SUGAR
MACHINERY

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A DESCRIPTIVE TREATISE DEVOTED TO THE MACHINERY
AND APPARATUS USED IN THE MANUFACTURE OF
CANE AND BEET SUGARS.

BY

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PREFACE.

As will be gathered from the title, this book is principally devoted to a description of the machinery and apparatus used in the manufacture of cane and beet sugars. The character of the work is thus almost sufficiently indicated, and any prefatory explanation rendered unnecessary.

The importance of the subject cannot be over-estimated and requires no enlarging upon; the sugar industry is one of vast extent, and the low prices prevailing render it imperative to employ only such machines, apparatus, and appliances, as will give the best results and the greatest possible returns.

The chief aim of the author has been to provide, within the circumscribed limits permitted to a volume of moderate cost, as complete a compendium on the subject as possible. Obviously, therefore, with the somewhat limited space at command, the description and illustration of the machinery and apparatus employed in the various stages of the processes of sugar making, have had to be as far as possible restricted to certain representative types of each class. Every endeavour has been made to select for this purpose those of the most advanced and improved design. The historical portion has been in all cases omitted except where a sufficient degree of interest seemed to warrant a short account.

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For the benefit of those in charge of sugar factories the subject of repairs, which is one of no small importance, has been gone into, and to this have been added notes on lubrication, and certain tables and memoranda, as being of utility for reference.

It is an astonishing fact, and one to which the writer feels impelled to take this opportunity of alluding, that in spite of the great suitability of the soil and climate of many parts of England and Ireland for the cultivation of the sugar beet-root, and of the enormous quantities of sugar manufactured from that material yearly imported, no such industry exists in these countries. One would imagine that some of the vast sums of money that are constantly going to start risky undertakings abroad could be more usefully and advantageously employed in establishing, and fostering, a home industry that would doubtless do much to relieve the present great agricultural depression. Government assistance to such enterprise in Ireland, either by way of loans or subsidy, would in all probability do more permanent good than the construction of any number of light railways leading from no place to nowhere.

A. J. WALLIS-TAYLER.

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CHAPTER I.

INTRODUCTION.

SACCHARINE bodies are divided by chemists into three classes, sucroses or the sugars proper ($C_{12}H_{22}O_{11}$), glucoses or grape-sugars ($C_6H_{12}O_6$), and amyloses or starch sugars ($C_6H_{10}O_5$). Each of these classes is composed of various distinct substances, having the characteristics of turning the plane of polarisation to the right, or to the left hand. Sucrose is found in the juice of the sugar-cane, sugar beet-roots, the sap of the sugar maple, etc., with an admixture of glucose.

Cane-sugar, or sucrose, which is commonly known as sugar proper, is derived principally from the sugar-cane, which is a native of Asia, and it has by far the greater sweetening powers, and is very much more readily crystallisable. The density of cane sugar or sucrose is 1·6, and it is soluble in about $\frac{1}{3}$ of its weight of cold water, or in a much smaller proportion of warm water. There are two methods of extracting the juice from the stalks, viz. :— mechanically, by crushing them in a roller mill, or other press, and thus expressing the juice ; and by diffusion, or drawing out the juice by boiling the cane stalks, previously cut into short lengths, in water. This latter process is the result of the actions known as endosmosis and exosmosis, as applied to the cut cane stalks, actions which take place between two liquids of varying densities and natures which are separated by a porous

diaphragm. In this instance, the diaphragm consists in the vegetable membrane which encloses the cane-juice, and the liquids of the latter, and the pure water.

Sugar-canes may be divided into three principal species, viz., the Otaheite, the striped cane, and the creole. The first of these is the most juicy and richest in sugar, and also grows with the greatest luxuriance ; it is the kind most grown, and is to be found on the West Indian, and South American, plantations. The second variety, which is a native of Batavia, is chiefly grown for the manufacture of rum, and is densely foliated. The third or last variety is an indigene of India, and is grown in South America, the Antilles, the Canaries, and Sicily, it is a less hardy plant than either of the others, and has a thin and much knotted stem or cane.

There are numerous other so-called distinct species which have been dignified by botanical names, but the bulk of them, if not the whole, are in all probability merely artificial varieties. The Bourbon cane, which is a native of Malabar, and is almost identical with the Otaheite, gives a fine quality of sugar, and a high return. The Batavian, or striped cane, includes four varieties—the yellow violet, the Java cane, the ribbon cane, and the Batavian cane proper. The sugar obtained therefrom is of good quality, but the yield is inferior to that of the Otaheite or Bourbon. The red Assam canes are exceedingly juicy and sweet, and the sugar produced from them is of fine grain, and good colour. These canes are free and strong in growth, and are stiffer and less liable to fall over than the Otaheite or Bourbon. The Chinese variety has an extremely hard rind, which whilst rendering it very difficult to express the juice is of

some advantage, inasmuch as it is rendered thereby invulnerable to the attacks of the white ant. The Cochin China cane attains to gigantic dimensions, often reaching a height of 12ft., and a diameter of 8ins., after only six months' growth.

The sugar-cane requires a hot tropical or sub-tropical climate, and, being by nature a bog plant, must have a moist and nutritive soil.

The method of propagating the sugar-cane is by slips, consisting of pieces or cuttings of the canes with buds on them, and from 18 inches to two feet in length. The time taken to arrive at maturity, which varies in accordance with the tempera-ture, soil, season, and variety of cane, is from 12 to 16 months. When ripe and fit for cutting the cane becomes heavy, the skin dry and smooth and somewhat brittle, the pith of a dark gray or brown colour, and the juice of a glutinous con-sistency and sweet taste. After being cut, which latter operation should be performed as close to the stole or root as possible, the latter will again strike and produce a fresh crop of canes, a few dead plants only having to be replaced, or planted up, here and there. This can be continued for five or six years, or even longer, according to the richness of the soil, after which they have to be removed, and the cane piece replanted. The canes produced from original cuttings are called "plant canes," and those subsequently produced from the roots are named "ratoons," and are designated as "first," "second," "third," "fourth," "fifth," or "sixth ratoons," in accordance with the age of the roots from which they spring. The juice of the sugar-cane, when newly expressed, is rendered turbid by the foreign matters held in suspension therein. The Otaheite cane consists, on the average, of 72·1 per cent. of water,

18 per cent. of sugar, and 9·9 per cent. of woody matter ; the creole cane of 65·9 per cent. of water, 17·7 per cent. of sugar, and 16·4 per cent. of woody matter.

The sugar beet-root, which, next to the sugar-cane, is the principal raw material employed, is indigenous to the southern parts of Europe. This plant will grow in almost any soil, that most suitable, however, being one of medium consistency, provided that the earth is deep and the subsoil one not likely to be retentive of moisture—this is rendered absolutely necessary by the predisposition of the sugar beet-root to throw out tap-roots. It has been conclusively proved by numerous analyses, that, under similar conditions, the white varieties of the sugar beet-root are richer in sugar than the red, and also that the round varieties are poorer than those of an elongated form. When a sugar beet-root passes a certain size it becomes poorer in sugar, the richest are those of a weight between 14ozs. and 24ozs., below these limits of weights, and above them, the roots are of inferior quality. In a 100lbs. weight of first quality beet-roots there are about 95lbs. of juice, the balance being composed of cellulose substance ; and in these 95lbs. of juice there are 10lbs. of crystallisable sugar, 2lbs. of solid matter, and 83lbs. of water. The value of the sugar beet-root depends, of course, in a like manner to that of the sugar-cane, upon the percentage of sugar which it contains.

The cultivation of the sugar beet-root is practically identical to that of turnips and mangel-wurzels, with this slight difference however, that in the case of the former, to ensure the maximum richness in sugar and purity of the juice, excesses of powerful manures, as also certain particular manures, must be avoided. In the best practice from 10 to 20

tons of ordinary farmyard manure, with an addition of about 5 cwt. of artificial manure rich in phosphates, are employed per acre ; the first being ploughed in, preferably in the latter end of the autumn, and the second being applied in the spring and lightly harrowed in. These manures should contain from 5 to 6 per cent. of phosphoric acid, from 4 to 5 per cent. of nitric and ammoniacal compounds, and from 6 to 8 per cent. of potash, capable of being assimilated. In some cases, from 5 to 10 tons per acre of the scum from the sugar factories can be added to the above with advantage.

The best distance between the rows or drills is 16ins., and that between the plants 12ins. The roots attain maturity about the end of October, but are usually pulled from the middle to the end of September, those not at once worked up being stored in silos, so as to enable the manufacture to proceed regularly during a fixed period without any stoppages.

The only treatment required by the roots previous to being delivered to the rasping, or when the diffusion process is employed, to the slicing or cutting machines, is washing to remove the adhering earth and gravel and the small rootlets. To effect this, the roots which have been previously topped and roughly cleaned, are placed in tanks filled with water, and are kept in motion by rotating shafts carrying wooden arms set spirally, the roots leave the washers at the ends at which the water enters. The washing is preferably carried on in two tanks, the rough dirt being removed in the first, and the partially cleansed roots passed on to the next for completion. The water from the washers is run into large reservoirs, and the mud and rootlets permitted to settle, the deposit forming excellent manure.

Bad washing will result in the rapid destruction of the rasps, or of the knives of the slicers, the deterioration of the residual pulp as a food for cattle, and the alteration of the natural density of the juice, by reason of the larger amount of impurities present therein.

The juice is likewise extracted in two ways, viz. :—Firstly, by subjecting the beet-root, previously rasped or pulped, to pressure in an hydraulic press ; this rasping or pulping serves to open the cells, and the more completely this is done, and the finer the pulp, the greater will be the return of juice from the pressing. Secondly, by the diffusion process, which latter is in many localities entirely replacing the first-named method.

The sugar-cane and the sugar beet-root being the two raw materials from which the principal portion of the sugar of commerce is manufactured, are the only ones that will be here treated of. With regard to the latter material, it is worthy of note that in spite of the large quantities of beet-root sugar annually imported into this country, and of the fact that the climate and soil of the south of Ireland, and of many parts of England are peculiarly suitable for its cultivation, no attempts have ever been made to grow the sugar-beet, and to manufacture sugar therefrom. Were Government to expend some of the money otherwise squandered in Ireland, and elsewhere, upon the encouragement of this industry, there can be little doubt but that it would in a very few years develop into an important trade, and relieve, if not entirely allay, the distress caused by the present agricultural depression, in those districts suitable for the growth of the sugar beet-root.

CHAPTER II.

COMPLETE FACTORIES.

THE simplest method of manufacturing cane-sugar, is that of making Muscovado sugar from the juice of the sugar-cane by concentration in open coppers.

This method, as still extensively practised in cane-growing countries, consists in either pumping, or, where the requisite difference in levels can be obtained, running the juice, which has been extracted from the cane stalks by the rollers of the crushing mill, into one of a set of clarifiers or defecating pans usually heated by the exhaust steam from the cane-mill engine, but provision being also made for the employment of live steam from the boiler when necessary. In these clarifiers the liquor is suitably tempered by the addition of finely ground slacked lime. This lime is formed into a milk with water, and is well stirred into the liquor when the latter is at a temperature of about 130 or 140 degrees Fahr., after which it is raised to the boiling point, and kept gently simmering until the scum rises to the surface. When this scum has attained a sufficient consistency, the clarified juice is drawn off from the bottom of the clarifier, and is run into the first of a set or battery of teaches or coppers. The scum is run into a tank or receptacle to be subsequently purified or distilled, or in some cases it is run to waste into the scummings pond, to be afterwards employed as manure. In the first teach or copper the clarified or defecated liquor is again treated with a small quantity of milk of lime, which causes the scum to rise after a certain time to the surface, from which it is removed or brushed off by means

of a skimmer. The boiling liquor is then baled or
passed with a long-handled dipper or ladle to the
next teach or pan, and so on through the battery
until it reaches the last or striking pan or teach,
which is the smallest of the set, and which is
situated directly over the furnace by means of which
the whole battery is heated, the boiling liquor
becoming concentrated and approaching more and
more towards crystallisation as it advances. In
the last or striking pan the condensed or con-
centrated liquor or syrup is tested either by
the touch test or by means of the saccharometer,
and when in a proper condition it is run into
the coolers, which latter are shallow pans of iron
or wood. The action of the hydrate of lime is to
coagulate the albumen, and separate it, together
with the earthy phosphates and waxy matter.
The resulting mass is partly composed of raw or
Muscovado sugar, and partly of molasses.

From these coolers the sugar is dug out after
a sufficient time has elapsed to admit of its
becoming properly set and cooled, and it is
transferred to hogsheads having perforated bottoms,
which hogsheads are placed on cross beams in
the sugar-curing house, or purgery, where the
molasses is permitted to drain off through the
said holes and run into a tank or cistern situated
beneath the floor. The granulation of the sugar
is improved by running several strikes, or portions
of strikes, into each cooler. When of good quality,
pure brown, or raw sugar is of a light colour, highly
crystallised in large grains, and free from moisture,
feeling dry to the touch, and with no clamminess
or stickiness.

The megass or bagasse (crushed cane stalks
which have passed through the cane-mill) is
usually spread out to dry, and is used as fuel

under the coppers or teaches, or boilers, any surplus being stored in the megass-house, which latter consists in a roof supported upon columns and unenclosed in any way by side walls, to be employed in the copper wall and boiler furnaces at the beginning of the next crop season.

In some cases the process of clarification or defecation is carried out in an apparatus wherein the juice is subjected to exposure to, and contact with sulphurous gas, the action of which retards fermentation, and prevents the consequent disorganisation of the sugar by the formation of grape - sugar or glucose, and the attendant decrease in the return of crystallisable sugar, and increase in that of the uncrystallisable sugar or molasses.

In usines or factories making a superior class of sugar or crystals, the liquor is subjected to one. or more filtrations, and the final concentration of the clarified and filtered liquor is carried out at a low temperature by boiling (after it has first been reduced to a certain density in the copper wall) in a vacuum pan, or it is first evaporated, or boiled down or sweet, in a triple effect or other multiple effect evaporating apparatus, and finished or the crystals built up in a vacuum pan. The *masse cuite* is then usually transferred direct to a mixer from which it is delivered to the centrifugal machines.

To prevent the coagulation of the albuminous impurities the juice should be heated as soon after leaving the crushing mill as possible. This is frequently effected by means of a heater wherein the heating surface consists of a large number of tubes of small diameter.

In many factories the liquor is delivered after clarification and defecation, into eliminators for

finally clearing the juice or liquor of impurities before passing it into the multiple effect evaporating apparatus. These pans do not differ to any material extent from the clarifiers and defecators.

All vegetable acids transform sucrose or sugar proper into glucose or grape-sugar, as do also all mineral acids and alkalies ; salts cause a considerable portion of the crystallisable sugar to pass into the molasses. From this it will be seen that the formation of salts or of glucose during the process of manufacture is to be prevented as far as possible. The first can be avoided by employing the diffusion process, the latter only by a rapid carrying out of the various operations, and if this is not attended to, the proportion of grape-sugar already naturally extant in the cane juice will be greatly increased, and consequently also the residuum of molasses.

The works or usines comprise usually more or less substantial buildings of wood or iron, or in some instances of stone or brickwork, that forming the boiling-house and containing the defecating and evaporating and concentrating plant, and the coolers for receiving the concentrated syrup, should be left open at one or more sides to admit a plentiful supply of fresh air, and should also have ample roof ventilation. The plan of any particular works must of course depend in a great measure upon the nature of the ground upon which it has to be erected, and upon the particular process of manufacture which it is intended to employ. The site for the works should, whenever possible, be so chosen that the canes when cut can be brought to the mill without the carts having to surmount any steep gradients, so that the full carts may, as far as practicable, travel down hill, and return empty up hill to be loaded. On level estates of large area

lines of rail are generally laid down from the cane-fields to the mill-yard. Various other considerations, such as the supply of water for the boilers, etc., convenience of transportation for the hogsheads, bags, etc., of cured sugar to the place of shipment, must of course also materially affect the choice of the site.

When lines of rails are laid down through the cane pieces, and to the mill-yard, locomotives are usually employed for hauling the loaded trucks to the said mill-yard, but in some instances mules are still used, either solely, or in conjunction with locomotives. The lines are as a rule narrow gauge varying from two feet to three feet six inches, with iron sleepers so arranged that they can be laid down or taken up with great facility and expedition. The best form of truck for carrying canes is one consisting of a framework and ends only, (Fig. 44) the absence of the sides admitting of the cane stalks being piled upon and across the frame of the truck or waggon between the vertical ends. The locomotives are small and light, running from five to twenty tons each.

In many parts of the West Indies and elsewhere, a considerable portion of the canes can be brought to the mill-yards by water carriage. The punts provided in the water trenches for this purpose usually consist of flat-bottomed round-ended boats, constructed of wrought iron plates, with angle irons along the tops and bottoms, stiffened here and there by T irons, and covered with stout planking on the bottoms.

Figure 1 shows a plan of a small cane sugar usine or factory. A is the cane-mill, B is the cane-mill engine, C C are the boilers for raising steam, D D are the clarifiers or defecating pans, E E are sets of teaches or coppers, E^1E^1 are the

filters for the mechanical purification of the liquor. F is a vacuum pan, F^1 is a heater, G G are open steam-heated evaporating pans, H H are the coolers, I I are the centrifugal machines, I^1I^1 are tanks or cisterns to receive the molasses extracted from the sugar by the centrifugals, K is a large tank placed at a high level and intended to contain a supply of water for
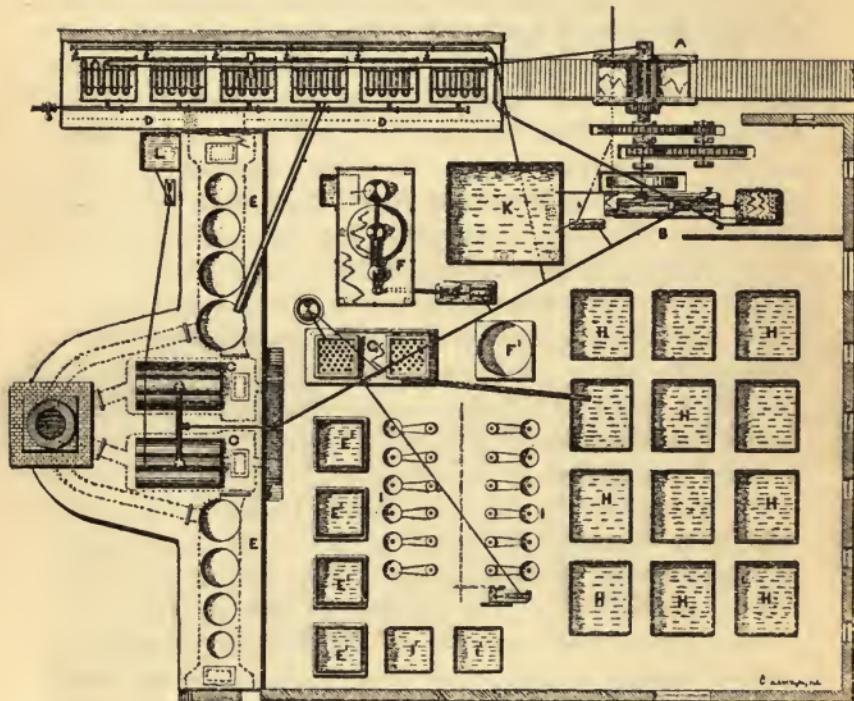
FIG. 1.

washing out the clarifiers and defecating pans, etc., and for other purposes, L is a tank or cistern intended to receive the water resulting from the condensation of steam in the clarifiers, condenser, etc., and to form a hot well for supplying the boilers C. The clarifiers or defecating pans are

erected upon an elevated platform, so that the liquor can be run direct through a chute or gutter to the copper wall. The juice is raised from the mill to the said clarifiers by a liquor pump worked off one of the gudgeons of the mill rollers. Two sets or batteries of coppers or teaches are provided, having a furnace at each end, the flue from each set being conducted to one of the boilers, but bye-passes being also provided, through which the waste products of combustion can be led direct to the chimney shaft when desired. Each of the boilers is provided, moreover, with a separate furnace, so that it can be fired direct when necessary. In a plant of this description, the clarified or defecated liquor is usually evaporated or concentrated in the copper wall, to a point below that at which the sugar becomes charred and injured to any appreciable extent in colour, by the high temperature to which it has to be raised in open coppers or teaches, and is then passed into the vacuum pan for completion and granulation.

The steam heated evaporating pans G can also be used for making strikes of sugar from liquor or syrup previously partially concentrated in the copper wall.

Instead of the old and extremely slow and tedious, and also most imperfect, method of curing the sugar by placing it in hogsheads with perforated bottoms, it is placed in the baskets of the centrifugal machines I, in charges of from three to five hundredweight according to the size of the grain, and the time occupied in curing will in like manner vary from five minutes to half an hour.

The cane-mill engine is in this instance one of the horizontal extended bed-plate type, fitted with a condenser, and the exhaust pipe from the engine is so arranged that when the exhaust steam is

required for use in the clarifiers or defecating pans, D, it can be cut off from the condenser and delivered direct thereto. The condensation water from the condenser is, as above mentioned, delivered to the hot well L.

The cane-mill is situated outside the main building and is provided with a cane carrier for facilitating the feeding of the canes to the crushing rollers, and with a trash carrier or elevator for removing the cane trash or megass.

The sugar-house, which is usually a separate building, is not shown in the plan, it would in this instance be situated contiguous to that end of the boiling-house furthest from the cane-mill.

The plans for beet-root sugar factories must of necessity vary in almost every instance in accordance with the particular mode of manufacture adopted, and the locality. In some cases a central establishment, or sugar factory wherein the juice is evaporated and concentrated, is supplied by a series of outlying rasping and extraction works, employing either hydraulic pressure or diffusion, or both. In this system the juice is conducted to the central factory by pipes, usually laid underground at a depth of from two to three feet, the size of the mains being usually five or six inches internal diameter, and that of the connecting pipes thereto three or four inches. The mains, which in some works extend to a total length of about 70 miles, are, as a rule, cast-iron socketed pipes proved up to a pressure of about 250lbs., and the joints are made with lead. The pressure in the mains is indicated by gauges at the outlying works, and may vary from 10lbs. to 200lbs., or more, in accordance with their position. Accumulations of gases in the mains are permitted to escape through valves placed at the highest points and opened daily, and discharge

valves are placed at the lowest points for cleaning purposes. When not in use the mains are plentifully flushed with pure water. The outlying works or stations are generally connected with the central establishment or factory by telephone.

The process of sugar refining, that is the discolourisation or purification of the raw or brown sugar, consists briefly in the following six stages, viz. : Firstly, the dissolution of the raw sugar in water in dissolving pans, or blow-ups, in which it is agitated by mechanical stirrers, tempered with a little lime water and blood, and kept at a temperature of about 165degs. Fahr., until at a specific gravity of about 29degs. Beaumé. Secondly, the passage of the syrup through bag and bone black, or charcoal filters. Thirdly, its evaporation in vacuum pans at a temperature of from about 180degs. Fahr., at the commencement to about 145degs. Fahr., when crystallisation had begun. Fourthly, the completion of the crystallisation by stirring in heaters at a temperature of 180degs. Fahr. Fifthly, the transference of the crystalline mass to conical moulds which are placed on end in a chamber, the atmosphere of which is maintained at a temperature of about 100degs. Fahr., a clear saturated solution of sugar being poured upon them so as to percolate through the sugar in the moulds and whiten it. And sixthly, the transference to stoves wherein they are baked at a temperature of from 130 to 140degs. Fahr., for two or three days until the sugar loaves are thoroughly dry.

In Boivin and Loiseau's process, the purification is carried out with the micrate of the hydrocarbinate of lime.

The various machines, apparatus, etc., will be found described in detail in the succeeding chapters, in the order, or as nearly so, as is consistent with

their proper and convenient classification, in which they are used in the process of sugar-making.

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CHAPTER III.

The Extraction of the Juice from the Raw Material.—Cane-Mills.

The best apparatus hitherto devised for mechanically extracting the juice from the stalks of the sugar-cane is the cane-mill with horizontal crushing rollers. These mills have been made in a great number of different patterns, some of the principal of which will be described and illustrated.

The three-roller cane-mill, which is the type of mill in most general use, consists in a series or set of three horizontal crushing rollers, two of which are placed in the same plane horizontally, and the third above and between the other two. Powerful setting-up screws are provided for adjusting the distance or space between the two lower rollers and the upper roller, the brasses or bearings being so constructed and supported as to admit of sufficient play or movement for that purpose. A clearance of from a quarter of an inch to three-quarters of an inch is left between the cane roller, or lower roller nearest that side of the mill at which the canes are fed, and the upper roller, whilst the other lower roller or megass roller is set nearly flush thereto, say with just sufficient clearance to admit of the introduction of a sheet of paper between them. The action of the top and cane roller should be to crush the cane stalks, and that of the top and megass roller to complete the expression of the juice therefrom. Flanges are formed

on the extremities of the two lower rollers, or of the top roller to prevent the canes passing out at the sides, or a fender plate is provided for that purpose. Between the cane and megass rollers is situated the dumb returner, sometimes also called the trash turner or dead plate, which consists in a curved plate the edges of which bear against the said rollers, and which is perforated to permit the juice to pass through it to the bottom or bed plate of the mill, which is so constructed as to form a sloping cistern or receptacle discharging into another tank or cistern placed at the side of, or convenient to, the mill. The dumb returner or dead plate must be capable of withstanding very heavy strains, and serves the purpose of receiving the canes from the cane roller and upper roller after the first crushing, and delivering them to the megass roller and upper roller for the second or final crushing. The top roller or the cane roller is sometimes slightly grooved or fluted to enable a better grip on the smooth and hard skins of the canes to be obtained, and when not so grooved or fluted it is usual to rough the surface with a chisel for the same reason. The grooves or flutings in the periphery of the roller are objectionable, by reason of their tending to tear the fibre of the canes and to damage the megass for subsequent use as fuel. The gudgeons, shafts, or axles of the rollers are supported in suitable bearings carried in the cheeks or side-pieces of the mill in such a manner as to admit, as above mentioned, of their having a certain play or movement therein for purposes of adjustment, and the said cheeks or side-pieces of the mill, as well as the base-plate and other parts of the framework, must be very massive in design, and also constructed of first-rate materials in order to enable them to with-

stand the severe and constant strains to which they are liable to be subjected when in use.

The three rollers are geared together, and the upper roller is further provided with a suitable clutch or coupling by means of which it can be coupled or connected through a suitable train of toothed wheels (see Fig. 1) with the driving or crank shaft of the cane-mill engine. This intermediate gearing is for the purpose of running the rollers of the cane-mill at the slow speed necessary to ensure the efficient grinding of the canes, and the expression of the maximum amount of juice therefrom. The said intermediate gearing is either single, or double or compound, by the employment of the latter the use of toothed or spur wheels of exaggerated and awkward dimensions is obviated. A considerable accession of power is also gained through the intermediate gearing. The pinions are shrouded or flanged, and together with the clutch or coupling should preferably be of steel, and carefully annealed so as to lose all brittleness. It is a good plan to employ teeth of the double helical class, thereby ensuring additional strength and the consequent increased immunity from liability to breaking or stripping of the said teeth.

The toothed or spur wheels in the intermediate gearing and the framing can be advantageously built up in sections, thereby enabling spare parts to be kept in stock, and any section broken or damaged through accident, or wear and tear, to be easily and expeditiously replaced or renewed ; the formation of the said spur or toothed wheels and framing in sections facilitates moreover their transport to the works, and the subsequent handling thereof during erection.

All the shafts or axles and the gudgeons of the crushing rollers should be made of mild steel, or of picked hammered scrap-iron, the latter material

FIG. 2.
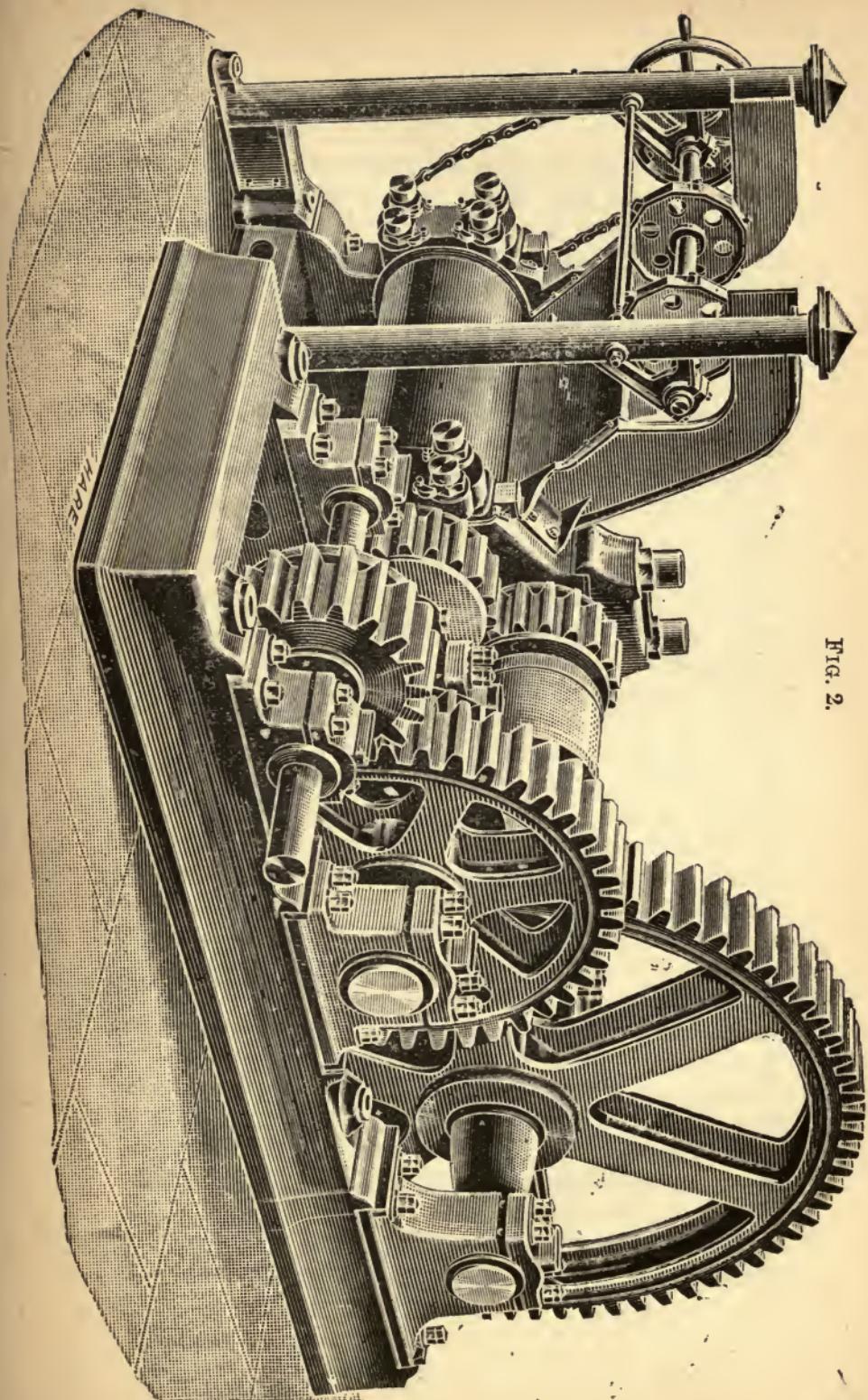
being preferred by some engineers as being more certain and less liable to crystallisation and fracture under heavy and continuous vibrating torsional strains. The horizontal and vertical through bolts should preferably be of very carefully selected Siemens-Martin forged mild steel, and should be invariably enlarged in diameter for the screw-threads. In a properly designed three-roller cane mill having the crushing rollers arranged triangularly, the journals are of large diameter, the housings and caps carefully machined to fit each other, and the framework is such that the mill will be as rigid and self-contained as possible, so as to preclude as far as practicable the liability of any particular part being subjected to any undue strains, and to distribute them evenly through the entire mill.

The cane stalks are fed to the crushing rollers of the mill down a sloping trough, board, or table called the cane board or table, and the megass or bagasse is received from the rollers upon another board, trough, or table sloping in a downward direction from the said rollers, called the megass board. When the mill is fed by hand it is usual to fix a supplementary table in front of the feeding trough or board, upon which the canes can be deposited within easy reach of the mill feeders.

In Fig. 2 is illustrated a powerful three-roller cane-mill and compound gearing of modern design, constructed by the Haslam Foundry and Engineering Company, Limited, Derby. The bed plate forming the base of this mill and the cheeks or standards are of unusually massive construction, and the facings are all planed up true. The standards are fitted with Rousselot bolts, and extra heavy gun-metal bearings for the crushing roller shafts, and provision is, moreover, made for enabling the lower

rollers to be removed from the mill through the sides. The crushing rollers are provided with convenient means of adjustment to any desired position, and are constructed of massive sections, and of special quality metal; the shafts are made of hammered iron turned perfectly true, and firmly keyed in position in the said rollers. The dumb or trash turner is of strong section and made of wrought-iron. The mill is intended to be secured to the foundation in the usual manner, that is to say, by massive iron vertical through bolts, which pass through the top caps, standards, bed plate, and the upper and lower timbers, this arrangement giving when firmly bolted together considerable stability, and at the same time affording a certain amount of elasticity or give to any extra strains caused by heavy feeding; the mill cap nuts are of very deep section and made of gun-metal, and locking collars are provided. A feature in this cane-mill is the tank or receptacle to catch the juice expressed from the canes, which takes the form of a tray delivering the said juice to the side of the mill, and is so constructed that it can be heated by steam when desired. The cane carrier and megass carrier or elevator can be arranged to be driven by means of toothed gearing, or pitch chains, the latter method being shown in the illustration.

The intermediate gearing for this mill is of the compound type, and is mounted (as will be seen from the illustration) upon a cast-iron bed plate of great strength, which can when desired be constructed in sections for facilitating transport. The facings for the plummer-block seatings are all planed up true. The toothed wheels and pinions are strong, accurately bored out at the eyes, and the larger sizes formed in halves, or built up in sections; in the latter case the segments being arranged to bolt to the turned rim
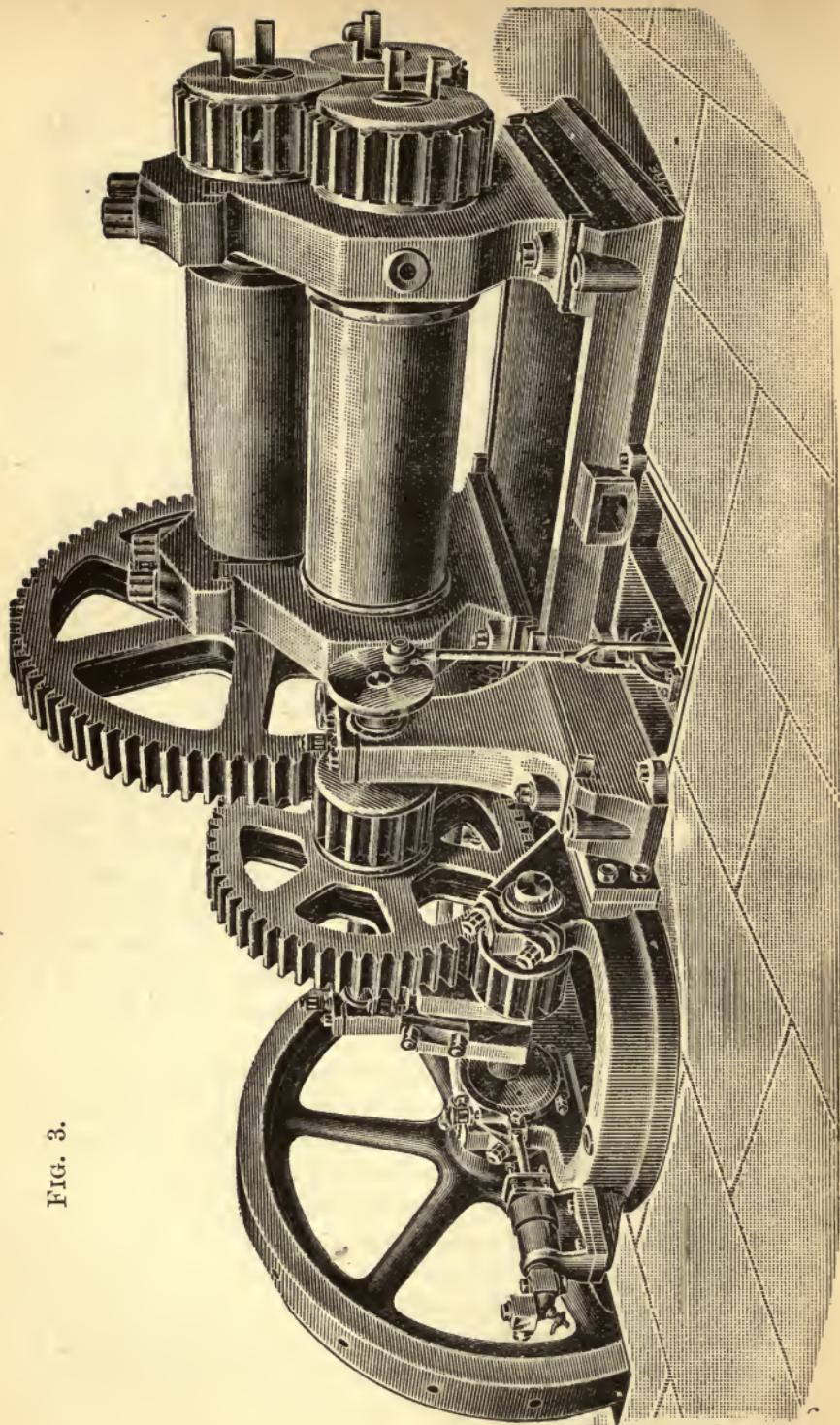
Fig. 3.

of the wheel. The shafts are of hammered iron carefully turned. When desired the pinions are made of cast-steel.

The liquor pump (which is not shown in the drawing) is fixed in a cast-iron cistern, and is driven from the end of the roller shaft, or from the intermediate shaft of the gearing. The barrel of the pump is lined with gun metal, and is fitted with gun metal buckets and seatings, the valves are of india-rubber specially prepared.

Fig. 3 shows another three-roller cane-mill made by the same company. This mill is of the kind or class known as "combined engines and cane-mills," that is to say, the mill, intermediate gearing, and engine are all self-contained and mounted on one bed plate. The mill in question is fitted with compound intermediate gearing, and is driven by an horizontal high pressure expansion engine, the latter having steel piston and valve rods, and crank shaft, connecting, and eccentric rods, of the best wrought-iron. The said engine is fitted, moreover, with high speed governors, combined stop and equilibrium valves, and a simple link motion reversing gear. The fly-wheel is very heavy and is turned up true on the rim and boss. The bed plate for convenience of transport and fixing is made in halves, as shown in the illustration, faced up true and firmly bolted together. The juice tank or tray delivers into a cast-iron tank fitted with a straining arrangement and liquor pump, which latter is driven off a disc-crank fixed upon the end of the intermediate shaft of the gearing. The crushing roller pinions are placed upon the opposite side of the mill from the gearing, thus permitting the mill and gearing to be placed closer together and securing more compactness of construction. Mills of this pattern are largely used on small estates,

and in positions where there is a difficulty in securing good foundations.

Combined engines and cane-mills are also constructed wherein the mill, gearing, engine, and boiler, the latter being of a vertical pattern, are all four carried upon the same bed or base-plate. The steam engine in this instance is usually one of the diagonal type, the latter being compact, and occupying a comparatively small space.

The approximate sizes of steam-engine cylinders required for driving three-roller cane-mills of various dimensions, the minimum initial steam pressure being 60 lbs., are as under :—

Dimensions of crushing-rollers of cane-mill.			Dimensions of steam-engine cylinder.					
			Horizontal engine.			Beam engine.		
in.		in.	in.		in.	in.		in.
16	×	24	9	×	18			
18	×	24	10	×	18			
20	×	32	10	×	20			
20	×	40	12	×	20			
21	×	42	12	×	24			
22	×	48	14	×	24	14	×	30
24	×	46	16	×	27	16	×	34
24	×	56	16	×	27	15	×	36
26	×	56	17	×	27	16	×	36
26	×	60	18	×	27	16	×	36
28	×	54	16	×	30	18	×	36
28	×	64	16½	×	30	18	×	36
28	×	72	16½	×	36	19	×	36
30	×	60	18	×	30	19	×	36
30	×	66	18	×	36	20	×	36
30	×	76	20	×	36	20	×	36
32	×	72	22	×	36	22	×	36
33	×	84	20	×	48	20	×	48
34	×	84	22	×	48	22	×	48

When the cane-mill engine is worked with a back pressure, and the exhaust steam is used for heating

the clarifiers, etc., either a higher initial pressure or a larger cylinder area will be required.

The following are the approximate amounts of juice expressed by three-roller cane-mills of various dimensions :—

Sizes of Crushing Rollers.	Juice per hour.
Inches.	Gallons.
16 × 24	200
18 × 24	250
18 × 30	350
20 × 32	400
20 × 36	500
20 × 40	600
21 × 42	650
22 × 42	700
22 × 48	850
24 × 46	900
24 × 48	950
24 × 56	1,200
26 × 54	1,200
26 × 56	1,300
26 × 60	1,450
28 × 54	1,400
28 × 60	1,550
28 × 64	1,650
28 × 72	2,000
30 × 60	1,650
30 × 66	1,900
30 × 76	2,300
32 × 66	2,000
32 × 72	2,400
33 × 84	2,900
34 × 84	3,000

A three-roller cane-mill having the crushing rollers arranged triangularly, although possessing many undoubted advantages, has been found in practical working to be open to certain serious objections; for instance, owing to its construction it is impossible to take the heavy strains tending to separate the rollers, when in use, by bolts lying

directly in the line of stress, and as these strains amount even in a mill of medium size to some hundreds of tons, the side cheeks of the mill have to be made of excessively massive construction, notwithstanding which, however, they are liable to frequent breakages. Moreover, the dumb returner, dead plate, or trash turner which is an absolutely necessary part of a three-roller cane-mill, and which, as already mentioned, is a species of knife-edged scraper placed between the lower rollers for the purpose of directing the partially crushed canes between the first and second crushing, is a source of constant annoyance and trouble, as all who have had anything to do with cane-mills are well aware. In order to enable it to withstand the severe strain to which it is subjected, it has to be made of very large dimensions in transverse section, running sometimes to solid forgings ten inches square or even more, and even these have been known to be frequently bent or broken ; and it is, by reason of the awkwardness of its position, very difficult to gain access to for adjustment or other purposes. Besides, the partially crushed cane stalks which collect between it and the top roller form perpetually a powerful brake, and consequently consume a very large percentage of the driving power.

Efforts have been made by The Mirrlees, Watson, and Yaryan Company, Limited, Glasgow, and others, to avoid these defects by constructing four-roller cane-mills. That of the above company, which is shown in side elevation in Fig. 4, was exhibited at the Glasgow Exhibition of 1888, and is of a patented design. It has two pairs of crushing rollers, between which the canes pass successively, the juice expressed therefrom falling into a tank or receiver formed in the framework, and from which
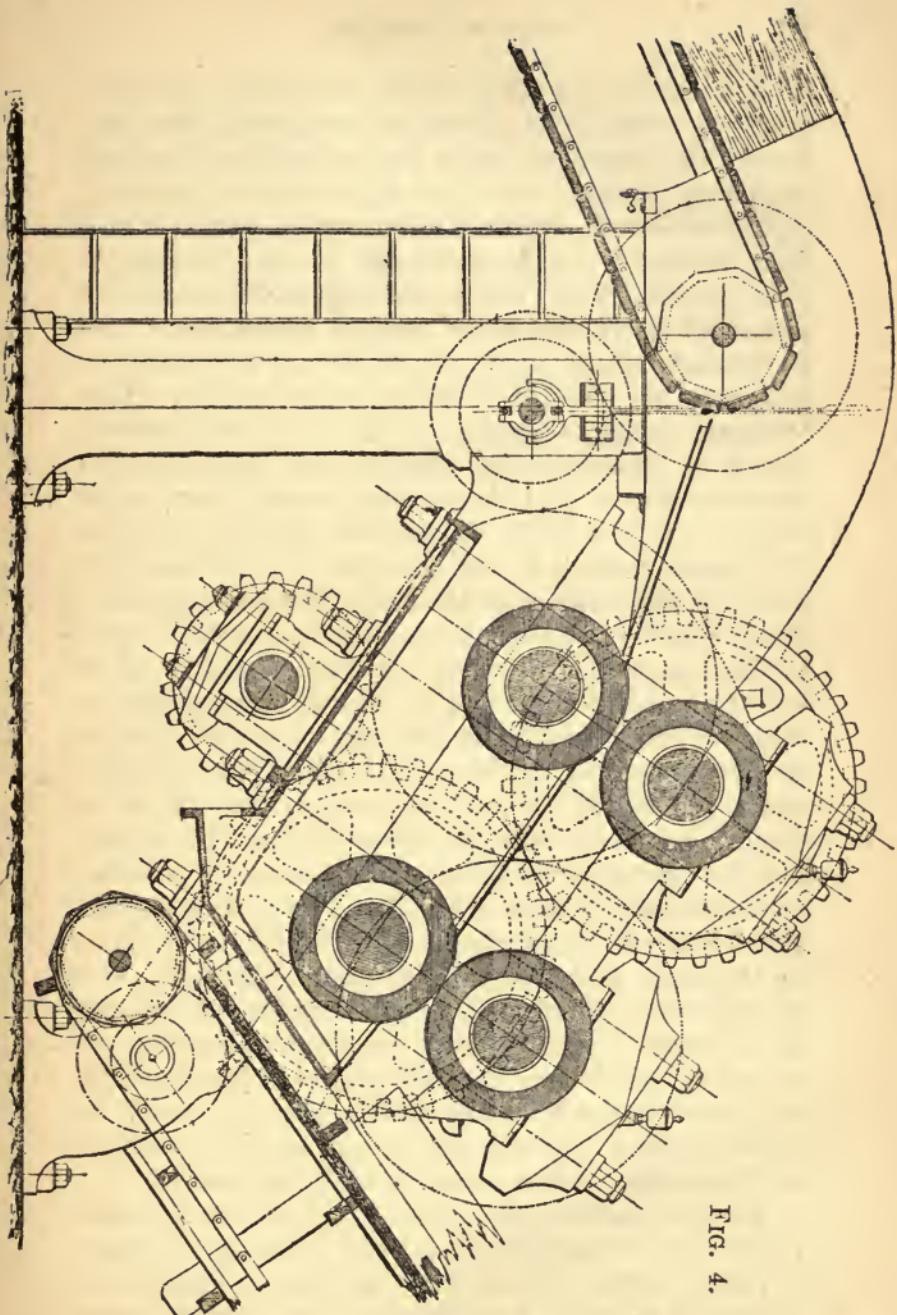
FIG. 4.

it is removed in the usual manner. The two pairs of crushing rollers are arranged in the side frames of the mill so as to be in positions inclined relatively to each other, and the main driving-shaft passes under the mill framing, which latter is of a half inverted V shape and beds on the ground in two places. The main driving-shaft carries a pinion at each extremity, one of which gears with a toothed wheel firmly keyed on the shaft or gudgeon of the first pair lower roller. This toothed wheel gears with another toothed wheel of corresponding dimensions firmly keyed on the shaft, or gudgeon of the second pair upper roller. On the other or opposite side of the mill this arrangement is reversed, that is to say, the pinion gears with a toothed wheel keyed upon the shaft or axle of the second pair lower roller, which in, its turn gears with another toothed wheel keyed upon the shaft or axle of the first pair upper roller. The canes are fed into the mill from a sloping board or table, and the partially crushed canes are conveyed or delivered down another sloping board or table from the first to the second pair of crushing rollers, and thence by another board or table out of the mill. The mill is usually fitted with a cane carrier for feeding the canes to the mill, and with an elevator or conveyor for taking away the crushed cane stalks or megass. This cane carrier and megass elevator or conveyor are driven through suitable intermediate toothed wheels from the mill gearing. It will be seen that the toothed gearing on each side of the mill forms in itself a complete train of wheels.

Another advantage claimed for this pattern of mill is that the friction in the gearing is greatly reduced, inasmuch as the crushing rollers are driven by toothed wheels .of a comparatively large

diameter, whilst in the ordinary three-roller mill they are driven by pinions of the same diameters as the crushing rollers. The arrangement of the crushing rollers in inclined or diagonal positions relatively to each other permits the opening or clearance between the rollers to be adjusted without altering the depth to which the toothed wheels gear into one another to any injurious extent.

In another four-roller mill, invented by De Mornay, the dumb returner is also dispensed with. Two main rollers of large diameter are provided, which are supported in a slightly inclined plane. Beneath the cane roller are provided two smaller supplementary rollers, so placed with respect to the periphery of the former that the canes which are fed between the main cane roller and the first supplementary roller are caught between the second supplementary roller and the main cane roller, and are directed thereby between the latter and the second main or megass roller, where the principal expression of the juice is effected.

The proper and judicious feeding of cane-mills is an operation of great consequence, both as regards the safety of the various parts and the efficient crushing of the canes. With inexperienced or careless feeding a cane-mill will be at one moment nearly or entirely empty, and at the next choked with canes, frequently to the extent of pulling up the engine, with the result that the latter will have to be reversed to clear the mill, thus entailing waste of time and bad crushing, to say nothing of the danger of breakage to some of the parts, or of the injury caused by the jarring and vibration occasioned. When choking and stoppage is avoided by passing a less amount of cane stalks through the mill, the rollers, having been regulated or adjusted for a certain prescribed and regular

feed of a heavier character, will not properly press the canes, and a ruinous percentage of juice will be left therein.

Large mills, and even those of moderate dimensions, are now generally provided with cane carriers or conveyors (see Fig. 1) for facilitating the feeding, and also with elevators or conveyors for removing the megass or bagasse and delivering it to the furnaces, or into or near the megass-house or shed, where it is dried and stored for use as fuel as before mentioned. These cane and trash carriers or conveyors may consist simply in endless bands or belts formed of thin slabs or laths of wood or metal secured upon pitch chains carried upon sprocket or chain wheels in the ordinary or usual manner, they are equal in width to the length of the rollers of the particular mill with which they are to be connected, and are of any suitable length. They are driven either by means of pitch chains or toothed gearing. The use of a cane carrier enables the canes to be spread upon the cane table or board with far more evenness and uniformity than can be done when they are pitched thereon by hand, in an irregular manner, by the men who collect them in ropefuls from the heaps in the mill-yard, where they are dumped by the carters, or from the trucks, in cases where lines of rails are laid down through the cane-fields and up to the said mill-yard. The trash carrier or elevator is also of much service, greatly facilitating the delivery of the megass or bagasse to the vicinity of the shed in which it is stored after drying, or direct to the boiler or copper wall furnaces, and thereby preventing the objectionable accumulations of the said bagasse or megass about the mill, and the liability of its getting into the gearing, which not infrequently occurs when removed by a gang of

coolies or labourers in baskets with more or less irregularity.

Another matter of vital importance, so far as regards the extraction of the maximum percentage of the juice from the cane stalks, is the speed at which the mills are run. One of the chief objections that have been brought against the system of extracting the juice by passing the canes between crushing rollers is that the time allowed for pressing is too short to admit of the juice being properly extracted from the cells in which it is stored. It follows, then, that the slower the speed at which the crushing rollers are revolved up to a certain point, the more efficient will be their action. The crushing rollers of mills of, say, two feet diameter were formerly speeded to revolve at about 210 feet per minute at their peripheries; this was soon found to be by far too great a velocity for efficient work, and was reduced to about 60 feet per minute. It is stated on good authority, that upon still further reducing the speed of a mill, having crushing rollers 28 inches in diameter, from eight revolutions per minute to two and a-half revolutions per minute, the yield of juice was increased from 46 per cent. to 70 per cent. Cane-mills in Cuba with crushing rollers 30 inches in diameter and 6 feet in length, and running at a speed of about two and a-half revolutions, or 20 feet at their peripheries, per minute, are said to extract 72 per cent. of the juice of the cane. The present practice is to speed the mill rollers to travel at a velocity of about 16 feet per minute at their peripheries.

In large factories it would be far preferable were two cane-mills of smaller dimensions employed in place of one of large size, not only on account of the extraction by the latter being inferior owing to the greater difficulty experienced in maintaining an

even and regular feed, but also by reason of the work not being completely stopped in the event of a breakdown occurring to one of the mills, the chance of an accident happening to both mills at the same time being comparatively remote.

Even, however, when working under the most favourable conditions a considerable amount of juice is still left in the crushed cane stalks or megass after passing through the mill, the loss in this way being estimated at from about 20 per cent. with mills of the most improved construction, to 40 per cent. or more with those of old and inferior design. The loss on all the operations is usually far higher, the total loss through imperfect extraction of the juice and the chemical changes which the latter undergoes owing to too much exposure to the atmosphere at ordinary, as well as at high temperatures, and the consequent degradation of the crystalline sugar into mucilaginous sugar or molasses, being about 50 per cent. The fresh canes contain from 17 to 20 per cent. of crystalline sugar, whilst the ordinary yield is not more than about $7\frac{1}{2}$ per cent. To prevent as far as possible the loss from the first cause, and to secure a better yield of juice, has given rise to the introduction of saturation, and maceration, or compound crushing, either in separate mills, or in compound mills, that is to say, mills wherein the cane stalks after passing between one set or series of crushing rollers, are delivered to one or more other sets or series (as many as nine rollers have been employed) before being removed.

The most usual number of rollers, however, and that which has been found to be the most effective in practice, is five.

A compound mill of this description was designed by Payen, many years ago. In Payen's cane-mill five

crushing rollers are employed, arranged horizontally as shown in the sectional side elevation Fig. 5. The cane stalks are fed into the mill between the lower or cane roller and upper roller of the first set, and then pass successively between the said upper roller and the second lower roller, and between the latter and third lower roller and second top roller out of the mill. The rollers are further covered with a hood or casing of iron, forming an enclosed chamber into which low pressure steam is intended to be injected through the pipes shown in connection
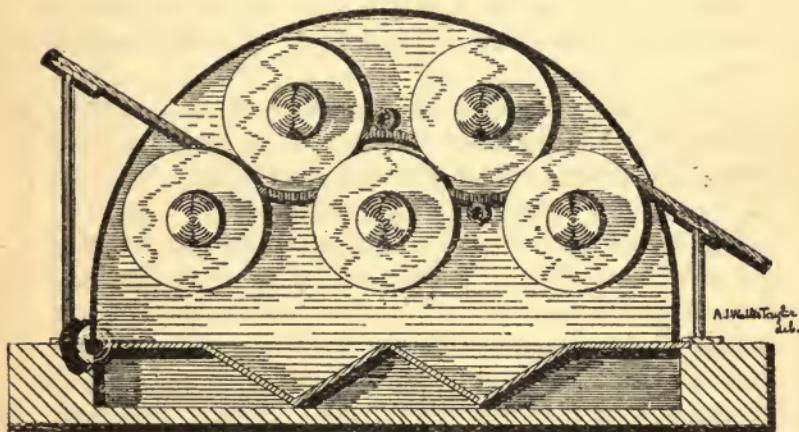
FIG. 5.

with the second and third dead plates or dumb returners, for the purpose of moistening the crushed cane-stalks during their passage between the various rollers.

Thompson and Black's five-roller mill consists in an ordinary three-roller mill, the side frames of which are extended, and support a pair of specially grooved rollers between which the canes pass, and are thoroughly split up, and the feed is brought to

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as great a degree of uniformity as possible, before passing to the main crushing rollers.

Fletcher and Leblanc's four-roller mill has the rollers so arranged that the canes are subjected to a triple crushing. Three of the rollers are placed in the same horizontal plane, whilst the fourth roller is situated immediately below, and in the same vertical plane as the central roller. The canes first pass between the first and second or central roller, and are conducted by one dumb returner to the central and lower roller, and by another to the central and third roller, from which they pass out of the mill. The rollers are so placed as to have a clearance of about one-sixteenth of an inch between them.

Russel and Risieu's, Duchassaing's, and Faure's methods of subjecting the canes to the action of water and steam at an intermediate stage between the crushings are the most practical.

In Russel and Risieu's arrangement for carrying out the maceration or imbibition process, the megass is delivered from one mill into a covered trough, running to a length of 30 feet or more, and near the top of which are provided perforated pipes, by means of which hot or cold water or cane juice can be impelled in the form of spray upon the said megass. The saturated megass is then delivered to the second mill, and the water or juice is expressed therefrom, carrying with it the soluble matter contained in the cells of the canes.

In Duchassaing's, the megass from the first mill is received on an endless band or apron, and during its passage to the second mill it is sprinkled, by means of suitable pipes, with water, and is also dipped into a tank or reservoir of boiling water.

In Faure's, the canes are likewise passed in succession between several sets of rollers or

mills, being conveyed from one set to the next by endless bands or carriers. The crushed canes are sprinkled with water between each crushing, so as to facilitate the extraction of the juice. By these means as much as 85 per cent. of the total amount of juice contained in the canes is said to be extracted.

The juice extracted by the maceration or imbibition process is subsequently treated in various ways, that most usual is to pass the juice from the first mill through a sulphurous gas churn, and that from the second mill straight to the clarifiers, together with the scums and other washings of the factory, where it is treated with an excess of lime and afterwards with carbonic acid. After carbonation, the latter juice (which should not be of a greater density at this stage than 5degs. Beaumé) is mixed with the juice from the first mill and is manufactured direct into first sugar.

In some works the crushed cane stalks or megass, having been previously moistened with water, is passed through the same mill a second and sometimes even a third time, instead of through a second or third mill. This practice is, of course, suicidal, and is indeed impossible except in some few cases where the mill power is greatly in excess of that required for the quantity of canes to be crushed.

It is very questionable indeed, in any case, whether the additional return of juice obtained is sufficient to compensate for the extra power that has to be expended in passing the canes through a mill with several sets or series of rollers, or in subjecting the megass to a second or third crushing by putting it through one or two auxiliary or additional mills, and for the fuel required to evaporate the extra amount of water with which

the juice would be diluted from the steam or water used to moisten the crushed canes during the operation. Besides the powerful and repeated crushing to which the canes are subjected naturally acts more severely upon the rind and upon the joints or knobs, as being harder and more woody than the rest of the cane, and various objectionable matters are expressed therefrom and mixed with the juice. And moreover, the megass or bagasse is so broken and pulverised as to be practically worthless for fuel, which latter objection alone renders this plan of treatment an impossibility in districts where fuel is extremely scarce and expensive.

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CHAPTER IV.

The Extraction of the Juice from the Raw Materials.—Safety Devices for Cane-mills.

As the shafts or gudgeons of the crushing rollers in cane-mills are liable to fracture, and the teeth of the pinions to be stripped by the excessive strains to which they are subjected, owing to the hereinbefore-mentioned choking of the mill from injudicious and unskilful feeding, numerous attempts have naturally been made to design a mill wherein the liability to these accidents would be reduced to a minimum. With this object in view, various safety devices have been devised for throwing the engine and mill out of gear, or for relieving and regulating the pressure of the crushing rollers.

The first of these plans consists in connecting the engine to the mill by means of some arrangement of friction clutch, so constructed that when the strain upon the rollers exceeds a given amount it ceases to act. This, although it may save the fracture of a gudgeon or the stripping off of the pinion teeth,

does not prevent the choking of the mill and the consequent trouble and annoyance of clearing it.

A large number of different mills have been designed from time to time upon the second plan, some of which are more or less successful in attaining the desired end. In some of these arrangements the upper rollers are fitted to move freely to or from the lower rollers in a vertical plane, a set of compound or other levers and heavy weights, hydraulic pressure, or of powerful springs being employed for maintaining the said upper rollers close enough to the lower rollers to produce good grinding under normal conditions. Should, however, the mills, be overfed the upper rollers will rise, thus regulating and relieving the pressure from the bearings, and admitting of an uninterrupted action without causing any undue strain. In practice many of these mills (although theoretically correct) are found to be undesirable owing to the fact that when large masses of canes are passing through them those on the inside are not properly crushed.

The arrangement wherein levers and weights are employed is cumbersome and unwieldy, and takes up a large amount of space, and it has in consequence been practically abandoned.

Hydraulic regulating apparatus for cane-mill rollers is by no means an invention of modern date. As far back as the year 1872 a patent was granted to one John Sheperd McDonald, of New Orleans, United States, for a cane-mill fitted with hydraulic bearings. McDonald's invention consists essentially in the following features, viz.: A ram or plunger is arranged in a suitable fluid-tight chamber situated beneath the mill, and is connected with the bearing blocks or caps of one of the rollers of the set or series. This

chamber is connected through a pipe with a suitable stand-pipe or accumulator, in which is arranged to work a plunger or piston, which presses upon the liquid contained therein, and consequently also upon that contained in the first-mentioned chamber, thereby acting through the said plunger to bear in a downward direction upon the said blocks or caps and upper roller, but with a yielding pressure. The amount of this pressure depends upon the difference of area between the pressure cylinder and stand-pipe or accumulator, and upon the weights or load applied to the stand-pipe or accumulator plunger. A hand force-pump is also provided by means of which the pressure in the said stand-pipe or accumulator can be raised to any desired point, or can be reduced, or the liquid entirely exhausted therefrom if desired.

In 1881 a British patent was granted to Duncan Stewart, of Glasgow, for an invention wherein hydraulic cylinders and rams are described as arranged in connection with the lower rollers of the cane-mill and take the place of the ordinary setting-up screws. In this arrangement air vessels are also employed, which latter are connected to the pipes supplying the liquid to the cylinders or chambers, and serve to impart a certain amount of elasticity to the device. A subsequent British patent granted in 1884 to the same inventor describes various improvements connected with the accumulator, comprising easily removable covers admitting of the inspection and adjustment of the hydraulic ram packing being made when desired, without the necessity of dismantling the whole apparatus as heretofore, and also in the provision of a suitable stop within the cylinder to limit the movement of the ram.

FIG. 6.
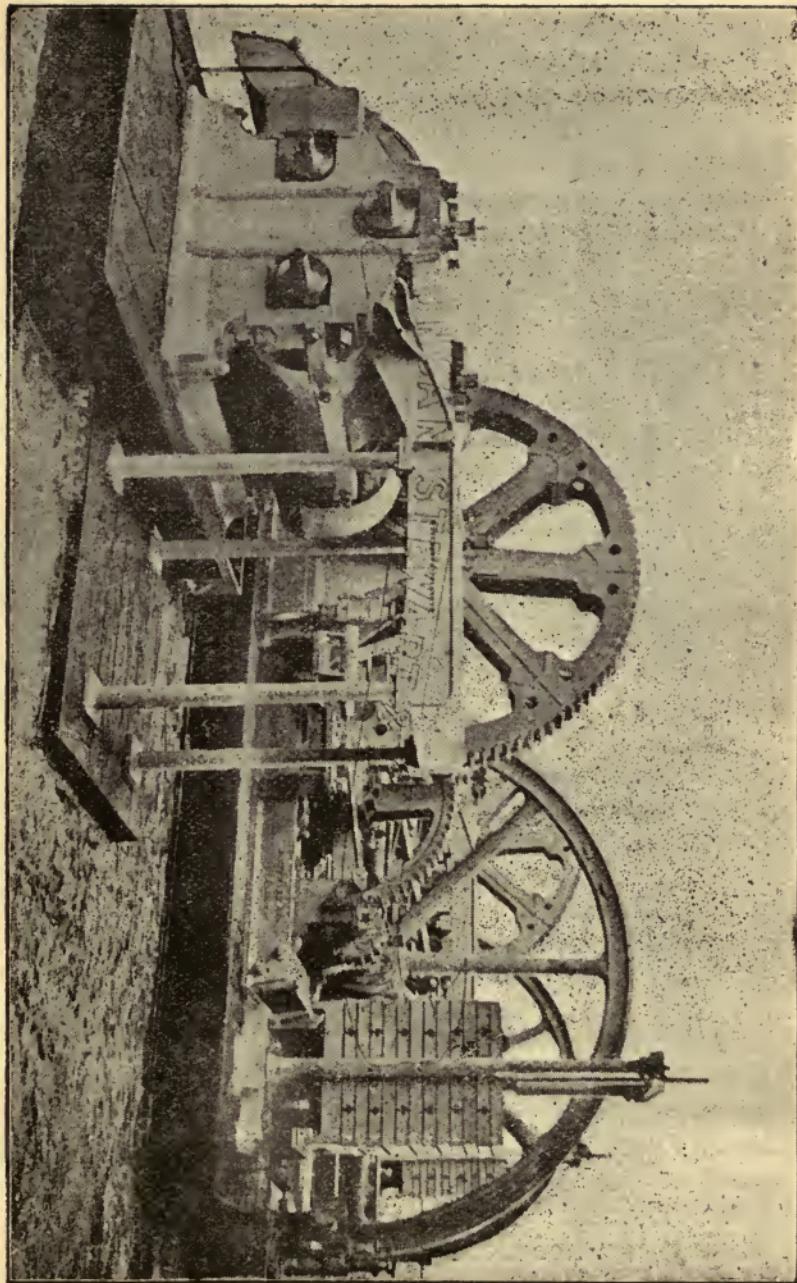
Hydraulic safety attachments, although sufficiently effective for the purpose of relieving the rollers when the latter were subjected to a very severe pressure, were nevertheless, as primarily constructed, open to several objections. Amongst these may be mentioned that the pressure exerted upon the rollers is at all times the same, consequently when the mill is overcharged inferior crushing results, as it is well known that the internal resistance to the escape of the juice increases with the thickness of the bed of canes that is passing through the mill, and that to secure perfect extraction the pressure should increase in a certain ratio with that of the feed. The hydraulic rams, moreover, entailed the use of an accumulator and a pump, and the apparatus was not only expensive, but also occupied a considerable amount of valuable space, was complicated in construction, liable to fail owing to leaky cup-leathers or joints, by reason of the wear and tear to the parts, and the difficulty experienced in making good joints to stand very high pressure, and the maintenance of the above-mentioned cup or hydraulic leathers in order consumed a considerable amount of skilled attention.

It is, however, only fair to remark that in the improved forms of hydro-mills, designed by Messrs. Stewart, these objections have been for the most part entirely overcome, and, with very moderate attention, the hydraulic safety devices act most satisfactorily. As will be seen from the illustration (Fig. 6), the accumulators, etc., are so placed as to occupy as little space, and to be as much out of the way as possible, and the construction of the several parts of the device has been greatly simplified.

De Mornay's four-roller mill, which has been already mentioned in the preceding chapter, is

FIG. 7.
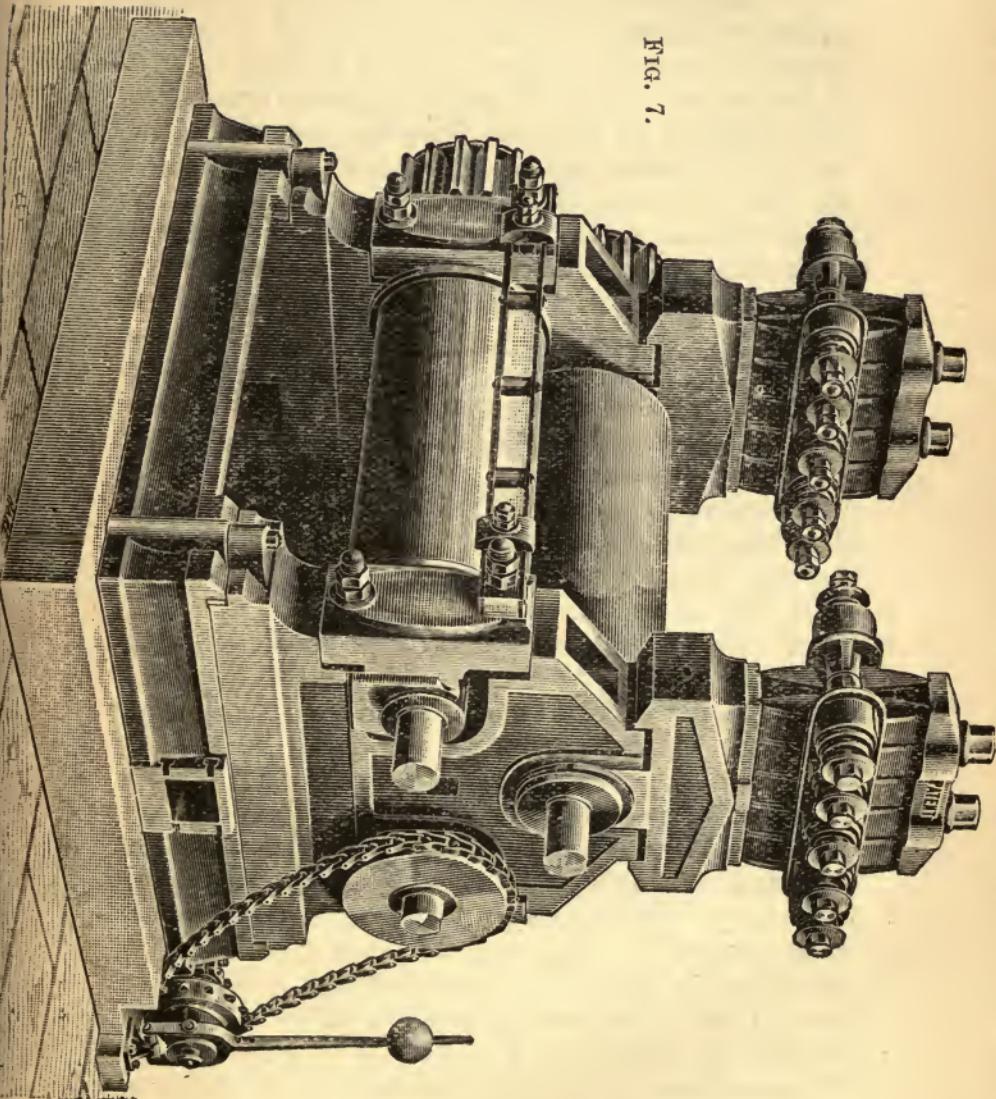
fitted with an arrangement for relieving the main cane-roller under excessive strains, consisting of sets of powerful coach-springs which bear upon the gudgeons through suitable blocks, and normally retain the two main rollers in close contact.

An improved form of the De Mornay four-roller mill, designed by Fawcett, Preston and Company, has an hydraulic regulating apparatus substituted for the above-mentioned springs. This mill is also fitted with a scraper which is carried up over the top roller so as to clear it slightly, and bent in a downward direction until it just touches the surface of the said roller. This scraper removes the megass from contact with the roller at once, so as to prevent it from reabsorbing any of the juice, and thereby avoiding what otherwise becomes a very serious loss.

Hydraulic attachments for cane-mills have been also designed by Manlove and others, which space does not admit of going into.

In Fig. 7 is illustrated a three-roller cane-mill fitted with a patent automatic pressure-regulating appliance and safety device made by the Mirrlees, Watson, and Yaryan Company, Limited, engineers, Glasgow. This contrivance, which can be readily adapted to any ordinary cane-mill, consists, as will be seen from the drawing, in an exceedingly ingenious and at the same time simple arrangement of toggle or knuckle joints. The particular combination of levers known as above is particularly characterised by a capacity of being able to exert an enormous amount of force through a short distance, and is therefore especially valuable for the purpose in question. The details of construction of the toggles are shown more clearly in the diagrammatical view (Fig. 8). The levers consist in plates with blunt knife-edge extremities which rest in
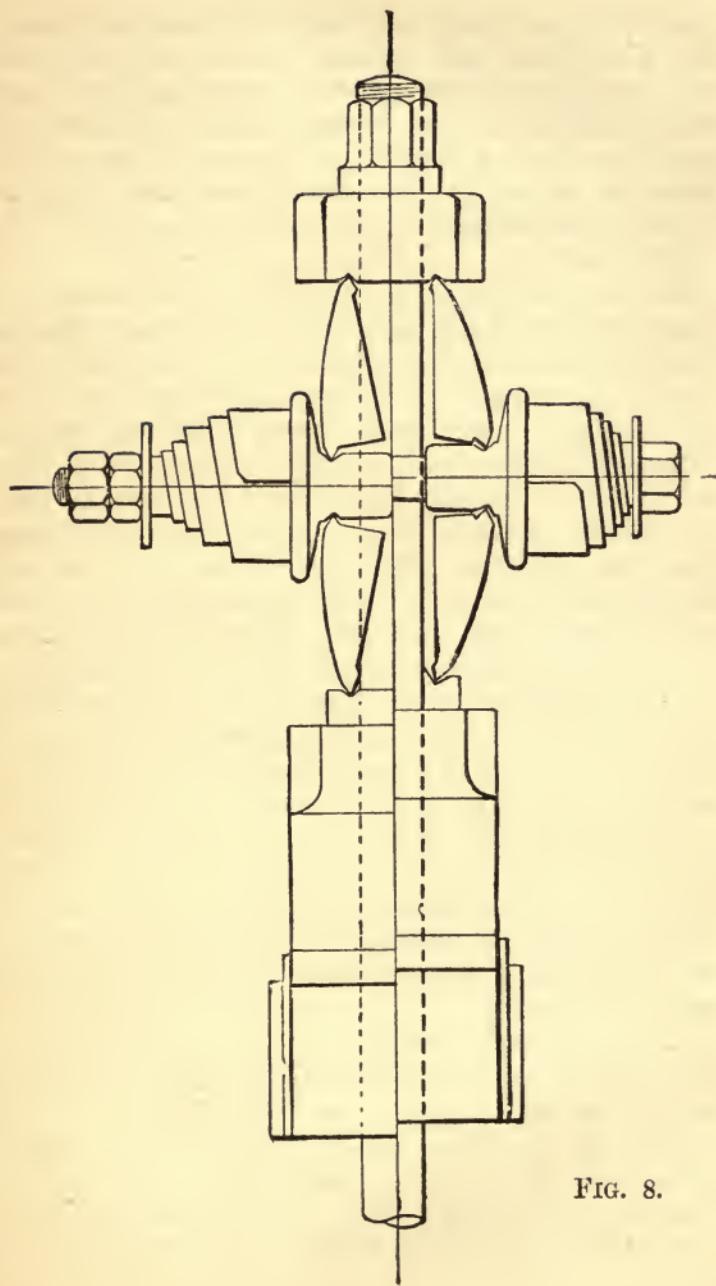
FIG. 8.

grooves formed in top and bottom and central plates. The top plates bear against the nuts of the cover bolts, and the bottom plates against the cap of the roller journal. The central plates are normally kept together by means of horizontal bolts and powerful spiral springs, the latter being similar in construction to those usually employed in railway buffers.

For convenience of illustrating the action of the gear the diagram is divided into two portions, that on the left-hand side of the vertical line being supposed to show the relative positions of the parts when the mill is empty, whilst that on the right-hand side is supposed to show their position when the mill is working with a very heavy feed. It will be seen that under the first condition the top roller rests upon its bearings, whilst in the second it lifts the caps which are controlled by the toggle gear until such time as this upward pressure is balanced by the resistance of the latter. Great care is exercised in the determination of the maximum amount of play which the said gear will permit even in extreme cases, so that the clearance allowed may be amply sufficient to provide a margin of safety under any circumstances that are likely to occur in ordinary practice. The pressure can be regulated, within limits quite sufficient for all ordinary requirements likely to arise in working the mill, by the adjustment of the nuts on the bolts which secure together the central plates.

An advantage claimed by the inventors for this toggle gear pressure-regulating and safety device is, that, owing to the cumulative and compensating action which it exerts, a thorough extraction, or as near a thorough extraction as can be secured in practice, is obtained, and that, notwithstanding very considerable variations in

the thickness of the bed of canes being passed through the mill. It will be seen that the spiral springs when least compressed, owing to a thin or light feed passing between the crushing rollers, and consequently exerting their minimum degree of thrust, will act upon the toggle levers at a maximum advantage, and when, on the contrary the most compressed, by a thick or heavy feed passing between the said rollers, and they are consequently exerting their maximum degree of thrust, will act on the said toggle levers at a minimum advantage.

It is therefore obvious, that by suitably selecting and adjusting the spring load upon the toggle levers, the pressure upon the crushing roller can be made quite uniform throughout the whole of the movement, as is the case in hydraulic regulated mills, or it can be otherwise adjusted if desired. In practice it is found preferable to take such advantage of this compensating feature of the toggle gear that a slightly increased pressure will be exerted as the thickness of the feed increases, keeping naturally well within the limits of safety, but thereby tending to ensure what is after all the main point to be aimed at—a thorough, or practically a thorough, extraction of the juice.

A two-roller safety mill, intended for use in factories where a second and third crushing of the megass or bagasse is in vogue, has been especially designed by the same company. The feeding-table or board of this crushing mill is so constructed as to be suitably adapted for the receiving and delivery to the mill of the megass or crushed cane stalks from the first or main crushing mill. The upper crushing roller is fitted with toggle pressure-regulating apparatus or safety-gear, substantially similar in principle to that hereinbefore described,

but somewhat differing in design. The vertical bolts of the toggles are still formed by continuations of the top cover or cap bolts, but the said covers or caps are rigidly fixed in position by means of nuts below the lower plates of the toggles, which nuts are screwed directly down upon them and do not lift with the roller. The necessary play for the top roller is provided below the caps or covers, and communication or connection between the said top roller and the toggle gears is made by means of plungers, formed on or firmly secured to the bottom plates of the toggles or knuckle joint levers, and working through suitable holes formed in the top caps or covers.

CHAPTER V.

The Extraction of the Juice from the Raw Material.—Motive Power for Cane-mills. —Foundations.—Boilers.

For driving cane-mills wind motors were at one time very extensively employed, and in many of the smaller West Indian islands and elsewhere they are still in use. The chief objection to wind-power is, of course, its uncertainty, and, moreover, the irregular velocity which is obtained, even when the wind is available, renders it by far the most inferior power that can be employed for cane crushing. With mills driven by wind motors of inferior construction only about 50 per cent. of the juice will be extracted from the canes, whilst even with those of the best possible construction no more than about 55 or 56 per cent. can be obtained.

Horse or mule gears are frequently used to drive the smaller classes of cane-mills, and the results

obtained therefrom are superior to those given by wind-power. The expense of the animals required to work the gear must, however, of course be taken into account.

Where obtainable, water-power is undoubtedly the best and most economical for driving, being not only as cheap as wind-power, but possessing the further advantage of a regularity far exceeding that developed by animal, or even by steam power. The results obtained from mills driven by water power have been found to be superior to those actuated by any other kind of motive power, not excepting steam.

A steam-engine of one kind or another is now, however, the most usual motor employed, and taking everything into consideration is (except in the comparatively few cases where a constant and ample supply of water-power is available) the best and most advantageous power for driving the crushing rollers of cane-mills. Moreover, as steam is required in all but plants of the very crudest description for heating and evaporating purposes, and as the whole, or the greater portion, of the exhaust steam can be thus utilised, the cost can be reduced to a minimum.

A steam-engine for driving a cane mill may be either of the beam or horizontal type, and either a high-pressure engine working expansively, a condensing engine, or an engine working with a back pressure of from 5lb. to 10lb. of steam. The latter is the case when the exhaust steam from the said engine is utilised for heating the clarifiers or defecators, eliminators, etc. The older patterns of cane-mills are usually driven by means of high-pressure or condensing beam engines, but those of modern construction are generally provided with horizontal engines, which latter are pre-

ferable on account of the greater steadiness with which they run under heavy work, and their consequent superior ability to bear the sudden and severe strains to which cane-mill engines are so frequently subjected.

The best engine for general use is a high-pressure horizontal engine, such as that illustrated in Fig. 9. The bed plate of this engine is massive and of the extended pattern, and the fly-wheel unusually heavy, thus ensuring the power being steadily transmitted through the gearing to the crushing rollers of the mill. The governor is of a high speed pattern, and the piston fitted with patent rings.
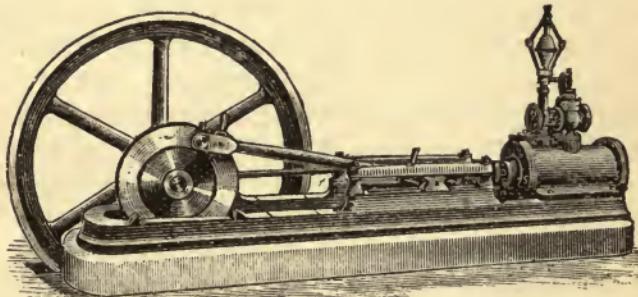

FIG. 9.

An economical engine for the purpose of driving the larger sizes of cane-mills is a compound horizontal engine of the tandem type.

Where a condensing engine is used to drive a cane-mill, and the exhaust steam is occasionally required, suitable valves, and a bye-pass, as shown in Fig. 1, should be provided, sothat the exhaust steam or a portion of it can be cut off from the condenser and admitted to the clarifiers or defecating pans, or wherever else it is desired to employ it for heating or evaporating purposes.

It becomes frequently necessary, even with careful feeding, to reverse the engine and mill in order to clear the latter when it becomes choked or packed with canes. This choking, when it does not entirely pull up the engine, gives rise, as already stated, to a serious jarring and vibration of the machinery, and its advent is heralded by a screeching noise given out by the mill, and caused by the compacted mass of the hard and woody portions of the canes, between the rollers and the dumb returner, acting upon the former in a similar manner to a brake block. It is, therefore, an almost absolute necessity that a cane-mill engine should be fitted with some description of reversing gear, otherwise the delay and inconvenience of pinching the engine and mill back by hand will have to be resorted to at more or less frequent intervals, in accordance with the quality of the canes being operated upon, and the skill and care of those employed in feeding the mill.

In some of the antiquated patterns of cane-mill engines the eccentric rod is so arranged that it can be thrown or lifted out of gear, and the slide valve operated by means of a hand lever to reverse the engine. This is an inexpensive plan, and is usually sufficiently effective for the purpose, as a few revolutions in the obverse direction are generally all that will be required to free the mill when choked. It is, however, slow, laborious, and requires a certain amount of skill on the part of the operator to move the valve by hand at the proper moment, this latter requirement giving rise to inconvenience should the engine-driver or other skilled attendant be temporarily absent. The modern cane-mill engine is, or ought to be, fitted with a simple link motion reversing gear, which is decidedly preferable to any other method of reversing for obvious reasons.

The longevity of the cane-mill and engine, and also of the intermediate gearing, depend to a great extent upon the stability of the foundations. In the case of light, fast-running, self-contained machines working upon the rotary principle but little difficulty is experienced, as a rule, with respect to foundations, as the stresses and vibrations are absorbed by the framing; in the case of a cane-mill, however, although working upon the rotary principle by reason of its slow speed and the heavy strains to which it is subjected, it is necessary to pay most particular attention to the solidity and stability of the foundations. When the soil is rotten and impregnated with water, as is frequently the case when the usine or factory is built on low land and in the vicinity of a lagoon or river, it will be necessary to put in very deep foundations, and means must be taken to get a firm and solid basis. The best method of effecting this is to drive in a series of piles of balata, sepe, or other suitable timber, the depth to which they should be driven and the distance apart at which they should be placed depending, of course, upon the size and weight of the mill, engine, and gearing, and upon the nature of the soil. The piles should be preferably creosoted, and stout planks or sleepers also creosoted should be fixed transversely along their tops, which must be previously cut or sawn off level. Piling may also be resorted to when a stratum of hard ground exists at a considerable distance below the soft upper soil, in which case the piles being driven into the said hard stratum will act as columns to support the superimposed foundation.

The concrete should consist either in good quality Portland cement and well-washed gravel in equal proportions, or of hydraulic lime, sand,

and broken stones in the proportions of lime one-seventh, sand two-sevenths, and broken stones four-sevenths, the quantity of lime varying, however, with its quality. The bed of concrete should be thick enough to prevent its breaking, through any transverse strain, should the subsoil (when no piles are employed) sink, and to enable it to settle in a solid mass. It should be laid in beds or strata of about twelve inches in thickness, and each strata well rammed before depositing the next.

For the masonry of foundations stone is the best, but the most expensive; the blocks of stone should be carefully dressed, and should not exceed in length from twice to three times their thickness, the masonry should be levelled with the utmost care, and good mortar or Portland cement be employed, and the uppermost blocks must be firmly secured together by means of cramps.

In the case of foundations constructed of brick-work, the bricks used must be very hard and well-burned. The necessity for this will be the better understood when it is remembered that according to the experiments carried out by Mr. Trautwine the crushing load of a soft brick is from 450lbs. to 600lbs. per square inch, whereas that of one of the best pressed machine-made bricks is from 4,666lbs. to 6,222lbs. per square inch, or nearly equal to that of the best sandstone, and more than ten times the weight required to crush a soft brick. Mr. Trautwine further states that splitting and cracking generally begin under about one-half the crushing loads, and recommends that in no case should the load exceed one-eighth or one-tenth of the latter. Neat Portland cement of good quality, or one of cement to one of clean sharp sand, should be used, the first invariably when extra strength is required, and the less water used in mixing the better. All

bricks, stones, etc., employed in the foundations should be thoroughly soaked in water when laid with cement.

In many places where sugar machinery has to be erected, owing to the unsound nature of the ground, to the next to impossibility of obtaining good materials and skilled workmen, and from various other causes, great difficulty is experienced in obtaining solid and lasting foundations for the cane-mill, engine, and intermediate gearing. This difficulty is naturally greatly increased by the above being carried upon three separate foundations, which are liable to settle to different amounts, and in opposite directions, to the great detriment of the gearing and other working parts, even when the said settlement is slight and takes place by slow degrees, and when to any considerable extent and rapid is the frequent cause of serious breakdowns. To meet this difficulty a combined engine and cane-mill, such as that illustrated in Fig. 3, is usually employed. In mills of this description the strains upon the various parts are upon the bed-plate and entirely self-contained, being completely independent of the foundations, consequently the expense otherwise entailed in constructing the latter of sufficient strength is rendered unnecessary. Another advantage is that in these mills, as generally designed, the level of the machinery is kept low, so that greater steadiness in working is the result.

As boilers are primarily required for the purpose of generating steam to supply the cane-mill engine (although the steam is, of course, also employed for the supply of the auxiliary engines driving the centrifugal machines, etc., and in the various steam pumps and evaporating plant), they may be taken to be a part of, or rather a necessary adjunct to, a cane-mill and engine, consequently it will not be out

of place to insert here a few remarks upon the type most suitable for a cane sugar factory. The best and most convenient boiler for the above purpose is one of the multitubular or locomotive pattern; this class of boiler can be transported with greater facility, is less expensive and difficult to set, takes up less room, and yet affords an equal heating surface to a Cornish or Lancashire boiler of far larger dimensions, enables steam to be raised quickly and maintained at a high pressure, and finally, but not least, is comparatively easy to repair. The following is a specification of a multitubular boiler (7 feet in diameter, by 12 feet in length, and having 142 tubes), and of the necessary furnace fittings, suitable for a sugar factory, which will be found to be useful for reference:—

Shell to be of "Martins-Siemens" steel plates $\frac{5}{8}$ inches thick, and double riveted in the longitudinal seams. *Ends* to be plates each in one piece $\frac{7}{8}$ inches thick of "Martins-Siemens" steel, flanged and riveted to shell and stayed longitudinally by W.I. stays. *Tubes* to be best lapwelded boiler-tubes, 142 in number, each $3\frac{1}{2}$ inches external diameter, and sent loose to be put in at sugar estate. *Man-hole* and *Mud-hole* to be strengthened by W.I. rings, and fitted with McNeil's patent covers complete. *Horizontal steam chest* to be 2 feet 6 inches diameter, by 12 feet in length, made of plates $\frac{5}{16}$ inches thick, and on shell ends $\frac{3}{8}$ inches thick, and said steam chest to be attached to the shell by connections of thick-edged Lowmoor iron flanged for bolting to wrought-iron faced blocks riveted to shell. *Fittings* to comprise two safety valves, with gun-metal seats, and having levers and weights, complete for attachment to steam chest. One $2\frac{1}{2}$-inch feed stop and

retaining valve with copper dip pipe. One $2\frac{1}{2}$-inch gun-metal double flanged and packed gland blow-off cock. One steam-pressure gauge with syphon. Water gauge and gauge-cocks mounted on a cast-iron pillar, connected to a cast-iron curved bracket on the boiler shell by two wrought-iron pipes, having flanges and bolts complete.

Furnace fittings to comprise one furnace and ash-pit frame with air-tight doors fitted with protection plates complete. Set of fire-bars with bearers and fire-plates complete (fire-bars 55—2ft. 6in. × 4in. × 2in. weight 1qr. 2lbs., each, or say 14cwts. 3qrs.) also cast-iron grating plates. Smoke-box frame of cast-iron with air-tight doors and protection plates complete. Two dampers, one double brick and one plate, each with frame and counterpoise complete.

Spares, etc. Six spare gauge glasses, and 24 india-rubber rings for water gauge. Fourteen spare boiler tubes and twelve wire tube brushes. Five spare fire-bars. A set of firing-irons, a tube scraper, and one tube expander.

Testing. Boiler to be tested to 120lbs. to the square inch under cold-water pressure.

Working pressure. Working pressure to be 70lbs. per square inch.

Painting. Boiler to be painted after testing in one coat of oxide of oil paint.

These boilers are in small factories usually set in connection with the flues from the copper wall as indicated by the dotted lines in the plan, Fig. 1, so that they are under ordinary conditions heated by the waste products of combustion from the copper-wall furnaces. They are, however, also provided with separate furnaces (as also shown by dotted lines in the plan), thus admitting of their being fired up either independently or in conjunction with the said copper walls when required.

Instead of supporting the shell of the boiler on fire-brick seating blocks it will be found advantageous, where a battery or set of three or more are arranged consecutively, to hang or suspend them by means of iron straps from metal girders. This plan admits of a more thorough and easier inspection of the outer shell of the boiler being made when required, and obviates the danger of unnoticed external corrosion taking place to a dangerous extent where the plates rest on the seating blocks.

The boiler should be so set as to have a slight inclination towards the furnace, and thus ensure the greatest depth of water where most needed.

Cornish and Lancashire boilers are also frequently used on sugar estates, and, for special purposes, vertical boilers. When a Cornish or Lancashire boiler is of more than 5 feet in diameter the longitudinal seams should be double riveted. Lowmoor or an equal brand of iron should be used for the plates round, and for a certain distance beyond, the furnace. Staffordshire best should be used for the shell, and also for the end plates, or some brand of equal quality.

Kettle or haystack, balloon, wagon, egg-ended, and other boilers of out-of-date and antiquated patterns are now happily only to be found in cane-sugar factories performing the harmless duty of storage tanks or reservoirs.

Megass, even when well dried, requires a furnace especially constructed. Owing to the ash containing silica (from 26 to 54 per cent.) it is peculiarly difficult to deal with, as this silica is apt to collect upon the fire-bars and become agglomerated into hard masses so as to prevent the ingress of the necessary air to support combustion. In order to ensure satisfactory results this must be obviated, and any apparatus for this purpose must be so

arranged that it will act before the silica becomes so agglomerated, in which case the space between the fire-bars will remain as free as with coal or wood fuel.

In some instances it is found advantageous to fit up a battery or set of boilers with an arrangement for a hot-air forced draught.

William's patent furnace is very effective for burning megass brought direct from the mill, or the exhausted chips from diffusion batteries, and it is stated to work satisfactorily with megass containing as high a proportion of moisture as 60 per cent.

Amongst numerous other furnaces, mention may be made of Ransome's portable engine, having a furnace for consuming megass, which is constructed on substantially similar principles to Head and Sahemioth's patent boiler for burning straw. Marie's apparatus for burning wet or undried megass is said also to give good results.

It is a great mistake and very false economy in any works, but doubly so in a remote cane-sugar factory, to employ boilers of inferior construction and material, and poorly equipped with fittings of a third or fourth-rate quality, or to neglect their proper and efficient setting. Every boiler should be provided with two safety-valves, one of which can be locked so as to prevent any possible tampering therewith. Where a battery or set of boilers are connected together it is advisable to fit the steam-pipes with reducing valves, which can be so arranged that the pressure in the different boilers can be kept at any pre-determined proportion. It is also desirable that each boiler be provided with a low-water alarum of some efficient construction, and with an injector, the latter for use in case the feed pump should get out of order, or as an adjunct thereto.

The feed-pipe of a boiler is especially liable to incrustation, and to get what is commonly called " made up," and it should therefore be of ample size. This latter is most important when the feed-water is taken from a hot well or is foul. The feed-water should be delivered at that end of the boiler remotest from the furnace, and not too near a plate, as in the latter case the liability of choking from accumulations of deposit is greatly increased, and disastrous results may ensue. Where it is absolutely necessary that the feed water should be delivered into the boiler at the furnace end it should be so arranged, by means of a bend, as to throw the water horizontally.

A prime factor in the economical working of boilers being that of keeping the plates as clean and as free as practicable from incrustation, the quality of the water employed for feeding purposes is of great importance. This will be better understood when it is remembered that it has been stated on good authority that every sixteenth of an inch of scale in thickness in a boiler will occasion a loss of fuel equal to about 15 per cent. Water containing mineral acids is highly injurious to boilers, and their presence can be easily detected by the use of litmus paper. River water, holding in suspension fine sand or grit, is very destructive to the boiler feed-pump, and such water should be carefully filtered before use.

Hundreds of fluids and compositions (some of which are patented) are sold for preventing and removing incrustation from steam boilers, and they are of widely varying degrees of efficacy. It is evident, moreover, that a solution or composition that might give tolerably good results with one kind of feed water is very likely to fail most lamentably with another. In the event of trouble

being experienced through incrustation of steam boilers, measures should be taken to procure a careful and accurate analysis of the feed water used, and if possible samples of the water should be submitted to a competent person for the purpose of permitting him to carry out experiments therewith, and of advising on the best fluid or composition to employ for the chemical purification of the said water.

Of the numerous standard remedies for incrustation few can be recommended. Without doubt the one in most general use and by far and away the most efficient, is tannate of soda, which material, indeed, probably forms the active ingredient in many of the so-called "Patent" or "Secret" cleansing solutions. The action of tannate of soda upon the hard crust or scale is somewhat slow, but when the latter is got rid of its value as a preventive agent is undoubtedly very great, and it is, moreover, a quality of no small importance, perfectly harmless to the plates. Its operation is to precipitate any carbonates of lime and magnesia contained in the feed water in the form of tannates of lime and magnesia, which are insoluble in water, and are slowly deposited in the bottom of the boiler, and can be blown out with the mud and other deposits in the usual manner.

Some of the boiler solutions sold contain a greater or lesser quantity of some powerful acid, which has a rapid and decisive action upon the scale, breaking it up and enabling it to be removed from the boiler in large flakes, which are pointed to with pride by the inventor as a proof of the good qualities of the solution. Unfortunately the effect produced upon the boiler plates by the use of this acid is equally decisive, and fatal, and any solution that contains any such ingredient, in sufficient

quantity to be injurious to the plates, should be avoided at all hazards.

Another most important requisite for ensuring the efficient and economical working of steam boilers is the proper proportion of the chimney shaft. This is not infrequently utterly disregarded, and in many sugar factories, as indeed in other industries also, boiler after boiler is added as the works are extended, and the necessity arises for an increased supply of steam, whilst the chimney area, barely sufficient in the first instance to ensure the requisite steady and even flow of air, remains unaltered. Wilson's rule is that the flues and chimney area at top be from one-eighth to one-tenth the area of the fire-grate, not taking into account the height of the chimney.

CHAPTER VI.

The Extraction of the Juice from the Raw Material.—Hydraulic Presses, etc.

To remove the juice from the sugar beet-root by crushing pressure, hydraulic presses are employed, from six to ten of which form a set. Before being placed in these presses the beet-roots are first shredded or pulped by passing them through a rasping or pulping machine. The machine most commonly employed for this purpose consists in a drum or barrel formed by three discs firmly keyed upon a shaft or spindle, mounted in bearings in a frame provided with a sheet-iron casing or hood, and having a pulley at each extremity, to be worked by a double belt. In grooves formed in the peripheries of these discs are fixed, longitudinally, toothed strips of iron or steel, which are

practically similar to saw blades having fleam-shaped teeth. Between these blades are inserted wooden laths, in such a manner that the teeth only of the said blades project beyond the periphery of the drum. The beet-roots are delivered into a hopper connected with the casing of the rasping machine by means of an elevator, and they are fed against the rasping drum by alternately moving cam operated pushers, the return movements of which are effected by means of counterweights. The drum is run at a speed of from 800 to 1,200 revolutions per minute, and the finer the pulp produced the better. Either water or thin liquor obtained from the second hydraulic pressing (where a second pressing is carried out) is added to the roots during rasping to the extent of from 20 to 30 per cent. of the weight of the latter. When pure water is employed great care must be exercised to see that it does not contain any salts, as the latter alter the density of the juice and injure the yield.

The pulp after leaving the rasping machine falls into a vat, from which it is delivered by an elevator, preferably of the bucket type, into woollen sacks. As each of these sacks is filled it is placed upon a table and the contents levelled off, the mouth closed up, and the sack covered with a screen or diaphragm. When a pile of sacks is thus made it is removed and placed upon the table of the hydraulic press, which can be charged with about 40 sacks, and screens or diaphragms rising to a height of about 36 inches. In some cases these preparing tables are so constructed that they can be swung round, thereby enabling the formation of another pile of sacks to be proceeded with whilst that on the other half of the table is being transferred to the hydraulic press. The tables are

surrounded with a trough to collect any juice that may escape whilst the mouths of the sacks are being closed, and the preliminary piles of sacks and diaphragms are being formed.

The hydraulic press is usually very simple in construction, consisting in a table fixed upon a ram, the stationary or pressure head being united to the cylinder by powerful columns. The pump plungers are worked by eccentrics on the main shaft and are continually working, but the action upon the ram can be arrested or otherwise by the opening or closing of a discharge valve. When the predetermined maximum pressure, usually between 2,000 and 3,000 pounds has been attained, the water pressure acts automatically through a set of levers to shut off any further in-flow of water, and the said maximum pressure is retained for from 6 to 10 minutes.

In some factories the sacks or bags of pulp are first passed through a preparing press having a rapid motion but a low pressure, in which they are subjected to a preliminary squeezing, and a portion of the juice got rid of. This press, which takes the place of the preparing table, is worked by gearing so constructed that it will be automatically thrown in and out of gear.

Several other methods have been tried from time to time for mechanically extracting the juice from the sugar-cane; for instance, the press devised by Henry Bessemer in 1849. Bessemer's apparatus consisted in a rectangular or other box, chamber, or casing, in which a correspondingly formed piston or plunger was arranged to be reciprocated by a suitable steam-engine or other motor. The canes were introduced through the vertical hoppers shown in the drawing, and the juice ran into the well or cistern provided in the bed plate through small holes formed in the underside of the said box. The

well or cistern was intended to be fitted with a self-regulating heating apparatus, by means of which the juice could be raised to the requisite temperature for clarification or defecation, within a few minutes of its expression.

The operation of the apparatus was theoretically as follows :—The canes being introduced through the . hoppers would be alternately cut into short pieces by the plunger, the throw or movement of which, in both directions, overpassed the apertures of the hoppers, the cane stalks dropping down into the box when the opening in one of the hoppers was left free by the movement of the plunger in the opposite direction, and *vice versa.* The cut pieces of cane would thus be forced at each stroke of the plunger towards the ends of the box which were left open, and a portion of the mass, equal to the solid part of the last interposed piece, displaced thereat. The resistance due to the friction of the said pieces of cane, when the said box or casing was full, was calculated to be sufficient to admit of the juice being very effectively expressed by the plunger during its stroke in either direction.

Two or more of the above described boxes were designed to be arranged side by side, and the plungers worked by means of cranks or eccentrics from the crank shaft of the same engine.

It was further claimed for this machine that the megass or bagasse would be delivered in a condition extremely favourable for use as fuel, and it was proposed to remove it upon a conveyor, carrier, or elevator, by which it would be passed through a drying apparatus and be delivered at the furnaces of the boilers, or of the evaporating pans or copper-wall.

This apparatus is said to have given highly

favourable results when dealing with canes of a hard, tough, or woody nature, by which a sufficient resistance was opposed to the efforts of the plunger to force the cut pieces through the box. When, however, fresh, soft canes, of a highly juicy nature, were operated upon, they were found to be discharged at the ends of the chamber without any considerable amount of juice being extracted therefrom. To prevent this the mouths or apertures of the chambers were reduced in bore, with the result that each stroke of the plunger caused so severe a shock to the apparatus as to render its life of but short duration, whilst the action upon the canes was found to be still most unsatisfactory, as a very small percentage of the juice only was expressed.

The lengthening of the box or casing, and of the chambers for receiving the pieces of cut cane stalks, or the formation thereof with one or more bends, would appear to offer a more feasible solution of the difficulty than tapering or forming the said chambers with choke bores. A sufficient resistance might then be obtained, in the first case, by the increased friction engendered by the larger area of cut and pressed canes in contact with the internal walls of the chambers in the box or casing; and in the second case, by that required to force or drive the compacted mass round the bends.

It would appear, however, difficult, if not impossible, to avoid, or even mitigate to any extent, the inevitable severe shock which must ensue when the plunger strikes against the said tightly packed and compressed columns or masses of crushed cane stalks.

A further objection to this machine is the enormous amount of labour that would be evidently required to keep a sufficient number of the hoppers supplied with canes.

Another class of apparatus, wherein the cane stalks are subjected to disintegration, are those known as defibrators, in which the canes are first cut up or shredded, by revolving knife-blades, into small pieces, and are subsequently ground into a pulp. In one mill of this kind the cane stalks are passed along an endless band or apron to feeding rollers, by which they are held, whilst revolving knives chop or cut them into short pieces or sections. The fine cut pieces of cane fall through a suitable hopper into a drum or chamber, where they are subjected to the action of one or more jets of steam whilst being ground into a pulp by a revolving wheel having lateral ribs or projections. The megass is delivered by a set of rollers to another endless band or belt, by which it is removed.

Machines of this kind are also employed (without the disintegrating or pulping mill) for cutting the cane stalks into cross slices, usually of about an inch in thickness, from which the juice is extracted by the diffusion process.

In William's patent defibrator, cane cutter, or shredder, the canes are delivered by a carrier into a hopper in the bottom of which is a rotating drum, having knife-blades mounted in slots in its periphery. The slices, the thickness of which can be varied at will, are removed by means of an elevator, and are in a very suitable condition either for double milling with maceration or for treatment in a diffusion battery.

Amongst other defibrators may be mentioned those of Faure, and Mignon and Rouart, the latter of which is substantially similar to the machine designed by the same inventors for crushing straw into pulp for paper-making.

CHAPTER VII.

The Extraction of the Juice from the Raw Material.—The Diffusion Process.

The method of extraction known as the diffusion process, which is one of by no means modern invention, having been first suggested by Constable, in 1844, is principally employed for the obtainment of the juice from the sugar beet-root.

It is the result, as already mentioned, of the endosmosis and exosmosis actions which take place between any two liquids of varying densities and natures, when the said two liquids are only separated from one another by a porous diaphragm. In the case of the sugar-cane these two liquids are, pure water on the one side, and on the other side the juice of the cane, which latter is enclosed in the cells, the walls of which consist of a vegetable membrane; and in the case of the sugar beet-root are pure water on the one side, and the beet-root juice on the other, which latter is enclosed in a similar manner to that of the sugar-cane. In point of fact, the diffusion process may be said to consist in the extraction of the juice from the raw material by boiling or cooking in water, the said raw material being previously cut up into small pieces or slices, so as to open the cells to as great an extent as possible.

This is usually performed in the case of the sugar-cane by means of machines such as those described in the end of the preceding chapter, the first of which is substantially similar in principle to that of an ordinary chaff cutter, but of more powerful construction.

The sugar beet-root is cut up into slices of a suitable thickness, which slices are technically

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known as "cossettes," by means of a machine only differing in minor points of detail from the ordinary turnip or root slicer, which is to be found on almost every farm. The knife blades, however, are so secured to the rotating disc as to be very readily removed and replaced in position. This is rendered necessary by the rapid manner in which they become blunted, a set only remaining workably sharp for from 8 to 12 hours, after which they have to be removed for sharpening, and others substituted; as if the cossettes are not cut clean the juice becomes charged with pulp, and is thereby rendered more liable to fermentation. This has given rise to the designing of a great variety of different shaped knife blades for use in the cutting or slicing machines, amongst which may be mentioned those of Goller and Naparawill, the former of which are of a lozenge shape, and the latter of a rectangular shape in section. The knife blades are usually sharpened by means of a file, or on a grindstone. The "cossettes" generally run from 0·06 to 0·12 of an inch in thickness, by from 0·16 to 0·32 of an inch in width, the length varying in accordance with the position of the beet-root when it comes in contact with the knife blades.

In the simplest method of carrying out the diffusion process the plant comprises a series or battery of open pans or vessels, and when the liquor in the first becomes too much charged with sugar to remove the whole of the juice from the slices, they are passed on to the next, in which the liquor is weaker, and so on. When the liquor in the first pan becomes sufficiently charged with sugar it is pumped or otherwise delivered into the vacuum pan or other evaporator, and the order of the pans is reversed, that one which was previously the first becoming the last.

In Roberts' contrivance the whole process is carried on in one vessel. The apparatus consists essentially in a cylindrical vessel of considerable height, and divided internally into several separate compartments or chambers of equal dimensions by means of perforated diaphragms or plates. Centrally in this cylindrical vessel is arranged a vertical shaft carrying lateral arms or blades, so arranged that upon the rotation of the said shaft they will revolve in the chambers or compartments. The lowest of the said chambers contains as many arms or blades as can be conveniently placed therein, whilst in each of the others there are but two, which are placed at a distance apart and in as close juxtaposition to the perforated plates or diaphragms as practicable. The vertical shaft carrying these blades or arms is arranged to be rotated by means of suitable gearing, and the upper portion is made hollow and serves as a conduit to introduce the necessary water into the apparatus, which is preferably distributed by two or more smaller pipes projecting laterally therefrom. The bottom of the lower chamber is formed hollow or double, and is fitted with a suitable steam coil for heating purposes. Connected with the lower chamber are two pipes, in one of which is fitted a shaft carrying screw blades or an endless screw, worm, or other device for conveying or feeding the pieces of the raw material, and forcing them into the said chamber, and the other of which pipes serves for drawing off the diffusion juice. At the upper and open end of the vessel is arranged a revolving scraper or rake, consisting of two or more arms carried upon a suitable spindle, and having prongs or teeth by means of which the pieces of material floating upon the surface of the liquor, and from which all the juice has been extracted, are swept off or removed. The combined areas of the

perforations or apertures, in each of the
diaphragms or plates, are equal to about one
eighth of the whole area of the said diaphragm;
and the said openings are not opposite to each
other, but are so placed that the slices or pieces
cannot ascend in a straight line, but are forced
to take a zigzag course when rising before they
reach the upper chamber of the diffusion vessel.

The slices or pieces of material, introduced into the
lower chamber or part of the vessel by the worm or
other feeding device, are spread over the surface of
the perforated diaphragms by the action of the
blades or arms which are slowly rotated therein,
and the said slices ascend gradually through the
openings in the diaphragms to the chambers, in
each of which the same action is performed succes-
sively, until they are removed at the top by the
rotating rakes or scrapers. It will thus be seen that
the fresh water, admitted slowly at the top of the
vessel, passes through the entire series of stages of
gradually increasing saturation and concentration,
until having been for a sufficient length of time in
contact with the slices or pieces of the raw material,
and becoming sufficiently charged or impregnated
with sugar, it is drawn off at the bottom; whilst on
the contrary the pieces of the raw material admitted
at the bottom of the said vessel rise slowly to the
top, the sugar being given off or extracted therefrom
during their upward progress.

Of the many other methods of carrying out the
diffusion process space will only permit of giving a
short description of a diffusion battery in general
use in beet-root sugar factories, which consists
in a set of 10, 12, or 14 pans or vessels of a
cylindrical form with conical ends, and arranged
either in a complete circle or in a semi-circle,
as indicated at A.A. in the diagram Fig. 11.

Each of these vessels is fitted with a perforated partition or diaphragm at the top and bottom, and a charging and emptying aperture, and they communicate through a series of pipes and heaters, B.B., in the latter of which the juice is heated when passing from one vessel to the other by

FIG. 11.

A.J.Wallis-Taylor. del.
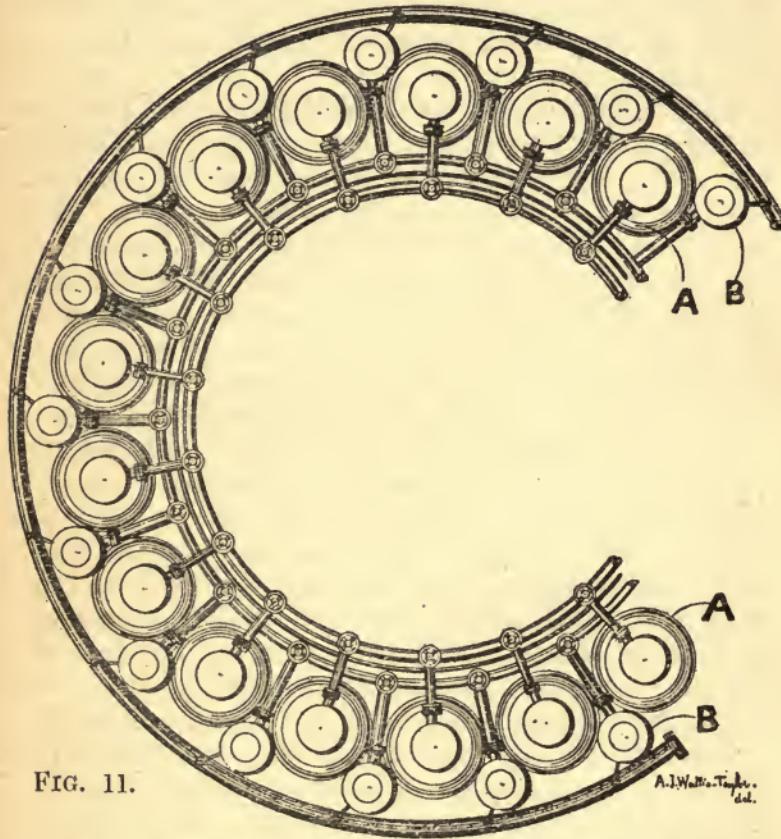
means of steam. Each of the said vessels is further in communication with a set of pipes for water or compressed air, another for steam, and a third for removing the juice. The juice is forced from one vessel to another by a pressure of water or air, the first being obtained by means of a tank

placed at an elevation of from 30 to 60 feet, and the second by means of an air-pump, and being only employed when the supply of water fails.

The slices of beet-root are subjected after leaving the diffusers to pressure in order to remove the water therefrom as far as practicable. For this purpose several presses are in use, amongst which may be mentioned those of Selwig and Lange, and Klusemann.

In the first of these, viz., that of Selwig and Lange, two grooved and perforated discs mounted upon axles inclined in opposite planes, but placed face to face and revolving slowly in the same direction, are employed. The saturated slices are fed in at the top or widest part of the space or clearance between these discs, and are carried round and compressed at the narrow part, after which they are thrown out or ejected by means of a scraper. The discs are covered with perforated sheet-iron.

In Klusemann's press the slices are forced downwards in a perforated cylindrical casing, placed vertically within an outer shell or casing, by a perforated cone having helical blades secured upon its periphery, and so mounted within the said cylindrical casing that its smaller diameter will be at the top. This cone can be rotated by means of suitable gearing at a speed of from 40 to 60 revolutions per minute, and the slices which are fed in at the top of the cylindrical casing, which forms a hopper, are forced downwards by the helical blades, and squeezed between the perforated cone and the lower portion of the said cylindrical casing, the expressed water passing into the cone and between the double casings, and being carried away by suitable pipes.

The presses are usually fed by means of an elevator, to the foot of which the exhausted

" cossettes " or slices are delivered from the diffusers by a conveyor.

The diffusion process, although found to be advantageous for several reasons in countries where fuel is cheap and plentiful, is totally impracticable where the contrary is the case. The juice being considerably diluted, an additional amount of heat has to be expended in evaporation, and in the case of canes the trash being so impregnated or saturated, with water, that it would have to be dried in artificially heated chambers before it could be used as fuel.

The sugar beet-root pulp from the slice press is also still charged with a large amount of water, and is far poorer in nutritious matter than the pulp produced, where the hydraulic press is employed as a medium of extraction, the latter pulp being worth not far short of 50 per cent. more than the former for cattle feeding purposes.

There is no doubt, however, as to the superior powers of extraction of the diffusion process. Professor Wiley, chemist to the United States Agricultural Department, gives, in a recent report made by him, some interesting and valuable statistics relative to its working in two cane-sugar factories in Spain. The apparatus was put up by the Fives-Lille Company, and at the first works, which is situated near Almeria, the canes are treated by the diffusion process, whilst at the second, which is located at Torre del Mar, near Malaga, the megass or bagasse is so treated. According to the analysis contained in the report a practically complete extraction of the juice was made both from the canes and from the megass or bagasse, the residue being only 3 per cent., whilst it will be remembered that the loss of juice experienced with single crushing by cane-mills of the most

advanced construction is about 20 per cent., and with double or treble crushing from 15 to 20 per cent.

The juice extracted from the sugar-cane by this process is subsequently treated in a practically similar manner to the juice of the sugar beet-root, that is to say, the scum is first removed by clarification or defecation, and filtering, after which it is concentrated in evaporating pans, or in a triple or other multiple effect evaporating apparatus, subjected to a mechanical filtering, and finally crystallised in a vacuum pan.

An important feature in the diffusion process is that the proportion of glucose is not increased during the operation. It must, however, be borne in mind that sugar-cane and beet-root juice are widely different in composition, the former containing naturally glucose which is absent from the latter ; this presence of glucose renders it necessary to take due precaution not to employ too much lime in tempering the juice. The yield of molasses owing to the repeated crystallisations is small, and, by reason of the absence of salts, the sugar is not taken up thereby during crystallisation, but by the contained glucose, and in consequence of this fact the processes employed in beet-root sugar factories for extracting the crystallisable sugar from the molasses, such as that of osmosis, &c., are useless. This is, however, of little importance as compared with the advantage of not forming additional glucose during the manufacture.

The yield of juice obtained by the treatment of sugar beet-root by the diffusion process is likewise larger than that given by extraction, by crushing or pressing, that from the former process being from 90 to 95 per cent. of the entire juice contained in the material, and from the latter only from 80 to 85 per cent. under the most favourable conditions.

CHAPTER VIII.

Raising or Pumping the Juice or Liquor.

The juice having been expressed from the canes by means of the cane-mill has, with the exception of the few instances in which the configuration of the ground admits of the latter being placed at a higher level than the clarifiers or defecating pans, to be raised thereto by means of a pump or a monte-jus. During its subsequent treatment it is likewise necessary to raise the liquor from one apparatus and deliver it into another, and the various pumps and other devices employed for this purpose will therefore be gone into under this heading, although of course not employed until later stages of the process of concentration.

When first run from the crushing rollers of the cane-mill the juice is difficult to deal with by means of pumps, owing to the pieces of crushed cane stalks, pulp, and other foreign bodies which it is liable to hold in suspension, nor does this difficulty subsequently decrease, but, on the contrary, is augmented by reason of the increasing specific gravity of the liquor and the high temperature at which it has to be operated upon, which conditions are obviously unfavourable to the smooth and uninterrupted action of pumping machinery. The above obstacles to raising the juice or liquor by means of pumps are likewise to be met with when dealing with the sugar-beet. Machinery indeed for raising the juice, or passing it from one vessel or apparatus to the other, during the several stages of the process of manufacture, constitute no unimportant part of the plant of a sugar factory, and one moreover which unless great care be taken is liable to give rise to a considerable amount of trouble and annoyance.

The juice or liquor is removed from one vessel and delivered to another in four different ways, viz. : Wherever rendered possible by different levels it is allowed to run by gravity through suitable gutters or pipes; it is baled or scooped; it is drawn off, and raised by some suitable description of pump; or, lastly, it is run into an invention of French origin, called a monte-jus, by which it is delivered or forced by steam pressure to the desired point.

The juice extracted or expressed from the canes, by the crushing pressure undergone whilst passing between the rollers of the cane-mill, runs by gravity from the reservoir, situated in the bed of the mill beneath the said crushing rollers, through a drainer or strainer into a small tank or reservoir sunk in the floor at the side of, or near the mill, as shown in Fig. 3.

This strainer consists in a set of several perforated plates or sieves of different degrees of fineness, the top plate or sieve having the largest holes, or the coarsest mesh. The mechanical impurities, such as pieces of cane stalk and the like, are arrested by this strainer, and those pieces of larger size which lodge upon the first plate or sieve should be frequently removed by hand or with a scraper, the remaining plates or sieves being thoroughly cleared out at each stoppage.

In some few cases, as already mentioned, the levels of the ground upon which the usine or factory is built admit of the cane-mill being conveniently placed on a slightly higher level than that of the clarifiers, in which case the juice expressed by means of the said cane-mill can be run by gravity into the latter. This arrangement not only saves the first cost of the pump otherwise required, and also the subsequent wear and tear

thereto (which item is considerable, owing to the action of the acid of the cane juice upon the metal), but, furthermore, the power consumed in driving the said pump, and prevents the mixture with the juice of oil and grease and metallic particles from the working parts of the latter.

When the above-mentioned difference in levels cannot be obtained, the juice is usually raised from the receiving tank or reservoir near the mill by means of a force pump of short stroke and barrel of large diameter, which pump is usually known as the liquor or juice pump. The pump plunger is either worked off one of the gudgeons of the crushing rollers of the cane-mill, or the intermediate shaft of the gearing, as shown in Fig. 3. The juice or liquor is delivered by this pump to a heater, or into a loose or movable channel, gutter, or pipe, generally of wood, by means of which the stream can be directed to any desired one of the set of clarifiers, or defecating pans, being passed through another fine strainer to catch any matter that may have escaped those in the liquor pump-tank. To avoid the delay that might otherwise occur should the liquor pump become choked, it is advisable to have two pumps.

In small works the clarified liquor is usually run by means of a similar movable gutter or channel to the copper wall, where it is delivered into the first or largest of the teaches or pans, the difference of level between the said copper wall and the clarifiers being secured by mounting the latter upon an elevated staging. The boiling liquor is then passed from one teach or pan to the next by means of large scoops or ladles mounted on long handles, and worked in kinds of rowlocks, provided on the side of the copper wall, and from the last or striking pan in a similar manner into

another movable gutter or channel down which it is allowed to run by gravity into one or other of the coolers. In some works a skipping teach is employed for removing the concentrated liquor from the striking pan, that is, a smaller vessel or pan of a corresponding form to that of the striking pan, having an aperture in the bottom fitted with a suitable valve arranged to be operated by a handle or lever, is so mounted and connected to a crane that it can be lowered into the striking pan, where it is filled by opening the above-mentioned valve, which latter is then closed and the skipping teach raised by the crane and brought over the cooler into which it is desired to discharge its contents, or the end of a gutter or channel leading thereto.

Where a copper wall is employed, as is frequently the case, in connection with one or more open steam-heated evaporating or concentrating pans, wherein the final boiling or concentration is performed, the charge is generally inserted into the latter by means of a steam-pump of some description.

Hot liquid is, as is well known, peculiarly difficult and trying upon a pump, owing to the steam generated thereby destroying or partially destroying the vacuum, and it should never be attempted to raise or draw the liquid from any considerable distance vertically, but wherever possible the pump should be so fixed that the supply will be on a level, or preferably slightly above it.

A type of pump very frequently employed in connection with these open steam-heated, evaporating pans, is one known as Tangye's "Special." This pump is driven by an engine which has a steam-moved slide valve, and is therefore very liable to be affected by dirty steam. The stroke of

the pump, however, is long in comparison to its diameter, and this renders it suitable for dealing with viscous liquor at a high temperature, especially where a small pump is required for intermittent work.

In order to ensure the satisfactory working of these pumps, and to avoid trouble and delay, the D plunger must be properly lubricated with the best oil or tallow; if the latter be employed, it should be melted down in a kettle to get rid of the sediment, and care should be taken not to use too great a quantity; or if it is obtainable mutton suet forms a first-rate material for lubricating purposes. The D plunger after working for some time will in all probability be found to require a slight adjustment, one or other of the small holes at its ends, which admit steam for driving it, requiring to be slightly closed. For instance, if the piston is found to travel towards the cylinder cover at a greater speed than when moving in an opposite direction, the small hole in the end of the D plunger, at the same side as the cylinder cover, must be slightly stopped up, and *vice versâ*. Especial care must be taken not to allow any dirt or grit to pass in with the steam, as it is likely to get under the tappet valves, and by causing them to leak greatly affect the action of the D plunger, and make the engine work irregularly. The following points should also be specially attended to: Grind the tappet valves occasionally into their seats with emery. Do not pack the stuffing boxes too tightly. After replacing the bucket, be very careful to see that the nuts on the end of the piston rod are screwed up tightly, and that the split cotter is replaced. Should the steam-chest joints require remaking, use either thin sheet rubber or canvas ; red lead may be employed but it

must be put on in a very thin layer, and must be free from any grit or other hard substances, otherwise the steam-chest will be sprung and the D plunger will work sluggishly. The piston speed should not exceed 100ft. per minute.

For boiler feeding and other purposes, and especially for use wherever space is a consideration, a donkey, or wall-pump of the kite motion pattern, such as one of those of the type made by F. Pearn and Co., Manchester, will be found to be the most convenient.

Where pumps of larger dimensions are required, say with pump barrels over 3ins. in diameter, those of the duplex pattern are preferable. Under this size, however, the strokes of these pumps are too short for viscous liquids. With a specially designed pump of this description all the liquids to be found in a sugar factory or refinery can be dealt with, including the newly expressed juice, the clarified or defecated liquor, the concentrated or partially concentrated liquor or syrup, and the molasses, and that either hot or cold ; in the first case, however, as before mentioned, the lift must be moderate, or wherever possible *nil*.

Amongst the many good qualities possessed by this type of pump special mention may be made of the following :—They have positive action slide valves, that of one engine being operated by the piston-rod of the other ; they have no dead point, one port being always open to steam, and will therefore start at any position ; they have a quadruple action, which gives a continuous flow and will deliver a greater quantity for a given size ; they work noiselessly and without injurious shock or hammering of the pump valves ; they are not seriously affected by dirty steam ; they have less working parts and consequently are easier to keep in proper repair ; and

finally, as they have no fly-wheels and are very compact in build they occupy comparatively little space.

Fig. 12 is a perspective view and Fig. 13 is a vertical section through one side, or half, of a duplex pump made by the Worthington Pumping Engine
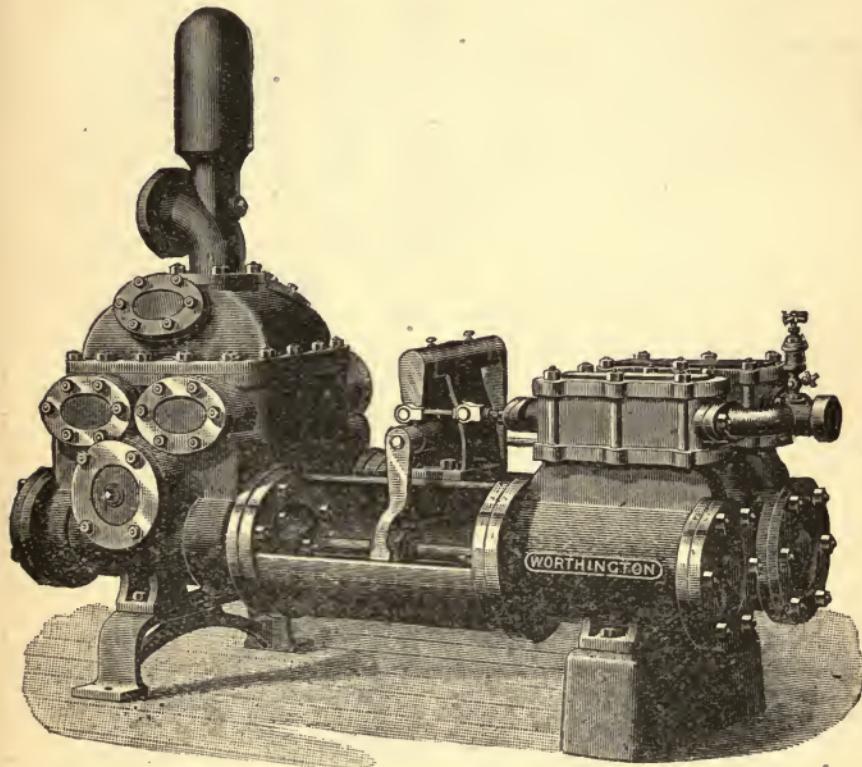
FIG. 12.

Co., London and New York, and especially designed for sugar plantation, factory, or refinery work. The engine slide-valves are, as will be clearly seen at E in the sectional view Fig. 13, of the ordinary pattern, working upon a plane surface over the ports or ways. The advantages of this form of slide valve over

those of more complicated construction are obvious,
and are evidenced by the fact that in spite of the
numerous attempts that have been made to supersede
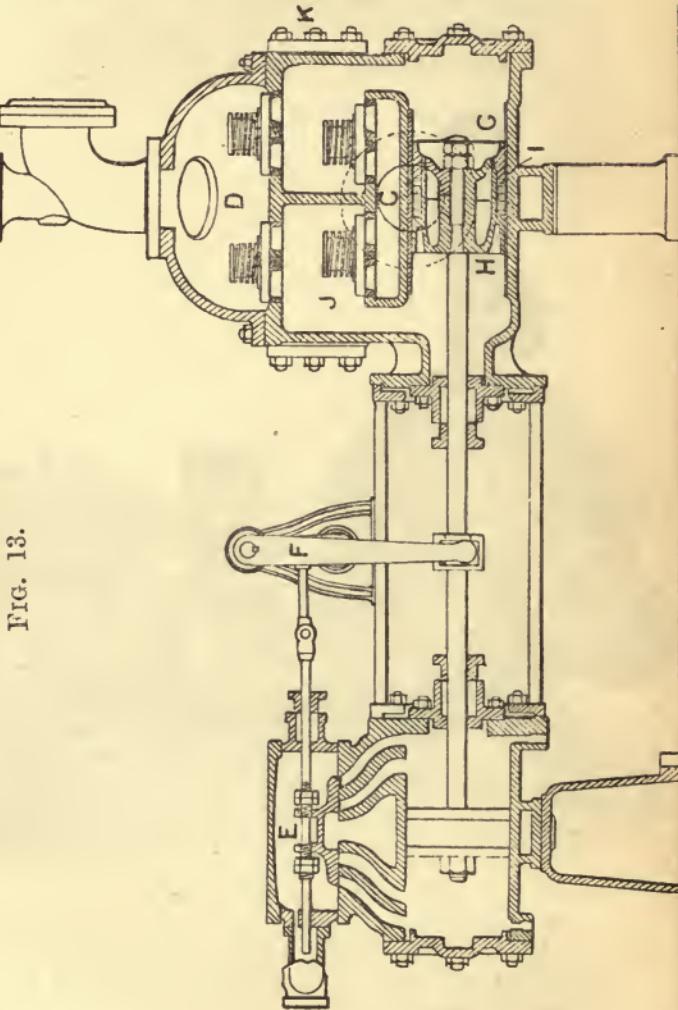
Fig. 13.

it, locomotive and other engineers still adhere to
its use on locomotives and other high pressure
crank engines. Water does not collect in its

cavities to produce trouble by freezing, it does not rust and get fixed to its seating, and no matter how long the engine may have been standing inactive, it is always ready to start when required. A special feature of the Worthington Pumping Engine is the means for imparting the required travel to these slide valves. The mechanism employed for this purpose comprises vibrating arms F arranged to swing through the whole length of the stroke, and having a long and easy leverage. This motion works very smoothly, and the hammering which is an unavoidable feature of the tappet system is entirely avoided, as the moving parts are always in contact. The double acting pistons or plungers H are packed as shown at I, and work through deep non-corrosive packing rings G bored to an accurate fit, and easily removable, thus admitting of their being either refitted, or exchanged for new ones, at a trifling outlay; and also if desired of varying the proportions between the steam-pistons and pump-plungers by increasing or diminishing the size of the latter, which is very advantageous, as an exact proportion between the power and the work is always desirable, if not absolutely necessary. C is the suction chamber, J are the suction valves, D is the delivery chamber, K are hand or access holes or apertures. The water cylinders are in all cases lined with composition, and the valve seats, plates, guards, and springs are made of the same material. The packing I of the piston H is so arranged that it can be easily renewed. It will be apparent that as the liquor cylinders are beneath the valves, the pump is always primed and ready for action. The valve areas and fluid passages are exceptionally large, and the valves are formed of india-rubber or metal, the former being preferable for cold liquids, and the latter for those of high

temperatures. As will be seen from the illustra-
tion, the parts are so arranged as to be easily got
at for examination or renewal.

When the pump is in operation the liquid enters
from the suction chamber C through the suction
valves J, and thence passes into the pump cylinders,
from which on the reversal of the stroke it is
expelled through the force or delivery valves into
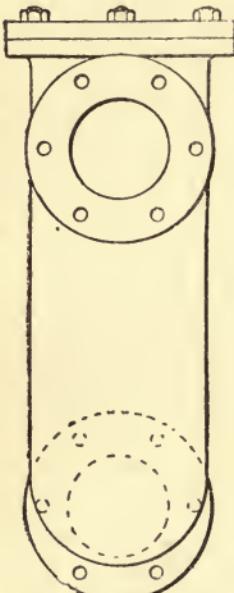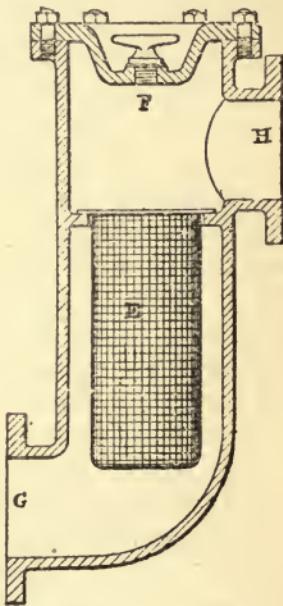
FIG. 14.   FIG. 15.

the delivery chamber D, thus traversing a very
direct and ample water way.

When it is required to remove syrup from a
multiple effect evaporating apparatus whilst the
latter is in action, or to drain the coils of a
vacuum pan and produce the necessary vacuum,
the above pump is slightly modified, water seals
being provided on the piston rods.

This pump also forms a very effective melter pan pump. When employed on this service, it is desirable to fit the suction pipe with a strainer box and strainer, such as that illustrated in Figs. 14 and 15, to collect and separate all the impurities, such as pieces of wood, straw, etc., and thus prevent any foreign bodies gaining access to the interior of the pump, and impairing its action. This strainer comprises, as will be seen from Fig. 15 of the illustrations, a box or casing, the flange G of which is intended to be attached directly to the suction opening of the pump, and the flange H to the supply pipe. E is a basket strainer which can be removed from or placed in position in the box or casing through the hand hole at the top. F is a screw plug which can be removed when the pump is stopped, and thus admit air into the suction pipe and prevent the liquid from syphoning out of the pump cylinders, so that the latter being charged the pump is enabled to lift its supply more readily when again started. This position is a more convenient one for a strainer than the end of the supply or suction pipe, where it is frequently very difficult of access in case it should become obstructed and require cleaning.

A simple and effective apparatus for raising or forcing up the liquor or syrup to any desired point is the monte-jus. The monte-jus which, as before mentioned, is an invention originating in France, obviates the objections to which pumps are liable, by reason of oily or greasy matter and metallic particles from the working parts becoming mixed with the liquor. The monte-jus is used for the purpose of delivering the juice expressed by the rollers of the crushing mill to the clarifiers or defecating pans, or for forcing up the partially concentrated liquor or syrup to the open steam-

heated evaporating pans, or to the storage tanks
for supplying the vacuum pan or other evaporat-
ing or concentrating apparatus.

It consists essentially in a suitable steam-tight
cylindrical or other conveniently-shaped vessel or
receptacle, having preferably a dished or conical
shaped bottom, or a well, and a pipe for admitting
a charge of liquor to the vessel, which pipe may
either terminate in a funnel, intended to receive
the end of a trough or channel down which the
liquor can be run by gravity, or may be continued
and arranged to dip into a reservoir or other
vessel containing the liquor, and from which the
latter will pass into the monte-jus, when the
steam employed to force the previous charge up
the delivery pipe has become condensed, and a
vacuum or partial vacuum has been thus formed
in the main vessel. A pipe for the admission of
live steam from the boiler, and a delivery pipe
which dips down to within a short distance of
the bottom of the well of the vessel, thereby
enabling it to clear out the liquor more effectually,
as also a relief or vent pipe for allowing the air to
escape from the vessel during charging, and which
dips down for a certain distance into the vessel
for the purpose hereinafter mentioned, and a pipe
for permitting steam to be blown through for
cleansing purposes are likewise provided. The
pipes are each fitted with a suitable stop-cock
or valve, that upon the delivery pipe is only
required, however, when the vacuum caused by
the condensation of the steam in the monte-jus
is utilised for the insertion of the next charge.
A manhole is also provided in the upper part
of the main vessel, and an access or handhole in
the lower part thereof for convenience of re-
pairing, cleansing, or for other purposes.

This monte-jus should be sunk in the ground, and enclosed with brickwork or masonry in a sort of well, a space of several inches being left between the said brickwork or masonry and the shell of the said monte-jus to prevent the corrison of the latter, and to admit of its being readily withdrawn when required for repairs or other purposes, and replaced in position. A manhole must also be provided in the side of the well for permitting of access to the handhole or aperture in the bottom of the vessel, and to the stop-cock or valve in the blow through pipe.

The operation of the apparatus is extremely simple. A suitable charge having been admitted into the main vessel, the stop-cock or valve in the admission pipe and that on the relief pipe are closed, and those on the delivery pipe and the steam pipe opened. The high-pressure steam which then enters into the upper part of the vessel bears upon the surface of the liquor contained therein, so as to force it downwards and consequently up the dip pipe and delivery pipe to the desired point of discharge.

Care should be taken not to fill the vessel or receptacle too full, as if this be done the steam will mix, or partially mix, with the liquor and become condensed instead of pressing evenly upon the whole surface thereof. To obviate this the air relief pipe is usually carried down a certain distance into the cylindrical vessel, and the cessation of the whistling noise made by the air escaping through the said pipe and valve when the liquor reaches the level of the bottom or lower end of this dip pipe, and seals it, gives warning to the attendant that a sufficient charge has been admitted. A gauge glass or pet cock might be provided for a similar

purpose. A cock or valve is usually also fitted to
the vessel through which some of the liquor can
be drawn off, should the latter be accidentally
filled too full.

Fig 16 illustrates an improved form of monte-jus
especially designed for use with a triple-effect
evaporating pan, by James Buchanan and Son,
Liverpool. It is fitted with a large stand pipe.
having charging and discharging cocks, an internal
copper discharge pipe, steam, valve, vacuum cock,
gauge cocks and glasses, manhole covers, drain
cocks, etc.

In some cases the monte-jus is arranged ·horizon-
tally, in which instance it is placed above the ground
or floor level, and stands and is mounted upon
stools or brackets so as to be raised a few inches
therefrom. A manhole is generally provided at
each extremity, and the fittings are substantially
similar to those of the vertical pattern.

A great advantage of these juice raisers is that
the liquor is at once brought to such a tempera-
ture by contact with the high pressure steam as
will retard fermentation, there is likewise com-
paratively little agitation or churning of the said
liquor. The chief drawbacks to their employment
are that they are wasteful of steam, and that unless
handled with judgment they are apt to create a
considerable and unpleasant spluttering of hot
liquor at the delivery pipe orifices.
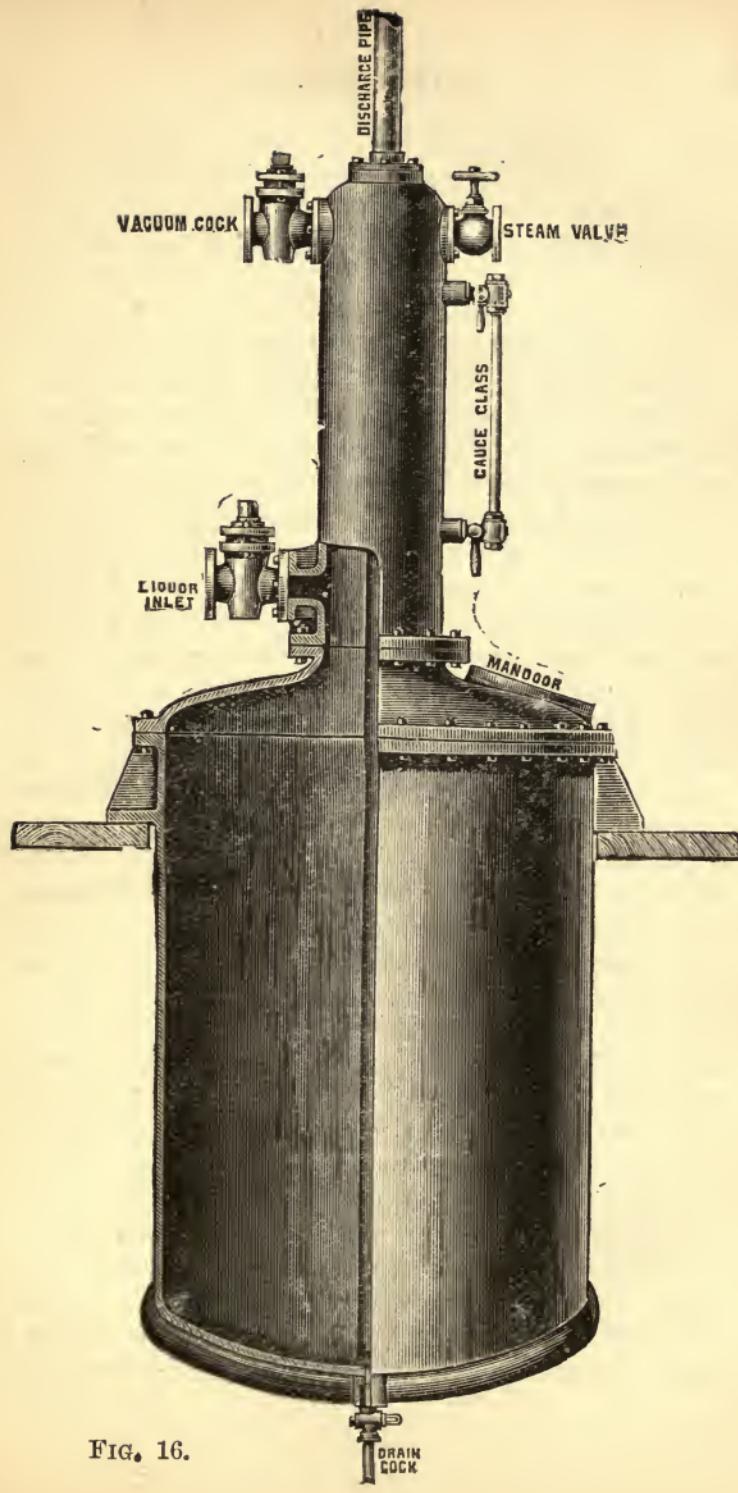
FIG. 16.

CHAPTER IX.

HEATERS, CLARIFIERS, DEFECATORS, AND

ELIMINATORS.

As mentioned at the end of the last chapter, it is most advisable to heat the juice or liquor as soon as practicable after expression. This has the effect of coagulating the albuminous impurities and thus greatly delaying all tendency to fermentation.

To effect this conveniently, the raw juice or liquor is usually delivered directly after expression into some form of heater, wherein it is raised to the desired temperature, before passing into the clarifier. A very convenient apparatus for this purpose consists of a cylindrical cast-iron vessel fitted with a tube plate at each extremity, and a large number of solid drawn brass tubes of small diameter, which should be so fixed in the said tube plates as to allow for expansion and contraction without the occurrence of any leakage. At the upper extremity of this vessel, which is intended to be fixed in a vertical position, is provided an open distributing chamber of somewhat larger diameter than the main vessel and having a central vertical division plate; and at the other extremity thereof is a lower or return chamber having a convex or dished bottom, in the centre of which is fitted a drain cock. This lower or return chamber is also provided with a manhole through which it can be readily cleaned out. Steam is admitted to the upper part of the space surrounding the tubes, an air cock being provided for allowing the contained air to escape, and the raw juice is pumped or delivered into one of the divisions of the open top chamber, from which it passes down through one half of the heating tubes

to the lower or return chamber, and from thence up through the remaining half of the heating tubes to the other division of the said top chamber, from whence it flows through a suitable outlet into the gutter or channel leading to the clarifier. The top or distributing chamber is provided with a light sheet-iron cover which can be readily removed, and should also be fitted at the delivery side with a thermometer, by means of which the temperature of the heated juice can be readily ascertained. A great advantage possessed by this apparatus is, that the heating tubes can be conveniently cleaned at any time without in any way interfering with the flow of juice.

The purification of the liquor is performed in two ways, by clarification or defecation, and by mechanical means or filtering.

Clarification is a process by which the feculent matter is removed from saccharine juices by heating, skimming, and precipitation. The juice expressed from the raw material is, as already mentioned, delivered by means of the liquor-pump or monte-jus, or where possible run by gravity, either direct or after passing through a heater, into one of a set of clarifiers or defecating pans, where it is raised to a proper temperature, tempered, and kept simmering for a sufficient time to cause the mechanical impurities still contained therein, and too small to be removed by the strainer through which it is passed after leaving the mill, to rise to the surface in the form of a thick scum, when the clear liquor is drawn off at the bottom and passed on to the evaporators for concentration. In some factories the clarified liquor is subjected to a mechanical filtering previously to entering the evaporators, in others it is passed through the filters at a later

stage of the process ; and in most modern well-
appointed sugar factories the juice is finally cleared
of all impurities in eliminators, before being passed
into the triple or other multiple effect evaporators.

The amount of lime which it is necessary to add
for tempering purposes varies with different kinds
of canes, and can be only accurately determined by
making practical experiments on the spot; as a
general rule, however, the quantity required may be
taken as about one pound of lime to each six-
hundred gallons of liquor. The lime, which should
be first ground into an impalpable powder, is formed
into a milk by the addition of water, and should be
added to the liquor in the clarifier, and well stirred
in when the said liquor has attained a temperature
of from 130 to 140 degrees Fahr.

Defecation is both a clarifying and a purifying
process, and it is absolutely essential that it should
be carried out with the utmost care, as upon its
proper and judicious performance depends the
purity of the liquor and the return of sugar. Lime
decomposes the salts and neutralises the organic
acids. The milk of lime, to save the additional
steam that would otherwise have to be used for
evaporation, may advantageously be raised, by the
addition of liquor recovered from the scum in the
filter presses, to a density of about 20 degrees
Beaumé before being stirred into the juice in the
clarifier.

In the manufacture of sugar from beet-root some
3 per cent. of lime, or some 15 per cent. of the milk
of lime to the weight of the beet-root is used, and
the clarification is carried out by defecation and
saturation, or by double carbonatation.

In the first process the liquor, having been treated
with the requisite quantity of milk of lime (the
exact amount required is so liable to variation in

accordance with the quality of the juice, the season of the year, etc., that it must, as in the case of cane juice, always rest upon the result of experiments), is drawn off at the bottom when clear, and is then subjected to an injection or saturation of carbonic acid, which removes the excess of lime in the clear liquor by precipitating it in the form of carbonate of lime. When all the carbonate of lime, as also the organic matter contained in suspension, have settled to the bottom, the clear liquor is drawn off from the top and conveyed to the filters.

The most generally employed method is that called double carbonatation. In this process the juice is raised to a temperature of from 165 to 190 degrees Fahr., and from 1 to 2 per cent. of lime is added little by little, and an injection of carbonic acid is made between each addition of lime, until a fixed point of alkalisation, say, some 0·10 to 0·12 per cent. of the liquor, is reached. After settlement the clear liquor is drawn off from the top and is subjected to a second carbonatation, which is conducted in a similar manner to the first with the exception that only from 0·20 to 0·30 per cent., of lime is introduced. The alkalisation is reduced at the termination to from 0·02 to 0·03 per cent., or in some cases to a complete neutrality. When settlement has taken place the clear liquor is conveyed to the filters.

After the clarified liquor has been passed through the filters, it is conveyed either to steam-heated condensing pans, or to condensers which are arranged to condense the vapours from the vacuum pan, and thereby utilise the waste heat therefrom for ensuring the preliminary boiling and evaporation of the said liquor. This arrangement is called the Derosné condenser, and is employed in what is known as the

Degrand train; it is open to certain objections, which will be gone into later on when dealing specially with the subject of the evaporation of the liquor.

It is, of course, obvious that the richer the cane-juice, and the smaller the proportion of foreign substances contained in it, the larger will be the yield of crystallisable sugar. This has been worked out by Walkhoff, and is given in the following tabulated form in the latest edition of *Laboulaye's Dictionnaire des Arts et Manufactures*.

Richness in sugar in every 100 parts of solid.	Yield.		Total.
	From the first operation.	From the second and third operations.	
per cent.	per cent.	per cent.	per cent.
84	58·3	9·7	68
85	60·2	9·8	70
86	62·0	10·0	72
87	63·6	10·4	74
88	65·4	10·6	76
89	67·0	11·0	78
90	68 8	11·2	80

The best form of steam-heated clarifier consists in a rectangular cast-iron tank, built up in sections in such a manner that it can be conveniently taken to pieces for transport, and easily put together and erected at the works or factory. It is usually of such dimensions as to be capable of containing about 500 gallons, but are made up to a capacity of 900 gallons or more. The bottom is formed double, and a coil of copper piping is provided inside the tank and supported at a suitable distance from the said bottom. The convolutions of this coil are connected together by brass horse-shoe bends, and

the said coil is formed in two sections, coupled to an exterior Y shaped or breeches pipe, communicating with the steam pipe and fitted with a suitable stop valve. A gutter with a waste pipe is provided at one side of the tank to receive scummings, as also a run off cock for the liquor, and a wash out plug valve and chain.

In a more complicated arrangement the tank is fitted with copper heating pipes usually firmly secured together by means of stays, and the extremities whereof are fixed in D shaped return pipes, one of which ends in cylindrical portions or trunnions which are carried in convenient trunnion chests or stuffing boxes provided in the side walls of the tank, and so arranged that they can be pivoted therein, and the coil or heating pipes can be raised when desired by means of a block and tackle secured to an eye or ring bolt thereon thereby facilitating the cleaning of the apparatus. One extremity of the coil is connected to the pipe bringing the exhaust steam from the engine, and the other end thereof communicates with the steam space in the above-mentioned double bottom. The water resulting from condensation is drawn off by means of a suitable cock or valve, or a steam trap is provided for that purpose. A passage or way is also formed through the said double bottom, communicating at one end with the interior of the tank, and fitted at the other end with a suitable stop-cock or valve by means of which the clarified liquor, as also the scum or dross, and the water used to wash the tank, can be drawn off. In some clarifiers the draw-off cock is provided with a perforated plug, the holes in which are placed at a certain height above the bottom of the clarifier, thereby obviating the possibility of any of the sediment formed during the process of clarification

being allowed to pass away with the clear liquor ; this plug is removed when the clarifier is being cleaned or washed out. The clarifier should be so fixed that it will have a slight slope towards the orifice communicating with the draw-off cock, and thereby ensure a complete discharge of the water used for cleansing purposes. The exhaust steam pipe is usually arranged to supply a battery or set of clarifiers, and has on its free or outer end a back-pressure valve, see Fig. 1, having an adjustable counterweight, by means of which a sufficient back-pressure can be maintained to cause the steam to circulate properly through the coils and double bottoms of the clarifiers. The clarifiers in the set are each connected to the exhaust steam pipe by means of a branch pipe fitted with a stop-cock or valve, so that the supply of steam to any of the said clarifiers can be regulated, or cut off altogether if desired. Provision is also made, as before mentioned, whereby live steam from the main boilers, or other source of supply, can be admitted to the coils and double bottoms of the clarifiers when sufficient heat is not obtained from the exhaust steam.

Due care must be taken, when adjusting the above-mentioned back-pressure valve, not to raise the pressure to such an extent as to totally impede the effective working of the engine, as even under the most favourable circumstances more or less loss of power must naturally result.

In some of the crudest arrangements of works the clarifiers or defecating pans are simply heated by means of the waste products of combustion from the copper walls. In this case they are merely hemispherical pans similar to the teaches, and are set in the flue or flues provided between the copper wall and the chimney-stack. These flues are then usually fitted with suitable dampers, and are so arranged

that the waste heat from the copper wall or battery can be passed under any particular one of the set, or direct to the chimney without heating any of the said clarifiers, when desired.

Clarifiers consisting of steam-jacketed hemispherical pans without steam coils are also sometimes employed. In this pattern the inner pan is usually formed of copper, the outer casing or pan being made of cast-iron.

Cylindrical clarifiers or concentrators, generally formed of copper and having circumferential gutters or channels round their rims, are also used for treating the syrup after it leaves the triple or other multiple effects. In the lower part of each of these clarifiers is fitted a copper worm, and in the centre of the bottom, which is concave or dished, a suitable discharge cock. The channel or gutter into which the scum is brushed as it rises on the syrup is provided with two pipes fitted with plugs, one of which pipes is connected to the pan and serves to return any clear liquor thereto, the other being a scum pipe and placed in a well or pocket, or a deeper part or portion of the gutter, to remove any sediment that becomes deposited.

When running the charge from the clarifier the first portion of the liquor will be found to be of a dirty colour. This is usually delivered to one of the other clarifiers of the set that is in process of being filled. When the bottom of the clarifier is reached and the liquor again commences to become muddy it is stopped, and the residue, consisting of scum from the top and bottom sediment, is either transferred to filter presses, by means of which any liquor contained in it is abstracted, or where rum is made it is delivered to the still-house. The liquor extracted by the presses is either re-clarified, or filtered, or both, and delivered to the evaporators.

A centrifugal form of clarifier was designed some years back, in which a truncated conical shaped basket or strainer is arranged to rotate rapidly within an annular casing kept supplied with sulphurous gas. The upper edge of the above-mentioned conical strainer is perforated, and during its rapid revolution the juice is caused by the centrifugal action thus generated to rise up and discharge through these perforations in the form of spray, being thereby very effectively brought into contact with the gas in the annular casing. The outer surface of the conical strainer is sometimes provided with blades or vanes, which during the rotation thereof promote currents of the gas in the annular casing, and thus ensure more perfect contact of the latter with the sprayed or atomised juice or liquor.

Eliminators are steam heated pans for giving a final clearing to the juices or liquor, to remove the remaining impurities, before passing it into the triple or other multiple effects for evaporation and concentration.

An eliminator does not differ to any material extent from an ordinary clarifier, the apparatus most generally employed consisting of a rectangular tank formed of cast-iron plates with planed joints, and fitted with a single steam heating coil. This tank is provided with a run or draw off cock, and an aperture fitted with a plug or valve for letting off any sediment that becomes deposited in the bottom and water used for washing the tank. A gutter or channel is also provided all round the top of the tank for receiving any scum removed or brushed from the surface of the liquor, and having an aperture and plug or valve for admitting of the withdrawal of the latter.

CHAPTER X.

Filters.

The liquor after clarification will still contain matter in suspension, and requires to be further purified by subjecting it to filtering, or mechanical purification. The most usual filtering medium used in factories turning out high-class sugars is bone or animal black, or charcoal. The principle of the filter is to arrest the mechanical impurities held in suspension in the liquor by passing the latter through the filtering medium, and this need not necessarily perform any specific chemical action. Animal and vegetable charcoal have, however, the additional faculty of readily absorbing gases, and organic and other deleterious effete matters.

Various types of filters for the mechanical purification of the liquor are in use. One to be found in almost every sugar factory or works is that commonly known as a bag filter, which is simple in construction and tolerably efficient in action. The filtration of the liquor is performed after clarification or at a later stage of the process of manufacture, and by its means the sugar is decolorised, and a further portion of the mechanical impurities too minute to be removed by the clarification or defecation are eliminated. The bag filter consists in a wooden or other box or casing, usually about ten feet in height, having a water-tight tank or compartment at the bottom and at the top or upper extremity thereof. The bottom of the upper tank or compartment is fitted with fine wire sieves, a set of four being usually employed, and is provided with holes, in which are fixed bell or conical shaped metal pieces

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or cups for facilitating the attachment of the filtering bags, two of which bags, one placed inside the other, are firmly secured by tying on each of the said cups or pieces. The first or innermost of these bags is formed of strong twilled cotton, and is several diameters larger than the outer one, which is made of coarse canvas. By having an internal bag of much greater diameter than the outer one a larger filtering surface is ensured, the coarse outer bag serving merely to retain the larger inner one within reasonable bounds. These filters are usually constructed on the spot, and the designs naturally are various, depending upon the fancy of the constructor, the space at his disposal, and the materials to be obtained. In all cases both top and bottom tanks or compartments must be furnished with suitable apertures governed by cocks or valves. That in the upper compartment is for drawing off or removing the liquor should it be decided for any reason not to pass it through the filter, and also for drawing off the water used for washing or cleansing purposes, and that in the lower compartment is for drawing off the filtered liquor.

Filters wherein the filtering medium consists in bone or animal black or charcoal, generally consist in a cylindrical casing formed of wrought iron and divided into three compartments, the uppermost of which has a perforated bottom covered with a blanket, and is intended for receiving the liquor to be filtered. The central compartment, which is the largest, contains the animal or bone charcoal, or filtering medium, and the lower chamber or compartment is fitted with a perforated partition or diaphragm for receiving the filtered liquor, and a draw-off cock or valve, situated in the lowest part of the

bottom, which latter is constructed conical or concave internally, to admit of the filtered liquor being drawn off completely. A small pipe, communicating at one end with the lower part of the chamber or compartment for the filtered liquor, and at the other with the atmosphere, is carried up to a slightly higher level than the top of the compartment for receiving the liquor to be filtered. This pipe serves the purpose of a vent, allowing the air contained in the lower chamber to escape when the hot liquor enters it, after passing through the filtering medium. An access hole or manhole is also provided for admitting of the removal and the renewal of the charge of charcoal when required, and for cleansing purposes. The apparatus is charged with liquor by means of a pump or monte-jus, where so placed that the liquor cannot be run in by gravitation.

A useful form of charcoal filter is that wherein a flat pan or vessel is mounted upon wheels, and arranged to run on a suitable line of rails laid along the floor of the factory. The pan is divided into three compartments, the central one containing the animal or bone black or charcoal, and is otherwise substantially similar in arrangement to the one above described. This filter possesses the advantage that, by reason of its little elevation above the floor level, the liquor can easily be run into it by gravitation, thereby saving the expense of a pump or monte-jus, and also the damage to, and loss of, liquor occasioned by having to raise it to the level of the filter.

In using charcoal filters it is important to maintain a certain quantity of liquor upon the top of the filter to prevent the charcoal from drying, as in the latter case it is liable to crack vertically, and

thus form false channels or passages through which the liquor will flow, and thus escape filtering.

A centrifugal filter of somewhat similar construction to the hereinbefore-mentioned centrifugal action clarifier, or defecating pan, was patented some fifty years ago in the United States, and also some years later in this country, but it did not give favourable results, and failed to find favour in sugar usines and factories, and to displace the ordinary bag and charcoal filters. The main features of this centrifugal filter are a cylindrical outer casing wherein is arranged to rotate freely a correspondingly shaped basket having a perforated periphery, which in some instances consists in two perforated rings or cylinders of sheet metal having an annular space between. In the centre of this basket is a perforated cylindrical chamber intended for the reception of the syrup or liquor to be treated, and between this chamber and the basket is another annular space or clearance which is filled with animal or bone black or charcoal. The syrup or liquor is delivered to the central chamber through a pipe fitted with a rotary joint, and both the basket and the outer casing are provided with tight-fitting doors or covers. Upon the basket being rapidly rotated, the liquor or syrup is forced or driven through the bone black or charcoal and the perforated sides of the central chamber and basket, and is received in the annular space or clearance provided between the latter and the outer casing, which is intended for the reception of the filtered or purified liquor, and from whence it is removed in any convenient manner. In action the above filter is naturally rapid, but on account of the expenditure of power necessary to produce the

requisite high speed, the very limited charge which a filter of this description is capable of containing at a time, the waste of time occasioned by filling, emptying, and cleansing, and for other obvious reasons, this good quality is more than neutralised.

The proposition has been frequently made to substitute for animal or bone black or charcoal fine sand or some other completely inert material. In Belgium, indeed, successful experiments are said to have been carried out, in the manufacture of beet-sugar, with a filtering medium composed of a specially prepared gravel, sulphuric acid being added for defecating purposes.

Amongst mechanical filters in extensive use, and giving good results, may be mentioned those of Buck, Loze, Pauvrez, and Helaers. In these filters the liquor or syrup is passed through large surfaces of filtering layers, composed of various tissues that are capable of being easily mounted and cleansed.

In Dehne's filtering presses for the treatment of beet-root juice, filter-cloths are replaced by perforated metal plates. In using the apparatus the holes or perforations in these plates quickly become plugged or filled with the fibres of the beet-roots, thereby forming a vegetable filtering bed through which the juice will freely percolate, and is said to issue in a clear, limpid, and satisfactory condition.

The duration of time which the filtering of the syrup or liquor should occupy will largely depend on the amount of charcoal employed, which latter is determined by the method of clarification or defecation used.

Cane-juice as run from the mill being assumed to contain about 80 per cent. of sugar, this per-

centage would, if it be filtered through a bed con-
sisting of 10 per cent. of animal black or charcoal,
be raised to 81·5 per cent., through a bed consisting
of 20 per cent. to 82·0 per cent., through a bed
consisting of 40 per cent. to 84·0 per cent., and
through a bed consisting of 50 per cent. to 84·5 per
cent.

It is impossible, however, to set down a hard and
fast rule, and the best plan to adopt in practice
is to find the exact time required for effectually
filtering the syrup or liquor by a series of test
experiments, and to so arrange the filters that the
filtering will be limited to that time, as no useful
results will be obtained after.

In some usines or factories the liquor or syrup
is subjected to a second filtering; the first filtering
operation is then performed directly after clarifica-
tion or defecation, and the second after the con-
centration of the syrup, and just as it leaves the
evaporating pans or apparatus.

CHAPTER XI.

The Manufacture, Cleansing and Revivification

of Animal Charcoal or Bone Black.

The animal black or charcoal used in the filters is
manufactured by the burning, carbonisation, or
calcination in tightly-closed vessels or retorts of
the bones or ivory of animals, which bones have
been previously crushed or broken in a bone-mill, or
otherwise, into pieces averaging, say, 0·2 by 0·2 by
0·6 in. in size, and have been thoroughly freed from
greasy matter by boiling. The result is an animal
charcoal formed of the earthy and saline portions
of the bone combined with carbon, all the volatile

matters having been distilled over in the process of calcination. Animal black or charcoal consists of carbonate of lime 8·4870, calcium 3·3165, phosphate of lime 76·2570, phosphate of magnesia 1·9395, organic charcoal 10·0000.

The animal black or charcoal has accomplished its duty as a filtering medium, and is incapable of producing any further useful effects, when its density reaches something more than half as much again as that at which it originally stood, which is about one pound in weight per pint. It must be then cleansed or revivified, and the impurities with which it has become thoroughly impregnated or saturated removed, and its decolouring and absorbent qualities more or less restored, so as to render it available for further use. This can be done some twenty or twenty-five times, at a loss, however, each time of from 5 to 10, or even sometimes of as much as 15 per cent., the exact amount depending to a great extent upon the method adopted.

A part of the matters that remain in the pores of the black are not soluble in water (such as the gluten) until it has undergone fermentation, or some analogous chemical treatment. This is effected by leaving the worn-out black to heat and ferment in a heap or in a tank, after which it is washed, dried, and reburned or recalcined.

Amongst the processes of revivification practised mention may be made of the following : washing the worn out black in a bath of pure water, or consisting of a weak solution of acetic or chlorhydric acid, or of dilute lye of potash or soda, purging or cleansing by subjecting to the action of highly superheated steam, recalcination, or recarbonisation in iron or fire-clay pots, or in vertical or horizontal pipes or retorts, and finally subjecting to roasting in

open cylinders arranged to rotate at a suitable speed.

The most common and usual method of cleansing, is that wherein the weak solutions of acetic or chlorhydric acids, or alkaline solutions, are employed for washing, after which the black or charcoal is reburned or recalcined to carbonise the organic matter that has been absorbed. The use of acidulated liquids is especially useful for the treatment of the lime that has been absorbed from the tempering of the liquor, precipitating it in the form of salts which can be easily and effectually removed, together with the acid, by subsequent washing with pure water. Care must be taken, however, not to dissolve the carbonate of lime, which forms an integral part of the animal or bone black or charcoal, and for this purpose the amount of acid employed must be carefully calculated, with due regard to the previously ascertained proportion of the carbonate of lime extant in the fresh charcoal.

In case it is thought desirable to also subject the old or worn out animal black or charcoal to fermentation, so as to destroy the nitrogenous organic matter separated during filtration, and thereby obviate its reduction to carbon during the recalcination, this fermentation is best effected by means of hot water in masonry tanks, and the duration of the operation will be from six to eight days.

In Belgian sugar factories the cleansing is usually carried out in washing machines turning on trunnions, and fitted with internal arms or blades which act on the black or charcoal to move it in an opposite direction to the current of hot water. Previously to insertion into these machines the black or charcoal is, as a rule, subjected to several preliminary washings in an ordinary vat with

successive charges of hot water. In these factories it is also customary to remove, after washing and before recalcination, the excess of water which is charged with organic matter, by exposing the black or charcoal to a pressure of steam in a closed vessel.

In Germany a favourite apparatus is that known as "Klusemann's washer." This apparatus, the principle of which is shown in the diagram Fig. 17, consists in an elongated casing A, set at a slight angle and fitted with a hopper B, for feeding in the black at its lower end, and a discharge aperture C, at its other or higher end. At the latter end steam
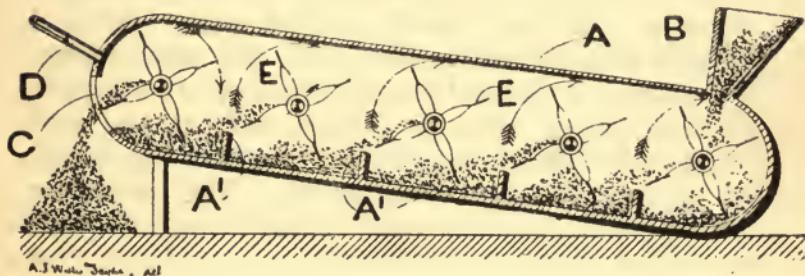
FIG. 17.

is also introduced through a suitable pipe D. The lower wall of the casing is provided at intervals with checks, bridges, or baffle plates A^1, A^1, and with spindles having blades or arms E, E, mounted thereon, in such a manner that, when rotated, they will remove or throw the black over the said checks or baffle plates, and from one set of rotating blades to the other, the last set, or that at the higher end of the casing, ejecting the cleansed or washed black from the apparatus through the discharge aperture C. The black to be cleansed falls from the feed hopper upon the first set of rotating blades or that at the lower end of the casing. This apparatus has to a

great extent superseded the old type of machine wherein the bone black is fed through the washing chamber by an endless worm or screw.

The recalcination of the bone or animal black or charcoal is carried out in some factories or works in a kiln composed of cast-iron or fire-clay pipes, the upper portions of which are placed directly in, and pass through, a furnace, where they are raised to a temperature of cherry red, and which contain the black to be re-carbonised or recalcined; and the lower portions of which are built into the outer walls and extend through and for a certain distance outside the furnace, and form receivers for the recalcined black, wherein it can be slowly cooled before removal without coming into contact with the atmosphere. The worn out animal black is delivered into a hopper communicating with the upper ends of the said tubes, from which it can be admitted to the latter by opening suitable slide valves. The lower or cooling portions of the pipes are also shut off from the upper parts, and from the atmosphere, by means of slide valves.

Before recalcination the animal charcoal should be well dried. This may be effected by spreading the black upon iron plates heated in any convenient manner, or, what is a far better plan, by placing it in ovens heated by the waste products of combustion from the calcining furnace.

In working the apparatus a charge is first admitted from the hopper into the upper or calcining portions of the pipes by opening the slide valves communicating therewith, and when the charge is properly burned or calcined, which should be completed in about twenty minutes, the slide valves for admitting of communication being made with the lower or cooling portions of the tubes are

opened and the charge is allowed to descend, after which the upper portions are again charged as before. Thus there is always a charge in the act of being calcined and one in the act of cooling, the latter being cool enough to be removed by the time the other is ready to descend.

In Eastwick's arrangement the retort is formed by three separate lengths or sections of pipe arranged vertically in a suitable furnace, and each of which is provided with its own distinct and separate supports, thereby preventing any liability of bending or damage to the lower portion from the super-imposed weight of the upper part when heated to a high degree. The furnace is so constructed that the middle length or section is subjected to the greatest heat and forms the burning or calcining portion or chamber, whilst the upper length or section forms the receiving chamber, and the last or lower length or section, which is not directly exposed to the fire, forms the cooling portion or chamber. The upper end is closed or cut off from the hopper by a removable door or plate, and the lower end is normally closed by a slide valve or draw plate.

Buchanan's revolving pipe kiln contains a number of burning pipes of large diameter, which are arranged in two rows vertically on each side of the furnace ; the rear rows have half their circumference exposed to the direct rays of heat, and each pipe is so mounted as to be capable of being rotated slowly upon its axis to offer all parts to the direct action of the fire. Within each of the burning pipes is fixed an internal pipe having perforations, which are protected on the interior by hollow louvres. The charcoal to be burned occupies the annular spaces or clearances between the internal and external pipes, the perforations whereof are kept free during

the descent of the black or charcoal by the said louvres, which likewise form vapour collectors, and the latter is carried away by the internal pipes thereby ensuring more efficient reburning. Each of the burning pipes has a cooler attached to it, and the section and lengths give so large a cooling surface that this, combined with the rotary motion, ensures the charcoal being quite cool when discharged.

The kiln is formed contracted on the interior, so that a small area only requires to be heated, and the walls, which are of considerable thickness, retain the heat, so that it takes speedy effect upon the charcoal. It is generally combined with a drying apparatus wherein the waste heat from the furnace is utilised to dry the black or charcoal previous to its entrance into the burning pipes. The use of this drying apparatus effects a considerable saving of fuel, prevents deterioration of the burning pipes, thereby increasing their longevity, as also that of the charcoal. The usual number of burning pipes in a kiln is 22, and when combined with the drying apparatus it is capable of calcining 24 tons per 24 hours, one indicated H.P. being required for driving. Speed cone gearing is provided so that suitable regulation can be made to vary the amount of feed in accordance with the quality of the charcoal. Any size apparatus can, however, be made to meet different requirements as regards the space available and quantity to be turned out.

In Hanford's (American) apparatus for cooling and separating the animal or bone black or charcoal after it has been reburned or recalcined, two cylindrical or other suitably shaped closed chambers, connected at their upper extremities by a suitable pipe, fitted with an air-pump or blower, are employed. The animal black is delivered from the

furnace into an hopper, from which it passes into a
pipe communicating at one end with the said air
pump or blower, and at the other end with the lower
part of the first or one of the above-mentioned closed
chambers. The black is forced along this pipe by
an air current and is driven against a perforated
conical check, deflector, or baffle arranged in the
upper part of the said chamber, by which the
coarser or larger particles are arrested and fall
downwards into the bottom of the chamber, from
which they can be removed through a suitable
aperture. The finer particles pass through the
perforations in the said baffle or deflector plate, and
through a perforated diaphragm or screen placed
above the latter, and are carried through the com-
municating pipe to the second chamber, in which
they are deposited. In order to facilitate the
deposition or settling of the fine dust or particles in
the second chamber, a jet of steam is sometimes
introduced into the connecting pipe between the
two chambers, so as to slightly damp the said dust.

In another arrangement for cooling the animal
charcoal or black after it leaves the calcining furnace,
which is also of American origin, the hot black
is emptied into hoppers, in the upper portions of
which are fixed conical casings forming with the
walls of the hoppers annular openings, through
which it passes to the lower parts of the said
hoppers, and into a pipe, through which it is dis-
charged into a suitable receptacle or truck for re-
moval. The hoppers are jacketed, and currents of
cold air or water are passed through the spaces
thus formed, and through the hollow cones fixed
in the said hoppers, so as to maintain the plates
with which the black comes in contact at a low
temperature.

CHAPTER XII.

The Treatment of the Scum.

The scum, under which head may be included the impurities which rise to the surface, and the sediment which settles at the bottom during the clarification or defecation of the liquor, and also the skimmings removed from the boiling liquor in the copper wall or teaches where the latter arrangement is in vogue, is, as before stated, either passed to the still house in factories where rum is produced, or to filter presses for the removal or separation of the liquor therefrom.

These filtering presses consist in a set of cast-iron removable frames, having grooves cut vertically in their faces, which grooves all communicate at the bottom with a way or channel also formed in the said frames. The above-described frames are supported by horizontal bars between two end plates, one of which is movable and can be adjusted by suitable setting-up screws. The grooves in the frames are covered with sheets of perforated sheet iron, wire gauze, and hempen cloth, firmly secured to the said frames, with the latter material on the exterior. The scum is forced into the filter through an aperture at the top by means of a force pump, and the clear liquor runs out through an outlet at the bottom.

In the filter-press known as the "Trinks press," the cast-iron frames are constructed with projecting lips or rims, which, when the said plates are in position between the end plates, form a series of intermediate chambers for the reception of the mechanical impurities removed by the filtration. In this filter press each of the frames is provided with a separate inlet.

In Daneck's filter-press a wooden frame of the same dimensions as the cast-iron ones is interposed between each of the latter, and a way or channel is formed through the top rim of the iron and wooden frames as an inlet for the scum. The wooden frames being entirely open centrally form suitable chambers between the iron frames for the reception of the impurities.
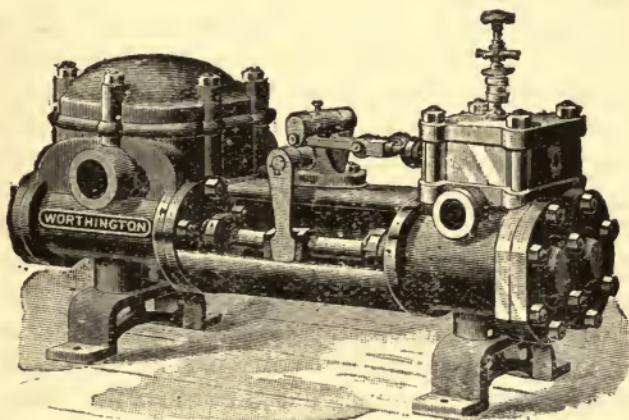
FIG. 18.

In Fig. 18 is illustrated a steam pump of the duplex pattern especially designed by the Worthington Pumping Engine Company for use with filter presses, and fitted with brass ball valves so as to enable it to deal with scums and other similar liquids.

CHAPTER XIII.

EVAPORATION, CONCENTRATION, AND GRANULATION UNDER ATMOSPHERIC PRESSURE.

AFTER clarification or defecation the liquor is either filtered or passed direct to the evaporators for concentration.

The evaporation of the liquor is carried out either at a high temperature by heating with a naked fire in open coppers or teaches, or by means of steam in open steam-heated pans, or in evaporating pans of the Wetzel type wherein the liquor is exposed in thin films to the cooling action of the atmosphere, or at a low temperature in vacuum pans wherein the air is rarified. In a small works or factory, where the crudest description of plant and process is in use, the evaporators, as before mentioned, are simply open pans or teaches heated by a furnace constructed to burn the megass or cane-trash, known as a copper wall or battery, which is also frequently employed in a larger factory as an auxiliary to, and in conjunction with, open steam-heated evaporating pans, and vacuum pans.

The copper wall consists in a battery or series of four teaches or pans of a hemispherical shape set in a flue, at one end of which is a suitable furnace and at the other the chimney stack, or another flue leading thereto. Bridges or checks are built between the said teaches to prevent the flames passing along the flue too rapidly. The furnace must be large, and have a hopper or door provided in the crown or upper part to admit of the introduction of the megass or cane-trash fuel. The ordinary door in the front of the furnace above the ash pit

should be kept closed, except when it is required to rake out the fire or to light up. As in a boiler furnace, the fire bars should be set at an angle, sloping inwards, so that the thinnest portion of the fire will be near the furnace door and over-heating of the latter avoided. The nice adjustment of the bridges or checks, to ensure the proper degree of heat to the different teaches in the battery or set can only be accurately arrived at, under the varying circumstances of each particular case, by actual experiments.

In some small works the clarification of the liquor is carried out in the copper wall, five separate pans or teaches being then employed. The juice from the mill is delivered into the fifth and largest teach, which is situated furthest from the furnace, and in which the clarification is carried out, after which it is baled or passed, as before described, from one teach to the other until it reaches the last or striking teach, which is, as before, the smallest of the set, and is situated directly over or in close proximity to the furnace. This arrangement originated in the French sugar-growing colonies, where the battery or set of five teaches is known as that of " Père Labat " and is still sometimes employed. The fifth teach from the furnace, which is, as above stated, the largest and receives the juice to be clarified from the mill is called *la grande*, the next, or fourth from the furnace, which receives the clarified or defecated liquor *la propre*, the third from the furnace *le flambeau*, the second from the furnace *le sirop*, and the first or nearest to the furnace *la batterie*.

The boiling liquor is scooped or bailed from one teach to the other by means of the long-handled ladles before mentioned worked from the side walls

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of the battery, and wooden rakes or skimmers are also provided for removing or brushing off the impurities that rise to the surface during the operation.

To know the right moment at which to draw or run off the charge from the last or striking teach, is a matter requiring some little experience. The test employed for ascertaining the state of the concentrated syrup is the workman's test known as the "touch test," which consists in taking some of the syrup between the finger and thumb and drawing them apart so as to form a rope or string of syrup, the length to which the latter can be stretched before breaking determining whether or not the liquor is sufficiently concentrated. According to the usual practice, if this thread or string of syrup extends for about half an inch in length before breaking the sugar is supposed to be fully boiled and the strike is made. This test is one of great delicacy, and the nice judgment required can only be attained by long and practical experience as a sugar boiler. This, together with various other tests employed by the sugar boiler will be gone into more fully, however, in a chapter devoted especially to the subject. The liquor when struck or skipped contains about 70 per cent. of crystallisable sugar.

The concentrated liquor or syrup is then run into one of the coolers, which are shallow rectangular vessels either made of hard wood or metal, and should preferably be constructed of sufficient dimensions to admit of each of them being capable of containing several strikes or charges, and where this is not the case each strike should be divided amongst several coolers. The object of this is to obtain or build up a larger grain or crystal, those from the first charge acting as a basis for those of the following strikes or charges.

The plant required for manufacturing sugar by this process is inexpensive and, moreover, enables, with the exception of the sugar boiler, and " *bo'sn,* " or attendant on the cane-mill engine, skilled labour to be dispensed with, but the heat of 240degs. Fahr., to which the liquor has to be raised, causes the colour of the sugar to be considerably darkened by charring, which reduces its value.

Open steam-heated evaporating pans are metal cisterns or tanks heated by steam (usually live steam direct from the boiler), which is admitted to one or more coils of copper piping, from which it generally passes to a double bottom, a steam trap being provided for allowing the water resulting from condensation to escape. A steam pan is in fact practically only a clarifier, with such additional heating surface as will admit of the required degree of temperature being imparted to the syrup or liquor to be concentrated.

Another very common, and, at the same time most effective form of steam pan, is that consisting in a rectangular cast-iron vessel with a double bottom ; the heating arrangement consisting in a series of vertical copper tubes screwed at their lower extremities into the inner plate of the said double bottom and stopped or closed at their upper ends. The pipes are also provided with nuts or square or hexagon collars at their lower ends, so that they can be removed from the false bottom, by means of a box spanner, for cleansing purposes. The steam enters the double bottom and passes up these vertical tubes, which are of such a height as to extend to within a short distance of the upper surface of the charge of liquor, and which are placed in as close proximity to each other as can conveniently be done, consequently, there being but a thin body of liquor

between the pipes, the temperature can be rapidly raised, and the required degree of concentration attained.

If the liquor or syrup be first partially concentrated in the copper wall and the charge inserted into the steam pan at, say, a density of from 27 degs. to 29 degs. Beaumé, when the boiling point is about 225 degs. Fahr., the strike can be made in from fifteen to twenty-five minutes in one of these pans.

Amongst the numerous other evaporators which have been from time to time devised for concentrating the liquor at atmospheric pressure, mention may be made of Clae's evaporating cone, which is usually known as the " Lembeck evaporating cone" from the name of the place near Brussels where it was first used ; of the evaporating pan known as the " Wetzel pan ;" of the Degrand condenser ; and of Fryer's concretor.

The first mentioned apparatus consists in a jacketted cone of considerable length which is fixed in a vertical position, and the space between the jacket or outer casing, and the inner casing of which is supplied with steam at a pressure of from 60 to 80 lbs. per square inch. At intervals along the exterior walls of the cone are secured hollow conical segments toothed or perforated at the edges near the walls of the cone ; and a corresponding number of hollow conical segments also toothed or perforated at the edges adjacent to the walls of the cone, are secured in a reversed position upon a shaft or spindle fixed centrally within the latter. The liquor to be evaporated is delivered from a receiving tank wherein the supply is maintained at a constant level by means of a ball-cock or valve or other contrivance, into two funnels or hoppers, from one of which it passes to the interior surface, and from the other to the exterior surface of the

cone. The liquid is distributed over the surfaces of the cone in complete films or layers, which in descending meet the above-mentioned hollow conical segments or vessels by which they are divided and redistributed. The concentrated syrup from the exterior surface is received at the bottom of the cone in an annular reservoir, and is delivered through a chute or trough, together with that from the interior surface, into a suitable cistern or reservoir. The amount of liquor admitted to the feeding or distributing funnels or hoppers at the upper end of the cone can be regulated by means of suitable stop-cocks or valves, and is adjusted in accordance with the evaporating capacity of the cone, and the degree of concentration required.

The form of concentrating apparatus known as the " Wetzel pan " consists in a jacketed, semi-cylindrical trough or vessel, into which space steam, generally the exhaust steam from the cane mill engine, is admitted for heating purposes. At both ends of this pan or trough are provided hollow discs mounted in suitable bearings by means of hollow or tubular trunnions, and connected together through a set of tubes arranged in a circle, and in close proximity to each other, near the peripheries of the said discs. Steam for heating purposes is also admitted through one or other of the hollow trunnions or gudgeons to one of the hollow discs, from which it passes through the before-mentioned tubes to the other hollow disc, and thence out at the other hollow or tubular gudgeon. The liquor to be concentrated is inserted into the pans, and the discs and tubes are slowly revolved by means of suitable belt gearing or otherwise, a train of toothed gearing being usually provided in any case for reducing the speed. The heated liquor is thus constantly

exposed to the cooling and evaporating action of the atmosphere in thin films, the lost heat being restored by the steam passing through the jacketed pan and the disc and tubes.

The evaporative power of these pans is very high, and they can usually be worked at an average temperature of about 195 degrees Fahr., which is below that injurious to the colour of the sugar. It is of the utmost importance, however, that these pans be of considerable length, and the rotating discs of small diameter, otherwise the liquor will become churned into froth and give rise to great inconvenience.

In a modification of the above description of pan the hollow steam heated discs and tubes are replaced by a series of thin discs mounted upon a revolving spindle. By this arrangement the objectionable frothing of the liquor above referred to is entirely got rid of, but the evaporating power of the pan is greatly reduced owing to the smaller amount of heating surface.

Other modifications of these pans have been also designed, the principle remaining, however, unaltered. For example, the hollow supporting spindle has a number of hollow discs mounted upon it, so arranged that they can be heated by steam, and having cups or buckets attached to their peripheries, by which the liquor is scooped or baled up during their revolutions, and is discharged over the heated surfaces of the said discs. The addition of these cups or buckets (which resemble and act in a similar manner to those on a dredger or elevator) is disadvantageous, insomuch as it tends to set up the before-mentioned churning action, and produces frothing in an aggravated manner. In another arrangement, a coil or worm, the extremities of which are connected with the

hollow discs, is provided. This latter is usually known as a helical pan.

In concentrating liquor in these pans, as also in other steam-heated evaporating pans, and in vacuum pans, it is a not unusual practice to insert the charge by degrees, that is, to add a new supply of liquor as that in the pan evaporates, thus maintaining the said pan nearly constantly full. The object of this is to obtain, or build up, a larger grain or crystal, as those formed by the concentration of the first supply establish a basis for those obtained from the subsequent charges. This can, however, be as, if not more, efficiently effected, as before mentioned, in the coolers.

The Degrand (Derosné) condensers perform the double work of evaporating or concentrating the liquor, and at the same time condensing the steam or vapour given off by the vacuum pan. This condenser consists of a high rack or coil formed out of convolutions of pipe some 6ins. in diameter, through which the steam or vapour from the vacuum pan passes, taking a zigzag course in a downward direction; the liquor to be concentrated being admitted (usually from the filters) in a thin stream at the top, dripping upon the outside of the first convolution of the said coil, and from that to the next, and so on until it reaches the bottom.

As has been previously stated this apparatus is found more or less objectionable in practice. This arises, amongst other reasons, from its being almost impossible to maintain the coils of pipe covered with an even film of juice or liquor, and from the clouds of steam or vapour which are given off into the building, and becoming condensed seriously interfere with the other operations of the factory. The latter defect can, however, be to a great extent got rid of by the provision of a suitable hood and flue communicating with the exterior.

The method of treating the cane-juice invented by Mr. Alfred Fryer, consists in concentrating the said juice until it becomes a solid mass known as concrete sugar, which can be shipped immediately and is not liable to drainage during the voyage. This method is found to be advantageous when it is desirable to deal with the cane-juice expeditiously, and forward it to the sugar refineries for subsequent treatment.

The apparatus required for concreting the liquor comprises a series of shallow pans or trays set at a slight incline or angle, and fitted with transverse partitions, alternately extending almost, but not quite, from one side to the other of the said pans or trays, which latter are placed end to end, and are heated by a furnace situated at the highest extremity thereof. At the lower end of the said pans is a tubular heater, wherein the waste heat from the furnace flues of the apparatus is employed to heat air for use in a revolving drum or cylinder.

The cane-juice having been clarified in the usual manner is delivered to the upper end of the said pans or trays—the first two or three of which, being directly over the furnace, are subjected to an intense heat—and passes by gravity down the incline, being prevented from flowing in a direct line by the above-mentioned transverse partitions, which are so arranged as to cause it to take a zigzag course from side to side of the trays. In this manner, the liquor can be made to traverse a distance of about eight times the length of the pans or trays, before passing into a tank or receiver situated at the lower end thereof, and it is maintained at a rapid boil, and is raised in density to about 30 degrees Beaumé during the ten or twelve minutes it takes to reach the above-mentioned tank,

from which latter it is delivered into the rotating drum or cylinder to be further concentrated.

This drum or cylinder is fitted internally with scroll-shaped blades of iron over which the liquor flows during its revolutions, a larger surface being thus exposed to the action of the heated air, which is drawn or forced through it by means of a fan or blower. After about twenty minutes the concentrated liquor is run out of the drum, when it will be at a temperature of about 200 degrees Fahr. and of such a consistency as to set in a solid mass on cooling.

Saccharine juices and solutions can be also concentrated up to a certain point by artificial freezing or congelation. The operation is very simple, and consists in reducing the temperature of the liquor by means of a suitable refrigerating machine, sufficiently low to freeze or congeal the watery particles, which latter are then removed, leaving the remainder of a greater strength.

CHAPTER XIV.

EVAPORATION, CONCENTRATION, AND GRANULATION.

—VACUUM PANS.

ALL sugar usines or factories of any size, and with any pretensions to modern plant now employ apparatus for concentrating the liquor by boiling it in vacuo, or rather in partial vacuo.

Since the time of its invention by E. C. Howard in the year 1812 many improvements in details have been introduced into the vacuum pan, but the principle upon which it works has

remained practically unaltered. The ordinary
form of vacuum pan comprises a spherical or
cylindrical vessel, the lower portion of which is
steam-jacketed and fitted with one or more internal
steam-heating-coils, having separate steam-pipes,
governed by stop-cocks or valves, for supplying
steam, and discharge or drain pipes for removing
the water of condensation therefrom. At the upper
portion of the said vessel is a dome which com-
municates through a suitable exhaust pipe, provided
with a safe or liquor trap, with a condenser, which
in turn is connected with the vacuum, or air-pump.
The steam or vapour given off from the charge of
boiling liquor passes along the exhaust pipe to the
condenser, where it is met by a jet or jets of cold
water, is condensed, and, together with the air and
any surplus steam, is drawn out by the air-pump.
Any liquor that might pass into the above-mentioned
exhaust pipe together with the vapour, in the event
of priming taking place, falls into the catch all, safe, or
trap, from which it can be returned through a suitable
connecting pipe to the main vessel. A smaller vessel
situated in close proximity to, and at a somewhat
higher level than the main vessel is also provided.
This smaller vessel is connected at its lower end to
the said main vessel just above the uppermost con-
volution of the internal steam coil or coils, and at its
upper end to the dome communicating with the
exhaust pipe, and a pipe is also led from its lower end
to the liquor cistern or tank. It holds a sufficient
quantity of liquor for a charge, and forms a measure,
and can be filled by opening the communication
between it and the exhaust pipe, and thus produc-
ing a vacuum therein, when the liquor rises from
the supply tank. The concentrated liquor is run
off through a port or way, governed by a suitable
valve, situated in the lower part of the main vessel

or pan. The measure, and safe, or trap, are provided with gauge glasses to enable the amount of liquor contained therein to be easily ascertained, and the main vessel or pan fitted with two or more plate glass windows or sight holes in its upper part, through one of which the condition of the boiling liquor can be ascertained by applying a light to the other or opposite one.

In order to enable a sample of the concentrated liquor or syrup to be extracted for testing purposes, without destroying the vacuum in the pan, a contrivance known as a proof-stick is employed. This proof-stick consists in a round rod formed of gun-metal, having a square portion with a cavity or recess at its inner or lower extremity, and a handle at its other or outer extremity, and fitting nicely into a hollow casing or tube secured in the wall of the pan, just above the heating coil, and in sloping direction so as to reach downwards and dip into the charge. At the free end of this tube or casing is provided a shell-cock, into a square cavity in the plug of which the square on the end of the above-mentioned rod is adapted to fit and form a key, by means of which it can be turned or opened, so as to permit a portion of the contents of the pan to enter the recess in the said square; or to close the hole or aperture communicating with the interior of the pan, when the rod can be withdrawn, and the syrup deposited in the recess at its inner end removed for examination or testing.

The vacuum pan should also be provided with a door or manhole, by which access can be had to the interior for cleaning or repairs, and with a pipe communicating with the boilers or other source of steam supply, by means of which live steam can be admitted to the interior for cleansing the pan. The

fittings usually also comprise a thermometer, and a barometer or pressure-gauge, for enabling the temperature and the degree of vacuum in the pan to be ascertained when desired.

The charge in the pan, when sufficiently concentrated, is, in most factories or usines, run direct into the centrifugal machines, where it is rapidly cured; sometimes, however, it is run into the coolers. In other factories again, as already mentioned, the practice is to first partially concentrate the liquor in the copper wall. In this case it is run from the latter into large tanks or receivers, which form subsiders wherein the impurities that are still contained in the syrup are permitted to settle, and can be separated therefrom. The concentration in the copper wall is not carried far enough to injure the colour of the sugar to any material extent. The vacuum pan is charged from these subsiders, and need not therefore be kept in constant operation, as a considerable supply of partially concentrated liquor can first be collected. This plan is used on estates not sufficiently large to keep a vacuum pan continually going.

In Fig. 19 is shown a modern vacuum pan, condenser, and air-pump, complete with staging, etc., made by the Haslam Foundry and Engineering Company, Limited, Derby. This pattern of pan is made in dimensions varying from 3ft. up to 12ft. or 14ft. or more in diameter, and is according to its size adapted to make from 5 cwts. to 20 or 30 tons of sugar per day. The shell of the pan is of cast-iron with wooden lagging, and the heating coils are of copper. A suitable manhole, closed by a door or cover, is provided in the pan for admitting of access being had to the interior for purposes of repairs or cleansing, and it has a discharge slide or valve that can be worked from the platform or staging
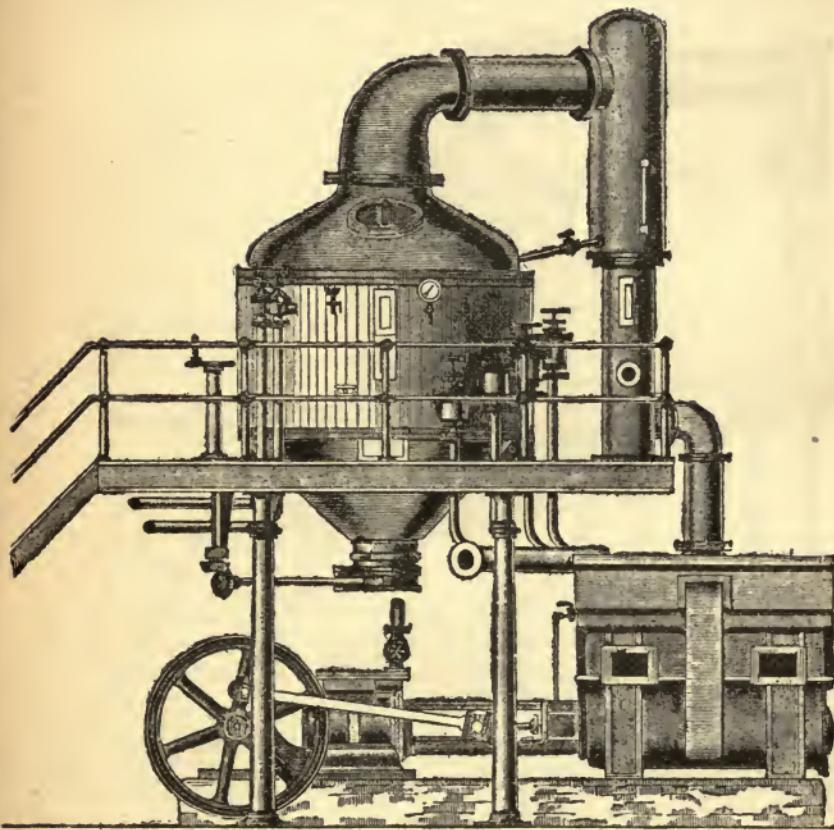
FIG. 19.

upon which the pan is mounted ; it is also fitted with light and sight glasses, butter cock, feed-valve, steam-valves, steam-traps, proof-stick, thermometer, and vacuum gauge. The condenser is of the injection type, and is provided with the necessary water-valve and vapour pipes. The air-pump is of a double acting

FIG. 20.
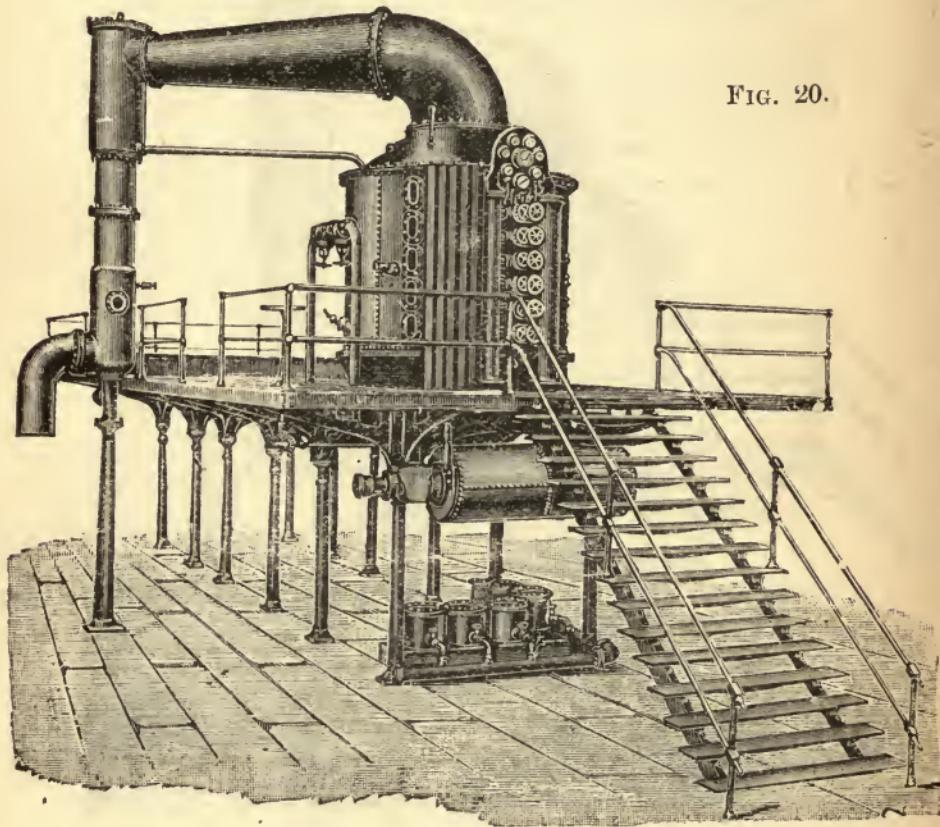
horizontal pattern, and is coupled direct to a high-pressure horizontal steam-engine fitted with two fly-wheels. The size of the air-pump in relation to that of the pan naturally varies in accordance with the temperature of the condensing water, and in tropical countries where this is high the pump should be of

larger capacity than is required in more temperate climates. The steam pressure necessary in the heating coils is from 10 to 15lbs. per square in., and the vacuum obtained is usually about 27ins., but may run a little higher or lower in accordance with the skill of the pan-man or sugar-boiler.

Fig. 20 illustrates another vacuum pan of modern design. This pan, which is built by Deacon, Maxwell, and Dore, of Birmingham, has a capacity of 2,200 gallons, and the body is made of mild steel having seamless copper coils giving over 500 square feet of heating surface. The pan is mounted upon a wrought-iron staging or platform, and is provided with a vacuum-pump of the displacement type, having a cylinder of 20in. diameter by 30in. stroke, and combined on one base plate with the engine, which latter has a cylinder of 16in. diameter by 30in. stroke. This vacuum pan is said to be working satisfactorily in the factory where it has been erected. A steady vacuum of 28ins. is maintained, the boiling off or strike taking place, with juice at a density of about 26 degs. Beaumé, in about four and a quarter hours with live steam from the boilers, or in about five hours with exhaust steam.

CHAPTER XV.

Triple and other Multiple Effect Evaporating Pans.

A TRIPLE effect is a modification of a vacuum pan, or rather a modified arrangement of vacuum pans, which originated in France, where it was invented by Mr. Rilleux, and was primarily intended for use in factories making beetroot sugar. A triple effect admits of a large saving being made in the consumption of steam required to raise the liquor to the requisite

temperature, and consequently in the fuel necessary for the production of steam. This saving is more marked when a liquid of a low density such as the juice of the sugar beet-root is being concentrated, but it is also very considerable in the case of cane-juice, and triple or other multiple effect evaporating pans are now extensively employed in cane-sugar factories or usines.

The principle upon which triple effect pans (and also other multiple effects) work is the well-known
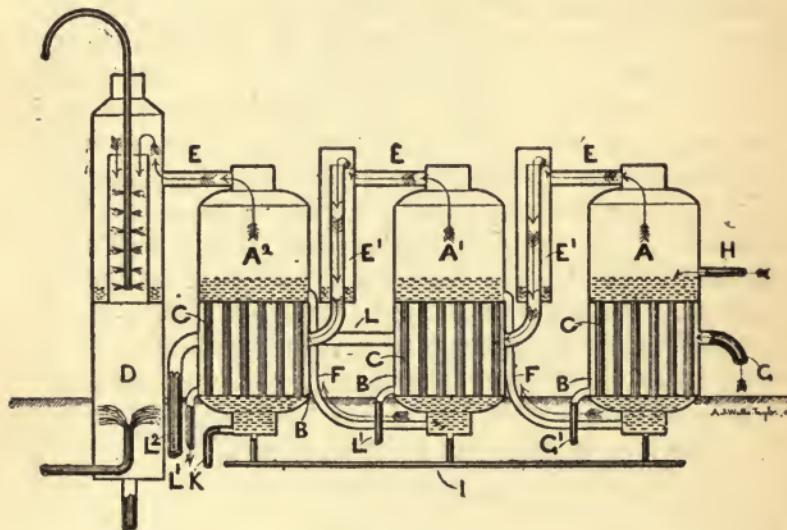
FIG. 21.

physical law that the latent heat of vapour is given off in condensing to a liquid, whilst the sensible heat is retained. Hence the employment of either live steam from the boiler, or the waste or exhaust steam from the various engines in use in the works, for heating the first pan or effect, and that resulting from the evapora-tion of the juice or liquor itself that is introduced into the apparatus for concentration, for heating the suceeding pans or effects, each effect

after the first thus forming, as it were, a condenser to the previous one, and its condensing power regulating the evaporative capacity of the other. This principle will be better understood by reference to the sectional diagrammatical view, Fig. 21, wherein A, A¹, A², represent the three pans constituting the effect. Each of these pans, which are usually cylindrical in form, is provided with two tube plates or diaphragms, one of which is situated near the bottom or lower end of the pan, and the other at about the centre thereof. The space between these tube plates forms a calandria or heating-chamber B into which the steam is introduced for heating purposes. C, C are tubes secured in the said tube plates, and forming communication between the upper and lower portions of the pan. It will thus be seen that the liquid to be evaporated circulates above and below the tube plates and through the said tubes, whilst the heating medium circulates between the tube plates and round the exterior of the tubes. The pans or vessels A, A¹, A² are only partially filled with liquor, thus leaving in the upper part of each a space for receiving the vapour produced by the evaporation of the said liquor, which spaces are connected by pipes E in the case of the pans or vessels A, A¹ with the heating space of the calandria B of the pan next in order, and in that of the last pan or vessel A², with the condenser D, wherein the vapour is met by sprays or showers of water, condensed, and together with any excess drawn off by the air pump. The connecting pipes E between the several pans or vessels are fitted with safes or traps E¹, E¹, to catch any of the liquor that might otherwise pass away with the vapour through priming. The liquor spaces of the calandrias of the three pans are connected together by pipes F. G is a pipe supplying steam to the heating space or

chamber B of the first pan A, and H is a pipe for
charging it with the liquor to be concentrated. I is
a pipe which is connected by a suitable branch to a
well in the bottom of each of the three pans, and
by means of which any particular one of the set
can be emptied, if desired, and which also serves for
the insertion of acidulated water for cleansing
purposes. K is a pipe for removing the concen-
trated syrup from the last pan A^2. L is a pipe
connecting the upper part of the heating space of
the calandria B of the second pan A^1, to that of the
third pan A^2, and L^1, L^2, G^1 are pipes for removing
the surplus steam or vapour, and the water
resulting from condensation, therefrom.

The operation of the apparatus is as follows:
The exhaust or waste steam from the cane-mill,
vacuum or air-pump, and other engines, is usually
employed for heating the first pan A. This steam
is collected in a receiver to which the pipe G forms
connection, and by which it is delivered into the
heating space of the calandria B of the said first
pan A, where it circulates round the tubes C and is
drawn out through the pipe G^1, together with the
water resulting from condensation, and is delivered
to a tank or hot well, to be utilised for feeding the
boilers. The steam or vapour given off by the
boiling liquor in the first pan A passes through the
pipe E to the heating space of the calandria B of
the second pan A^1 where it circulates in like manner
round the tubes C, and then passes through the pipe
L to the heating space B of the third pan A^2, and
together with the vapour given off by the boiling
liquor in the second pan A^1, which also passes to
the said heating space through the pipe E, circulates
round the tubes C. The condensation water is
drawn off by the air pump, from the heating spaces
B of the second pan A^1, and of the third pan A^2,

through the pipes L^1, and the excess of vapour from the chamber B of the latter pan through the pipe L^2. The steam or vapour given off from the boiling liquor in the third or last pan A^2 passes through the pipe E to the condenser D, where it is met by a double series of jets or sprays of condensing water, projected from above and below, and is drawn off by the air pump through the large pipe at the bottom. The juice or liquor passes through the apparatus from one pan to another on account of the difference of vacuum, and is withdrawn from the last pan or effect by a pump or monte-jus. The progress of the liquor, and that of the vapour or steam for heating purposes, is indicated on the diagram by the arrows.

The juice to be evaporated is either admitted directly from the receiver or reservoir to the evaporating chamber in the first pan A, or it is first run into a measure or container. From the first pan A the partially concentrated liquor can be run or drawn into the concentrating or evaporating chamber of the second pan A^1, and from the latter to that of the last pan A^2, through the pipes F, which are fitted with suitable stop-cocks or valves, and, as before mentioned, by means of the pipe I any particular pan of the set can be emptied independently of the others. The main outlet from the last pan A^2 communicates with a monte-jus ; this outlet is only used when the whole set is at work.

Any liquor that may pass over with the steam or vapour through the pipes E, by reason of priming, is caught in the safes or catch-alls E^1, from which, when a sufficient quantity has been collected, it can be drawn off or returned to the pans by means of suitable pipes and stop-valves.

The receiver or container, into which the exhaust steam is delivered from different parts of the usine,

should be fitted with a safety valve in order to permit the escape of the steam, should the pressure from any cause rise above a certain point, and also with a pipe and connections, for the admission of live steam from the boilers when required. The water, resulting from condensation in the receiver, may be delivered to the above-mentioned hot well for supplying the boilers. Suitable means should also be provided, for regulating the intensity of the jets of condensing water, in accordance with the degree of vacuum required.

The apparatus is usually so arranged that it can be also worked as a double effect, or either pan singly if desired.

When employed as a triple effect apparatus the first vessel or pan A^1 should have a vacuum of 3 or 4 inches, and the temperature should be about 200 degrees Fahr., the second pan A^1 should have a vacuum of about 14 inches, and the temperature should be about 180 degrees Fahr., and the third pan A^2 should have a vacuum of at least 24 inches, and the temperature should be about 130 degrees Fahr., or less in accordance with the vacuum. In practice it is usually found that the steam from the first pan A will be about 20 per cent. hotter than the liquor in the second pan A^1, and that from the latter about 20 per cent. hotter than the liquor in the third pan A^2.

It will be seen that the apparatus is largely self-heating, that is to say, the first pan only is heated by extraneous means, the latent heat of the steam or vapour from the boiling liquor in the said first pan being utilised to heat the liquor in the next or second, and the latent heat of the steam from the liquor in the latter to heat that in the third or last. Not taking the loss of heat experienced by radiation into consideration, a double effect is twice, and a

triple effect three times, as economical of steam as a single effect.

In some instances the number of pans or vessels in the set are increased to four, which is the usual limit of number in this system. The latent heat of the steam or vapour from the liquor boiling under the low vacuum in the first pan being thus employed to boil that in a second pan under a higher vacuum, and that from the second a third, and from the third a fourth, under gradually increasing vacuums. This arrangement is claimed to reduce the cost of fuel to about a fourth of that required for a single vacuum pan or an open evaporating pan, but it has not been found to be advantageous to go beyond a quadruple effect. The respective vacuums obtained in the pans or vessels of a quadruple effect are usually as follows, —first about 5ins., second about 12ins., third about 19ins., and fourth about 27ins.

The syrup when leaving the third or last pan A will be at a density of from 20 to 30 degrees Beaumé, and is generally filtered, either mechanically or through animal charcoal, and is again evaporated or concentrated up to a degree that will admit of the crysallisation of the bulk of the sugar contained in it. Crystallisation can either be produced after the syrup has been passed through the heater by cooling, or during the heating process, the latter plan possibly affords the higher return and is that most frequently adopted. The reason for the greater return by the latter method is that the concentrated syrup retains only about 4 per cent. of water, whilst by the former it contains as much as 10 per cent., the said water holding a large proportion of sugar in solution. When the latter process is employed, moreover, the sugar can be placed at once in the centrifugals,

and, besides, far larger and harder and more easily purified crystals are produced.

The concentrated and granulated syrup is delivered, after final concentration, into a shallow tank or cooler of large area, when it is at a temperature of about 160 degs. Fahr., and has sufficient fluidity to run and to take an uniform level, but not to permit the more liquid portion to rise to the surface. Before curing it should be passed through a mixing machine or mill, and have a sufficient quantity of diluted syrup mixed with it, to soften the molasses which it contains, and facilitate the extraction thereof. After syrup ceases to run from it in the centrifugals, it can be further clarified or decoloured by passing steam at a low pressure through it, which will remove any molasses that may still be adhering to the crystals, after which, if the first clarification or defecation has been properly performed, a perfectly colourless sugar in regular and separate grains, and within so small a fraction as to be practically pure, will be obtained.

Figs. 22 to 26 illustrate an ordinary triple effect evaporating apparatus of modern design, made by the Mirrlees, Watson, and Yaryan Company, Limited, Glasgow. A triple effect of this pattern will work regularly, evaporating from 6·5lbs. to 7·5lbs. per square foot of heating surface. The vacuum pumping engine is of the double connecting-rod type, with the steam piston acting directly on to the pumping plunger. The vacuum pump is of the double acting displacement type, in which the water level becomes lower as the plunger recedes, and rises again with the return, consequently expelling all the air, or uncondensable vapour, from the pump, before the condensed vapour and condensation water reach the valves. A special feature of this vacuum

FIG. 22.
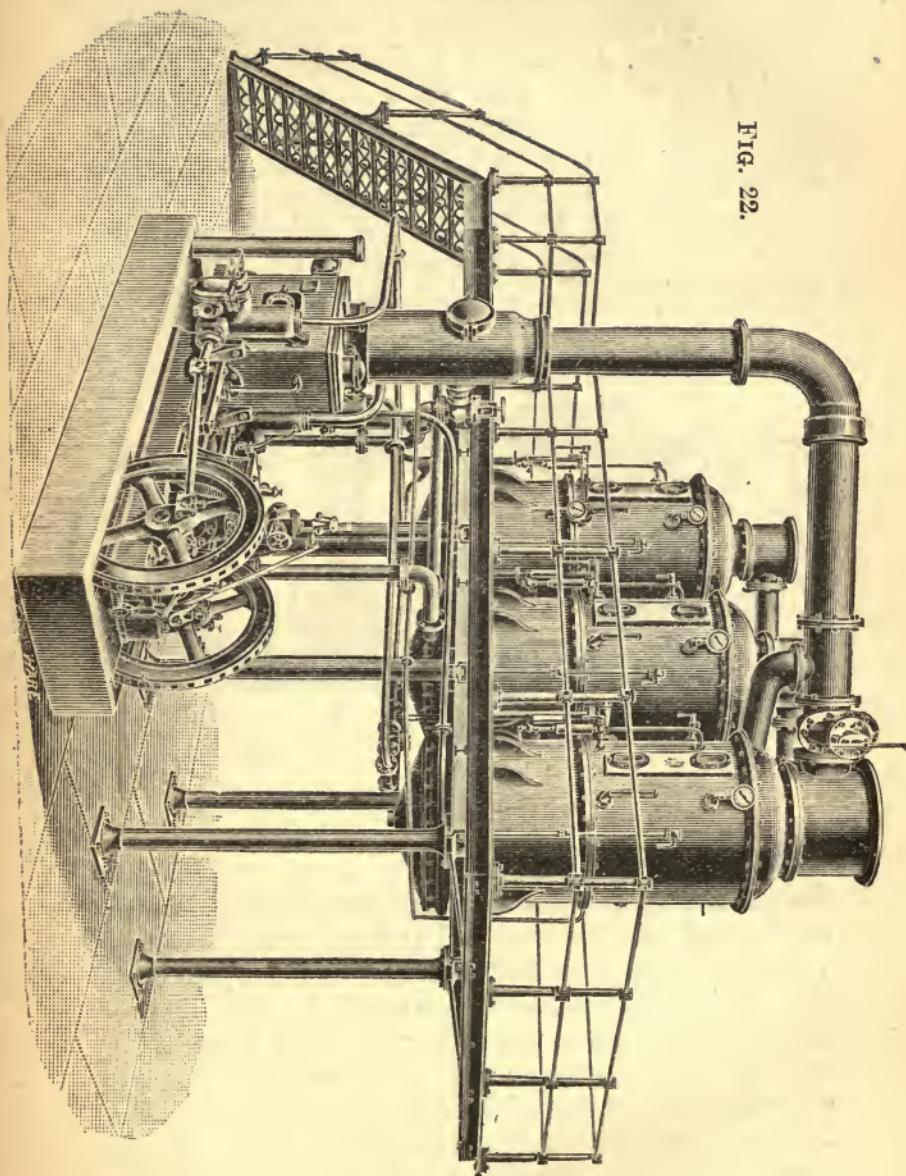
pumping engine is the powerfully built bed-plate, and
the position of the crank-shaft which is placed behind
the cylinder. It is fitted, as shown in Fig. 22, with
double fly-wheels. Fig. 22 is a perspective view
showing the general arrangement of the apparatus as
fixed ready for use, and Figs. 23 to 26 are various
views drawn to an enlarged scale showing details of
construction. A, A¹, A² (Fig. 23) indicate the three
pans, the internal arrangements of which are
substantially similar to those shown in the sectional
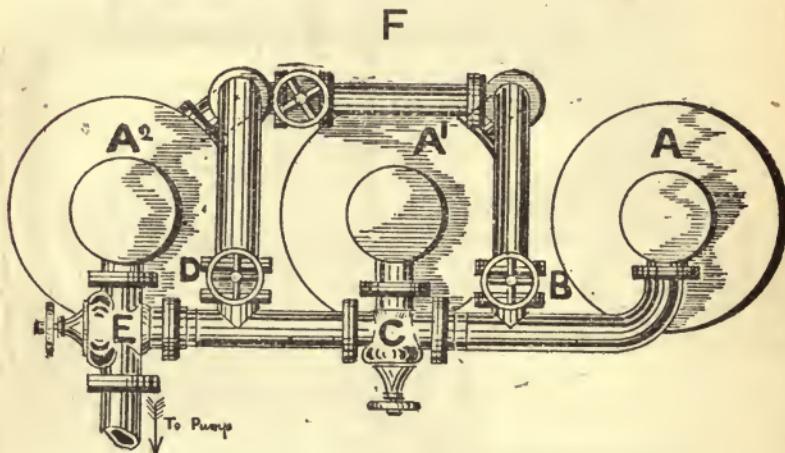
FIG. 23.

diagram, Fig. 21. The heating space of the calandria
of the first pan is connected through a suitable stop-
valve and pipe (Fig. 22) with the exhaust pipe from
the engine, or it may be supplied with live or
direct steam from the boiler through a reducing
valve. The water resulting from the condensation
of steam is drawn off through a steam trap. Fig.
23 is a plan showing the arrangement of the vapour
pipes, which are provided with change or isolating
stop-cocks or valves B, C, D, E, and F, and are so
arranged that either the three pans or effects form-

ing the set can be worked together, or any two of
them, or any particular one thereof can be worked
independently. The thin juice or liquor enters the
first pan A, and when the apparatus is used as a
triple effect will be found to be boiling in the said
first pan at a temperature of about 203 degrees
Fahr., with a vacuum of about three inches, in the
second pan A^1 at a temperature of about 180 degrees
Fahr., with a vacuum of about 14 inches, and in the
third pan A^2 at a temperature of about 125 degrees
Fahr., with a vacuum of about 27ins. The con-
densed steam is drawn off from the second pan A^1 by
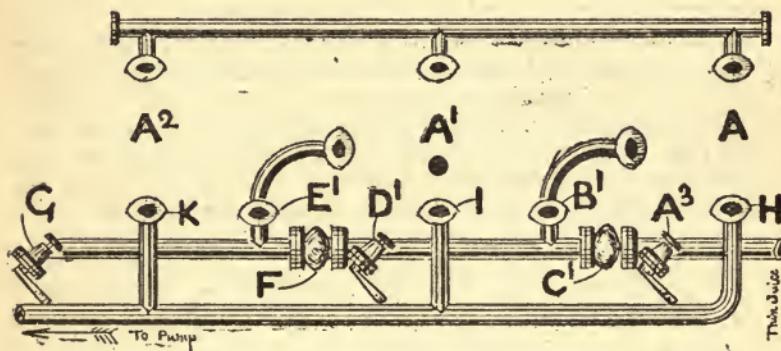
FIG. 24.

an auxiliary pump, and the third pan A^2 is con-
nected directly with the condenser and vacuum or
air-pump.

A^3, B^1, C^1, D^1, E^1, F, and G (Fig. 24) are
the juice-cocks, and H, I, and K are the discharges.
In addition to these there are also connections
between A^1 and A^2 and the condenser, which help
the vacuum of A and A^1 if necessary, but as the
vapour thus drawn off does no work, these
connections should only be employed as hereinafter
mentioned.

The table below gives the positions of the vapour valves and juice cocks, for working the apparatus with various combinations of the pans or effects, the letters referring to Figures 23 and 24.

How Working.		Vapour Valves.					Juice Cocks.							Discharge		
		B	C	D	E	F	A³	C¹	B¹	D¹	E¹	F	G	H	I	K
Triple Effet..	A to A¹ to A²..	O	out	O	in	S	O	S	O	O	S	O	O	S	O	O
Double „	A to A¹	O	out	S	out	S	O	S	O	O	S	S	S	S	O	O
Double „	A to A²	S	in	O	in	S	O	S	O	S	S	O	O	S	S	O
Double „	A¹ to A²	S	out	O	in	S	S	O	S	O	S	O	O	S	S	O
Double „	A to A¹ & A² ..	O	out	S	mid	O	O	S	O	O	S	O	O	S	S	O
Single „	A to condr.	S	in	S	out	S	S	O	S	S	S	S	S	O	S	S
Single „	A¹ to condr. ..	S	out	S	out	S	S	S	O	S	O	S	S	O	O	S
Single „	A & A¹ to condr.	S	mid	S	out	S	S	O	O	S	O	S	S	O	O	S

Note.—O signifies open, S signifies shut. B, D, F are plain valves, and C and E are double-faced or change valves. A³, D¹, G are the charging cocks of the pans, and if marked open in the above table may be closed partially, or altogether, as may be found requisite during the working of the said pans ; but if marked shut they must be rigorously kept so, it being advisable in this case to remove the handles.

As has been already mentioned with reference to the diagram, Fig. 21, the loss of heat experienced by radiation being ignored, a double effect is twice, and a triple effect three times, as economical of steam as a single pan or effect. If the vapour from the first pan be passed into the second and third pans, an increase of work of from 30 to 35 per cent. is gained, but double the quantity of steam is used, and it therefore works with two-thirds the economy of a triple effect. If the vapour from the first and second pans or effects be passed straight to the condenser, direct or live steam from the boilers being applied to both pans, the maximum amount of work or double that of a triple effect is obtained, but six times the amount of steam is employed, and consequently it only works with one-third of the economy.

The following is the method of working the apparatus as a triple effect recommended to be pursued by the makers.

To Start Working with Empty Pans.

Be careful to see that the change and juice valves are right for working as a triple effect, as given in the foregoing table. Open the juice or charging cocks as wide as possible.

When the liquor reaches the normal working level, open full the steam valve, and regulate the vapour valve so that the liquor will remain at the said working level in the first pan or effect. When the liquor reaches the working level in the second pan or effect regulate the vapour valves, to keep the liquor at the said working level in the second pan or effect ; and when the liquor reaches the working level in the third pan or effect, open the connection to monte-jus or pump sufficiently to keep the liquor at the said working level in the latter. Discharge the monte-jus when full, or allow the pump to work as above till the vacuum-pans are able to go about, when the triple effect will have time to boil sweet. To effect this, shut the second juice or charging-cock and use as much steam as possible, provided the first pan or effect does not boil over, and a sufficient vacuum can be maintained to draw in the liquor fast enough. All three pans must be kept up to the normal working level, and they should now boil briskly, and great care must be taken to prevent the first and second from boiling over. On the appearance of foam in top glasses of the first pan, and of the second pan, the valves may be slightly regulated, but it is not well to alter any connection much at a time, or the regularity, which is essential to the performance of the best work, will be disturbed.

By the time the vacuum-pans begin to draw syrup rapidly, the liquor in the third pan or effect should be at a density of 24 degrees Beaumé, or higher if it is desired.

To get the maximum amount of work out of a triple effect after it has been started, keep the connections of the first and second pans or effects with the condenser closed, and put as much steam on the first pan as you can without making it boil over, or bringing the vacuum too low to draw in the liquor fast enough. Keep the connection between the first and the second pan so adjusted that the liquor in the first will remain at the working level without considering either the vacuum or temperature in the second, so long as it does not boil over, to prevent which, open a little wider the connection with the third pan. In like manner, keep the connection between the second and third pan so adjusted that the liquor will stand at the working level in the second, and do not mind about vacuum or temperature, unless the former should fall to 20ins., when the supply of steam to the first pan or effect must be reduced, and the monte-jus (if there is one) shut off. Keep the connection between the monte-jus and the third pan so adjusted that the liquor will stand at the proper working level in the latter, and the connection with condenser proportionately open. When the monte-jus becomes full, shut off the connections with the condenser and the third pan, and admit steam to empty it. When the monte-jus is empty, shut off the steam, and open full the connections with the third pan and the condenser, until the liquor in the former is down to half way up the bottom glass, after which regulate as before.

Should more liquor pass through than is required for the pans, partially close the connection between

the first pan and the supply tank, altering the other connections in proportion ; but there should be sufficient storage between the triple effect and the vacuum-pans for the former to be able to stop with the cane and pumping-engines, otherwise it will have to be worked to a considerable extent with live steam direct from the boilers. Should the liquor boil too sweet, reduce the supply of steam to the first pan.

To Boil Off the Pans.

Ordinarily the pans are left with liquor at the working level in all three, but should the liquor have to stand more than a few hours, the pans must be emptied and the liquor boiled off in the vacuum-pans, or stored at a density of not less than 19 degrees Beaumé. In order to effect this, after the supply tank is empty, boil down the liquor until it just covers the upper tube-plates in all three pans. Then shut off the steam supply from the first pan, let steam into the heating space of the calandria of the second pan, open wide the connection between the first and second pans, close the valve which shuts off the vapour pipe connection between the first and second pans, and then destroy the vacuum in the said first pan by opening the air-cock. As soon as all the liquor is drawn out of the first pan, which is known by the pipe drawing air, close the connection between the first and second pans, shut the air-cock, turn half way in the first change valve, and open the connection with the liquor cistern which should have been filled with water acidulated with sulphuric acid, about 3lbs. of the latter to enough water to cover the upper tube-plate in each pan being required.

When the liquor has been boiled down in the second and third pans, to a level just above that of the upper tube-plates, shut off steam from the

former, open wide the connection between the two pans, turn the first change valve right in, and destroy the vacuum in the second pan by opening the air-cock. When all the liquor has passed over to the third pan, close the connection between the two pans, shut the air-cock, turn the first change valve out again, and open the first vapour valve and the connection with the first pan, so as to fill the second pan up to the top of the middle glass, leaving the acidulated water in the former just covering the upper tube-plate. The liquor or syrup should be permitted to remain in the third pan as long as it will boil, which it will do for some time on account of its being warmer in the second than in the third pan. When the said liquor or syrup stops boiling it should be drawn off, then shut the monte-jus cock, and fill the third pan with acidulated water up to the top of the upper tube-plate by opening the connection with the second pan, and allow the said water to stand in the pans all night, and in the morning run out and clean the tubes with a tube brush. To perform this latter operation wrap the tube brush round with hemp, dip in hydrochloric acid diluted with its own bulk of water, and remove all deposit from the tubes with this dilute acid. When all the tubes of one pan have been cleaned, go round them again with dry hemp and remove the acid, otherwise it will eat into the tubes.

The apparatus for sampling which is fitted to the third or last pan is of different construction to the proof-stick described with reference to vacuum-pans. Figs. 25 and 26 are diagrammatical views showing the various positions of the handles of the cocks when using the device; the first-named figure is a front elevation indicating by dotted lines the position of the upper handle, and the second is a

plan showing by dotted lines the positions of the lower handle. In the lower part of the contrivance is a glass chimney or test-glass suitably connected to the upper portion or funnel. To draw a sample of the liquor or syrup into this glass chimney, turn the upper handle horizontally into the position marked A^4 Fig. 25, and the lower handle into the position marked A^5 Fig. 26, when the cock will be shut; in about half a minute the upper part of the sampling apparatus will be full of liquor or syrup, when the upper handle should be turned down into the dotted
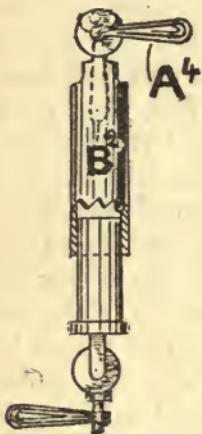
Fig. 25.
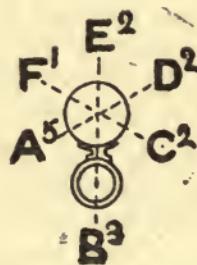
Fig. 26.

position shown at B^2 Fig. 25, and the lower handle moved so as to stand straight out underneath the chimney, in the position marked B^3 Fig. 26.

To draw or suck the sample of liquor or syrup back from the glass test-tube or chimney into the pan or effect, the upper handle should be moved into the horizontal position A^4 Fig. 25, leaving the lower handle in the position B^3 Fig. 26, until the glass chimney or test-glass and the reservoir or funnel are empty, when the upper handle should be

turned down into the dotted position B^2 Fig. 25.
Should the funnel or reservoir not have been quite
emptied, some liquor will then flow back into the
glass chimney or test-tube, in which case the upper
handle must be again raised to the position
marked A^4 Fig. 25, until the funnel or reservoir
is quite emptied, after which the lower handle
should be turned back to the closed position on the
left of the glass chimney marked A^2 Fig. 26.

When it is desired to draw a sample straight
down, so as to be able to take it away, the lower
handle should be turned into the closed position to
the right of the chimney or test-glass marked C^2
Fig. 26, and the upper handle into the horizontal
position marked A^4 Fig. 25; in about half a minute
the reservoir or funnel will be full, then turn the
upper handle down into the dotted vertical position
B^2 Fig. 25, and the lower handle into the position
marked D^2 Fig. 26, which admits of the liquor or
syrup being drawn straight down. When a sufficient
quantity has been obtained, move the lower handle
back to the closed position to the right of the
chimney marked C^2 Fig. 26, and the upper handle
to the horizontal position A^4 Fig. 25, until the
reservoir or funnel is empty, when the lower handle
should be adjusted to the closed position to the
left of the chimney or test-glass marked A^5 Fig. 26,
and the upper handle down into the dotted position B^2
Fig. 25. As soon as the glass chimney or test-tube is
filled, and it is desired to draw the sample down in
order to take it away, turn the lower handle into the
position marked F^1 Fig. 26, which allows the sample
to be drawn from the glass chimney or test-tube;
keep the said handle in this position until sufficient
syrup has been obtained, when it should be turned
right under the chimney into the position marked
B^3 Fig. 26, and the rest drawn back into the pan
in the manner above described.

TRIPLE EFFECT BOILERS SHOULD BE CAREFUL

TO OBSERVE THE FOLLOWING RULES.

1. The connections between the first and second pan or effect and the condenser should always be closed, except when going about.

2. The steam pipe to the heating space or chamber of the calandria of the second pan or effect should always be closed, except when boiling off.

3. Always work the pans in the regular way, viz., as a triple effect, unless something goes wrong with one of the pans, or when boiling off.

4. Always try to keep an even flow through the pans, and regulate the handles gradually.

5. Open the injection as full as you can, without overcharging the pump and causing it to knock or throw water.

6. Always wash the saccharometer after using, otherwise sugar will gather about it, and the reading will be incorrect.

7. If the liquor is at all acid, great care must be taken to prevent it from boiling over.

Fig. 27 shows another triple effect evaporating apparatus of somewhat different design, constructed by Deacon, Maxwell, and Dore, Birmingham. As will be seen from the drawing the pans are not supported upon the usual platform or staging, but stand on the ground, having been specially so designed to meet the requirements of the sugar factory where it has been erected. This type of triple effect has given exceptionally favourable results, and has been found very convenient in practice, besides which it lessens the first cost of the apparatus by enabling the usual expensive staging or platform to be dispensed with; and it is probable, therefore, that it will come into general favour.

L

The set or installation shown in the illustration has a heating surface of about 2,400 square feet. The outer shells or bodies of the pans are of mild
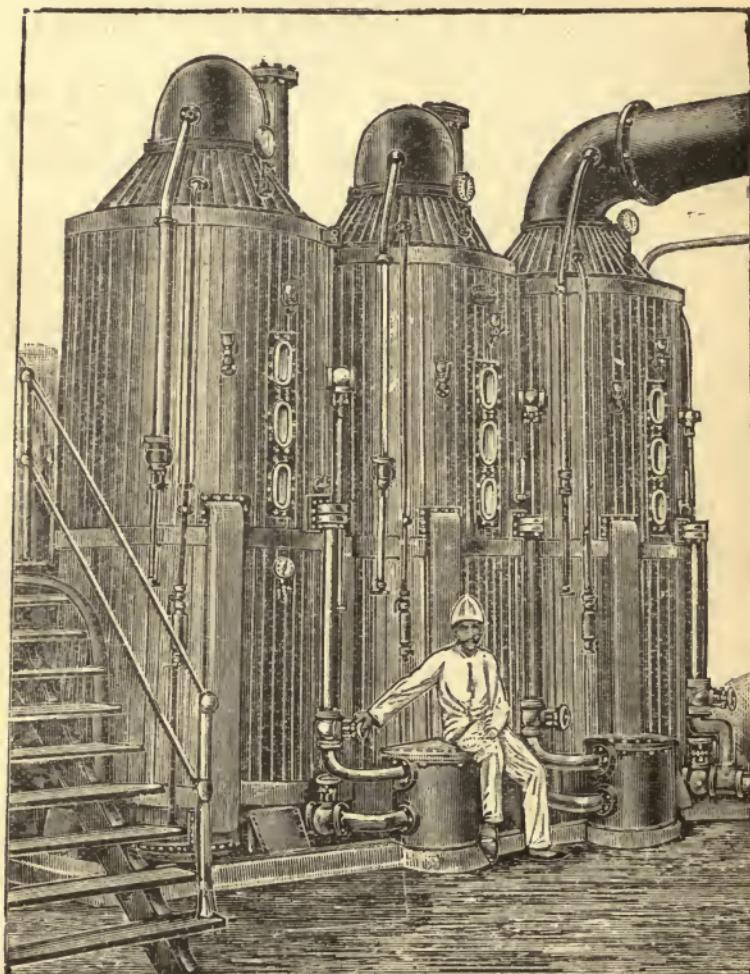
FIG. 27.

steel wood lagged, and the tube plates are of steel, and fitted with seamless brass tubes 2ins. in
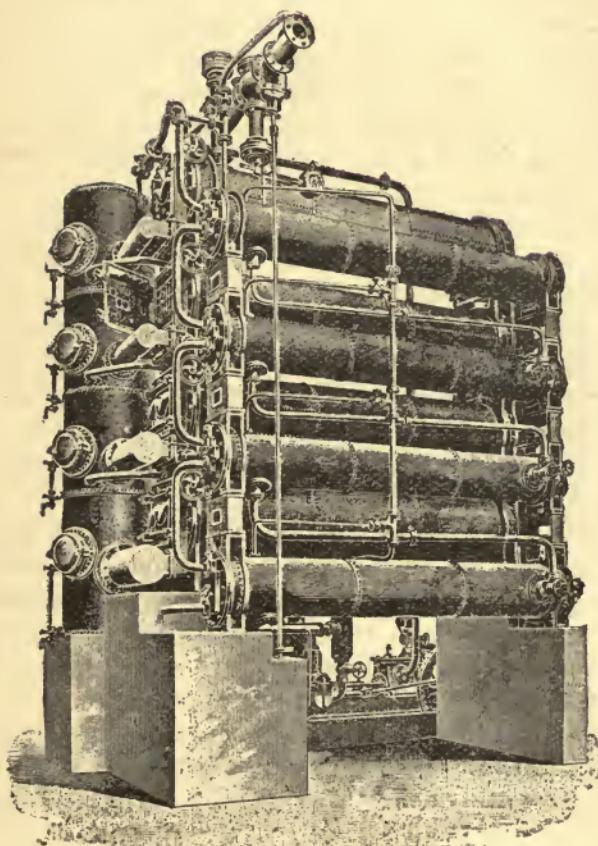
Fig. 28.

diameter. The pans or vessels are each fitted with external circulating pipes and rectangular vapour inlets, of a design patented by Mr. Maxwell, a member of the firm who made the plant. To admit of the examination of the pans or vessels, and the cleaning of the tubes being effected, a channel is provided under the apparatus, the latter being supported over it on suitable wrought-iron girders.

The air, or vacuum-pump, is on the displacement principle and is fitted with a metal plunger 18ins. in diameter working through a cast-iron ring packed with lignum-vitæ, and it has a 30in. stroke. The vacuum-pump engine has a cylinder 14ins. in diameter, and a stroke of 30ins. and together with the pump cylinder is carried upon a bed-plate of box girder section. The crank is of the cut-out type, and an overhanging turned fly-wheel is provided at each end of the crank-shaft, in one of which a crank-pin is fitted for coupling up the juice and liquor pumps.

This installation will be seen to be very compact in design, and, as already mentioned, it is said that very good results have been obtained from its use.

A multiple effect evaporating apparatus which has within the last few years come into extensive use not only in sugar factories but also in chemical and other works, is that known as the " Yaryan Concentrator ;" it is the invention of Mr. Homer Taylor Yaryan. a manufacturer, of Toledo, Ohio, U.S.A., and a patent was taken out by him for it in this country in the year 1886, as also subsequent patents for various improvements in details of construction. The sole licence for this invention for sugar purposes in Great Britain, the colonies, and other countries has been obtained by The Mirrlees, Watson, and Yaryan Company, Limited, Glasgow, and Fig. 28 represents a complete apparatus on this system constructed by the said company.

The characteristic feature of this system is film evaporation, that is, the blowing of the entire mass of liquid into spray, and the rapid motion of the sprayed liquid through the heating or evaporating tubes during the process. There is a great gain in absorption of heat by liquid as its velocity increases, due to the fact that new particles of the said liquid are being constantly brought into contact with the heated surfaces, and the more rapid the motion the more frequently, of course'
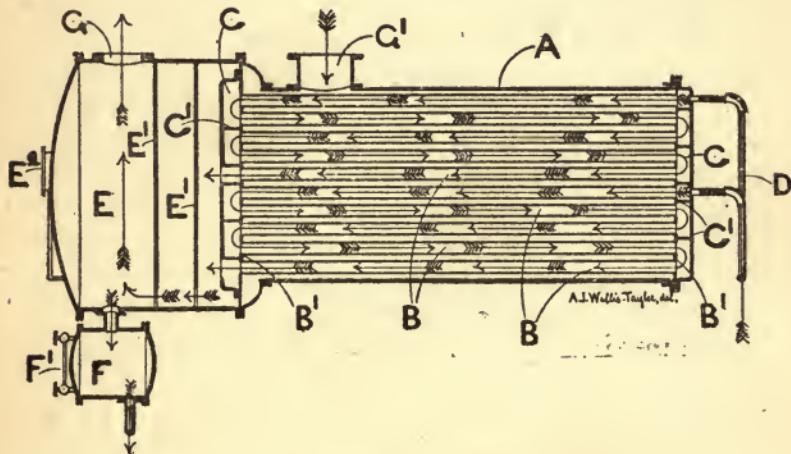
FIG. 29.

does this take place. This principle is utilised in the Yaryan evaporator, wherein the liquor is driven through the heating tubes at a velocity of 2ft. per second.

The working of the apparatus will be better understood by reference to the diagram, Fig. 29, which represents a vertical section through one of the pans or vessels, somewhat simplified for clearness of illustration. The pattern shown in the drawing, Fig. 28, is a quadruple effect, the four pans or vessels constituting the apparatus being arranged in line

vertically; but it may consist of a set of two, three, or of any convenient number of pans up to ten or twelve, or even more, and the said pans or vessels may be either arranged as shown, or in line horizontally.

In the diagram, Fig. 29, A indicates the outer shell or casing of one of the cylindrical pans or vessels; B, B, are tubes secured in tube-plates or sheets B^1, B^1, and communicating at each end with chambers C, which latter are divided by partitions C^1 in such a manner as to form return bends. D is the pipe for supplying liquor to the apparatus, E is the separating chamber for receiving the concentrated syrup. E^1, E^1 are dash plates or baffles against which the concentrated syrup entering the separating chamber is projected, and which helps to separate it from the steam or vapour. F is a chamber or vessel for receiving the concentrated syrup; and F^1 is a gauge-glass for showing the height of the liquid therein. G is an aperture for admitting of the escape of the steam or vapour from the separating chamber E; and G^1 is an aperture for admitting steam or vapour to the heating chamber or space surrounding the tubes or coils B. The aperture G^1 of the first pan or effect is connected to the pipe supplying the exhaust or other steam utilised for heating the said effect, and those of the second, third, and fourth effects to the apertures G of the first, second, and third effects, as more clearly shown in the diagram Fig. 30. The aperture G of the fourth or last pan or effect is connected with the condenser and vacuum-pump. The pipes for removing the vapour or steam from the separating chambers E are provided with safes or catch-alls.

The operation of the apparatus is as follows: The feed pump for supplying the liquor to the pipe

D, and the vacuum pump being started simul-
taneously, a partial vacuum throughout the appara-
tus is formed. Upon the appearance of liquor in
the gauge-glass of the concentrated liquor or syrup
chamber of the fourth or last pan or effect, a pump
provided for withdrawing this liquor is started, and
steam is admitted to the heating space or chamber
of the first pan or effect, and the pressure properly
regulated. The liquid to be evaporated is made to
flow evenly from the chamber C, into the first of
the evaporating tubes B, of the first set or coil, in a
small but continuous stream, and immediately com-
mences to boil violently, becoming a mass of spray,
and taking the path indicated by the arrows, and
finally, after rushing along the heated tubes with a
constantly increasing proportion of steam, passing
in a partially concentrated form from the last tube
of the coil into the separating chamber, as does in
like manner the partially concentrated liquor from
the other sets of evaporating tubes or coils. In the
separating chamber E the steam or vapour of
evaporation with its entrained liquid, which has
been reduced in volume by the evaporation, strikes
with violence against the baffle, dash, or check-
plates E¹, and owing to the mechanical action of
the latter and to the enlarged area of the chamber
E, the liquor becomes separated from the steam,
the former falling to the bottom, and the latter
passing off through the pipe attached to the orifice
G, and being conducted into the chamber sur-
rounding the tubes or coils in the second pan or
effect. This tube is provided with a safe or catch-
all which removes any liquor still remaining, or
which might pass over through priming. The
partially concentrated liquor passes from the
bottom of the separating chamber E into the con-
centrated liquor-collecting chamber F, from which

it is delivered to the evaporating coils of the next pan or effect, and so on through the battery. The action of the coils shown in the sectional diagram, Fig. 29, being typical of that of all the coils in the pans.

In the specification of a patent granted to Homer Taylor Yaryan in 1888, and numbered 213, for improvements on the apparatus described in the specification of the patent already referred to, the inventor mentions an arrangement wherein the partially concentrated liquor is delivered from the collecting chamber of the first pan or effect into the evaporating tubes of the third pan or effect, where there exists a better vacuum than in the evaporating tubes or coils of the second pan, and consequently the flow and transfer of the partially concentrated liquor is more rapidly accomplished than were the said liquor transferred from the first to the second pan. The liquor supplied by the feed pump to the evaporating tubes of the second pan or effect is in like manner partially concentrated therein, and a similar action takes place in the separating chamber of this pan to that described with reference to the first pan or effect, the steam or vapour being delivered to the heating space round the evaporating tubes or coils of the third pan or effect, and the partially concentrated liquor to the evaporating tubes of the fourth or last pan or effect, which latter is heated by the steam or vapour from the separating chamber of the third pan or effect, and wherein a much superior vacuum is maintained than in the other three or preceding pans. The steam or vapour from the separating chamber of the last or fourth pan passes directly to the condenser and vacuum, or air-pump.

If exhaust steam is used for heating the evaporating tubes or coils of the first pan, and the said steam be admitted to the heating space or

chamber at a pressure of, say, about five pounds per square inch, the vacuum indicated upon the gauges of the separating chambers of the different pans or cylinders will be approximately as follows, viz.— That of the first pan will indicate 3ins. of vacuum, that of the second pan 11ins., that of the third pan 19ins., and that of the fourth or last pan of the set or battery 26ins. It is stated to have been found in practice that by skipping one pan or cylinder in making the connections of the liquid transfer pipes, that is, by connecting the first to the third pan and the second to the fourth pan, the advantage of obtaining a better vacuum is gained, thereby; as already stated, attaining an easier transfer, feed, and circulation of the liquor to be concentrated through the evaporating tubes or coils of the multiple effect; and, moreover, that multiple effects, comprising a set or battery of twelve or more evaporating or concentrating pans, can be economically and successfully so worked.

It will be seen that the concentrated liquor from the first pan or effect is finished in the third pan, and that from the second pan is finished in the fourth, consequently the concentrated liquor from both the third and fourth pans will be of the same gravity, but owing to the less perfect vacuum maintained in the third pan, it will be at a higher temperature than that from the fourth or last pan, which has the best vacuum. To bring the concentrated liquor from both pans to the same temperature previous to the removal thereof by the pump for withdrawing the concentrated liquor, or tail pump, that from the concentrated liquor receiving chamber of the third pan or effect is delivered through a suitable pipe into the separating chamber of the fourth or last pan, where the latent heat escapes with the vapour to the condenser.

This arrangement enables the additional pump that would otherwise be required for withdrawing the liquor from the third pan to be dispensed with, and saves the subsequent reduction to an uniform temperature of the concentrated liquor.

The water resulting from condensation is removed from each of the pans or effects by suitable pipes communicating with the condenser, and any liquid that may get into the traps or catch-alls in the pipes, for conducting the vapour or steam from the separating to the heating chambers, is led through suitable pipes, in the case of the first three pans, into the evaporating tubes, and of the fourth pan direct to the tail pump. The internal arrangement of the said traps or catch-alls is as follows :—The steam or vapour, on entering impinges against a plate or diaphragm wherein are mounted a number of small tubes extending nearly, but not quite, to the opposite wall of the trap, and surrounding the outlet pipe, which latter projects for a certain distance into the said trap. It is thus rendered practically impossible for any liquor to pass over with the steam or vapour.

By means of the return heads or partitioned chambers C, at the ends of the evaporating tubes, the latter are thrown into sets of five, thus practically forming coils (according to the dimensions usually employed) of three-inch pipe sixty feet in length. When copper evaporating tubes or coils are employed, the increased thickness and weight that becomes necessary as the diameter of the tubes are increased renders the weight and cost of the enlarged evaporating tubes entirely out of proportion to the additional evaporating capacity gained. Furthermore, if the said evaporating tubes be of too large a diameter, a sufficient current of vapour will not be formed to throw the

liquid being evaporated into commotion, so as to constantly bathe the whole inner surface of the tubes, which is essential to the attainment of the maximum efficiency, and for preventing clogging. Again, if the evaporating tubes or coils be of too great a length, friction will be set up amounting to several inches of mercury. The areas of the coils are therefore preferably increased gradually, to correspond with the increasing volume of vapour being formed, and to obviate the excessive friction that would otherwise result from its passage through the tubes. The return head or partitioned chamber, which is inside the separating chamber, against the flue or tube sheet or plate, has an opening the full size of the tube from every fifth tube, to permit the vapour and condensed liquor to escape into the separating chamber. In an apparatus with, say, pans or effects of six feet in diameter, the difference in vacuum between the first and second pans is not sufficient to get a reliable feed to the upper coils, and the feed pump is therefore arranged to supply liquor to the evaporating tubes of both pans or effects, the liquid discharge pipe from the separating chamber of the first pan being connected to the feed ducts of the third pan, and that from the second pan to the feed ducts of the fourth pan, thereby ensuring the advantage of a superior vacuum in the pans or effects nearest the exhaust pump, and consequently a better and more positive circulation of liquor through the evaporating tubes or coils, and from one pan to the other throughout the series. The feed of liquor can be adjusted up to a certain point by the regulation of the feed pump, but this method is objectionable owing to want of regularity, and a feed regulator, or device consisting of a float and valve arranged in a liquor supply tank, with which

the suction pipe of the feed pump is connected, is preferably employed. By this arrangement, as a given amount of liquor is constantly running into the said liquor tank, should the feed pump run too fast the float will descend and prevent any air, or an excess of liquor, from being forced into the apparatus, thereby rendering the supply absolutely uniform regardless of the speed at which the said feed pump may be running.

In a triple effect apparatus constructed on the above principle and intended to treat say sixty thousand gallons of liquor or thereabouts in the twenty-four hours, each of the pans or effects was primarily fitted with eighteen sets or coils of three-inch tubes, each coil comprising five tubes.* The feed duct or branch from the main feed pipe, to each of these coils, has an area of half an inch in transverse section, thus being of sufficient dimensions to obviate any risk of its becoming stopped up or choked by any ordinary mechanical impurities that may be held in suspension in the liquor.

It is claimed by the inventor that multiple effect apparatus for concentrating liquor can be constructed on this system with greater facility and economy ; that it is more compact and requires less ground space ; that it demands less attention and skill than those of the ordinary pattern ; that it is by far more economical in steam, using the latent heat at different temperatures, with a greater number of effects than any other system hitherto known ; that it is perfectly automatic in its action, taking its own supply as required, and delivering the product continuously, concentrated to the exact pre-

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*In more modern practice, however, it has been found advantageous to employ an evaporator for the duty specified with a heating surface somewhat in excess of this, or say twenty coils.

determined density; that the liquor is not subjected to high and injurious temperatures for more than two minutes, whilst with other systems large quantities are retained for a long time under those conditions; that there is absolutely no colouring of the liquor during the process of concentration; that the evaporative efficiency is more than double per square foot of heating surface that of other systems; and that the rapid flow of the liquor through the coils prevents scaling.

The most valuable feature of this system, next to the great saving of fuel effected, is the extremely short time during which the liquor is subjected to the action of heat, which does not exceed five minutes, and which reduces the loss by inversion and discolouration of the syrup to a minimum. This is of the greatest importance to manufacturers of sugar both from the sugar-cane and sugar beet-root, and especially to sugar refiners for the reduction or concentration of "sweet-water."

As the apparatus does not require to be charged with a large body of liquor previous to steam being turned on, it may be started immediately the juice comes from the clarifiers or defecating pans, and syrup of the required density will be discharged from the last pan or effect within a few minutes, and kept up as long as the apparatus is in operation. Directly the supply of juice for concentration fails, a small quantity of water can be passed through the tubes or coils to cleanse them, after which the steam is shut off and the operation completed. This latter quality of being able to start or stop the working of the apparatus almost immediately is especially advantageous in factories not running continuously night and day, as the operations of charging and boiling off occupy, with ordinary multiple effects, a considerable time.

The Yaryan concentrator, however, cannot be used for building up crystals in sugar-making, this must be done in a vacuum pan.

The low prices obtainable for their products is daily bringing more and more home to sugar manufacturers, refiners, and others using apparatus for the evaporation, concentration, and distillation of liquids, the importance of utilising heat in as economical a manner as possible.

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CHAPTER XVI.

ROBERTSON AND BALLINGALL'S PATENT MULTIPLE HEATERS.

THE double and triple effect system of evaporation is undoubtedly rapidly growing obsolete, and four or even more effects are in general use on the continent, and wherever else due attention is given to economy of heat. In triple, but more especially in quadruple effect evaporation, a greater difference in temperature has been found to exist between the vapour in the last but one and the vapour in the last effect, than between that in the first and second effects. In the course of a series of experiments carried out by the Mirrlees, Watson, and Yaryan Company, Limited, with the object of ascertaining the reason for this difference of temperature between the different effects, they found that, when working under ordinary conditions, increasing the number of effects increases the deviation in a greater ratio, and that with a ten effect evaporator there can be little or no variation of temperature between the first and second effects, thus limiting the duty of the first effect to heating the liquid.

It is a not unusual custom, to raise the liquid to be treated to the temperature of the boiling point, in the first effect by direct steam, an amount of heat being thus expended which cannot be reduced by increasing the number of effects, but is in fact increased, in so far as the additional effects necessitate an increased initial pressure. Consequently the steam used for evaporation is the only quantity reduced by the increased number of effects.

To ensure a multiple effect apparatus working with approximately uniformly varying temperatures, and thus to obtain the maximum advantage out of the heating surface; to heat the liquid to be treated with little or no direct steam; to economise steam (or heat) in direct proportion to the number of effects; and to add effects to existing evaporators, and still increase the output, without any increase in the steam pressure, are problems of the greatest importance.

To the solution of these points the above-mentioned company have devoted special attention for some considerable time past, and they claim to have found that Robertson and Ballingall's patent multiple heaters meet all the foregoing requirements, and that their principle is based on the only possible correct action of evaporation in multiple effect.

The principle of these multiple heaters is illustrated in the diagram, Fig. 30, wherein they are shown applied to a quadruple effect Yaryan concentrator. In the diagram, A, A^1, A^2, A^3 are the four effects; B, B the heating tubes or coils; B^1, B^1 the tube plates; C, C the return heads or chambers fitted with partitions C^1; E, E are the separating chambers fitted with dash plates or baffles E^1; F is the concentrated liquor-receiving chamber; G is the steam inlet to the first pan or

effect A; H, H are the outlets or apertures for admitting of the escape of the steam or vapour from the separating chambers E of the first, second, and
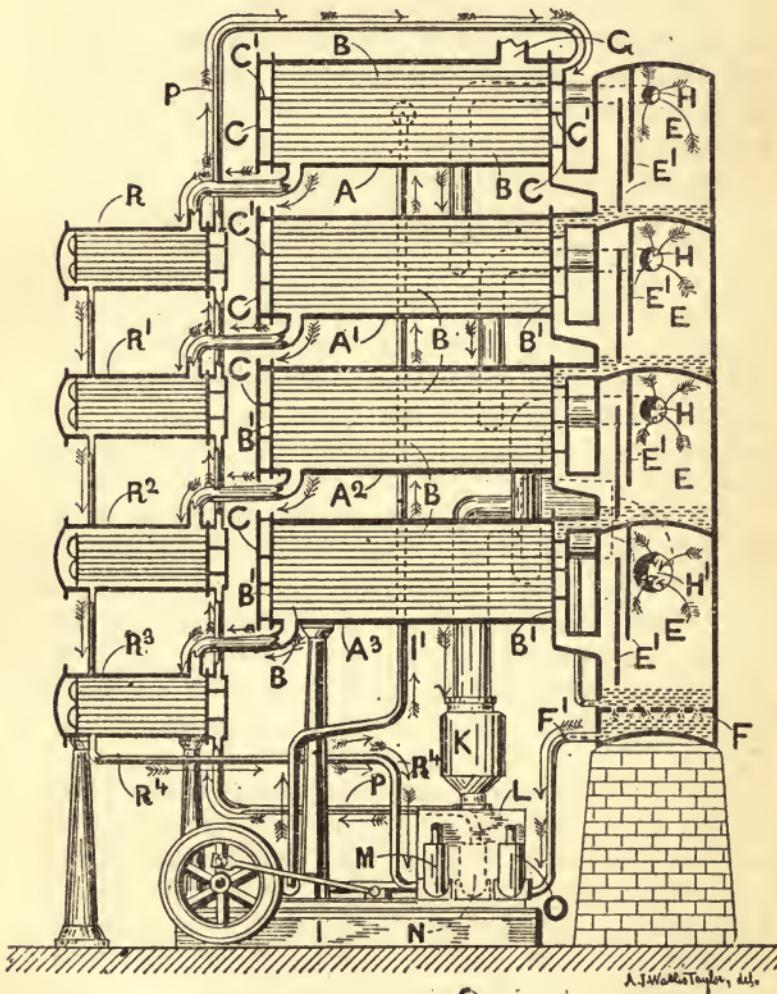
FIG. 30.

third pans, and which outlets are connected by suitable pipes to the heating chambers or spaces of

the second, third, and fourth pans; H^1 is an outlet or aperture for admitting of the escape of the steam or vapour from the separating chamber E of the last, or fourth pan or effect, which is connected through a suitable pipe with the condenser and air or vacuum-pump; I is the vacuum-pumping engine; K is the condenser; L is the vacuum-pump; M is the pump for withdrawing the water resulting from condensation; N is the feed pump for supplying liquor to the apparatus; O is the tail pump, or pump for withdrawing the concentrated liquor; P is the pipe for conducting or delivering the liquor from the feed pump N to the multiple heaters and concentrating pans; R, R^1, R^2, R^3 are the multiple heaters; and R^4 is a pipe connecting the heating spaces or chambers of the latter with the pump M. The paths traversed by the liquor or juice to be concentrated, the steam or vapour for heating, and the water resulting from concentration of the latter, are indicated by the arrows. Each effect has connected with it a heater. The liquid to be treated is forced by the pump N first through the heater R^3, where it receives an increment of heat from the vapour, after that heat has performed a triple evaporation; from R^3 the liquid passes to the heater R^2, where it receives a further increment of heat; after the heat has performed a double evaporation, and so on until it passes into the heater R. This latter heater is in direct communication with the steam, and is mainly of advantage in giving the liquid the final small increment of heat requisite to bring it to the boiling point of the first pan or effect.

These heaters are claimed to inc ease the work of the multiple effect in the^r following manner: In a multiple effect apparatus, each effect (as already mentioned) forms the condenser

M

of the previous effect, and the work done by each effect is regulated by the condensing power of the subsequent effect. If, therefore, to the heating chamber of the fourth or last pan or effect, a heater be connected, through which cold juice is passed, the condensing power of that effect will be increased, and a certain amount of work, which for demonstration will be called (A) is done by the third effect. In doing this the third effect condenses (A) more vapour, thus making the second effect do (A) more work, and so on, so that this heater will make the apparatus do (A × 3) more work. The heater connected with the third effect makes that effect a better condenser, and therefore enables the second effect to do an extra amount of work which will be called (B), which again makes the first effect do a like amount of extra work (B). This heater, therefore, increases the work of the apparatus by (B × 2). Similarly the heater in connection with the second effect may be said to increase the work of the apparatus by (C), the total increase being (A × 3 + B × 2 + C). The effect of this is not to disarrange the working of the apparatus, as might have been expected, but on the contrary to equalise the work done, as an exactly contrary process is going on in every multiple effect. Thus, when the liquid passes from the first effect to the second effect, it gives off a certain amount of vapour due to the fall of the boiling temperature in that effect. This vapour means extra work of condensation in the third effect, and also in the fourth effect. In the same way as the liquid passes from the second to the third effect, vapour is given off which has to be condensed in the fourth effect. The object of the heaters is to make each of the pans or effects not only do more, but nearly equal, work, and con-

sequently with nearly uniform differences of temperature.

The whole process can be traced out step by step, and an accurate balance-sheet made out showing what becomes of every unit of heat, but the calculation is a tedious one, and is moreover only of interest with reference to that particular application of multiple effect apparatus dealt with.

The following table shows the comparative efficiency of multiple effects working under ordinary conditions.

	3 Effect	4 Effect	5 Effect	6 Effect
	per ct.	per ct.	per ct.	per ct.
Saving of heat effected, as compared with any ordinary three-effect		17	27	34
Saving of heat effected by adding patent heaters, compared with an ordinary three-effect	18	37	49	57
Saving of heat effected by adding heaters to ordinary multiple effects	18	24	30	35

From the above table it will be seen that the same economy is obtained from a triple effect, by the addition of these heaters, as by converting it into a quadruple effect, and the work will be increased to an extent varying from 20 per cent. to 100 per cent. in accordance with the description of apparatus, and the liquid being treated.

In the case of a user of multiple effects short of boiler power, it is said that these heaters can be generally added at a less cost than an additional boiler would amount to, and the strain on the existing boilers would be considerably relieved. As a large proportion of the heat usually carried to the condenser is taken by these heaters, there is also a

very considerable saving in injection water, varying from 18 per cent., in a three effect, to 30 per cent., in a six effect.

In the arrangement described and illustrated in the diagram, Fig. 30, the liquor to be concentrated is carried direct through the heaters to the first effect; but in several processes the liquor has to be clarified or further treated at a definite temperature. This can be readily done, by withdrawing the said liquor from the particular heater in which the desired temperature is reached, and returning it after treatment to the next heater. It may sometimes happen that the liquor, as brought to the concentrator, is at a temperature higher than that of the last effect. In this case the heater in connection with the latter may be omitted, but it is advisable to make use of it wherever possible for heating water, or any other liquid in use in the factory.

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CHAPTER XVII.

CONDENSERS, VACUUM PUMPS, ETC.

THE condenser and vacuum or air-pump form an important part of the necessary adjuncts to a vacuum pan, or to a multiple effect apparatus, and usual and effective forms thereof are shown in connection with the installations illustrated in Figs. 19, 22, and 29.

Figs. 31 and 32 are two views of a special patented condenser and vacuum, or air-pump, made by the Worthington Pumping Engine Company. The apparatus shown in the drawing is one in use with a vacuum pan, 12 feet in diameter, and having over 1,000 square feet of heating surface; it operates on the wet system, and performs the functions of

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MAY 25 8?

WORTHINGTON
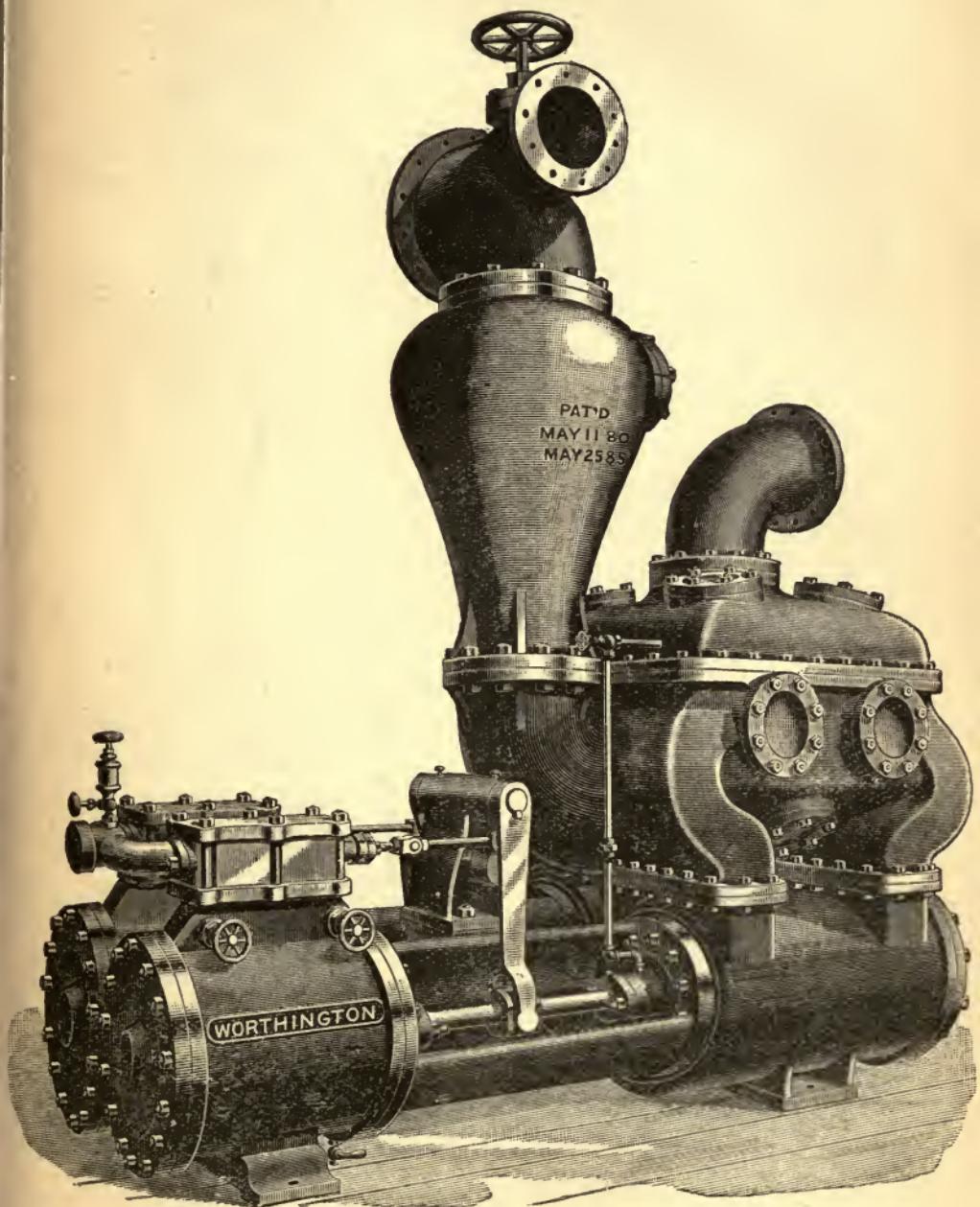
FIG. 31.
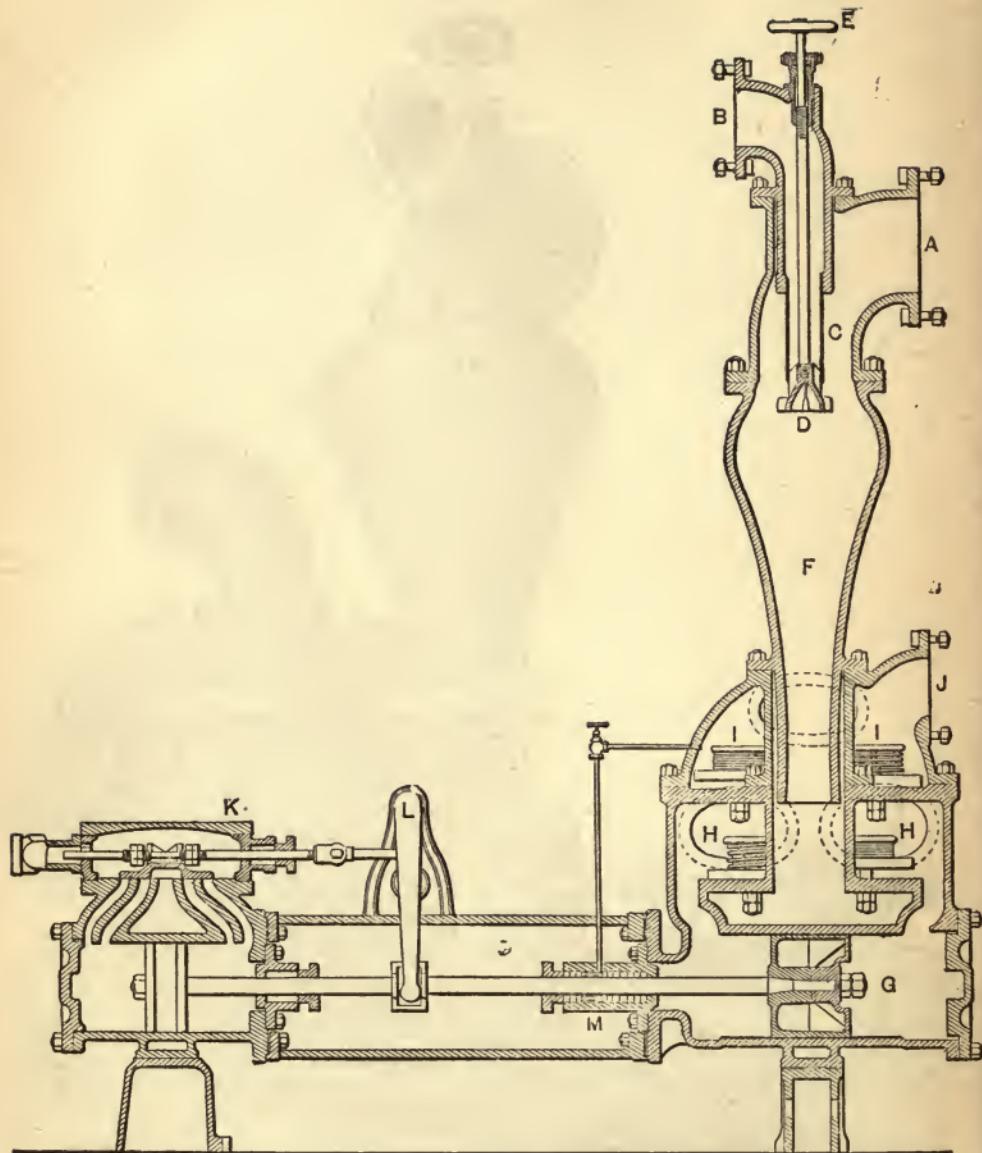
Fig. 32.

three pumps, viz., injection or cold water pump, vacuum pump, and hot water pump. The construction will be readily understood from Fig. 32, which shows a vertical longitudinal section through a condenser, and one side of a duplex vacuum pump and engine, working on a similar principle, but of smaller dimensions, and somewhat differing in design from that illustrated in Fig. 31. In Fig. 32, A indicates the vapour opening or inlet, to which is intended to be attached the pipe which communicates with the apparatus, the steam or vapour from which is to be condensed, and wherein a vacuum is to be made and maintained. B is the injection opening or aperture to which is intended to be connected the pipe supplying the injection water required to produce the condensation of the steam or vapour. C is a spray pipe, at the end of which is arranged a winged cone D, which can be regulated and adjusted from the exterior by the hand wheel and screwed spindle E, passing through a suitable stuffing box and gland, and by means of which the water is thoroughly separated and distributed, and its complete admixture with the steam in the conical condensing chamber F is ensured. G is the pump cylinder; H, H are the suction valves; I,I the force or delivery valves; J the delivery or discharge aperture; K is the steam engine cylinder; L the valve motion; M is the stuffing box and gland of the pump piston-rod, which is provided with a water seal. The pump and engine on the other side are of course identical in construction.

An important feature in the above apparatus is its ability to lift or force the discharge water to any desired height, it being frequently desirable, in sugar factories and refineries where large quantities of water are used, to be able to raise this
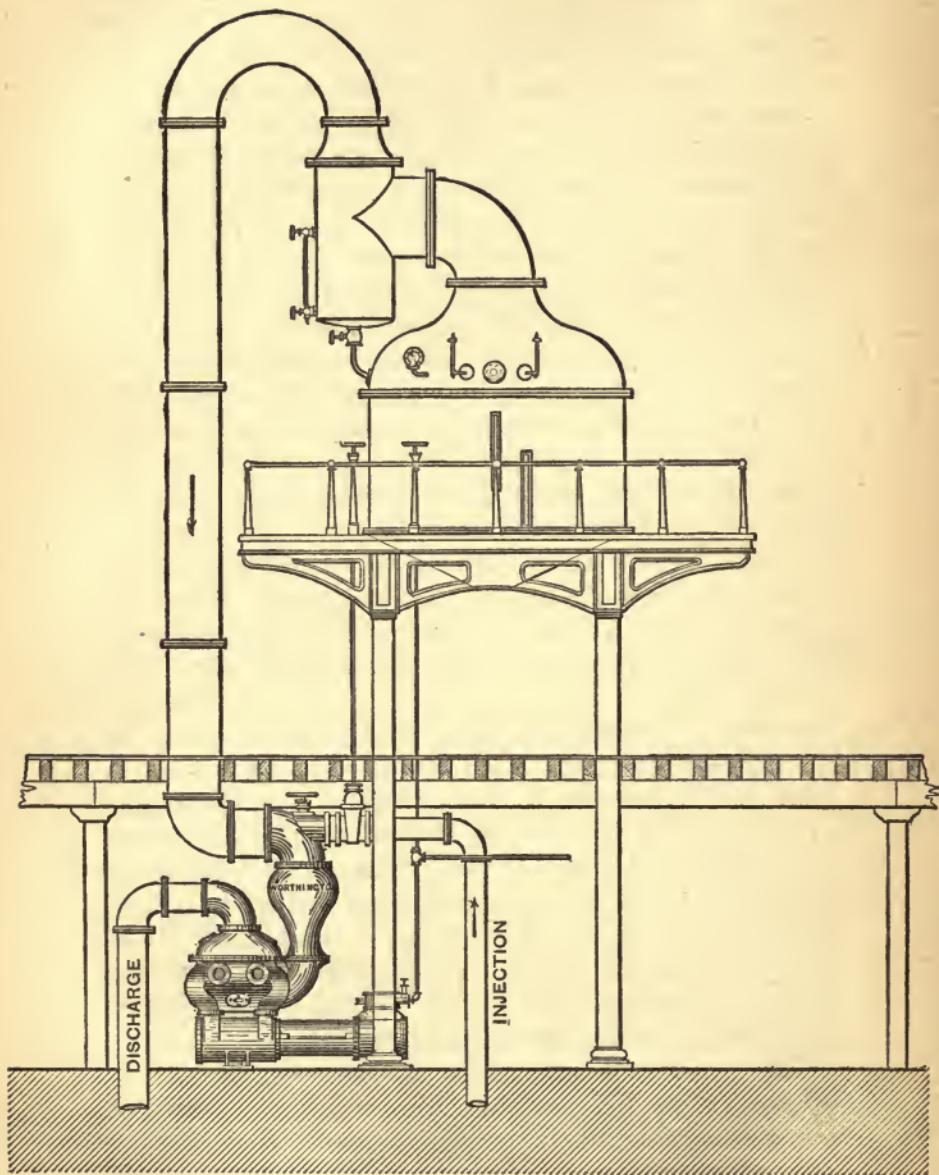
FIG. 33.

water to an elevated tank (such as that shown in Fig. 1) by means of the same pump that produces

INJECTION

DISCHARGE TO COOLING TOWER

CHECK VALVE

STEAM

WASTE DELIVERY

FROM COOLING TOWER
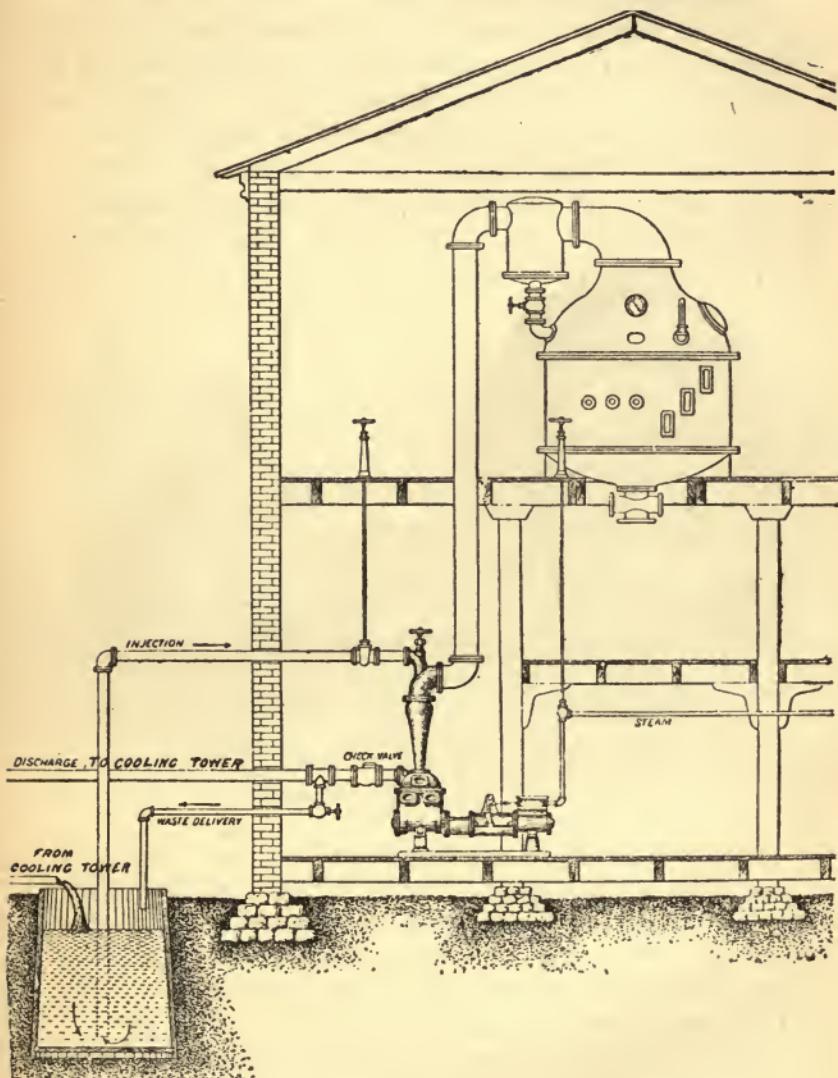
FIG. 34.

the vacuum, and where the discharge water is cooled in towers and re-employed in the condenser,

the separate pump usually employed for raising the said water from the hot well to the top of the said tower can be dispensed with.

Figs. 33 and 34 are side elevations showing plans usually adopted for connecting this condenser to a vacuum pan. The condenser can, if desired, be placed at the side of the pan, but it is preferable to arrange it so that the injection opening or aperture will be within suction distance (15 feet, measured vertically) from the surface of the water, and
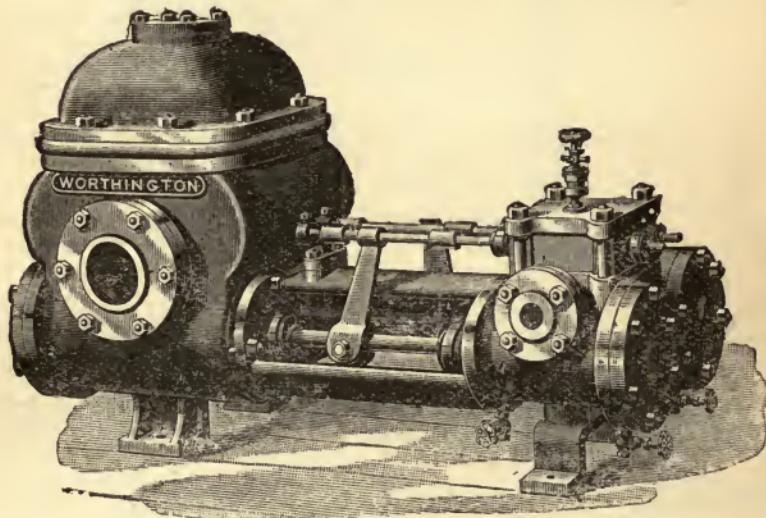
FIG. 35.

thereby be able to lift its own water, and the ordinary water-pump, otherwise required to supply the condensing water, be dispensed with. The apparatus is simple and compact, and has comparatively few joints and flanges, thus diminishing the possibility of leakage.

Fig. 35 represents a patent Worthington wet vacuum-pump. In this pump all the working parts that require oiling are situated in the steam chest, so that they are sufficiently lubricated by the

steam and oil contained in it, and consequently the pump can be run for long periods without requiring attention. If a small quantity of water be provided to seal the valves, this pump will also work efficiently on the dry system.

Fig. 36 is a perspective view showing the Worthington patent dry vacuum-pump, and Fig. 37 is a side elevation showing a method of applying the pump to a vacuum pan. All the valves in this pump are plain slide valves, and consist of two in the steam end and two in the pump end; the
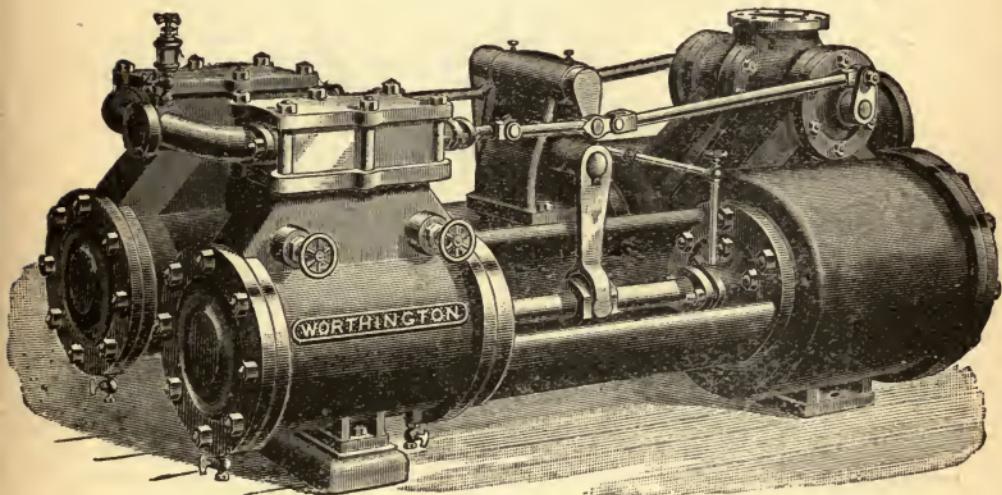
FIG. 36.

usual voluntary valves, springs, etc., which are so liable to become inoperative being dispensed with. The steam and air valves move in unison, being both operated by the ordinary Worthington valve motion (see page 81), and as there are no lifting valves, and no waste spaces between them to fill, no water for that purpose is necessary; should, however, water be required, or gain admission by any means to the pump, it can be promptly expelled. In the
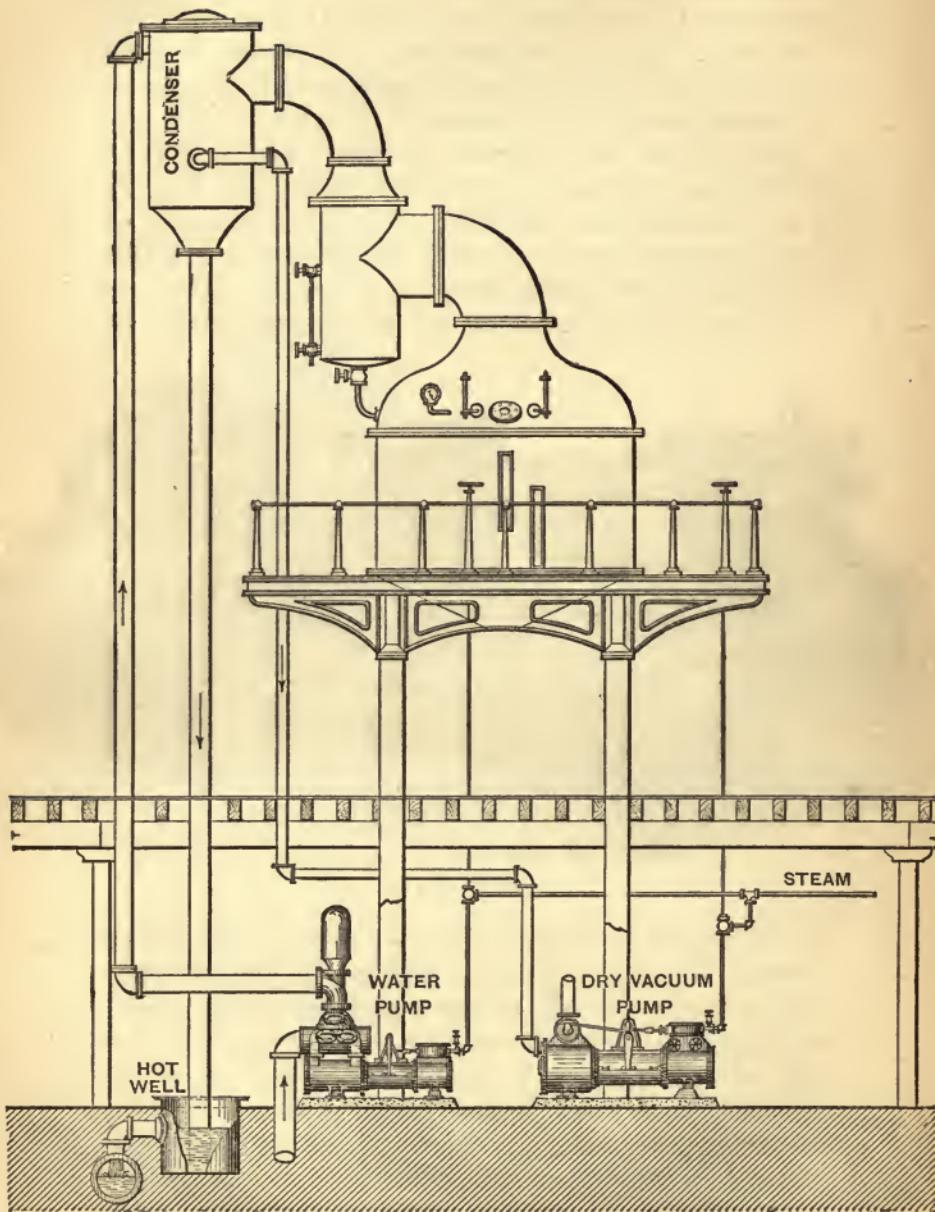
FIG. 37.

arrangement shown in Fig. 37, the condenser is placed at such a height that the condensing water will be discharged through the outlet or tail pipe by gravity, and delivered into the hot well. The water necessary for condensing purposes is supplied by a separate water pump, and the air and other uncondensible vapours are removed by the dry vacuum pump. The vacuum pump can be either placed on the ground, as shown in the illustration,
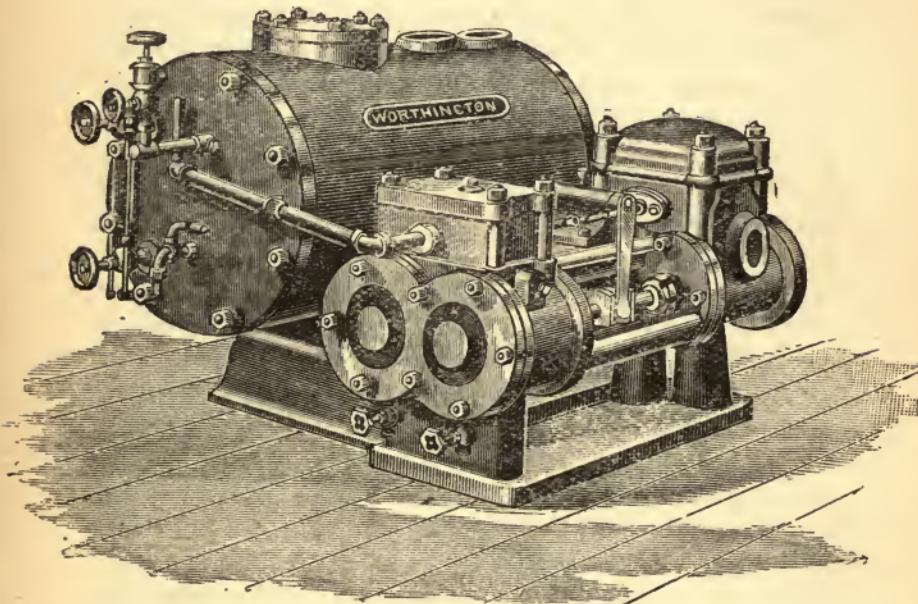
FIG. 38.

or upon the platform of the vacuum pan so as to be convenient for the sugar boiler. The position of the water pump relatively to the water supply must be studied, as already mentioned with reference to Fig. 33 and 34. It is essential to bear in mind that the former pump must only be employed to remove air from a Toricellian tube or tail pipe, as shown in the drawing.

The above system is equally applicable to other styles of evaporating pans, and to double, triple, quadruple, and other multiple effects.

Fig. 38 illustrates a Worthington patent automatic feed pump and receiver, which is especially adapted for effectually and automatically draining either the coils of vacuum pans, or those of open steam-heated evaporating pans. It is intended to utilise the water resulting from the condensation of the steam without any loss of heat taking place through exposure to the atmosphere.

The receiver, which is cylindrical in form, rests upon a solid bed-plate whereon is also supported the pump, which is substantially similar in pattern to that described with reference to Figs. 12 and 13. The receiver is fitted with a gauge glass, and suction and steam pipes from the pump to the receiver are also supplied.

The operation of the apparatus is as follows : The supply of steam for working the pump engine is controlled by a valve and float in the receiver, and as water resulting from condensation in the coils to be drained enters the latter, the said float rises, and so acts upon the valve as to admit steam to the said pump engine and start the pump, by which the said condensation water is fed to the boiler without being permitted to cool. Upon the water level in the receiver becoming lowered the float descends, and partially or entirely closes the steam supply valve, thereby either reducing the speed of the pump or entirely stopping it. In this manner any water that enters the receiver will be immediately supplied to the boiler automatically.

CHAPTER XVIII.

Touch or Workman's Tests. The Saccharometer.

The tests employed for ascertaining whether or not the syrup is sufficiently condensed or concentrated for the required purpose, are either made by hand or with the saccharometer.

The former, which are merely workman's tests, are of French origin. They are eight in number, and are known as follows : 1st. *Preuve au filet*, or string test, which is performed by taking a small portion of the syrup between the finger and thumb and quickly moving them apart, when, if the syrup draws out into a thin or fine thread without breaking, the test is considered to be satisfactory. 2nd. *Preuve au crochet leger*, or the weak hook test. This is performed as above, but the thread of syrup should break and curl up into a slight hook. 3rd. *Preuve au crochet fort*, or the strong hook test, is the same as the previous test, but a stronger and more determined hook is formed. 4th and 5th. *Preuve au souffle leger*, or light bubble test, and *preuve au souffle fort*, or strong bubble test, are performed by dipping a perforated skimmer, or other convenient article, into the concentrated syrup in the open teach or boiler, holding it vertically, and blowing through the holes, when, if only a small number of bubbles are detached it is said to be the first test, and if a large number the second. These tests are made for candies. 6th, 7th, and 8th. *Preuve au casse petit*, or the little fracture test, *preuve au casse grand*, or the great fracture test, and *preuve au casse sur le doigt*, or the finger fracture test. All three are made by first dipping the finger into water, then into the concentrated syrup, and then again

into cold water, when the sugar or syrup adhering to the finger can in the first and second case be rolled into balls, which if thrown upon the ground will, in the former split and become shapeless, and in the latter fly into several pieces. In the third or last case the syrup adhering to the finger will be converted into a brittle envelope, which breaks upon being handled. These tests are used for barley-sugar and other similar sweetmeats.

The following table, compiled by M. Payen, gives the boiling point of the syrup, and also the proportion of sugar and water contained in every 100 parts of the said syrup at each test.

Tests.	Boiling point. Farenheit.	Percentage of sugar.	Percentage of water.
1st. String ...	228·2°	85	15
2nd. Weak hook ...	230·9°	87	13
3rd. Strong hook ...	233·6°	88	12
4th. Light bubble ...	240·8°	90	10
5th. Strong bubble ..	249·8°	92	8
6th. Little fracture ...	251·6°	92·67	7·33
7th. Great fracture ...	263·3°	95·75	4·25
8th. Finger fracture ...	270·5°	96·55	3·45

The little testing instrument known as a saccharometer, is simply a hydrometer so graduated as to indicate the amount of sugar that is contained in a saccharine solution. This is done by reading off the specific gravity of the solution on the graduated scale of the saccharometer, each degree on which indicates the presence of 0·019 per cent. of sugar in the liquor, therefore if the saccharometer floats in the said liquor so as to indicate 10 deg. Beaumé there will be 19 per cent. of sugar therein.

The saccharometer is either made of brass or of glass, and consists simply in a weighted ball or sphere

with a graduated cylindrical stem. One form frequently to be met with (known as Beaumé's) has two bulbs, the smaller one of which is situated at the bottom and is weighted either with shot or mercury; 'the stem is graduated to read the specific gravity of saccharine solutions. Saccharometers are also used by brewers for ascertaining the amount of sugar in worts. In testing liquors with the saccharometer it must be borne in mind that syrups when hot will be lighter by about 3degs. than when cold. With thin juices, however, no difference is experienced, they being practically the same at any temperature.

Mitscherlich invented what is called an optical saccharometer. This is a form of polariscope specially devised for testing sugars by means of polarised light. The angles of polarisation are measured upon a graduated scale, and a standard is set up which serves as a basis for the comparison of different qualities.

A further description of the polariscope, and of its use for detecting the presence of grape sugar, will be found in another chapter.

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CHAPTER XIX.

Curing or Extracting the Molasses from the Sugar by Natural Drainage.

The process of curing or drying the concentrated and crystallised syrup consists in the separation therefrom, in a more or less perfect manner, of the uncrystallisable or rock portion of the sugar, known as molasses. This process is carried out in two ways, viz., by subjecting the sugar either to a natural, or to an artificial drainage.

Natural drainage, which was the system formerly universally employed, and is that still in most general use on small estates where raw or muscovado sugar is manufactured, consists in placing the soft sugar in hogsheads having perforated bottoms, through which the molasses drains or runs by gravity. The hogsheads are arranged in the curing house upon a floor laid with transverse beams, and sloping towards one or more drains or outlets leading into a storage-tank or cistern for the molasses, which is placed beneath.

The semi-liquid mass of soft sugar is dug out from the coolers, and is removed to these hogsheads after it has remained for a sufficient length of time to cool and to granulate, or form into a soft mass of crystals imbedded in molasses, which it does in about twenty-four hours, during which time it should be frequently stirred with long iron rods to bring it to a comparative uniformity of temperature and consistency. It is preferable to only half fill the hogsheads at first, so as to secure a more effectual drainage, and in order to facilitate and hasten the said drainage or curing, plantain stalks, or crushed canes of a sufficient length to reach to the top of the hogsheads, are sometimes inserted in the holes in the bottom of the latter, the molasses gradually draining away through the spongy stalks or canes. Another plan is to insert bulrushes or rods in a similar manner, but which are removed after a day or two when the sugar has settled down, thus leaving holes or passages through the mass which form conduits for the molasses. The time occupied in curing or draining the molasses from the sugar in this manner, varies, in accordance with the size of the grains or crystals, from two or three weeks if the granulations be of fair size, to five or six weeks or longer if the grains be small and the mass very mucilaginous.

In filling hogsheads for shipment with sugar cured in this manner it is first well packed in, and after being left for a certain time to settle, a sufficient quantity of additional sugar is put in to make up for such settlement. The filled or packed hogsheads of raw muscovado sugar still continue to drain heavily, both whilst in the sugar house waiting for shipment and also during the voyage, owing to taking up of moisture from the atmosphere, and the loss of weight in this manner is from 15 to 35 per cent., and that of sugar carried out with the molasses often amounts to as much as 15 per cent.

Curing or drying sugar by natural drainage is under all circumstances extremely lengthy and tedious, and is, moreover, most ineffectual, especially in the treatment of sugars of the lowest class.

In some instances the sugar from the vacuum pan heater is run into conical moulds or receptacles calculated to contain from 15 to 60 pounds or thereabouts. These receptacles or vessels are fixed or supported in suitable frames with their apexes or small ends downwards, and are provided with holes or ways which can be tightly stopped by means of plugs, which are kept in whilst the filling is going on, and for about a day afterwards. The atmosphere of the room where these receptacles are fixed is maintained at a high temperature to facilitate the removal of the molasses, and when the above-mentioned plugs are withdrawn the latter drains or runs through the holes or ways into jars or receptacles, or into a suitable gutter, by which it is conveyed to the molasses tank or receiver. The process is completed by pouring defecated liquor on the upper parts of the conical receptacles, and allowing it to filter through and wash or cleanse the crystals of their impurities. This plan is analogous to that employed for the formation of loaf sugar in refineries.

CHAPTER XX.

Curing or Extracting the Molasses from the
Sugar by Artificial Drainage.

Artificial curing or drainage is now most commonly employed. By artificial is understood any method by means of which the natural tendency of the molasses to drain or run off by gravity is hastened or expedited.

In the case of the conical moulds or receptacles, mentioned at the end of the last chapter, the apertures are sometimes arranged to communicate with a pipe connected to an air-pump, by means of which a vacuum is produced, and the molasses sucked or drawn from the sugar in the moulds.

Another plan is to place the granulated mass from the coolers in a receptacle having a perforated second or false bottom, the space beneath which is connected by means of a suitable pipe with an air-pump, by which the air is exhausted and a vacuum formed beneath the said perforated plate or false bottom.

A mode of extracting the molasses from the soft or crude sugar by subjecting it to pressure in boxes or receptacles having perforated sides has been also tried. An apparatus for this purpose usually consists in a perforated cylinder open at the top and bottom, but which can be closed at the latter extremity by a suitable door or cover. This cylinder is provided with a ram or piston which can be reciprocated by means of a powerful screw or other device admitting of a considerable pressure being set up. When this pressure has been applied to a sufficient extent the door or cover at the bottom of the cylinder is opened and the dry sugar falls out of the press, which latter should be fixed upon a raised platform.

The door or cover is then closed, the ram or piston raised, and a fresh charge inserted into the cylinder.

In Steffen and Langen's process, the loaves in the moulds are treated with cleansing liquor under pressure. Their apparatus consists essentially in a mould fitted with a lid or cover which can be pressed tightly against the said mould, by means of a screw and hand-wheel, so as to form with a packing ring or insertion a fluid-tight joint. The cleansing liquor is delivered under pressure from a suitable pipe, through a central aperture or passage in the lid or cover, and, after passing through the sugar in the mould, is discharged through a hole in the lower extremity or nozzle of the latter, into a trough. The operation is completed by forcing compressed air through the loaf, and the latter is subsequently further dried in a centrifugal.

The method of artificial draining or curing, however, which has been found in practice to give the most satisfactory results, and that in most universal use, is the one wherein the molasses is removed from the saturated sugar by centrifugal action. This is performed in what are now called centrifugals, which are machines substantially similar to those originally first employed for drying cotton or woollen fabrics, and known as hydro-extractors.

The centrifugal machine is decidedly an appliance which is of the greatest importance and value, and one which is, in fact, indispensable in a modern sugar plant. It is beyond doubt the most efficient machine extant for thoroughly and rapidly separating a liquid from a substance of a granular nature, or of liquids of varying specific gravities.

Since the time, about forty years ago, when one of these machines was first adapted for the extraction of molasses from uncured sugar a vast number have

been designed, and many improvements (patented and otherwise) have been introduced, laying claim to special advantages for this class of work. The principle of extraction upon which they all operate, however, is identical, the differences being only in details of construction, and the main features of all centrifugal machines are a cylindrical basket or receptacle for the uncured sugar, formed of wire gauze or perforated sheet metal, and so arranged as to be capable of being rotated either with, or upon, a vertical shaft or axis at a high-rate of speed (from 10,000 to 15,000 feet per minute at the periphery) within a suitable fixed or stationary outer casing or shield. Between this fixed casing and the rotating basket or receptacle is a space or clearance, which receives the molasses expelled by centrifugal force from the sugar through the meshes of the said wire gauze, or the perforations of the sheet metal basket, during the rapid revolutions of the latter. The molasses is removed from the above-mentioned space or clearance, and is delivered to the storage tank or reservoir through a suitable pipe or gutter.

The time required for curing a charge of sugar (which should preferably consist of about three hundredweight, and in no case should exceed five hundredweight, for a centrifugal machine having a basket or receptacle of four feet in diameter) varies from four or five minutes or less for large grained sugar to half an hour or more for sugar of low quality and of a sticky nature. With the last description of sugar it is advisable to insert only about half the usual charge into the basket or receiver.

Amongst the numerous different centrifugal machines mention may be made of the following, viz., those of Walker, Henderson, and Co.; Manlove,

Alliott, and Fryer ; Lessivare ; and Watson, Laidlaw, and Co. (Weston).

Walker, Henderson and Co.'s machine is driven by overhead bevel gearing from a separate or independent vertical engine, attached to the outer casing of the said machine, and has a powerful friction brake provided for convenience of stopping when the charge is effectually cured or drained.

. A type of machine by Manlove, Alliott, and Fryer is under driven by means of belt or strap gearing from the fly-wheel of an independent engine, arranged horizontally upon the same bed-plate. The basket of this machine is made of wire, and it is rotatably mounted by means of a cast-iron dome upon the central shaft or spindle, which latter is carried in suitable footstep and neck bearings in a central bracket, and is fitted with a pulley by means of which it and the basket can be driven off the fly wheel of the engine through a belt or strap. The outer casing, which supports the bracket carrying the central shaft or spindle, forms an annular chamber round the basket, into which the liquor or molasses thrown off from the sugar in the latter is received and collected, and falling to the bottom thereof is conveyed away through a suitable pipe. Two or more doors are arranged in the basket, either of which can be brought opposite an aperture or chute in the casing, through which the dried sugar can be discharged. A brake, which can be operated through a convenient hand lever to act upon a ring attached to the bottom of the basket, is also provided.

The Lessivare machine is under driven by means of mitre gearing, the mitre wheel being normally retained in gear with the mitre or bevel pinion on the driving spindle by a spiral spring. The basket is secured upon the upper end of the vertical driving spindle by means of a cone upon the

latter which fits into a correspondingly shaped recess in the bottom of the basket. The basket is formed with three casings, the first or innermost one being of closely perforated sheet copper, the second or central one of wire gauze, and the third or external one of coarsely perforated sheet copper. A pipe is also provided for the admission of steam to the space between the external casing and the basket, by means of which the perforations or meshes of the latter, which are liable to clogging, can be effectually freed or cleansed.

In some types of machines frictional gearing is substituted for toothed gearing, the liability to stripping of the teeth of the latter being thereby avoided.

The original balanced "Weston" centrifugal, which was introduced into this country in the year 1870, is now in the hands of Watson, Laidlaw, and Co., Glasgow, who make two distinct types of machines upon this principle, viz., the over-driven machine, and the under-driven machine. The former, which is preferable for sugar, when the baskets run above 24ins. in diameter has a double or compound spindle or shaft, consisting of an internal one suspended vertically from a ball and socket joint, and an outer hollow or tubular spindle or sleeve supported by and arranged to rotate freely upon the first. The outer spindle is secured to the basket, and is provided at its upper end with a pulley, by means of which it can be driven through suitable belt gearing. The side or periphery of the cylindrical basket is perforated for the passage of the liquor expelled during rotation; and the bottom is provided with a central aperture, which is normally closed by a suitable plate or valve, for permitting the dried or cured sugar to be easily removed. The basket rotates in an outer annular

casing, admitting in this instance of a certain amount
of play, and the molasses expelled from the sugar
is received in an annular trough situated at the
bottom of the said outer casing, from which it
passes through a suitable hole or aperture to a
pipe or gutter leading to the molasses tank or
receiver. The ball and socket bearing allows the
shaft or spindle to assume a perfectly vertical
position when the basket is filled, and ensures a
great regularity of motion during its rotation. In
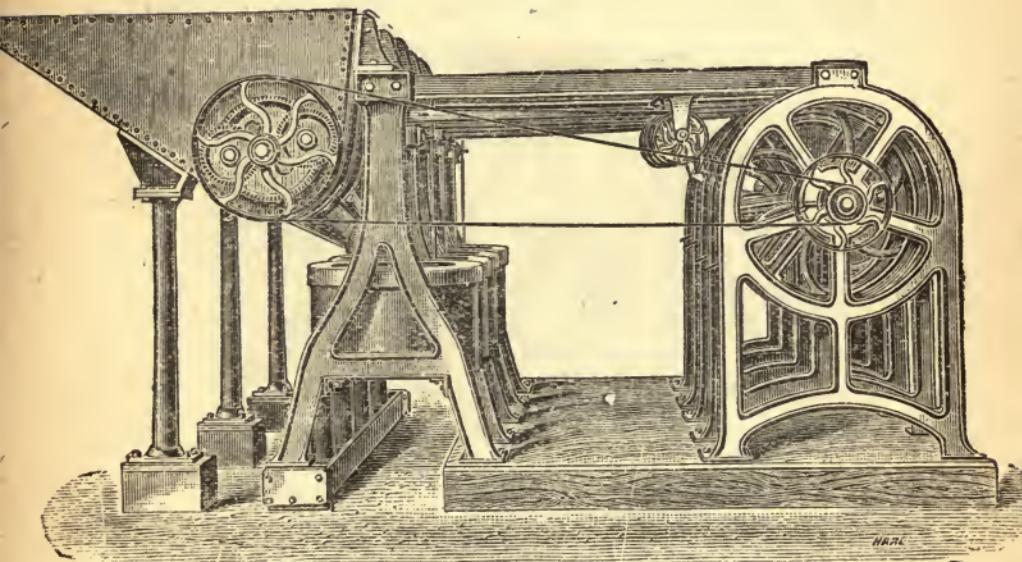
FIG. 39*.

this machine free access can be had at any time
to the bottom as well as to the top of the basket.

The soft sugar is usually supplied to the centri-
fugals from a mixer or pug mill, as shown in Fig.
39*, and the cured or dried sugar is delivered into a
trough (Fig 40), along which it is fed or conveyed
by means of an endless worm or screw.

Fig. 39 is a perspective view illustrating a pair
of 30in. machines, with independent framing,

countershaft, friction pulleys, and driving gear and fitted with Watson, Laidlaw, and Co.'s more recently patented improvements. Fig. 40 is a vertical central section through one of the machines, and Fig. 41 is a vertical section through the upper part of the spindle, drawn to an enlarged scale. The self-balancing arangement which allows of the oscillation of the basket within certain limits, so that it may be free to assume, as a centre of gyration the centre of gravity of the basket and its load, will be readily understood from the enlarged
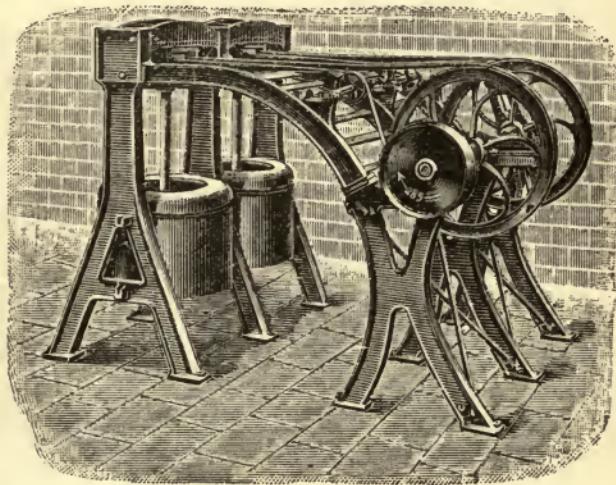
FIG. 39.

sectional view, Fig. 41, wherein B is a strong bracket or block which is firmly bolted to the overhead beam of the framing. S is the internal spindle, which is made of steel and is so suspended by means of the top nut and washer and elastic buffers I, I, supported in the block B, as to permit, whilst at the same time controlling, the oscillations of the basket. The outer spindle is carried upon the spindle S by means of the special bearing F so as to be free to rotate thereon, and is provided at

FIG. 40.
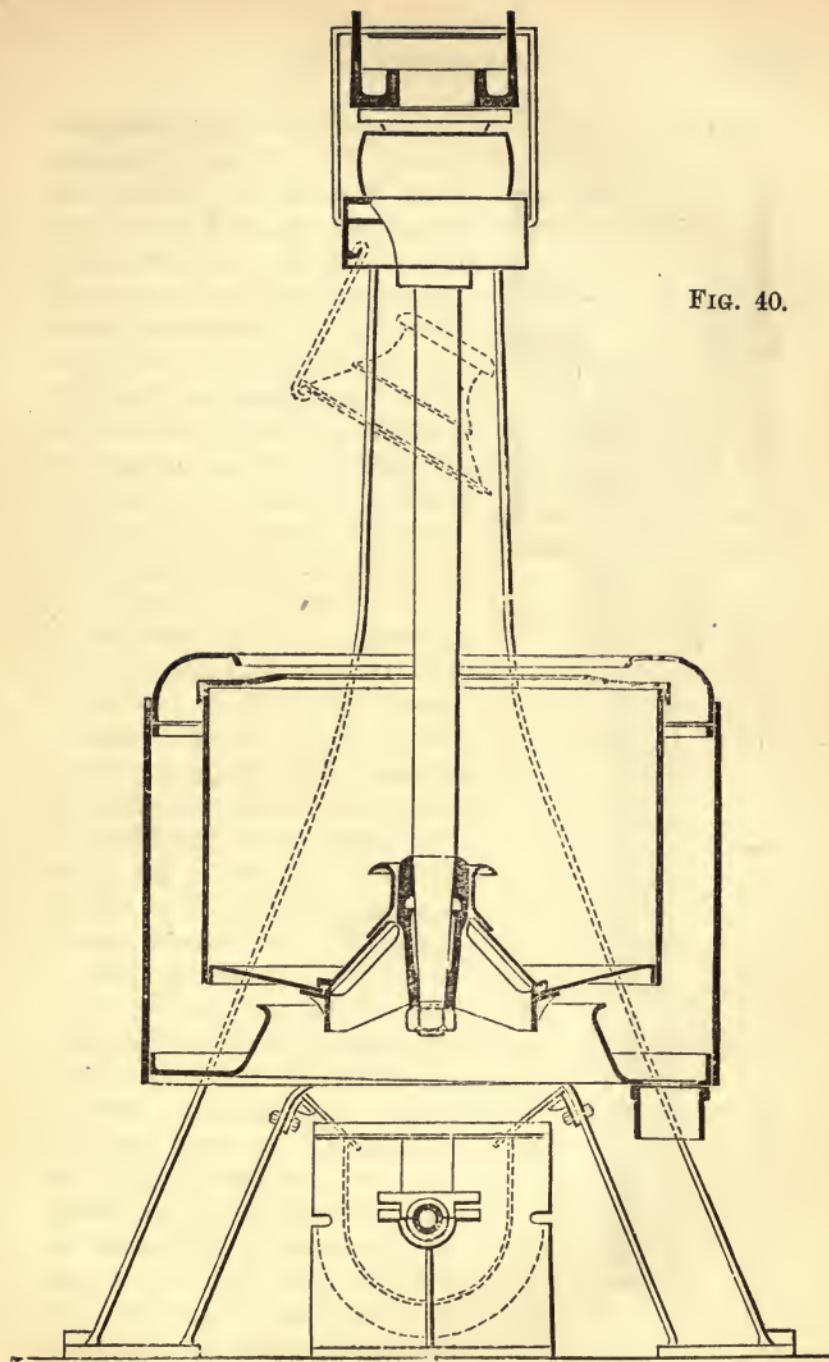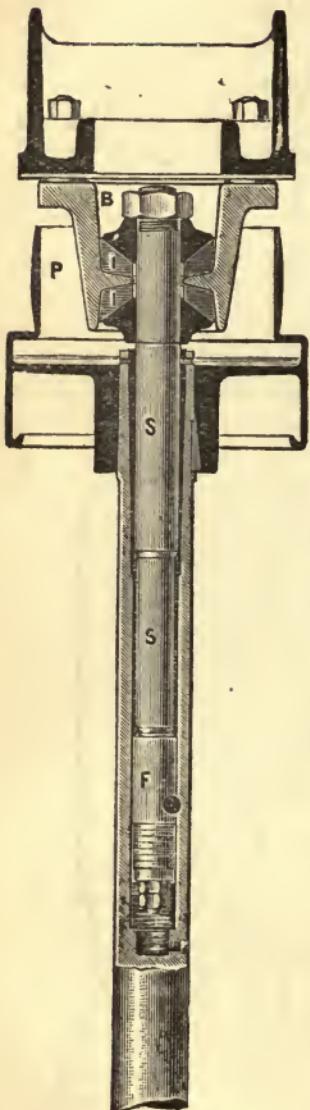
FIG. 41.

its upper extremity with a pulley P. It will be seen that the hollow portion of the outer spindle forms an oil chamber, so that the principal bearing F runs in a bath of oil. A screw plug in the lower part of the hollow or recess admits of the said oil being cleared out when necessary, but one supply is usually sufficient to keep the machine running in good order for twelve months.

The discharge aperture in the bottom of the basket, as clearly shown in the vertical section Fig. 40, is normally closed by a conical cover, which effectually prevents the passage there through of any liquid or undried sugar. When this cover is lifted to discharge the dried or cured sugar, the wall of the latter is completely broken down, and instead of having to be laboriously lifted over the lip of the basket, it can be easily and expeditiously swept through the central opening into the conveyor, which, as already mentioned, is usually fixed beneath. The outer or monitor case is also so bolted to the side frames or standards that, on lowering

the spindle and basket therein, it can, by simply removing the two top bolts, be readily swung or pivoted on the lower bolts, and the said spindle and basket removed. Sufficient clearance or space is provided beneath the monitor case to allow of the dried or cured sugar being removed in sugar barrows or otherwise, when no conveyor is employed for that purpose.

The great advantages of the self-balancing type of centrifugal are obvious, the basket is not compelled to revolve about a fixed centre, as is the case in every other construction of machine no matter how the load may be distributed, but is enabled to find its own proper centre of rotation. The result of this is that vibration is reduced to a minimum, and friction is very considerably lessened thereby permitting a very high speed to be attained with a comparatively small consumption of power, and an insignificant amount of wear and tear. The cost of fixing is likewise much less, as all heavy foundations can be dispensed with, and the machine can be worked under conditions otherwise inadmissible. This latter characteristic is of great value in cases where it is desirable to fix an installation of from say twelve to thirty machines on an upper floor.

In the arrangement illustrated in Fig. 39, the attendants are effectually protected from the belts running overhead, when working between the frames, by the wood spars which are fitted, as shown, between the cast-iron arch beams that connect the front A-shaped side-frames or standards with the rear K-shaped side-frames or standards. The brake and driving pulley are combined, the lower or brake portion being enlarged so as to give an increased brake surface, and also forming a guide which prevents the belt running down on the said brake.

In using these centrifugal machines it is well to bear in mind the following observations of the makers, which are indeed equally applicable to other types:—"There is often much greater risk attending the use of a centrifugal machine than there is with a steam boiler. In the 'Weston' centrifugal the pressure is often as high as 120 lbs. per square inch, and the strain is severe owing to its intermittent nature. The tendency to corrosion is also very great in a centrifugal; it should be kept clean and free from rust. We have frequently seen shells rusted down to $\frac{1}{64}$ inch in thickness, which is not at all safe. It is usually found that the part to give way first is where the shell of the basket joins the bottom. Whenever a machine has to stand idle for some time, the linings should be removed, and the whole thoroughly cleaned.

"Thorough inspection for strength should be made at least twice a year; in fact, a centrifugal should be treated exactly like a steam boiler in this respect, or even more carefully."

In another pattern of centrifugal machine sometimes met with the basket is fixed on a vertical shaft or spindle suspended from an overhead bearing, and the lower extremity of the said shaft is also carried in a suitable bearing. This arrangement however is objectionable; as it does not admit of the shaft and basket adjusting themselves to a perfectly vertical position, nor of their running dead true when rapidly rotated.

In a machine of this construction the shaft is usually supported at its upper end in a bearing of considerable length arranged in a hanger or bracket, and the driving pulley is also placed at this end. An oil cup is provided on the shaft above the bearing, and the oil or lubricant, after passing through the latter, is received in a drip cup secured

upon the said shaft below the bearing. In some cases the basket is constructed of corrugated metal, suitably perforated, and surrounded by wire gauze. The basket is also arranged to revolve in a cylindrical outer casing, but having a conical shaped bottom, which causes the molasses discharged into the said casing to flow to the outer edge and discharge itself through an aperture or vent provided in the outer wall.

Various attempts have been made to drive centrifugal machines by means of electric motors, but their adaptability to this purpose is not, under ordinary conditions, very great. The reason for this is obvious, centrifugal machines, even under the most favourable circumstances, and with every care, do not run with any degree of smoothness, and as a consequence a considerable amount of sparking usually results. The care of the commutator moreover which, together with the brush, has usually to be fixed below the drum, is very troublesome.

An electric motor has, however, been lately brought out by the *Allgemeine Elektricitats Gesellschaft* which it is claimed meets successfully all the requirements of centrifugal machines. It is a polyphase motor having neither commutator nor brushes, and is well adapted to start under medium and heavy loads, and to maintain an uniform speed when running. The motor is readily adaptable to various types of centrifugal machines. When applied to a balanced machine of the " Weston " pattern such as that illustrated in Fig. 40, the armature is fixed upon the upper extremity of the hollow or tubular outer spindle or sleeve.

CHAPTER XXI.

The Extraction of the Waste Sugar from the Molasses.

A VERY considerable proportion of sugar, which is for the most part free, and is not combined with any of the accompanying substances, is carried away with the molasses, and it is therefore frequently desirable to recover as much of this sugar as practicable.

The extraction of this waste or derelict sugar from the molasses is now performed to a great extent in works or factories where beet-root sugar is made, by an application of the principles of endosmosis and exosmosis. This process, which is termed osmosis, and is very easily carried out, consists in placing the molasses in a suitable receptacle and separating it by means of a sheet of parchment or other suitable material from a body of water, a current of endosmosis then takes place from the water towards the molasses, and a current of exosmosis from the molasses to the water, the result of which action is that the salts, such as those of potassium and soda, are removed from the molasses, and a portion of the sugar which these substances had rendered non-crystallisable can be recovered.

The apparatus that is required for the treatment of the molasses by osmosis is extremely simple and comprises merely a series of cases or frames, preferably constructed of wood, so arranged that a sheet of parchment can be placed between each of them, that they can then be firmly clamped or bolted together, and that every chamber thus formed can be alternately

filled with molasses and with water. The action takes place through the parchment diaphragms or membranes, part of the salts of sodium and potassium contained in molasses, as also a small quantity of sugar, passing into the water, and part of the water passing into the molasses.

In a very instructive and interesting paper written by M. A. Melin, "On the Manufacture of Sugar in Belgium," which was read before the Institution of Mechanical Engineers at their meeting in Liège in 1883, it is stated that if the operation be properly carried out, as much as 50 per cent. of saline matter can be eliminated by osmosis, the amount of sugar recovered varying, of course, with the molasses under treatment. The loss averages about 20 per cent. of the total weight of molasses treated.

Whether or not it is worth while to employ the above process in a sugar works will, of course, depend upon the relative value of sugar and molasses.

The water of exosmosis which is charged with salts, and a portion of the sugar (as above mentioned) soluble in water, is in some factories concentrated, the salts crystallised, and the new molasses obtained subjected to re-osmosis. A product is thus obtained consisting of a mixture of nitrates and alkaline chlorides, which salts are valuable in agriculture for fertilising purposes.

In *Dingler's Polytechnical Journal* (1874, CCVII. 410) Peller states that in an experimental trial of Sebor's method of preparing sugar from molasses, made with 250 cwts of the latter containing 45 per cent. of sugar, and worked up to 450 cwts of sugar-lime, the diffusion water carried away 3 per cent. of sugar. The result of the entire operatio ₁ stood as follows :—

o

250 cwts. of molasses containing
    45 per cent. of sugar...   ... 112·5 cwts. of sugar.
Loss in 1,700 cwts. of diffusion
    water, at 3 per cent.   ... 51·0 ,,   ,,
                        —————
    Yield ...   . 61·5 ,,   ,,

This it will be seen is equal to the recovery of 24·6 per cent., or considerably more than half the total amount contained in the molasses, the loss being 20·4 per cent.

CHAPTER XXII.

The Polariscope.—The Copper or Chemical Test, etc.

To ascertain the presence and proportion of glucose or grape sugar it is usual to employ a polariscope.

The principle of polarisation is based upon the changes imparted to a ray of light by a column of saccharine solution. In considering the results of tests made by the aid of the polariscope it must be borne in mind, however, that such observations cannot be taken as anything approaching perfect accuracy, inasmuch as the results must of necessity vary to a greater or less extent with different observers, and even with the same observer under the action of certain moral or physical conditions which influence the vision, either by impairing its power, or by causing apparent differences in the shades of colour visible.

From the first discovery in 1678 of the phenomenon of polarisation of light by Hugghens, over a century passed before the further discoveries of Malus, Arago, Fresnel, Brewster, and Biot were made.

The latter of these investigators made a special study of the phenomenon of circular polarisation as relating to the determination of both dextrose and levulose sugars, the first of which diverts the plane of polarisation to the right, its power of rotation being 56 deg., and the latter to the left with a divergence of from 53 to 106 degs., in accordance with the temperature. The power of rotation of sucrose is 73degs. 8mins. to the right. By some chemical authorities a distinction is made between dextrose, or right-handed glucose or grape sugar, and the sugar obtained from acid fruits or vegetables, such as grapes, currants, etc., by expressing the juice, treating with chalk, clarifying with white of egg, boiling, filtering, and evaporating to dryness. Fruit or levulose sugar turns the plane of polarisation to the left.

Cane-sugar is very readily transformed into fruit-sugar under the action of dilute acids, and by the action of ferments before entering into fermentation. High temperatures transform grape-sugar into caramel. Cane-sugar boiled with dilute acids is turned into a sugar which turns the plane of polarisation to the left, while on the contrary glucose or grape-sugar undergoes no change, but still continues to divert the plane of polarisation to the right. Glucose or grape-sugar crystallises with difficulty and in an uneven manner, is less soluble in water, and is less sweet in taste than cane-sugar. Glucose can be manufactured from potato starch, etc., by saccharising under the action of dilute sulphuric acid, and is largely used for adulteration.

As has been already mentioned in a previous chapter, the polariscope when designed especially for dealing with sugar, is termed an optical saccharometer. The following is the general

principle upon which all these instruments are
designed, the differences being only in certain
details of construction :—A ray of light is passed
through a polarizer consisting of a prism of Iceland
spar, and this polarized ray is then caused to
traverse a column of sugar solution of known
length, and a second prism of Iceland spar which
is called the analyser. To find the extent to which
the plane of polarised light has been rotated by the
sugar solution, it is passed, on its emerging from
the second prism of Iceland spar or the analyser,
through a layer of quartz, the thickness whereof is
capable of being readily adjusted, so as to
compensate with great nicety for the rotation
occasioned by the sugar solution, and which, more-
over, can be measured with accuracy. An optical
saccharometer has either a coloured field of vision,
or one of an uniform faint or pale tint, when set
exactly at zero. The latter are known as half
shade polariscopes, and are adapted for use by
persons suffering from colour blindness, but can be
also used by others.*

The rotatory dispersion of sugar is asumed to
correspond with that of quartz.

The following table, drawn up by M. Biot from
the results of his observations, is given in Labou-
laye's "Dictionnaire des Arts et Manufactures." In
it are determined the rotations imparted to the
plane of polarisation of a single red ray by various
proportions of cane-sugar dissolved in distilled
water, and observed through an uniform thickness
of 160 millimetres.

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*Those who wish to enter more fully into the subject of
polarisation should refer to one of the many able treatises
that have been written upon the analyses of sugar.

Proportion of Sugar in the Solution.	Density of the Solution, that of distilled water being 1.	Arc of Rotation described by the plane of polarization of a red ray through a thickness of 160 millimeters.
0·01	1 004	0·888
0 02	1 ·008	1 ·783
0·03	1 ·012	2 ·684
0·04	1 ·016	3 ·593
0·05	1 ·020	4 ·509
0·06	1 ·024	5 ·432
0·07	1 ·028	6 ·363
0 08	1 ·032	7 ·300
0·09	1 ·036	8 ·244
0·10	1 ·040	9 ·196
0·11	1 ·045	10 ·153
0·12	1 ·049	11 ·128
0·13	1 ·053	12 ·104
0·14	1 ·057	13 ·087
0·15	1 ·062	14 ·079
0·25	1 ·105	24 ·413
0·50	1 ·231	54 ·450
0·65	1 ·311	75 394

A very efficient test for the presence of grape-sugar or glucose is the copper test. It is one upon which great dependance can be placed, and is much used by manufacturers. Testing by elimination, or the process invented by M. Péligot, may also be resorted to, but the first-named test is not only the quickest but is positive, and gives the best and most reliable results. It is carried out in the following manner : Soda tartrate of copper, obtained by the dissolution of newly precipitated tartrate of copper in a solution of soda, or soda carbonate, should be employed. This forms a liquor of a deep blue in colour, and if a minute proportion of glucose or grape-sugar be added at a boiling heat it is decom-

posed, and a hydrated dioxide of copper is pre-
cipitated which is of a yellow hue, becoming,
however, red on being filtered, washed, and dried.
To find the proportions in which glucose or grape
sugar is mixed with the cane-sugar, the discolora-
tion produced by a simple mixture should be first
found, and subsequently the power of discoloration
gained by an equal quantity of the mixture, the
cane-sugar having been boiled with some acid.

In carrying out the above test, it is desirable to
bear in mind that some sugars, especially those of a
dark colour, contain albuminous and other
substances which are as capable of reducing the
copper solution as the fruit-sugar, and which should
therefore be removed before accurate results can be
obtained. For this purpose the best method to
adopt is the addition of lead acetate to the sugar
solution until no further precipitate is formed, as
has been recommended by Fresenius. The following
mode of procedure, which is said to answer very
well, is taken from the *Chemical News* :—" Five
grammes of the sample are dissolved in a moderate
quantity of water, and the insoluble matter
allowed to subside. The supernatant liquid is then
carefully poured into a 100 cc. flask, the insoluble
treated with more hot water and finally collected
in a small weighed filter, and the washing
continued till the flask is about three-quarters full.
To the sugar solution a little solution of tribasic
acetate of lead is added, the whole well shaken, and
the precipitate allowed to subside. The clear liquid
is then tested with a drop or two of acetate, and if
no further precipitate is produced, the contents of
the flask are cooled to the proper temperature, and
finally made up to the mark with water, the whole
being thoroughly mixed. When the precipitate has
subsided, the liquid is passed through a dry filter

into a clean dry glass, and, when sufficient has passed through, is ready for the fruit-sugar determination. If it is desired to determine the extractive matters directly, the precipitate in the flask is washed several times by decantation, and then placed in the filter (previously weighed), and the washing continued till a drop of the filtrate no longer gives a precipitate with sulphuretted hydrogen; the filter and contents are then dried as usual. By the above method of treatment, a clear colourless solution is always obtained, which renders the further operations with the copper liquor much easier."

CHAPTER XXIII.

Miscellaneous Machinery and Apparatus.

Under this head it is purposed to include a number of accessories which it was not found convenient to deal with in the foregoing chapters, but which are nevertheless of considerable importance in the economy of sugar plantations and factories.

Figures 42, 43, and 44 illustrate a portable railway-track, a small locomotive, and cane-truck suitable for plantation work. As can be clearly seen from the illustration, Fig. 42, the rails are secured to channel-shaped iron sleepers, and all that it is necessary to do, in order to lay the track, is to place them on the ground in the required position, and secure them together by means of the fish plates. This form of portable railway, which is designed and made by Kerr, Stuart and Co., Glasgow, is very useful upon level estates.

It is frequently a necessity on sugar plantations to employ some form of pump for raising water

from a stream or river, situated at a level much lower than that of the sugar factory, to the storage pond for supplying the boilers, etc., or for raising water from a storage pond at a low level to another at a higher level, and also for raising water and forcing it up to a higher level for a variety of purposes.

This can be very conveniently and inexpensively effected by means of a pump worked by a small wind motor. The sails of the wind engine should be of an annular pattern and very strong and light, and the blades must be readily adjustable to any desired angle.

When such pumping service is only occasionally required, and
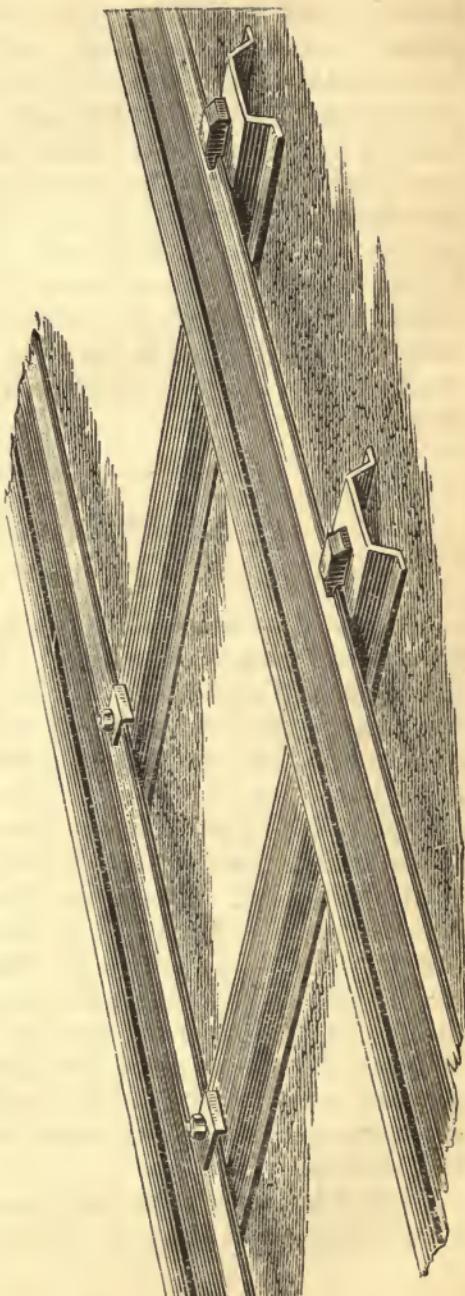
Fig. 42.

that at estates situated at considerable distances apart, some form of portable pump will be found to be useful, such as a portable force pump adapted to be worked by animal power, the gearing being made for one or two horses or mules, or for four bullocks. The crank shaft should
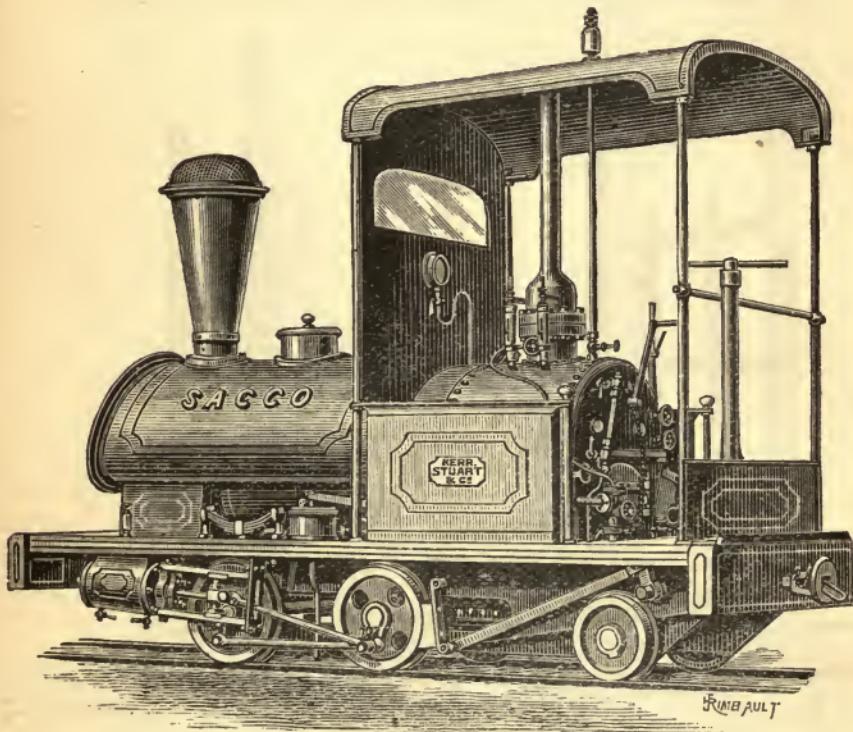
FIG. 43.

be of wrought iron, and have three, or other number, of bent cranks connected through suitable rods with an equal number of ram pumps. The horse gear and the said treble-barrel ram pumps should be fixed on a strong oak frame mounted upon cast-iron wheels. This type of pumps will raise water lying twenty-five feet below the level of the ground upon which

it stands, and, with suitable delivery pipe or hose, will force it up to any height required. They may be also made with a combination of wind motor and horse-gearing, so that the latter can be employed should there be a failure of wind.

Where a large quantity of water is required to be raised quickly a portable steam pump and boiler,
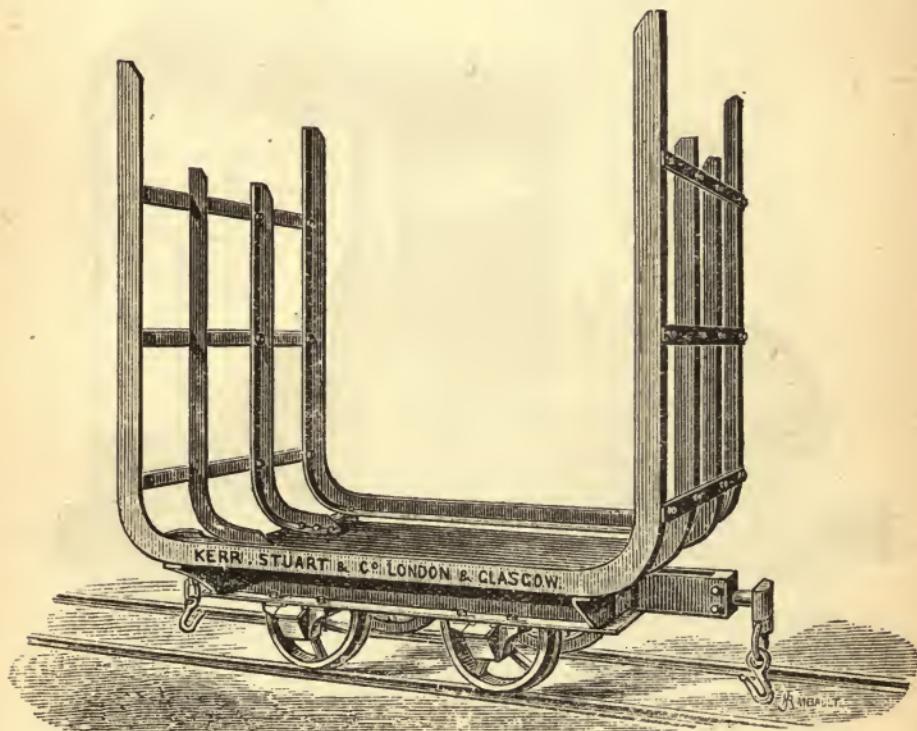
FIG. 44.

such as that illustrated in Fig. 45, or in Fig. 46, will be found extremely useful. In the illustrations the boilers are shown standing upon the ground, but when employed for the above service they should be mounted upon wheels and axles in a similar manner to a portable engine.

The apparatus, shown in Fig. 45, is made by Lee, Howl, & Co., Limited, Tipton. It comprises a duplex steam pump fixed ready for use upon an
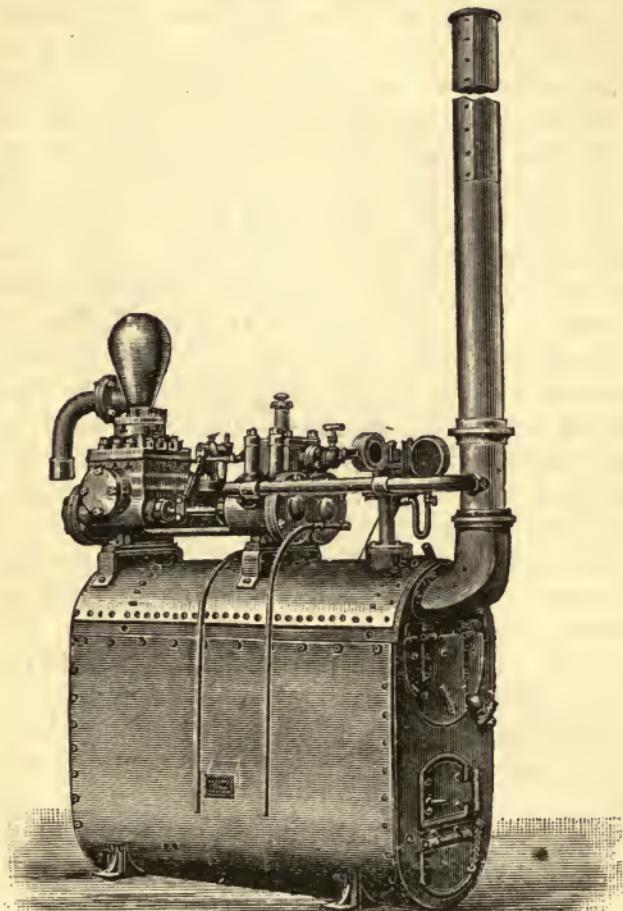
FIG. 45.

horizontal boiler especially constructed for colonial use, with an extra large heating surface for burning megass, wood, refuse, etc.

The pump is fitted with Roger's patent valve motion, which consists essentially in levers pivoted

to clamps adjustably secured to the piston rods, and the free extremities of which work in holes provided in blocks firmly keyed to or formed on rocking shafts or spindles supported horizontally, one below the other, in suitable bearings in a bracket bolted to the intermediate piece between the steam and pump cylinders. At the other end of the upper spindle is provided a crank arm or lever extending in a downward direction ; and at the other end of the lower spindle one extending in an upward direction, which crank arms are coupled by means of suitable connecting rods to the slide valve spindles. The lever for operating each of these rocking shafts is connected to the piston rod of one engine and to the slide valve of the other, thus the slide valve of one engine is moved by the piston rod of the other, and *vice versâ*. The arrangement of the suction and delivery valves, which are both situated above the pump plungers, and of the various other parts admits of their being readily got at for purposes of inspection or renewal.

Fig. 46 illustrates a Worthington steam pump and vertical boiler combined, being complete with auxiliary feed, boiler base plate, smoke bonnet, shaking and dumping grate, water columns, gauge glass, gauge cocks, steam pressure gauge, safety valve, globe valves, two-way exhaust cock, blow-off cocks, steam and exhaust pipes, boiler feed connections, and all other necessary fittings.

The boiler base plate and bracket supporting the pump are so designed as to be as light as possible whilst affording the necessary strength and stiffness, this feature being of great advantage where it is desired to move the apparatus from place to place for temporary duty. The shaking and dumping grate are so arranged that the contents can be dumped without having to open

the fire door, and the ash-pit door is provided with
air holes regulated by suitable plates, so that the
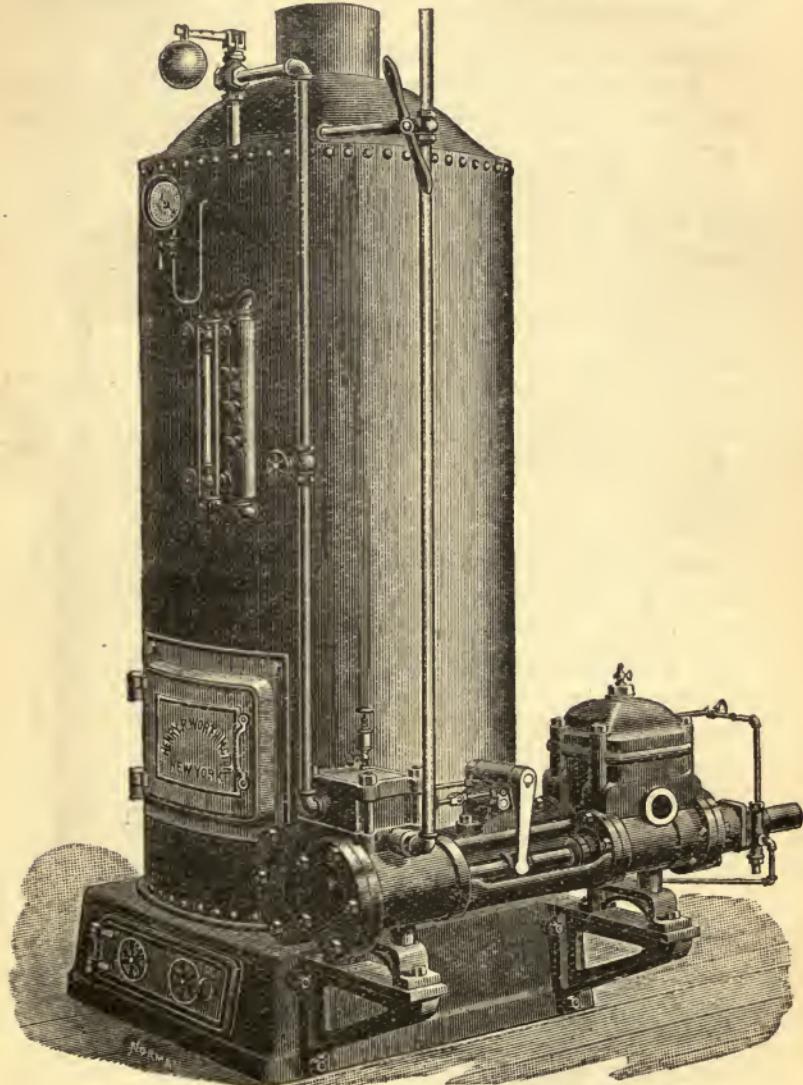
FIG. 46.

draught can be very readily and effectually con-
trolled. The two-way exhaust cock is an important

improvement, as by fitting this cock in the exhaust pipe the waste steam may be either discharged direct into the open air, or, when required, into the uptake to force the draught.

The pump is either a regular pattern Worthington designed for general service, or, in cases where the water is not required to be forced to a greater height than from 50 to 75 feet, it may be one of the low-service or tank-pump type.

When it is required to constantly move the apparatus from place to place it can be easily mounted upon a low trolly, either temporarily or permanently, and thus rendered portable.

For raising the soft uncured sugar into the mixer, or pug mill, of the centrifugal machines, a chain pump, such as that shown in Fig. 47, or a convenient modification thereof, is frequently employed. The pump can be driven by means of bevel gearing, and a belt from the counter shaft of the centrifugals, or in any convenient manner.

This form of pump can likewise be advantageously employed where muddy water has to be dealt with, or for pumping other liquids wherein any considerable quantity of mechanical impurities are held in suspension, or a centrifugal pump, such as that illustrated in Fig. 48, may in some cases be found to be the most suitable. It is provided with a pulley, and is intended to be driven by
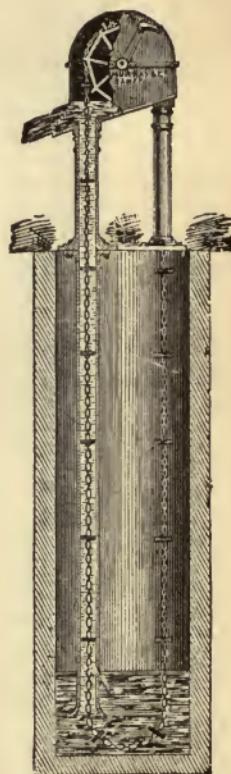
Fig. 47.
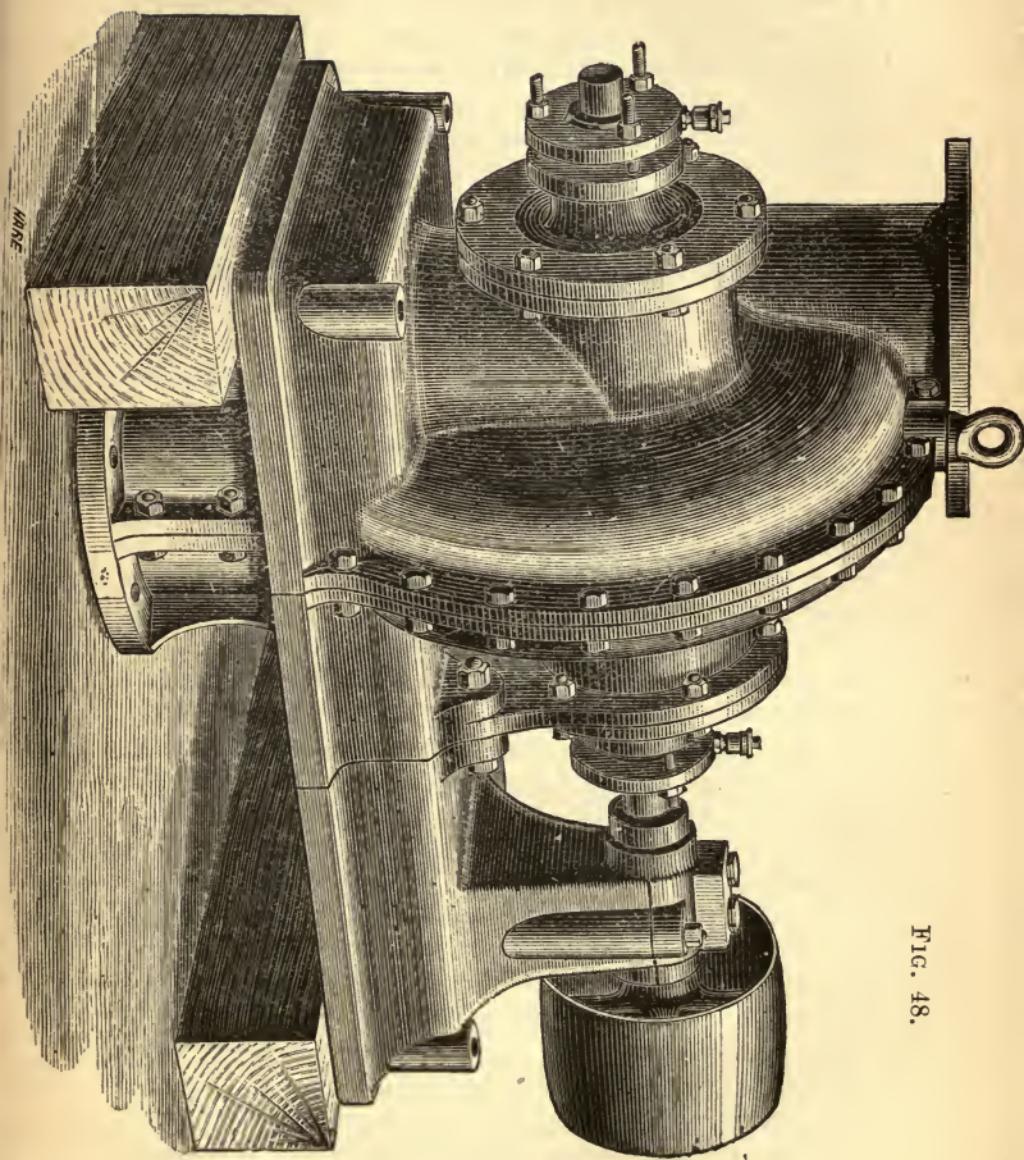
FIG. 48.

means of a belt or band from a portable or other steam engine ; it could, however, be arranged to be driven direct by a special engine, or by horse or other animal power, or by a wind motor or engine.

When practicable, an economical method of driving a pump for raising water from a lower level and forcing or delivering it to a higher, is by connecting it with a turbine or other water motor or hydraulic engine, the latter being the most suitable for this duty, as a turbine runs at too high a rate of speed.

Wherever a sufficient fall can be obtained, however, by far the least troublesome and most inexpensive device is an hydraulic or water ram. The hydraulic ram, although an invention of very considerable antiquity, has only of late years come into any extended use ; it was first thought of by Whitehurst in the year 1772, whose machine, however, was not automatic, but depended upon the opening and closing of a water supply. The hydraulic ram (Belier hydraulique) was improved and rendered automatic in its action, by the simple addition of a waste valve, by Montgolfier in 1796-1802, and was subsequently further improved by his son. Later improvements have rendered the ram more economical in action, and durable, but the principle remains the same, which is, that a larger column or body of water, with a certain fall, will force or raise a smaller column or volume of water to a higher level than that of the driving water supply. This is simply a practical application of an old and well-known mechanical law of forces, viz., that the useful effect produced by a body, is as its weight multiplied by its velocity, the momentum being its actual force.

Fig. 49 illustrates an hydraulic ram designed and made by Owens & Company, London.

An hydraulic ram of an improved pattern is perfectly automatic in action, and will continue to work with extreme regularity so long as the machine remains undamaged, and the water supply lasts. As, however, they are usually left to take charge of themselves, care should be taken
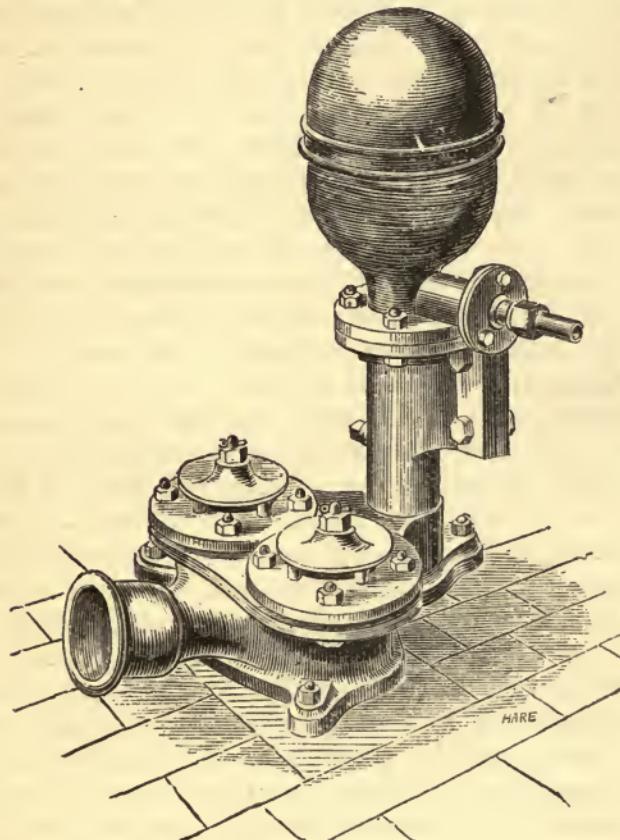
FIG. 49.

to choose only those that are simple in design and strongly constructed, and especially to observe that the beat, delivery, and shifting valves are of the most approved patterns, and of the best material and workmanship.

In fixing an hydraulic or water ram, too high a fall of driving water should, if possible, be avoided, as in this case the friction engendered by the force of the water causes a rapid deterioration of the working parts ; on the other hand, again, if the available fall be very low the quantity of water that can be raised will be of course small. The proportion of fall required to the lift is about one to ten, and the proportion of water lifted or forced to a higher level, to the total supply, is about the same ; that is to say, one gallon of water will be raised or forced to a given height for every ten gallons of driving water that pass through the ram. As an approximate rule, it may be taken, that water can be forced or driven up by a water ram to ten times the height of the head of driving water. Suppose, by way of example, a fall of 6ft. in the supply or injection pipe, this will maintain a percussive action on the ram sufficient to force the water in small quantities to a height of 60ft., a fall of 12ft. to a height of 120ft., and so on. A rapid decrease in the percentage of efficiency will be experienced, as the height to which the water is to be raised increases above that of the fall.

It is often very desirable in sugar usines or factories to ascertain accurately the amount of fluid handled, and in order to do this some form of meter must be employed. An excellent meter for sugar-house work is that made by the Worthington Pumping Engine Company, which is simply a modification of their well-known water meter, but especially adapted in this instance for measuring cane juice, liquor, syrup, or molasses. This meter is positive in action, the principle upon which it works being the re-ciprocation of two pistons or plungers, each

stroke of which is marked upon a counter. The valves, which are plain slide valves, are operated by the plungers or pistons, and are so arranged as to enable all levers, rocking-shafts, and other complications to be dispensed with. When intended for measuring cane juice the meters are constructed of a special brass composition.

An expansion or faucet joint must be inserted in a long line of steam or hot-water piping, having no elbow or curve in its length, so as to permit of its expanding and contracting under variations in temperature, without injury to the joints between the various lengths. A simple joint of this description is formed telescopic, one portion passing through a stuffing-box and gland and being capable of a certain amount of endwise movement relatively to the other. This form of expansion joint affords the advantage of allowing for considerable expansions and contractions of the line of piping, without offering the obstruction to the passage of the steam or water which is done by a copper or other bend.

Another form of joint which is known as an "elastic joint," enables troublesome stuffing-boxes and glands to be dispensed with. The elastic diaphragms employed in this latter arrangement are objectionable, however, inasmuch as they set up a piston-like action, the steam pressure operating against the movement due to expansion.

The co-efficient for expansion in length by heat for every degree Fahrenheit above 32 degrees is for cast-iron ·00000650, for wrought-iron ·00000681, for copper ·0000101, for bronze and gun-metal ·0000104, for brass ·0000106, for tin ·0000132, for zinc ·0000173, and for lead ·0000159.

The following rule for finding the amount of expansion of a given length of pipe at any particular

degree of temperature is given by Hutton in "The Works Manager's Hand-book." "Multiply the co-efficient of expansion by the difference in temperature of the outside and inside of the pipe, which result multiply by the length of the pipe. Thus with a cast-iron steam pipe 160 ft. long, with the temperature of the air at 60° and the steam at 324° Fahr., the difference of temperature will be $324 - 60 = 264°$, and the increase in length due to expansion will be $\cdot 0000065$, rate of expansion, $\times 264°$ temperature, $\times 160$ ft. $\times 12$ inches $= 3\cdot294$ inches."

A useful apparatus for emptying the masse cuite cars into the sugar mixers is a dumping machine. In those of the best construction the cradles or framings for receiving the cars or trucks containing the masse cuite are constructed of wrought or malleable iron, the brackets, which should be of ample strength, may be of cast iron. The machine should be carefully balanced so as to be capable of being turned with ease when a car with a full load is in the cradle. The mechanism for tilting or turning the frame or cradle consists in a crank handle and suitable toothed, bevel, and worm gearing.

In large sugar factories an installation of the electric light is usually employed. The electric light affords peculiar advantages for use in works where motive-power is available, or where steam has to be raised for other purposes, and the great facility with which it can be led to any point where a wire will go renders it specially applicable to sugar factories or usines.

Fig. 50 shows a handy form of dynamo and vertical steam engine combined upon one bed plate, made by the Brush Electrical Engineering Co., Ltd. The Brush type of generator consists of four horizontal electro-magnets arranged in two pairs with

a revolving armature, which latter is composed of
a cast-iron ring notched or recessed out at inter-
vals to receive coils of insulated copper wire, in
which the currents are set up. The weight of the
armature is reduced by parallel grooves cut round
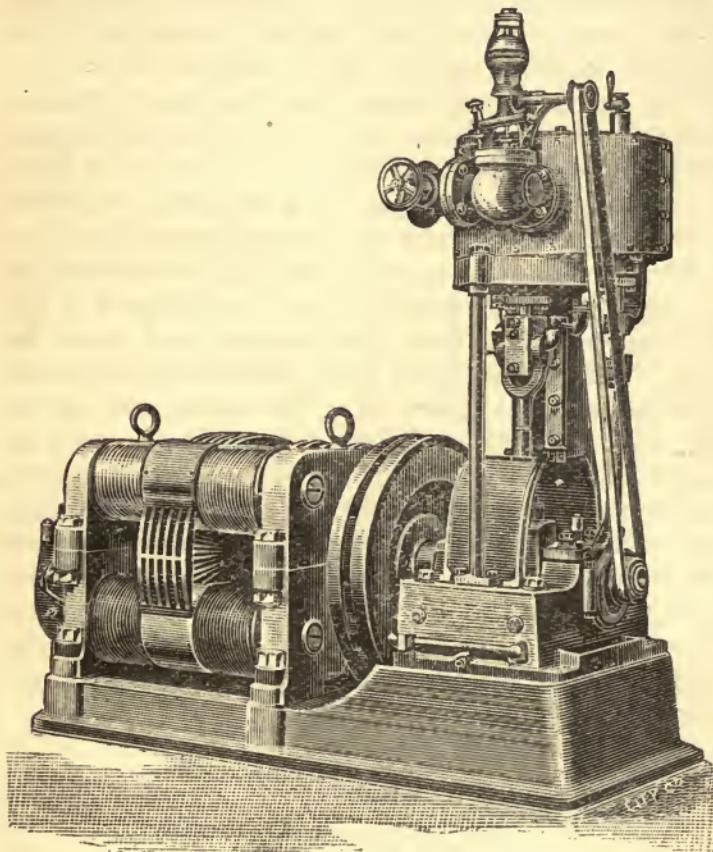
FIG. 50.

the ring, which grooves also prevent heating thereof.
The free ends of the coils are brought to a com-
mutator on the shaft, where they are collected by
copper combs, and led away by copper ribbons for
use.

An important feature in this system is that by a special arrangement of the commutator each opposite pair of bobbins as it passes the vertical or neutral line, or the position wherein it is beyond the inductive influence of the electro-magnets, and therefore is not electrified, is cut out of the circuit of the rest of the bobbins, thus eliminating these bobbins whilst they are in an unproductive condition, and avoiding weakening the effect of those producing the current, and also giving the former time to cool. By extending the pole of each electro-magnet by means of a crescent or curved piece of iron, three coils are brought simultaneously under the influence of each pole ; thus when there are eight coils, two will remain unaffected in the vertical or neutral line, and disconnected from the rest. The commutator is moreover so contrived that the current from only two pairs out of the three pairs of coils or bobbins, brought at one time under the influence of the magnets, is used to feed the lamps, the current from the third pair being sent round the coils of the electro-magnets ; thus making it a continuous-current machine without having to allow the current from the revolving coil to flow through the said coils, and also through the lamps, as is obligatory in other types of continuous-current machines.

* * *

CHAPTER XXIV.

Repairs and Renewals.—Machinery.

As many sugar estates are situated at long distances from the nearest engineering establishment, it would naturally be imagined that one of the most important adjuncts to a sugar works or usine of any

size would be a properly fitted up repair shop. This, however, is seldom the case in the British Colonies, or indeed elsewhere in the case of cane sugar factories. An estate that can boast of a lathe is a comparative rarity, and with the exception of the poorly equipped and tumble-down shanty doing duty as a forge, which is to be found on the larger estates for shoeing the mules, and the coloured blacksmith, whose assistance can occasionally be called into requisition, sole dependence has to be placed upon the engine-driver, or, as he is frequently called on sugar estates, the "bo'sn," and the coloured engineer's assistants, armed with a stock of tools usually comprising a damaged movable spanner or two, a much-used set of stocks and dies, and a few worn-out files. The coloured assistants (each of whom is usually the owner of a hand-hammer, a couple of cold chisels, and a two-foot rule) are, considering the opportunities they have had, exceptionally handy men for rough jobs, and will do a fair day's work in a temperature that would soon knock up a European had he to persist in severe physical exertion for any length of time.

It is obvious that if true economy be studied no extensive estate, or series of small estates, should be without a properly fitted up engineer's shop to enable all small repairs to be executed at once and on the spot. The saving of the delays caused by having to go long distances to get the most trifling jobs executed, to say nothing of that of the mistakes that constantly occur, by reason of the distance of the place where the work is being executed from that at which it is required, and the difficulty of communication, and also of the high rate of profit charged by the local engineers, would repay in a very short time the first outlay.

Such a repair shop to be really efficient should contain an 8-inch centre self-acting, double-geared sliding, surfacing, and screw-cutting gap lathe, a 9-inch stroke self-acting double-geared shaping machine, a self-acting double-geared pillar drilling machine to bore up to 10-inch diameter, a good Newcastle grindstone, an 18-inch emery wheel, properly fitted up benches, with three or four 6-inch vices, and a good supply of stocks and dies, ratchet braces, drills, rimers, cold chisels, files, and other loose tools, such as are constantly required in an engineer's fitting shop.

The wet season in the tropics gives time for the requisite repairs to be executed, to enable the plant to withstand the severe strain put upon it during the dry season, when the canes are ripe and the cutting of the crop takes place. At the latter season a break-down and the consequent stoppage for repairs is most undesirable, and may cause serious loss if any quantity of canes should happen to be cut at the time, as they are liable to go sour when kept too long before being ground.

In spite of every care and precaution on the part of those in charge, however, accidents will occasionally happen, and duplicate parts should be always at hand to meet such an emergency. This more especially should not be neglected in the case of the cane mill rollers and toothed gearing connecting the latter with the steam or other motor. The gudgeons of the crushing rollers are apt to break or twist off suddenly and without warning, and indeed without any apparent cause, and the teeth of the pinions are liable to strip, althogh they may have been running satisfactorily for a considerable period, and seemed likely to continue to do so for a long time to come.

The gudgeons of the crushing rollers are gradually and constantly becoming deteriorated, not only by the natural wearing away of the metal, but by the change which takes place in its texture, owing to the constant heavy strains to which the parts are subjected when the mill is at work, causing the grain of the said metal to alter, and finally to become short. The result of this is that, upon an extra severe strain occurring, the defective gudgeon goes or twists off without any warning.

Should one or two teeth only on one of the pinions or toothed wheels happen to strip, in the middle of the crop season or later, it is sometimes more advisable to execute a temporary repair which will enable the grinding to be completed, than to remove and replace the defective pinion or toothed wheel, even when a spare one is handy. The removal of the old one is frequently a difficult and lengthy job, and even when the duplicate one is in place it may be found necessary to do a lot of chipping to render the new teeth (and in the case of a roller pinion the shrouding) suitable for working with the old and worn ones of the remaining pinions or toothed wheels. New teeth can be inserted in the place of those broken or stripped off by cutting grooves at the roots of the old teeth, and mortising in new ones of wrought-iron or steel. A quicker way is to drill three or more holes, in accordance with the width of the toothed wheel or pinion, at the roots of the broken teeth, and of a diameter and depth according to the strength of the teeth to be replaced. These holes must be tapped, and wrought-iron or steel studs or pins, correspondingly threaded, and a tight fit, screwed firmly home, and afterwards cut off and shaped to the unbroken teeth. This latter, of course, is only a very makeshift job, but if

properly executed generally suffices to carry a pinion or toothed wheel through the remainder of the crop season, after which there is more time for executing the repairs in a proper and workmanlike manner.

When a toothed wheel or pinion has to be removed, and has become so firmly fixed in position, that heating and all ordinary means fail to move or loosen it, the only remedy is to cut or split it off the shaft or gudgeon. The latter is performed by drilling a suitable line of holes radially therein, and splitting by means of wedges. The removal of a part (which has become set fast, or which has been shrunk on hot in the first instance) by heating, is usually rendered difficult by the next to impossibility of applying the heat to the said parts in such a manner as to prevent it from being communicated with too great rapidity throughout the entire mass, and thereby failing to ensure a sufficient difference in expansion solely in the part to be removed, to loosen it. In some instances where gas blow-pipes and other means would be useless, the part can be so heated, as to secure the desired expansion, by running molten lead round it. This method will be found especially effective for the removal of cranks which have been shrunk on the shafts.

The wear to which the crushing rollers of cane-mills are subjected during use causes them to become hollow, and consequently they will require to be periodically turned, or trued up. This is best and most easily effected by turning them in their places by means of a removable slide rest and bed, which can be secured to the side frames or cheeks of the mill.

Cane-mills are usually carried upon large baulks of hard wood, which latter are supported upon masonry or brickwork running down six, eight, or

more feet in depth in accordance with the nature of the soil upon which the foundation has to be made. The holding-down bolts pass through the above-mentioned baulks of timber, and partially through the brickwork foundation. These holding-down bolts are usually without heads, but are provided at their lower extremities with elongated slots running lengthways of the bolts, and are secured in chambers or recesses formed in the masonry or brickwork by means of plates, washers, and keys or cottars. This arrangement admits of the foundation bolts being drawn or removed at any time for renewal, or to admit of the said baulks of timber under the cheeks or side frames of the mill being replaced. The bolts should be enlarged at the screw-threaded ends to an extent, at the very least, equal to the depth of the said threads.

The heating or seizing of bearings is a great source of trouble in sugar factories as well as in other works. The bearings of the cane-mill crushing roller are particularly liable to run hot, owing to the very heavy pressure to which they are subjected; and those of the centrifugal machines by reason of the high speed at which they are driven.

A bearing may become hot and seize owing to its having run dry, by reason of the oil way having become clogged or stopped, through neglect, or from insufficiency of lubrication; from the shaft or spindle being out of truth, either on account of its not having been originally turned perfectly cylindrical, or from its having become sprung; from the cap being too tightly screwed up; from lack of surface, through the insufficient length of the bearing; from an improper fit; or from the bearing being subjected to an abnormally heavy pressure.

Should a bearing heat, first try whether it is loose enough to allow of sufficient play; if it is not too

tight screw down the cap, and turn slowly to see if the shaft or spindle catches in any particular place. To detect any want of truth in the shaft hold a point against it whilst running. If the heating is serious the shaft or spindle must be removed from the steps or brasses, the faces of the latter let together, and all the abrasions caused by the seizing carefully removed with a scraper, after which the steps should be accurately rebedded on their journal. The cap should be carefully examined to see whether it is perfectly steady, or whether it does not shift so as to bind on the sides.

In using the scraper on a bearing for a rotating shaft, care should be taken that it is not moved in the direction of the length of the said bearing, but transversely round its surface, so that any marks that are left will be in the line of motion, and not across it; otherwise there is a probability of the wear of the parts, as also their liability to heat, being increased. Revolving shafts should be filed up by being rotated very slowly in the lathe, the file being traversed laterally by degrees; thus the marks left will be in the form of a very fine pitched screw, and to all practical intents represent circles. Where the motion is of a reciprocating kind, such as that of piston rods, pump plungers, and other similar arrangements working through stuffing-boxes longitudinally, draw filing must be resorted to. This is usually performed by revolving the object to be operated upon slowly in the lathe, whilst at the same time the file is placed across the work in the usual manner, but instead of being moved in the direction of its length it is traversed in a lateral direction.

The bearings of new machinery, especially steam engines, are very liable to heat, more or less according to the degree of perfection in the fitting. The

parts should be allowed to cool and then kept so with water, and the rubbing surfaces will gradually accommodate themselves to each other.

The most difficult bearings to keep cool are the journals of shafts or spindles made from puddled iron. The process of manufacturing puddled iron, no matter how carefully performed, leaves some portion of slag, which causes a fibrous appearance when broken. In spite, therefore, of the greatest trouble being expended in fitting, a journal made from this material, owing to the uneven texture of its composition, is liable when at all over-strained in transmitting power to expand and get out of shape ; and by throwing the whole load upon a limited surface generate heat, which soon spreads through the whole journal.

The larger the journal in area, the less liable it is to heat, up to a certain point, after which it is difficult to keep a long journal cool, on account of its being practically impossible to secure a perfect contact, particularly when it is running in rigid bearings.

It is a good plan to have water pipes leading to the bearings most likely to run hot, so that, where there is no objection to its use, sufficient water can be kept playing upon any particular bearing to absorb the heat as fast as it is generated. In many cases, however, the employment of water as a cooling medium is undesirable on account of the situation of the bearing, but it can generally be applied without detriment to the crushing roller bearings. Where no water pipe is provided, a can or vessel filled with water, and having a small hole or perforation for the supply of a constant stream thereof to the journal, can be suspended above the latter, should symptoms of heating occur.

It must, however, be borne in mind, that an

application of cold water should never be made to a bearing whilst it is in a highly heated condition, as if this be done, the brasses or steps are liable to crack, and the shaft or spindle to twist and become distorted. The water should be applied before any considerable degree of heat has been engendered, or if such excessive heating has already taken place, the bearing should be first allowed to cool down.

Many remedies are recommended for hot journals, which are of more or less efficiency, but it is obvious that what will succeed in one case will entirely fail in another. Changing the oil sometimes has a good effect. For journal bearings subjected to heavy pressures, and where the speeds are comparatively slow, such as the crushing roller bearings of cane-mills, the application of heavy cylinder oil or castor oil will be found useful. This is due to the greater body of these oils tending to keep the metals apart. Under contrary conditions, viz., comparatively low pressures and high speeds, such as the bearings of centrifugal machines, a change to a lighter and more fluid oil will sometimes be found beneficial.

The following applications can be recommended as useful in cases of hot bearings, and as they are very simple remedies there is no harm in trying them, the more especially as the heating of a bearing occurs frequently when it is not practicable to stop, and some means have to be employed to keep it cool enough to work, at least for a time, until it can be examined to find out, and if possible remedy, the cause of the mischief. Olive oil and very finely powdered plumbago mixed together into a paste as thick as it can possibly be used ; flour of sulphur mixed with the lubricant that is being employed ; water with as much common salt as it will hold in solution, used instead of oil ;

pieces of wet waste kept round the cap of the heated bearing and changed as fast as they get warm.

The general management of bearings may be said to consist principally in paying due attention to their proper lubrication. Friction is really want of lubrication. A journal running dry will heat and seize, and, if it be rotating at a high rate of speed, the brasses will be destroyed almost instantaneously. Crank shaft bearings are sometimes liable to give trouble on account of the uneven strains to which they are subjected, and owing to the throw of the cranks forcing the oil out of the bearings. To obviate the latter an oil cup may be fitted to the lower side, so that the revolutions of the crank will tend to dash the oil up into the bearing. The bearings of heavy crank shafts should be fitted with an additional lubricator to hold tallow, or other semi-solid unguent, so that should heating occur owing to failure of the ordinary supply of lubricant, seizing or galling may be prevented by the said tallow melting and running into the bearing.

Connecting rod bearings also require a very considerable amount of attention to be bestowed upon them to maintain them in proper working order.

Bearings subjected to a constant and high pressure are far harder to keep efficiently lubricated than those wherein the direction of the said pressure varies, or of light shafts revolving at a high velocity. The oil in the first, being with great difficulty got between the rubbing surfaces, and moreover being liable to be expelled before it has time to perform its duty, by the constant grinding pressure to which the parts are subjected.

Steam engine cylinders require the best oils,

those of inferior quality becoming decomposed, from the heat of the steam, and useless as lubricants.

The diameter of a shaft or gudgeon should be sufficient to admit of a belt being torn in two, without damaging its supports or the machinery, should the belt wind. For toothed or spur gearing a shaft should be stronger than for belt-gearing, owing to the lack of elasticity of the former, and should be so proportioned as to be capable of crushing or stripping the teeth off cast-iron wheels without twisting.

The brasses or steps of a bearing are of course of the same internal diameter and length as the journal, minus the slight amount of clearance absolutely necessary, and the lower part or half of the steps or brasses is usually subjected to the most wear and should consequently be the thickest.

The connecting rod and crank shaft brasses of an engine are especially liable to wear, to compensate for which they will require frequent adjustment, and if this is not attended to a disagreeable knocking or thumping will be heard when the engine is passing its centres, which if allowed to continue will result in much injury to the working parts of the engine. The eccentric strap should be tightened by screwing up the bolts which join the strap together, and when the edges of the brasses touch, they should be taken out, and their edges filed away, so as to allow for still further adjustment when required later on. Great care must be taken not to screw up the bearings too tightly.

The knocking or hammering of engines arises, also, from various other causes, besides the above-mentioned wear or slackness of the connecting rod and crank shaft brasses, such, for instance, as the wear or fracture of the piston-rings, some unevenness in the cylinder or in the guide-bars, the presence of water in the cylinder from priming or

condensation causing the piston-rings, when slack, to come together in violent contact. Knocking or hammering from any of the above causes invariably takes place when the engine is at the end of its stroke ; it may, however, also arise from the shaft and other parts being out of truth, and from other causes, which are in many cases difficult to detect. Whatever the reason for the knocking or pounding it must be carefully sought for, and when found the defect remedied at once, otherwise a break-down will result sooner or later.

The crank shaft of an engine will sometimes, after running for a certain period, develop a crack. This often results from the corners of the journals being square instead of filleted, the former reducing their strength by about 20 per cent. If the crack is not of a serious nature the shaft may continue in use, a small hole being drilled at the extremity of the said crack to prevent its extending.

Cracks are also liable to appear in the cylinders of engines, more especially in those of large size. These may occur from the cylinders or covers being made of bad or unsuitable metal, the presence of water in the cylinder, damaged piston or rings, from the man in charge starting the engine too quickly and without blowing through, and from various other causes too numerous to mention. When the crack is not of too serious a nature, and the cylinder is still capable of doing useful work, straps should be placed across it, so as to strengthen the cylinder at that point, and prevent if possible its extension. Where these straps or clamps cannot be placed right round the cylinder, and they have to be secured by means of set screws, the holes for the latter should be drilled slightly further apart than those in the straps, so that, when they are screwed up tight, the tendency will be to draw the edges of the crack together.

For renewals of the piston rod packing, some form of asbestos will be found, as a general rule, to be the best and most serviceable, as it has great heat-resisting powers, and is easy of application; that made up in the form of ropes with india-rubber cores is perhaps the best. When filling the stuffing or packing box with the packing it should not be crammed too full, and care should be taken to see that the gland bears evenly upon it all round, otherwise unequal compression will result and leakage occur. The gland must not be screwed up too tight, as if this should be done to such an extent as to cause the packing to firmly pinch or clamp the piston rod, it may engender severe friction and cause heating to take place. An objectionable practice prevalent with some engine tenders, is that of inserting a piece of new packing on the top when the gland leaks, with the result that the old worn-out packing left at the bottom of the gland is liable to get tough and hard, and to score the piston-rod.

The common packings of rope, or hemp, or a cotton-rope packing with a core of chalk, are all that are required for ordinary duty. In using rope, it should be cut in lengths, slightly less than the circumference of the rod to be packed, and the pieces inserted into the stuffing box so as to break their joints. Hemp should be cut into convenient lengths according to the dimensions of the rod, and, after having been soaked in grease, be wound round the latter, and shoved into the stuffing box with some handy implement.

Numerous patent packings are on the market, but none of them are equal to asbestos for rough usage, and, moreover, the latter is capable of working with moderate lubrication, and is unaffected by the action of fatty acids formed by the use of improper lubricants, or by moisture.

Metallic packings consisting of rings arranged to automatically adjust themselves to the rods, have been in use for many years on locomotives, and if properly made and fitted will last for a long time, and give good results, provided the rod is perfectly true and is maintained in first-rate order. Another convenient form of metallic packing is Duval's, which is flexible, and is made of very fine brass wire braided into a square rope. Metallic packing should be preferably employed where steam at a very high pressure, or highly superheated or surcharged, is used. When first placed in position metallic packings are apt to leak slightly, but usually stop or take up after a few days' wear.*

The covers of the engine and pump cylinders and steam chest cover, and in the case of a condensing engine the condenser valve box-covers, etc., as also various other parts of the machinery, with face joints, have occasionally to be removed, and consequently the broken joints must be remade. Before attempting to make the new joint all the old lead should be most carefully cleaned off from the faces, and the latter wiped over with boiled linseed oil. The red lead should be well worked up, and be soft and pliable and free from grit or other foreign bodies. In applying it to the joint, roll it into a thin rope of about half an inch in diameter, according to the dimensions of the joint to be made, and lay it on inside the bolt holes. The faces should be carefully brought together and the nuts screwed up evenly all round. String, hemp, tarred twine, etc., should only be employed for rough jobs; their use with properly faced surfaces merely prevents the

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*For further particulars as to the care and managemen of bearings, packings, etc., see "Bearings and Lubrication, by the same author.

parts from being brought close together, and the formation of really sound joints.

For cylinder covers, joints of brown paper, asbestos, blue lead, etc., etc., are frequently employed.

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CHAPTER XXV.

REPAIRS AND RENEWALS.—BOILERS.

THE repairing of boilers is a matter of great importance, and one that unfortunately seldom receives the attention it deserves. In sugar factories or usines, and more especially upon sugar estates where cane-sugar is made, the steam boilers are frequently continued in work until one of them gives out, when it is botched or tinkered up to serve another turn, or, if this be impossible, is replaced, often by another old derelict boiler badly repaired and almost as dangerous and worthless as the one removed. The method of setting the boilers adopted in many works is also frequently old-fashioned and erroneous in principle, and precludes the possibility of any proper inspection being made, consequently their exact state is to a great extent a matter of mere conjecture.

The usual primary working pressure of the multi-tubular form of boiler, most commonly to be met with in cane sugar works abroad, is 70lbs. per square inch, and this pressure is not often reduced below 60lbs. as time goes on, and the boiler grows old and weak through natural decay, and by reason of injuries caused by badly executed repairs. Indeed, on the contrary, it is not uncommon, in small factories, to find a boiler originally calculated to supply steam to the cane-mill engine and clarifiers only, which, in its old age, with

cracked and patched tube plates, leaky tubes, and badly corroded shell, is expected to produce the additional steam required for one or two open steam-heated evaporating pans, and occasionally for a small steam pump or a monte-jus. To effect this purpose the safety valve will have an old fire bar or two hanging on the end of the lever in addition to the usual weight; in fact, those in charge are, as a rule, reckless in their endeavours to keep the leaky valve firmly upon its seating and to maintain a pressure of 60lb. indicated upon the gauge. In reply to remonstrances it is usual to point to the fact that this ancient and probably faulty gauge seldom shows a pressure beyond 60lb., which is likely enough considering the work that the boiler is, as a rule, expected to do, but, nevertheless, it is a fact that the boiler is working practically without a safety valve, and when, in addition to the above, it is not unfrequently found that the try cocks are corroded to their seatings, and that the water gauge is never blown through or tested for a similar reason, all that one can do, is to silently wonder, that, under these dangerous conditions, disastrous explosions are not the rule instead of the exception.

Owing to the fierce heat and flames produced by the megass fuel commonly used on sugar estates, cracked tube plates are frequently met with. These faults, as a rule, extend from the edge towards the centre of the plate, and are the result of uneven expansion and contraction. If not of a serious nature cracks of this description may be prevented from extending by drilling small holes at their extremities, or where they terminate at the edges of the tube plates, at one extremity of each crack, tapping them and screwing in wrought iron plugs, after which the cracks can be caulked to prevent or arrest leakage.

Should however, any crack exceed four or five inches in length, or be situated between and extending into two or more rivet holes, the defective plate should be at once removed, or at least a large piece of it cut out, and a patch properly inserted.

A new plate for an old boiler should be of a thinner gauge than the other or original plates, and in patching, care should be taken to cut the defective piece out of the old plate in such a manner as to leave no sharp corners, and as circular as can conveniently be done. All rivet holes, moreover, should be drilled, and no punched holes or drifting should be permitted. Patches placed over weak parts, and fixed by means of set screws or studs, without cutting out the old plate underneath, should on no account be countenanced except as a temporary repair.

The tubes of multibular boilers will occasionally require to be expanded in the tube plates to arrest leakage; and the defective or worn-out ones should be removed and replaced. Care must be taken not to carry the expansion of the tubes too far, as they may become split by a too free use of the mandrel or tube expander. If the tubes persistently give trouble by leaking, it is better to ferrule them. To draw the tubes, after having first knocked out or removed the ferrules, when the latter are employed, either by means of a long bar or rod, or, preferably, by means of a patent extractor, it is usual to turn over and inwards, by means of a hammer and chisel, the ends resting in the tube plates, and drop the loosened tubes to the bottom of the boiler, from whence they can be withdrawn through the mud hole. Tubes extracted in this manner cannot, of course, be used again, except it were for a shorter boiler, to suit which they might be cut down. It should therefore be only employed for the removal of

completely worn-out and worthless ones. These old tubes may be usefully employed for carrying a road over a narrow stream or gully, etc.

The above-mentioned patent ferrule extractor affords several important advantages over the old method of knocking them out by means of a long bar or rod, which requires the services of two men, one to hold the bar and the other to ⌐strike with a sledge. This operation ⌐also frequently results in the tubes having holes knocked through them or in their being otherwise damaged, which is objectionable in cases where sound tubes are being taken out which it is desired to use again. The heavy and repeated blows of the sledge, moreover, are apt, especially when the ferrules are very tightly wedged in position, to set up a jarring, which, although perhaps only three or four tubes have to be extracted, will loosen and render leaky half the other tubes in the boiler, besides shaking and injuring the whole boiler by the concussion.

The device is very simple in construction and easy to apply, and with its help a lad can easily remove the ferrules from boiler tubes, no matter how tightly they may be wedged in position. It consists in a mandrel fitted with a bridge which can be moved upon one end thereof by means of a nut. The other end of the said mandrel is provided with movable nibs or projections operated by an external sleeve. To use the tool, the nut must first be screwed partly off the spindle, and the bridge moved back to it. The mandrel or cylindrical end should then be inserted into the tube, until the nibs or stops that project slightly therefrom are behind the ferrule, when by rotating the hollow portion or sleeve of the said mandrel through half a revolution, the said nibs or stops will be moved outwardly so as to engage with the said ferrule. All that will be then required to draw the

ferrule will be to tighten up the nut with a key or spanner.

When it is necessary to draw sound tubes, they should first be cleaned as far as possible of all scale or deposit, and the ferrules, if any, removed, when they can be gradually forced from the boiler by means of a tube rod, which consists of a strong bar of iron, circular in transverse section, and having an enlarged portion or collar, or a washer secured in position by a nut, and of a diameter equal to that of the tubes to be removed, situated at a suitable distance from one of its extremities. This rod is inserted into the tube to be removed and used as a battering ram, the collar or washer, striking against the end of the tube, by which means it is, little by little, driven out through the opposite tube plate. Or it may be held in position by one man, with the collar or washer against the end of the tube, whilst another strikes it repeated blows with a heavy sledge. This method of drawing tubes is objectionable by reason of the jarring and concussion; and is equally injurious to the boiler, as is the similar method of knocking out the ferrules.

In some instances the rod is provided at one extremity with an eye to which a pair of blocks may be secured to haul out the tube.

Instead of a rod, a chain having at one end a steel disc of a corresponding diameter to that of the outside of the tube, and the other end of which is connected to a suitable windlass, may be employed. In this case the chain is passed through the tube, and the disc engages with the end thereof, and it is gradually drawn out by the windlass. The tubes may be also forced or drawn out by hydraulic power.

Sometimes a beading is formed on the tubes just outside, or both inside and outside, the tube plate, in

'order to ensure a more perfect steam tight joint. In this case the ends of the tubes must be cut off, and the tubes cannot of course under any circumstances be used again in the same boiler.

It not infrequently happens, that a tube becomes incurably leaky at a time when it is not desirable, or even possible, to draw and replace it ; in this case some device for stopping up the ends of the tube may be resorted to. This can be performed by driving a slightly tapered plug of iron, or hard wood, or asbestos, firmly into the faulty tube. If the split be too long to be stopped by one plug, one may be driven in past the crack and another following. Another plan is to insert a wooden plug into each end of the cracked tube, so as to be flush with the said tubes. Holes should then be bored through these plugs, and a rod, screw-threaded at its extremities and of slightly greater length than that of the tube, be passed through the latter and these holes. Discs or washers of somewhat larger diameter, and preferably slightly concave on the sides next the tube sheets or plates, are then placed on the rod, and red lead or asbestos packing having been first inserted between them and the said tube sheets or plates, the said discs or washers are wel tightened up against them by means of nuts placed on the screw threaded ends of the rod. If the discs or washers are well fitted, the wooden plugs may be dispensed with.

In the case of a crack in the tube-plate, running between two of the tube holes, the corresponding tubes may be cut off flush with the tube sheet or plate, and a plate or strap of sufficient dimensions to cover the crack, and the said adjacent tubes, be secured by means of bolts or rods passed through the said tubes and plate or strap, red lead or asbestos packing being placed between the latter and the tube-plate or sheet.

These repairs are, of course, only of a very make-shift order and not by any means to be recommended, and they should only be employed in cases of dire necessity, where it is of the utmost importance to continue a boiler in use, for a short period only, and it would be absolutely impossible without serious loss to stop for the length of time required to execute proper repairs, or to replace the boiler.

Several forms of plugs or devices, patented and otherwise, have been designed for stopping leaky tubes, some of which are of more or less complicated construction. These contrivances, however, which can be very advantageously and expeditiously applied, are more usually kept on hand on board steamships; engineers in charge of machinery upon sugar estates having as a rule to depend upon some more rough and ready method of accomplishing the object.

The simplest, and, at the same time, the most effective tool for expanding boiler tubes, consists in a set of interchangeable rollers mounted in a ring, in such a manner that they can be forced outwardly, by inserting a taper mandrel or rod into the central hole of the ring, and forcibly rotating it, whilst at the same time pressing it inwards, by means of a key or lever passed through an aperture provided in the head of the said mandrel.

The beading of the tubes is performed by means of a tool comprising a mandrel, which can be securely fixed in the tube to be beaded, and two or more beading rollers adapted to engage with the end of the said tube, and which can be rotated and gradually fed forward by means of a ratchet arrangement. Many different patterns of tube expanders and beaders

are manufactured, and also some very handy combination tools, by means of which the triple operation of expanding, beading, and cutting off, can be performed.

Amongst the advantages derived from the use of beaded boiler tubes may be enumerated the following :—The employment of ferrules is rendered unnecessary, thereby enabling the boiler to make steam better, the obstruction occasioned by the said ferrules, which reduces the internal diameter of the tubes, being got rid of. The tube ends are also strengthened, and there is less liability to leaky tubes; and in the event of any leak occurring, it is far easier to stop it. The bulging or drawing of the tube plates or sheets over the tubes, when externally beaded, is rendered impossible, and when internal beadings are employed, the collapsing or bulging inwards of the said plates or sheets is prevented; a combination of both these advantages being of course obtained by the use of tubes both externally and internally beaded, when every individual tube is made into a stay.

Burnt out fire-bars should be immediately renewed, and should not be kept in the furnace until the whole set is completely worn out. Care should also be taken to provide a sufficient space between the fire-bars for the passage of air, otherwise they will soon warp or twist, and for a like reason the bearers should not be fixed too close to the head plate. Revolving, shaking, and hollow water-cooled fire-bars are also in use. In the latter arrangement, the water circulated through the hollow fire-bars for cooling purposes is usually delivered to the hot well, and is used for feeding the boiler. The plan is objectionable, owing to the liability of accidents through bursting of the fire-bars.

It is sometimes required to make joints between pieces of lead or compo piping, or between these and other metals. These joints can of course be made in the usual manner with solder, either a blown or wiped joint, but preferably the latter being employed, on account of its capability of standing a higher pressure. To avoid the delay and the difficulty experienced in making wiped joints, when no experienced plumber is at 'hand, or when they have to be made in an awkward or inaccessible position, the device shown in Fig. 51 will be found useful.
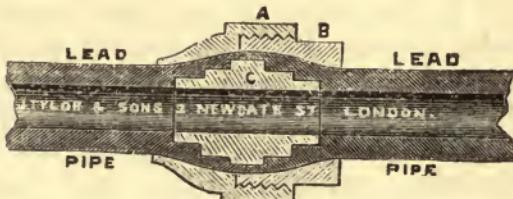
FIG. 51.

This patent joint, which is the invention of, and manufactured by J. Tylor and Sons, Limited, London, enables a sound, strong, and perfectly water-tight joint to be quickly made, wet, single-handed, without skilled labour, and without solder or fire. The coupling or union consists in a brass nut A, a socket or ring B, and a grooved sleeve, thimble, or intermediate piece C. In using the device, the nut A and socket or ring B are first passed over the extremities of the pipes to be united, and the latter spread by means of a turn-pin or tan-pin ; the piece C is then placed in position as shown and the nut A screwed upon the socket B. Diminishing linings are provided for rendering a single union suitable for various thicknesses of pipes, and the said unions are made in a number of forms adapted for a variety of different joints.

APPENDIX A.

Notes on Lubrication.

The sums of money annually expended on the purchase of various unguents for lubricating purposes are enormous, and the careful lubrication of the rubbing surfaces of machinery does much to promote its longevity. Friction is loss of power, and the real definition of friction has been conclusively proved to be want of lubrication. The question of lubrication is therefore one of the utmost importance to all users of machinery. Every day some so-called new lubricating compounds are placed before the consumer, most of which consist of old lubricants mixed with other components of less value, and disguised under some new and high-sounding name. It is most obviously necessary for his own protection that the consumer should be able to judge the real value of lubricants, and it is astonishing how little attention is given to this important subject by proprietors, who afford their unsparing personal supervision to other details connected with their businesses.

Lubrication is intended to diminish, as far as possible, the friction that takes place between rubbing surfaces, and thereby to prevent those surfaces from heating, and to reduce to a minimum the wear and tear of the parts. This friction is the result of one body rolling or sliding upon another body, the amount of friction thus engendered being governed by the pressure to which these bodies are subjected, conjointly with the nature of the surfaces that are in contact, but the greater or lesser extent of those surfaces being immaterial so far as the amount of the said friction is concerned. Heating of the rubbing surfaces of

machinery is produced by the interlocking of the unavoidable inequalities of these surfaces, as they pass over each other, and the constant vibration produced thereby. It is practically impossible to produce two bearing surfaces perfectly pure or true, and were this even not the case, such surfaces would be undesirable, as pressure would cause them to unite as one piece, which sometimes occurred when the thrust of a propeller shaft was received upon a block or piece of steel, and, the oil having worn off, the two surfaces scraped each other so as to mutually present pure metallic surfaces. The friction between two surfaces in rubbing contact can only be reduced by filling up the above-mentioned inequalities with lubricants, and thereby preventing, to a greater or lesser extent, the vibration caused by the violent interlocking of these inequalities. The aim of perfect lubrication should be to cause the journal to be completely oil-borne, and to approximate the friction as nearly as possible to that of liquids, or rather to that of solids upon liquids.

Two kinds of lubricants are employed, viz., liquid lubricants for reducing friction, and greases of a solid or semi-solid consistency for preventing the over-heating of the parts by melting and running into the bearing as soon as the temperature begins to rise. The latter are now, however, much used in special lubricators, by which they are forced into the bearing, for ordinary purposes of lubrication. Liquid lubricants comprise such fluids as water, and vegetable, animal, and mineral oils. Solid and semi-solid lubricants comprise greases, tallows, fresh lard, soap, palm oil, powdered plumbago, graphite, talc, etc., etc., and numerous artificial mixtures consisting of fats, resins, water, soda, and many other compounds.

The principal features to be looked for in a good lubricant are the following, viz. :—

It should reduce the friction to a minimum, be perfectly neutral, and uniform in composition.

It should be absolutely free from any inorganic matter or grit, and from any gumming properties or disagreeable smell.

It should not become altered by exposure to the air.

It should be capable of standing a high temperature (612 deg. Fahr.) without any loss or decomposition, and a low temperature (18deg. Fahr.) without solidifying or depositing solid matters. The latter quality, however, being of minor importance, as only obviating the inconvenience that might otherwise result, from the oil congealing in the lubricators and oil cans, or other vessels, in cold climates.

It should be entirely free from acids, which have a highly corrosive action on bearings, and on other parts of machinery, and it should not stain bright work, even when left upon it for a considerable time.

The adaptability of a lubricant to the requirements of light or heavy bearings is an important question. For bearings subjected to light pressures oils of a fluid nature are most suitable, whilst for bearings subject to heavy pressures lubricants of greater consistency are the best. Under certain conditions solid or semi-solid lubricants are to be preferred.

The vegetable oils used for lubrication are extracted chiefly from the colza or rape seed, the olive, and (castor oil) from the seeds of a species of palm. Vegetable oils mostly belong to that class which oxidise or dry to a greater or lesser degree on exposure to the air, but the drying tendency of the above is low if they are carefully

refined. Oxidation clogs the working parts and gives rise to danger from liability to spontaneous ignition. When pure, colza oil preserves its fluidity for a long time, and forms an excellent oil for lubrication. If adulterated, however, as is most frequently the case, with linseed oil, it turns in a few days, sometimes even in a few hours, into a viscous substance, which hinders far more than it assists the movement of the machinery it is employed to lubricate. Newly-expressed, or raw colza oil, contains a certain proportion of water and a kind of whitish mucus, and turns acid, attacking and corroding metallic surfaces; it must therefore be refined and not used in its natural condition ; care being taken that it is subsequently thoroughly cleansed or freed of the sulphuric acid employed in its purification. Olive oil is possessed of valuable qualities as a lubricant, by reason of the small quantities of free oleaginous acid, and slimy albuminous matter, which it contains, and its consequent less liability to clog, also on account of its moderate degree of cohesion, and the complete absence of mineral acids. For bearings subjected to a heavy pressure, and especially for those of new machinery, and in hot climates, castor oil is the most suitable.

The chief animal oils are neatsfoot and whale, both of which belong to the non-drying class. Other fish oils belong to the drying class. Unless eliminated by refinement, animal oils contain a large percentage of free or latent acid, and they are also liable to freeze too easily, which, as already mentioned, is objectionable in cold climates. A judicious mixture of vegetable, mineral, and animal oils forms a first-rate lubricating compound.

Mineral oils comprise the natural oils, and those obtained artificially by distillation from tar, boghead,

cannel coal, bituminous schist or asphalte, etc., etc. Hydro-carbons or mineral oils may be further divided into crude and refined. They are produced by the decomposition of vegetable matter by heat, etc., whilst animal and vegetable oils are the productions of vitality. Many of the mineral oils labour under the serious disadvantages of low boiling and firing points, excessive fluidity or want of body, and of emitting exceedingly disagreeable odours when used, particularly on heavy machinery. The chemical nature of mineral oils differs from that of animal and vegetable oils (though consisting, like them, for the most part, or completely, of carbon and hydrogen) inasmuch as they do not form an easily decomposable compound of acid and glycerine. The special advantages possessed by mineral oils and fats as lubricants are :—That they do not absorb oxygen, and consequently cannot produce spontaneous combustion when smeared on cotton waste; which advantage is, however, more or less negatived by their very low boiling and firing points. They are exceedingly stable, thus being very suitable for taking the place of other oils in cases where the latter would be liable to become decomposed, for instance, by the action of superheated steam. They do not become rancid, and therefore are non-corrosive. And lastly, they do not become gummy, but, on the contrary, act to dissolve the gummy matter that other oils gradually form, leaving, however, a small amount of hard residue.

The volatile nature of mineral oils is more or less irremediable, as is also their offensive smell, but their fluidity can be easily modified when desired. Notwithstanding their want of body, the greater proportion of mineral oils are physically similar to rape oil, the greater fluidity of the first being balanced by the lesser specific gravity of the

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second.   A drop of mineral oil rolls as fast as a
drop of rape oil, as, although smaller, it is heavier ;
for a similar reason they are both acted upon to an
equal degree by the capillary attraction of cotton
wick.   It is their fluid nature that renders mineral
oils preferable for the lubrication of extensive
surfaces, or where there is high velocity and
little pressure.   When the bearings are small and
work under heavy pressure, or where the speed
is very slow, an unguent possessing greater
cohesion is required, and the mineral fats such
as paraffin or napthaline may be employed, or,
what is better, a sufficient body or density can
be given to the mineral oils, by the admixture of
animal or vegetable oils or fats, rosin, rosin oil,
caustic lime, or oxide of lead.   Mineral oils mix
exceedingly well with other oils and with
melted fats, and the mixtures never exhibit the
slightest tendency to separate again.   The
greatest objection to the use of mineral oils is
that many of them contain a very large percentage
of spirit, and this, combined with the injurious
effect that they have on some metals, especially
upon iron, greatly reduces their value for purposes
of lubrication.   For ordinary use, mineral oils
should have a specific gravity of 90 at 60degs. Fahr.,
and not give off inflammable vapours under 350degs.
Fahr.

Oils for use in steam-engine cylinders and on
slide valves should not be liable to oxidise, and
should be absolutely free from the objectionable
quality of developing acids which corrode metals,
and of depositing in the cylinders, steam chests,
condensers, and boilers, deposits of a mucilaginous
substance, which interfere to no small extent with
efficient working.   Cylinder oils, moreover, are
subjected to high temperatures and must possess

much more body or consistency than oils only intended for the ordinary purposes of lubrication. Owing to their stability mineral oils are peculiarly suitable for this purpose, but they should be free from light oil or naptha (of which the flash-point is an indication), which is injurious to packings, especially of india-rubber, they should not have a boiling point below 600 degs. Fahr., give off smoke under 400 degs. Fahr., and their firing or flashing point should not be under 550 degs. Fahr.; they should have at least an equal body to castor oil, or five or six times that of colza oil. A mixture of lard oil 2 parts; good quality mineral oil 3 parts; and finely powdered graphite $\frac{1}{8}$ part forms a good cylinder lubricant.

Tallows consist of animal fats, which are separated from the membranous matter by fusion. They are composed of stearine with a small admixture of oleine, and are, as already mentioned, chiefly used as an additional safeguard against the heating of bearings, and all extra heavy ones should be fitted with an additional cup or lubricator to hold tallow.

The fluidity of oils can be readily determined by means of a glass tube about four inches long and $\frac{5}{8}$ of an inch in diameter. drawn or tapered at one extremity so as to reduce the orifice to a $\frac{1}{16}$ of an inch. The oils to be tested having been brought to an uniform temperature, the tube is filled up with each in succession, and the time which they take to run out at the small aperture and to empty the tube is noted.

The following table gives the results of a series of experiments made by Mr. Grothe, which may be taken as standards of comparison for the liquids mentioned :—

Liquid.	Temperature.	Time taken to run through aperture in tube.
Water	60° Fahr.	9 seconds
Linseed oil ...	,, ,,	88 ,,
Colza oil ...	,, ,,	142 ,,
Olive oil ...	,, ,,	195 ,,

By this it will be seen that olive oil is more than twice as viscous as linseed oil.

To ascertain during what length of time a given oil will continue in a fit state for lubricating purposes a simple apparatus designed by Mr. Nasmyth may be employed. It consists in a plate of iron 6½ ft. long by 4 inches in breadth, on the surface of which a number of parallel longitudinal grooves are cut by a planing machine, which plate is placed upon a table or other support in an inclined position, one end being raised from 8 to 10 inches higher than the other. Small portions of equal weight of the different oils are poured into the upper ends of the groves, and after an interval of several days the distance traversed by each oil down its particular groove is noted, as also the length of time that elapses before each oil becomes thickened by oxidation and ceases to flow.

In the absence of the above-mentioned apparatus, a sheet of plate glass two or three feet in length may be employed, upon which are placed single drops of the oil to be experimented with.

Neatsfoot oil is found to alter but slightly by exposure to the air, and to preserve its fluidity for a very long time, only exceeded, indeed, by certain purified olive oils and fish oils of American manufacture especially intended for clock work.

Sperm oil will be found upon the first day to fall to the rear, but eventually will overtake the others. If

an oil has a light body, it will run quickly, and also dry quickly. It is possible for an oil to have a good body, and still to have a very strong tendency to gum ; whether or not an oil is possessed of both a good body and a free flow will be readily detected by the above test.

When carrying out these experiments care should be taken to keep the oils covered, and perfectly free from dust.

The adulteration of lubricating oils, with fats and oils of lower prices, is practised to a great extent, paraffin oils and oils obtained in coal distilling, being the most generally employed for that purpose. These are usually betrayed by the alteration in colour of the oils and by their odour. Sometimes, however, a finer quality of coal oil coming from Scotland, which is free from the peculiar odour, taste, and colour of ordinary coal oil, and which has a specific gravity equal to colza oil, is employed. To detect adulteration by the addition of this coal oil saponification must be resorted to, and the soap extracted with ether, any coal oil contained in the mixture going into solution, and being easily separated by distillation.

The following tests for detecting the adulterations to which oils are the most frequently subjected are given by Mr. R. S. Christiani : " Tallows are adulterated with water, which is incorporated in them by a process of beating or churning, cooked and mashed potatoes, fecula, kaolin, white marble, sulphate of baryta, etc. The principal adulteration, however, is by the addition of bone tallow, or other grease of an inferior quality, which is not so much a falsification, as a change in the quality of the pro- duct. The presence of mineral matters, fecula, and cooked potatoes is easily ascertained by dis- solving the tallow in ether, or sulphide of carbon,

when all the foreign substances remaining insoluble their nature can be easily determined. Iodine water or alcoholic tincture of iodine will colour the residuum blue if it contains fecula or starch, or its presence can be determined in the tallow by trituring it with iodine water and adding a few drops of sulphuric acid, when a blue shade will instantly appear. To detect the admixture of mineral substances melt the tallow in twice its weight of either plain or acidulated water, when the foreign substances will be precipitated, and the grease will float on the surface. The cooling should be carried out slowly, to give time to the impurities to separate and deposit, and the addition of iodine will disclose the presence of fecula or starch. To detect the presence of water, knead a determined weight of the tallow with half its volume of dried powdered sulphate of copper, and if much water be present the mixture will turn a blue colour if the tallow be white, and green if it be yellow. To determine the exact quantity of water added, a sample must be dried in an oven.

" Linseed oil is falsified with hemp-seed oil, and more frequently with fish oils. Pure linseed oil treated with hyponitric acid becomes pale pink, with ammonia dark yellow, giving a thick and homogeneous soap.

" Olive oil is ordinarily adulterated with cole-seed oil, cotton-seed oil, and poppy oil, and is sometimes coloured green by means of indigo as a disguise, and to create the impression that green olive oil is present. Black poppy oil is a very favourite adulteration both on account of the cheapness of the oil and by reason of its having a sweet taste, and very little odour.

" Castor oil is also frequently adulterated with black poppy oil, which can be easily detected by

dissolving a sample of the suspected oil in alcohol, when the foreign substance will remain as a residuum.

" Neatsfoot oil is commonly falsified by a mixture of whale or black poppy oil, or olein, and is perhaps the most adulterated oil found in commerce.

" Lard, when exposed to the air in imperfectly closed jars, becomes rancid and turns yellow. If kept in copper vessels, or in earthenware jars glazed with sulphide of lead, it will by contact with the air attack the copper or the glazing, and will then contain stearic or oleic of copper or lead. The copper can be detected by pouring a few drops of ammonia on the grease, which immediately turns blue. A red colouration is given by a solution of yellow prussiate of potash. Lead can be detected by burning the lard, and carefully examining the residuum to see if there are any metallic globules, the residuum being treated with nitric acid which dissolves the metal, filtered, and sulphuric acid added which gives a white precipitate. Lard also contains an excess of water, to ascertain which it should be pressed and softened with a wooden spatula, when the water will ooze out from it in the form of drops, or it may be determined by melting it at a low temperature when the water will separate from the grease.

" The principal adulterations of lard are the addition of common salt, the admixture of greases of an inferior quality, or that of a kind of grease obtained by the cooking of pork meat, and plaster of Paris is also sometimes added. The addition of salt can be easily detected by digesting the lard with hot distilled water, and precipitating the salt by adding nitrate of silver, which precipitate will be white, soluble in ammonia and insoluble in nitric acid, it becomes black when exposed to the light.

Plaster of Paris can be detected by melting the lard in warm water, when the plaster will fall to the bottom in the form of a white powder. The addition to the lard of inferior greases is difficult of detection, but their presence may be implied by the lard being less white in colour, and by the difference in taste; the grease obtained from the cooking of pork meat causes the lard to assume a greyish colour and a soft consistency, and imparts to it a distinct, salty, and disagreeable flavour.

"Rape-seed oil is falsified with linseed, mustard, and whale oils, oleic acid, etc. The pure oil treated with ammonia gives a milk-white soap, but when mustard and whale oils are present it is of a yellowish colour. Gaseous chlorine colours rape-seed oil brown when it contains whale oil, but if pure it remains perfectly colourless.

"Palm oil has frequently mixed with it, or it is manufactured entirely from yellow wax, lard, or mutton suet, coloured with turmeric and aromatised with powdered orris-root. By treating with ether, all the fatty bodies are dissolved, the turmeric and orris-root remaining insoluble, and by saponification the mixed or artificial oil takes a reddish shade, due to the action of the alkali on turmeric. In some instances it is falsified by the addition of powdered resin, this can be detected by treating the oil with alcohol, when the resin will be dissolved whilst the oil remains insoluble.

"Cocoa-nut oil is very commonly adulterated with mutton suet, beef marrow, or other animal greases, sometimes also with the oil of sweet almonds and wax. The oil falsified by these substances does not dissolve completely in cold ether, the ethereal solution being muddy like that given by pure butter; it has also an unpleasant taste and odour and is of a more greyish colour than the pure oil."

The purity of different oils can be approximately ascertained by taking their specific gravity by means of Hutchinson's thermo-hydrometer and comparing them with the known specific gravities of standard samples, when if any wide divergence be found to exist the oil may be safely set down as impure.

The following are some of the lubricating compounds that are in use :—

Heavy paraffin oil.—Which is a distillate of petroleum, the light and offensive oils having been driven off, and the remaining nearly odourless neutral heavy oil mixed with good lard oil.

For high speed machinery.—Soapstone ground to an impalpable powder, and mixed with oil or grease in the proportion of from 30 per cent. for light bearings, to about 50 per cent. for heavy bearings.

Railway carriage axle grease.—Black-lead 1lb., tallow 4lbs., beeswax 1lb., well mixed together, and ground perfectly smooth.

Booth's lubricating composition.—Scotch soda 1lb., boiling water 2galls., palm oil or tallow 10lbs., heated together to a temperature of from 200 to 210 degrees Fahr. mixed and kept well stirred until cooled to about 65 degrees Fahr. A thinner composition—Soda ½lb., water 1gall., rape-oil 1gall., and tallow or palm oil 1gal.

Mankettrick's composition.—Caoutchouc dissolved in oil of turpentine 4lbs., scotch soda 10lbs., glue 1lb., dissolved in 10galls. of water, oil 10galls. The soda and glue are dissolved by heat in the water, the oil being then added, and lastly the caoutchouc, stirring until thoroughly incorporated.

Moride and Joute's fish oil.—The fish are treated with 5 per cent. of their weight of a solution of perchloride or persulphate of iron at 45 degrees Beaumé and the mass ground to a pulp, which is

put into bags and pressed, the small quantity of oil remaining being extracted by means of a dissolvent such as the light oils of petroleum.

Chard's preparation for heavy bearings.—Petroleum (gravity 25 degrees) 12ozs., caoutchouc 2ozs., sulphur 2ozs., plumbago 4ozs., beeswax 4ozs., salsoda 2ozs., stirred and heated to 140 degrees Fahr. for about half an hour.

Munger's preparation.—Petroleum 1gall., tallow 4ozs., palm oil 4ozs., plumbago 6ozs., soda 1oz., well mixed and kept at a temperature of 180 degrees Fahr., for an hour or two, and after cooling for 24 hours again stirred.

Maguire's hot neck grease.—Tallow 16 lbs., fish 60lbs., soapstone 12lbs., plumbago 9lbs., saltpetre 2lbs., the fish to be steamed and macerated, and the jelly thus formed pressed through fine sieves before mixture with the other constituents.

Johnson's composition—Petroleum (30 to 37 degs. of gravity) 1gall., crude paraffin 1oz., wax (myrtle, Japan, and gambier) $1\frac{1}{2}$oz., bicarbonate of soda 1oz., powdered graphite 3ozs. to 5ozs.

Hendrick's composition.—Whale oil, white-lead, and petroleum, the white-lead and oil are mixed together and heated gradually to between 350 and 400degrees Fahr., after which they are mixed with a quantity of petroleum sufficient to reduce the mixture to the required consistency.

Fraser's axle grease—Resin oil partially saponified, that is to say, a resin soap, and a resin oil. To prepare it $\frac{1}{2}$gall. of No. 1 resin oil and $2\frac{1}{2}$galls. of No. 4 resin oil should be saponified, with a solution of $\frac{1}{2}$lb. of sal soda, dissolved in 3pints of water, and 10lbs. of sifted lime. After standing for six hours or more, draw off, leaving behind the sediment and then thoroughly mix with 1gall. of No. 1, $3\frac{1}{2}$galls. of No. 2, and $4\frac{2}{3}$galls. of No. 3 resin oil.

Pitt's car, mill, and axle grease—Black oil or petroleum residuum 40galls., animal grease 50lbs., powered resin 60lbs., soda lye 2½galls., salt dissolved in a small proportion of water 5lbs., with the exception of the soda lye all mixed together and heated to about 250degs. Fahr., after which the lye is gradually stirred in, and at the expiration of about 24 hours the compound is ready for use.

Black anti-friction grease—Black-lead ground very fine 1 part, lard 4 parts.

Common railway axle grease—Dissolve in a small boiler about 60lbs. of soda in 3galls. of water, and in another boiler 2cwts. of tallow, to which when melted add 1½cwt. of palm oil; after boiling let the mixture cool gradually to blood heat, stirring meanwhile, then strain through a sieve into the soda solution, stirring continually during the operation.

Various other railway axle greases—(1) Tallow 4½cwts., palm oil 2½cwts., sperm oil 27lbs., crystallised soda 1cwt. 8lbs., water 12cwts., 26lbs. The fats are first melted and heated in one vessel to about 180degs. Fahr., and the water and the crystallised soda in another to 200degs. Fahr., both the fluids are then run into a wooden butt, and kept well stirred until cold. The slower the cooling process the harder will be the produce, it is, therefore, advisable to make a considerable quantity at a time. The above proportions are for summer use; when the grease is intended for winter use, ¾cwt. less tallow, 8lbs. more sperm oil, 6lbs. more soda, and 10lbs. more water are required. (2) Fine black-lead ground to an impalpable powder 1 part, lard 4 parts, with or without the addition of a small quantity of camphor. (3) Three parts of asphalte to two parts of rape oil, or of rape oil and wood tar.

(4) Refined rape oil with about 3 per cent. of litharge rubbed up in it, with the addition of a little water, and the whole warmed in a water bath. The free oleic acid combines with the lead oxide, and all deleterious action on metal is prevented.

For railway purposes the best axle greases should contain at least 35 per cent. of a mixture of tallow and palm oil. The addition of the tallow slightly increases the cost, but very much improves the quality; a grease containing 35 per cent. of mixed fats will go as far as one containing 45 per cent. of palm oil only. The economy of good grease is obvious, an axle box full lasting for some thousands of miles, whilst an inferior kind would be used up in a few hundred. A grease containing too much tallow by itself is too hard.

American anti-friction grease—Hog's lard, gutta-percha, and black-lead powdered very fine.

Common heavy machine and engine oil—Petroleum 35 per cent., crude paraffin oil 15 per cent., lard oil 20 per cent., palm oil 10 per cent., cotton seed oil 20 per cent. Also many other mixtures of paraffin or heavy petroleum oils, lard oils, whale or fish oils, and cotton seed and resin oils.

Liard (French compound)—Rape oil 1gall., caoutchouc cut up small 3ozs., dissolved by heat.

The following are a few of the compounds that have been patented :—

Bayberry wax and graphite.

Pine tar, turpentine, camphor, and alcohol.

Animal oil, croton oil, spermaceti, tallow, beeswax, soda, and Glauber's salts.

Spermaceti and india-rubber.

Sulphur and petroleum.

Resin, flowers of sulphur, antimony, oil of rosemary, lampblack, water, carbonate of soda, and sheep's tallow.

Mercury, bismuth, tin, and antimony.

Animal oil, palm oil, and paraffin.

Lime, chalk and carbonate of potash.

Soapstone, petroleum, sulphur, antimony, and oil.

Animal oil, croton oil, spermaceti, tallow, soda, potash, glycerine, and ammonia.

Caustic soda, tallow, petroleum, and animal hair.

Tallow, sulphur, and soapstone.

Petroleum, tallow, beeswax, soda, and Glauber's salts.

Asbestos and graphite.

Palm oil, tallow, borax, salt, and water.

Lampblack and petroleum.

Coal oil, isinglass, Irish moss, and glue.

Oil, lime, graphite, castor oil.

Petroleum residuum, salt, caustic potash, sal ammoniac, spirit of turpentine, linseed oil, and sulphur.

Graphite, oil, caoutchouc.

Ivory dust and spermaceti.

Petroleum residuum, alkali, ammonia, and salt-petre.

Plastic bronze and caoutchouc.

Asbestos and grease.

Shorts, soapstone, and castor oil.

Petroleum residuum and flour.

Lignum vitæ and spermaceti.

Tin and petroleum.

Tallow, palm oil, salts of tartar, and boiling water.

Zinc and caoutchouc.

Saponified resin, wheat flour, petroleum, animal fat, and soda.

Mercury, bismuth, and antimony.

Sulphur, plumbago, mica, tallow, and oil.

Flax seed oil, cotton seed oil, tallow, and lime water.

Sheets of paper, or woven fabrics, impregnated with graphite, steatite, paraffin, tallow, size, and soluble gums.

Petroleum residuum, lard, sulphur, and soapstone.

Tallow, oil, paraffin, and lime water.

Type metal and caoutchouc.

Mixed heavy and light petroleum.

Paraffin oil and milk of lime.

Oil, wax, caoutchouc, resin, and potash.

Asbestos and tallow.

Petroleum residuum, sal soda, sulphur, and kerosene.

Soapstone, magnesia, lime, and oil.

Tallow, petroleum, soda, and hair.

Palm oil, paraffin, tallow, alkali, and asbestos.

Anthracite coal and tallow.

Glycerine, graphite, asbestos, kaolin, manganese, soapstone, sulphide of lead, carbonate of lead, and cork.

Tin oxide and beeswax.

Vulcanised caoutchouc, petroleum, and tallow.

Petroleum, sal soda, lime, tallow, lard, salt.

Paraffin, resin, and cotton waste.

Petroleum, plumbago, beeswax, mutton tallow, and soda.

Leather boiled in carbonate of soda, oil, and sulphuric acid.

Water, salts of nitre, sulphur, soft soap, and salt pork.

Borax and oil.

Boiling water, tallow, palm oil, and salts of tartar.

Shorts, soapstone, and graphite.

Oil, wax, resin, india-rubber and potash.

Coal oil residuum, chloride of sodium, hydrated potassa, muriate of ammonia, spirits of turpentine, linseed oil, and flowers of sulphur.

Crude petroleum, sal soda, lime, tallow, lard, salt, pine-tar, spirits of turpentine, camphor, and alcohol.

SPECIFIC GRAVITIES OF VEGETABLE OILS USED AS LUBRICANTS.

Oil.	Specific gravity.	Quality.
Castor	0·9611	Drying
Colza	0·9136	Greasy
Cocoa nut	0·9202	Greasy
Cotton seed	0·9252	Drying
Cocoa-nut butter... ...	0·8920	Greasy
Flax	3·9347	Drying
Grape seed	0·9202	Drying
Hemp	0·9276	Drying
Linseed	0·9347	Drying
Nut	0·9260	Drying
Olive	0·9176	Greasy
Palm	0·968	Greasy
Piney tallow	0·926	Greasy
Rosin	0·990	Drying
Rape	0·9136	Greasy
Sunflower	0·9262	Drying
Turpentine	0·864	Drying

SPECIFIC GRAVITIES OF ANIMAL OILS USED AS LUBRICANTS.

Oil.	Specific gravity.	Quality.
Cod liver	0·917 to 0·920	Greasy
Lard	0·938	Greasy
Neat's foot	0·925	Greasy
Sperm...	0·881	Greasy
Sun-fish	0·874 to 0·879	Drying
Whale...	0·911 to 0·922	Greasy

SPECIFIC GRAVITIES OF MINERAL OILS USED AS LUBRICANTS.

Oil.	Specific gravity.	Quality.
Petroleum	0·88	Greasy
Paraffine, volatile ...	0·700 to 0·865	
Paraffine, heavy ...	0·865 to 0·900	
Paraffine, solid... ...	0·900 to 0·930	
Tar	1·260	Drying

APPENDIX B.

Useful Tables and Memoranda.

TABLE OF POWER REQUIRED TO RAISE WATER
FROM DEEP WELLS.—*Appleby.*

Gallons of water raised per hour	200	350	500	650	800	1,000
Height of lift for 1 man working on crank, in feet	90	52	36	28	22	18
Height of lift for 1 donkey working on gin, in feet...	180	102	72	56	45	36
Height of lift for 1 horse working on gin, in feet	630	357	252	196	154	126
Height of lift for 1 horse-power steam engine, in feet	990	561	396	308	242	198

This table is based on the assumption that a good class of treble or double barrel pump is used, with an additional retaining valve for lifts above 100 feet.

Formula to find horse-power of pumping engines (Appleby):

G, equals the number of gallons required per hour.

C, equals the number of cubic feet required per hour.

F, equals the height in feet to which the water is to be raised.

X, equals horse-power.

Then x equals $\frac{G \times F}{198000}$ or x equals $\frac{C \times F}{31750}$

Add 70 per cent. to the number obtained by the above formula to allow for friction, leakage, etc. The result obtained is not nominal but actual horse-power (33,000 foot lbs.).

Contents of Cisterns, etc.—*Hutton.*

To find the number of gallons contained in a cistern. Multiply the length, width, and depth together all in feet. This will give the contents in cubic feet, which multiply by 6·24, and the product will be the number of gallons. If the dimensions are in inches use ·003607 in place of 6·24.

Two dimensions of a cistern being given to find the third, to contain a given number of gallons, multiply the required number of gallons by ·16046 if the dimensions are in feet, or by 277·274 if the dimensions are in inches, and divide the result by the product of the two given dimensions. The quotient will be the third dimension required.

To find the number of gallons contained in a cylinder, multiply the square of the diameter in feet by the length in feet of the cylinder, and multiply the product by 4·895; or multiply the square of the diameter in inches by the length in feet, and multiply the product by ·034; or multiply the square of the diameter in inches by the length in inches, and multiply the product by ·00283.

The diameter of a cylinder being given, to find the length, multiply the number of gallons by ·2043, and divide the product by the square of the diameter in feet, and the quotient will be the length in feet.

The length of a cylinder being given, to find the diameter, multiply the number of gallons by ·2043, and divide the product by length in feet, and the square root of the quotient will be the diameter in feet. If the dimensions are in inches, use 353 in place of ·2043.

Weight and Capacity of Water.—*Hutton.*

A cubic inch of water equals ·0361lb.
A cubic foot of water equals 62·42lbs.

A cubic foot of water equals ·557cwt.

A cubic foot of water equals ·028 ton.

A cubic foot of water equals 6·24galls.

1 cwt. of water equals 1·8 cubic feet.

1 cwt. of water equals 11·2 galls.

1 ton of water equals 35·9 cubic feet.

1 ton of water equals 224 galls.

1 lb. of water equals 27·7 cubic inches.

1 lb. of water equals 0·16 cubic feet.

1 cylindrical inch of water equals ·0284lb.

1 cylindrical foot of water equals 49·10lbs.

1 gallon of water equals 10lbs.

11·2 gallons of water equals 112lbs.

224 galls. of water equals 2,240lbs.

1·8 cubic feet of water equals 112lbs.

35·84 cubic feet of water equals 2,240lbs.

277·274 cubic inches equal 1gall.

353 cylindrical inches equal 1gall.

Cubic inches multiplied by ·0036 equal gallons.

Cubic feet multiplied by 6·24 equal gallons.

Cubic inches divided by 277·274 equal gallons.

Gallons mutiplied by ·16045 equal cubic ft.

Cylindrical ft. multiplied by 4·895 equal gallons.

A column of water 1 in. diameter and 12ins. high equals ·341lb.

A column of water 1in. square and 12ins. high equals ·434lb.

The capacity of a cylinder 1in. diameter and 12 ins. long equals ·034 gall.

The capacity of a cylinder 12ins. diameter and 12 ins. long equals 4·895 galls.

The capacity of a cylinder 1in. diameter and 1in. long equals ·00283 gall.

The capacity of a 1in. cube equals ·0036gall.

The capacity of a 12in. cube equals 6·24galls.

The capacity of a sphere 1in. diameter equals ·00188gall.

The capacity of a sphere 12ins. diameter equals 3·26 galls.

The cube of the diameter of a sphere in feet multiplied by 3·26 equals gallons.

Or the cube of the diameter of a sphere in inches multiplied by ·00188 equals gallons.

A column of water produces approximately a pressure of half a pound per square inch for every foot in height.

Pressure of water.—The side of any vessel containing water sustains a pressure equal to the area of the side in feet multiplied by half the depth in feet, that product multiplied by 62·5 will give the pressure in pounds on each side of the vessel.

The pressure in pounds on the bottom of a vessel is equal to the area of the bottom in feet multiplied by the depth of water in feet, that product multiplied by 62·5 will give the pressure in pounds.

Speed of pumps.—The greatest speed at which water will flow through a suction pipe, is 500 feet per minute; but, in practice, water should not flow through a suction-pipe at a greater speed than 200 feet per minute, to ensure the pump barrel being properly filled at each stroke, that is 200 feet of the suction-pipe should hold as much water as the pump will deliver per minute, and the pump should work at such a speed that it will deliver per minute the quantity of water contained in 200 feet of its suction-pipe.

Table showing the quantity of water discharged per minute by single, double, and treble barrel pumps at various speeds, exclusive of slip.—*Hutton.*

Diameter of pump.	Length of stroke.	Single barrel.		Double barrel.		Treble barrel.	
		30 strokes per min.	40 strokes per min.	30 strokes per min.	40 strokes per min.	30 strokes per min.	40 strokes per min.
Inches.	Inches.	Galls.	Galls.	Galls.	Galls.	Galls.	Galls.
1½	9	1¾	2¼	3½	4½	4½	6¾
2	9	3	4	6	8	9	12
2½	9	4¾	6¼	9½	12	14	19
3	9	6¾	9	13¾	18	20	27
3½	9	9¼	12½	18½	25	28	37
4	9	12¼	16	24½	32	36	48
4½	9	15½	20¾	32	42	46	62
5	9	19	25½	38	50	57	76
5½	9	23¼	32	46¼	62	69	92
6	9	27½	37	55	73	82	110
2	10	3½	4½	6	9	10	13
2¼	10	5¼	7	10	14	15	22
3	10	7½	10	15	20	22	30
3½	10	10½	13¾	20	27	32	42
4	10	13½	18	27	36	40	54
4½	10	17	23	34	45	52	68
5	10	22	28	42	56	63	84
5½	10	25½	34	51	68	77	102
6	10	30½	40	62	82	92	122
2	12	4	5	8	10	12	16
2½	12	6¼	8	12	17	19	25
3	12	9	12	18	24	27	36
3¼	12	12½	16	24	33	37	50
4	12	16¼	22	32	43	49	65
4½	12	20½	27	42	55	62	82
5	12	25¼	33	50	68	76	100
5¼	12	30¾	42	62	82	92	123
6	12	36½	49	73	97	110	146
6½	12	43	57	86	114	129	172
7	12	50	66	100	134	149	199
7½	12	57	76	114	152	171	229
8	12	65	87	130	174	195	262
9	12	82	110	165	220	246	330
10	12	102	134	202	268	303	404
12	12	146	195	294	390	440	588

LIFT OF PUMP VALVES OR CLACKS.

If the valve be raised to the proper height, the area of a cylinder, of the same diameter as the valve and length as the lift thereof, should be equal to the area of the said valve. Therefore if x=diameter of valve and y = lift of valve, the area of cylinder will=$x \times 3{\cdot}1416 \times y$, and the area of valve will=$x^2 \times {\cdot}7854$, thus $x \times 3{\cdot}1416 \times y = x^2 \times {\cdot}7854$, and $x = y^2 \times {\cdot}7854 = y$. From this has arisen the well-known rule that the lift of a pump valve should equal one quarter the diameter of the sate-valve, and by increasing the lift beyond this nod thing is gained.

POWER REQUIRED TO DRIVE CENTRIFUGAL

PUMPS.—*Hutton, &c.*

Diameter of suction and delivery pipes, in inches.	Quantity of water delivered per minute, in gallons.	Horse-power required for every foot in height the water is raised.
1	16	·01
2	50	·02
3	100	·05
4	200	·08
5	300	·16
6	£00	·25
7	700	·35
8	800	·40
9	1,000	·50
10	1,500	·75
11	1,800	1·
12	2,000	1·01
13	2,300	1·08
14	2,500	1·20
15	3,000	1·31
16	3,500	1·60
17	3,800	1·75
18	4,200	2·

HYDRAULIC RAMS PROPORTIONS OF THE SUPPLY PIPES AND DELIVERY PIPES TO THE NUMBER OF GALLONS.—*Hutton.*

Number of gallons to be raised in 24 hours	500	1,000	2,500	4,000	6,000
Diameter of fall or supply pipe, in inches	1½	2	2½	3	4
Diameter of rising main or delivery pipe, in inches ...	¾	1	1½	2	2

EFFICIENCY OF HYDRAULIC RAMS.—*Hutton.*

Number of times the height to which the water is to be raised contains the fall	4	5	6	7	8	9	10	11	12	13	14	15	16	18	19	20	25	
Efficiency per cent.	75	72	68	62	57	53	48	43	38	35	32	28	23	17	15	12	0	

USEFUL INFORMATION.

(WORTHINGTON PUMPING ENGINE COMPANY.)

One Imperial Gall.	= 277·274	Cubic Inches
,, ,,	·16	Cubic Foot
,, ,,	10·00	Lbs.
,, ,,	1·2	U.S. Gallons
,, ,,	4·537	Litres

One U.S. Gall.	231	Cubic Inches
,, ,,	·133	Cubic Foot
,, ,,	8·33	Lbs.
,, ,,	·83	Imperial Gallon
,, ,,	3·8	Litres
One Cub. In. of Water	·03607	Lb.
,, ,,	·003607	Imperial Gallon
,, ,,	·004329	U.S. Gallon
One Cub. Ft. of Water	6·23	Imperial Gallons
,, ,,	7·48	U.S. Gallons
,, ,,	28·375	Litres
,, ,,	·0283	Cubic Metre
,, ,,	62·35	Lbs.
,, ,,	·557	Cwt.
,, ,,	·028	Ton
One Lb. of Water	·10	Imperial Gallon
,, ,,	·083	U.S. Gallon
,, ,,	·4537	Kilo.
One Cwt. of Water	13·44	U.S. Gallons
One Ton of Water	268·8	U.S. Gallons
,, ,,	1,000	Litres (Approximately)
,, ,,	1	Cubic Metre (Approx.)
One Litre of Water	·22	Imperial Gallon
,, ,,	·264	U.S. Gallon
,, ,,	61	Cubic Inches
,, ,,	·0353	Cubic Foot
One Cubic Metre of Water	220	Imperial Gallons
,, ,,	264	U.S. Gallons
,, ,,	1·308	Cubic Yards
,, ,,	61,028	Cubic Inches
,, ,,	35·31	Cubic Feet
,, ,,	1,000	Kilos.
,, ,,	1	Ton (Approximately)
,, ,,	1,000	Litres
One Kilo of Water	2·204	Lbs.
One Atmosphere	1·054	Kilos. per square inch
A pressure of 1 lb. per square inch		Column of water 2·31 ft. high
One Imperial Gallon Crude Petroleum	8·2	Lbs. (Approximately)
One U.S. Gallon Crude Petroleum	6·5	Lbs. (Approximately)
One Ton Petroleum	275	Imperial Gallons (Approx.)
,, ,,	360	U.S. Gallons (Aprox.)

PRESSURE OF WATER.

(Worthington Pumping Engine Company.)

The pressure of water in pounds per square inch for every foot in height to 270 ft. By this Table, from the pounds pressure per square inch the feet head is readily obtained, and *vice versâ*.

Feet Head.	Pressure per square inch.	Feet Head.	Pressure per square inch.	Feet Head.	Pressure per square inch.	Feet Head.	Pressure per square inch.	Feet Head.	Pressure per square inch.	Feet Head.	Pressure per square inch.
1	0.43	46	19.92	91	39.42	136	58.91	181	78.40	226	97.90
2	0.86	47	20.35	92	39.85	137	59.34	182	78.84	227	98.33
3	1.30	48	20.79	93	40.28	138	59.77	183	79.27	228	98.76
4	1.73	49	21.22	94	40.72	139	60.21	184	79.70	229	99.20
5	2.16	50	21.65	95	41.15	140	60.64	185	80.14	230	99.63
6	2.59	51	22.09	96	41.58	141	61.07	186	80.57	231	100.06
7	3.03	52	22.52	97	42.01	142	61.51	187	81.00	232	100.49
8	3.46	53	22.95	98	42.45	143	61.94	188	81.43	233	100.93
9	3.89	54	23.39	99	42.83	144	62.37	189	81.87	234	101.36
10	4.33	55	23.82	100	43.31	145	62.81	190	82.30	235	101.79
11	4.76	56	24.26	101	43.75	146	63.24	191	82.73	236	102.23
12	5.20	57	24.69	102	44.18	147	63.67	192	83.17	237	102.66
13	5.63	58	25.12	103	44.61	148	64.10	193	83.60	238	103.09
14	6.06	59	25.55	104	45.05	149	64.54	194	84.03	239	103.53
15	6.49	60	25.99	105	45.48	150	64.97	195	84.47	240	103.96
16	6.93	61	26.42	106	45.91	151	65.49	196	84.90	241	104.39
17	7.36	62	26.85	107	46.34	152	65.84	197	85.33	242	104.83
18	7.79	63	27.29	108	46.78	153	66.27	198	85.76	243	105.26
19	8.22	64	27.72	109	47.21	154	66.70	199	86.20	244	105.69
20	8.66	65	28.15	110	47.64	155	67.14	200	86.63	245	106.13
21	9.09	66	28.58	111	48.08	156	67.57	201	87.07	246	106.56
22	9.53	67	29.02	112	48.51	157	68.00	202	87.50	247	106.99
23	9.96	68	29.45	113	48.94	158	68.43	203	87.93	248	107.43
24	10.39	69	29.88	114	49.38	159	68.87	204	88.36	249	107.86
25	10.82	70	30.32	115	49.81	160	69.31	205	88.80	250	108.29
26	11.26	71	30.75	116	50.24	161	69.74	206	89.23	251	108.73
27	11.69	72	31.18	117	50.68	162	70.17	207	89.66	252	109.16
28	12.12	73	31.62	118	51.11	163	70.61	208	90.10	253	109.59
29	12.55	74	32.05	119	51.54	164	71.04	209	90.53	254	110.03
30	12.99	75	32.48	120	51.98	165	71.47	210	90.96	255	110.46
31	13.42	76	32.92	121	52.41	166	71.91	211	91.39	256	110.89
32	13.86	77	33.35	122	52.84	167	72.34	212	91.83	257	111.32
33	14.29	78	33.78	123	53.28	168	72.77	213	92.26	258	111.76
34	14.72	79	34.21	124	53.71	169	73.20	214	92.69	259	112.19
35	15.16	80	34.65	125	54.15	170	73.64	215	93.13	260	112.62
36	15.59	81	35.08	126	54.58	171	74.07	216	93.56	261	113.06
37	16.02	82	35.52	127	55.01	172	74.50	217	93.99	262	113.49
38	16.45	83	35.95	128	55.44	173	74.94	218	94.43	263	113.92
39	16.89	84	36.39	129	55.88	174	75.37	219	94.86	264	114.36
40	17.32	85	36.82	130	56.31	175	75.80	220	95.30	265	114.79
41	17.75	86	37.25	131	56.74	176	76.23	221	95.73	266	115.22
42	18.19	87	37.68	132	57.18	177	76.67	222	96.16	267	115.66
43	18.62	88	38.12	133	57.61	178	77.10	223	96.60	268	116.09
44	19.05	89	38.55	134	58.04	179	77.53	224	97.03	269	116.52
45	19.49	90	39.98	135	58.48	180	77.97	225	97.46	270	116.96

DIAMETERS, AREAS, AND DISPLACEMENTS.

(WORTHINGTON PUMPING ENGINE COMPANY.)

Dia-meter.	Area.	Displacement in Imperial Gallons per foot of Travel.	Dia-meter	Area	Displacement in Imperial Gallons per foot of Travel.	Dia-meter	Area	Displacement in Imperial Gallons per foot of Travel.
⅛	.0122	.0005	7¼	41.28	1.783	18¼	261.5	11.297
¼	.0490	.0021	7½	44.17	1.908	18½	268.8	11.612
⅜	.1104	.0047	7¾	47.17	2.037	18¾	276.1	11.927
½	.1963	.0084	8	50.26	2.171	19	283.5	12.247
⅝	.3068	.0132	8¼	53.45	2.309	19¼	291.0	12.571
¾	.4417	.0190	8½	56.74	2.451	19½	298.6	12.900
⅞	.6013	.0259	8¾	60.13	2.597	19¾	306.3	13.232
1	.7854	.0339	9	63.61	2.747	20	314.1	13.569
1⅛	.9940	.0429	9¼	67.20	2.903	20½	330.0	14.256
1¼	1.227	.0530	9½	70.88	3.062	21	346.3	14.960
1⅜	1.484	.0641	9¾	74.66	3.225	21½	363.0	15.681
1½	1.767	.0763	10	78.54	3.393	22	380.1	16.420
1⅝	2.073	.0895	10¼	82.51	3.564	22½	397.6	17.176
1¾	2.405	.1038	10½	86.59	3.740	23	415.4	17.945
1⅞	2.761	.1192	10¾	90.76	3.920	23½	433.7	18.735
2	3.141	.1356	11	95.03	4.105	24	452.3	19.539
2⅛	3.546	.1531	11¼	99.40	4.294	24½	471.4	20.364
2¼	3.976	.1717	11½	103.8	4.484	25	490.8	21.202
2⅜	4.430	.1913	11¾	108.4	4.682	25½	510.7	22.062
2½	4.908	.2120	12	113.0	4.881	26	530.9	22.935
2⅝	5.411	.2337	12¼	117.8	5.088	26½	551.5	23.824
2¾	5.939	.2565	12½	122.7	5.300	27	572.5	24.732
2⅞	6.491	.2804	12¾	127.6	5.512	27½	593.9	25.656
3	7.068	.3053	13	132.7	5.732	28	615.7	26.598
3⅛	7.669	.3313	13¼	137.8	5.952	28½	637.9	27.567
3¼	8.295	.3583	13½	143.1	6.182	29	660.5	28.533
3⅜	8.946	.3864	13¾	148.4	6.410	29½	683.4	29.522
3½	9.621	.4156	14	153.9	6.649	30	706.8	30.533
3⅝	10.32	.4458	14¼	159.4	6.886	31	754.8	32.607
3¾	11.04	.4769	14½	165.1	7.132	32	804.2	34.741
3⅞	11.79	.5193	14¾	170.8	7.388	33	855.3	36.949
4	12.56	.5426	15	176.7	7.633	34	907.9	39.221
4¼	14.18	.6125	15¼	182.6	7.888	35	962.1	41.562
4½	15.90	.6868	15½	188.3	8.147	36	1017.9	43.973
4¾	17.72	.7655	15¾	194.8	8.415	37	1075.2	46.448
5	19.63	.8480	16	201.0	8.683	38	1134.1	48.993
5¼	21.54	.9348	16¼	207.3	8.955	39	1194.6	51.607
5½	23.75	1.026	16½	213.8	9.236	40	1256.6	54.259
5¾	25.96	1.121	16¾	220.3	9.516	41	1320.3	57.037
6	28.27	1.221	17	226.9	9.802	42	1385.4	59.849
6¼	30.67	1.325	17¼	233.7	10.095	43	1452.2	62.735
6½	33.18	1.433	17½	240.5	10.389	44	1520.5	65.686
6¾	35.78	1.545	17¾	247.4	10.687	45	1590.4	68.688
7	38.48	1.662	18	254.4	10.990	46	1661.9	71.794

In estimating the capacity of Worthington (and other duplex) Pumps (*i.e.*, the delivery in gallons per minute or per hour) at a given rate of piston speed, it should be borne in mind that as they have *two* double-acting water plungers, their capacity is double that of any ordinary double-acting pump of same size, or four times as large as a single-acting pump.

FRICTION IN PIPES.

Friction loss in pounds pressure for each 100 feet in length of cast-iron pipe discharging the stated quantities per minute.—*G. A. Ellis*, C.E.

Imperial Gallons	Sizes of Pipes, inside diameters.															U.S. Gallons
	¾″	1″	1¼″	1½″	2″	2½″	3″	4″	6″	8″	10″	12″	14″	16″	18″	
4	3·3	0·84	·31	·12												5
8	13·	3·16	1·05	·47	·12											10
12	28·7	6·98	2·38	·97	·27											15
16	50·4	12·30	4·07	1·66	·42											20
20	78·	19·00	6·40	2·62	·67	·21	·10									25
25		27·5	9·15	3·75	·91	·30	·12									30
29		37·	12·4	5·05	1·26	·42	·14									35
33		48·	16·1	6·52	1·60	·51	·17									40
37			20·2	8·15	2·01	·62	·27									45
41			24·9	10·00	2·44	·81	·35	·09								50
62			56·1	22·40	5·32	1·80	·74	·21	·05							75
83				39·	9·46	3·20	1·31	·33	·07							100
103				48·1	14·9	4·89	1·99	·51	·10							125
124					21·2	7·00	2·85	·69	·14	·02						150
145					28·1	9·46	3·85	·95	·17	·03						175
166					37·5	12·47	5·02	1·22	·26	·05	·01					200
207					47·7	19·66	7·76	1·89	·37	·07	·03					250
249						28·06	11·20	2·66	·50	·09	·04	·005				300
290						33·41	15·20	3·65	·65	·11	·05	·007				350
332						42·96	19·50	4·73	·81	·15	·06	·01				400
373							25·00	6·01	·81	·20	·08	·02				450
415							30·80	7·43	·96	·25	·09	·04	·017	·009	·005	500
621								14·32	2·21	·53	·18	·08	·036	·019	·011	750
830									3·88	·94	·32	·13	·062	·036	·020	1,000
1,037										1·46	·49	·20	·091	·049	·028	1,250
1,245										2·09	·70	·29	·135	·071	·040	1,500
1,450											·95	·38	·181	·095	·054	1,750
1,660											1·23	·49	·234	·123	·071	2,000
1,867												·63	·297	·153	·086	2,250
2,075												·77	·362	·188	·107	2,500
2,490												1·11	·515	·267	·150	3,000
2,905													·697	·365	·204	3,500
3,320													·910	·472	·263	4,000
3,735														·593	·333	4,500
4,150														·730	·408	5,000
4,980															·585	6,000

The frictional loss is greatly increased by bends or irregularities in the pipes.

Evaporative Power of Various Fuels as Compared with Coal.—*Hutton.*

1lb. of good coal will evaporate 9lbs. of water which has
    been raised to ...   . 212°
$\frac{5}{8}$lb. of petroleum   ...   ...   ditto   ditto
2 lbs. of dry peat ...   .   ditto   ditto
$3\frac{1}{2}$ lbs. of dry wood...   ...   ...   ditto   ditto
$2\frac{1}{4}$ lbs. of cotton stalks   ...   ...   ditto   ditto
$3\frac{1}{2}$ lbs. of brushwood   ...   ...   ditto   ditto
$3\frac{3}{4}$ lbs. of wheat or barley straw ...   ditto   ditto
4 lbs. of megass or sugar-cane refuse ditto   ditto

To Find Nominal H. P. of Boiler.

For plain cylindrical boiler.—Multiply the length by the diameter in feet and divide by 6.

For single flue boilers.—Add together the diameters of shell and flue-tube in feet, multiply by the length, and divide by 8.

For double flue boilers.—Add together the three diameters in feet, of shell, and flue-tubes, multiply by the length, and divide by 8.

Armstrong's rule.—One square yard of heating surface and one square foot of grate for average coal, or $\frac{3}{4}$ square foot for best coal per nominal h.p. In improved modern setting, the heating surface being increased beyond this rule, it is usual to allow 15 square feet of heating surface per nominal h.p. for Cornish or Lancashire boilers; from 18 to 26 square feet of heating surface per nominal h.p. for multitubular boilers, and from ·5 to ·85 of grate area per nominal h.p.

All dimensions in inches. For double riveted joints add two-thirds to the depth of lap given for single joints.

RIVETED JOINTS, PROPORTIONS OF.—*Fairbairn.*

Thickness of plate.	Diameter for rivets.	Length of rivets from the head.	Distance of rivets from the head.	Depth of lap for single joints.
·19	·38	·88	1·25	1·25
·25	·50	1·13	1·50	1·50
·31	·63	1·38	1·63	1·88
·38	·75	1·63	1·75	2·00
·50	·81	2·25	2·00	2·25
·63	·94	2·75	2·50	2·75
·75	1·13	3·25	3·00	3·25

It is recommended by Armstrong to make the diameters of the rivets rather less, and the spaces rather wider, than those prescribed in the above table.

TABLE OF THE LENGTHS OF $\frac{3}{4}$-IN. AND $\frac{5}{8}$-IN. RIVETS FOR MACHINE AND HAND (SNAPPED) RIVETING TO GO THROUGH TWO THICKNESSES OF PLATE.—*Sexton's "Boilermaker's Pocket Book."*

Thickness of plate.	Machine Riveting.	Hand Riveting.
Two $\frac{3}{4}$-in. plates	$3\frac{1}{4}$ in. long	$3\frac{1}{8}$ in. long
,, $1\frac{1}{16}$-in. ,,	$3\frac{1}{8}$ in. ,,	3 in. ,,
,, $\frac{5}{8}$-in. ,,	3 in. ,,	$2\frac{7}{8}$ in. ,,
,, $\frac{9}{16}$-in. ,,	$2\frac{5}{8}$ in. ,,	$2\frac{1}{2}$ in. ,,
,, $\frac{1}{2}$-in. ,,	$2\frac{1}{4}$ in. ,,	$2\frac{1}{8}$ in.
,, $\frac{7}{16}$-in. ,,	$2\frac{1}{8}$ in. ,,	$1\frac{7}{8}$ in.
,, $\frac{3}{8}$-in. ,,	$1\frac{7}{8}$ in. ,,	$1\frac{3}{4}$ in. ,,
,, $\frac{5}{16}$-in. ,,	$1\frac{3}{4}$ in. ,,	$1\frac{11}{16}$ in. ,,

PROPORTIONS OF RIVETS.—*Hutton.*

Snap or cup shaped rivet-head: diameter $1\frac{3}{4}$ depth $\frac{3}{4}$, the diameter of rivet.

Conical shaped rivet-head: diameter 2, depth $\frac{3}{4}$, the diameter of rivet.

Pan shaped rivet-head: diameter $1\frac{5}{8}$, thickness $\frac{3}{4}$, the diameter of rivet.

Countersunk rivet-head: diameter $1\frac{1}{2}$, thickness $\frac{1}{2}$, the diameter of rivet.

To form a conical or cup shaped rivet-head, a length of rivet equal to $1\frac{1}{4}$ times diameter is required.

To form a countersunk rivet-head a length of rivet equal to one diameter is necessary.

To Cut Gauge Glasses.

An easy method of accomplishing this, is to first notch the glass upon the outside at the place where it is to be cut, and afterwards scratch round the inside of the glass at the same point with a small round file, the glass can than be broken off by the exertion of a slight degree of pressure.

Remedies for Incrustation in Steam Boilers.

Ritterbrandt's recipe consists in feeding into the boiler daily a small quantity of muriate of ammonia or sal-ammoniac, which decomposes any bicarbonate of lime that may be held in solution in the water. This remedy is of no value for preventing incrustation by sulphate of lime.

Salt 12 parts, extract of oak bark $\frac{1}{8}$ part, caustic soda $2\frac{1}{2}$ parts, potash $\frac{1}{2}$ part.

Molasses fed into the boiler at intervals of two or three days at the rate of about $1\frac{1}{2}$lbs. per horse-power.

Crushed or pulped potatoes.—This remedy is more especially recommended where carbonate or sulphate of lime is present, the potato pulp acting mechanically and surrounding or enveloping the sulphate of lime crystals as they are formed, and acting to prevent their adhesion to each other.

Quick, or newly-slaked lime put at frequent intervals into the boiler. The lime converts the soluble bicarbonate into insoluble carbonate, when

it is precipitated to the bottom of the boiler and can be easily removed.

Tranter's Patent Solution has a basis of saccharine and paraffin.—Citric acid 6ozs. to 68 pints, quassia chips, etc., etc. Proportions : 32 pints of water, 32lbs. of sugar, 6ozs. of tartaric acid, 4lbs. of soda, 1quart of paraffin, 1lb. of quassia chips.

If water be exceptionally hard, add soda crystals, soda ash, or tartrate of soda. Where peeling off of already formed incrustation is stubborn, the inventor assists it by adding hydrochloric acid, bicarbonate of potash, or citric acid. It is recommended that $1\frac{1}{2}$ pints of this solution per nominal horse-power be used per month.

Where sulphate of lime is present in the water, some animal substance which will become converted into a jelly by boiling is recommended, by some authorities, to be inserted into the boiler.

Petroleum, preferably that of the heavier kind and perfectly pure, applied in small quantities, say, of about $\frac{1}{8}$ of a pint to each horse power of the boiler per week, sometimes has beneficial effects, especially where the feed water contains lime in large quantities, when it penetrates and rots the scale, thus rendering it porous and causing it to detach itself from the surfaces of the plates. It can be mixed with the feed water and introduced into the boiler through the feed pump, or through the safety valve, or in any convenient manner. The light and refined oils are useless, as, owing to their volatile nature, they are speedily vaporised and expelled by the heat.

Tallow and black-lead applied hot, to inside of boiler, at intervals of two or three weeks.

Caustic soda of a strength of not less than 98 per cent., dissolved in water, and constantly mixed with the feed water in the proportion of from 1oz. to every 5 or 20 gallons, according to the degree of

hardness of the water. This softens the water and is highly recommended for the prevention of incrustation. The boiler must be blown off frequently.

Soda ash may be used as a substitute for caustic soda, but is not so good as the latter when pure.

Mahogany or oak sawdust, slippery elm, bark, turf, peat, manure, chloride of tin, leaves, sawdust, spent tanners' bark, charcoal, urine, night soil, glue, blood, sugar, starch, flour, malt, dregs of beer barrels, and other remedies too mumerous to mention have been from time to time recommended and patented. Some of the above, which act mechanically, can possibly be employed to advantage where only a small quantity of sulphate is present.

HANDY METHOD OF SETTING A SLIDE-VALVE.—

Dunn.

Remove the lid from the steam-chest, revolve the main shaft, or slack the set screws in eccentric, and revolve eccentric until full throw of same is made in one direction, opening the port to its largest size. Make a tapered wedge out of a lath and slip it down in the open port, marking with a knife or pencil the edge of the wedge on the valve seat. Revolve eccentric until full throw is made towards the opposite end of the steam-chest and until the port is open to its largest size; slip the wedge down in port, marking on valve seat as before; divide the distance between the two lines on the edge of the wedge, marking a third line in the centre ; then, with the eccentric at full throw, lengthen or shorten the cam rod until the wedge with its centre line fits one port neatly, and it will fit the other one as neatly when full throw is made in the opposite direction. Now place your engine on a centre, and revolve the eccentric until the port over the end of cylinder in which the follower is

placed has opened about one-sixteenth of an inch, and tighten your set screws. This done, your slide-valve, also your eccentric, is properly adjusted, and no time wasted hunting dead-centre or chalk marking fly-wheels.

DIMENSIONS OF CHIMNEYS.
American System.

Nominal horse-power of boiler.	Height of chimney, in feet.	Inside diameter at top.	
		ft.	in.
10	60	1	2
12	75	1	2
16	90	1	4
20	99	1	5
30	105	1	9
50	120	2	2
70	120	2	6
90	120	2	10
120	135	3	2
160	150	3	7
200	165	3	11
250	180	4	4

DIMENSIONS OF CHIMNEYS.—*Armstrong*.

Nominal horse-power of boiler.	Height of chimney, in feet.	Inside diameter at top.	
		ft.	in.
10	60	1	6
12	75	1	8
16	90	1	10
20	99	2	0
30	105	2	6
50	120	3	0
70	120	3	6
90	120	4	0
120	135	4	6
160	150	5	0
200	165	5	6
250	180	6	0

The heights and diameters in the foregoing tables are calculated for any description of fuel.

DIMENSIONS OF CHIMNEYS.—*Wilson*.

Height of chimney in feet.	$W = \dfrac{A\sqrt{H}}{\cdot 07}$ = lbs. of coal per hour per 1 foot of area at top of chimney.	$H_o = 0\cdot 192\ Hp\ (0\cdot 761)$ = Height in inches of column of water balanced by draught pressure.	$HP = \dfrac{A\sqrt{H}}{\cdot 75}$ = H.p. of each sq. ft. of chimney, assuming 7 lbs. of coal per horse power.	$A = \dfrac{\cdot 8}{\sqrt{H}}$ = area of top of chimney in feet per horse power for one of two boilers.	$A = \dfrac{\cdot 5}{\sqrt{H}}$ = area of top of chimney in feet per horse power where several boilers are working together.	$A = \dfrac{1\cdot}{\sqrt{H}}$ = area of flue in feet per horse power.
30	78·24	·218	7·3	·146	·091	·182
40	90·35	·296	8·4	·126	·077	·55
50	101·01	·364	9·4	·113	·070	·140
60	110·65	·437	10·3	·103	·064	·129
70	119·52	·5	11·2	·095	·059	·119
80	127·77	·58	11·9	·089	·055	·111
90	135·52	·656	12·6	·084	·052	·105
100	142·85	·729	13·3	·08	·05	·01
125	159·71	·911	14·9	·071	·044	·089
150	174·96	1·09	16·3	·065	·04	·082
175	188·98	1·26	17·6	·060	·038	·075
200	202·03	1·45	18·8	·056	·035	·07
225	214·28	1·64	20	·053	·033	·066
250	225·87	1·82	21	·05	·031	·063
275	236·90	1·99	22	·048	·03	·06
300	247·43	2·18	23	·046	·028	·057

When the area at top is given as in the 5th and 6th columns the dimensions of the side of square in a square chimney can easily be found by taking the square root of the area, or side of square = √A, and the ameter for a round chimney = $\dfrac{\sqrt{A}}{\cdot 7854}$.

T

MAXIMUM HORSE-POWER OF FACTORY CHIMNEYS WITH FLUES 50 FEET LONG IN CIRCUIT FROM THE FURNACE TO THE BOTTOM OF THE CHIMNEY.—*Hatton.*

Size at the top, inside.	Height, 40 feet.		Height, 50 feet.		Height, 60 feet.		Height, 70 feet.		Height, 80 feet.		Height, 90 feet.		Height, 100 feet.		Height, 120 feet.	
	Round.	Square.	Round.	Square.	Round.	Square.	Round.	Square.	Round.	Square.	Round.	Square.	Round.	Square.	Round.	Square.
ft. in.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.	h. p.
1 3	15	19	17	21												
1 6	22	28	25	32	27	34										
1 9	30	38	34	43	37	47	40	50	43	55						
2 0	40	50	44	56	49	62	53	67	57	73	60	76				
2 3	50	64	56	71	62	79	67	85	72	92	76	97				
2 6	63	80	70	89	77	98	83	106	89	114	94	120	100	128		
2 9			85	108	94	120	101	126	108	138	114	146	122	156		
3 0			101	126	111	142	120	153	129	165	136	174	145	185	158	200
3 6							163	208	175	224	185	237	197	252	214	274
4 0									229	293	242	310	258	330	281	360
4 6									291	373	307	393	327	419	356	456
5 0											378	484	403	516	439	562
5 6											458	587	488	625	531	680
6 0											546	700	581	744	633	810

Horse-power of Engine to Find by means of a Friction Brake.

The dynamometrical horse-power of an engine is found, according to the rule employed by the Royal Agricultural Society of England, by multiplying the weight lifted by 6·28 times the radius of the point of suspension in feet, then by the number of revolutions made in a given number of minutes, and dividing the amount thus obtained by the number of minutes and 33,000. Thus, if the weight equal 100lbs., the radius 2 feet 7 inches, the time 90 minutes, and the number of revolutions 10,000, then $\frac{100 \times 2 \cdot 7 \times 6 \cdot 28 \times 10000}{90 \times 33000} = 5 \cdot 7$ h.p.

Lightning Conductors.

A lightning conductor for a factory chimney should be of $\frac{1}{2}$in. or $\frac{3}{8}$in., copper rod or wire rope. It should extend above the top of the chimney stack for a distance about equal to that of the inside diameter of the said chimney, and should be fixed on the outside of the latter by means of non-insulated fastenings placed from 4 to 6 feet apart. The connection to the ground should be about 8 yards, and when wire-rope is employed the strands should be unwound and spread out in such a manner as to expose as large a surface to the soil as possible. A rod may terminate in a bed of old broken iron or steel. The soil round the earth connection of a lightning conductor should be damp. A good termination is formed by a well or a water pipe.

Jet Condensers.

The quantity of water required for condensing purposes is about 46 gallons per hour for each horse-power of the engine (indicated). The temperature of the hot well should not exceed

100degs. Fahr. If the pump be labouring heavily it is a sign that too much water is being used. Excessive clearances, giving rise to spaces wherein vapour will be trapped and afterwards expand, is frequently the cause of an imperfect vacuum; as also leaky glands, cocks, and joints, insufficient exhaust passages, hot water passing in with steam through boiler priming, etc. The speed of the air-pump plunger should not be too high, otherwise the water will not be able to follow it, thus leaving a space between the water and the plunger for the accumulation of air. The plunger speed should be from 100 to 200 feet per minute. The efficiency of vertical air-pumps is about 10 per cent. higher than that of horizontal ditto.

SURFACE CONDENSERS.

In this form of condenser the steam does not come in contact with the condensing water, which is circulated by a pump through a large number of tubes round which the steam passes. The cooling surface required is from 2 to 3 square feet for each horse-power indicated, and 1 gallon of condensing water should be circulated through the tubes for each cubic foot of steam to be condensed.

BREAKING STRAIN OF THE TEETH IN SPUR WHEELS.

Find square of thickness of tooth and multiply by width and by 6,000, the product divided by the length of the tooth will give breaking strain in pounds for cast-iron.

Wrought-iron wheels are about three times, malleable cast-iron wheels are about twice, gun-metal wheels about twice, and cast steel wheels are about four times as strong as cast-iron ones. Shrouded toothed wheels are about one-half stronger than plain ones. Double helical toothed wheels are about $\frac{1}{4}$ stronger than the ordinary pattern.

JOINTS.

RUST JOINTS.—Rust cement for caulking joints in cast-iron pipes, tanks, etc., etc., may be made with iron filings 10 parts, chloride of lime, 3 parts ; mixed to a paste with water. Joint must be given time to set.

Quick-setting do, sal ammoniac 1 part, flowers of sulphur 2 parts, iron borings 80 parts.

Slow-setting do, sal ammoniac 2 parts, flowers of sulphur 1 part, iron borings 200 parts. The two latter receipts are given by Molesworth.

To disconnect a rust joint, raise to a red heat, and strike the part with repeated light blows of a hammer.

RED LEAD JOINTS.—In making joints between male and female threads, care must be taken to place the red lead upon the female thread when the pressure to be resisted is internal, and upon the male thread when the pressure to be resisted is external. The lead should be most thoroughly worked up before use. For faced joints, that is, joints which have been brought to a high degree of truth by scraping or otherwise, red lead mixed with white lead and boiled linseed oil to the consistency of paint should be used.

TO LOOSEN NUTS THAT HAVE SET FAST.

To remove a nut that has become rusted in position apply petroleum by means of waste soaked in the latter, or by forming a dam or funnel round the nut and filling it with same. It should be allowed some hours to soak in.

THERMOMETERS.

Formulæ for the conversion of degrees Centigrade or Reaumer into degrees Fahrenheit, and *vice versa*. Let F equal degrees Fahrenheit ; C equal degrees Centigrade ; R equal degrees Reaumer.

$$F = \tfrac{9}{5} C + 32 = \tfrac{9}{4} R + 323.$$
$$C = \tfrac{5}{9} (F - 32) = \tfrac{5}{4} R.$$
$$R = \tfrac{9}{4} (F = 32) - \tfrac{4}{5} C.$$

COMPARATIVE TABLE OF THE THREE PRINCIPAL THERMOMETER SCALES.

Fahr. Degrees.	Cent. Degrees.	Reau. Degrees.	Fahr. Degrees.	Cent. Degrees.	Reau. Degrees.	Fahr. Degrees.	Cent. Degrees.	Reau. Degrees.	Fahr. Degrees.	Cent. Degrees.	Reau. Degrees.
221	105	84	167	75	60	113	45	36	60.8	16	12.8
219.2	104	83.2	165.2	74	59.2	111.2	44	35.2	59	15	12
217.4	103	82.4	163.4	73	58.4	109.4	43	34.4	57.2	14	11.2
215.6	102	81.6	161.6	72	57.6	107.6	42	33.6	55.4	13	10.4
213.8	101	80.8	159.8	71	56.8	105.8	41	32.8	53.6	12	9.6
212	100	80	158	70	56	104	40	32	51.8	11	8.8
210.2	99	79.2	156.2	69	55.2	102.2	39	31.2	50	10	8
208.4	98	78.4	154.4	68	54.4	100.4	38	30.4	48.2	9	7.2
206.6	97	77.6	152.6	67	53.6	98.6	37	29.6	46.4	8	6.4
204.8	96	76.8	150.8	66	52.8	96.8	36	28.8	44.6	7	5.6
203	95	76	149	65	52	95	35	28	42.8	6	4.8
201.2	94	75.2	147.2	64	51.2	93.2	34	27.2	41	5	4
199.4	93	74.4	145.4	63	50.4	91.4	33	26.4	39.2	4	3.2
197.6	92	73.6	143.6	62	49.6	89.6	32	25.6	37.4	3	2.4
195.8	91	72.8	141.8	61	48.8	87.8	31	24.8	35.6	2	1.6
194	90	72	140	60	48	86	30	24	33.8	1	.8
192.2	89	71.2	138.2	59	47.2	84.2	29	23.2	32	0	0
190.4	88	70.4	136.4	58	46.4	82.4	28	22.4	30.2	1	.8
188.6	87	69.6	134.6	57	45.6	80.6	27	21.6	28.4	2	1.6
186.8	86	68.8	132.8	56	44.8	78.8	26	20.8	26.6	3	2.4
185	85	68	131	55	44	77	25	20	24.8	4	3.2
183.2	84	67.2	129.2	54	43.2	75.2	24	19.20	23	5	4
181.4	83	66.4	127.4	53	42.4	73.4	23	18.4	21.2	6	4.8
179.6	82	65.6	125.6	52	41.6	71.6	22	17.6	19.4	7	5.6
177.8	81	64.8	123.8	51	40.8	69.8	21	16.8	17.6	8	6.4
176	80	64	122	50	40	68	20	16	15.8	9	7.2
174.2	79	63.2	120.2	49	39.2	66.2	19	15.2	14	10	8
172.4	78	62.4	118.4	48	38.4	64.4	18	14.4	12.2	11	8.8
170.6	77	61.6	116.6	47	37.6	62.6	17	13.6	10.4	12	9.6
168.8	76	60.8	114.8	46	36.8						

The Beaumé scale is based on a purely arbitrary standard which was devised by Antoine Beaumé, a chemist, in Paris, in 1768. Some twenty-three different hydrometer scales for liquids heavier than water have been published, each purporting to be Beaumé's, but no one of which is in fact computed in accordance with Beaumé's directions. The principal hydrometer scales are given in the following table drawn up by the Yaryan Company, the relative specific gravities, however, of two only are shown, the values of the degrees of the others are referred to the specific gravities equivalent to the degrees of the Beaumé sale adopted by the U.S. Chemical Manufacturing Association.

COMPARISON OF VARIOUS HYDROMETER SCALES.

Degrees Beaumé.	Specific Gravities.		Degrees Densimetric 15·5° C.	Degrees Twaddell 60 Fahr. T°=200 (Sp. gr.−1)	Degrees Brix. Official Prussian Hydrometer 15·6°C. $Sp.\ gr. = \frac{400}{400 - Bx°}$	Degrees Beck 12·5°C. $Sp.\ gr. = \frac{170}{170 - Bk°}$	Degrees Brix Saccharimetric (Per cent. Sugar).	Gay-Lussac (Centigrade) $Sp.\ gr. = \frac{100}{100 - C°}$
	Standard adopted by U. S. Chem. Mfg. Ass. 15·5° $Sp.\ gr. = \frac{145·04}{145·04 - B}$	Modulus 144·38. Custom in France.						
0	1·000	1·0000	0·0	0·0	0·0	0·0	0·0	0·0
1	1·007	1·0070	0·7	1·4	2·8	1·2	1·8	0·4
2	1·014	1·0140	1·4	2·8	5·5	2·3	3·6	1·4
3	1·021	1·0215	2·1	4·2	8·2	3·5	5·4	2·1
4	1·028	1·0285	2·8	5·6	10·9	4·6	7·1	2·7
5	1·036	1·0380	3·6	7·2	13·9	5·9	9·0	3·5
6	1·043	1·0435	4·3	8·6	16·5	7·0	10·7	4·1
7	1·051	1·0510	5·1	10·2	19·4	8·3	12·6	4·8
8	1·058	1·0585	5·8	11·6	21·9	9·3	14·3	5·5
9	1·066	1·0665	6·6	13·2	24·8	10·4	16·1	6·2
10	1·074	1·0745	7·4	14·8	27·5	11·7	18·0	6·9
11	1·082	1·0825	8·2	16·4	30·3	12·9	19·8	7·6
12	1·090	1·0905	9·0	18·0	33·0	14·1	21·5	8·3
13	1·098	1·0990	9·8	19·6	36·0	15·2	23 3	8·9
14	1·107	1·1075	10·7	21·4	39·0	16·4	25·2	9·7
15	1·115	1·1160	11·5	23·0	41·3	17 6	27·0	10·3
16	1·124	1·1245	12·4	24·8	44·2	18 8	28·9	11·0
17	1·133	1·1335	13·3	26·6	46·5	20·0	30·7	11·7
18	1·142	1·1425	14·2	28·4	49·7	21·2	32·6	12·4
19	1·151	1·1515	15·1	30·2	52·5	22·3	34·4	13·1
20	1·160	1·1607	16·0	32·0	55·2	23·5	36·2	13·8
21	1·169	1·1705	16·9	33·8	57·8	24·6	38·0	14·5
22	1·179	1·1795	17·9	35·8	60·7	25·8	40 0	15·2
23	1·188	1·1895	18·8	37·6	63·3	26·9	41·7	15·8

(For continuation of table see next page).

24	1·198	1·1995	19·8	39·6	66·1	28·1	43·6	16·5
25	1·208	1·2095	20·8	41·6	68·9	29·3	45·5	17·2
26	1·218	1·2195	21·8	43 6	71·6	30·4	47·3	17·9
27	1·229	1·2300	22·9	45·8	74·5	31·7	49·4	18·6
28	1·239	1·2405	23·9	47·8	77·2	32·8	51·2	19·3
29	1·250	1·2515	25 0	50 0	79·3	34·0	53·2	20·0
30	1 261	1·2625	26·1	52·2	82·8	35·2	55·1	20·7
31	1·272	1·2735	27 2	54·4	85·5	36·4	57 0	21·4
32	1·283	1·2850	28·3	56·6	88·3	37·5	58·9	22·1
33	1·295	1·2960	29·5	59·0	91·1	38·8	60·9	22 8
34	1·306	1·3080	30·6	61·2	93·7	39 9	62·7	23·4
35	1·318	1·3200	31·8	63·6	96·5	41·0	64·7	24·1
36	1·330	1·3320	33 0	66·0	99·2	42·2	66·7	24·8
37	1·342	1·3445	34·2	68·4	101·9	43·3	68·6	25·5
38	1·355	1·3570	35·5	71·0	104·7	44·6	70·7	26·2
39	1·368	1·3700	36 8	73·6	107·6	45·8	72·7	26·9
40	1·381	1·3830	38·1	76·2	110·3	46·9	74·7	27·6
41	1·394	1·3955	39·4	78 8	113·5	48·0	76·7	28·3
42	1·408	1·4100	40·8	81·6	115·9	49·3	78·8	28·9
43	1·421	1·4240	42·1	84·2	118·5	50·4	80·8	29·6
44	1·436	1·4380	43·5	87 0	121·3	51·5	82·9	30·3
45	1·450	1·4525	45·0	90 0	124·1	52·8	85·1	31·0
46	1·465	1·4675	46·5	93·0	126·7	53·9	87·2	31·7
47	1·479	1·4827	48·0	96·0	129·7	55·1	89·4	32·4
48	1·495	1·4980	49·5	99·0	132·4	56·3	91·5	33·1
49	1·510	1·5135	51·0	102·0	135·1	57·4	93·6	33·8
50	1·526	1·5300	52 6	105·2	137·9	58·6	......	34·5
51	1·542	1·5460	54·2	108·4	140·6	59·8	......	35 2
52	1·559	1·5630	55·9	111·8	143·4	61·0	......	35·9
53	1·576	1·5800	57·6	115·2	146·2	62 2	......	36·6
54	1·593	1·5965	59·3	118 6	148·9	63·3	......	37·2
55	1·611	1·6150	61·1	122·2	151·7	64 5	... ...	37·9
56	1·629	1·6355	62·9	125·8	154·5	65·7	......	38·6
57	1·648	1·6520	64·8	129·6	157·3	66·9	......	39·3
58	1·666	1·6715	66·7	133·4	160·0	68·0	......	40·1
59	1·686	1·6910	68·6	137·2	162·8	69·2	......	40·7
60	1·706	1·7110	70·6	141·2	165 5	70·4	......	41·4
61	1 726	1·7315	72·6	145·2	168·3	71·5	......	42·1
62	1·747	1·7525	74·7	149·4	171·0	72·7	... ...	4·28
63	1·768	1·7740	76·8	153·6	173·8	73·8	......	43·4
64	1·790	1·7950	79·0	158·0	176·5	75 0	......	44·1
65	1·812	1·8185	81·2	162·4	179 3	76·2	......	44·8
66	1·835	1·8420	83·5	167·0	182·0	77·4	......	45·5
67	1·859	1·8660	85·9	171·8	184·8	78·6	... ...	46·2
68	1·883	1·8910	88·3	176·6	187·5	79 7	......	46·9
69	1·907	1·9151	٤0·7	181·4	190·2	80·9	......	47·6
70	1·933	1·9410	93·3	186 6	193·0	82·1	......	48·3
72·5	2·000	2·0085	100 0	200·0	200·0	85·0	... ..	50·0

TABLE SHOWING THE PERCENTAGE OF ORIGINAL VOLUME TO BE EVAPORATED BETWEEN GIVEN DENSITIES IN CONCENTRATION OF CANE JUICE.—*The Yaryan Company, New York.*

Degrees Beaumé	2°	4°	6°	8°	10°	12°	14°	16°	18°	20°	22°	24°	26°
1°	50·23	75·50	83·93	88·14	99·67	92·35	93·56	94·46	95·27	95·73	96·19	96·58	96·91
2°		50·79	67·71	76·17	81·25	84·63	87·06	88·86	90·29	91·43	93·35	93·13	93·79
3°		25·58	51·17	63·97	71·64	76·76	80·42	83·18	85·31	87·03	88·43	89·61	90·60
4°			34·89	51·58	61·90	68·77	73·69	77·39	80·26	82·57	84·46	86·04	87·37
5°			17·27	38·94	51·95	60·62	66·82	71·49	75·11	78·02	80·39	82·39	84·07
6°				26·21	41·92	52·40	59·90	65·54	69·91	73·43	76·30	78·71	80·75
7°				13·20	31·69	44·01	52·83	59·46	64·61	68·74	72·12	74·95	77·35
8°					21·30	35·50	45·66	53·29	59·23	63·99	67·88	71·14	73·90
9°					10·76	26·86	38·38	47·04	53·77	59·17	63·58	67·28	70·40
10°						18·04	30·95	40·65	48·19	54·24	59·18	63·32	66·83
12°							15·76	27·59	36·78	44·16	50·19	55·25	59·52
14°								14·05	24·96	33·72	40·87	46·87	51·94
16°									12·69	22·88	31·23	38·18	44·08
18°										11·67	21·20	29·19	35·95
20°											10·79	19·83	27·48
22°												10·13	18·70
24°													9·53
26°													
28°													
30°													
32°													
34°													
36°													

Degrees Beaumé	28°	30°	32°	34°	36°	38°	40°	42°	44°	46°	48°	50°
1°	97·19	97·44	97·65	97·84	98·01	98·16	98·30	98·42	98·54	98·64	98·74	98·93
2°	94·35	94·85	95·28	95·66	96·00	96·30	96·58	96·83	97·06	97·27	97·46	97·64
3°	91·46	92·21	92·85	93·43	93·94	94·40	94·82	95·20	95·55	95·87	96·16	96·43
4°	88·52	89·53	90·39	91·17	91·86	92·48	93·04	93·53	94·02	94·44	94·84	95·20
5°	85·52	86·80	87·88	88·86	89·73	90·51	91·22	91·86	92·45	92·99	93·48	93·94
6°	82·49	84·04	85·35	86·53	87·58	88·53	89·38	90·16	90·87	91·52	92·12	92·68
7°	79·40	81·22	82·76	84·15	85·39	86·50	87·51	88·42	89·25	90·02	90·73	91·38
8°	76·27	78·36	80·14	81·74	83·16	84·44	85·60	85·65	87·61	88·50	80·31	90·07
9°	73·09	75·47	77·48	79·29	80·91	82·36	83·68	84·87	85·06	86·06	87·88	88·74
10°	69·84	72·50	74·75	76·78	78·60	80·22	81·71	83·03	84·25	85·38	86·41	87·37
12°	63·20	66·44	69·19	71·67	73·88	75·86	77·66	79·29	80·78	82·15	83·41	84·58
14°	56·30	60·15	63·41	66·36	68·98	71·34	73·47	75·41	77·17	78·80	80·29	81·68
16°	49·15	53·63	57·42	60·85	63·90	66·64	69·12	71·39	73·42	75·31	77·05	78·67
18°	41·75	46·88	51·22	55·14	58·64	61·77	64·61	67·19	69·64	71·71	73·70	75·55
20°	33·85	39·85	44·78	49·20	53·15	56·70	59·91	62·83	65·49	67·94	70·20	72·29
22°	26·06	32·56	38·07	43·04	47·39	51·45	55·05	58·31	61·29	64·04	66·57	68·91
24°	17·72	24·91	31·07	36·60	41·53	45·55	49·95	53·59	56·92	59·96	62·77	65·37
26°	9·05	17·03	23·80	29·91	35·35	40·23	44·65	48·67	52·33	55·71	58·81	61·68
28°	...	8·78	16·21	22·92	28·90	34·27	39·13	43·54	47·56	51·27	54·68	57·84
30°	...	...	8·14	15·49	22·04	27·91	33·23	38·07	42·47	46·53	50·26	53·72
32°	...	...	...	8·00	15·12	21·51	27·30	32·39	37·35	41·76	45·83	49·59
34°	...	...	...	...	7·74	14·68	20·96	26·67	31·87	36·66	41·07	45·16
36°	...	...	...	...	...	7·51	14·32	20·49	26·13	31·31	36·09	40·51

Useful Information.—Heat.—*Yargan, &c.*

One gallon of water evaporated at atmospheric pressure will produce about 200 cubic feet of steam,

One gallon of water evaporated under a 27-inch vacuum will produce 2,000 cubic feet of vapour.

A cubic inch of water evaporated under atmospheric pressure is converted approximately into one cubic foot of steam.

The boiling point of water containing substances in solution is raised.

In order to determine the temperature at which any liquid will boil in a 27-inch vacuum, find the boiling temperature in an open vessel and deduct 100degs. Fahr.

One pound of water at 60degs. Fahr. requires 152degs. of sensible heat, and 966degs. of latent heat to convert it into vapour. The same amount of fuel is required whether this be done in a vacuum or under pressure.

The sensible heat of a liquid is the amount indicated by the thermometer when immersed in it.

Specific heat is the amount of heat absorbed to produce sensible heat.

Latent heat is the amount of heat required to convert into vapour after the liquid has reached its boiling point.

The latent heat of vapour is given off in condensing to a liquid ; the sensible heat is retained. This is the physical law upon which the invention of multiple effects is based.

Steam at atmospheric pressure flows into a vacuum at the rate of about 1,550 feet per second, and into the atmosphere at the rate of about 650 feet per second.

MECHANICAL EQUIVALENT OF HEAT.—*Joule's.*

Heat requires for its production, and produces by its disappearance mechanical energy, in the ratio of 1,390 foot pounds for every thermal unit, centigrade scale, or 778 foot pounds for every unit Fahr. scale, in lat. 45 degs. at sea level.

The differences of the temperatures of the boiling points of liquids is constant at all pressures. Example :—Ether boils at atmospheric pressure at 100degs. Fahr., water at 212degs. Fahr., 212degs.—100=112degs. Water under pressure of six atmospheres boils at 319degs. ; 319degs.—112 =207 degs., which is the boiling temperature of ether under the same pressure.

The best designed boilers, well set with good draught and skilful firing, will evaporate from 7 to 10½lbs. of water per lb. of first-class coal.

One quare foot of grate will consume on an average about 12lbs. of coal per hour.

In calculating horse power of tubular boilers, 15 square feet of heating surface is considered to represent one nominal horse power.

The temperature of water boiling at atmospheric
    pressure is   ...   .   212degs.
The temperature of water boiling under 5 inches
    vacuum is   ...   .   195 ,,

,,	,,	,,	10	,,	185	,,
,,	,,	,,	15	,,	160	,,
,,	,,	,,	20	,,	150	,,
,,	,,	,,	25	,,	130	,,
,,	,,	,,	26	,,	120	,,
,,	,,	,,	27	,,	112	,,
,,	,,	,,	28	,,	100	,,
,,	,,	,,	29	,,	72	,,
,,	,,	,,	29½	,,	52	,,

To Use the Steam-engine Indicator.

Screw the stop cocks which form part of the fittings into the cylinder covers. Before the indicator is applied care must be taken to see that the piston moves freely in the cylinder, and that the moving parts are properly lubricated; for the piston, olive, or good high-grade spindle oil, may be employed, but for the pivots and other parts which are not in communication with the steam, and are not liable to contamination from the inferior grades of oils used in the cylinder of the engine, the very finest watch oil should be employed. A well pointed hard pencil of the best quality must be fixed in the socket of the pencil holder, and the leg turned back so as to keep the point free of the paper, when a sheet of the latter having upon its face a graduated scale can be placed in position upon the revolving barrel beneath the clip springs. The latter must have imparted to it a motion coincident with that of the engine piston, and to effect this the small line at the bottom of the revolving barrel of the indicator must be connected through a suitable cord or line with the cross-head, or (with a beam engine) the radius bar of the engine; the barrel is returned to its normal position during the reverse stroke of the engine by a spring (usually similar to a clock or watch-spring) arranged internally. Having satisfactorily effected the above, the pencil can be turned down so as to bring the point in contact with the paper, and the indicator be permitted to work for a few strokes with the stop-cock closed, so as to form an atmospheric line. The stop-cock can then be opened, and a figure will be traced by the point of the pencil which in the case of a non-condensing engine indicates the steam pressure, and of a condensing engine the vacuum, at every

part of the stroke. When the diagram has been sufficiently traced, which will be after two or three strokes, the pencil should be again turned back, the cord at the bottom of the revolving barrel disengaged, and the paper can then be easily removed.

To maintain the indicator in good working order it should be invariably wiped dry and cleaned before it gets cold, otherwise the parts are liable to get rusted or gummed up. A sponge is, perhaps, preferable to waste for cleaning, as it is not liable to leave pieces of lint stuck in the levers and other working parts. The brass and nickel plate portions of the indicator may be cleaned with fine polishing paste. To keep the cocks free from dirt and dust they should be plugged when not in use, or, better still, screw caps should be provided for that purpose.

It is very important to be sure that the indicator is correct. The piston in the steam cylinder of the indicator is normally held down by a spiral spring, and it is in this spring that lies the chief source of error, and frequent testing should be resorted to. Another source of inaccuracy, and one frequently but little suspected, is the apertures above the piston being accidently closed, and there being in consequence no outlet for any steam that might leak past the said piston. A case of this kind is given by the Hartford Boiler Insurance Company in a journal called *The Locomotive*, which is published by them, and in which they say : " Not long since an indicator which had been in use several years was sent to this office for the purpose of having the springs tested. We found that the vent holes in the outer body were completely closed by the screwed portion of the inner body, to which the cylinder is attached, so that the only outlet for the steam escaping around the indicator piston was what could leak out through the hole in

the cap through which the piston rod passes. This was entirely insufficient, so much so that the pressure accumulating on the top of the piston amounted to from 5lbs. to 8lbs. per square inch at ordinary engine speeds, and with a boiler pressure of 80lbs. per square inch, with the result, of course, that the pressure shown on the indicator diagram was just that much too low."

INDEX.

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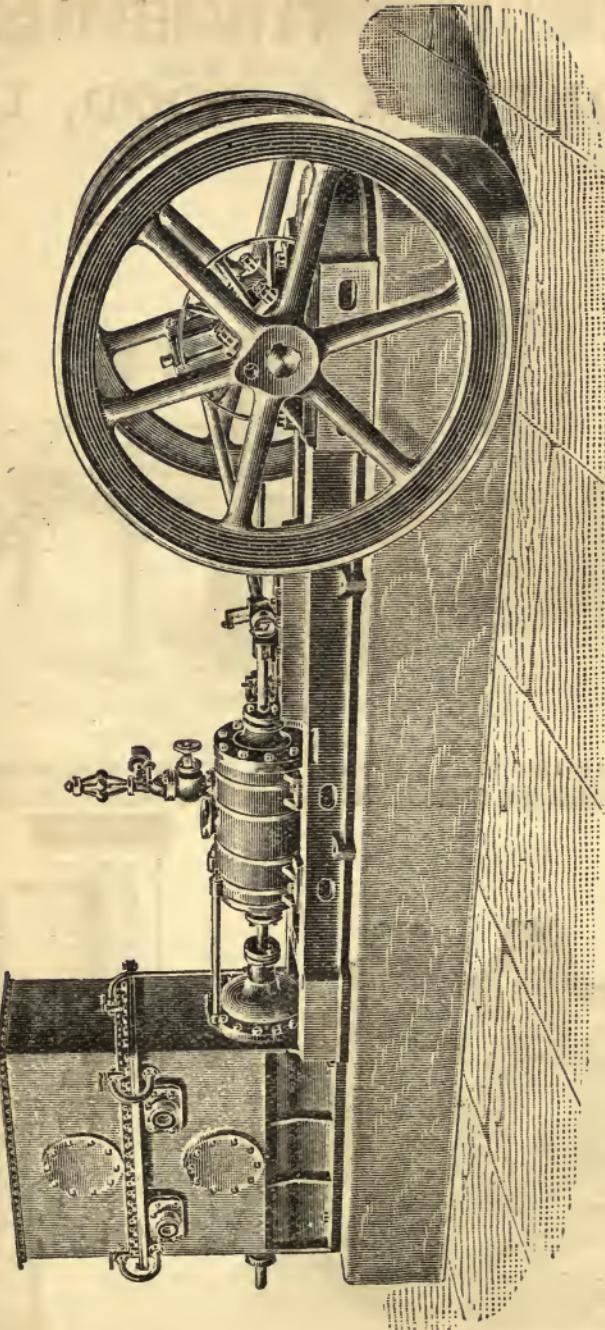
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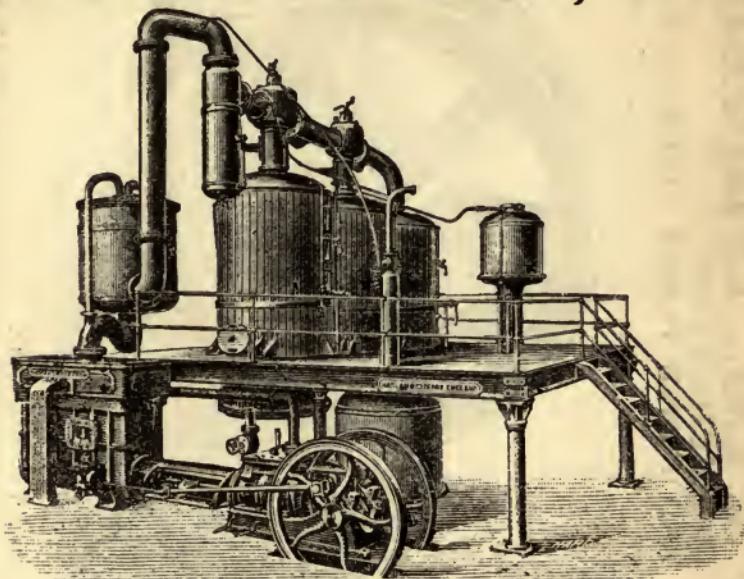
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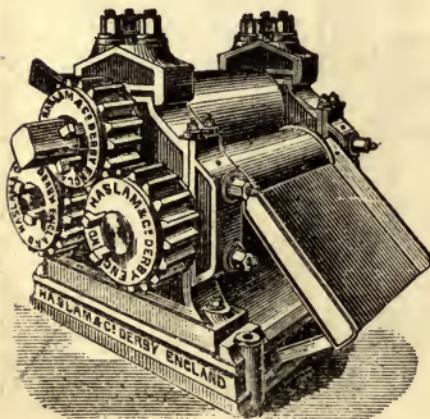
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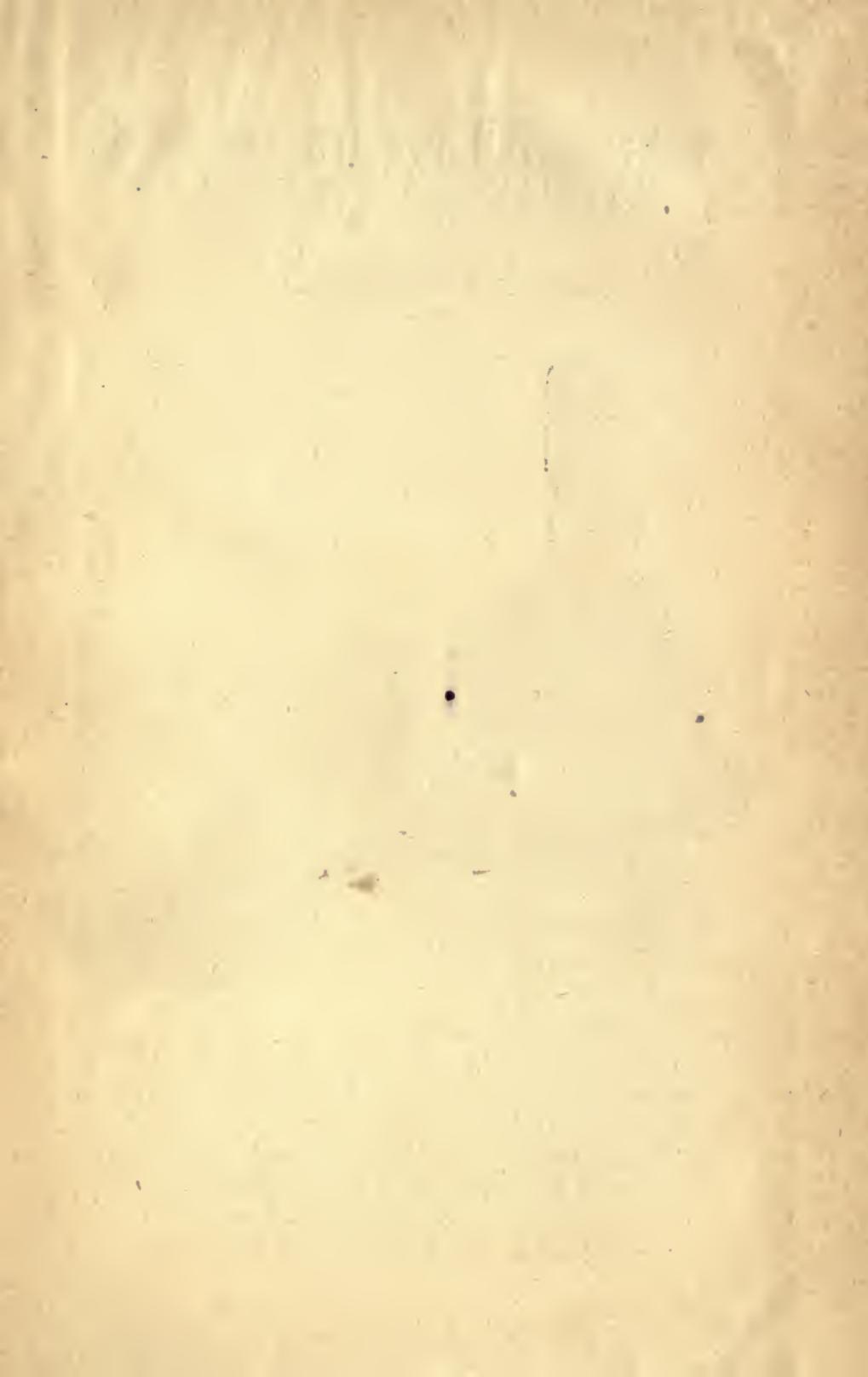
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