NOTES

ON THE

SELECTION OF RUBBER FACTORY EQUIPMENT

AND THE

MANUFACTURE OF SMOKED SHEET*

BY

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Introduction

Extensive improvements have taken place in the last few years in equipment for the manufacture of smoked sheet rubber on estates. The slump conditions of 1932 caused close attention to be directed to the reduction of sheeting and curing costs, and while much was done at that time to effect economies, other ideas emerged which were recognised as good, but which involved a capital outlay difficult to justify at that time. The improved conditions under Restriction have persuaded most Companies that such capital outlay could be justified, so that most factories now have up-to-date equipment consisting of aluminium-lined coagulating tanks, and power-driven, line-ahead sheeting batteries, and are so arranged that handling of the coagulum has been reduced to a minimum. The result is that estate factory work has been much improved, and that a cleaner, more uniform sheet is being produced at a lower cost. One result of the emphasis placed on the value of new machinery and equipment has been to induce a feeling that further improvements in sheet manufacture must, of necessity, wait on further improvements in tanks and rolling machinery.

Although work is being carried out continuously to this end, and it is dangerous to prophesy what future developments may be, it seems unlikely that there will be any far-reaching changes in the next few years. Manufacturing costs are now so low that a saving of 10 per cent. on the coagulation and machining costs would have an almost negligible effect on the f.o.b. costs of the estate. Thus, even if new designs are produced shewing savings of this order, those estates which have recently purchased

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new machinery will not find it economic to scrap the existing equipment and replace it with the new type, until the present machinery gets badly worn, or has been written off by depreciation. It is therefore apparent that attention to factory organisation, and the methods of operating existing types of machinery, present the most promising methods of attaining further economies. Any small reduction of cost obtained, for example, by reorganising the factory labour is a direct saving, since it does not have to be set off against the cost of new equipment.

Another consideration which has prompted the writing of this paper is that our recent experience of advisory work indicates that drying remains the most troublesome part of smoked sheet manufacture. Defects due to dirt, fermentation etc., have been largely overcome with present equipment, and the smoke-house remains to be blamed for most of the defects that now arise in smoked sheet. While it is true that the curing process is the most difficult one to control, and the one most likely to give trouble, the fact remains that by strict attention to details of procedure in the factory much can be done to facilitate the drying and smoking.

Ideal Conditions for Drying

The manifest advantages of rapid drying have been, if anything, over-emphasised during the last few years. Rapid drying has obvious advantages, in that a much smaller smoke-house is required to deal with a given daily crop, and space and capital outlay are thereby saved. A large saving in fuel is also frequently claimed for this method. The disadvantages of very rapid curing are less obvious but are none the less serious.

The two major ways in which drying can be accelerated are by the production of thinner sheet, and by the use of higher temperatures. Very thin sheet is not easy to produce, since close control over the coagulation is required, and the machines must be in good condition. Any wear in the bearings will cause the rolls to spring open as the rubber enters. Very thin sheet may prove difficult to handle as the lower ends tend to stick together when it is hung over *beroties*, and the massing together when the sheet is piled is more pronounced. The production of thin sheet reduces the output of the machines, thereby increasing the running costs. In some cases it would be necessary to reduce the dry-rubber-content at which the rubber is coagulated, in order to get thinner sheet, and this would involve more machining as well as increased expenditure on tanks. Finally, the thinner sheet occupies a greater space per lb. in the smoke-house.

The use of higher temperatures is also likely to give rise to difficulties, since this method involves the operation of the smoke-house at temperatures much nearer the danger limit at which blisters are formed on the sheet. To maintain an operating temperature near this danger limit, without damaging a proportion of the sheet, necessitates a close temperature control. This can be obtained automatically if heating is carried out by steam, oil, or electricity, but is almost impossible to secure with a direct wood fire. Another objection to the use of higher temperatures is that the heat loss from the smoke-house to the surrounding air is thereby increased. This heat loss is quite a large factor in the efficiency of the smoke-house. The heat lost by convection and radiation per unit area is given by a formula of the type

$$q = \alpha \left\{ \left(\frac{T_1}{100} \right)^4 - \left(\frac{T_2}{100} \right)^4 \right\} + b \; (T_1 - T_2)^n$$

where α is a constant depending on the emissivity of the surface.

T_1 and T_2 are the absolute temperatures of the surface and the surrounding air, respectively.

b is an empirical constant approximately = 2.9.

n is an empirical coefficient approximately = 1.2.

A rough numerical example will best indicate the magnitude of the loss.

Assume α = 3.6 (which is the Peclet figure for brick or wood).
Let the wall temperature be 35° C = 308° Abs.
Let the air temperatures be 27° C = 300° Abs.

$$\text{Thus } q = 3.6 \left((3.08)^4 - (3.0)^4 \right) + 2.9 \; (8)^{1.23}$$
$$= 66.3$$

i.e. Heat loss = K × 66.3.

Now let wall temperature be increased by 3° C.

$$q = 3.6 \left\{ (3.11)^4 - (3.0)^4 \right\} + 2.9 \; (11)^{1.23}$$
$$= 84.1$$

i.e. Heat loss = K × 84.1.

Thus a 3° C rise in wall temperature gives an increase of 26.9 per cent. in the heat loss.

This disadvantage of increased heat loss may be overcome by paying careful attention to the thermal insulation of the building. No matter what working temperatures are used the effective insulation of the smoke-house is important, but as operating temperatures increase this problem becomes increasingly serious and expensive.

Finally, the curing process involves smoking in addition to drying. Thin sheet dried rapidly is frequently very pale in colour.

Such sheet is not only less resistant to mould attack, but there is also some prejudice among manufacturers against the use of this pale-coloured rubber. A corresponding preference for reasonably dark sheet has grown among buyers.

The arguments against the production of very thin sheet and rapid drying have been emphasised to shew that there is a limit to the progress which can be made in this direction, and it appears that this limit is being approached with the factory equipment and smoke-houses now available. It is possible to dry rubber in from two to three days, but for the reasons given it is still recommended that provision should be made for four days. A number of types of smoke-house in which sheet not excessively thin can be dried in four days are now available. Thus, with the smoke-house, as with the factory machinery, the immediate problem is to make the best use of the present types, rather than to evolve new types, since although there is undoubtedly scope for improvements in smoke-house design, changes are likely to be confined to those affecting ease of handling, and reductions in initial cost, rather than radical alterations in ventilation, drying time etc.

It thus becomes apparent that the immediate ideal for curing rubber is a smoke-house of a type which is already available, but which is economical and as nearly automatic as is possible. The process must be so arranged that once the degree of ventilation is set, and the labourer has been trained to keep a reasonably level fire, the rubber can be dried consistently to good quality sheet, with a minimum of supervision. This cannot be achieved unless the wet sheet which reaches the smoke-house is uniform. It is now proposed to discuss the factory equipment and processes, paying particular attention to those factors which can assist in the preparation of uniform sheet.

Factory Lay-out

All modern factories are arranged on one of two standardized systems. The earlier system employs two lines of stationary coagulating tanks butting on to a central chute which conveys the coagulum to the machine, as shewn in Fig. 1. This arrangement is improved by the use of the flooding system with which the coagulum may be floated over the end of the tank into the chute. In the more recent system the coagulating tanks are mounted in pairs on trolleys which run on a track at right angles to the centre line of the battery, and so arranged that each tank in turn may be pushed along until its end is opposite and close to

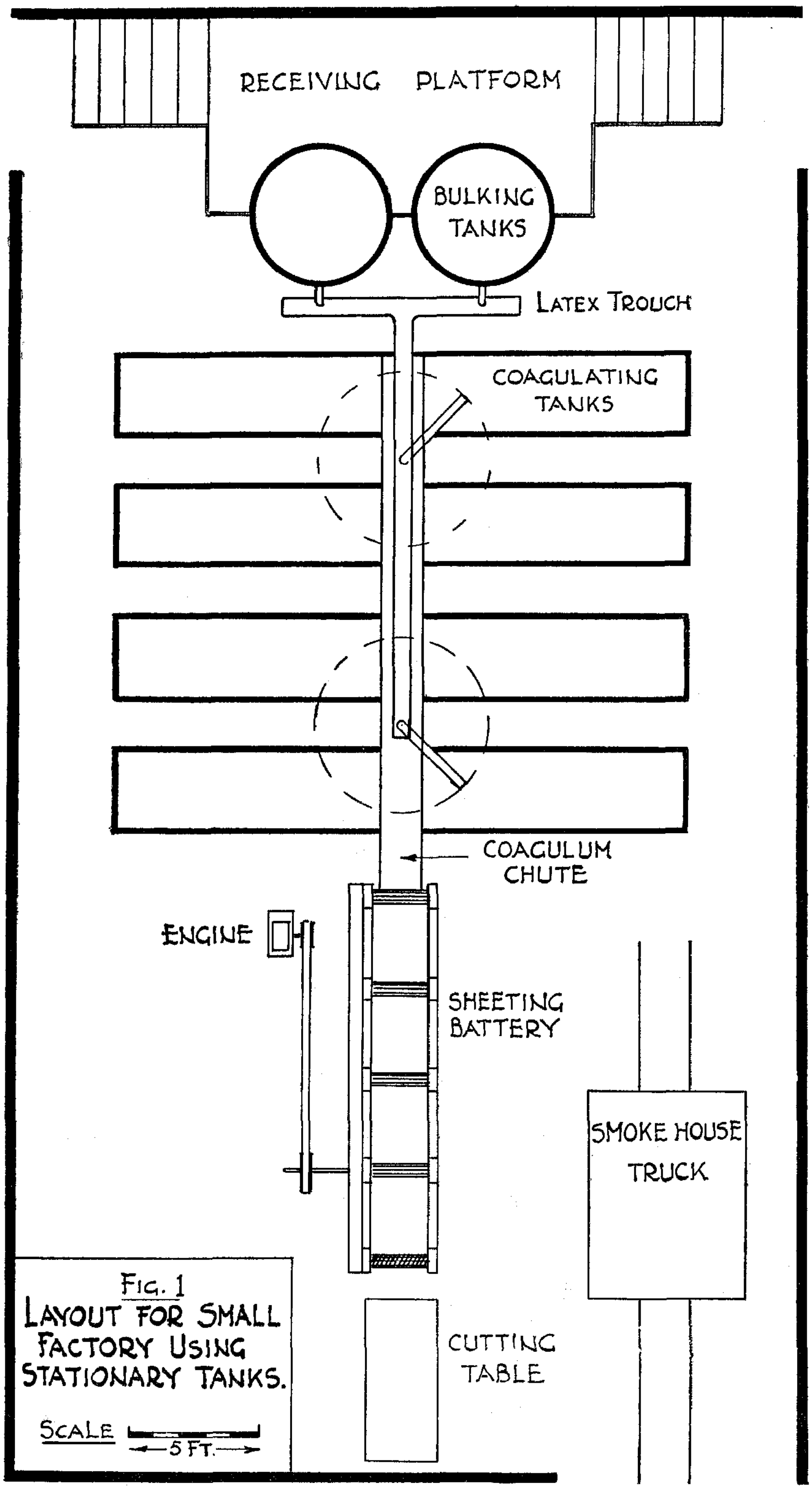

FIG. 1
LAYOUT FOR SMALL FACTORY USING STATIONARY TANKS.

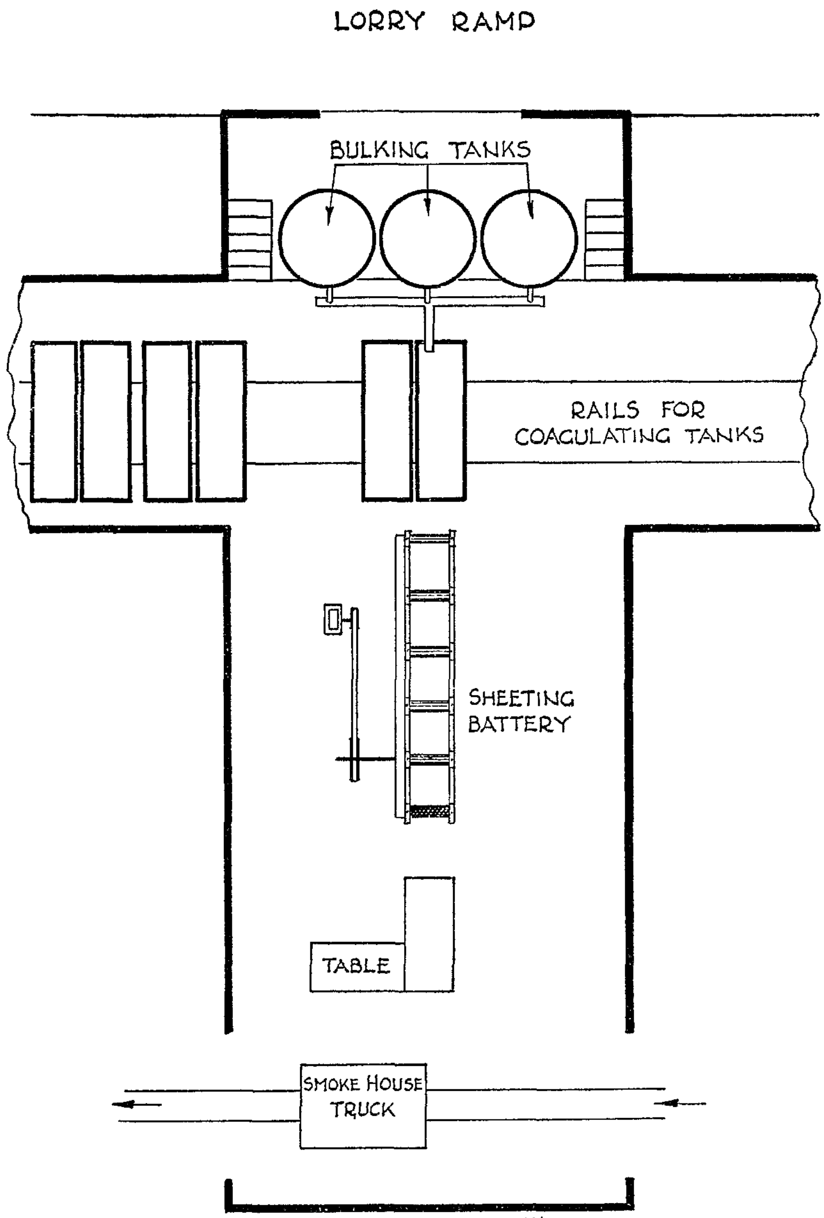

FIG. 2
- LAYOUT FOR MEDIUM SIZE FACTORY USING TANKS ON TROLLEYS.
SCALE 8 FT

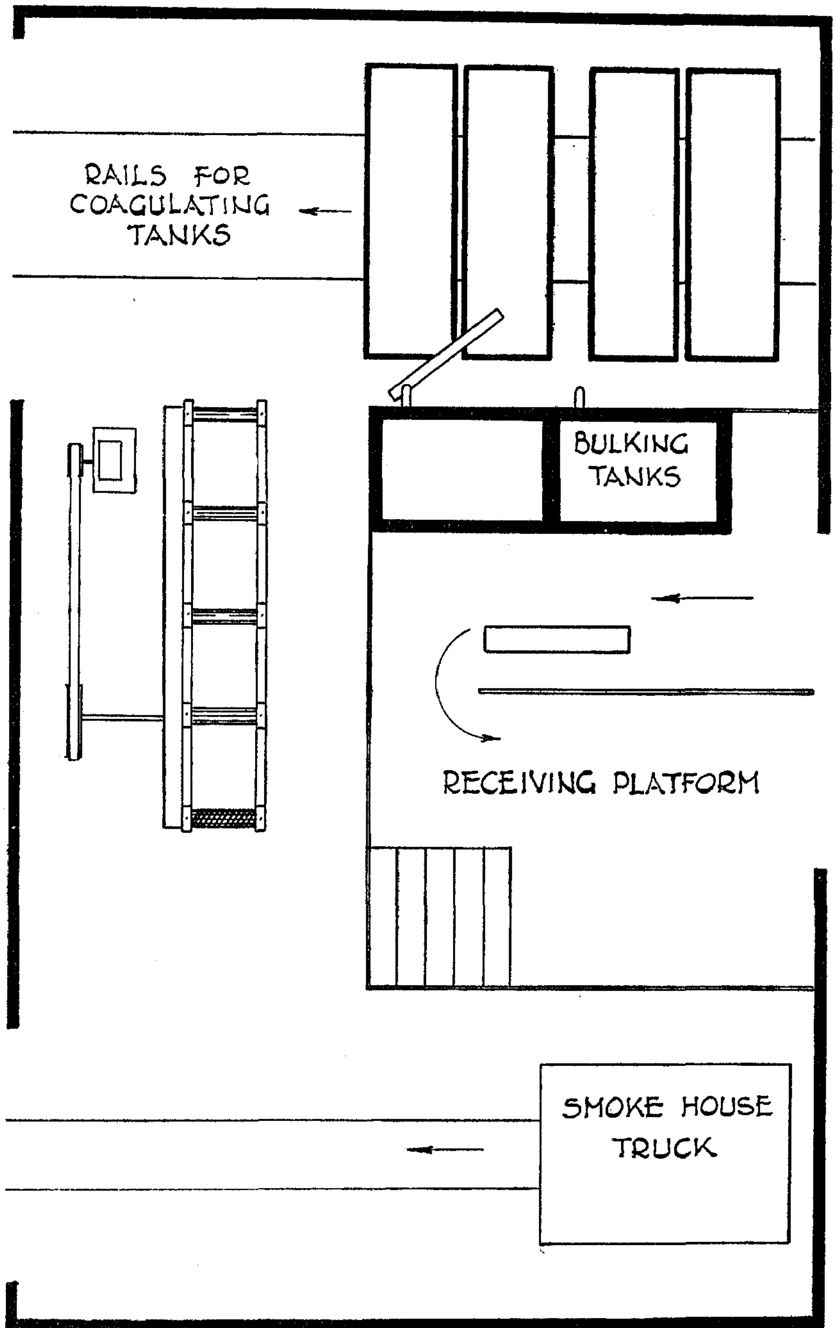

FIG. 3
LAYOUT FOR SMALL FACTORY USING TANKS ON TROLLEYS.

SCALE ← 5 FT. →

the first pair of rolls, as shewn in Fig. 2. An interesting modification of the arrangement has been developed by Mr. D. J. Gibson of Beradin Estate and is depicted in Fig. 3.

For small estates, having not more than eight coagulating tanks, the central chute system either with or without flooding attachments is very satisfactory, and is cheaper in initial cost than the rail system. The arrangement shewn in Fig. 3 also gives a very compact factory and has the advantage of requiring less water. It also makes it possible to dispense with one labourer when high machine outputs are not required. With the fixed tanks it is necessary to have one man lifting coagulum from the tank and one feeding the machine, but in the other system the one labourer can do both, provided the machining is stopped when each tank is finished and the whole factory staff is set to remove partitions from the next tank and push it into position. This lay-out more readily lends itself to extensions, than does the one using fixed tanks.

For estates having larger crops and requiring from ten to twenty tanks, the scheme shewn in Fig. 2 seems to give the best arrangement. By employing one man to remove partitions, push tanks, and assist the labourer feeding the machine, a fast uniform rate of feed to the battery can be obtained, whereas with fixed tanks and a long central chute an extra man may be required to help push the coagulum from the tank to the battery. Here again the rail system has the same advantages of economy in water, and facility for extensions. It also confines the tank-washing to one bay which helps to keep the factory clean, and enables special water-points and partition tables to be installed for the purpose. In this case, where a fairly long length of rail is required, the design in Fig. 3 does not appear to give such a compact arrangement.

For very large estates where more than thirty tanks are required, two machines become desirable. A satisfactory method of duplicating the arrangement in Fig. 2, under one roof, with only one set of bulkers and one truck line to the smoke-house, has not yet appeared, whereas a very compact design can be evolved using fixed tanks, by duplicating the lay-out shewn in Fig. 1 and running the smoke-house truck-line in a central trough between the two units.

For use in conjunction with continuous sheeting batteries the system using tanks on rails has an undoubted advantage, since the long ribbon of coagulum can be fed straight into the machine; whereas with the fixed tanks the coagulum has to be turned through ninety degrees to enter the chute and may suffer distortion. This difficulty can be reduced by arranging the tanks in echelon formation at an angle to the central chute. It is important that where the tanks are mounted on trolleys the rails should be very carefully levelled. If this is not done the tanks will be difficult to move and may become badly strained in use.

Bulking Tanks

Bulking tanks are shewn in each type of lay-out. Their original purpose was to remove much of the fine sand and dirt from the diluted latex by sedimentation, and they are therefore designed with a main latex run-off just above the bottom of the tank, so that when the latex has been diluted and allowed to settle for about twenty minutes, it can be removed without disturbing the sludge, which is drained off through a secondary cock. In this way much of the dirt which is too fine to be sieved out of the latex may be removed. The bulking tanks are useful in another respect since they reduce the possibility of variations in the dry-rubber-content of the latex in the coagulating tanks. Provided that the latex and water are well mixed in the bulking tank, each coagulating tank filled from that bulk will contain latex of identical dry-rubber-content. The metrolac, although useful, is not very accurate and there are possibilities of appreciable variations in the coagulum produced if each tank is standardised separately by this means. Apart from the risk of errors in observation, it is probable that the latices from different parts of the estate will differ, due to variation in the age and type of trees, or to the amount of preservative added. Bulking will tend to smooth out these differences and will assist in the preparation of uniform sheet.

Bulking tanks may be constructed of reinforced concrete, steel, or aluminium. It is important that the tanks should have a smooth inner surface which is easily cleaned. Concrete tanks, once placed in position, are permanent, and cannot be altered to suit any factory re-arrangement. The preparation of a good smooth surface is difficult. Tiles have been used, but the joints provide cracks which are impossible to clean. Fairly satisfactory results have been obtained by treating the smoothly-rendered cement surface with sodium silicate solution, followed by a coating of special corrosion-resisting paint. Steel tanks should be welded to give a smooth inner surface, which also needs to be treated with a special paint. Aluminium tanks, although more expensive initially, need no surface treatment and therefore involve no maintenance costs.

Coagulating Tanks

Aluminium-lined coagulating tanks have been largely standardised, and are available in two types, for making either a continuous coagulum or separate sheets. Various depths can be obtained, and the depth of tank employed should be selected according to the machine which is to be used. Some batteries cannot handle successfully a coagulum more than nine inches wide, in which case tanks deeper than twelve or fourteen inches are not required. For convenience in packing, the sheet should be approximately nineteen inches wide when wet. In some smokehouses provision has been made for sheet twenty-two to twenty-four inches wide, and it may be necessary to make sheet of this width in order to take full advantage of the smoking capacity available. Batteries vary to some extent in the width of sheet they will produce from a given width of coagulum, and attention should be paid to this point in selecting the depth of tank to be used. The number of tanks should be sufficient to deal with the maximum crop likely to be obtained, without the necessity of increasing the dry-rubber-content at which coagulation is carried out, or of placing in the tanks more latex than has been found to give the best width of coagulum for the particular machine.

The optimum dry-rubber-content for coagulation also depends upon the type of battery used. One-and-a-half pounds of rubber per gallon is the concentration usually employed, but a light machine working at fairly high speed with only four pairs of rollers may require a lower dilution to produce sufficiently thin sheet without undue strain.

Little need be said with regard to the actual process of coagulation. Economy in the use of acid is desirable, since, apart from the cost of this material, excess acid tends to produce a harder coagulum, which increases the work to be done by the sheeting machine. It is possible, by a systematic routine, to reduce the possibilities of personal errors, which would lead to variations in the sheet. The advantage of the bulking tank in standardising the dilution has already been mentioned, as has the desirability of feeding a standard width of coagulum to the machines. This is achieved by using exactly the same quantity of latex in every tank every day. If this is done, a fixed quantity of acid is always required for each tank. The measurement of a constant quantity of acid offers much less risk of error than the calculation and measurement of varying quantities to suit the different volumes of latex in each tank. In practice the size of the crop varies, and it is therefore necessary to provide an additional tank, of the utility type, or one which has a movable sealing partition arranged to cut off any desired length of the tank for coagulation.

Sheeting Battery

The sheeting battery is a machine consisting of from four to six pairs of rollers arranged in line-ahead formation, with a common drive. The upper and lower roller of each pair run at the same speed, and the speed of each pair is greater than that of the preceding one in the line. The last pair of rollers is an exception to this, since it is grooved to provide a marking on the sheet, and is run at a lower speed than that of the preceding smooth pair.

A number of machines conforming to this general description, but incorporating special details of design and construction, are manufactured and are sold at competitive prices. The first problem to be decided when selecting a machine is whether continuous coagulum or separate pieces are to be rolled, since, owing to the difference in roll speeds required, the same machine will not work equally well for both purposes. In factories which are being reorganised this will usually be determined by the coagulating tanks already available, but where a complete new equipment is to be installed the choice is often difficult.

On theoretical grounds, the continuous sheeter should give a higher economic efficiency, since the rubber passes through in a long continuous ribbon, whereas when separate sheets are used there is an interval, during which the rolls are running idle, between the end of the sheet and the entry of the next. Thus a machine working on continuous coagulum will usually give a higher output per hour. The difference between the two will depend on the efficiency with which the separate sheets are fed into the machine. For example, a machine which delivers one foot of rolled wet sheet per second will have a theoretical output of 3,600 feet per hour, whereas an average interval of four seconds between sheets which are usually about six feet long will reduce the output to 2,160 feet per hour. An average interval of 1½ seconds between sheets may be considered as very efficient feeding, and 2½ seconds is a good average figure which should be attainable in most factories. It will be noticed that the output is expressed as length of wet sheet per unit time, and that for a given roll-speed the output in terms of weight will depend upon the width and thickness of the wet sheet.

In practice the difference in output between the continuous and separate sheet machines is reduced by using higher roll-speeds on the latter, and the continuous sheeting machine should be regarded as the one which will give the required output with a lower roll-speed, rather than the one with the higher output per hour. This means that for a given output the machine rolling continuous coagulum will be subject to less wear on the bearings and should consume slightly less power. The slower roll-speed has another advantage, in that the longer time for which the rubber remains in the nip between the rolls ensures a more efficient squeezing action and less recovery after rolling. The slip between the rollers and the coagulum increases with increase of roll-speed, and slip represents a loss of power. There are some disadvantages in the manufacture of continuous coagulum. The difference in the initial cost of the two types of machine is not great, but the special tanks required for continuous coagulum are more expensive. A rather harder coagulum is usually required for continuous working and since this is more difficult to roll out, it will tend to cancel the advantage gained by the more efficient squeezing action of the continuous machines. A machine working on separate pieces of coagulum requires less critical setting and is less sensitive to variations in the coagulum than when the continuous strip is used.

The final consideration is the labour required for working each type of machine. If continuous coagulum is used, there is no necessity for a labourer between each pair of rollers, but the handling of the wet sheet as it leaves the rollers is more difficult, since twice as much cutting is required for each tank of coagulum. In order to reduce the handling of wet sheet to a minimum it is advisable to cut the sheet and hang it on the smoke-house trolleys as it is delivered from the machine. With the continuous sheeting battery working at a fairly high rate of output, three labourers will be required to carry and hang the rubber, while a skilled labourer is required to cut the sheet. In many cases this method is not attempted, but the sheet is cut into pieces six feet long and piled until the machine is stopped. The piles of rubber are then cut through and the sheet is hung. It frequently happens that in the cutting the sheet becomes massed together and time and energy are wasted in separating it again before hanging, so that if manufacturing time is reckoned from the time at which machining is started until the rubber is on the trucks, the machine operating on continuous coagulum by this method may not compare favourably in output per hour with one using separate pieces. In considering the labour required it is necessary to regard the process as a whole rather than stage by stage. Labour is required for sorting and packing, and for cleaning the coagulating tanks, and it may prove more economical to bring the packing shed staff into the factory while the machining is in progress, and allow the factory staff to help in the packing shed later, than to keep the two staffs separate, and try to reduce the number of labourers in the factory to a bare minimum.

Machines can be obtained with from four to six pairs of rolls, and with machines in which each pair has to be fed separately the tendency is to use the minimum number of pairs in order to save labour. Usually, however, better results will be obtained by using a larger machine, which is better able to deal with variations in coagulum and small inaccuracies in roller setting, and will be less heavily stressed in operation.

In the foregoing comparison, the machines working on separate sheet have been assumed to be of the type in which the pairs of rollers are a considerable distance apart, and which require a separate labourer to feed each pair of rolls. There is, however, one type of machine available for rolling separate sheets in which the pairs of rollers are placed close together and in which an automatic feed is obtained from one pair to the next by means of an ingenious patented chute. This, like the continuous machine, avoids the necessity for a labourer between each pair of rolls and the next, and, at the same time does not require the more expensive continuous tanks, nor involve the difficulty in cutting the rubber.

On large estates maximum economy will usually be attained by working at high machine outputs since this will avoid the necessity of duplicating the machinery. On small estates, smaller and cheaper machinery with a slower rate of working will often give equally good results while requiring less close supervision, and a lower initial outlay. The machines should normally be set to deliver wet sheet between one-tenth and one-eighth of an inch thick, and if it is required to increase the output, attention should be paid to increasing the width of the wet sheet and, where separate sheets are used, the efficiency of feeding, before any attempt is made to increase the roll-speeds, since excessive speed leads to slip and tearing of the sheet. The machines should be so set that each pair of rollers plays its part in compressing the rubber. If the coagulum is uniform the rollers may be left for long periods once the gap has been set, but variable coagulum will require frequent readjustment of the rollers for the best results. In feeding the rollers a uniform rate should be the ideal to aim at. It is not uncommon to find, when changing over from one tank to the next, that there is a temporary hold-up in the supply of coagulum, after which a number of pieces reach the feeding end of the battery in quick succession, and the labourer at this point is tempted to pass them into the machine too rapidly, causing doubled-over corners and folds in the sheet. A reasonably fast even rate of working will give far better results than a series of quick rushes and temporary lulls. Labourers should therefore be trained to this end, and a pace set which they can maintain without fatigue for several hours.

Owing to the variations in weather, seasonal effects, the change-over of fields in tapping etc., it will never be possible to obtain perfectly uniform wet sheet, but attention to the various details of procedure outlined above will do much to reduce the variations to a minimum.

Drying

It is not proposed to discuss here the theory of drying nor the construction of any particular type of smoke-house, since considerable space has been devoted to these matters in an earlier issue of this *Journal*[1]. Attention will be confined to a few practical points which are applicable to all types of smoke-house.

As was mentioned earlier, sheet-thickness and temperature are the major factors controlling the rate of drying. The latter is limited by the risk of damaging the rubber, and it is advisable to leave a reasonable safety margin below this limit, since close temperature control is impossible where direct wood firing is employed. Much however can be done by training the labourer to maintain a steady fire and to add small quantities of wood frequently, rather than large quantities at long intervals. A maximum and minimum thermometer is usually the only check available on the conditions inside the smoke-house. This is not entirely satisfactory, since no record is obtained of the time during which the temperature has been maintained at any particular level between the two limits. A thermograph is the only satisfactory instrument for this purpose. The ordinary maximum and minimum thermometer will, however, give more information than is sometimes realised, if it is used carefully and attention is paid to the minimum as well as to the maximum reading. The thermometer is frequently reset when the chamber is opened up for the introduction of a fresh charge of rubber, and in this case the minimum reading tells only the outside air temperature. The thermometer should be set after the smoking chamber has warmed up to its normal working temperature, and should be read again, before the smoke-house is opened next morning. In this way it is possible to tell from the minimum reading whether the smoke-house labourer has allowed the temperature to fall unduly during the night. The position of the thermometer should be selected with care since many smoke-houses have small "dead" spots in which the temperature is considerably different from that in the rest of the house, and a thermometer placed in one of these spots will not give an accurate reading.

The minimum temperature is particularly important in the early stages of drying, when the rubber is losing water very rapidly, for unless an abnormally high rate of ventilation is employed the air in the drying chamber will be nearly saturated, and a sudden slight fall in temperature will cause the deposition of dew. For example, air which is only 80 per cent. saturated at 105°F. will be on the point of depositing moisture at 98°F. Thus to avoid condensation in the smoke-house it is necessary to keep the minimum temperature as close as possible to the working temperature decided upon. If the trouble persists in spite of close temperature control, it will be necessary to increase the air flow through the chamber. This however will increase the fuel consumption required to maintain the working temperature and will also tend to dilute the smoke.

With regard to sheet thickness, the only point which it is desired to emphasise is that the day's crop is not dry until the thickest part of it is dry. The ideal condition would be realised if the whole crop became dry at the same time. This cannot be realised in practice, but with uniform coagulum, evenly-set machines carefully operated, and a well-designed smoke-house in which cold pockets are avoided, reasonable uniformity in drying rate can be achieved. The avoidence of variations between one day's crop and the next is as important as uniformity throughout the sheet manufactured in any one day. For efficient economic drying the smoke-house ventilation and firing need fairly critical setting, and it is a matter of experiment in each particular case to find the best conditions. Once found it is possible to train a labourer to maintain those conditions fairly accurately. It is not however possible to state off-hand what alterations in ventilation and firing will be required to allow for an alteration in the supply of wet sheet; and it is therefore futile to expect the labourer to adjust his operation of the smoke-house to accommodate variations in the sheet.

Packing

Comparatively little attention has been devoted to the organisation of packing, which remains a slow and rather costly part of the process. The only mechanical aids which would be of practical value would be hydraulic presses, and mechanical conveyors and stackers. These machines are expensive and it is unlikely that the scale of operations in an estate rubber factory will justify the cost of such equipment. Failing such devices a fairly high degree of efficiency can be obtained by planing the packing shed so that the rubber follows a short straight-line course from the smoke-house via the sorting bench, weighing machine, and press to the storage bay. Carrying of sheets, and piling, with the subsequent necessity for separating it again, should be reduced to a minimum. The careful selection and training of labour for sorting and clipping appears to offer the greatest scope for economies in the packing shed. It appears that it would be as easy for a sorter to fold the clipped sheet and drop it into a case as to spread it carefully on a pile, which is later carried away, separated and folded, yet this method has not yet been observed in practice. In this problem it appears that a careful study of working conditions, lighting, and even motion study, offers a more profitable line for research than attempts at mechanisation.

Summary

In the foregoing paper an attempt has been made to set out some of the factors which need consideration in the design of an estate rubber factory and selection of equipment for the manufacture of smoke sheet. Attention has also been drawn to a number of details of operation which are regarded as important at the present time, since it is believed that improvements and economies in the immediate future will be effected by attempts to make the best use of existing types of equipment rather than by violent departures from current designs. The speed of the manufacturing process is that of its slowest part, and efficiency will be lost rather than gained, by accelerating one stage at the expense of others. A smooth, even production will give the greatest economy and will be the most easily operated.

Reference

(1) PIDDLESDEN, J.H. This *Journal*, **7** (1937) 110

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