity are called polariscopes. The laws which govern these phenomena are:—

1. The angle through which the plane of polarisation is rotated is proportional to the length of the active material effecting rotation through which the ray of polarised light passes.

2. The angle through which the plane of polarisation is rotated is in general (very nearly) proportional to the concentration of the solution.

3. The angle through which the plane of polarisation is rotated is dependent upon the temperature, the nature of the light, and of the solvent.

In the case of cane sugar the variation with temperature and concentration is very small, and may be neglected within fairly wide limits, especially so in technical analysis, where much larger sources of error are introduced; the kind of light used and the nature of the solvent must always be the same. For scientific observations the light always used is the yellow monochromatic sodium light, the rotations being expressed as  $[\alpha]_D$ , and being the observed angle of rotation; but for technical sugar analysis, instruments are generally made to use ordinary white light such as that given off



by a paraffin lamp ; a Welsbach gas burner or incandescent electric light are also recommended where available ; where monochromatic light is used, the flame of a specially-constructed spirit lamp or Bunsen burner is usually coloured by a bead of sodium chloride (common salt). Dupont states that better results are obtained by using molecular proportions of sodium chloride and sodium phosphate.

The standard length of solution used in analysis is 20 c.m., and observations are always referred to this as standard ; for special purposes longer or shorter tubes may be employed.

Polariscopes specially constructed for sugar analysis are provided with a scale, such that when a certain weight of pure sugar, called the normal weight, is dissolved in 100 c.c. of water, a reading of 100 is observed when using a 20 c.m. tube ; when the normal weight of a substance containing sugar is dissolved in 100 c.c. of water and observed in a 20 c.m. tube, the reading, with the limitations mentioned above, will give in the absence of other active bodies the percentage of sugar in the substance under analysis ; or instead of weighing out the normal weight some other weight may be taken, and the percentage of sugar obtained from the observed reading by calculation ; when dealing with liquids as cane juices, a quantity may be weighed out, or the substance may be polarised directly or after dilution, the pounds of sugar per gallon or grams per litre being obtained by calculation ; the percentage of sugar being found when the density of the solution is known.

The tubes used for observing the polarisation of the solution are made of metal or glass, with a screw thread cut on the ends; the ends are exactly flush, and are closed by glass discs kept in place by metal caps screwing on to the ends of the tube. For exact work tubes are made provided with a water jacket to maintain constant temperature; in the most recent form of tube the solution is introduced into the tube by a funnel, the solution entering the tube expelling that already in through a syphon apparatus; this form is very convenient for rapid work.

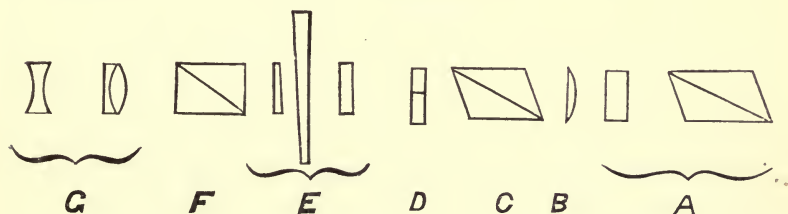
All forms of polariscopes depend for their working on the same principle; when the scale of the instrument is set at zero and no optically active solution is introduced, on looking through the instrument towards the source of light a sharply-defined, easily recognisable field, termed the neutral position, is seen, which is destroyed on moving the scale a very little from the zero position; if an optically active solution be introduced into the instrument, the neutral position is also destroyed; the instruments are provided with an appliance called the compensator, by means of which a rotation equal and opposite to that due to the optically active solution is produced, so that the neutral position again appears; the rotation due to the adjustment of the compensator is read off a scale, and this is the same due to the optically active solution.

When reading polariscopes extraneous light should be excluded; the most convenient method of effecting this is to use the polariscope in a dark room, the source

of light being kept in another room, and light admitted to the instrument by a slit in the partition; where this is inconvenient, good results can be obtained by enclosing the instrument in a wooden box, about 4 ft. long by 2 ft. in width and depth; one side near the eye piece is left open, the light from the lamp being admitted through a slit in the opposite end; the internal parts of the box should be painted black.

Polariscopes in use in sugar laboratories may be divided into two classes, the transition tint and the half shadow instruments.

The optical parts of this transition tint instrument are shown below: *A* is the colour compensator, and



serves to correct the colour due to dark coloured solutions; it consists of a Nicol Prism\* and a plate of quartz. *B* is a convex lens serving to make the rays of light parallel. *C* is a Nicol Prism, called the polariser. *D* is a plate of quartz, either 3.75 m.m. or 7.50 m.m. thick; one half of this is of laevorotatory, and one half of dextrorotatory quartz. *E* is the compensator, the action of which is explained below. *F* is a Nicol Prism termed the analyser, the principal

\* For the explanation of this and for more detailed information, see Landolt's "Handbook for the Polariscopes."

section of which may be parallel to that of the polariser, in which case  $D$  is 3.75 m.m. thick, or perpendicular thereto when  $D$  is 7.50 m.m. thick.  $G$  is a telescope serving to focus the field on the eye of the observer. To understand the principle of the instrument, consider the parts  $C$ ,  $D$ ,  $F$ . Ordinary white light passing through  $C$  is polarised, and meeting the active plate of quartz,  $D$ , suffers rotation; ordinary white light is believed to be composed of red, orange, yellow, green, blue, indigo, and violet rays; these different components of white light are not rotated in the same degree by a quartz plate, the red rays being rotated least, and the blue and indigo most; the white light, now decomposed into its components, passes on to the analyser  $F$ , and thence to the eye of the observer; if, when the principal axes of  $F$  and  $C$  are parallel,  $D$  be 3.75 m.m. thick, the yellow rays do not pass through  $F$ , but are totally eliminated, the remainder combining to form a pale rose tint. This rose tint is very sensitive, and immediately is destroyed if either  $C$  or  $F$  be rotated, or if any active material be introduced between the source of light and the eye of the observer; for then, owing to the quartz plate  $D$  being made up, one half of laevo and one half of dextrorotatory quartz, the different coloured rays into which white light is decomposed are differently rotated on either side of the field, on the one side red rays and on the other green rays predominating, so that the field of vision appears as two differently-coloured halves; if, then, an active material be so introduced, producing a rotation of  $\alpha$  degrees, the pale rose tint could be restored by

turning the analyser  $F$  through an angle  $-a$  degrees, thus neutralising the rotation due to the active material, the angle through which  $F$  was turned being read off a scale; compensation is not, however, effected in this way. The compensator consists of a plate of quartz, which may be either dextro or laevorotatory, and of two wedges of quartz—one of which is fixed and carries a scale, the other being movable by a rack and pinion gear and carrying a vernier. These quartz wedges are of similar optical activity, but different to that of the quartz plate; when the scale is at the zero position, the combined thickness of the wedges is equal to that of the quartz plate, so that the compensator produces no effect on the polarised light; if, then, an active material be introduced into the field of vision by moving the sliding quartz wedge, a rotation equal in magnitude, but opposite in sign, to that due to the active material is obtained in the compensator, the critical point in the observation being determined by the reappearance of a uniform pale rose tint in the field of vision. The colour compensator  $A$  consists of a Nicol prism and plate of quartz; when working with dark coloured solutions, the sensitive rose tint does not appear owing to the absorption of yellow light from the solution itself; by rotating the compensator  $A$ , the components of white light which pass to the eye of the observer can to a certain extent be regulated, serving to restore the rose tint at the neutral position.

The half shadow instruments depend on the fact that when light passes from one Nicol prism to a second, the principal axis of which is perpendicular to the first, no

light is transmitted and darkness results; if, however, the prisms have their principal axes parallel all the light is transmitted, and when set at an angle a portion passes. If, then, between two Nicol prisms, set so that their principal sections are perpendicular, an optically active solution be placed, light will reach the eye of the observer, the active solution having the same effect as if one of the prisms had been turned through an angle; to again obtain the position of total darkness, one of the prisms must be turned through an angle equal and opposite to that through which the plane of polarisation is rotated by the active material. As the position of total darkness cannot be recognised with exactitude, the following device is used to render the instrument sensitive: one half of the field of vision is covered by a thin plate of active quartz; then, when the two Nicol prisms are so set as to have their principal sections perpendicular to each other, that half of the field which is not covered by the plate of quartz will be totally dark, but the other half will be illuminated; when set so that the principal planes of the Nicol prisms are at an angle equal and opposite to that through which the plane of polarisation is rotated by the thin plate of quartz, that half of the field covered by the thin plate of quartz is totally dark, and the other half is illuminated. Between these two positions there is a point where both halves are equally in shadow, and this position is taken as the neutral position. In the Laurent form of instrument, compensation is effected by rotating one of the Nicol prisms called the analyser through an angle equal and opposite to that due to the active solution under

examination, the rotation being read off a circular scale ; in other forms compensation is effected by sliding wedges of quartz, as described under the transition tint instrument. In the latest form of instrument the field is divided into three parts, which at the neutral position are uniformly in shadow ; but in other positions the central portion is shaded, the two outer divisions being light or *vice versa*.

The manipulation of a polariscope is exceedingly simple. The first step is to check the zero ; this is done by reading the instrument with no active body interposed in the body of the instrument ; if the neutral position does not coincide exactly with the zero, the necessary correction must be determined as the mean of several observations, and be added or subtracted from the subsequent observations as the case may be. As different observers seldom find the same neutral position as a zero, means are provided to adjust for zero by constructing the analyser (the Nicol prism next the eye) so that it may be slightly rotated ; it is, however, better, especially when instruments are used by others than experts, to use a correction than to attempt to adjust the instrument. Polariscopes are now constructed with such skill that errors in the position of the zero may safely be attributed to rough usage. After checking the zero the glass cap is put in position on one end of the tube, the cover being screwed securely into position, but not so as to place any undue pressure on the glass cap ; the tube is rinsed out with the solution under analysis, and then filled and closed by the second glass cap ; the tube is then placed in the body



of the instrument and the reading observed ; to obtain good definition the solution must be quite bright and clear, and the glass caps perfectly clean.

A polariscope should be treated with exceptional care ; when not in use it should be kept in a case. If the optical parts ever require cleaning, this should be done with a clean piece of chamois leather ; the polariscope must not be placed too close to the lamp, as a rise in temperature may cause the setting of the prisms to melt, disturbing their proper position.

Polariscopes are only accurate for the temperature at which they are graduated, and for one definite weight of sugar. Collecting all the corrections into one, Dr. Wiley found that, for ordinary Mohr flasks, a polariscope correct at  $17.5^{\circ}$  C. gave a reading too low by  $.029^{\circ}$  for each rise of  $1^{\circ}$  C. ; for average work in the tropics at  $30^{\circ}$  C., this is equivalent to an error of about  $.4^{\circ}$  between  $17.5^{\circ}$  C. and  $30^{\circ}$  C. ; polariscopes are now made which are stated to be independent of the temperature.

For the transition tint instrument, 26.048 grams sugar dissolved in 100 c.c. water give a reading of  $100^{\circ}$  ; for the half shadow instruments, the normal weight is given by different observers as 16.19 grams, 16.2 grams, 16.3 grams, 16.35 grams ; the table given below is calculated for a value of 16.35 grams. Calculations are made : 16.250 grams molasses dissolved in 100 c.c. water, give a reading of 23.2 in the transition tint instrument ; the percentage of sugar calculated from the direct reading then is  $\frac{26.048 \times 23.2}{16.250} = 37.2$  ; or



when dealing with juices measured volumetrically : polarisation in half shadow instrument of a juice of density 1.0760 is, after a 10 % dilution with lead acetate, 95.6 ; the sugar expressed as pounds per gallon then is  $95.6 \times 1.1 \times .01635 = 1.719$ , and expressed as a percentage on the weight of the juice  $\frac{17.19}{1.0760} = 15.91\%$ .

*Specific rotatory power.* The angle through which polarised light of definite wave length is turned, when it passes through a layer whose thickness is inversely proportional to the specific gravity of the liquid, is called the specific rotatory power of that liquid. It is denoted by  $[\alpha]$ , and we have the relation  $[\alpha] = \frac{\alpha}{ld}$  where  $\alpha$  is the observed angle,  $l$  the thickness of the layer, and  $d$  the density of the liquid. The decimetre is usually employed as the unit of length. (*Ostwald.*)

Below is given a table of the rotatory power of the sugars of technical interest, as well as one of the equivalence of the degrees of the various polariscope scales.

TABLE OF THE SPECIFIC ROTATION OF VARIOUS SUGARS.

Sugar.	$[\alpha]_D$	$[\alpha]_J$
Saccharose ..	+ 66.5 in 10% solution at 20° C. .. ..	+ 73.8
Maltose ..	+ 139.2 .. ..	+ 154.5
Dextrose ..	+ 52.7 in 10% solution at 20° C. .. ..	+ 58.5
Levulose {	- 101.38 - .56 <i>t</i> + .108 ( <i>p</i> - 10), <i>t</i> = degrees C° and <i>p</i> the unit concentration of 40 grams per 100 c.c.	- 109.7
Raffinose ..	+ 105 .. ..	
Lactose ..	+ 52.7 at 20° C. .. ..	+ 58.5
Dextrin ..	+ 195.0 .. ..	+ 216
Invert Sugar {	Calculate from rotations of dextrose and levulose ; inactive at 87.2° C.	

*Equivalence of the degrees of various scales.*

Grams of Sugar in 100 c.c.

1° Scale of Mitscherlich = .750.

1° ,, ,, Soleil-Duboscq = .1619 to .1635.\*

1° ,, ,, Ventzke-Soleil = .26048.

1° ,, ,, Wild = .10.

1° ,, ,, Laurent or Duboscq = .1619 to .1635.\*

1° ,, ,, Mitscherlich = 4.635 Laurent = 2.879

Ventzke = 7.5 Wild.

1° Scale of Laurent = .215 Mitscherlich = .620

Ventzke = .1619 Wild.

1° Scale of Ventzke = .346 Mitscherlich = 1.608

Laurent = 2.6048 Wild.

1° Scale of Wild = .618 Laurent = .384 Ventzke =  
.133 Mitscherlich.

1° Wild = .1328 circular degree D.

J 1° Soleil-Duboscq = .2167 ,, ,, D.

J 1° ,, ,, = .2450 ,, ,, J.

J 1° Soleil-Ventzke = .3455 ,, ,, D.

J 1° ,, ,, = .3906 ,, ,, J.

\* This figure was originally determined by Clerget as .16417. Later determinations have given .1619 and .1635. The last determination by Tollens gives .16337.

## PRODUCTS OF '1635.

	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	0·00	·016	·033	·049	·065	·082	·098	·114	·131	·147
1	·164	·180	·197	·213	·229	·246	·262	·278	·295	·311
2	·327	·343	·360	·376	·392	·409	·425	·441	·458	·474
3	·491	·507	·524	·540	·556	·573	·589	·605	·622	·638
4	·654	·670	·687	·703	·719	·736	·752	·768	·785	·801
5	·818	·834	·851	·867	·883	·900	·916	·932	·949	·965
6	·981	·997	1·014	1·030	1·046	1·063	1·079	1·095	1·112	1·128
7	1·145	1·161	1·178	1·194	1·210	1·227	1·243	1·259	1·276	1·292
8	1·308	1·324	1·341	1·357	1·373	1·390	1·406	1·422	1·439	1·455
9	1·472	1·488	1·505	1·521	1·537	1·554	1·570	1·586	1·603	1·619
10	1·635	1·651	1·668	1·684	1·700	1·717	1·733	1·749	1·766	1·782
11	1·799	1·815	1·832	1·848	1·864	1·881	1·897	1·913	1·930	1·946
12	1·962	1·978	1·995	2·011	2·027	2·044	2·060	2·076	2·093	2·109
13	2·126	2·142	2·159	2·175	2·191	2·208	2·224	2·240	2·257	2·273
14	2·289	2·305	2·322	2·338	2·354	2·371	2·387	2·403	2·420	2·436
15	2·453	2·469	2·486	2·502	2·518	2·535	2·551	2·567	2·584	2·600
16	2·616	2·632	2·649	2·665	2·681	2·698	2·714	2·730	2·747	2·763
17	2·780	2·796	2·813	2·829	2·845	2·862	2·878	2·894	2·911	2·927
18	2·943	2·959	2·976	2·992	3·008	3·025	3·041	3·057	3·074	3·090
19	3·107	3·123	3·140	3·156	3·172	3·189	3·205	3·221	3·238	3·254
20	3·270	3·286	3·303	3·319	3·335	3·352	3·368	3·384	3·401	3·417
21	3·434	3·450	3·467	3·483	3·499	3·516	3·532	3·548	3·565	3·581
22	3·597	3·613	3·630	3·646	3·662	3·679	3·695	3·711	3·728	3·744
23	3·761	3·777	3·794	3·810	3·826	3·843	3·856	3·873	3·890	3·906
24	3·924	3·940	3·957	3·973	3·989	4·006	4·022	4·038	4·055	4·071
25	4·088	4·104	4·121	4·137	4·153	4·170	4·186	4·202	4·219	4·235
26	4·251	4·267	4·284	4·300	4·316	4·333	4·349	4·365	4·382	4·398
27	4·415	4·431	4·448	4·464	4·480	4·507	4·523	4·539	4·556	4·572
28	4·578	4·594	4·611	4·627	4·643	4·660	4·676	4·692	4·709	4·725
29	4·742	4·758	4·775	4·791	4·807	4·824	4·840	4·856	4·873	4·889
30	4·905	4·921	4·938	4·954	4·970	4·987	5·003	5·019	5·036	5·052
31	5·069	5·085	5·102	5·118	5·134	5·151	5·167	5·183	5·200	5·216
32	5·232	5·248	5·265	5·281	5·297	5·314	5·330	5·346	5·363	5·379
33	5·396	5·412	5·429	5·445	5·461	5·478	5·494	5·510	5·527	5·543
34	5·560	5·576	5·593	5·609	5·625	5·642	5·658	5·674	5·691	5·707
35	5·723	5·739	5·756	5·772	5·788	5·805	5·821	5·837	5·854	5·870
36	5·887	5·903	5·920	5·936	5·952	5·969	5·985	6·001	6·018	6·034
37	6·050	6·066	6·083	6·099	6·115	6·132	6·148	6·164	6·181	6·197
38	6·214	6·230	6·247	6·263	6·279	6·296	6·312	6·328	6·345	6·361
39	6·377	6·393	6·410	6·426	6·442	6·459	6·475	6·491	6·508	6·524
40	6·540	6·556	6·573	6·589	6·605	6·622	6·638	6·654	6·671	6·687
41	6·704	6·720	6·737	6·753	6·769	6·786	6·802	6·818	6·835	6·851
42	6·867	6·883	6·900	6·916	6·932	6·949	6·965	6·981	6·998	7·014
43	7·031	7·047	7·064	7·080	7·096	7·113	7·129	7·145	7·162	7·178
44	7·194	7·210	7·227	7·243	7·259	7·276	7·292	7·308	7·325	7·341
45	7·358	7·374	7·391	7·407	7·423	7·440	7·456	7·472	7·489	7·505
46	7·521	7·537	7·554	7·570	7·586	7·603	7·619	7·635	7·652	7·668
47	7·685	7·701	7·718	7·734	7·750	7·767	7·783	7·799	7·816	7·832
48	7·848	7·864	7·881	7·897	7·913	7·930	7·946	7·962	7·979	7·995
49	7·912	7·928	7·945	7·961	7·977	7·994	8·010	8·026	8·043	8·059
50	8·175	8·191	8·208	8·224	8·240	8·257	8·273	8·289	8·306	8·322

## PRODUCTS OF 1635.—CONTINUED.

	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
51	8·338	8·354	8·371	8·387	8·403	8·420	8·436	8·452	8·469	8·485
52	8·502	8·518	8·535	8·551	8·567	8·584	8·600	8·616	8·633	8·649
53	8·665	8·681	8·698	8·714	8·730	8·747	8·763	8·779	8·796	8·812
54	8·829	8·845	8·862	8·878	8·894	8·911	8·927	8·943	8·960	8·976
55	8·992	9·008	9·025	9·041	9·057	9·074	9·090	9·106	9·123	9·139
56	9·156	9·172	9·189	9·205	9·221	9·238	9·254	9·270	9·287	9·303
57	9·319	9·335	9·352	9·368	9·384	9·401	9·417	9·433	9·450	9·466
58	9·483	9·499	9·516	9·532	9·548	9·565	9·581	9·597	9·614	9·630
59	9·646	9·662	9·679	9·695	9·711	9·728	9·744	9·760	9·777	9·793
60	9·810	9·826	9·841	9·857	9·873	9·900	9·916	9·932	9·949	9·965
61	9·973	9·989	10·006	10·022	10·038	10·055	10·071	10·087	10·104	10·120
62	10·137	10·153	10·170	10·186	10·202	10·219	10·235	10·251	10·268	10·284
63	10·300	10·316	10·333	10·349	10·365	10·382	10·398	10·414	10·431	10·447
64	10·464	10·480	10·497	10·513	10·529	10·546	10·562	10·578	10·595	10·611
65	10·627	10·643	10·660	10·676	10·692	10·709	10·725	10·741	10·758	10·774
66	10·791	10·807	10·824	10·840	10·856	10·873	10·889	10·905	10·922	10·938
67	10·954	10·970	10·987	11·003	11·019	11·036	11·052	11·078	11·085	11·102
68	11·118	11·134	11·151	11·167	11·183	11·200	11·216	11·232	11·249	11·265
69	11·281	11·297	11·314	11·330	11·346	11·363	11·379	11·395	11·412	11·428
70	11·445	11·461	11·478	11·494	11·510	11·527	11·543	11·559	11·576	11·592
71	11·608	11·624	11·641	11·657	11·673	11·690	11·706	11·722	11·739	11·755
72	11·772	11·788	11·805	11·821	11·837	11·854	11·870	11·886	11·903	11·919
73	11·935	11·951	11·968	11·984	12·000	12·017	12·033	12·049	12·066	12·083
74	12·099	12·115	12·132	12·148	12·164	12·181	12·197	12·213	12·230	12·246
75	12·262	12·278	12·295	12·311	12·327	12·344	12·360	12·376	12·393	12·409
76	12·426	12·442	12·459	12·475	12·491	12·508	12·524	12·540	12·557	12·573
77	12·589	12·605	12·622	12·638	12·654	12·671	12·687	12·703	12·720	12·736
78	12·753	12·769	12·786	12·802	12·818	12·835	12·851	12·867	12·883	12·899
79	12·916	12·932	12·949	12·965	12·981	12·998	13·014	13·030	13·047	13·063
80	13·080	13·096	13·113	13·129	13·145	13·162	13·178	13·194	13·211	13·227
81	13·243	13·259	13·276	13·292	13·308	13·325	13·341	13·357	13·374	13·390
82	13·407	13·423	13·440	13·456	13·472	13·489	13·505	13·521	13·538	13·554
83	13·570	13·586	13·603	13·619	13·635	13·652	13·668	13·684	13·701	13·717
84	13·734	13·750	13·767	13·783	13·799	13·816	13·832	13·848	13·855	13·871
85	13·897	13·913	13·930	13·946	13·962	13·979	13·995	14·011	14·028	14·044
86	14·061	14·077	14·094	14·110	14·126	14·143	14·159	14·175	14·192	14·208
87	14·224	14·240	14·257	14·273	14·289	14·306	14·322	14·338	14·355	14·371
88	14·388	14·404	14·421	14·437	14·453	14·470	14·486	14·502	14·519	14·535
89	14·551	14·567	14·584	14·600	14·616	14·633	14·649	14·665	14·682	14·698
90	14·715	14·731	14·748	14·764	14·780	14·797	14·813	14·829	14·846	14·862
91	14·878	14·894	14·911	14·927	14·943	14·960	14·976	14·991	15·008	15·024
92	15·042	15·058	15·075	15·091	15·107	15·124	15·140	15·156	15·173	15·189
93	15·205	15·221	15·238	15·254	15·270	15·287	15·303	15·319	15·336	15·352
94	15·369	15·385	15·402	15·418	15·434	15·451	15·467	15·483	15·500	15·516
95	15·532	15·548	15·565	15·581	15·597	15·714	15·630	15·646	15·663	15·679
96	15·696	15·712	15·729	15·745	15·761	15·778	15·794	15·810	15·827	15·843
97	15·859	15·875	15·892	15·908	15·924	15·941	15·957	15·973	15·990	16·006
98	16·023	16·039	16·056	16·072	16·088	16·105	16·121	16·137	16·153	16·169
99	16·186	16·202	16·219	16·235	16·251	16·268	16·284	16·300	16·317	16·333

## PRODUCTS OF 26048.

	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
0	0·0	·026	·052	·078	·104	·130	·156	·182	·208	·234
1	·260	·286	·313	·339	·365	·391	·417	·443	·469	·495
2	·521	·546	·573	·599	·625	·651	·677	·703	·729	·755
3	·781	·808	·833	·860	·886	·912	·938	·964	·990	·996
4	1·042	1·068	1·094	1·120	1·146	1·172	1·198	1·224	1·250	1·276
5	1·302	1·328	1·354	1·381	1·407	1·433	1·459	1·485	1·511	1·537
6	1·563	1·589	1·615	1·641	1·667	1·693	1·719	1·745	1·771	1·797
7	1·823	1·849	1·875	1·902	1·928	1·954	1·980	2·006	2·032	2·058
8	2·084	2·110	2·136	2·162	2·188	2·214	2·240	2·266	2·292	2·318
9	2·344	2·370	2·396	2·422	2·448	2·475	2·501	2·527	2·553	2·579
10	2·605	2·631	2·657	2·683	2·709	2·735	2·761	2·787	2·813	2·839
11	2·865	2·891	2·917	2·943	2·969	2·996	3·022	3·048	3·074	3·100
12	3·126	3·152	3·178	3·204	3·230	3·256	3·282	3·308	3·334	3·360
13	3·386	3·412	3·438	3·464	3·490	3·516	3·542	3·569	3·595	3·621
14	3·647	3·673	3·699	3·725	3·751	3·777	3·803	3·829	3·855	3·881
15	3·907	3·933	3·959	3·985	4·011	4·037	4·063	4·090	4·116	4·142
16	4·168	4·194	4·220	4·246	4·272	4·298	4·324	4·350	4·376	4·402
17	4·428	4·454	4·480	4·506	4·532	4·558	4·584	4·610	4·637	4·663
18	4·689	4·715	4·741	4·767	4·793	4·819	4·845	4·871	4·897	4·913
19	4·949	4·975	5·001	5·027	5·053	5·080	5·106	5·132	2·158	5·184
20	5·210	5·236	5·262	5·288	5·314	5·340	5·366	5·393	5·418	5·445
21	5·460	5·496	5·522	5·548	5·574	5·600	5·626	5·653	5·678	5·705
22	5·731	7·757	5·783	5·809	5·835	5·861	5·887	5·913	5·939	5·965
23	5·991	6·017	6·043	6·069	6·095	6·121	6·147	6·173	6·199	6·226
24	6·252	6·278	6·304	6·330	6·356	6·382	6·408	6·434	6·460	6·486
25	6·512	6·538	6·564	6·590	6·616	6·642	6·668	6·684	6·710	6·736
26	6·772	6·799	6·825	6·851	6·877	6·903	6·929	6·955	6·981	7·006
27	7·032	7·059	7·085	7·111	7·137	7·163	7·189	7·215	7·241	7·267
28	7·293	7·319	7·346	7·372	7·398	7·424	7·450	7·476	7·502	7·528
29	7·554	7·580	7·606	7·632	7·658	7·684	7·710	7·736	7·762	7·788
30	7·814	7·840	7·867	7·893	7·919	7·945	7·971	7·997	8·023	8·049
31	8·075	8·101	8·127	8·163	8·189	8·215	8·241	8·267	8·293	8·319
32	8·335	8·361	8·387	8·414	8·440	8·466	8·492	8·518	8·544	8·570
33	8·596	8·622	8·648	8·674	8·700	8·726	8·752	8·778	8·804	8·830
34	8·856	8·882	8·648	8·674	8·700	8·726	8·752	8·778	8·804	8·830
35	9·117	9·143	9·169	9·195	9·221	9·247	9·273	9·299	9·325	9·351
36	9·377	9·403	9·429	9·455	9·482	9·508	9·534	9·560	9·586	9·612
37	9·638	9·664	9·690	9·716	9·742	9·768	9·794	7·820	9·846	9·872
38	9·898	9·924	9·950	9·976	10·003	10·029	10·055	10·081	10·107	10·133
39	10·159	10·185	10·211	10·237	10·263	10·289	10·315	10·341	10·367	10·393
40	10·419	10·445	10·471	10·487	10·513	10·550	10·576	10·602	10·628	10·654
41	10·680	10·716	10·742	10·768	10·794	10·820	10·846	10·872	10·898	10·924
42	10·940	10·966	10·992	11·018	11·044	11·071	11·097	11·123	11·149	11·175
43	11·201	11·227	11·253	11·279	11·305	11·331	11·357	11·383	11·409	11·435
44	11·461	11·487	11·513	11·539	11·565	11·591	11·618	11·644	11·670	11·696
45	11·722	11·748	11·774	11·800	11·826	11·852	11·878	11·904	11·930	11·956
46	11·982	12·008	12·034	12·060	12·086	12·112	12·139	12·165	12·191	12·217
47	12·243	12·269	12·295	12·321	12·347	12·373	12·399	12·425	12·451	12·477
48	12·503	12·529	12·555	12·581	12·607	12·633	12·659	12·686	12·712	12·738
49	12·764	12·790	12·816	12·842	12·868	12·894	12·920	12·946	12·972	12·998
50	13·024	13·050	12·076	12·102	13·128	13·154	13·180	13·206	13·232	13·258

## PRODUCTS OF '26048—CONTINUED.

	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
51	13·285	13·311	13·337	13·363	13·389	13·415	13·441	13·467	13·493	13·519
52	13·545	13·571	13·597	13·623	13·649	13·675	13·701	13·727	13·743	13·779
53	13·805	13·831	13·857	13·883	13·909	13·935	13·962	13·988	14·004	14·040
54	14·066	14·092	14·118	14·144	14·170	14·196	14·222	14·248	14·274	14·300
55	14·326	14·352	14·378	14·404	14·430	14·456	14·483	14·509	14·535	14·561
56	14·587	14·613	14·639	14·665	14·691	14·717	14·733	14·759	14·785	14·811
57	14·847	14·873	14·899	14·925	14·951	14·977	15·003	15·030	15·056	15·082
58	15·108	15·134	15·160	15·186	15·212	15·238	15·264	15·290	15·316	15·342
59	15·368	15·394	15·420	15·446	15·472	15·498	15·525	15·551	15·577	15·603
60	15·629	15·655	15·681	15·707	15·733	15·759	15·785	15·811	15·837	15·863
61	15·889	15·915	15·941	15·967	15·993	16·019	16·046	16·072	16·098	16·124
62	16·150	16·176	16·202	16·228	16·254	16·280	16·306	16·332	16·358	16·384
63	16·410	16·436	16·462	16·488	16·514	16·540	16·567	16·593	16·619	16·645
64	16·671	16·697	16·723	16·749	16·775	16·801	16·827	16·853	16·879	16·905
65	16·931	16·957	16·983	17·009	17·035	17·061	17·087	17·114	17·140	17·166
66	17·192	17·218	17·244	17·270	17·296	17·322	17·348	17·374	17·400	17·426
67	17·452	17·478	17·504	17·530	17·556	17·582	17·608	17·634	17·661	17·687
68	17·713	17·739	17·765	17·791	17·817	17·843	17·869	17·895	17·921	17·947
69	17·973	17·999	18·025	18·051	18·077	18·103	18·129	18·155	18·182	18·208
70	18·234	18·260	18·286	18·312	18·338	18·364	18·390	18·416	18·442	18·468
71	18·494	18·520	18·546	18·572	18·598	18·624	18·650	18·676	18·702	18·729
72	18·755	18·781	18·807	18·833	18·859	18·885	18·911	18·937	18·963	18·989
73	19·015	19·041	19·067	19·093	19·119	19·145	19·171	19·197	19·223	19·250
74	19·276	19·302	19·328	19·354	19·380	19·406	19·432	19·458	19·484	19·510
75	19·536	19·562	19·588	19·614	19·640	19·666	19·692	19·718	19·744	19·770
76	19·797	19·823	19·849	19·875	19·901	19·927	19·953	19·979	20·005	20·031
77	20·057	20·083	20·109	20·135	20·161	20·187	20·213	20·239	20·265	20·291
78	20·318	20·344	20·370	20·396	20·422	20·448	20·474	20·500	20·526	20·552
79	20·578	20·604	20·630	20·656	20·682	20·708	20·734	20·760	20·786	20·812
80	20·838	20·865	20·891	20·917	20·943	20·969	20·995	21·021	21·047	21·073
81	21·099	21·125	21·151	21·177	21·203	21·229	21·255	21·281	21·307	21·333
82	21·359	21·386	21·412	21·438	21·464	21·490	21·516	21·542	21·568	21·594
83	21·620	21·646	21·672	21·698	21·724	21·750	21·776	21·802	21·828	21·854
84	21·880	21·906	21·933	21·959	21·985	22·011	22·037	22·063	22·089	22·115
85	22·141	22·167	22·193	22·219	22·245	22·271	22·297	22·323	22·349	22·375
86	22·401	22·427	22·454	22·480	22·506	22·532	22·558	22·584	22·610	22·636
87	22·662	22·688	22·714	22·740	22·766	22·792	22·818	22·844	22·870	22·896
88	22·922	22·948	22·974	23·001	23·027	23·053	23·079	23·105	23·131	23·157
89	23·183	23·209	23·235	23·261	23·287	23·313	23·339	23·365	23·391	23·417
90	23·443	23·469	23·495	23·522	23·548	23·574	23·600	23·626	23·652	23·678
91	23·704	23·730	23·756	23·782	23·808	23·834	23·860	23·886	23·912	23·938
92	23·964	23·990	24·016	24·042	24·069	24·095	24·121	24·147	24·173	24·199
93	24·225	24·251	24·277	24·303	24·329	24·355	24·381	24·407	24·433	24·459
94	24·485	24·511	24·537	24·563	24·590	24·616	24·642	24·668	24·694	24·720
95	24·746	24·772	24·798	24·824	24·850	24·876	24·902	24·928	24·954	24·980
96	25·006	25·032	25·058	25·084	25·110	25·137	25·163	25·189	25·215	25·241
97	25·267	25·293	25·319	25·345	25·371	25·397	25·423	25·449	25·475	25·501
98	25·527	25·553	25·579	25·605	25·631	25·658	25·684	25·710	25·736	25·762
99	25·788	25·814	25·840	25·866	25·892	25·918	25·944	25·970	25·996	26·022

## PRODUCTION.

No absolute statistics can be given for the different sugar-producing countries, the produce varying greatly from year to year with the season and other causes. The figures given below approximately represent the limits of production at the time of writing (1899).

				Tons.
British Guiana	....	....	....	90,000 to 120,000.
British West Indies	....	....	....	120,000 to 160,000.
Mauritius	....	....	....	140,000 to 180,000.
Australia	....	....	....	80,000 to 120,000.
British India	....	....	....	1,500,000 (for local consumption).
Natal	....	....	....	50,000 to 70,000.
Straits Settlements	....	....	....	60,000 to 80,000.
Egypt	....	....	....	100,000 to 120,000.
Cuba	....	....	....	200,000 to 1,000,000.
Porto Rico	....	....	....	50,000 to 100,000.
Martinique and Guadeloupe	....	....	....	60,000 to 80,000.
Java	....	....	....	500,000 to 700,000.
Philippines	....	....	....	200,000 to 250,000.
Louisiana	....	....	....	200,000 to 300,000.
Hawaii	....	....	....	200,000 to 250,000.
Peru	....	....	....	60,000 to 80,000.
Brazil	....	....	....	200,000 to 250,000.
Argentina	....	....	....	100,000 to 150,000.
Germany	....	....	....	1,700,000 to 1,900,000.
Austria	....	....	....	750,000 to 1,000,000.
France	..	....	....	600,000 to 900,000.

				Tons.
Russia	....	....	....	600,000 to 900,000.
Belgium	....	....	....	200,000 to 300,000.
Holland	....	....	....	100,000 to 200,000.
Other Countries	....	....	....	200,000 to 250,000.

## PUMPS.

TABLE OF THE APPROXIMATE DIMENSIONS OF WET VACUUM PUMPS.

Stroke of Piston: inches	12	14	16	18	20	22	24	26	28	30
Diameter of Air Cylinder: inches	10	12	14	16	18	20	22	24	26	28
Diameter of Steam Cylinder: inches	8	8	10	10	12	12	14	14	16	18
Diameter of Condenser: inches	16	18	20	22	24	26	28	30	32	34
Height of Condenser: inches	55	60	65	70	75	80	85	90	95	100
Revolutions per minute	70	65	65	60	60	55	55	50	45	40
Vapours condensed per hour: lbs.	650	1,000	1,600	2,150	3,050	3,750	4,800	5,800	6,500	7,250
Capacity in gallons of Syrup at 50° Brix concentrated per hour	130	200	320	430	610	750	960	1,160	1,300	1,450

TABLE OF THE APPROXIMATE DIMENSIONS OF DRY VACUUM PUMPS.

Stroke of Piston: inches	12	16	18	20	24	28	32	36	40
Diameter of Air Cylinder "	10	14	15	18	22	26	30	34	38
" Steam " "	8	10	12	14	16	18	20	22	24
" Condenser " "	80	100	130	140	160	180	80	90	100
Height of " "	25	30	40	45	50	55	80	90	100
Revolutions per minute..	120	110	100	90	80	70	60	50	50
Vapours condensed per hour: lbs.	2,500	6,500	9,000	11,500	18,000	25,000	35,000	45,000	60,000



TABLE OF THE DIMENSIONS OF WORTH-  
INGTON PUMPS FOR TANK OR  
LIGHT SERVICE.

SIZE OF PUMP.			Displacement in Gallons per Stroke of one Plunger.	Proper Strokes per minute of one Plunger, varying with kind of Work and Pressure.	Gallons deliver- ed per minute by both Plungers, at stated number of Strokes.	SIZE OF PIPES.			
Diameter of Steam Cylinders.	Diameter of Water Pistons.	Length of Stroke.				Steam.	Exhaust.	Suction.	Discharge
INCHES	INCHES	INCHES				INCHES	INCHES	INCHES	INCHES
3	2 $\frac{3}{4}$	3	.062	100-200	12-24			1 $\frac{1}{2}$	1
4 $\frac{1}{2}$	3 $\frac{3}{4}$	4	.16	100-200	30-60			2 $\frac{1}{2}$	1 $\frac{1}{2}$
5 $\frac{1}{4}$	4 $\frac{3}{4}$	5	.32	100-200	60-125			3	2
6	5	6	.56	100-150	110-160	1	1 $\frac{1}{2}$	4	2 $\frac{1}{2}$
7 $\frac{1}{2}$	5 $\frac{3}{4}$	6	.56	100-150	110-160	1 $\frac{1}{2}$	2	4	3
6	7 $\frac{1}{2}$	6	.95	100-150	190-280	1	1 $\frac{1}{2}$	6	5
7 $\frac{1}{2}$	7 $\frac{1}{2}$	6	.95	100-150	190-280	1 $\frac{1}{2}$	2	6	5
7 $\frac{1}{2}$	8 $\frac{3}{4}$	6	1.22	100-150	240-360	1	1 $\frac{1}{2}$	6	5

TABLE OF THE DIMENSIONS OF WORTH-  
INGTON STANDARD FEED PUMPS.

SIZE OF PUMP.			Maximum Gallons per Hour.	Floor Space Required.	SIZE OF PIPES.			
Diameter of Steam Cylinder.	Diameter of Water Cylinders.	Length of Stroke.			Steam.	Exhaust.	Suction.	Delivery.
INCHES.	INCHES.	INCHES.						
2	1 $\frac{1}{2}$	2 $\frac{3}{4}$	100	21 x 6			1	3 $\frac{3}{4}$
3	1 $\frac{1}{2}$	3	200	26 x 10			1 $\frac{1}{4}$	1
3	1 $\frac{1}{2}$	3	300	26 x 10			1 $\frac{1}{4}$	1
3	2	3	400	26 x 10			1 $\frac{1}{4}$	1
4 $\frac{1}{2}$	2 $\frac{3}{4}$	4	1,000	33 x 13			2	2
5 $\frac{1}{4}$	3 $\frac{1}{2}$	5	1,800	38 x 15			2 $\frac{1}{2}$	2 $\frac{1}{2}$
6	4	6	2,500	44 x 16	1	1 $\frac{1}{2}$	3	3
7 $\frac{1}{2}$	4 $\frac{1}{2}$	6	3,300	48 x 24	1 $\frac{1}{2}$	2	4	3
7 $\frac{1}{2}$	4 $\frac{1}{2}$	10	4,000	72 x 29	1 $\frac{1}{2}$	2	4	3
7 $\frac{1}{2}$	5	10	5,000	72 x 30	1 $\frac{1}{2}$	2	5	5
9	5 $\frac{1}{4}$	10	5,500	72 x 30	2	2 $\frac{1}{2}$	5	5
9	6	10	7,200	72 x 31	2	2 $\frac{1}{2}$	6	5
10	7	10	10,000	72 x 33	2	2 $\frac{1}{2}$	6	6
12	8 $\frac{1}{2}$	10	15,000	80 x 42	2 $\frac{1}{2}$	3	6	6

## TABLE OF DIMENSIONS OF CARBONIC ACID PUMPS.

Quantity of Gas sucked per hour : cb.m.	650	825	1,050	1,300	1,800	2,050	3,375	4,050
Diameter of Steam Cylinder : m.m.	275	350	375	400	470	500	600	700
Diameter of Carbonic Acid Cylinder : m.m.	500	550	600	650	750	800	1,000	1,100
Piston Stroke : m.m. ..	470	550	550	630	700	700	800	1,000
Revolutions per minute..	75	70	70	65	60	60	55	45
Steam inlet : m.m. ..	60	80	80	90	110	110	140	170
Steam outlet : m.m. ..	70	90	90	100	120	120	150	185
Diameter of Suction Pipe : m.m.	110	125	135	150	175	190	240	270
Diameter of Delivery Pipe : m.m.	100	110	125	140	160	170	220	250

(WEGELIN AND HUBNER.)

## REAGENTS.

*Normal Hydrochloric Acid.* 1 c.c. = .03646 gram  $HCl$  = .03546 gram  $Cl$  = .02804 gram  $Ca O$ . Dilute about 80 c.c. acid of density 1.20 to 1000 c.c.; standardise against standard alkali, or determine the chlorine as silver chloride.

*Normal Sulphuric Acid.* 1 c.c. = .04904 gram  $H_2SO_4$ . Dilute about 28 c.c. of the strong acid to 1000 c.c.; standardise against standard alkali, or determine the sulphuric acid as barium sulphate.

*Normal Oxalic Acid.* Prepare by repeated crystallisation pure oxalic acid; dry on a porous earthenware plate or between blotting paper, and select well-formed crystals. Dissolve 63.035 grams ( $O = 16$ ) in 1000 c.c.; 1 c.c. = .063035 gram  $H_2C_2O_4 \cdot 2H_2O$ .

*Normal Alkali Solution.* Dissolve 60 grams caustic soda or 80 grams caustic potash in 1000 c.c., and

standardise against standard acid. 1 c.c. = .0401 gram  $NaHO$  = .0560 gram  $KHO$ .

*Decinormal Potassium Permanganate.* Dissolve about 5 grams  $KMnO_4$  in 1000 c.c., and standardise against pure oxalic acid or ammonium oxalate. 1 c.c. = .00316 gram  $KMnO_4$  = .006303 gram  $H_2C_2O_4 \cdot 2H_2O$  = .007104 gram  $NH_4C_2O_4 \cdot H_2O$ .

*Decinormal Sodium Hyposulphite (Thiosulphate).* Dissolve about 26 grams of the commercial salt in 1000 c.c., standardise with potassium bichromate and iodine. 1 c.c. = .0248 gram  $Na_2S_2O_3$  = .0127 gram  $I$  = .004907  $K_2C_2O_7$ .

*Saccharate of Lime Solution.* Agitate about 10 grams of dry slaked lime in 100 c.c. of a 10% solution of loaf sugar; filter, and keep in a stoppered bottle.

*Pure Sugar.* Powder the best cane loaf sugar, wash with 80% alcohol, and finally with absolute alcohol; dry over sulphuric acid.

*Basic Lead Acetate.* Heat on the water bath for 30 minutes 430 grams neutral lead acetate, 130 grams litharge and 1000 c.c. water; allow to cool, filter, and dilute to a density of 55° Brix.

*Litmus.* Extract powdered litmus five or six times with boiling 80% alcohol; reject the alcoholic solutions, extract the residue with boiling water, and filter; divide the filtrate into two equal portions; to one add a very small excess of acid, and mix the two portions; repeat until the solution is exactly neutral. The papers are prepared by soaking strips of unsized paper in portions

of the neutral solution which have been made just acid or alkaline.

*Plenolphthalein.* Dissolve 1 gram in 100 c.c. proof spirit: if the spirit is acid, neutralise carefully with decinormal alkali; this reagent is colourless in acid, and crimson in alkaline solution; it cannot be used in the presence of ammonia.

*Alumina Cream.* Precipitate a 10% solution of alum by a slight excess of ammonia, and wash by decantation until all the ammonia is removed; preserve suspended in water; this reagent may be used to prepare sugar solutions for the polariscope where the use of lead acetate is inadvisable; when used, the alumina cream and sugar solution should be shaken for a few minutes.

*Invert Sugar Solution.* Dissolve 2.375 grams pure sugar in 50 c.c. water; add 5 c.c. concentrated hydrochloric acid; heat to 68° C. to 70° C., and keep at this temperature for 8 minutes; cool rapidly, and dilute after neutralisation to 1000 c.c. Instead of heating to 70° C., Borträger recommends the solution, after addition of acid, to be allowed to stand overnight; 20 c.c. of this solution contains .05 gram invert sugar.

*Ammonium Molybdate.* Dissolve 10 grams ammonium molybdate in 40 c.c. of ammonia solution, sp. gr. .96; mix with 160 c.c. of dilute nitric acid (120 c.c. of strong acid, and 40 c.c. of water).

*Magnesia Mixture.* Make up 110 grams crystallised magnesium chloride, 140 grams ammonium chloride, and 700 c.c. strong ammonia to 1300 c.c.

TABLES OF THE SPECIFIC GRAVITY OF  
MATERIALS USED IN SUGAR  
HOUSE WORK.

CAUSTIC SODA AT 82.5° F.

(GEERLIGS.)

Percentage of Soda.	Specific Gravity of a percentage of Na <sub>2</sub> O.	Specific Gravity of a percentage of NaOH.	Percentage of Soda.	Specific Gravity of a percentage of Na <sub>2</sub> O.	Specific Gravity of a percentage of NaOH.
1	1.012	1.009	31	1.434	1.339
2	1.027	1.020	32	1.446	1.347
3	1.040	1.032	33	1.458	1.359
4	1.055	1.043	34	1.471	1.370
5	1.071	1.056	35	1.484	1.380
6	1.086	1.067	36	1.496	1.391
7	1.111	1.078	37	1.511	1.401
8	1.116	1.089	38	1.526	1.411
9	1.129	1.100	39	1.539	1.422
10	1.142	1.112	40	1.554	1.433
11	1.158	1.123	41	1.566	1.443
12	1.172	1.133	42	1.579	1.452
13	1.187	1.145	43	1.593	1.464
14	1.200	1.156	44	1.606	1.474
15	1.215	1.167	45	1.617	1.484
16	1.230	1.178	46	1.632	1.495
17	1.241	1.184	47	1.645	1.503
18	1.254	1.198	48	1.658	1.514
19	1.266	1.209	49	1.673	1.524
20	1.284	1.221	50	1.685	1.535
21	1.296	1.234	51	1.700	1.545
22	1.311	1.243	52	1.714	1.555
23	1.325	1.254	53	1.725	1.565
24	1.337	1.265	54	1.740	1.575
25	1.351	1.275	55	1.755	1.586
26	1.365	1.286	56	1.770	1.596
27	1.374	1.296	57	1.780	1.606
28	1.391	1.306	58	1.795	1.617
29	1.406	1.317	59	1.810	1.628
30	1.420	1.328	60	1.825	1.638

## SODIUM CARBONATE AT 82.5° F.

(SCHIFF.)

Specific Gravity.	Percentage of $\text{Na}_2\text{CO}_3$ in $\text{H}_2\text{O}$ .	Percentage of $\text{Na}_2\text{CO}_3$ .	Specific Gravity.	Percentage of $\text{Na}_2\text{CO}_3$ in $\text{H}_2\text{O}$ .	Percentage of $\text{Na}_2\text{CO}_3$ .
1.0038	1	.370	1.1035	26	9.635
1.0076	2	.741	1.1076	27	10.005
1.0114	3	1.112	1.1117	28	10.376
1.0153	4	1.482	1.1158	29	10.746
1.0192	5	1.853	1.1210	30	11.118
1.0231	6	2.223	1.1242	31	11.448
1.0270	7	2.594	1.1284	32	11.859
1.0309	8	2.965	1.1326	33	12.230
1.0348	9	3.335	1.1368	34	12.600
1.0388	10	3.706	1.1410	35	12.971
1.0428	11	4.076	1.1452	36	13.341
1.0468	12	4.447	1.1494	37	13.712
1.0508	13	4.817	1.1536	38	14.082
1.0548	14	5.188	1.1578	39	14.453
1.0588	15	5.558	1.1620	40	14.824
1.0628	16	5.928	1.1662	41	15.195
1.0668	17	6.299	1.1704	42	15.566
1.0708	18	6.670	1.1746	43	15.936
1.0748	19	7.041	1.1788	44	16.307
1.0789	20	7.412	1.1830	45	16.677
1.0830	21	7.782	1.1873	46	17.048
1.0871	22	8.153	1.1916	47	17.418
1.0912	23	8.523	1.1959	48	17.789
1.0953	24	8.894	1.2002	49	18.159
1.0994	25	9.264	1.2045	50	18.530

## MILK OF LIME AT 17.5° C.

(BLATTNER.)

Degree Beaumé.	Grams Lime per 1,000 c.c.	Weight of one litre of Milk of Lime.	Degree Beaumé.	Grams Lime per 1,000 c.c.	Weight of one litre of Milk of Lime.
		GRAMS.			GRAMS.
1	7.5	1,007	16	159	1,125
2	16.5	1,014	17	170	1,134
3	26	1,022	18	181	1,142
4	36	1,029	19	193	1,152
5	46	1,037	20	206	1,162
6	56	1,045	21	218	1,171
7	65	1,052	22	229	1,180
8	75	1,060	23	242	1,190
9	84	1,067	24	255	1,200
10	94	1,075	25	268	1,210
11	104	1,083	26	281	1,220
12	115	1,091	27	295	1,231
13	126	1,100	28	309	1,241
14	136	1,108	29	324	1,252
15	148	1,116	30	339	1,263

## CAUSTIC POTASH AT 15° C.

(TUNNERMANN.)

Specific Gravity.	Percentage of K <sub>2</sub> O.	Specific Gravity.	Percentage of K <sub>2</sub> O.	Specific Gravity.	Percentage of K <sub>2</sub> O.
1·3300	28·290	1·1979	18·671	1·0819	8·487
1·3131	27·158	1·1839	17·540	1·0703	7·355
1·2966	26·027	1·1702	16·403	1·0589	6·224
1·2803	24·895	1·1568	15·277	1·0478	5·002
1·2648	23·764	1·1437	14·145	1·0369	3·961
1·2493	22·632	1·1308	13·013	1·0260	2·829
1·2342	21·500	1·1182	11·882	1·0153	1·697
1·2268	20·935	1·1059	10·750	1·0050	0·5659
1·2122	19·803	1·0938	9·619	1·0000	0·0

## SODIUM SULPHATE AT 19° C.

Percentage of Na <sub>2</sub> SO <sub>4</sub> to H <sub>2</sub> O.	Specific Gravity.	Percentage of Na <sub>2</sub> SO <sub>4</sub> to H <sub>2</sub> O.	Specific Gravity.	Percentage of Na <sub>2</sub> SO <sub>4</sub> to H <sub>2</sub> O.	Specific Gravity.
1	1·0040	11	1·0439	20	1·0807
2	1·0079	12	1·0479	21	1·0849
3	1·0118	13	1·0520	22	1·0890
4	1·0158	14	1·0560	23	1·0931
5	1·0198	15	1·0601	24	1·0973
6	1·0238	16	1·0642	25	1·1015
7	1·0278	17	1·0683	26	1·1057
8	1·0318	18	1·0725	27	1·1100
9	1·0358	19	1·0766	28	1·1142
10	1·0398				

## ACETIC ACID AT 15° C. (OUDEMANN'S.)

Percentage of Acetic Acid.	Specific Gravity.	Percentage of Acetic Acid.	Specific Gravity.	Percentage of Acetic Acid.	Specific Gravity.
1	1·0007	16	1·0228	35	1·0470
2	1·0022	17	1·0242	40	1·0523
3	1·0037	18	1·0256	45	1·0571
4	1·0052	19	1·0270	50	1·0615
5	1·0067	20	1·0284	55	1·0653
6	1·0083	21	1·0298	60	1·0685
7	1·0098	22	1·0311	65	1·0712
8	1·0113	23	1·0324	70	1·0733
9	1·0127	24	1·0337	75	1·0746
10	1·0142	25	1·0350	80	1·0748
11	1·0157	26	1·0363	85	1·0739
12	1·0171	27	1·0375	90	1·0713
13	1·0185	28	1·0388	95	1·0660
14	1·0200	29	1·0400	100	1·0553
15	1·0214	30	1·0412		

## AMMONIA AT 14° C.

(CARIUS.)

Percentage of Ammonia.	Specific Gravity.	Percentage of Ammonia.	Specific Gravity.	Percentage of Ammonia.	Specific Gravity.
1	·9959	13	·9484	25	·9106
2	·9915	14	·9449	26	·9078
3	·9873	15	·9414	27	·9052
4	·9831	16	·9380	28	·9026
5	·9790	17	·9347	29	·9001
6	·9749	18	·9314	30	·8976
7	·9709	19	·9283	31	·8953
8	·9670	20	·9251	32	·8929
9	·9631	21	·9221	33	·8907
10	·9593	22	·9191	34	·8885
11	·9556	23	·9162	35	·8864
12	·9520	24	·9133	36	·8844

## OXALIC ACID AT 17·5° C.

Specific Gravity.	Percentage of $\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$ .	Percentage of $\text{H}_2\text{C}_2\text{O}_4$ .	Specific Gravity.	Percentage of $\text{H}_2\text{C}_2\text{O}_4 \cdot 2\text{H}_2\text{O}$ .	Percentage of $\text{H}_2\text{C}_2\text{O}_4$ .
1·0032	1	·714	1·0204	7	4·99
1·0064	2	1·43	1·0226	8	5·72
1·0096	3	2·14	1·0248	9	6·42
1·0118	4	2·86	1·0271	10	7·14
1·0160	5	3·57	1·0289	11	7·85
1·0382	6	4·28	1·0309	12	8·56

## HYDROCHLORIC ACID AT 15° C.

Specific Gravity.	Percentage of H Cl.	Specific Gravity.	Percentage of H Cl.	Specific Gravity.	Percentage of H Cl.
1·0020	·408	1·0318	6·524	1·0697	14·271
1·0040	·816	1·0337	6·932	1·0798	16·310
1·0060	1·224	1·0357	7·340	1·0899	18·349
1·0080	1·631	1·0377	7·747	1·1000	20·388
1·0100	2·039	1·0397	8·155	1·1102	22·426
1·0120	2·447	1·0417	8·563	1·1206	24·466
1·0140	2·854	1·0437	8·971	1·1308	26·505
1·0160	3·262	1·0457	9·379	1·1410	28·544
1·0180	3·670	1·0477	9·786	1·1515	30·582
1·0200	4·078	1·0497	10·194	1·1620	32·621
1·0220	4·486	1·0517	10·602	1·1721	34·660
1·0239	4·893	1·0537	11·010	1·1822	36·700
1·0259	5·301	1·0557	11·418	1·1910	38·738
1·0279	5·709	1·0577	11·825	1·2000	40·777
1·0298	6·116	1·0597	12·233		



## PHOSPHORIC ACID AT 82.5° F.

(GEERLIGS.)

Specific Gravity.	Percentage of $H_3PO_4$ .	Percentage of $P_2O_5$ .	Specific Gravity.	Percentage of $H_3PO_4$ .	Percentage of $P_2O_5$ .
1.0537	10	7.260	1.1856	30	21.780
1.0597	11	7.986	1.1928	31	22.506
1.0658	12	8.712	1.2000	32	23.232
1.0719	13	9.438	1.2073	33	23.958
1.0781	14	10.164	1.2148	34	24.664
1.0844	15	10.890	1.2224	35	25.410
1.0907	16	11.616	1.2298	36	26.136
1.0970	17	12.342	1.2375	37	26.862
1.1032	18	13.068	1.2453	38	27.588
1.1097	19	13.744	1.2532	39	28.314
1.1163	20	14.520	1.2611	40	29.040
1.1203	21	15.246	1.2698	41	29.766
1.1296	22	15.972	1.2772	42	30.492
1.1364	23	16.698	1.2854	43	31.218
1.1432	24	17.424	1.2936	44	31.944
1.1501	25	18.150	1.3018	45	32.670
1.1571	26	18.876	1.3102	46	33.496
1.1641	27	19.602	1.3186	47	34.222
1.1712	28	20.328	1.3272	48	35.674
1.1784	29	21.054			

## SULPHURIC ACID AT 15° C.

Percentage of $H_2SO_4$ .	Specific Gravity.	Percentage of $H_2SO_4$ .	Specific Gravity.	Percentage of $H_2SO_4$ .	Specific Gravity.
1	1.0064	16	1.1136	35	1.2640
2	1.0130	17	1.1210	40	1.3060
3	1.0190	18	1.1290	45	1.3510
4	1.0256	19	1.1360	50	1.3980
5	1.0320	20	1.1440	55	1.4480
6	1.0390	21	1.1516	60	1.5010
7	1.0464	22	1.1590	65	1.5570
8	1.0536	23	1.1670	70	1.6150
9	1.0610	24	1.1740	75	1.6750
10	1.0680	25	1.1820	80	1.7340
11	1.0756	26	1.1900	85	1.7860
12	1.0830	27	1.1980	90	1.8220
13	1.0910	28	1.2066	95	1.8376
14	1.0980	29	1.2150	100	1.8426
15	1.1060	30	1.2230		

## NITRIC ACID AT 15° C.

Percentage of HNO <sub>3</sub> .	Specific Gravity.	Percentage of HNO <sub>3</sub> .	Specific Gravity.	Percentage of HNO <sub>3</sub> .	Specific Gravity.
2.00	1.010	27.00	1.166	60.00	1.374
4.00	1.022	28.00	1.172	65.07	1.400
7.22	1.045	29.00	1.179	69.96	1.423
11.41	1.067	30.00	1.185	75.00	1.442
13.00	1.077	35.00	1.218	80.00	1.460
15.00	1.089	40.00	1.251	85.00	1.478
17.47	1.105	45.00	1.284	90.00	1.495
20.00	1.120	49.97	1.317	95.27	1.514
23.00	1.138	55.00	1.346	100.00	1.530
25.71	1.157				

## LEAD ACETATE AT 15° C.

(GERLACH.)

Specific Gravity.	Percentage of Lead Acetate.	Specific Gravity.	Percentage of Lead Acetate.	Specific Gravity.	Percentage of Lead Acetate.
1.0127	2	1.0939	14	1.1704	24
1.0255	4	1.1084	16	1.1869	26
1.0386	6	1.1234	18	1.2040	28
1.0520	8	1.1384	20	1.2211	30
1.0654	10	1.1544	22	1.2395	32
1.0796	12				

## EXPANSION OF GLASS VESSELS.

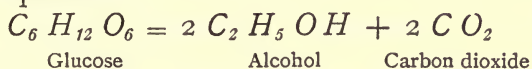
(BAILEY.)

Temper- ature Centigrade.	Volume.	Temper- ature Centigrade.	Volume.	Temper- ature Centigrade.	Volume.
15	1.00000	25	1.00025860	50	1.00090510
16	1.00002586	26	1.00028446	55	1.00103440
17	1.00005172	27	1.00031032	60	1.00116370
18	1.00007758	28	1.00033618	65	1.00129300
19	1.00010344	29	1.00036204	70	1.00142230
20	1.00012930	30	1.00038790	75	1.00155160
21	1.00015516	35	1.00051720	80	1.00168090
22	1.00018102	40	1.00064656	90	1.00193950
23	1.00020688	45	1.00077580	100	1.00219810
24	1.00023274				

Most of the above tables are for the temperatures prevailing in Europe ; for dilute solutions the expansion may without sensible error be taken as the same as for water (*q.v.*), but for more concentrated solutions this correction, when applied, will still introduce an appreciable error.

### RUM.

In the fermentation of cane molasses and water, by far the greater part of the sugars present are by the action of yeast converted into alcohol ; with absolutely pure yeast an almost theoretical yield in accordance with the equation



is obtained.

In general, in tropical sugar houses no attempts are made to prepare pure yeast, so that in addition to the yield falling considerably below that indicated by the above equation a number of other bodies are formed ; these include higher alcohols, particularly amyl alcohol (fusel oil), formaldehyde, furfural, methyl alcohol, some fatty acids (including acetic, formic, butyric and capric acids), and as a result of interaction between the alcohol and fatty acids, some ethereal salts, as ethyl acetate, butyrate, etc., are formed. The presence of these bodies, with the exception of the ethereal salts, is objectionable, and it is the object of distillation to effect their removal ; to the amyl alcohol is usually attributed the after effects of an excess of bad spirits ; the fatty acids, especially those of high molecular weight, have repulsive odours ; to butyric acid is due the smell of rancid butter, the peculiarly offensive odour

of goats being due to capric acid; the formaldehyde and methyl alcohol, when using the old forms of pot stills, pass over in the first runnings, the fatty acids coming over in the last runnings; with the continuous stills the former are found in the cold feints, and the latter in the hot feints; a complete separation is, however, impossible; of the ethereal salts (to which the flavour of rum is due), ethyl acetate, having nearly the same boiling point as alcohol (see below), is present in largest quantity; the other ethereal salts, having a higher boiling point, are chiefly present in the last runnings or in the hot feints. Artificially flavoured rums may be prepared by adding ethereal salts to spirits; to add the manufactured bodies entails great expense, so occasionally, particularly in Jamaica, fruits, as guavas, mangoes, pine apples, are mixed with the wash, or the rum is allowed to flow over trays holding slices of these fruits. The flavour of the best rum is generally supposed to be due to ethyl butyrate; the Jamaica practice of fermenting large quantities of sour cane juice containing large quantities of acetic acid would, however, lead to the conclusion that the superior flavour of this rum is due to ethyl acetate, a conclusion borne out by the analyses quoted below.

Stade (S.C. 267) states:—

1. That the rum ferment is most active at from  $30^{\circ}$  C. to  $35^{\circ}$  C.
2. That it is very sensible to cold.
3. That at  $18^{\circ}$  C. to  $20^{\circ}$  C. the fermentation slackens, the acidity increases, and the yield of alcohol diminishes.
4. That the degree of concentration of the wash has

a distinct influence on the vegetation of the ferment.

5. That a solution of saccharose of 18 % to 19 % appears to give the best yield ; of course, this means pure sugar, and does not apply to liquids such as molasses.

6. That the rum ferment, both in its proper form and as a mycelium, separates a diastase which converts saccharose into glucose.

Stade (*loc. cit.*) analysed rums from Jamaica, Cuba, and British Guiana, and found, expressed as grams per 100 c.c., fusel oils, .037 to .141 ; ethyl formate, .008 to .022 ; ethyl acetate, .092 to .612 ; ethyl butyrate, trace to .103 ; ethyl caprate, .005 to .027 ; formic acid, .003 to .012 ; acetic acid, .047 to .156 ; butyric acid, trace to .011 ; capric acid, .003 to .012 ; the writer would add that the only difference between the Jamaica rums and the others was the larger amount of ethyl acetate in the former, the Jamaica rums containing on an average .044 grams per 100 c.c., as against an average of .029.

The following are the boiling points in Fahrenheit degrees of the principal constituents of rum :—Alcohol, 173° ; methyl alcohol, 145° ; formic acid, 216° ; acetic acid, 246° ; butyric acid, 315° ; capric acid, 380° ; ethyl formate, 129° ; ethyl acetate, 168° ; ethyl butyrate, 246° ; ethyl caprate, 322° ; formaldehyde, 70°.

Recently, complaints have been made of "faultiness" in rum, *i.e.*, the rums are cloudy, have a sediment, and on dilution with water become turbid. V. H. and L. J. Veley attribute this faultiness to the presence of a bacterium capable of life and reproduction in 75 % alcohol ; they call this organism *Coleothrix Methystes*, and state that it is extremely resistant to ordinary

methods of destruction, survives dessication, is air borne, and both aerobic and anaerobic. Scard and Harrison, whilst admitting the presence of the remains of this organism in certain samples of faulty rum, deny that it is the cause of faultiness; they attribute faultiness to rum being drawn off before being properly settled, to the presence in the colour of a caramel, soluble in 75 % alcohol but insoluble in proof spirit, to the accidental presence of low wines due to careless distillation, and to resins extracted from the casks by the spirit, both the latter impurities being precipitated by an excess of water; whichever view is correct, and the writer sees no reason for supposing that all the above-mentioned causes may not be at work, no harm can accrue by taking antiseptic precautions (see "The Micro-organism of Faulty Rum," published at the Oxford University Press, and the papers on the subject in "The Sugar Cane").

### SACCHARATES.

With lime, strontia, baryta, sugar forms bodies known as saccharates, in which the sugar acts the part of an acid; if finely-divided lime (one molecule to one molecule of sugar) be dissolved in a 6 % to 12 % solution of sugar, alcohol will precipitate the monobasic saccharate  $C_{12} H_{22} O_{11} Ca O + 2 H_2 O$ , which is quite soluble in water; two molecules of lime give  $C_{12} H_{22} O_{11} 2 Ca O$ , separating in the cold; if lime be added to this at temperatures below 35° C.,  $C_{12} H_{22} O_{11} 3 Ca O$  separates; this is sparingly soluble in water. On these reactions are based the various substitution methods for the extraction of sugar from molasses; both strontia and

baryta are also used in beet sugar factories, but owing to the large percentage of glucose in cane molasses, the schemes are not applicable to cane sugar work.

### SIKES.

The Sikes hydrometer is the one almost invariably used in English-speaking countries for the determination of the apparent strengths of spirit; a table for use with this instrument, covering the usual limits occurring in tropical distilleries, is appended.

TABLE CONNECTING SIKES DEGREES  
AND STRENGTH OF SPIRITS.

Degree Sikes.	Specific Gravity corresponding to the degree Sikes at 84° F.	80° F.	81° F.	82° F.	83° F.	84° F.	85° F.	86° F.
		Percentage over Proof.	Percentage over Proof.	Percentage over Proof.	Percentage over Proof.	Percentage over Proof.	Percentage over Proof.	Percentage over Proof.
17·0	·8443	46·0	45·7	45·4	45·1	44·8	44·5	44·2
17·2	·8446	45·8	45·5	45·2	44·9	44·6	44·3	44·0
17·4	·8450	45·6	45·3	45·0	44·7	44·4	44·1	43·8
17·6	·8453	45·4	45·1	44·8	44·5	44·2	43·9	43·6
17·8	·8457	45·2	44·9	44·6	44·3	44·0	43·7	43·4
18·0	·8460	45·0	44·7	44·4	44·1	43·8	43·5	43·2
18·2	·8464	44·8	44·5	44·2	43·9	43·6	43·3	43·0
18·4	·8467	44·6	44·3	44·0	43·7	43·4	43·1	42·8
18·6	·8471	44·4	44·1	43·8	43·5	43·2	42·9	42·6
18·8	·8474	44·2	43·9	43·6	43·3	43·0	42·7	42·4
19·0	·8478	44·0	43·7	43·4	43·1	42·8	42·5	42·2
19·2	·8481	43·8	43·5	43·2	42·9	42·6	42·3	42·0
19·4	·8485	43·6	43·3	43·0	42·7	42·4	42·1	41·8
19·6	·8488	43·3	43·1	42·8	42·5	42·2	41·9	41·6
19·8	·8492	43·1	42·9	42·6	42·3	42·0	41·7	41·4
20·0	·8495	42·9	42·6	42·3	42·0	41·7	41·4	41·1
20·2	·8498	42·7	42·4	42·1	41·8	41·5	41·2	40·8
20·4	·8502	42·5	42·2	41·9	41·6	41·3	41·0	40·6
20·6	·8505	42·2	42·0	41·7	41·4	41·1	40·8	40·4
20·8	·8509	42·0	41·8	41·5	41·2	40·9	40·6	40·2
21·0	·8512	41·8	41·5	41·2	41·0	40·6	40·3	39·9
21·2	·8516	41·6	41·3	41·0	40·7	40·4	40·1	39·7
21·4	·8519	41·4	41·1	40·8	40·5	40·2	39·9	39·5
21·6	·8523	41·2	40·9	40·6	40·3	40·0	39·7	39·3
21·8	·8526	41·0	40·7	40·4	40·1	39·8	39·5	39·1
22·0	·8530	40·8	40·5	40·2	39·9	39·6	39·3	38·9
22·2	·8533	40·6	40·3	40·0	39·7	39·4	39·1	38·7
22·4	·8537	40·4	40·1	39·8	39·5	39·2	38·9	38·5
22·6	·8540	40·1	39·9	39·6	39·3	39·0	38·7	38·3
22·8	·8544	39·9	39·7	39·4	39·1	38·8	38·5	38·1
23·0	·8547	39·7	39·4	39·1	38·8	38·5	38·2	37·8

## SPECIFIC GRAVITY AND STRENGTH OF MATERIALS.

The specific gravity of a body is the weight of the body compared with the weight of an equal volume of water ; for refined calculations specific gravities are referred to water at 4° C. as unity ; for technical purposes no corrections for temperature are necessary. A table of the specific gravities and strength of some more important materials is appended.

### TABLE OF THE SPECIFIC GRAVITY AND STRENGTH OF MATERIALS.

Material.	Specific Gravity.	Weight of a Cubic foot in lbs.	Tensile strength per Square inch in lbs.	Crushing Strength per Square inch in lbs.	Transverse Strength per Square inch in lbs.
Copper Bolts ..	8.85	552.4	39,100		
Copper, Cast ..	8.607	537.3	18,800		
Iron, Cast ..	7.23	451	16,300	107,000	5,800
Iron, Wrought ..	7.78	485.6	49,300	37,900	8,500
Lead, Sheet ..	11.4	711.6	3,360		
Brass, Cast ..	8.4	524.37	17,900		
Steel ..	8.0	499	116,000	336,000	
Deal ..	.689	43	12,000	5,850	1,562
West Indian Cedar )	.748	47	5,000	5,700	1,443
English Elm ..	.553	34	13,200	10,300	782
Canadian Elm ..	.725	45	14,000		1,100
Oak ..	.777	48	10,000	6,400	1,600
Iron Wood ..	1.15	71			3,000
White Pine ..	.492	27			1,229
Teak ..	.74—86	46—54	8,000—15,000	12,000	2,100
Green Heart ..	1.14	70		13,000	
Stock Brick ..	1.84	115			
Fire Brick ..	2.2—2.4	134—150			808
Portland Cement	1.6—1.76	100—110	400—600	3,795—5,984	
Roman Cement	1.6	100	185		

### STEAM.

(See also *Boiler, Heat, etc.*)

The steam pipe from the boilers to the factory should not be too large in diameter, to avoid an unnecessary surface which would cause a loss by condensation. For



ordinary short pipes and low pressure the steam should have a velocity of 15 to 20 metres per second; with a pressure of 5 to 6 atmospheres and higher, 40 metres. For very long pipes it is always necessary that the pressure in the boilers should be about one atmosphere higher than that required for driving the engine; for the steam stop valve and the pipes from the boilers to the main steam pipe, a velocity of 20 metres per second can be taken as a basis; from the steam pipe to the boiling apparatus, 40 metres as a basis for the highest consumption of steam. Steam engines, working with a cylinder capacity of 0.80, require 20 metres velocity, and the same for a higher capacity and higher expansion and full capacity. Each square metre of steam pipe, if not well protected, condenses from  $1\frac{1}{4}$  to  $1\frac{1}{2}$  kilos. of steam per hour. Therefore it is necessary to make these pipes as short as possible, and to protect them with a non-conducting composition; also to place the engine in a central position, and to work it as economically as possible; the last especially, as the loss by condensation from a badly working engine directly effects the evaporating plant. (*Felinek.*)

The loss of heat by naked steam pipes to engines, etc., is very considerable; and where the length is great it becomes serious, not only from waste of fuel, but from the formation of water by condensation, which is obstructive to the working of the engine. . . . The loss may be greatly reduced by casing the pipes in a material which conducts heat badly. The woollen felt which is made for this purpose is the best and cheapest material. (*Box.*)

Steam pipes expand and contract about 1 in. in 50 ft.; hence the necessity for inserting expansion pipes between each rigid connection. (*Adams.*)

*Consumption of Steam in a Diffusion Factory.*

Raising juice to and maintaining at 212° F.	40 %
Concentration from 212° F. to sugar	... 38 %
Molasses sugar	... .. 5 %
The various engines	... .. 17 %
	<u>100</u>

(*Llewellyn Jones.*)

*Consumption of Steam at Aba-el-Wakj.* The horse-power employed, assuming each cubic foot of water at 17° C. (62° F.) evaporated to represent 1 H.P. of boiler duty :—

H.P.

The four cane mill engines take 68 H.P. each ; allowing 25 lbs. steam per H.P. hour, which will cover loss by steam pipes, etc., will require of boiler power	... ..	112·0
The clarifiers to heat 6,000 gallons of juice per hour from 72° F. to 212° F., and to boil for five minutes, will absorb	... ..	163·5
The concentrators having to raise 5,473 gallons of juice from 160° F. to 230° F., and to evaporate 3,118 gallons under 3 lbs. pressure, will take...	... ..	519·0
Steam under 60 lbs. pressure used in steaming in centrifugals, calculated	... ..	11·2
Sulphurous acid pumps, calculated	... ..	1·5
Donkey feed pumps	... ..	2·3
Total	... ..	<u>809·5</u>

or nearly 11 H.P. per hour, per ton of sugar, per 24 hours. (*Lock and Newlands.*)

In estimating the consumption of steam in a factory, it is advisable to separate the process into the different operations, and to calculate the heat required for the different processes. There will be very considerable differences in the percentage consumption for different factories, and no great degree of accuracy can be obtained. A scheme for calculation is appended:—

1. *Raising juice to boiling point.* Let  $w_1$  = weight of water per cent. in juice, and  $w_2$  = weight of solids per cent.; then, to raise 1 ton juice from  $t^\circ$  F. to  $212^\circ$  F. are required  $2240 \{w_1 (212 - t) + s w_2 (212 - t)\}$  B.T.U.,  $s$  being the specific heat of the solids; as sugar is the solid present in largest proportion,  $s$  may be taken as  $\cdot 301$ , the specific heat of sugar.

2. *Cleaning juice in open pans.* Let  $B_1$  = degrees Brix of mill juice,  $B_2$  = degrees Brix of juice entering evaporator; then, water evaporated per cent. on weight of original juice =  $\frac{B_2 - B_1}{B_2} \times 100$ ; the evaporation of each pound of water in open vessels will take on an average 1200 B.T.U.

3. *Evaporation in Multiple effect.* If  $B_3$  = degrees Brix of syrup,  $B_1$  = degrees Brix of mill juice, the water evaporated per cent. on original mill juice is  $\frac{B_3 - B_1}{B_3} 100$ ; this quantity, less that found in 2, gives the evaporation in the multiple effect; to accurately determine the B.T.U. required to evaporate a pound of water in the particular apparatus, a trial similar to a boiler trial must be made; in general each pound of water will

require about  $\frac{1050}{x}$  B.T.U. for its evaporation,  $x$  being the number of bodies in the apparatus.

4. *Heat used in pans.* The degree Brix is no longer available, so the water content of the massecuite must be obtained, which, when subtracted from that originally present in the syrup, gives the water removed in the pans; each pound of water may, without appreciable error, be taken as requiring 1050 B.T.U. for evaporation.

5. *Molasses sugar.* A similar calculation to that used in 4 may be made; the evaporation is usually from 7% to 9% of the weight of the molasses.

6. *Centrifugals.* From 3 to 5 H.P. are required per each centrifugal dependent on the number used.

7. *Distillery.* The gallons of wash resulting from a ton of canes being known, the heat necessary to raise this to the boiling point, and to evaporate the resulting proportion of alcohol and water can be calculated; specific heat of alcohol, .622; latent heat of evaporation per pound = 457 B.T.U.

8. *Engines.* The number of pounds of steam or B.T.U. consumed by the various engines will vary largely in different factories; for an approximation the horse-power of the engines may be calculated from the formula (see *Horse-power*). Thurston gives the formula  $S = \frac{K}{\sqrt{N}}$ ,  $S$  being the pounds of steam per horse-power hour,  $N$  the pressure in pounds per square inch,  $K$  a constant varying with the nature of the engine from 150 to 200, as connecting consumption of steam and horse-power; in general, with engines of the type

usual in sugar factories, about 20 lbs. of steam are required per horse-power hour.

9. *Losses in steam pipe.* A table, abstracted from one given by Box, is appended below.

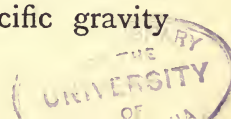
Loss of heat in steam pipes, cased in woollen felt, covered with thin canvas, pipes heated to 212° F., freely exposed to external air at 60° F.

Thickness of the Felt Casing: inches.	Diameter of the Pipe outside, without Casing.							
	2 inches Diameter.		4 inches Diameter.		8 inches Diameter.		12 inches Diameter.	
	Loss of Heat per hour per foot run.	Temperature of external Surface.	Loss of Heat per hour per foot run.	Temperature of external Surface.	Loss of Heat per hour per foot run.	Temperature of external Surface.	Loss of Heat per hour per foot run.	Temperature of external Surface.
0	173.4	212	308.7	212	576.5	212	851.0	212
1/4	79.6	128	142.6	133				
1/2	52.4	102	93	107	174.3	110	236.4	108
1	33.54	82.8	56	86	101.9	89	148.2	90
2	21.95	70.9	34.7	73	59.37	75	77.9	75
4	15.47	64.8	22.4	65.9	37.07	67.35	47.87	67.63
6			18.1	63.58	27.28	64.35	36.00	64.8

Working on these lines, the writer calculated for a modern factory that the consumption of heat expressed as percentages of the total consumption was:—Raising juice to 212° F., 13 % to 15 %; cleaning juice in open pans, 9 % to 10 %; evaporation in triple effect, 24 % to 26 %; evaporation in pans for first sugar, 15 % to 17 %; evaporation in pans for molasses sugar, 2 % to 3 %; distillation of rum, 3 % to 5 %; cane engine, 14 % to 16 %; vacuum pumps, 11 % to 13 %; small pumps, 1 % to 2 %; centrifugals, 2 % to 4 %; losses in steam pipes, 2 % to 3 %.

### SUGAR.

Also known as saccharose sucrose. Composition,  $C_{12}H_{22}O_{11}$ ; molecular weight, 342; specific gravity



at 3.9° C., 1.598 (Playfair and Joule); specific heat, .301; heat of combustion, 6959 B.T.U. per pound; specific rotation,  $[\alpha]_D = + 64.1$ ;  $[\alpha]_J = + 73.8$ . At temperatures above 180° C. decomposes, giving caramel (*q.v.*), acetic and ulmic acids, etc.; heated with acids it undergoes inversion (*q.v.*); soluble in water (*v.inf.*); insoluble in ether and alcohol; with alkalies and alkaline earths forms saccharates (*q.v.*); unites with certain salts giving molecular compounds, *e.g.*, saccharate of sodium chloride,  $C_{12} H_{22} O_{11} Na Cl 4 H_2 O$ ; many other bodies possess this property, which is one of the great causes of the formation of molasses (*q.v.*).

*Sugar, Determination of.* (See also *Polariscope, Juice, etc.*)

(a) *By the Polariscope.* In the absence of any quantity of invert sugar, and of other active bodies which are not precipitated by lead acetate, the material containing sugar is either weighed or measured volumetrically, clarified by the addition of lead acetate, filtered, and the polariscope reading taken; if  $N$  be the normal weight for the polariscope used,  $W$  be the weight of material taken,  $X$  be the reading of the instrument, then percentage of sugar =  $\frac{N \cdot X}{W} \times 100$ .

In the presence of invert sugar for accurate work, Clerget's method must be adopted:—

Weigh out a quantity of material containing approximately 13.024 grams sugar; dissolve in 100 c.c., water after addition of lead acetate, filter, and polarise as usual. Let  $P$  denote the percentage of sugar as shown by this reading, called the direct reading; remove 50 c.c. of the solution used for the direct reading at 5 c.c. strong hydrochloric acid, raise to a tempera-

ture of 67° C. to 70° C. on the water bath, and keep at this temperature for five minutes; cool rapidly, dilute to 100 c.c., polarise, and observe the temperature immediately after polarisation. Let  $I$  denote the reading after inversion, corrected proportionally to a normal solution; then, if  $S$  denote the true percentage of sugar,  $t$  be the temperature in the centigrade scale at which the observation was made, and  $i$  be the observed polarisation of the inverted solution in a 200 m.m. tube, without any correction,  $S = \frac{P - I}{141.84 + \frac{i - t}{20} \cdot \frac{t}{2}}$  (see Ling, "Int. Sugar Jour.," No. V.).

(b) *By determination of glucose before and after inversion.* The glucose present is determined in the material directly; let  $x$  = percentage of glucose before inversion. A convenient quantity of material is then taken, inverted under the conditions given above, and the glucose present determined by one of the methods given under *Glucose*. Let  $y$  = percentage of glucose after inversion, then percentage of sugar =  $.95(y - x)$ .

This method, though more tedious than the polariscope method, gives results more reliable. It is not, however, adapted for use by unskilled workers, for whose use the simplicity of the polariscope method is specially adapted.

*Sugar, Tests for.* 1. To 15 c.c. of sugar solution add 5 c.c. of a 5% solution of cobaltous nitrate; after mixing, add 2 c.c. of a 50% solution of sodium hydrate; pure sugar gives an amethyst-violet colour, which is permanent; pure dextrose gives a turquoise-blue, which passes into a light green. With mixtures of sugar and dextrose the sugar reaction is predominant, so that one

part of sugar to nine of dextrose can be recognised ; in the presence of gum arabic or dextrine, etc., treatment with alcohol or lead acetate is necessary (see Wiley, "Agricultural Analysis").

2. To the solution supposed to contain sugar, add a few drops of an alcoholic solution of  $\alpha$ -naphthol or thymol ; allow a few drops of strong sulphuric acid to flow to the bottom of the test tube ; in the presence of sugar,  $\alpha$ -naphthol gives a pale lilac, and thymol a crimson colouration at the line of demarcation of the two liquids. This test is sufficient to detect one part of sugar in 10,000,000 of water.

3. Boil the solution for a minute with hydrochloric acid, neutralise, and boil with Fehling's solution ; a brown colouration indicates the presence of sugar. The solution must be tested for glucose before inversion.

Below are given tables containing the chief properties of sugar solutions, etc.

TABLE GIVING THE EXPANSION OF SUGAR SOLUTIONS. (GERLACH.)

Temperature C°.	10 per Cent.	20 per Cent.	30 per Cent.	40 per Cent.	50 per Cent.
0	1·0000	1·0000	1·0000	1·0000	1·0000
5	1·0004	1·0007	1·0009	1·0012	1·0016
10	1·0012	1·0016	1·0021	1·0026	1·0032
15	1·0021	1·0028	1·0034	1·0042	1·0050
20	1·0033	1·0041	1·0049	1·0058	1·0069
25	1·0048	1·0057	1·0066	1·0075	1·0088
30	1·0064	1·0074	1·0084	1·0094	1·0110
35	1·0082	1·0092	1·0103	1·0114	1·0132
40	1·0101	1·0112	1·0124	1·0136	1·0156
45	1·0122	1·0134	1·0146	1·0160	1·0180
50	1·0145	1·0156	1·0170	1·0184	1·0204
55	1·0170	1·0183	1·0196	1·0210	1·0229
60	1·0197	1·0209	1·0222	1·0235	1·0253
65	1·0225	1·0236	1·0249	1·0261	1·0278
70	1·0255	1·0265	1·0277	1·0287	1·0306
75	1·0284	1·0295	1·0306	1·0316	1·0332
80	1·0316	1·0325	1·0335	1·0345	1·0360
85	1·0347	1·0355	1·0365	1·0375	1·0388
90	1·0379	1·0387	1·0395	1·0405	1·0417
95	1·0411	1·0418	1·0425	1·0435	1·0445
100	1·0442	1·0450	1·0456	1·0465	1·0477



TABLE SHOWING THE SOLUBILITY OF  
LIME IN SUGAR SOLUTIONS.

Sugar in 100 parts of Water.	Density of Syrup.	Density after Saturation with Lime.	Residue dried at 120° C. Per Cent. of Lime.	Residue dried at 120° C. Per Cent. of Sugar.
5	1·018	1·026	15·3	84·7
10	1·036	1·053	18·1	81·9
15	1·052	1·080	18·5	81·5
20	1·068	1·104	18·8	81·2
25	1·082	1·128	19·8	80·2
30	1·096	1·148	20·1	79·9
35	1·110	1·166	20·5	79·5
40	1·122	1·179	21·0	79·0

TABLE SHOWING THE SOLUBILITY OF  
SUGAR IN WATER.

(HERZFELD.)

Temperature C°.	Sugar per Cent.	Temperature C°.	Sugar per Cent.	Temperature C°.	Sugar per Cent.
0	64·18	35	69·55	70	76·22
5	64·87	40	70·42	75	77·27
10	65·58	45	71·32	80	78·36
15	66·53	50	72·25	85	79·46
20	67·09	55	73·20	90	80·61
25	67·89	60	74·18	95	81·77
30	68·80	65	75·88	100	82·97

TABLE SHOWING THE BOILING POINTS  
OF SUGAR SOLUTIONS.

(GERLACH.)

Sugar per Cent.	Boiling Point, C°.	Sugar per Cent.	Boiling Point, C°.	Sugar per Cent.	Boiling Point, C°.
10	100·4	40	101·5	70	106·5
20	100·6	50	102·0	79	112·0
30	101·0	60	103·0	90·8	130·0

TABLE SHOWING THE SOLUBILITY OF  
SALTS IN SUGAR SOLUTIONS.

(JACOBSTHAL.)

Solution Containing.	5 % of Sugar.	10 % of Sugar.	15 % of Sugar.	20 % of Sugar.	25 % of Sugar.
	GRAMS.	GRAMS.	GRAMS.	GRAMS.	GRAMS.
Calcium Sulphate	2.095	1.946	1.593	1.539	1.333
„ Carbonate	0.027	0.036	0.024	0.022	0.008
„ Oxalate ..	0.033	0.047	0.012	0.008	0.001
„ Phosphate	0.029	0.028	0.014	0.018	0.005
„ Citrate ..	1.813	1.578	1.505	1.454	1.454
Magnes. Carbonate	0.317	0.199	0.194	0.213	0.284

### SULPHUR.

Sulphur dioxide is used in the clarification of cane juice either before or after the addition of lime, the proportions of each being so arranged as to give a juice as neutral as possible. The proportion of sulphur generally used is about 1 to 10,000 of juice; the best form of apparatus for impregnating the juice with sulphur fumes consists of an upright wooden box about 10 feet in height, and of cross section about 4 feet; in this box are placed a series of perforated trays; the juice enters at the top and flows down the trays, meeting a current of sulphur dioxide ascending. Another form consists of a cylindrical vessel in which is rotated a series of paddles, and into which both sulphur fumes and juice are led. Sulphur dioxide is also employed at a later stage, just before the juice enters the evaporator, to give the acid reaction required for making light sugars for direct consumption, and to break up organic salts of lime; an objection to the use of sulphur is the liability of the calcium sulphite formed to oxidise to calcium sulphate, which is deposited in the evaporators as scale.

## SYRUP.

The analysis of syrups is performed as described under *Juice*. Owing to the viscosity of syrups, they should be weighed and not measured.

## TEMPERATURE.

To convert Centigrade scale into Fahrenheit:  $C = \frac{F-32}{1.8}$ .

To convert Fahrenheit scale into Centigrade:  $F = 1.8 C + 32$ .

## COMPARISON OF CENTIGRADE AND FAHRENHEIT SCALES.

Centigrade.	Fahrenheit.	Centigrade.	Fahrenheit.	Centigrade.	Fahrenheit.
0	32	34	93.2	68	154.4
1	33.8	35	95	69	156.2
2	35.6	36	96.8	70	158.0
3	37.4	37	98.6	71	159.8
4	39.2	38	100.4	72	161.6
5	41	39	102.2	73	163.4
6	42.8	40	104	74	165.2
7	44.6	41	105.8	75	167
8	46.4	42	107.6	76	168.8
9	48.2	43	109.4	77	170.6
10	50	44	111.2	78	172.4
11	51.8	45	113	79	174.2
12	53.6	46	114.8	80	176
13	55.4	47	116.6	81	177.8
14	57.2	48	118.4	82	179.6
15	59	49	120.2	83	181.4
16	60.8	50	122	84	183.2
17	62.6	51	123.8	85	185
18	64.4	52	125.6	86	186.8
19	66.2	53	127.4	87	188.6
20	68	54	129.2	88	190.4
21	69.8	55	131	89	192.2
22	71.6	56	132.8	90	194
23	73.4	57	134.6	91	195.8
24	75.2	58	136.4	92	197.6
25	77	59	138.2	93	199.4
26	78.8	60	140	94	201.2
27	80.6	61	141.8	95	203
28	82.4	62	143.6	96	204.8
29	84.2	63	145.4	97	206.6
30	86	64	147.2	98	208.4
31	87.8	65	149	99	210.2
32	89.6	66	150.8	100	212
33	91.4	67	152.6		

## VACUUM PAN.

For each ton of cane there are evaporated in the vacuum pans, assuming a 72% extraction, about 220 lbs. of water; assuming each square foot of heating surface to evaporate 12 lbs. of water per hour, there are required a minimum of 18 square feet per ton of cane per hour; allowing for the time expended in discharging the pan, at the lowest 25 square feet should be allowed, and 30 square feet per ton of cane per hour would be a preferable allowance; again, to give 1 cwt. of massecuite are required approximately 2 cwt. syrup, of density 1.22, entailing the evaporation of 90 to 100 lbs. water; allowing the pan 4 hours to fill, and an evaporation of 12 lbs. water per square foot of heating surface per hour, there will be required, per cwt. of massecuite per hour, 8 square feet of heating surface; so that a pan to give 100 cwt. of massecuite per strike will require  $\frac{100}{4} \times 8 = 200$  square feet of heating surface.

TABLE OF DIMENSIONS OF VACUUM PANS.

Diameter of Pan : feet.	Length of Cylindrical part of Pan : feet.	Dimensions of Air Cylinders of Pump : ins.	Gallons of Massecuite.	Cwt. of Massecuite.	Cwt. of Dry Sugar at 60% recovery.	Heating Surface : Square feet.
5	4	12 x 10	545	70	42	140
5	5	12 x 10	685	90	54	180
5	6	12 x 10	755	100	60	200
6	5	14 x 12	975	130	78	260
6	6	16 x 14	1,150	155	93	310
7	6	18 x 16	1,600	210	126	420
7	7	18 x 16	1,800	240	144	480
8	6	18 x 16	2,050	265	159	530
8	7	20 x 18	2,400	315	189	630
8	8	20 x 18	2,750	365	219	730
9	6	20 x 18	2,550	350	210	700
9	7	22 x 20	3,050	405	243	810
9	8	22 x 20	3,500	465	279	930
10	6	22 x 20	3,250	430	258	860
10	7	22 x 20	3,800	500	300	1,000
10	8	24 x 22	4,300	570	342	1,040
11	6	24 x 22	3,900	520	312	1,020
11	7	26 x 24	4,550	605	363	1,080
11	8	28 x 26	5,250	690	414	1,380
12	6	26 x 24	4,750	630	378	1,260
12	7	28 x 26	5,550	730	438	1,460
12	8	30 x 28	6,300	835	501	1,670

## VACUUM PAN, BOILING OF.

The boiling of the pan may be divided into three parts—the granulation, the growing of the crystals, and the bringing up to strike. The granulation is effected by forming in the pan a solution of sugar saturated at a certain temperature, and then, by causing the temperature to fall, to make the sugar crystallise out; slightly different methods obtain in the granulation. Some pan boilers prefer to take in at one time the whole amount of syrup required for grain, and to boil this down until a point is reached at which the appearance of the “sling” shows that on cooling crystals will form; when this point is reached, the temperature is lowered by increasing the amount of injection water or by lowering the pressure of the steam in the coils, with the result that sugar crystallises out in the form of very fine grain; others prefer to charge gradually, taking in enough syrup to cover the bottom coil only as a first charge, boiling this down to a certain pitch and taking in fresh charges until sufficient has accumulated to form the necessary grain. In forming grain the following points are of importance:—When a large grained sugar is required, the number of grains formed should be small; this object is, of course, obtained by boiling down to grain a small quantity of syrup, and is called graining low down. Where a fine grained sugar is required, a larger quantity of syrup is used for grain; this is called graining high up. When the granulation is effected, the next step is to feed the grain with charges of syrup, the object of the pan boiler being to deposit the sugar on the crystals already formed,

and not to form new crystals (false grain). To avoid a false grain the pan must be allowed to boil evenly; there must be no sudden alteration in temperature, due to variation in injection water or steam pressure, nor must the charges of syrup be too large; the attendant must be guided by the vacuum gauge, the steam pressure in the coils, and the temperature as to when to charge, and the amount of injection water admitted must be regulated by the same checks; at this period a vacuum of 25 inches, and steam pressures varying between 10 lbs. and 20 lbs. are usual. The practice of feeding the pan continuously, as opposed to feeding it intermittently, is dangerous, as owing to variations in the steam pressure a little carelessness on the part of the pan boiler is liable to cause false grain, but where the attendant is sufficiently skilful to keep a continuous charge, a more even grain in the sugar results; should false grain occur, the temperature of the pan must be raised by cutting off some injection water; so that, the temperature being raised, the false grain along with some of the true grain is redissolved, or a large charge being admitted, the false grain will dissolve in it and may be boiled down afresh; when the pan is full no more syrup is taken in, but the injection is slowly cut off, raising the temperature. The water content to which the massecuite can be boiled depends on the size of the outlet and the time available for discharging the pan. After a pan has been filled once, it is often advisable to discharge only half, and to continue boiling on the remainder; this operation is known as "doubling," and the discharged massecuite as the

“first cut”; before syrup is admitted to the pan after a cut the residual massecuite should be boiled, else false grain is sure to form. There is a limit to the size to which the crystals can be grown; with very pure juices as many as four or five cuts can be taken, an impure juice sometimes not allowing of a single double. The great object in pan boiling should be to obtain a large, even grain, with sharp edges; a massecuite, with crystals of uneven size, gives endless trouble in the centrifugals.

### WASH.

(See also *Distillery*.)

The analysis of the wash for the control of the distillery only needs the determination of the total glucose. For this purpose 10 c.c. of wash should be clarified with normal lead acetate, the excess of lead removed by sulphate of soda, acidified with acetic acid to break up any lead levulosate, made up to 200 c.c., and filtered; 50 c.c. are inverted as described under *Sugar*, neutralised, and made up to 100 c.c. The total glucose is then determined by one or other of the methods given under *Glucose*; in case the sugar as well as total glucose is required, determinations of glucose before and after inversion are necessary; owing to difficulty in obtaining a light coloured solution, the polariscope cannot be relied on to determine the sugar. Determinations of nitrogen, potash, and phosphoric acid are useful from time to time, to ascertain if a sufficiency of food for the yeast is present; the nitrogen is determined by Kjeldahl's method (*vide* under *Juice*), the potash and

phosphoric acid in the ash ; the methods employed for the analysis of the ash of plants may be followed. The alcohol in the fermented wash is obtained by distilling about 200 c.c. until about half has passed over ; the distillate is made up to the original bulk, and the proof strength of the distillate taken with a Sikes, or other form alcoholometer.

## WATER.

### TABLE GIVING THE EXPANSION OF WATER.

(KOPP.)

Temperature: Centigrade.	Volume.	Temperature: Centigrade.	Volume.	Temperature: Centigrade.	Volume.
0	1·00000	14	1·000556	35	1·005697
1	·999947	15	1·000695	40	1·007531
2	·999908	16	1·000846	45	1·009541
3	·999885	17	1·001010	50	1·011776
4	·999877	18	1·001184	55	1·014100
5	·999988	19	1·001370	60	1·016590
6	·999903	20	1·001567	65	1·019302
7	·999938	21	1·001776	70	1·022246
8	·999986	22	1·001995	75	1·025440
9	1·000048	23	1·002225	80	1·028581
10	1·000124	24	1·002465	85	1·031894
11	1·000213	25	1·002715	90	1·035397
12	1·000314	30	1·004064	100	1·042986
13	1·000429				

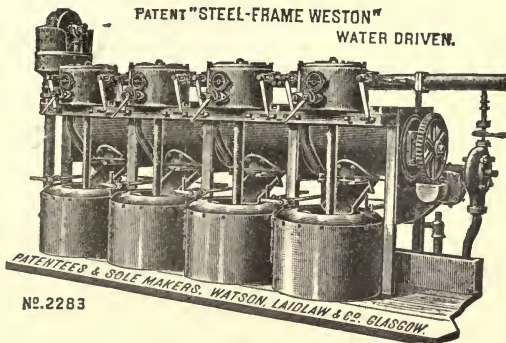


THE END.



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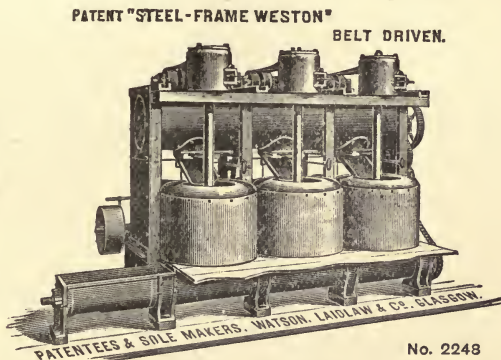
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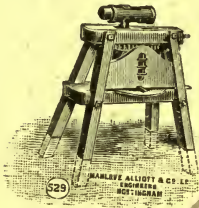
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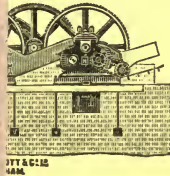
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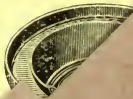
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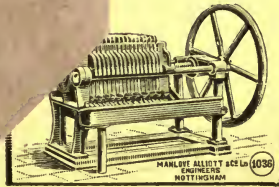


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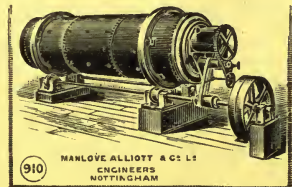
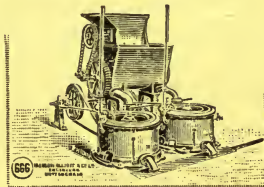
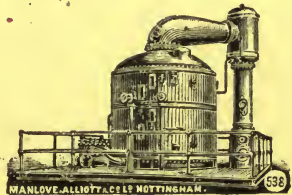
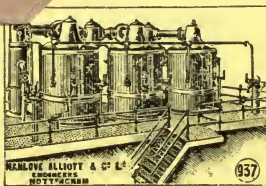


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