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THE VEGETABLE OIL REFINING PROCESS AND ITS INDUSTRIAL ECONOMY [1]

by

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erucic acids ,which are mono-unsaturated, and finally linoleic and linolenic acids which are respectively di- and tri-unsaturated.

2. Due to the trivalency of the glycerol molecule one and the same triglyceride molecule may contain three different fatty acids. Whereas the chain length of the fatty acid has a relatively minor influence on the physical properties of the fat the number of unsaturated fatty acids as well as their degree of unsaturation give rise to wide variations of the melting points and other physical properties of the fat.

3. Coconut, palm kernel and palm oils have as indicated by their low iodine values high contents of saturated fatty acids and relatively high melting points whereas olive, peanut and corn oils having a high percentage of oleic acid are fluid at room temperature.

4. Cottonseed, rapeseed, mustardseed and sesamy oils contain not only oleic acid but also the di-unsaturated linoleic acid. Sunflower seed and soyabean oils contain small amounts of the tri-unsaturated linoleic acid the percentage of which is even higher in the typical drying oils such as linseed oil and tung oil which are, however, hardly used for edible but mainly for technical purposes. Many of those vegetable fats do, however, contain number of substances such as gums, pigments and odoriferous matters which make the natural oils and fats unpalatable. The purpose of the refining of vegetable oils is therefore the removal of the impurities contained in the crude oil which impair the desired properties of the fat when used for edible purposes. Examples of such substances are free fatty acids, phosphatides, other gums, pigments, oxidation products as well as other components which will impair the taste, the odour, the keeping quality a.s.o.

The quantitively most important impurities in natural fats are the fatty acids which have been formed by hydrolysis of the triglycerides either already in the seeds or when storing the crude oils. In order to avoid high acidity and excessive refining losses great care should therefore be taken in handling and storing the seeds and the crudes. The seed should be dried to low water content and stored in silos with ventilation and proper temperature control. The crude oil should also be kept at as low a temperature as possible and contact with water or moist should be prevented.

5. Of the non-glyceridic components of the fats various phosphatides as for instance lecithin and cephalin are often present in amounts of up to 2-3 %. These components are normally removed immediately after the extraction of the seeds and the distilling of the solvent by precipitation with water. After upgrading the phosphatides can be used for a number of purposes, for instance as emulsifiers in the margarine industry.

6. Many crude oils also contain small amounts of waxes, sterols and tocopherols, the lastmentioned substance being important as an anti-oxidation agent.

7. Of the pigments carotenoids, xantophylls and chlorophylls are the most important. They are relatively stable against strong alcali and are mainly removed during the bleaching operation. Finally, the crude oils contain minor amounts of metals such as calcium, magnesium, manganese, copper and iron. The reason for the presence of copper and iron is normally that equipment partly constructed from these metals has been used for the production of the oils. Even very small amounts of copper and iron are, however, extremely harmful to the oxidation stability of fats and oils and great care should therefore be taken to avoid their presence.

8. In most cases the refining of the crude oil is carried out in three successive operations, i.e. the alkali refining with caustic soda, which removes the fatty acids completely as well as the phosphatides and part of the pigments, the bleaching with activated bleaching earth, which reduces the colour of the oil to the desired level, and the deodorization, which is essentially a steam distillation, where the odoriferous and nonpalatable substances are removed.

9. During the refining processes a number of by-products are formed, mainly: the soapstock, which consists of the soap formed by neutralization of the fatty acids and by some saponification of the neutral oil together with the bulk of nonglyceridic impurities; the spent bleaching earth containing a certain amount of fat, and the condensate from the deodoriser consisting of fatty acids, neutral fat and some other volatile components such as tocopherols and sterols.

10. The soapstock is normally split with sulphuric acid and eventually hydrolized in autoclaves and distilled under vacuum in order to recover the fatty acids. The condensate is treated in a similar way even if the literature indicates ways of recovering sterols and tocopherols. The bleaching earth finally can be extracted with hexane to recover a second-grade neutral oil.

11. The control of the refining operations and of the quality of the refined fat is made both by chemical, physical and organoleptic methods. Whereas the physical methods are of minor importance for the evaluation of the palability and the keeping quality of the oil they are necessary criteria for the practical field of application of the fat in question. Thus cooking and salad oils should be liquid at the ambient temperature, fats used for margarine production should, in order to obtain the characteristic plasticity and spreadibility, be composed of a mixture of oils and fats with different melting

points, whereas such physical characteristics as "the solid fat index" are of decisive importance for the use of fats in shortenings and pastry margarine.

12. By various methods and chemical analyses it is ensured that the impurities contained in the crude oil have been more or less completely removed by the refining processes. Determination of the free fatty acid content, the phosphorus content (from which the amount of phosphatides in the oil can be roughly calculated), the soap content a.s.o. give the refiner the necessary information. The absence of foreign matter in the refined oil is a necessary but not a sufficient criterium for the suitability of the fat for edible purposes. The organoleptic properties such as odour and taste must, however, always be evaluated. This evaluation should be carried out by a panel consisting of several persons carefully selected according to their ability to distinguish the various flavours of the oils. Usually the samples to be tested are compared to a blank of well-known properties, but not more than two or three samples should be compared to the same blank. Each member of the panel gives his evaluation of the difference between the sample to be judged and the blank using a scale normally running from 0 to 6. The type of flavour of the sample is traditionally expressed by words like neutral, nutty, gummy, rancid etc. The average estimate of the members of the panel indicates the organoleptic properties of the fat.

15. As there is normally a time lag of several weeks and even months between the manufacture and the consumption of the various fat products, the keeping qualities of the oils and the fats is of utmost importance. Fats, and especially the unsaturated ones, are subject to atmospheric oxidation, which after a certain time gives rise to unpleasant flavour and later on to a pronounced rancid taste. The initial phase of the oxidation can be followed by

determining the increase in the peroxide value but later the peroxides are broken down to other substances, mainly aldehydes and ketones some of which are undoubtedly responsible for the rancid taste and flavour of the oxydized fat.

14. The rate of oxidation of a given fat depends on many other factors than the chemical composition of the triglycerides, especially the presence of antioxidants, natural or added, and of oxidation catalysts such as metal and ions. The keeping qualities of the particular fat can therefore only be judged by aging tests where fat samples are kept in contact with air or oxygen at various temperatures and where the progress of oxidation is followed by determining such analytical characteristics as peroxide, aldehyde, ketone and benzidine values as well as the changes in organoleptic properties.

III - THE REFINING PROCESS

The removal of substances harmful to the use of fats and oils for edible purposes is most oftenly carried out by three different treatments - alkali refining, bleaching and deodorizing - all of which have traditionally been carried out batch-wise but which are nowadays effected by continuous methods.

III A - THE ALKALI REFINING

1. The free fatty acid content of crude oils and fats do normally represent the biggest amount of impurities to be removed. The oldest method to obtain the removal of the fatty acids is the neutralization with caustic soda. This process does, however, involve undesired losses partly through the emulsification of neutral oil in the soapstock and other waste products and partly through saponification of the neutral oil. In order to reduce

these losses several other methods such as neutralization with soda ash or ammonia and the so called physical or steam refining where the fatty acids are removed by steam distillation are or have been used. Of all known methods the alkali refining is, however, still the one most generally used, the reason being that not only the fatty acids but also most of the other non-glyceridic components which must be removed to produce an oil of adequate quality are attacked by the caustic soda. In the traditional batch neutralization process the oil is pumped to a vessel (fig. 1) provided with a steam coil, a stirrer and a spraying device for adding caustic and water. The oil is heated to a temperature of about 60 - 90°C and caustic soda added. The practitioner distinguishes between the wet and the dry neutralisation methods. In the first case a relatively weak caustic solution (4 - 10° Bé) is sprayed on the top of the oil and allowed to sink through the oil to the bottom of the vessel. In the second case a stronger caustic solution (16 - 20° Bé) is added when the stirrer is in slow rotation (30 r.p.m.). The soapstock sinks to the bottom when the agitator is stopped. In both cases the soapstock is then tapped from the bottom of the vessel and the oil washed several times with about 10 % of hot water to remove the last traces of soap. The first washing is, in order to avoid the formation of emulsions, usually carried out without agitation. In the following washings agitation or direct steam blowing is used to secure the complete removal of the soap.

2. The wet method of neutralization is mainly used for oils which are easy to neutralize and which do not contain large amounts of gums and pigments such as coconut and palm kernel oils as well as other oils with low acidity. Oils having a high content of impurities must be treated with stronger caustic in order to remove the pigments and the gums. Oils with high acidities (other than coconut and palm kernel oils) must also be

treated with strong alkali to avoid the formation of emulsions.

3. The stochiometric amount of caustic solution necessary is calculated from the amount and the acidity of the oil to be neutralised. In practice an excess of 5 - 50 % of caustic is used depending on the kind and amount of impurities. As the fatty acids usually constitute the major part of impurities to be removed from the triglycerides it has been customary to judge the efficiency of the neutralization process by means of a soapstock factor which is the quotient between the total amount of fatty matter in the soapstock and the amount of fatty acids in the amount of oil neutralized. When calculating the amount of fatty acids in the oil an average molecular weight obtained from the saponification value of the fat in question is used. This way of expressing the losses accounts for both the saponification and the emulsification losses but not for the loss of other impurities. The true refining factor can therefore only be determined by weighing both the crude and the neutralised oil but few refineries are equipped to do this.

4. The inherent limitation of the batch refining process is that the same condition which reduces the emulsification and contributes to the removal of foreign matters, i.e. the use of strong caustic, increases the saponification losses as any excess of caustic present is consumed for saponification due to the long contact time between oil and caustic prevailing in the batch process.

5. The change from batch to continuous processing in the neutralisation of fats and oils has been made possible by the use of the centrifugal separator. In these continuous processes for the refining of fatty oils which have been developed during the last 45 years it has been found possible to reduce the losses in alcali refining substantially.

6. The first continuous process, the straight caustic process, was developed in the United States where two oils alone, soyabean oil and cottonseed oil, dominate the production of vegetable fat for human consumption. The concentration of the production to only two kinds of crude oil,taken in conjunction with the relatively large overall capacities of the American refineries and the high level of wages there, did much to pave the way from batch to continuous operation. The continuous processes were in view of these conditions of production found to offer considerable economics in running costs.

7. In the straight caustic process the caustic and the oil are mixed at room temperature and then heated to break the emulsion formed at the reaction temperature. Oil and soapstock are then separated in centrifugal separators and the neutralized oil is washed with water for the removal of soap. The washing water is also separated from the oil by centrifugal separation.

8. As a rule the quantity of caustic used in this process greatly exceeds the quantity actually demanded by stochiometric calculation. This is because a considerable excess of caustic is necessary to ensure complete removal of phosphatides and pigments. Since the contact time between oil and caustic is relatively long (approximately 5 - 10 minutes) considerable saponification losses arise. It has also been found difficult to break completely by heating and centrifugal separation the emulsion formed during the mixing at room temperature so that the emulsification loss is also relatively high. According to American data the losses in the straight caustic process are 25 - 30 % less than those obtained by batch refining. But in Europe the development of the batch process has progressed so far that the losses when refining many kinds of oil were only negligibly greater than the losses obtained in the continuous straight caustic process.

9. A further progress was the so called Short Mix process introduced in Europe at the end of the 1940's. Like the straight caustic process it uses sodium hydroxide for the neutralisation of the fatty acids but working conditions have been arranged to give the maximum yield. In the Short Mix process the oil is heated to a temperature of 70 - 90°C before the caustic is added. At this temperature no real formation of emulsion takes place. Instead the soapstock formed agglomerates immediately to relatively large particles of low oil content. Another characteristic of the process is that the caustic is added to the oil in a mixer placed immediately before the centrifuge used for separating the soapstock from the oil. The contact time between oil and caustic is limited to less than 30 seconds thus greatly reducing the saponification. Another characteristic feature of the Short Mix process is the use of a hermetically closed centrifuge for separating the soapstock and the oil. This machine has several advantages over the conventional "open bowl" separators. In the last mentioned type of machine (fig. 2) the components are heavily beaten and whipped and mixed with air as they fall by gravity into the bowl. In the hermetic machine (fig. 3) the mixture of oil and soapstock is introduced into the bowl under pressure through the hollow rotating separator spindle. This constitutes a much milder treatment of the reacting materials and reduces the risk of particle break up and emulsification. Both the inlet and the outlet of the hermetic separator are fitted with axial seals so that the machine forms a completely closed system together with all apparatuses connected to it.

10. In all types of continuously operating separator bowls it is necessary to adapt the boundary zone between the two phases with reference to the difference in their specific gravities. In the open separator this is effected by means of interchangeable regulating discs with varying diameters past which the

heavy component leaves the bowl. The regulating discs cannot be changed during operation and the bowl must be stopped every time it is desired to alter the position of the boundary zone. In contrast, the position of the boundary zone in the bowl of the hermetic separator and thus also the separating result can be altered while the separator is in operation by using a throttle valve to vary the back pressure in the outlet line.

11. The different above mentioned features characteristic for the Short Mix process allow the use of relatively strong caustic which suppresses the emulsification losses without causing excessive saponification. For oils which are especially easy to saponify and oils with a very high acidity such as palm oil, grignon oil and rice bran oil it has been found advantageous to reduce the contact time even further. This in easily done by introducing the caustic directly into the spindle of the separator thus reducing the contact time to only a fraction of a second. When refining palm oil the refining factor can be as low as 1.5 when using this Ultra Short Mix method.

12. The Short Mix and the Ultra Short Mix neutralizations undoubtedly reduce the overall refining losses but the short contact time is not always sufficient to remove other impurities than fatty acids completely. This is especially true when the crude oils contain phosphatides and pigments such as in the case of soyabean, rapeseed and cottonseed oils. It is therefore sometimes necessary to subject such fats to a second alkali treatment usually called re-refining. As soap is an excellent catalyst for the saponification reaction the overall losses are normally reduced when adding the excess of alkali necessary for the removal of phosphatides and pigments after removing the bulk of the soapstock. The amount of saponification occurring is then independent of the acidity of the crude and depends only on the

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SUMMARY [1]

THE VEGETABLE OIL REFINING PROCESS AND ITS INDUSTRIAL ECONOMY

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concentration of the caustic used and the saponification velocity of the oil in question. Normally, the losses in re-refining are about 0.4-0.6 % of the oil.

13. It has for a long time been known that certain oils, especially soyabean and rapeseed oils, do contain phosphatides which cannot be removed completely even by repeated treatment with caustic. Complete elimination of these phosphatides can, however, be obtained by treating the oils with a small amount of concentrated phosphoric acid prior to neutralization. The mineral acid is neutralized together with the fatty acids and the amount of caustic calculated correspondingly. The phosphoric acid treatment and the subsequent neutralization also greatly reduce the amount of metal ions in the oil.

14. The neutralized or re-refined oil is washed with about 10 % of water to remove the soap which may otherwise give rise to an increase in the fatty acid content when the oil is bleached with acid-activated earth. Alkali-soaps are removed without difficulties by water washing, while calcium and magnesium soaps are soluble in the oil. It is advisable to use softened water both for the washing of the refined oils and for preparing the caustic solution used for neutralization. When using separators with a disc stack and taking the above mentioned precautions to avoid the presence of calcium and magnesium the soap content after a single water wash is approximately 50-60 p.p.m. and can by double water wash be brought down to 10-30 p.p.m. The washed oil is finally dried in a vacuum dryer to a water content of less than 0.05 %.

15. The sequences of apparatuses and the positions where the various refining agents are added in the continuous neutralization process are clearly seen in fig. 4. Due to the use of the hermetic separators the whole plant forms a completely closed system where the oil has no contact whatsoever with air from the moment

the crude oil is pumped into the plant until the refined and dried oil leaves the drying section thus avoiding any oxidation during the process. When using batch refining or open separator an increase in peroxide values,and sometimes a considerable one, is always observed.

16. When continuous neutralization was introduced to the industry it was the only fully continuous refining process. Intermediary tanks between the different process were therefore common standard, and short stops in the neutralization plants, which are at intervals necessary to clean the separator bowls when clogged by solid impurities, were of minor importance. As both the bleaching and the deodorizing are nowadays also carried out continuously, the stops for cleaning of the bowls are becoming more and more undesirable.

It must be taken into consideration that even the biggest separator bowls have sludge spaces of only 15 litres, whereas the amount of oil passed through the bowl is between 50 and 300 tons per 24 hours. Even very small amounts of solid materials with a higher specific gravity than that of the soapstock will therefore clog the bowl after a certain time. Such solids may be fine parts of the shells of the nuts or the seeds, which have not been completely removed by the filtering of the expeller-pressed or solvent-extracted oil. By the phosphoric acid treatment of the oil prior to the neutralization the natural calcium and magnesium contents of many oils, especially soyabean and rapeseed oils, are precipitated as unsoluble phosphates with high specific gravity. Calcium and magnesium carbonate may also be present especially if hard water is used.

17. The latest development is therefore a separator which is both hermetic and self-cleaning (see fig. 9).

18. This machine combines in one unit all the valuable properties of the hermetic separators and the constructional features of the solid-ejecting centrifugal separator. The bowl of the solid-ejecting separator is divided into two parts, the upper one and the lower one. When the bowl is in operation the lower part is pressed against the upper part by a separate sliding bowl bottom to which a water pressure created by the centrifugal force is applied. Thus the bowl is kept tight until this water pressure is removed when the lower part of the bowl is falling down a few millimetres opening a ring-formed slit around the bowl. The sludge is then thrown out of the bowl together with some of the soapstock. The opening of the bowl can be arranged in such a way that only sludge and soapstock are lost but absolutely no neutral oil, and it is not even necessary to stop the feed to the separator when the emptying is done. As the amount of sludge is relatively small, the opening of the bowl needs only to be done every second or third hour which can be automatically regulated through a timing device.

19. The continuous neutralization plant with self-cleaning separators is shown in fig. 6.

20. The soapstock coming from the neutralization plant can be fed into the continuous soapstock splitting process shown in fig. 7.

21. The soapstock is mixed with diluted sulphuric acid and fed to a settling tank from which the main part of the acid water is let to drain. The acid oil from the top of the tank is fed to the separator and washing water added so that the mineral acid and sludge are completely removed from the acid oil. The separator is also of the solid-ejecting type.

22. For oils containing large amounts of gums for instance soyabean and sunflowerseed oils, the addition of some emulsion-breaking agent such as casein may be necessary. The pH can be measured and regulated by automatic devices and does not need to be lower than 3 to obtain a complete splitting of the soapstock. The high pH which can be used in such a plant means big reduction in the consumption of sulhpuric acid and less cost for the neutralization of the acid water.

III B. THE BLEACHING PROCESS

1. As already mentioned many crude oils contain a number of undesirable pigments or coloured matters. They are often oil-soluble and pretty resistant to the effect of caustic so that they must be removed by other methods. The method most commonly used is the adsorption bleaching by means of acid-activated clays and/or activated carbon. These adsorbants are not very selective and will normally adsorb all pigments present in the neutral oil even if different adsorbants show somewhat different affinities to the various kinds of pigments, for instance the green colour caused by chlorophyllic substances is more effectively removed by active carbon whereas the activated clays show a good bleaching effect against the reddish or brownish colours caused by carotenoids, xantophylls and gossypol and its degradation products. The activated carbons are capable to a much higher degree than the bleaching earth of absorbing flavours and odours and may therefore contribute substantially to quality improvement of the fat.

2. The oil retention of active carbon is higher than that of bleaching earth and the filtration rate considerably lower for which reason carbon is normally used in mixture with bleaching earth, a procedure which is also of economic advantage as the price of the carbon is much higher than that of the bleaching earth.

3. At the contact surface between the activated earth and the oil hydrolysis of the triglycerides in the presence of water and oxidation of the fat easily take place. The bleaching is therefore carried out in vacuum. Fig. 8 shows a vacuum vessel for batch bleaching with mechanical agitation and steam heating coils. The bleaching earth is added to the oil when the temperature has reached approximately 70-75°C, either directly or in the form of a thick slurry of oil and earth previously prepared in a separate mixing tank. The heating is continued under agitation, the vessel being kept under vacuum until the temperature has reached about 100°C at which point it is kept for about 15-20 minutes after which period the heating is discontinued. The oil is then pumped to the filter presses, the first oil being returned to the bleaching vessel until a press cake has been formed and a clean oil obtained.

4. The first filter presses used were simple plate and frame filters. The plates contained channels through which the oil passed to a drainage channel common to all the plates. Each plate was covered with a filter cloth of cotton, sometimes also with filter paper. In order to reduce the amount of oil left in the filter cakes, the filter was usually blown with air and/or steam before being emptied. The vertical position of the plates often gave rise to fissures in the filter cakes causing a bad filtration and the cleaning of the filter was a very tedious and time-consuming operation.

5. A more modern filter, the Niagara filter, has the same vertical arrangement of the plates but uses stainless steel cloth and has the whole filter arrangement enclosed in a steel vessel. When the filtration and the steam blowing are finished the filter arrangement is removed from the vessel by an electromotor, and the filter plates are automatically drawn apart so that the filter cake falls down into the collecting vessel. This arrangement greatly reduces the manual work involved

in cleaning the filters.

6. The last ten years filters having the plates arranged horizontally on a common shaft have been developed, fig. 9. The filter plates are covered with a filter cloth in stainless steel thorugh which the oil passes into the hollow shaft. Due to the horizontal arrangement of the filter plates a very homogeneous cake is formed and no fissures in the filter cakes occur, a fact which facilitates both the filtration and the de-oiling of the cake. The filter can be nearly completely emptied by the so called "rest volume filtering method", where the oil is recirculated from the top to the bottom of the filter while an inert gas such as nitrogen is used to press the oil through the filter plates.

7. The amount of oil left in the cakes is approximately 25-35% which is at least 10 % lower than what can be obtained in the plate and frame filter. The main part of the oil remaining in the cake can be displaced and recovered by passing hot water through the filter resulting in a final oil content as low as about 15 % in the dry cakes. When the filter operation is finished, the cakes are removed by rotating the shaft with the plates so that the cake is thrown off by centrifugal force and forced down into the bottom of the filter from where it is discharged through the bottom valves.

8. The filters are eminently suited for use in continuous bleaching plants. In such plants the oil and the bleaching earth are continuously fed to the bleaching reactor, fig. 9. The daytank for the bleaching earth is equipped with a "fludizing bottom", and compressed air is blown through the bleaching earth. This system prevents the earth from sticking and gives an easily flowing powder which through a proportioning valve is transferred to a de-aerating chamber kept under vacuum to remove air from the bleaching earth. The earth is dosed to the bleaching

vessel by means of a sluice feeder which incorporates two alternatively working valves with a filling space in between. Thus the filling frequency of the feeder decides the amount of bleaching earth added. The amount of earth and the flow of oil are ratio-controlled which ensures a constant percentage of earth in the oil irrespective of variations in the oil flow. The bleacher is a vessel divided in four compartments each compartment communicating with the compartment below. Via special low pressure drop butterfly valves enabling a very quick passage of the oil/earth mixture from one compartment to another the oil passes from the top to the bottom of the column. To safeguard a proper mixture between earth and oil each compartment is equipped with a stirring device mounted on a common shaft. The bleacher is working under a vacuum of 15 - 35 Torr.

9. The oil enters the bleacher through four spray-nozzles and forms a film on the plate from which it flows down into compartment No 1, forming an oil screen which prevents the bleaching earth from entering the vacuum system. In the same compartment the de-aerated bleaching earth is added and the decolorization starts. After a holding time set in advance the oil/earth mixture goes to compartment No 2 and further to compartment No 3. The system allows a fixed holding time independent of the capacity. The only change in the bleacher at different throughputs is that the level in the compartments will vary. The total contact time between oil and bleaching earth can be altered between 10 to 30 minutes. The arrangement of the bleaching reactor allows an exact adjustment of the average holding time simultaneously eliminating the risk of short-circuits.

10. The complete Auto-Bleach plant is shown in fig. 11. The two filters of the plant work alternately in the following way: When the filter plates of one filter are covered with bleaching earth the oil flow is automatically switched over to the other

filter, and when the plates of this filter are in their turn covered with earth the oil flow is automatically switched back to the first filter. Between the filtering cycles the bleaching earth on the filter plates is de-oiled as described above and the filter cake thrown off. The Auto-Bleach process is completely automatic, regulating, indicating and/or recording such process data as oil flow, total amount and percentage of bleaching earth, oil levels, temperatures and filter pressures.

11. The advantage of the described continuous bleaching process is that a reduction of the amount of bleaching earth of up to 40 % as compared to the amount necessary by batch bleaching can be obtained due to the exactly controlled contact time. The plant is of hermetic design and operates under vacuum so that oxidation of the oil is completely avoided. Due to the high degree of automatization and as the filters are self-cleaning the manual work is considerably reduced.

III C. THE DEODORIZING PROCESS

1. The rapid development of the margarine industry at the end of the 19th century also created a great demand for oils and fats with an absolutely neutral flavour. It was found that the steam distillation of the neutralized and bleached oil under high vacuum produced the desired results. Fig. 12 shows a batch deodorizer with a steam coil for heating, another channel for cooling water and at the bottom of the vessel a system of perforated pipes and plates for the introduction of live steam. At the top the vessel is provided with a baffle to prevent oil drops passing into the vacuum system, and an amply dimensioned vapour-off-take.

2. The batch deodorization is usually carried out at 170 - 190°C and at pressures of about 10 - 20 Torr. The vacuum is produced by means of a 3-stage steam ejector. To prevent condensation of the steam in the oil, dry and superheated steam is used for the steam blowing. This steam should also be free of oxygen and organic matters. The duration of the deodorization at the temperature and vacuum here indicated is about 4 - 6 hours, somewhat shorter for oils which are easy to deodorize but longer for difficult oils such as soyabean and rapeseed oils. At the end of the deodorization the oil is cooled down to below 100°C before it is pumped out of the deodorizer.

3. Batch deodorizers are normally manufactured in mild steel; copper and brass should be avoided as construction materials. In order to avoid the harmful effects of small amounts of metal ions present in the oil a strong aqueous solution of nitric acid (lactic or tartaric acid may also be used) is added. A nitric acid concentration of 50 - 100 p.p.m. is usually sufficient. The nitric acid forms complex salts with the metals present and acts as synergist together with antioxidants which have passed through previous refining processes, for instance tocopherols.

4. During the steam blowing volatile substances will be distilled off from the oil. The most easily distilled substances in fats and oils are the fatty acids and the acidity of a deodorized oil is often of the order of magnitude of 0.02 depending on the vacuum used and the chain length of the fatty acid present. Sterols, tocopherols and other volatile matters are also found in the condensate. The loss of triglycerides is very small under the conditions here mentioned but highest for oils and fats having a low molecular weight such as for instance coconut oil. The condensed volatile matters often form difficult emulsions with the cooling water for which reason

they are often recovered in a scrubber filled with fatty oil. This procedure also reduces the amount of fatty material in the condenser water considerably.

5. A couple of chemical reactions are taking place during the deodorization. Thus the peroxides are completely destroyed at the temperature in question and the oxidation stability of the fats is therefore improved by the deodorization. Aldehydes and ketones which have been present in the bleached oil or formed by the destruction of the peroxides are also distilled off provided the molecular weight is low. Higher aldehydes and ketones may remain in the oil and are associated with the bad flavour and low oxidation stability of deodorized oils. During the deodorization a substantial colour reduction may also take place especially if carotenoid pigments which are unstable to heat are present.

6. The consumption of stripping steam in a batch deodorizer is of the order of magnitude of 150 kg/h whereas the amount of steam necessary for the steam ejectors is often more than three times as much, depending on the desired vacuum. Taking into consideration that the deodorizer must be kept under vacuum even when being filled and emptied and for intervals between these operations, the total steam consumption is often 300 - 500 kg per ton of deodorized oil. The consumption of cooling water of 20°C is about 25 tons/h.

7. Already before the introduction of continuous deodorization the practice in the United States had been to increase the deodorizing temperature in order to shorten the time necessary and thus the steam consumption. Based on the vapour pressures of fatty acids it can be estimated that the rate at which volatile substances are removed from the oil by stripping with steam is tripled for each

temperature increase of 25°C. Temperatures of 200 - 225°C were therefore used already for batch deodorization, the equipment then being manufactured in stainless steel in order to avoid contamination with iron. As many vegetable oil refineries do not possess steam boilers with sufficiently high steam pressure to obtain temperatures up to 250°C it is now customary to heat the oils partially by means of Dowterm, the trade name for an eutetic mixture of diphenyl and diphenyl oxide having a boiling point of 258°C at atmospheric pressure and 293°C at 2 atm.

8. The full advantage of these improvements is obtained in the modern continuous deodorizers which can be divided into two main groups. The first group is termed the semi-continuous (Girdler) type and the other the fully continuous type, of which the so called "cross stream" deodoriser is here taken as an example.

9. One of the drawbacks of the batch deodorizers is that the pressure increases by 1 Torr for each 17 mm oil layer. For a batch deodorizer with an oil height of 2 - 3 m the absolute pressure at the bottom of the vessel will be approximately 150 Torr higher than the pressure at the oil surface, the volume of vapour necessary for the stripping of the volatile components increasing correspondingly. To avoid this the continuous deodorizers all have only a thin layer of oil through which the stripping steam is passed. Another drawback inherent with the batch deodorizer is that any leakage in the vessel will introduce air directly into the oil thus causing damaging oxidation. The continuous deodorizers all have some kind of "double-wall" construction so that air leaking through the outer shell will not come into contact with the oil but will be evacuated by the steam ejector.

10. Fig. 13 shows the semi-continuous Girdler deodorizer having a series of superimposed trays each containing about 500 kg of oil. In the first tray the oil is deaerated and heated with indirect steam to about 170° C. In the second it is heated to operating temperature (normally about 230 - 250°C) with Dowterm wapour. In the third and fourth trays it is subjected to stripping and in the last tray it is cooled before being dumped into a drop tank from where it is pumped through a polishing filter to storage.

11. The absolute pressure which is the same over all trays is about 8 - 10 Torr. The height of the oil layer in each tray is approximately 600 mm. The holding time in the deodorixer is 2 - 3 hours. The operation of the units is made fully automatic by use of timing devices which open and close the various oil and steam valves.

12. This semi-continuous deodorizer requires a much shorter time than a batch deodorizer to be started up and shut down and can be quickly switched over from one type of oil to another simply by emptying the first tray before feeding a new type of fat to the deodorizer. This flexibility in operation also greatly reduces the steam consumption as the time the deodorizer has to be kept under vacuum is reduced to a minimum.

13. Another type of continuous deodorizer, the"cross stream"deodorizer, is shown in fig. 14. The oil is pumped to a deaerater and then through an internal heat exchanger,where the ingoing oil is heated with the finished deodorized oil. The heating to deodorizing temperature (230-250oC) is made with Dowterm before the oil enters the deodorizer. The interior of the deodorizer contains a number of bottoms where the oil is flowing through spirals from the periphery to the centre of each bottom before it is discharged to the periphery of the

the next bottom (see fig. 15). The thickness of the oil layer is determined by an overflow dam and is only 300 mm. The bottom plate is perforated and steam let through continuously. The spiral arrangement for the oil flow gives a longh path for the oil to pass where it is all the time stripped with fresh steam. It has been found that with a total holding time of 150 minutes 95 % of the oil has had a contact time of at least 120 minutes. In the bottom of the deodorizer the oil is cooled with water and then pumped through a polishing filter to storage. There are no oil valves to be operated, only the rate of the oil flow and the temperature have to be controlled. The deodorizer operates at 5 - 10 Torr absolute pressure. The steam consumption for stripping is about 40 kg per ton of oil and 260 kg per ton of oil for heating when the temperature of the cooling water is 20°C. The amount of steam for heating is reduced if Dowterm heating is used and a certain amount of fuel oil is then necessary.

14. The continuous all-hermetic neutralisation plant, the continuous Auto-Bleach plant and the continuous deodorizer can be operated in series without the necessity of any intermediate tanks, the whole refining process thus being carried out in a completely closed system partly under a high vacuum so that absolutely no oxidation takes place, a fact that greatly improves the quality and the stability of the refined oil. A layout of such a plant is shown in fig. 16 from which the extremely small space requirements for the continuous plants are also seen. The operating personnel for such complete refining plant with capacities from 100 to 300 tons per 24 hours is only two men per shift.

IV. THE CONTROL OF THE REFINING EFFICIENCY, STORAGE AND PACKING OF REFINED OILS

1. The losses of neutral oil occurring during the different refining operations are of the utmost importance for the economy of the refining process, and the losses should therefore be carefully controlled. It has for a long time been customary to weigh all the oil coming into the factory as well as all the oil leaving it. This allows the determination of the overall loss during a certain period, for instance a month or a year, but it is not possible to determine the losses in each separate refining operation, nor can the refining conditions be adjusted during running so that minimum losses are obtained.

2. The determination of the overall loss is therefore combined with other methods for measuring the losses in each refining stage. Thus the fatty acid factor is determined by measuring the amount of acid oil obtained after the splitting of the soapstock. The bleaching losses are calculated from the amount of bleaching earth used and the oil content of the spent earth and so on. These measurements can, however, only be carried out when the refining operation in question is finished and as the analytical work involved requires some time it is still not possible to adjust the working conditions during the refining operation in order to obtain the optimum yield.

3. It should also be remembered that the difficulties in obtaining representative samples, the choice of analytical methods and so forth may influence the results to a considerable degree. Furthermore, water and water-soluble substances present in the crude oil or formed during the refining operation are not accounted for by these methods. The only correct way of determining the losses is therefore to weigh the oil before and after each refining operation, and it is nowadays, by means of automatic computer-controlled

scales, possible to measure the losses during the refining operations so that the refining conditions can be optimized during operation.

4. Fig. 17 shows such an automatic weighing system. The oil going to the refining plant is passing three small tanks, the first of which has an automatically regulated bottom valve, which is open at the beginning of the weighing. When approximately 100 kg of oil has been fed to the intermediate tank, the bottom valve of which has been closed during the filling up, the upper valve is automatically closed. The weighing is then carried out, after which the lower valve is automatically opened and the oil is running to the lowest tank, from where it passes to the plant. When the intermediate tank has been emptied, a new weighing is carried out, the difference between the two weighing operations giving the exact amount of oil fed to the plant. The oil leaving the plant is weighed in exactly the same way.

5. The computer integrates the amounts of in- and outgoing oil as well as the difference between them, all these values being at any moment indicated by a counter. If desired these values can at predetermined intervals be written down by a typewriter, thus providing the plant supervisor with a complete production report even during the night when the operators are alone. As the total amount of oil contained in the weighing system is only about 200 kg the intervals between the loss determinations is only half a minute to two minutes depending on the capacity of the installation. The actual loss occurring is therefore indicated at very short intervals and the operating conditions can be changed until the optimum yield is obtained.

6. It may even be possible to let the computer change certain operational variables when the loss is abnormally high, but as the optimum result is depending on several variables this may be somewhat difficult.

7. There are, of course, other sources of losses which cannot be so easily controlled even if they can always be exactly determined by a proper weighing control. A big oil refinery, where several different types of oil are refined, has a pretty complicated pipeline system connecting the various tanks for crude, intermediate and refined products with the different refining plants and the sewage system. A single valve left open by human mistake can give rise to a considerable oil loss, but the sooner the mistake is discovered the smaller the loss will be. The correct placing of scales and the number of weighings necessary to obtain a reasonable control without too high costs should therefore be determined with due consideration taken to the number and type of oils refined and the outlay of the whole of the plant. For oils with a high acidity the losses in the neutralization process are of decisive importance for the overall loss, and weighing directly before and after the refining operation should therefore be carried out. For oils with a low acidity but of very dark colour the losses in the bleaching plant may be more important than those in the neutralization stage for which reason the control of the losses during the bleaching should not be omitted. The losses during the deodorization are normally so small that there is no need for a separate loss determination for this operation.

8. Refined oils are normally oxydized more easily than crude ones, because natural antioxidants are partly removed during the refining operations. Special precautions should therefore be taken during storage and as a rule the oils should as soon as possible be packed, bottled or used for other purposes such as the production of margarine.

9. When the refined deodorized fat is to be used as salad or cooking oil or as a shortening the best is to pack or bottle the fat immediately after the refining operation. Tinned cans and glass or plastic bottles are used for packing. The containers should be filled completely and thoroughly sealed so that no contact with air

during storage and transport is possible. In some cases the fat is filled into the containers under the cover of nitrogen. Transparent containers are preferably made of dark material to protect the fat from the harmful effects of light and the packed or bottled fat should be kept as cool as possible. In the case of properly bottled fluid or solid fats without any water content storage at room temperature is usually sufficient.

10. If the fat is to be submitted to further processing, such as the production of margarine, it should be kept at a constant temperature slightly higher than the melting point thus avoiding breathing of the tank. A nitrogen blanket may also be used to avoid contact with air. It is sound practice not to store refined oils and fats for more than 24-48 hours before further treatment.

11. Certain refined fats which have been rendered flavour- and odourless by deodorization may develop objectionable flavours through oxidation long before rancidity or even any noticeable increase in peroxide value has occurred. Such changes in flavour and odour are usually termed flavour reversion. The oils subject to flavour reversion are those containing linoleic acid or other polyunsaturated fatty acids such as marine oils, linseed oil as well as soya bean oil and rapeseed oil. Especially soya bean oil has a tendency to develop an unpleasant flavour which in the early stage is characterised as "beany" and in more advanced stages as "grassy", "painty" or "fishy". The unpleasant flavour and odour are accentuated when the oil is heated, for instance when used as a cooking or frying oil. Although the exact chemical mechanism of flavour reversion is still not completely cleared up,practical experience has shown that the tendency towards flavour reversion can be controlled to a large extent by suitable refining treatment. Especially important is the complete removal of phosphatides and metal ions and the application of the appropriate time and temperature of the deodorization process.
If the fat has been properly refined the above mentioned precautions during storage and packing will be sufficient to prevent flavour reversion of the fat.

V. ECONOMIC ASPECTS

1. All types of plants for the extraction and refining of fatty oils have a number of cost factors in common, the most important of which are the transport and storage requirements. Especially if imported seeds are used as a raw material for the oil production the factory should be placed in the immediate neighbourhood of a deep-water harbour in order to keep the transport costs of the bulky raw material as low as possible. Good railway connections will also facilitate the bulk transport of crude or refined oil in tank waggons, even if transportation, especially of the finished products, is nowadays often carried out by truck, as this permits a door-to-door delivery and thus limitates the transport time.

2. An appropriate supply of water, especially of cooling water and feeding water for the boiler, for which the requirements of an oil factory are large, is also of decisive importance. Furthermore, a suitable source of electrical energy should be at hand. As for the steam requirements which are also high, an oil refinery is normally equipped with its own boiler.

3. The storage requirements vary widely depending on the type of raw materials used, the intervals of delivery, the number of oils to be treated as well as on the way of distribution and the intervals of delivery to the customers. Here the variations depending on local and other special conditions are so great that no general recommendation can be given even if proper storage facilities are of the utmost importance both for the effective function of the factory and for the production costs.

4. A comparison between production costs for batch and continuous refining plants is, of course, no easy matter. As a thumbs'rule it can be said that the investment costs are higher for a continuous plant than for a batch plant, but that the latter does have higher running costs due to the higher consumption of utilities such as steam and water as well as higher labour costs. For very small plants

treating up to 30 - 40 tons of oil a day batch-wise operation may be the economically more advantageous one but the number of such refineries is rapidly decreasing today, as they are normally too small to carry the necessary investment costs.

5. When a new oil factory is built the planner naturally always has a choice not only between batch or continuous operation but he could and should also consider a combination of the two main production methods. In making such a choice many factors must be taken into account such as investment cost (local customs duties or import regulations may disrupt any normal calculations), type and average acidity of the fat to be refined, local price of utilities such as steam, water and electric energy and finally labour costs.

6. By continuous operation a considerable reduction in the number of operators is obtained, especially for plants with high capacities, but maintenance personnel with high vocational skill is necessary to avoid costly breakdown periods of the plant.

7. As this paper has been dealing exclusively with the refining operations proper but not with the extraction of the oils, nor with auxiliary equipment such as steam boilers, cooling towers and demineralising plants for water, nor with other facilities for the whole factory such as workshop, laboratory or offices, only the refining equipment proper is taken into consideration in the following economical comparison between batch-wise and continuous operation. The comparison is also made between the two extremes, i.e. fully continuous operation or batch operation of all the four refining processes, without considering the possibilities of carrying out some process continuously and others batch-wise.

8. Table I summarizes the investment costs including machinery, erection and building costs for batch and continuous plants with yearly capacities of 12,500, 37,500 and 75,000 tons of oil. It should, however, be remembered that the continuous plants have a further advantage as the consumption of steam is considerably reduced and the investment

costs for the boiler installation are correspondingly smaller.

9. Table II gives the average refining costs per ton of oil. No consideration is taken to the relatively small variations in running costs, due to the size of the plant. The costs are calculated for a crude oil with an acidity of 3 % and for an oil with a relatively light colour which can be bleached with 1.5 % of activated bleaching earth. For oils with higher acidities or for oils of a very dark colour the economical advantages of continuous operation are considerably greater than those calculated.

10. The price levels of all costs given are approximately those prevailing in Western Europe. For other countries the costs stated by us will have to be substituted for the local costs for building, labour and utilities. The consumption of chemicals is roughly the same at batch-wise and continuous operation.

11. It should finally be noted that the cost of the raw material is of extreme importance for the cash flow of an oil refining plant. As the crude oil price is roughly 300 US $ per ton, the cost of the raw material for the three sizes of plant here discussed is approximately 4, 17 and 34 million US $ a year, or 10 to 30 times the total investment cost of the refining plant itself.

12. As different fats and oils can to a certain extent be substituted one for another (depending, of course, on the use intended of the finished product and the quality demand made upon it)it is of the utmost importance that such raw material is bought which is at any moment the cheapest. Unfortunately, the frequent price fluctuations of fats and oils as well as the frequent changes in other trade conditions make the purchase of raw material for an oil refinery a very difficult and risky matter.

13. In spite of all the limitation adherent to the generalized and summary method of calculation it is clearly seen from the tables that the in-

I. INTRODUCTION

The importance of fats in the human diet and the sources of raw material for edible fats and oils.

II. THEORETICAL ASPECTS AND QUALITY CONTROL NECESSITIES

1. The purpose of the refining of vegetable oils is the removal of certain impurities contained in the crude oil which impair the desired properties of the oils when used for edible purposes. Examples of such impurities are free fatty acids, phosphatides, other gums, pigments, oxidation products as well as other substances which will impair the taste, the odour, the keeping quality and/or other desired properties of the refined oil.

2. The quality control of the finished oil is made partly by determining a couple of analytical data such as the amount of water, free fatty acids, soap and phosphatides left in the oil as well as the peroxide, the aldehyde and the benzidine values. The taste and flavour of the deodorized oil is also judged normally by a panel of several persons and by comparing the different samples to a standard sample. Finally the keeping quality of the oil is determined by repeating the analytical and the flavour tests after the oil has been stored under well-defined conditions for a certain period of time, either at the ambient temperature or at a somewhat increased temperature. The finished oil should be stored and bottled at a temperature as low as possible, protected from direct sunlight and avoiding contact with air (oxygen).

3. The influence of the removal of the above-mentioned substances on the desired properties of the oil is described.

vestment cost per ton of oil is considerably decreased with the increasing size of the refining plant. This is especially true for the continuous plants. As for the running costs the continuous plants have lower steam consumption, lower oil loss and lower labour requirements. The higher investment costs for continuous plants are therefore outweighed by the lower running costs, and the total production costs are lower for the continuous plants than for the batch plants.

14. It is also seen that a plant with a capacity of approximately 50 tons a day is the smallest for which continuous operation is economically motivated even if the installation of continuous plants for one or more of the four refining processes here discussed may well be considered even for smaller capacities.

Table I

Estimated machinery, building and erection costs for batch and continuous neutralization calculated for fatty oils with FFA = 3 %

Yearly capacity		12.500 t 1)		37.500 t 2)		75.000 t 3)	
	Units	Batch	Continuous	Batch	Continuous	Batch	Continuous
Machinery:							
Neutralization	US $	40,000 4)	90,000	110,000 5)	130,000	230,000 6)	160,000
Soapstock splitting	US $	20,000	50,000	40,000	50,000	80,000	60,000
Bleaching	US $	50,000 7)	140,000	150,000 8)	180,000	270,000 9)	230,000
Deodorizing	US $	60,000 10)	150,000	150,000 11)	240,000	320,000 12)	360,000
Total machinery investment	US $	170,000	430,000	450,000	600,000	900,000	810,000
Erection cost 13)	US $	45,000	85,000	95,000	120,000	230,000	120,000
Building volume 14)	m^2	140 x 2	110 x 2	260 x 2	150 x 2	560 x 2	170 x 2
Building costs 15)	US $	56,000	35,000	105,000	48,000	224,000	54,000
Total cost	US $	271,000	550,000	650,000	768,000	1,354,000	984,000
10 % annuity	US $	27,100	55,000	65,000	76,800	135,400	98,400
		298,100	605,000	715,000	844,800	1,489,400	1,082,400
Capital cost per year and ton of oil	US $	2.38	4.84	2.81	3.15	1.99	1.44

Notes to Table

1) 50 tons per 24 hours, 250 working days per year

2) 150 tons per 24 hours, 250 working days per year

3) 300 tons per 24 hours, 250 working days per year

4) 3 neutralization vessels, 10 m^3 each

5) 5 neutralization vessels, 15 m^3 each

6) 8 neutralization vessels, 20 m^3 each

7) 2 bleaching vessels, 10 m^3 each

8) 4 bleaching vessels, 15 m^3 each

9) 5 bleaching vessels, 20 m^3 each

10) 2 deodorizers, 10 m^3 each

11) 4 deodorizers, 15 m^3 each

12) 5 deodorizers, 20 m^3 each

13) 25 % of machinery cost for all batch installations and for smallest size of continuous plant, 20 % and 15 % respectively of machinery cost for bigger continuous plants.

14) For all batch plants, the soapstock splitting plant is placed outside the building, thus causing certain extra foundation costs. For the continuous plants, the soapstock spitting plant is located inside the building, and all building costs are included.

15) Building costs are calculated for a two-storey building of about 10 m height. For continuous plants, the building costs are estimated at 160 US \$ per m^2. For batch plants, where the building has to support the higher weight of the vessels including the oil content, the building costs are estimated at 200 US \$ per m^2.

Table II Average refining costs per ton of oil refined, calculated for batch and for continuous refining. Calculated for a capacity of 150 tons of oil a day.

	Units	Batch refining		Continuous refining	
Steam consumption	Kg per ton oil				
Neutralization		200		100	
Soapstock splitting		200		50	
Bleaching		70		50	
Deodorizing		600		400	
		1070		600	
Price	4 US $ per ton		4.30		2.40
Electricity	Kwh per ton oil				
Neutralization		5		10	
Soapstock splitting		2		5	
Bleaching		10		10	
Deodorizing		7		7	
		24		32	
Price	0.03 US $ per Kwh		0.72		0.96
Water	Kg per ton oil				
Dehardened water	Kg per ton of oil	400		200	
Price	0.05 US $ per ton		0.02		0.01
Cooling water of 20°C	Ton per ton of oil	50		35	
Price	0.02 US $ per ton		1.00		0.70
Maintenance, spare parts	US $ per year	30,000		60,000	
	US $ per ton oil		0.80		1.60
Labour	Man per shift	5		3	
	Man per day	15		9	
Cost a year	10,000 US $ per man/year	150,000		90,000	
Cost per ton of oil	US $ per ton of oil		4.00		2.40
Oil loss	Kg per ton oil				
Neutralization		4.80		3.90	
Bleaching		3.75		2.25	
Deodorizing		0.15		0.15	
		8.70		6.30	
Price	0.20 US $ per ton oil		1.74		1.26
Consumption of chemicals, sodium hydroxide, phosphoric and citric acids and bleaching earth	US $ per ton of oil		1.00		1.00
Total refining cost	US $ per ton of oil		13.58		10.33

Table III.

Average total refining costs per ton of oil refined, calculated for batch and for continuous refining

Yearly capacity		12,500 t		37,500 t		75,000 t	
	Units	Batch	Continuous	Batch	Continuous	Batch	Continuous
Running costs	US $ per ton oil	13.58	10.33	13.58	10.33	13.58	10.33
Capital costs	US $ per ton oil	2.38	4.84	2.81	3.15	1.99	1.44
Total costs a year	US $ per ton oil	15.96	15.17	16.39	13.48	15.57	11.77
Profit by continuous refining	US $ per ton oil		0.79		2.91		3.80
Total yearly profit	US $		9,875		109,125		285,000

LIST OF ILLUSTRATIONS

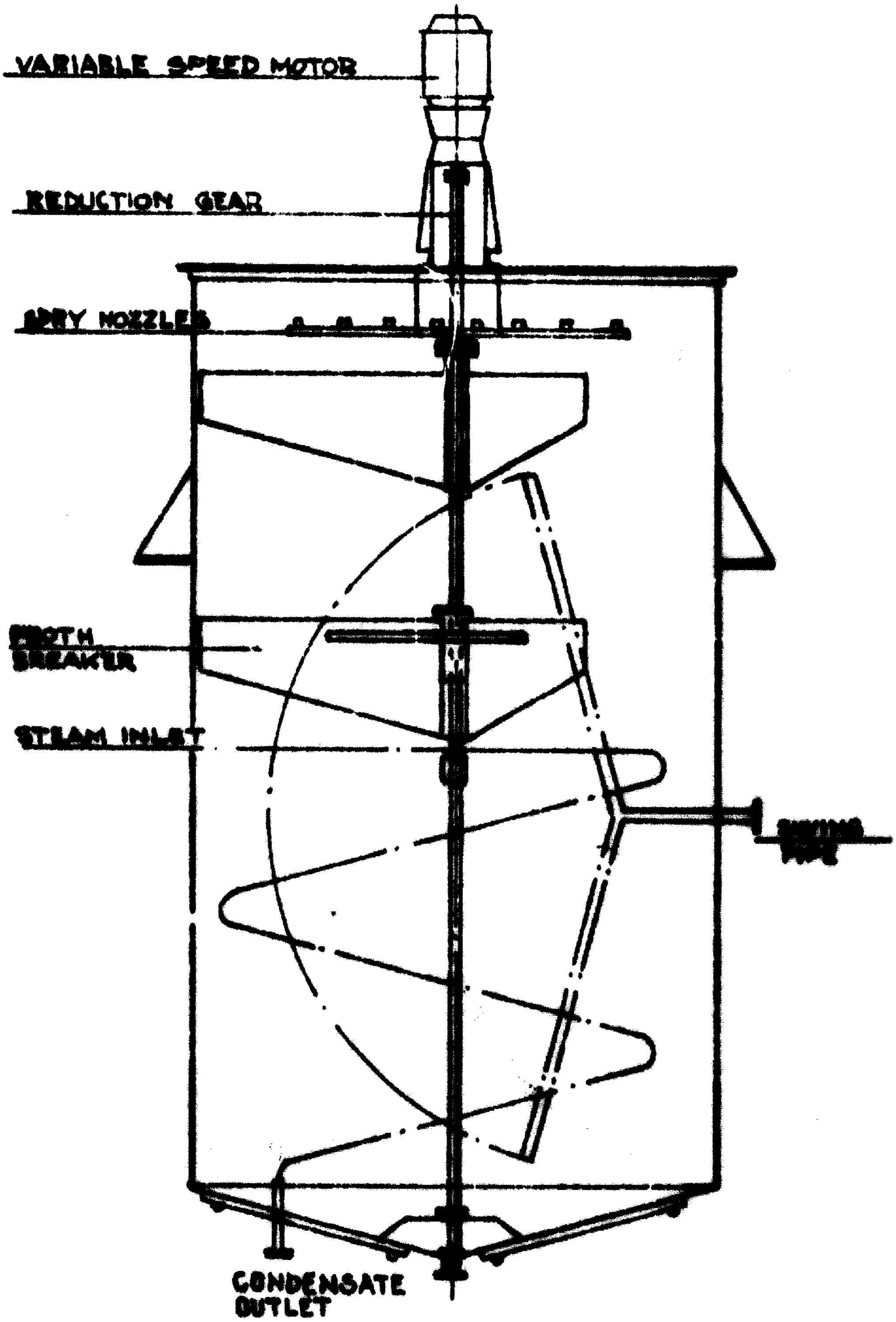

Fig 1 Open top neutralizer

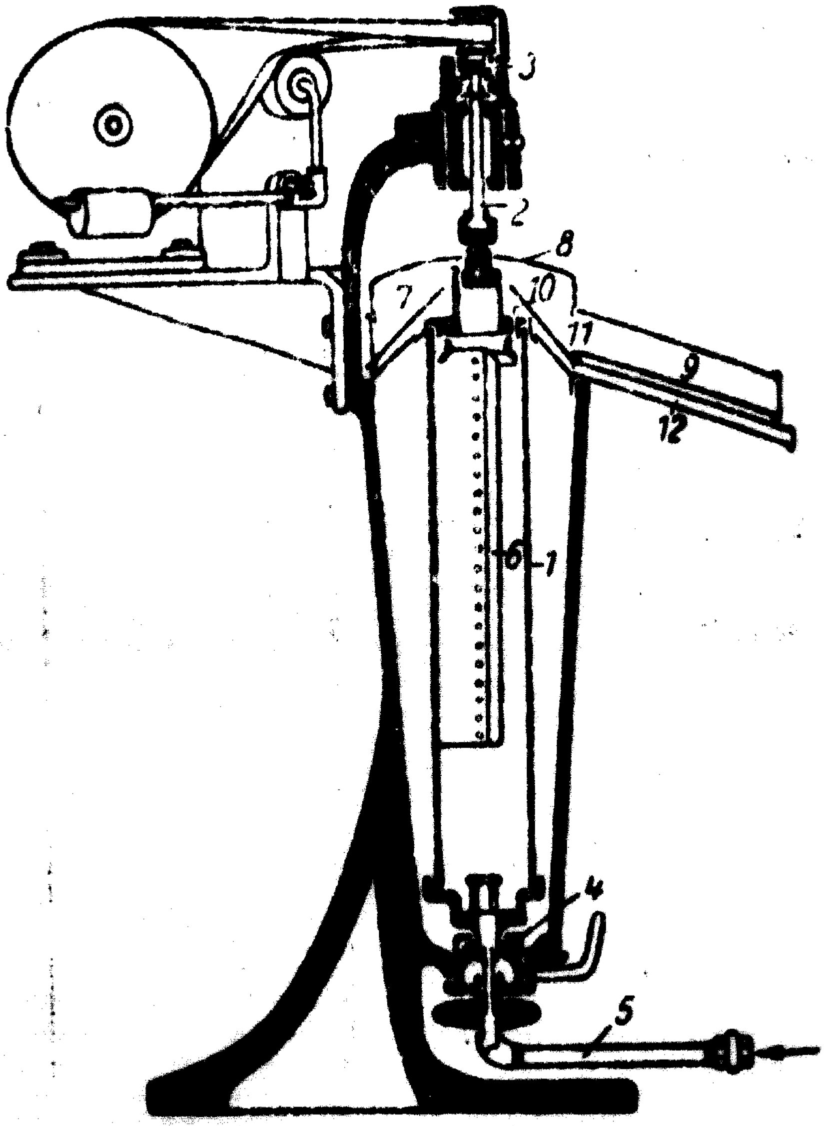

Fig 2 Open bowl separator (Sharples)

Fig 3 Hermetical separator with intermediate discs, Alfa-Laval type

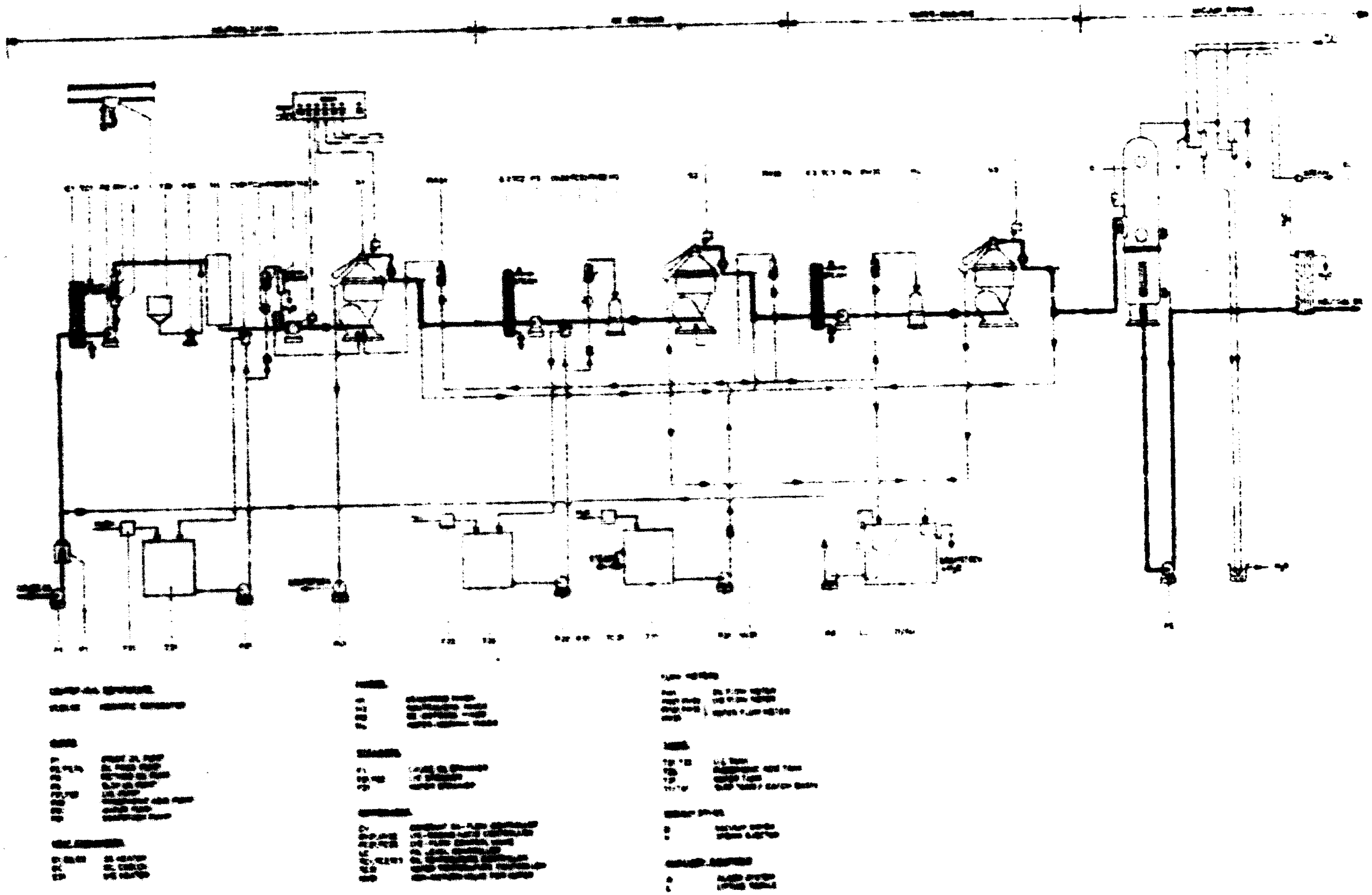

Fig 4 All-hermetic Short-Mix continuous alkali neutralisation plant

II. THE REFINING PROCESS

The removal of substances harmful to the use of the oils for edible purposes is most often carried out by three different treatments - alkali refining - bleaching and deodorization - all of which have traditionally been carried out batch-wise.

III A. THE ALCALI REFINING

1. In the first process the free fatty acids are neutralized with sodium hydroxide forming the so called soapstock which has a higher specific gravity than the oil so that the two phases can be separated by gravity settling or by centrifugal force. Normally a certain excess of caustic is used in order to remove some of the other impurities contained in the oil. Other chemicals lika phosphoric acid may be added to the oil prior to the neutralization in order to remove certain components, especially non-hydratable phosphatides, which are not completely removed by caustic treatment alone.

2. A short description of the equipment used for batch refining is given and the technique of batch refining and its limitation are described.

3. Continuous neutralization plants using centrifugal separators giving the advantage of lower neutralization losses, lower consumption of utilities, smaller space and labour requirements are described.

III B. THE BLEACHING PROCESS

In the bleaching process the oil is treated with activated clay, which adsorbs the pigments in the oil, the bleaching earth then being removed by filtration. In order to reduce the oil losses the bleaching earth may be percolated with water, blown with steam or extracted with a solvent. Both batch-wise bleaching and con-

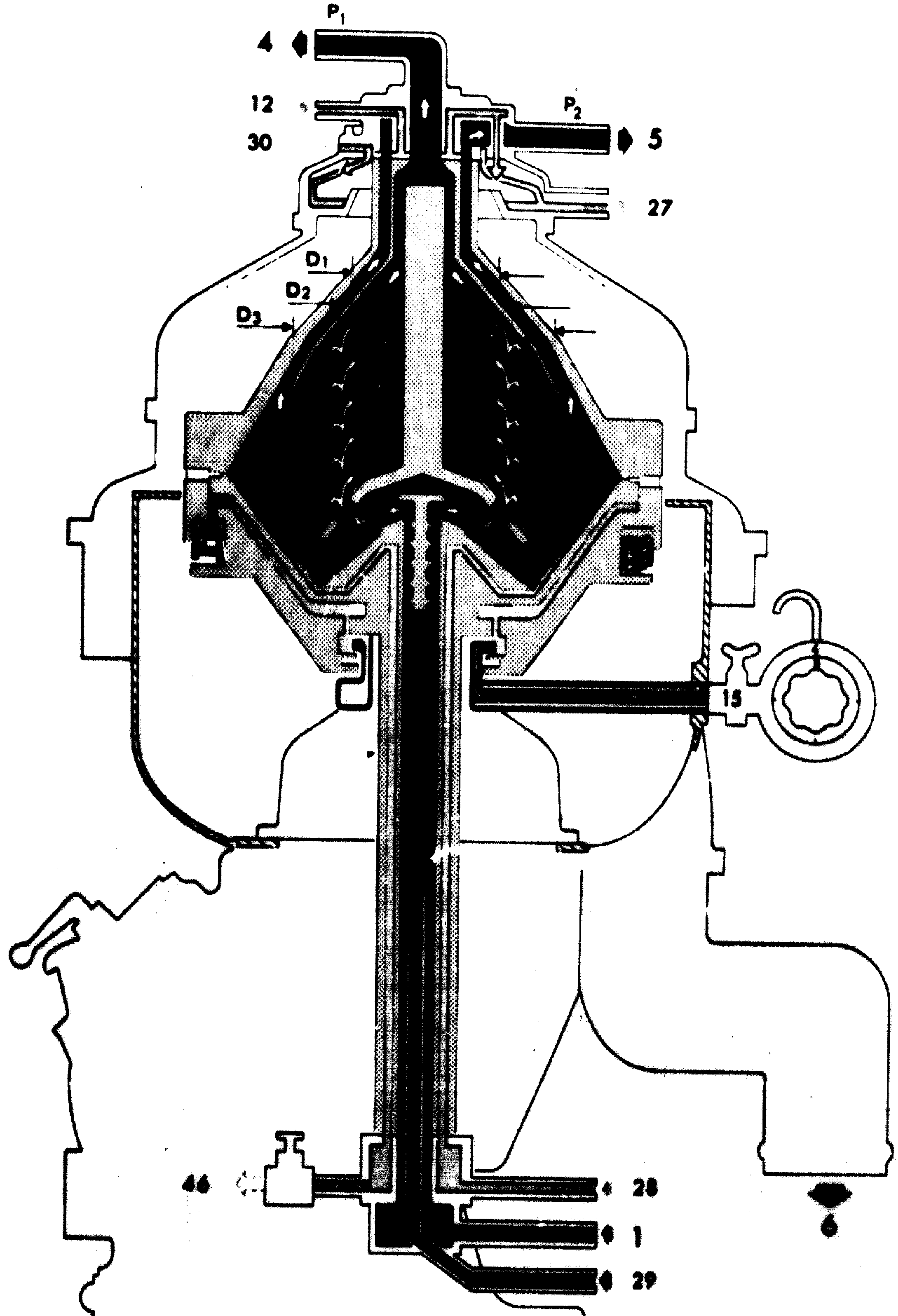

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Fig 5 Hermetic and self-cleaning separator

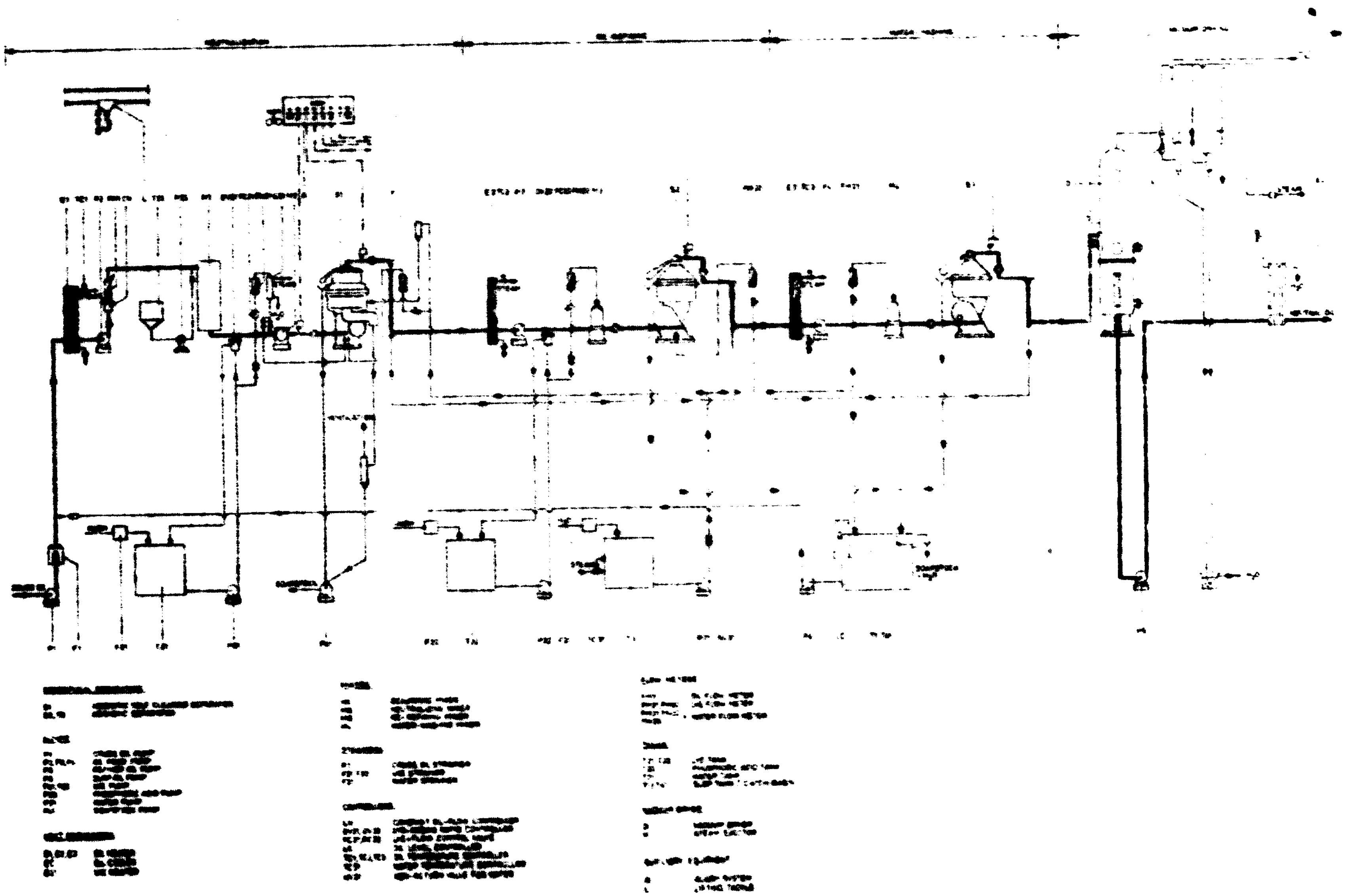

Fig 6 Continuous all-hermetic neutralization plant, using self-cleaning separator

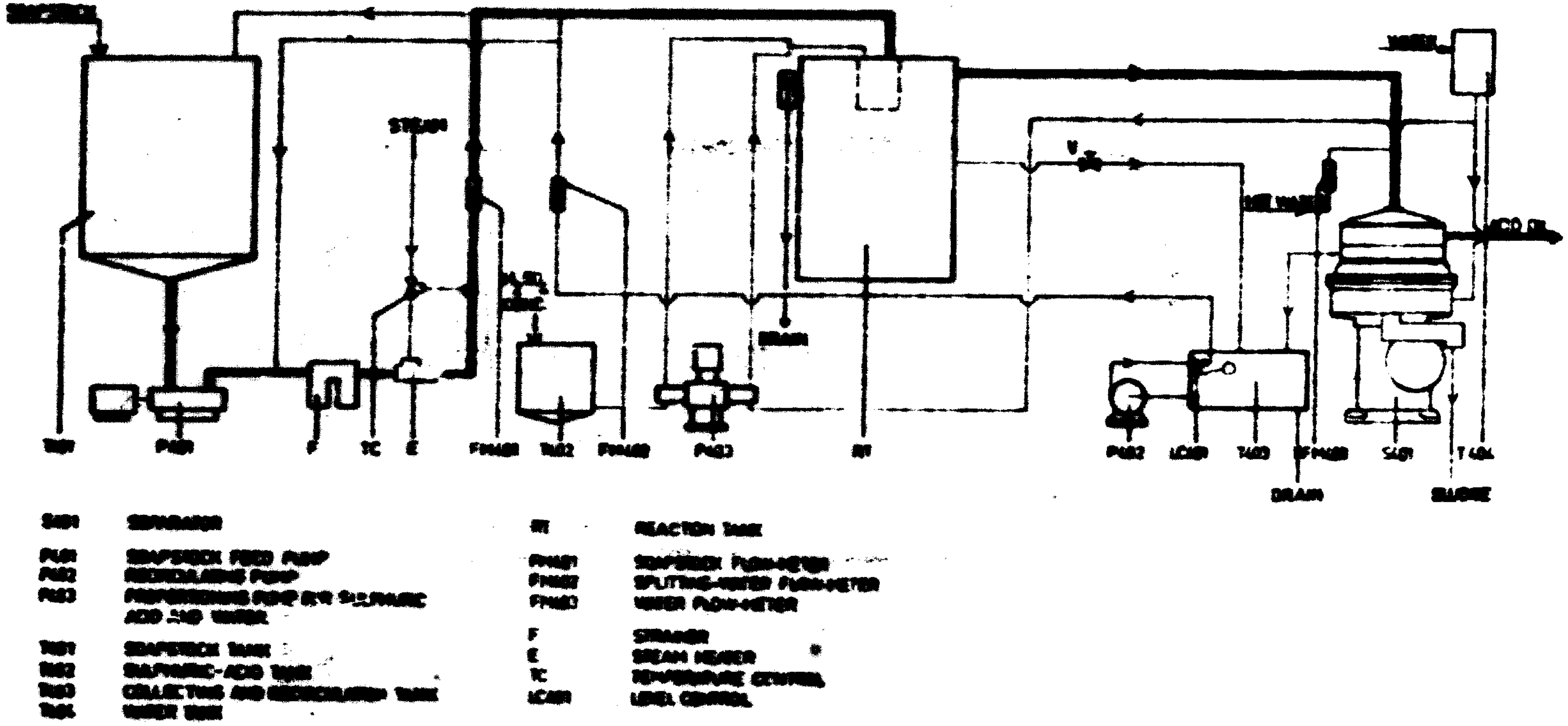

Fig 7 Continuous soapstock splitting plant

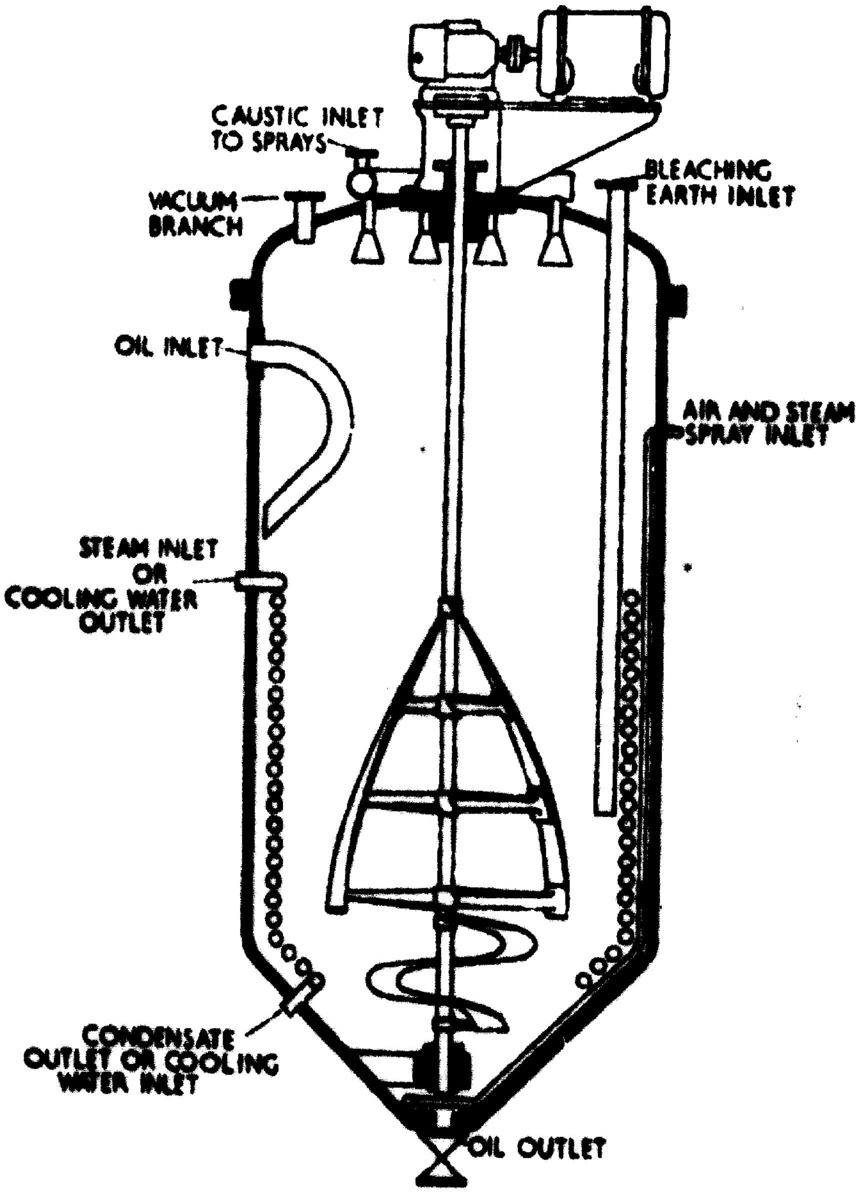

Fig 8 Vacuum batch bleacher

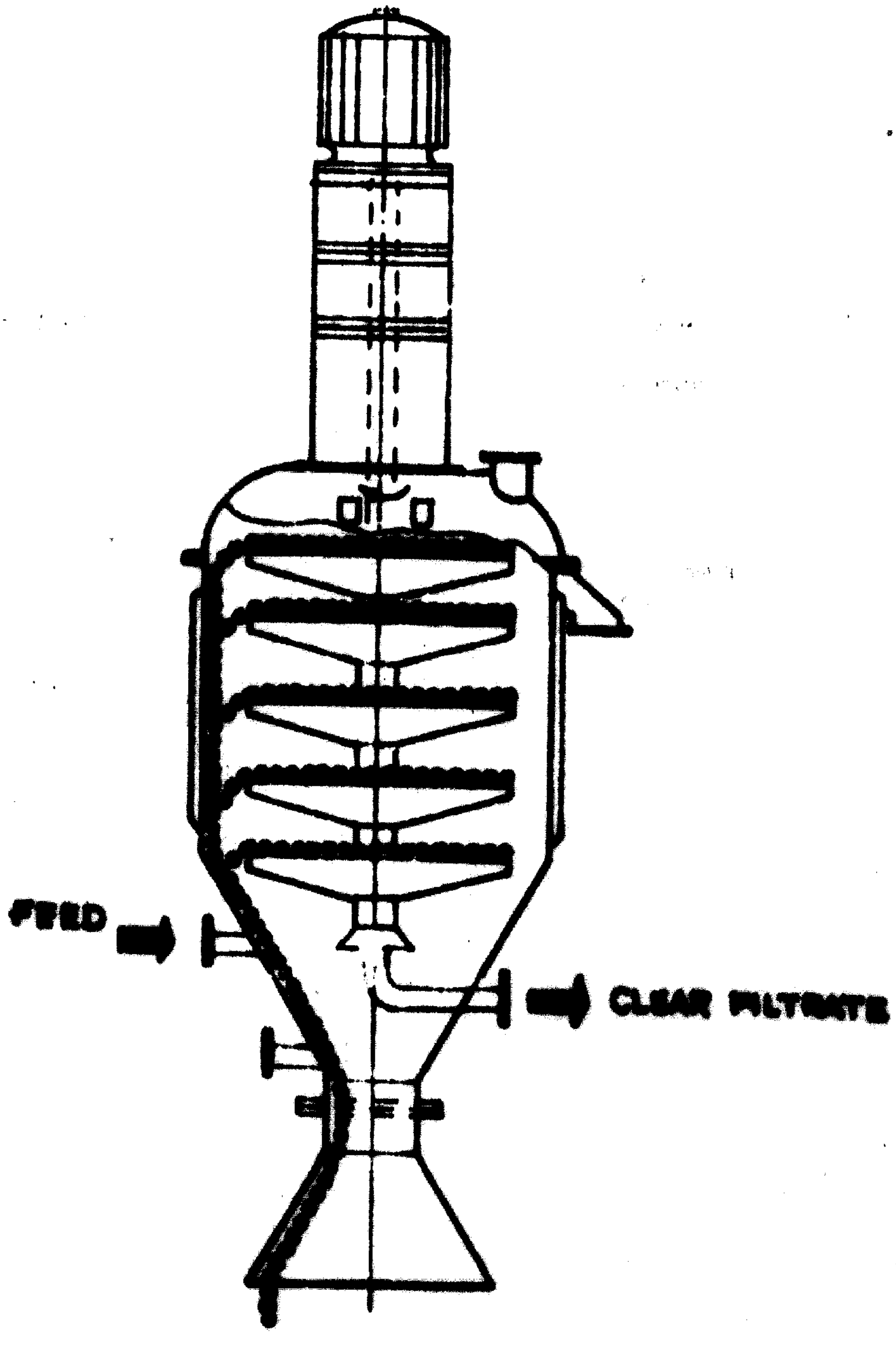

Fig 9 Funda filter

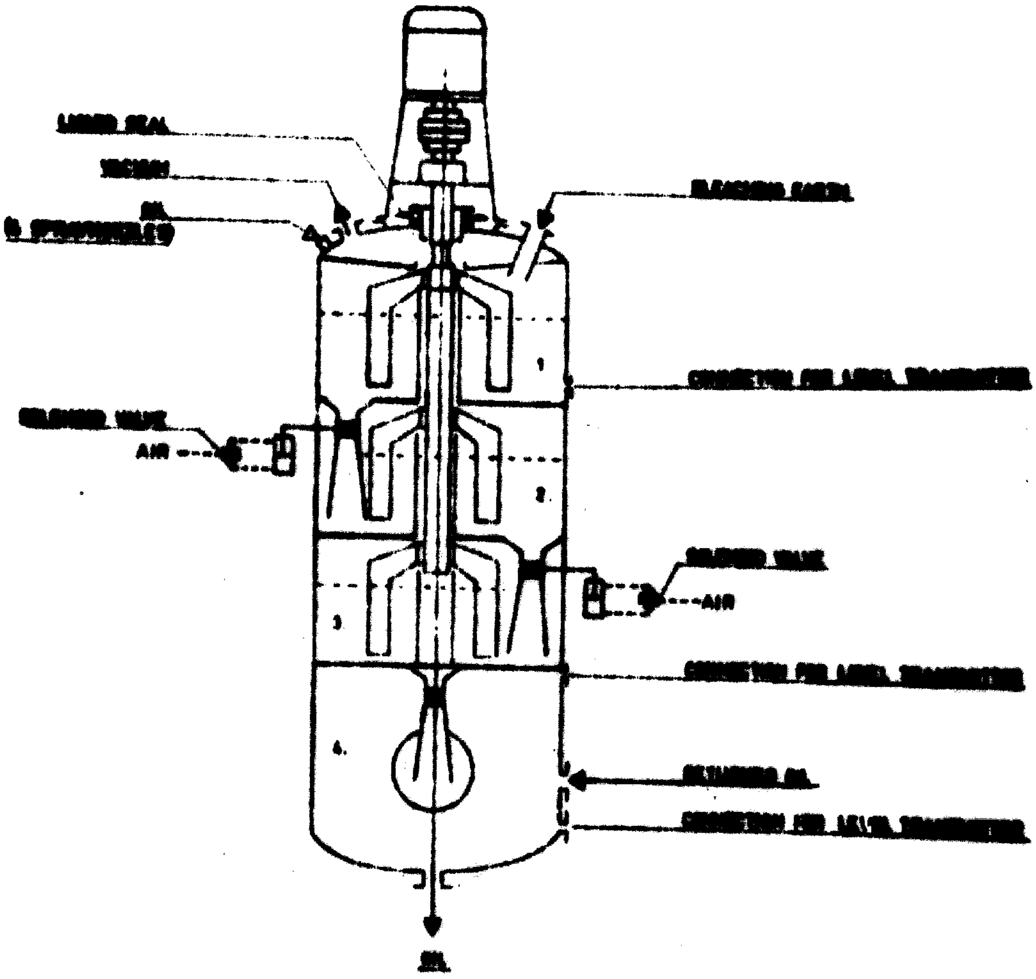

Fig 10 Continuous bleaching vissel

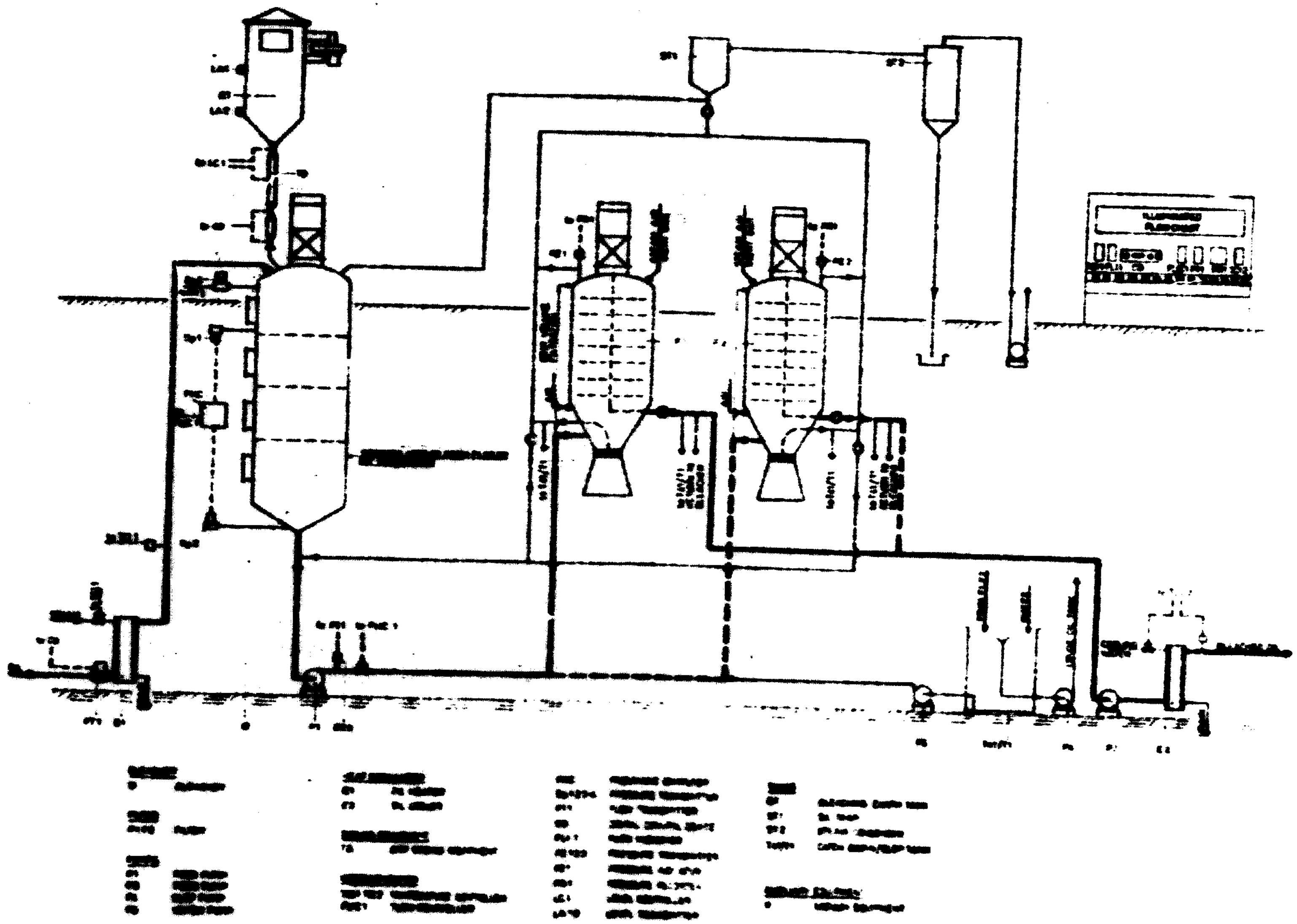

Fig 11 Auto-Bleach process

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tinuous bleaching and the equipment used are described. The continuous method reduces the amount of bleaching earth necessary and therefore also reduces the oil losses. When self-cleaning automatical filters are used the tedious and labour-consuming cleaning of the filters can be avoided.

III C. THE DEODORIZING PROCESS

1. The deodorizing process is essentially a steam distillation process carried out under vacuum, where the steam passed through the oil carries away odoriferous material thus improving the flavour and the odour of the oil.

2. Batch and continuous equipments for carrying out the deodorisation process are described. Modern continuous deodorizers made in stainless steel allow a considerably higher deodorization temperature and the steam is passing only a thin layer of oil for which reason the steam consumption is considerably reduced.

IV. THE CONTROL OF THE REFINING EFFICIENCY, STORAGE AND PACKING OF REFINED OILS.

1. Traditionally, the refining efficiency, especially in the alkali refining, has been expressed as refining factor, i.e. the quotient between the total loss and the amount of free fatty acids contained in the oil. As many oils contain other impurities such as sludge, water, phosphatides, pigments and so on it is more correct to compare the actual refining loss with the theoretical minimum loss which can be analytically determined by the Wesson loss method or the chromatographic loss method. Even though the actual refining loss may be estimated by deternation of the amount of soapstock or bleaching earth and by analysing its fat content, such methods are tedious and time-consuming. The volumes of crude and refined oil may also be measured during the refining but the change in specific gravity of the oil with the temperature may introduce errors.

2. The safest and most exact way of determining the losses is by weighing the oil before and after the refining treatment in question. Having two scales it is possible by means of a small computer to read the actual refining loss at any moment during the operation.

V. ECONOMIC ASPECTS

1. The investment costs including building, machinery and erection costs as well as the running cost for batch plants and continuous plants with yearly capacities of 12,500, 37,500 and 75,000 tons of oil are given. Only the refining plant proper is taken into consideration.

2. The calculation shows that the investment cost per ton of oil is considerably decreased with the increasing capacity of the refining plant. This is especially true for the continuous plants. As for the running costs the continuous plants have lower steam consumption, lower oil loss and lower labour requirements. The higher investment costs for continuous plants are therefore outweighed by the lower running costs and the total production costs are lower for the continuous plants than for the batch plants.

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THE VEGETABLE OIL REFINING PROCESS AND ITS INDUSTRIAL ECONOMY

I. INTRODUCTION

1. Fats are an important part of the human diet and are contained in larger or smaller amounts in most types of food stuffs used for human consumption. Since ancient times three types of nearly pure fats, for instance olive oil, butter and animal fat such as lard and grease have played a traditionally important role in human diet.

2. When newly produced all these fats have a natural pleasant odour and taste and are therefore palatable without any chemical treatment. Only purely mechanical operations such as pressing, clarifying, churning and melting are necessary to obtain the desired product.

3. The increasing demand for fats, especially since the introduction of the margarine industry, has made it necessary to look for substitutes for the traditional fats and fortunately enough the fruits of many plants do contain large amounts of fats. At the same time the natural growth cycles of many of these plants allow a much more rapid reproduction of the fats than what is possible in the case of animal fats or for that matter of olive oil.

II THEORETICAL ASPECTS AND QUALITY CONTROL ASPECTS

1. The main constituents of natural fats and oils are, of course, the triglycerides which are esters of various fatty acids with the trivalent alcohol glycerol. The most important fatty acids contained in the fat are lauric, myristic, palmitic and stearic acids, all of which are completely saturated; oleic and

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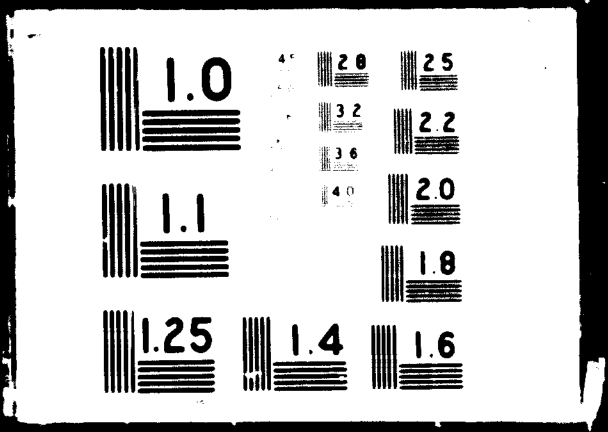

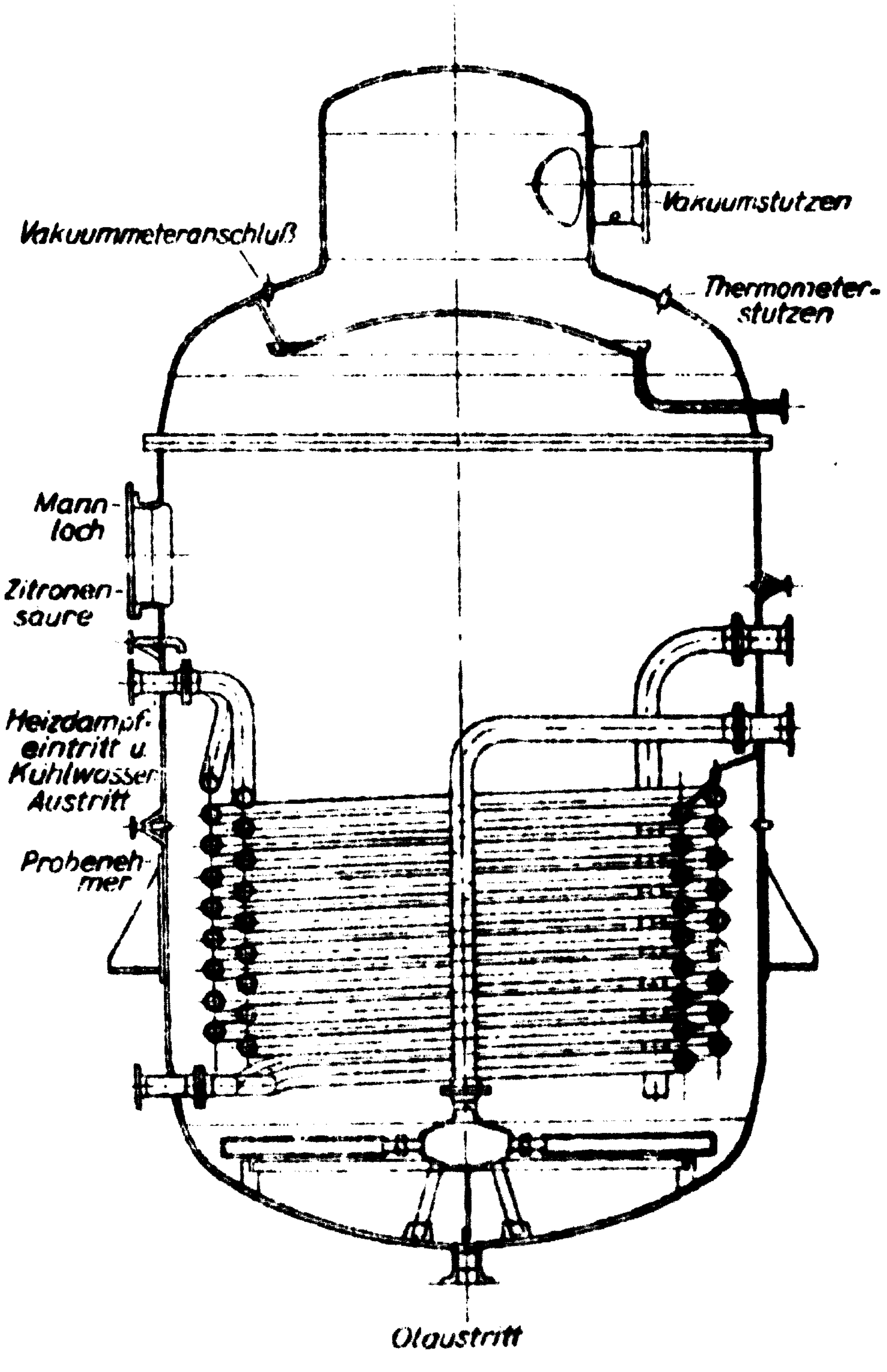

Fig 12 Batch deodorizer

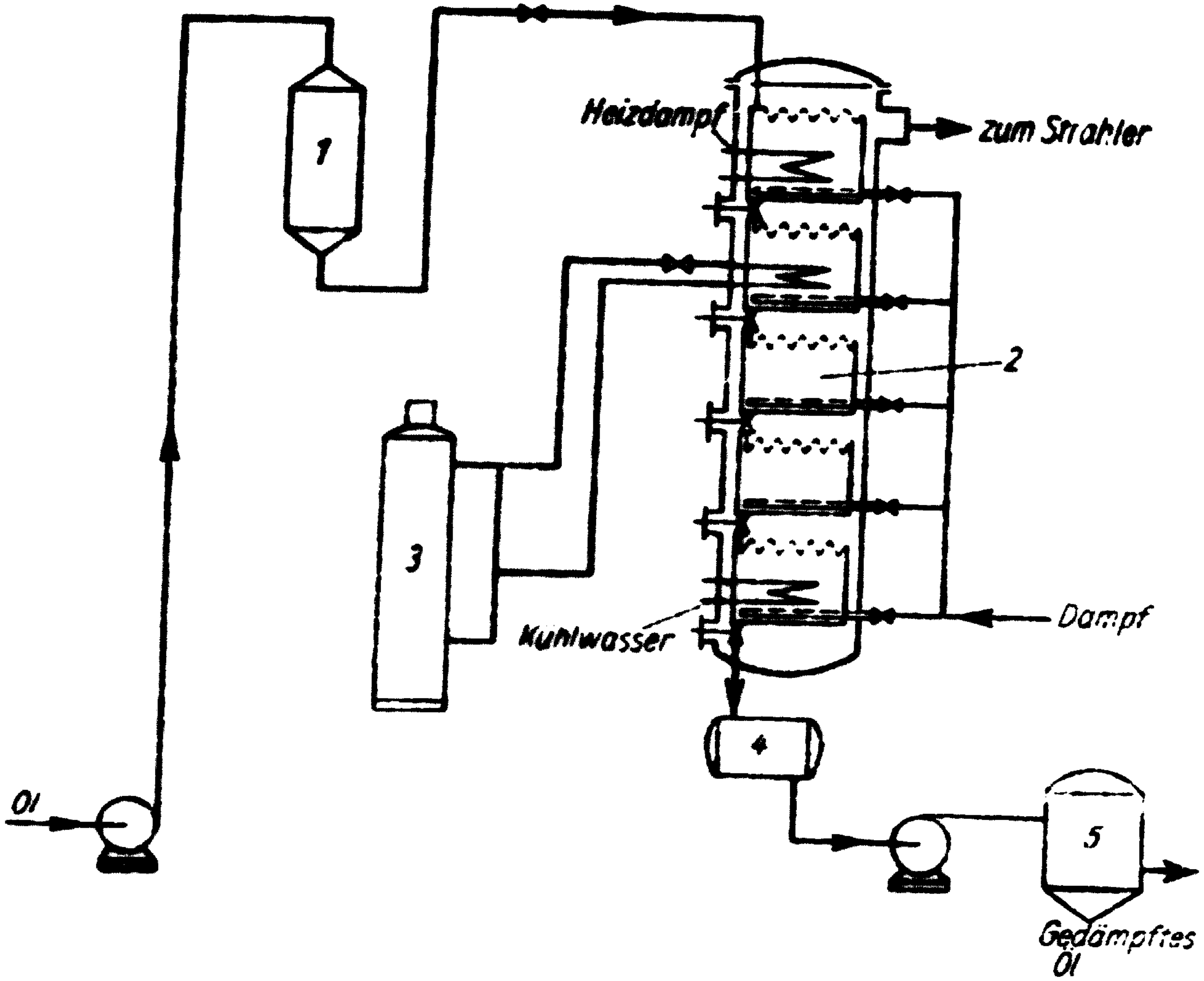

Fig 13 Semicontinuous Girdler Deodoriser

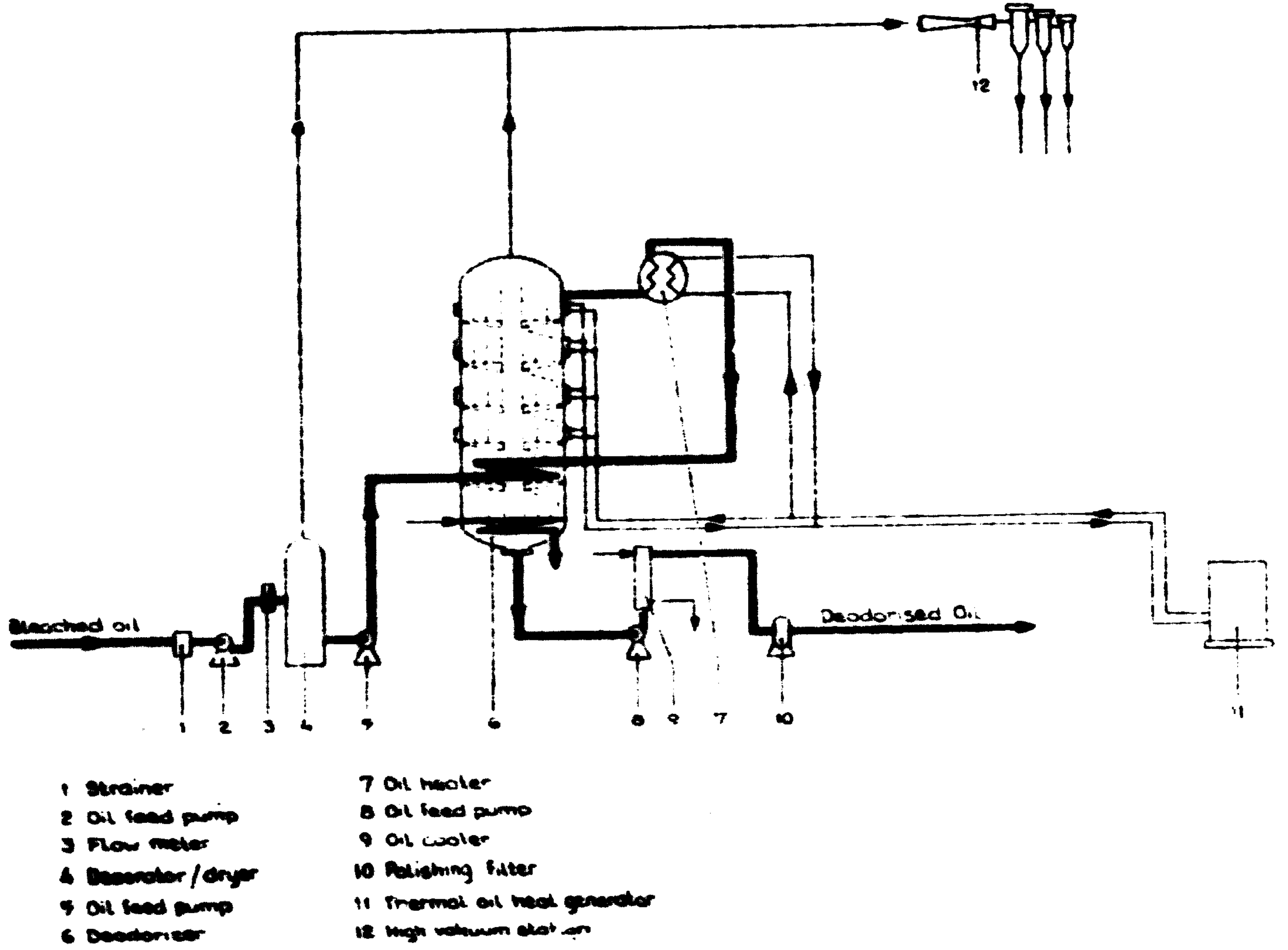

Fig 14 Continmous corss-stream deodorizer

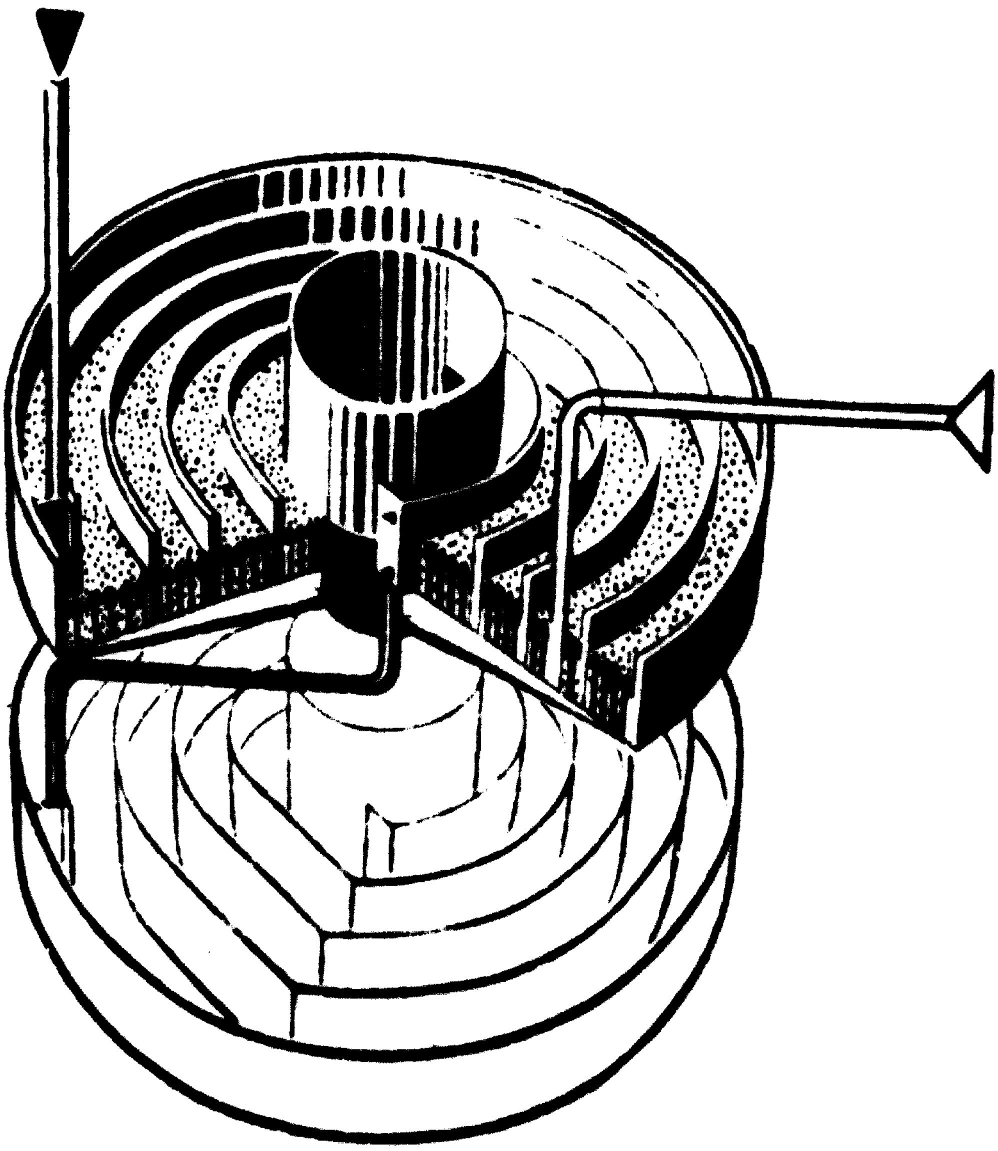

Fig 15 Principle of cross-stream deodorizer

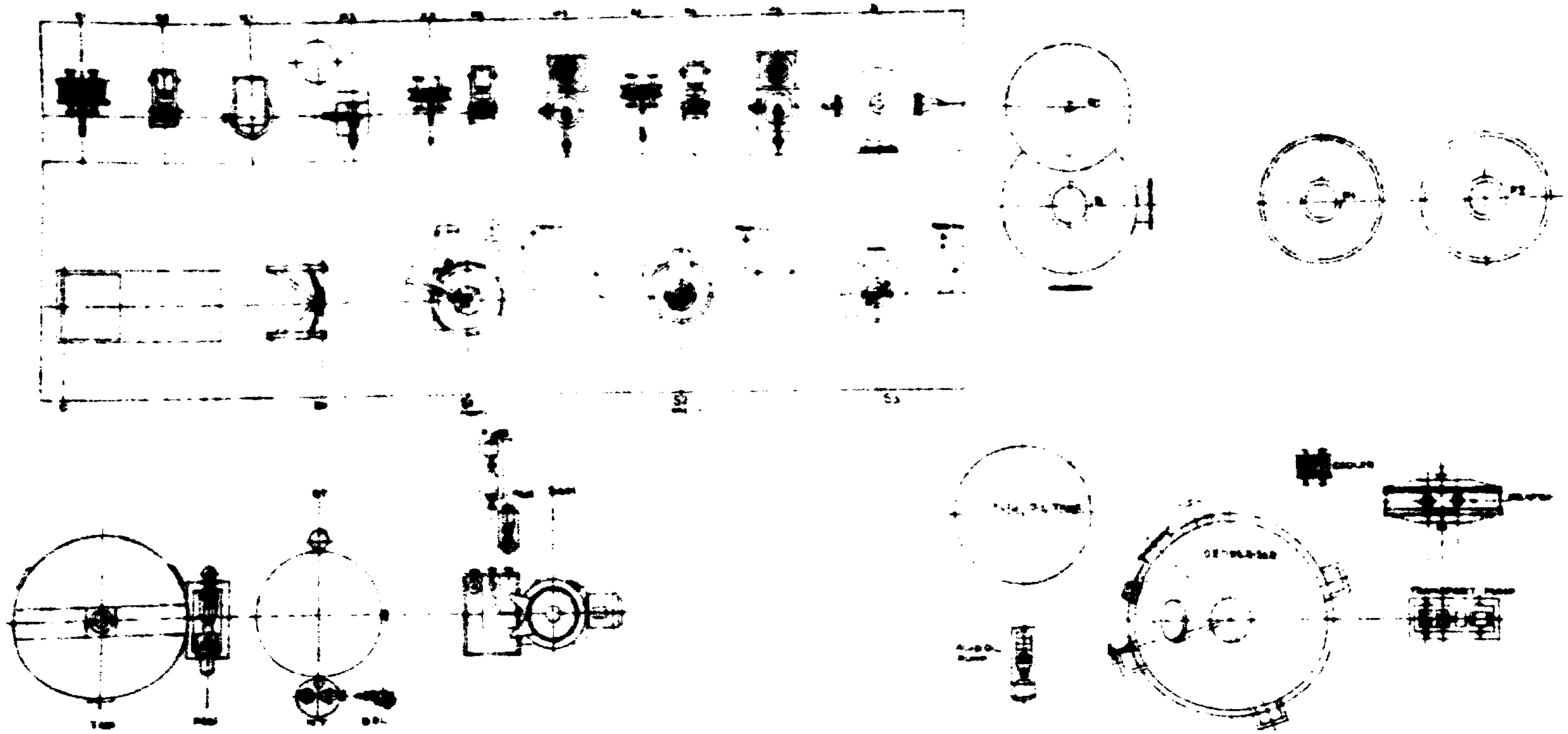

Fig 16 Layout of a completely continuous vegetable oil refining plant comprising neutralization, soapstock splitting, bleaching and deodorizing, 150 t/capacity

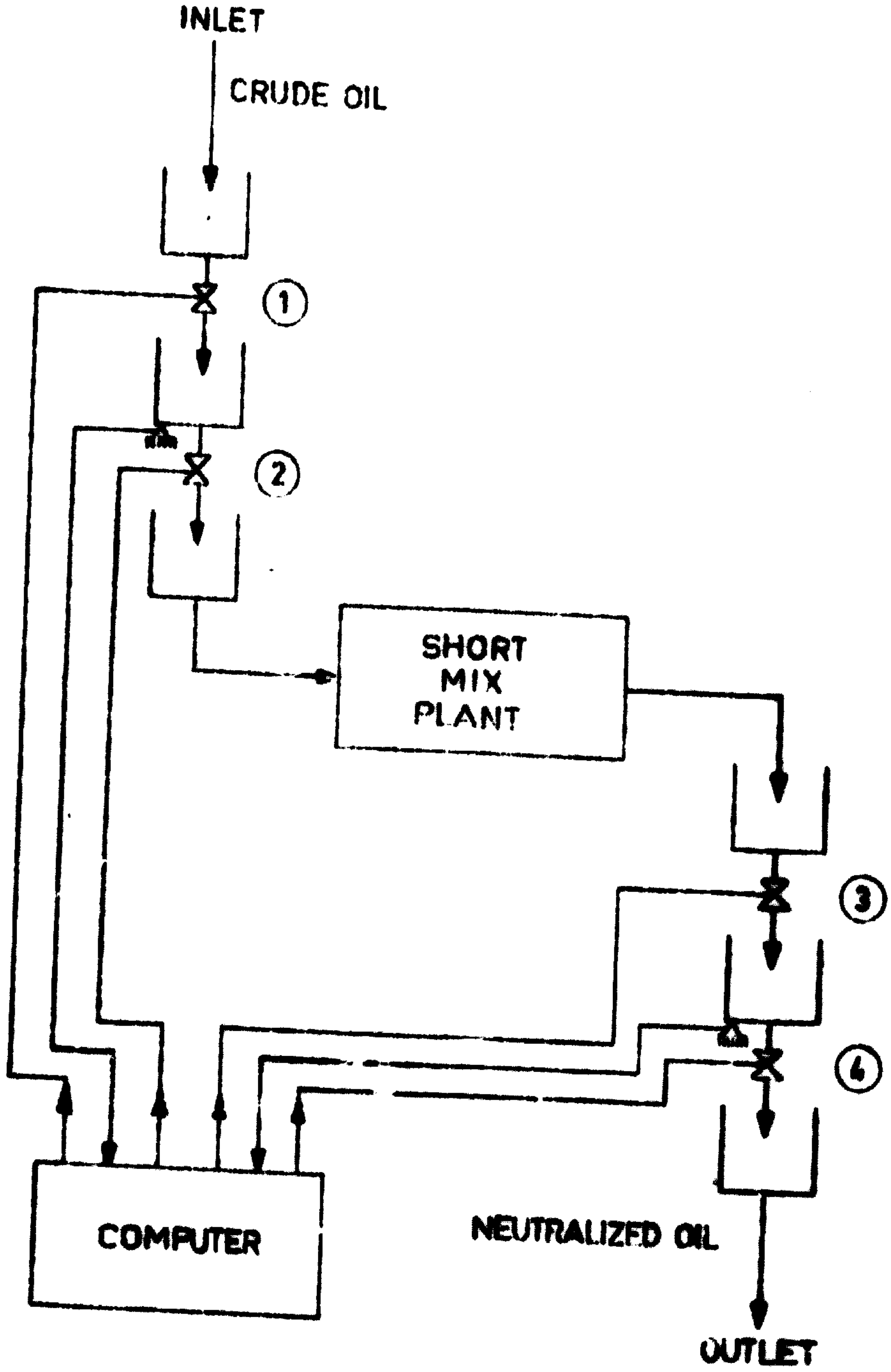

Fig 17 Automatic weighing system

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