CHAPTER FOUR

Jute Batching Oils and Emulsions

IF the jute fibre is taken from the bale and passed directly over the spinning machinery, then the yarn which is made from it is weak and irregular and the amount of waste in processing is high. In order to produce an acceptable yarn it has been customary from the earliest days of jute manufacture on an industrial scale to condition the fibre for spinning by adding oil and water to it—this operation is known as batching.

The water softens the fibre and increases its extensibility, both of which factors prevent excessive fibre breakage at the cards, make it easier for the fibre to bend round pins and rollers, and reduce waste losses. The exact nature of the part played by the oil is not fully understood but it is thought to have an important role in giving cohesion to the slivers, helping them to be drafted properly at the later stages. Originally, the oil and water were added separately but now they are, almost invariably, added simultaneously as an emulsion.

JUTE BATCHING OILS

The requirements of a good batching oil are as follows

(1) It must have no harmful effect on either the jute or the machines.
(2) The colour must be acceptable.
(3) There must be no danger of spontaneous combustion.
(4) It should not go rancid or sticky on standing.
(5) It should not have an objectionable odour.
(6) It must be cheap and in plentiful supply.

In the early days of the industry whale oil was used extensively for batching, mainly because Dundee was a whaling port at that time and there was a copious and cheap supply of this type of oil, but now mineral oil of the light spindle variety is used almost exclusively, although small amounts of whale oil are still used in spinning fine yarns.

Most jute yarns are spun with 5–6 per cent oil but for special purposes it may be necessary to reduce this to 1 per cent or less. Yarns with an oil content as low as 1 per cent are more expensive than those with the higher oil contents because to arrive at the same total weight extra fibre must be added to compensate for the reduced quantity of oil present, and raw jute is costlier than mineral oil. On the cost of materials alone these yarns must be sold at a higher price, quite apart from any additional processing costs. From this it may be deduced that it is economically desirable to work with as high an oil content as possible, but there is a technical limit to the amount which can be added. Oil contents much in excess of 6 per cent cause difficulty because the pins, conductors, and rollers of the machinery become coated with a black dirty deposit which can lower the quality of the jute passed over them.

Once the oil level has been decided the quantity of oil required is calculated from the weight of fibre which is to be put through the system. Some of this added oil, however, is lost in the fibre wastes beneath the machines. This waste is always heavily loaded with oil, particularly at the cards. The amount of oil which is lost varies somewhat but a common amount is 10 per cent of the oil that was added at batching; thus if 20 lb of oil had been added to 400 lb of jute, at the end of the process only 18 lb of oil would be left in the yarn.

Though jute spinning without oil is not a commercial proposition the amount of oil and its nature do not appear to be critical. Table 4.1 gives the results of tests in which the oil content of the yarn was changed from 0·5 per cent to 9·0 per cent and the strength of the yarn examined.

TABLE 4.1. EFFECT OF OIL CONTENT ON THE STRENGTH OF YARNS

Oil content (per cent)	*Tenacity (g/tex)*
0·0	12·2
0·5	14·0
1·0	14·6
2·5	14·4
5·0	14·5
9·0	13·9

It can be seen from the Table that as long as some oil is present the tenacity of the yarn is not altered significantly, and even if almost twice the usual amount is added the strength is not changed radically. Other tests showed that although oils of high viscosity do lower the breaking load of a yarn and make it more irregular, these effects do not become apparent until the oil is two or three times as viscous as normal batching oil.

END-USE PROBLEMS ASSOCIATED WITH BATCHING OIL

As time passes and the uses of jute become more widespread and specialized it is sometimes necessary to use lesser amounts of oil or different types of oil. Examples of such end-uses are found in the packing of food, carpet yarns, and tufted carpet backings. Some foodstuffs, such as flour, are in their final state when they are packed in jute bags and it is important that the contents do not become contaminated in any way with the batching oil since this may impart an oily taste. The best answer to this particular problem is to use a more highly refined oil which is tasteless and odourless, although reducing the normal batching oil content to 1 per cent or less will also meet the case in most circumstances. In carpets, be they woven or tufted, where a viscose or cotton pile is used it is usually necessary to reduce the oil content to 1 per cent or below to avoid the problem of soiling. Soiling of the pile yarns is caused by the batching oil 'wicking' the pile fibres and holding the dust particles in their crevasses. With the low oil content material, wicking is reduced to such a level that soiling does not occur. If a jute fabric is to be used as a base cloth for PVC coating then it sometimes happens that the oil migrates into the plastic and gradually turns yellow forming diffuse stains; these are particularly noticeable with pastel shades of PVC. This may be overcome by using 1 per cent or less of normal batching oil or changing to a technical white oil which does not turn yellow on exposure to light.

In these problems certain factors are common. The problem is associated with the batching oil, and that at the usual 5 per cent level; in all cases the difficulties may be overcome either by reducing the amount of oil present or changing to a more highly refined oil; the reason for the trouble lies in the transfer of the oil from the jute to the other material. The transfer rate depends chiefly on the following.

(1) The oil content. The higher the oil content the faster is the transfer; in fact oil migrates from jute at a speed depending on the cube of the oil content, i.e. the amount of oil migrating from two cloths with 4 and 6 per cent oil, respectively, will be in the ratio of $4^3 : 6^3$ or 64 : 216 (about 1 : $3\frac{1}{2}$).

(2) Time. The quantity of oil which will pass from the jute to the neighbouring material depends on the time of contact and varies as the square root of the time; in other words, if a certain amount migrates in 1 week, twice that amount will migrate in 4 weeks, three times as much in 9 weeks, and so on.

(3) The nature of the absorbing material. Fine powders absorb more oil than coarse ones, low tex pile fibres more than high tex ones, etc.

It will have become apparent from the previous paragraphs that if these problems are to be overcome then the jute must not soil or stain the material it is in contact with. Yarns of low oil content (1 per cent or less) are therefore called 'stainless'. Table 4.2 gives a summary of the use of oils required for jute's more specialized applications.

TABLE 4.2. JUTE BATCHING OILS FOR SPECIAL PRODUCTS

End-use	*Problem*	*Oil addition*
Carpet backings for all pile yarns, except 100% jute, 100% wool, 100% nylon, wool/nylon mixtures	Soiling	Less than 1%
Upholstery	Stains on hide or PVC	Less than 1%
Packing foodstuffs	Tainting	3·5–4·5%
Packing easily tainted food, e.g. flour, sugar	Tainting	5% odourless oil
Base cloth for PVC	Yellowing	Less than 1% normal oil or 5% technical white oil

JUTE BATCHING EMULSIONS

Jute batching emulsions are of a simple nature, usually containing only the mineral oil, water, and an emulsifying agent. An emulsion is an intimate mixture of two immiscible liquids, one dispersed in droplet form inside the other. This apparently contradictory definition requires expansion. Oil and water are usually immiscible but if the oil can be split up into minute drops which are prevented from coalescing then they can be dispersed throughout the water—this is then called an emulsion. Emulsions are said to have two phases, an external phase and an internal phase. In jute batching emulsions the external phase is water and the internal phase (which is dispersed through it) is the mineral oil. Batching oil is normally a golden, amber colour and water is, of course, colourless, but when the two are mixed as an emulsion the resultant liquid is milky white. The reason for this lies with the extremely small oil droplets which scatter the light in all directions giving a white appearance, just as ground glass appears white because of all the minute pits in its surface.

A typical batching emulsion may have 30 gal of mineral oil and 80 gal of water and the problem is to split this 30 gal of oil into microscopically small drops and then disperse them throughout the water in such a way that they will stay as droplets and not reconstitute themselves into one mass of oil.

Some idea of the task may be had from the following calculation. If the water and oil were poured in a cylindrical tank 2 ft (60·96 cm) in radius the two will mix crudely but very quickly the oil will float to the top of the tank because its density is lower than that of water, and a well-defined boundary will form between the two liquids. This boundary is called the interface. The area of the interface between the oil and water in this tank will be 11,669 cm² (πr^2). Now if this amount of oil is to be emulsified successfully it must be transformed into droplets which are about 5 microns in diameter and it is interesting to calculate how many drops there will be.

$$\begin{aligned}
\text{Total volume of oil} &= 30 \text{ gal} \\
&= 136{,}290 \text{ cm}^3 \\
\text{Volume of one drop} &= \tfrac{4}{3}\pi r^3 \\
&= 65{\cdot}4 \times 10^{-12} \text{ cm}^3 \\
\text{Number of drops} &= \frac{\text{Volume of oil}}{\text{Volume of drop}} \\
&= 2{\cdot}1 \times 10^{15}
\end{aligned}$$

i.e. 2,100 million million drops

The original interface was 11,669 cm² but once the drops have been made it has been increased about 600,000 times.

The first part in the work of making an emulsion is to split up the oil into this vast number of extremely small drops. This is done by agitating the oil violently and the greater the amount of energy put into the preparation of the emulsion at this stage the smaller will be the drops and the better the emulsion. This energy may be supplied by whirling paddles, high pressure pumps, or vibrating blades as will be shown later but in all the methods the principle is the same. The object being to shear the oil, tear it apart, and smash it into drops. However, some other stage in the preparation is necessary otherwise these drops, no matter how fine, will quickly re-unite until the original quantity of oil is one homogeneous mass again.

When water drips from a tap the globules are at first pear-shaped then as they break away from the metal they very quickly become spherical. This phenomenon is caused by a force called surface tension acting in the skin of the drop, pulling it into a shape which exposes as little of the water as possible to the atmosphere. The body with the smallest surface area in relation to its volume is the sphere—it is well known that the hedgehog curls itself up into a ball when danger threatens, to present as little of its surface as possible to the enemy. Surface tension can be regarded as doing the same to the droplet. Thus, after the first drops of oil have been made there are surface tension forces acting in the skin of each drop which try to prevent further splitting and it becomes more and more difficult to break the drops up into small enough particles to form an emulsion. If, however, some substance could be used which would destroy or at least reduce the strength of the surface tension in the oil drops then it would be easy to split the oil drops still further until they were of such a size as to be capable of forming an emulsion. This is one of the roles of the emulsifying agent, it reduces surface tension and makes droplet formation easier. The other function of the emulsifying agent is to prevent the droplets re-uniting. There are two parts to the molecule of the emulsifying agent; a hydrophilic (water-loving) portion and an oleophilic (oil-loving) portion. The oleophilic 'heads' attach themselves to the oil droplets leaving the hydrophilic 'tails' projecting into the water phase. In this way each drop is surrounded by a layer of emulsifying agent which acts as a buffer and when the droplets collide, as they do many times each second, they are prevented from re-uniting. Emulsifying agents belong to the class of chemical compounds known as surface-active agents because of their ability to bring about these special effects at the surface of liquids. The emulsifier therefore (1) reduces surface tension, (2) stabilizes the emulsion. In addition it must be inert to any chemicals which may be added to the emulsion and must cause no damage to the jute. Most modern surface-active agents are extremely powerful and usually only about 1 part of emulsifier to 20 or 30 parts of oil are required to form a jute batching emulsion.

DEFECTS IN EMULSIONS

The most glaring defect in an emulsion is for it to have the wrong proportions of oil and water. This is so obviously due to carelessness in preparation that no more will be said about it at this stage. Apart from this obvious fault, two defects may arise.

(1) *Creaming*. When an emulsion is prepared it is impossible to make all the drops exactly the same size, some will be much smaller than others and there will be a few quite large drops. In general, the smaller the drops and the less scatter there is in their diameters the

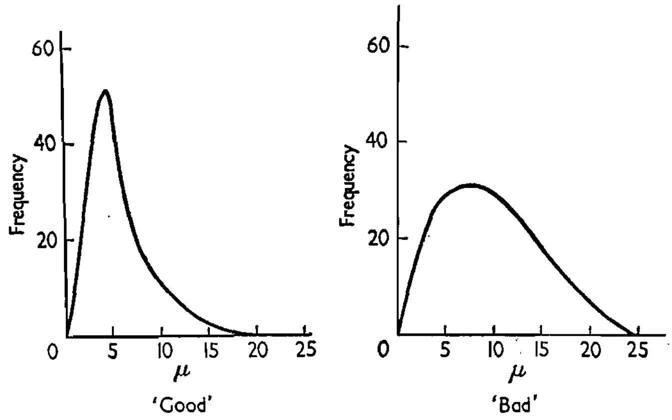

Figure 4.1. Droplet size distributions

better is the emulsion. Figure 4.1 illustrates a 'good' and a 'bad' distribution of droplet sizes. If there are a number of comparatively large drops of oil they will slowly rise to the top of the emulsion because of their lower specific gravity until a layer of them forms at the surface of the emulsion. In emulsion technology this is known as 'creaming'. The same phenomenon will be seen if a bottle of milk is left to stand; the large drops of milk fats rise to the top. As would be expected those emulsions with a large number of big drops will cream more quickly than those with small drops and, again, emulsions made from oils with low specific gravities cream more readily than those with higher gravities.

While creaming is a defect it is not a serious one. Rather, rapid creaming should be taken as a sign of a poor emulsion and attempts should be made to decrease the droplet size. The danger with a creamed emulsion is that supplies of emulsion for the spreaders may be drawn off the top layers which have become heavily loaded with the oil. When this happens the oil content of the jute will be high, but when the emulsion level has dropped and it is now being taken from the oil-deficient layers then the oil content will be low. This trouble can be overcome by arranging a slow-running paddle to keep the contents of all emulsion storage tanks in gentle motion as creaming will only occur in a standing emulsion.

(2) *Breaking.* Breaking can be regarded as the opposite of emulsification where the droplets of the internal oil phase unite to form large drops which then float to the surface of the emulsion. It is a sign of complete instability in the emulsion and once begun cannot be arrested. No amount of re-agitation will split these drops once they have formed and a broken emulsion is useless. The process may be quick or it may take several days, but in jute batching emulsions the presence of drops of free oil on the surface should lead one to suspect a poor emulsion on the point of breaking. Apart from the fact that if this kind of emulsion is put on to the jute the oil droplets will be large and will not spread evenly along the fibres, there will be parts of the emulsion which are deficient in oil and so the oil content of the jute will vary over a period of time. An emulsion may be broken by prolonged violent agitation where the turbulent action breaks down the protective sheath of surface active agent, allowing the drops to coalesce. (This is the basis of butter-making; milk is an emulsion of fat in water and when it is churned the fat droplets conglomerate into butter.) Therefore, while violent mechanical action is necessary and desirable when the emulsion is being prepared it is undesirable and harmful once the emulsion has been made. In storage tanks a gentle stirring action is wanted to prevent creaming but a violent action may break down the emulsion altogether.

SPECIAL ADDITIONS TO EMULSIONS

In order to confer certain particular properties upon a yarn some chemical substance may be added to it. This may be done by treating the finished yarn or cloth but there is much to be gained by adding it to the batching emulsion as the cost of impregnating and drying is eliminated. As long as the additive is compatible with the oil/water emulsion, produces no undesirable side-effects in the process, and achieves the necessary goal then its application along with the emulsion should be considered. Such additives do not usually require great changes in emulsification technique but they do need accuracy in their use and care in making the emulsion. An example of this technique is the addition of rot-proofer at batching. Several rot-proofers are available but one which is commonly used is lauryl pentachlorophenate (LPCP), a brown oily liquid miscible with oil. To make up the emulsion the oil and LPCP are pre-mixed in a special tank and then the emulsion is prepared in the usual way, using this oil/rot-proofer mix just as the mineral oil is used. Amounts of up to 2 or 3 per cent of the LPCP may be added to the jute so it is advisable to reduce the amount of oil somewhat otherwise there will be an excessive quantity of 'oily' material present.

Another example of an addition to the emulsion is found in the use of dyestuffs to give a tint to the fibre. This process is not dyeing, be it noted, and the depth, uniformity, and range of colours obtainable with this technique cannot match those resulting from normal dyeing methods, but for many purposes the tint is satisfactory. The dyestuff may be added via the oil or the water; in the former case an oil-dispersing dye must be chosen which will enter into the oil droplets and be carried along with them to be deposited on the fibre, in the latter case a water-dispersing dye must be used.

EMULSIFICATION EQUIPMENT

The formation of an emulsion is a two-stage process; the correct conditions must be created by the physico-chemical action of the emulsifying agent and the energy of emulsification must be supplied mechanically. Emulsification equipment is not complicated, remembering that the essence of the system is to tear the internal phase into drops and that the more vigorous the action the better is the equipment.

(1) *Paddle-mixers and agitators.* The simplest type of emulsifying plant and one that is common in the jute industry consists of a tank with a rotating paddle inside it (Figure 4.2). There are usually three tanks situated above the mixing tank so that their contents can be

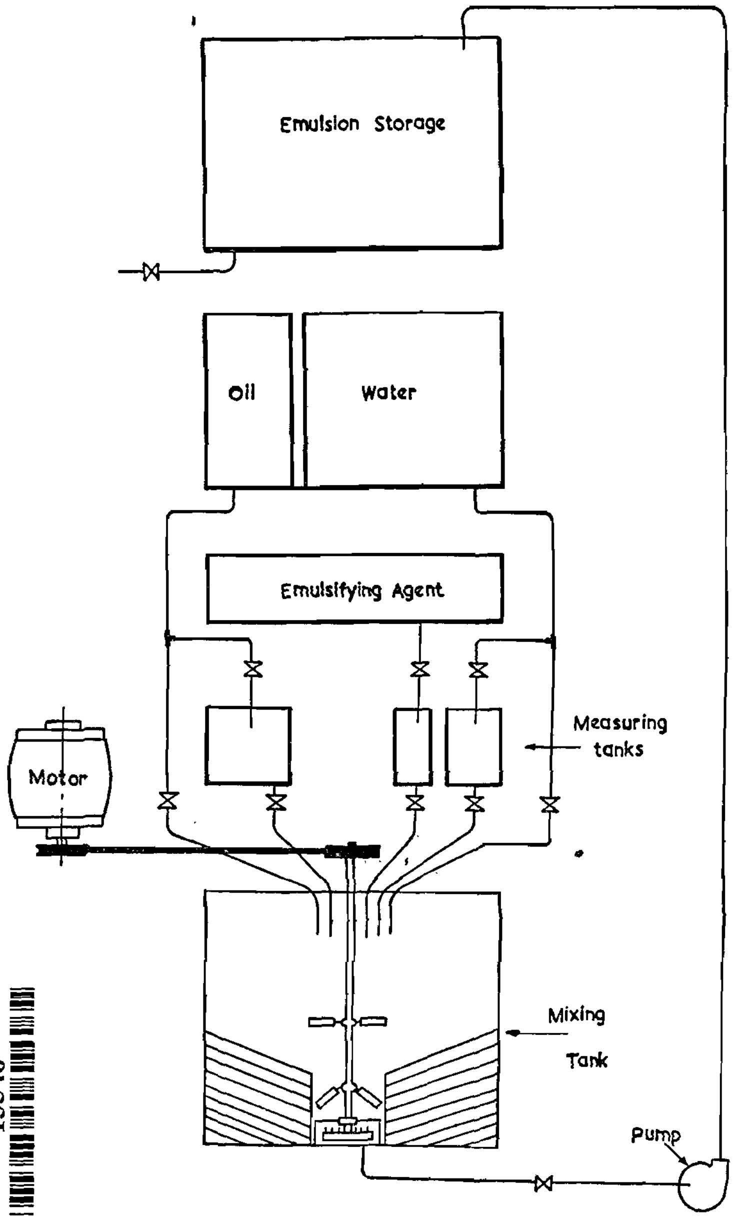

Figure 4.2. Simple emulsion mixing plant

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fed to it by gravity. The dimensions of the tanks are in direct proportion to the amounts needed for the emulsion; one holds the water, another the oil, and the third the emulsifying agent. To stop the contents of the mixing tank swirling as a mass when the paddle is running, baffles must be fitted to sides of the tank. These break up the motion of the liquids and give the shearing action which is so necessary. It is good practice to have a small well in the foot of the mixing tank with the agitator blades projecting into it so that the small quantities of emulsifier and water which are added first are mixed efficiently. From the mixing tank the emulsion is pumped to a storage tank where it is held until needed.

This type of equipment will prepare emulsions which are adequate for jute batching but, nevertheless, the emulsions are not of a very high standard. Where an emulsion does not have to remain stable for long periods of time there is no need to install highly efficient emulsifying plant, and as most jute emulsions are used within a few hours of mixing this simple equipment is satisfactory. Even so, some manufacturers adopt the view that good emulsifying machinery is not too expensive and is worth installing for the sake of getting correct emulsification with the minimum of mistakes.

(2) *Homogenizers.* There are many types of homogenizers on the market, all of which work on the same general principle. A coarse mixture of the liquids to be emulsified is forced through a small aperture under high pressure. There are two parts to the homogenizing unit; the pump which generates the high pressures (1,000 lb/in^2 or more) and a special valve with a clearance of a few thousandths of an inch. The degree of emulsification can be controlled by altering the pump pressure or varying the size of the valve clearance or both. Homogenizers can be fitted into a plant preparing emulsion on a batch system. (Note: the term *batch system* is used here in its wider context of one quantity of material being made and passed to storage, then another quantity being made and so on. It does not refer specifically to jute 'batching'.) Figure 4.3 shows a suitable arrangement for using a homogenizer. In the emulsion preparation there are three phases: first, the coarse emulsion is made up in the pre-mix tank; second, this emulsion is pumped under pressure through the homogenizer; and, third, the emulsion is passed to storage.

(3) *Colloid Mills.* These machines are capable of producing extremely fine droplets and, like the homogenizers, they usually work on a coarse pre-mixed emulsion. Basically, the machine consists of a

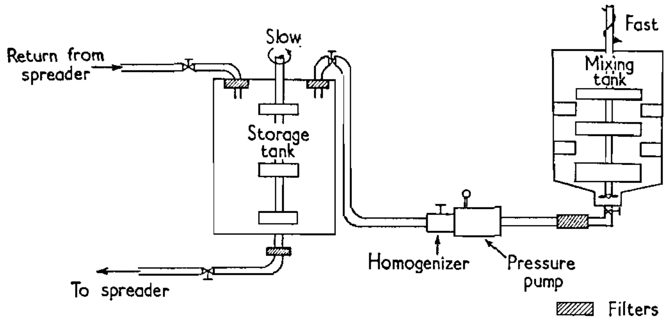

Figure 4.3. Homogenization plant for emulsions

high-speed rotating disk or cone fitting closely inside a shield. The liquid passes between the disk and the shield and in so doing is subjected to strong shearing forces which reduce the particle size. Colloid mills may carry out the work of emulsification or reduce the droplet size of a coarse pre-mixed emulsion.

(4) *Ultrasonic Emulsification.* A plant based on ultrasonic emulsification has been in use in the industry for a few years. The principle is analogous to that used in woodwind musical instruments; in these, air from the mouth is blown across a thin reed causing it to vibrate. The vibration produce air waves which the ear interprets as sound. Ultrasonic vibrations are similar pressure waves but with a frequency too great for the ear to detect. In the ultrasonic homogenizer a jet of liquid strikes the edge of a thin blade, setting up vibrations of the order of 22,000 c/s. These extremely rapid vibrations cause miniature 'explosions' within the liquid, tearing it into fine drops. Figure 4.4 shows the layout of such an emulsifier with the jet and the blade enclosed in a resonating bell to intensify the vibrations. This is the basis of the plant manufactured by Douglas Fraser Ltd, an outline of which is shown in Figure 4.5. The oil, water, and emulsifying agent

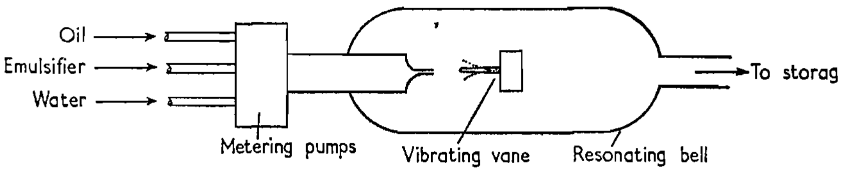

Figure 4.4. Basic principle of ultrasonic emulsification unit

flow by gravity to tanks with ball valves, the valves stopping the flow of liquids when the plant is closed down and switching on a warning light if there is a stoppage anywhere in the supply line. The liquids are withdrawn from these tanks by pumps which are set to

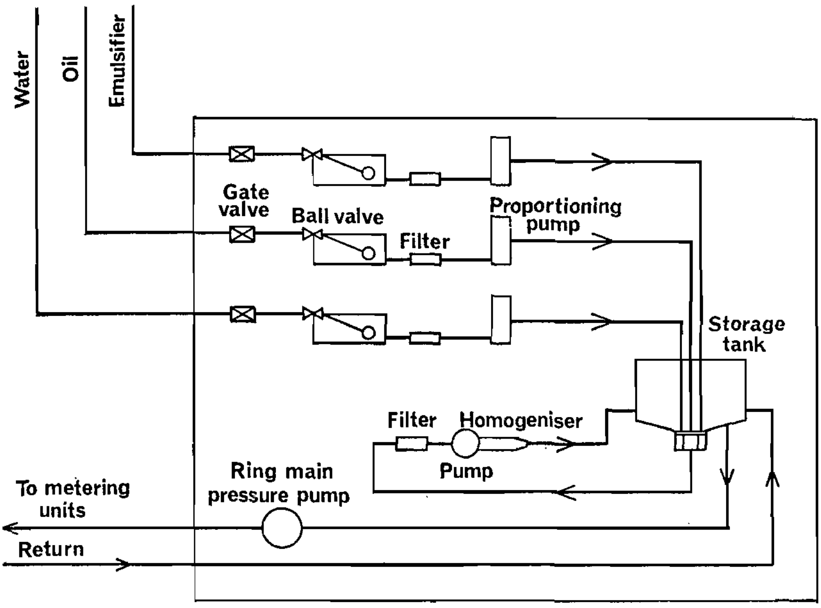

Figure 4.5. Fraser plant

deliver a known volume at each stroke. From the pumps the liquids pass to the ultrasonic homogenizer where the reciprocating blade instantaneously emulsifies the oil. This plant can either be set to produce the required concentration of oil : water ready for application or it may be set to give a 50 : 50 emulsion which then is pumped to a metering unit at the spreader or softener. At the metering unit there are two precalibrated valves, one for metering the 50 : 50 emulsion and the other for metering water. Each valve is set to deliver the necessary quantities within a certain time and, with this system, changes in the oil concentration of the emulsion can be achieved quite easily by adjusting the rate of flow of the water. Once the stock emulsion has been diluted this emulsion is fed to the spreader or the softener. The Fraser unit can emulsify 1,200 lb of oil per hour, enough to add 5 per cent of oil to 24,000 lb of jute in an hour.

THE FORMULATION AND MIXING OF EMULSIONS

If an emulsion with a given oil : water ratio is added to the jute at a certain application rate it is important to appreciate that this will add a fixed amount of oil to the fibre. Emulsion recipe, application, and addition are rigidly interrelated and it is impossible to alter one and leave the other two as they were. If one wishes to change the amount of oil added to the fibre but to keep the amount of water that one is adding the same, then both the recipe of the emulsion *and* the application rate must be altered. If, in the emulsion, there are w parts of water and m parts of oil, and if this emulsion is added to the jute at the ratio of e parts of emulsion to 1 part of jute, then there will be we parts of water added to the fibre and me parts of oil added to the fibre. For example, if an emulsion is made up of 30 lb of oil and 90 lb of water and is to be added at a rate of 20 per cent to the jute, how much oil will be added to the jute?

For every 100 lb of jute, 20 lb of emulsion will be added.

The 20 lb will have oil and water in the ratio of 30 : 90 or 1 : 3. That is to say, there will be $\frac{3}{4} \times 20$ lb of water and $\frac{1}{4} \times 20$ lb of oil

Amount of oil added = 5 lb on every 100 lb of jute

i.e. $$\frac{5}{100} \times 100 = 5 \text{ per cent}$$

Similarly, 15 per cent of water will be applied. It is impossible to add a different amount of water and/or oil without changing the emulsion recipe and the application rate.

The common range of application rates for jute is from 16 to 25 per cent, with up to 30 per cent being added when cuttings are being run through. With the usual 5 per cent of oil, on the finished goods this corresponds to about 70–80 per cent water in the emulsion, for stainless yarns about 92–95 per cent water. The quantity of emulsifying agent depends upon the particular type used but is usually in the ratio of 1 to 20 or 30 parts of oil.

One of the essentials in emulsion preparation is to measure out the ingredients accurately. Unless this is done there will be an unnecessarily large day-to-day variation in the oil content of the yarn and while this is perhaps not of vital importance in 5 per cent oil material it can assume very great importance in stainless goods where the variation may take the oil level over the permitted 1 per cent. In many plants the liquids are measured out from tanks fitted with sight-glasses which have been calibrated from the calculated volume of the tank but it is essential to check the calibration by adding known volumes to the tanks. It is much better practice, however, to fit fluid meters on the supply lines or to have an accurate level indicator in the tank. Fluid metering is, of course, an integral part of the Fraser ultrasonic emulsifying plant and it can be shown that this system gives a lower day-to-day variation in the oil content of the yarn than one relying upon sight-glasses and dipsticks to measure out volumes. Accuracy is particularly important when additional substances are being added to the emulsion where too little additive may fail a consignment of yarn when it is tested or too much may make the process uneconomic. Needless to say, all the ingredients of an emulsion should be added by weight and not by volume.

As most jute batching emulsions are made with the simple stirrer-type apparatus this method of preparation will be dealt with at length. With homogenizers or colloid mills it is common practice to make a coarse emulsion in a stirrer-plant and then reduce the particle size later; with the ultrasonic method the process is automatic and all that is necessary is to set the pumps and valves correctly. The method used for the simple plant is known as the 'mayonnaise' method. The emulsifying agent and an equal amount of water are added to the tank and stirred together. As this may only amount to 2–3 gal of liquid it is clear that a sump in the bottom of the tank helps to mix the two liquids at this stage. The oil is added slowly and soon a thick creamy paste forms, the 'emulsion base', which has the consistency and appearance of mayonnaise—hence the name of the method of mixing. This base has powerful oil-absorbing properties and is expanded by adding the remainder of the oil. While the oil is forming the emulsion base the stirrer is breaking it up into small drops which acquire a protective coating of the surface active emulsifying agent. The water is then added slowly, the stirrer operating continually. Once about half the water has been added at the slow rate the remainder can be put in quickly. After a few minutes final mixing the emulsion is pumped to a storage tank where it is stirred gently until required. Some manufacturers prefer to heat their emulsions, in which case heating may be carried out by passing the emulsion through a heat-exchanger on its way to the storage tank, heating it once it is in storage by means of closed steam coils or heating while it is on its way from the storage tank to the point of application.