BRIDGE

A David Bridge and Company Lecture given by H. Ellwood

DEVELOPMENTS IN THE MIXING OF RUBBER AND PLASTICS

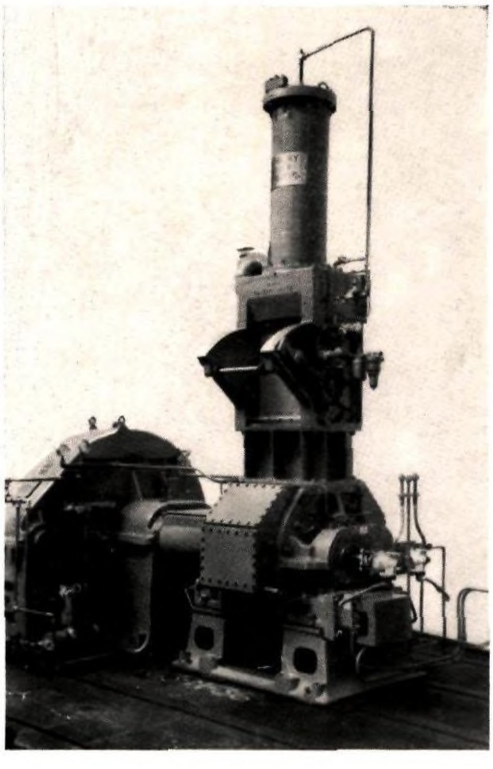

Figure 1. The Banbury Mixer

Methods of Mixing

The methods of compounding rubber and plastic materials fall into three main groups.

a. Open mixing in two-roll mills. This was the method first employed and its general principles are well known.
b. Batch mixing in an internal mixer with an enclosed chamber, the Banbury Mixer being among the most pre-eminent machines of this class.
c. Continuous mixing, where the ingredients are fed continuously into the machine and processed at a uniform rate.

The first part of this lecture will be devoted to the Banbury Mixer, and the second to the Farrell-Bridge Continuous Mixer. The first slide illustrates a modern high-pressure, unidrive, drop door, 3D Banbury Mixer. It was designed with the following objectives in mind: (1) Maximum mixing efficiency, (2) efficient heat control of the product being mixed, (3) elimination of contamination from batch to batch, (4) cleanliness of operation, (5) minimum time for feeding, (6) minimum time for mixing, and (7) minimum time for discharging.

Compared with two-roll mills, the Banbury Mixer gives increased output per operator, consumes less electrical energy per pound of material and enables the formulation to be strictly controlled. These advantages have been apparent from the introduction of the Banbury Mixer nearly fifty years ago.

However, industry's requirements have changed over the years and the Banbury Mixer has been developed to meet these changes. The machine must now be capable of mixing tougher and harder rubber and plastic compounds, with the maximum output per unit, and the minimum loss of time resulting from changes of formulation and maintenance. Present-day specifications and production methods demand more accurate formulation and dispersion, and the use of quick curing stocks which must all be dealt with adequately in the mixer.

Figure 2 illustrates how the operating efficiency of the Banbury Mixer has been increased by changes which have been made in the machine specification and design, to meet modern requirements.

The diagram is in three sections, illustrating feeding time, mixing time and discharging time.

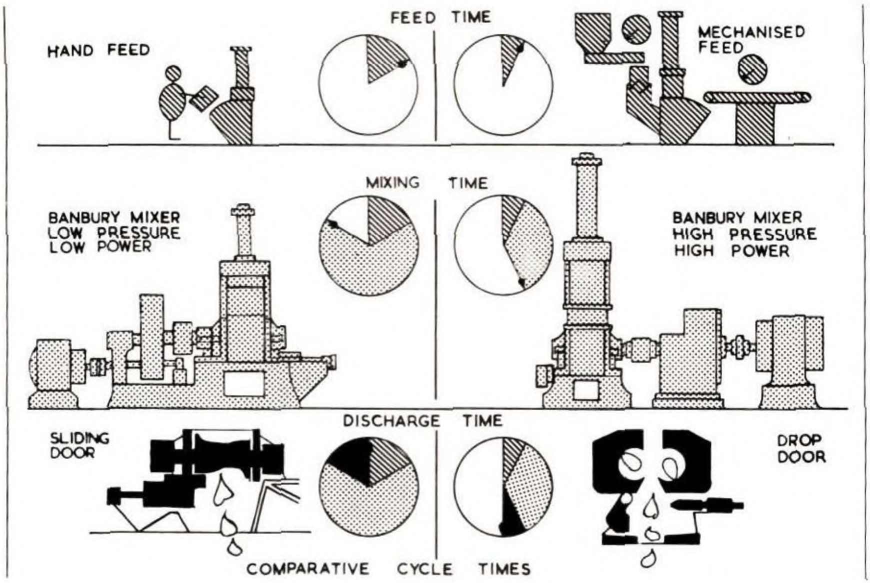

Figure 2.

Feeding Time
At the top, the time taken to feed a low pressure machine by hand is compared with the time taken when the raw materials are weighed and fed into the machine mechanically.

Mixing Time
In the next section the time taken in mixing in the older types of machine is compared with that of the modern high pressure, high powered machines which show time savings of up to 70 per cent. This is usually achieved by having sufficient power available to run the machine through the entire batch with the full ram pressure on the mix. It also enables certain formulae to be mixed with a "one-shot" feed whereas with the low pressure machine, it is necessary to feed the ingredients in several stages to prevent the motor being overloaded.

Discharge Time
Approximately one minute is required for the sliding door to open, the stock to be discharged, and the door to close again. This represents a considerable amount of the total mixing time. This situation resulted in the development of the drop door, with which the whole cycle of opening, discharging and closing can be completed in 10 to 20 seconds.

Cleaning and Maintenance Time
This is not shown in the diagram but it must be borne in mind when comparing the outputs of the two machines. The drop door has considerably reduced the area which has to be cleaned in changing from one colour to another, and the use of hard wear resistant materials and roller bearings has considerably reduced the maintenance time.

Rubber Compounding Installation
Figure 3 illustrates diagrammatically a typical modern rubber compounding installation.

Rubber is weighed by the Banbury Operator by means of a weigh scale with a power-driven conveyor on its weighing platform. The weigh scale incorporates a limit switch which prevents the scale being started unless the correct weight is present on the scale.

Feed hoppers are provided in which the bulk fillers are stored. These hoppers are often arranged so that they can be filled directly from transporter wagons, to avoid the use of paper bags, or alternatively, from bulk bins which can be handled by fork-lift trucks. Screw conveyors control the discharge from the hoppers into the weigh scale, which is situated in a chute so that the weighment is discharged directly into the hopper of the Banbury Mixer.

Process oils can be added directly into the mixing chamber by the use of high pressure oil pumps which deliver the oil from the storage tanks in

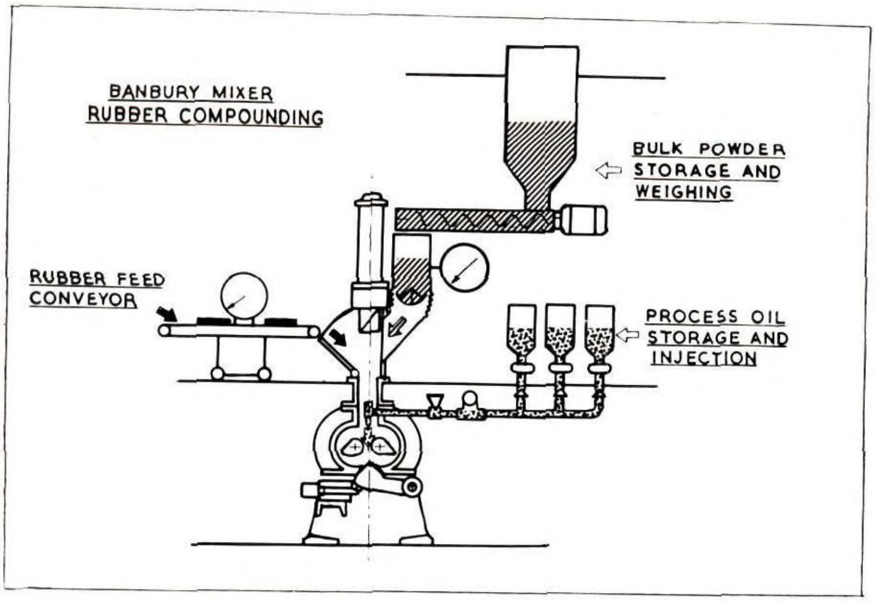

Figure 3.

volumetrically measured quantities. By adding oil directly into the chamber, the ram and the hopper are kept free from oil; this eliminates the sticking of powder to the hopper parts and cuts down considerably the amount of time spent on cleaning. Moreover, as the oil is added uniformly into the mix, it is rapidly dispersed. This reduces the mixing cycle considerably and improves the quality.
Sulphurs and accelerators can be added through side chutes in the same way as the bulk fillers, or by the more commonly used method of placing the materials into a plastic bag which is compatible with the mix and feeding via the weigh conveyor and hopper door.

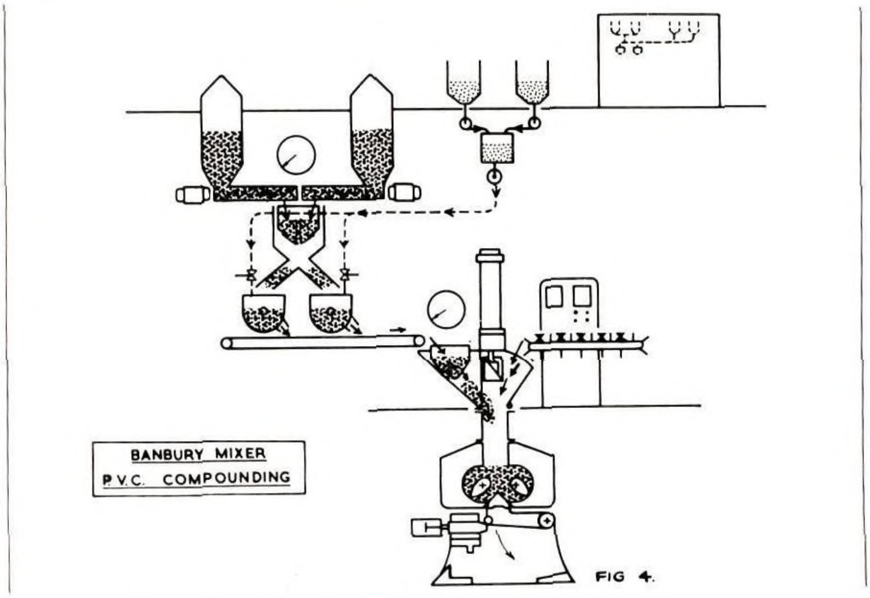

Figure 4.

P.V.C. Compounding Installation

Figure 4 illustrates a typical installation for the compounding and reworking of P.V.C. Storage hoppers are arranged to feed the various ingredients in the correct formulation to two pre-mixers. Each pre-mixer is arranged to store the material for approximately 20 minutes before feeding it into the Banbury Mixer. Pumps and flow-meters are provided to deliver plasticiser in measured quantities to the pre-mixers. The outlets from the pre-mixers are connected to a weigh scale at the back of the Banbury Mixer hopper, so that the weighment is fed directly into the chamber. Pigments and stabilisers, etc., are fed by means of a small conveyor into the front of the hopper. The use of this arrangement leaves the front of the hopper open for the feeding of scrap materials for re-working.

Automation
Installations of this kind can be made completely automatic. The practicability of automation depends upon the ability to weigh all the ingredients. For example, in a rubber installation, it is necessary to have the rubber in the form of pellets, so that they can be automatically weighed; while in the plastic installation, it is necessary to granulate the scrap material, so that it can be automatically weighed.

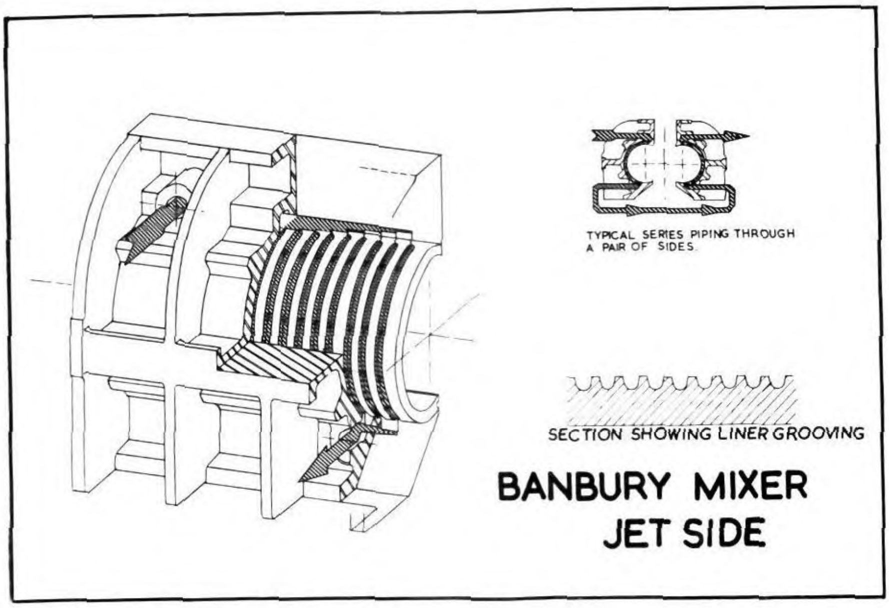

Figure 5.

Banbury Mixer Specification
To maintain maximum mixing efficiency over a prolonged period, special materials are used in the construction of the chamber. The rotors are tipped with No. 1 Stellite and the rotor bodies are hard industrial chromium plated. This ensures that the rotors keep their desired dimensions for as long a period as possible. The mixing chamber sides are lined with a dual metal which has a hardness of over 600 Brinell in the bore. The ends of the mixing chamber and also the discharge door are torch-hardened and chromium plated. To ensure efficient heat control of the product being mixed, the rotors are internally cored, the core following the outer contour of the rotor for maximum heat transfer. The liners are welded into cast steel housings which can be used for water cooling or steam heating. Figure 5 illustrates this construction, which is known as the "Jet Side". Water requirements are approximately 50 per cent. of the previous spray type design and the heat transfer is more constant.

Elimination of Contamination
These points which are known to produce contamination are the dust seals, the area at the end of the mixing chamber and the discharge door. The dust seals which we now recommend for use with high-pressure machines are known as the "SSA" or Self-sealing type. These are arranged so that they automatically compensate for changes of pressure in the chamber. The principle is as follows:–

> Material from the mixing chamber enters the labyrinth passage between the rotor end plates and the ring which rotates on the rotor. This ring, which is known as the floating ring because of its ability to float axially, automatically adjusts itself to suit the particular pressure and temperature requirements of the chamber. A special

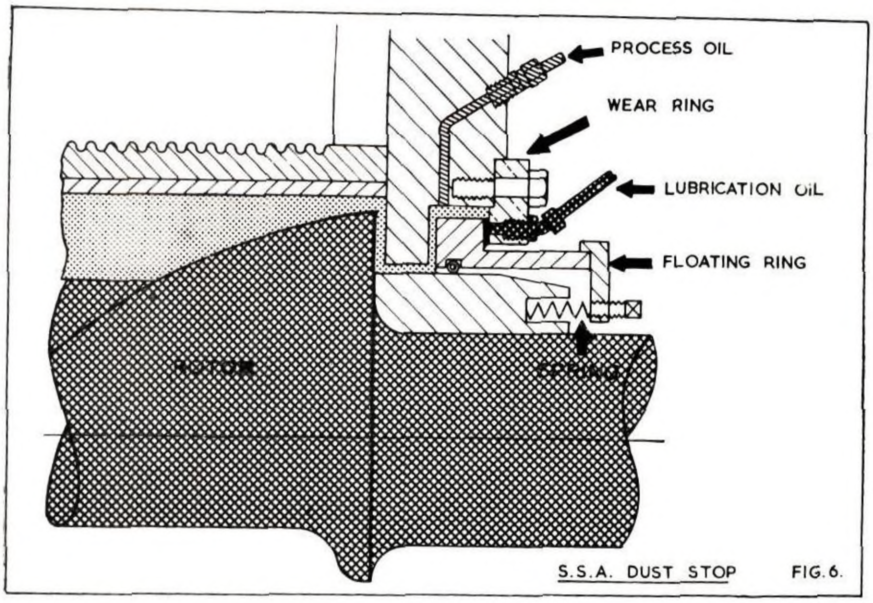

Figure 6.

'O' seal is fitted in the bore. A series of springs pre-load the floating ring against the wear ring. The geometry of this patented design is such that the sealing pressure between the floating ring and the wear ring is always greater than the pressure in the chamber. With this design of dust stop, two types of lubricants are used, one being a process oil which is pumped into the cavity behind the floating ring, and the other a lubricating oil. The process oil keeps the material in the cavity soft and reduces the temperature at this point. The components of this dust ring are in halves so that they can be more easily dismantled.

The self-sealing design is suitable for use with all rubber compounds and most thermo-plastic materials.

The Discharge Door

As previously mentioned, the drop door was designed to reduce the discharge time. However, this design has other advantages: (1) it gives a complete discharge without contamination; (2) there is no leakage of rubber or powders; (3) there are no lubricated slideways to cause contamination; and (4) the sealing surfaces do not deteriorate as the machine wears.

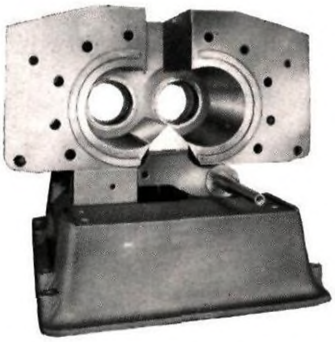

Figure 7. Drop-Door Closed

Figure 7 illustrates the drop door in the closed position. The door fits on tapered surfaces and is arranged to centralise itself automatically as it closes. The closing is helped by a hydraulically operated wedge which works against rollers on the door, ensuring that it is held firmly closed during the mixing operation. The door is illustrated in its open position in Figure 8. The door swings through an arc of 130° in under one second, exposing the full discharge orifice and allowing for a complete and clean discharge. A hydraulic pump unit is provided to operate this door.

Feed Hopper

The feed hopper is equipped with a cylinder of large diameter. A pressure-regulating valve is provided so that the downward pressure of the mix can be adjusted to suit both the particular material being mixed, and also the available house power. Between the mixing chamber and the feed hopper is a neck extension which enables all the materials to be fed quickly into the mixing chamber. This is particularly important in mastication, Masterbatch making, and final mixing. The hopper door is air-operated so that it is held firmly closed during the mixing cycle. Passage ways are provided for the flow of air to the dust collection system.

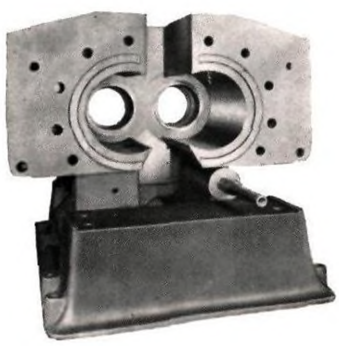

Figure 8. Drop-Door Open

Unidrive Gearbox

To enable the high power and speed to be applied to the rotors, it was necessary to remove the gears from the machine and put them into a separate gearbox, the power being transmitted to the rotors from the two output shafts via gear type couplings.

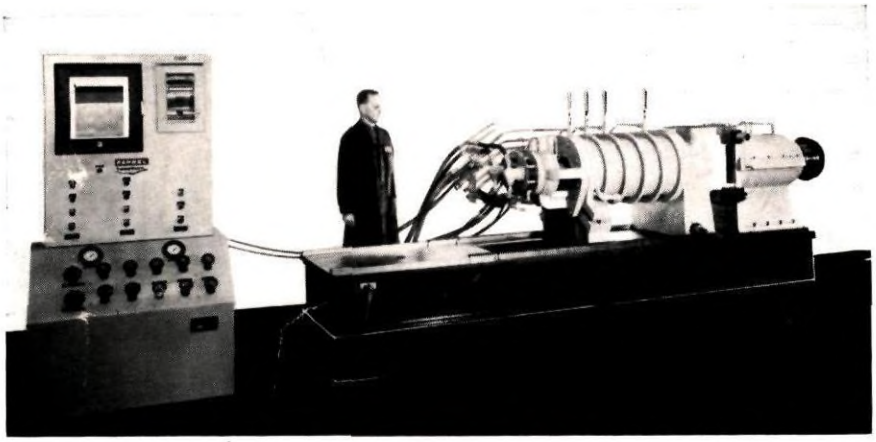

Figure 9.

The Farrel-Bridge Continuous Mixer

The Farrel-Bridge continuous mixer is not a twin screw extruder. It is a two rotor mixing machine which was designed and developed with a quality of mix obtained in the Banbury Mixer as a criterion. In some cases the quality of the mix surpasses that obtained in the Banbury Mixer. Certain analogies can be drawn between the two machines.

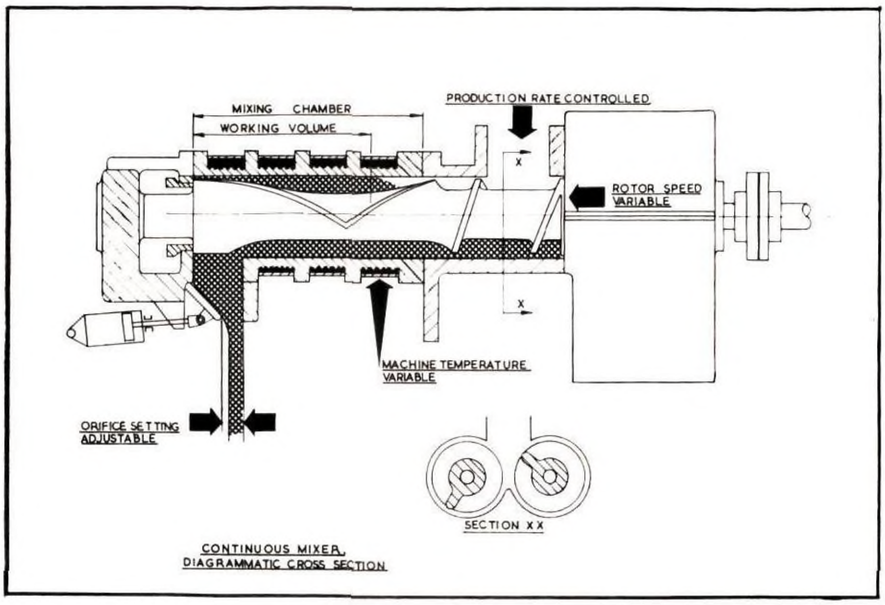

Figure 10

There are four variable conditions that control and affect the operation of the Farrel-Bridge Continuous Mixer.

1. Production Rate
2. Rotor Speed
3. Orifice Setting
4. Mixer temperature

These variables affect the gross power input, the discharge temperature of the stock being mixed, the dwell or residence time of each pound of material, and the actual working volume of the material in the chamber. All of these variables are inter-related and a change in one will produce a change in the other.

To illustrate, Figure 11 shows the inter-relation between Production Rate, Rotor Speed, and Orifice Opening versus the Work Input per pound of material being mixed. The curves on this chart are not intended to be quantitative in nature but merely indicate the direction of increase or decrease

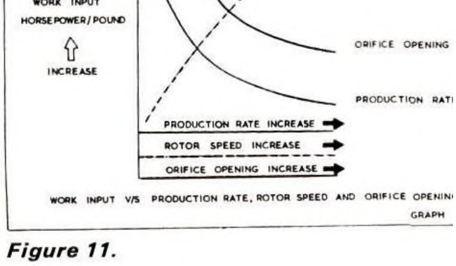

Figure 11.

Production Rate

With a fixed Orifice Opening and Rotor Speed an increase in the Production Rate reduces the amount of work put into each pound of material.

Rotor Speed

With a fixed Production Rate and Orifice Setting an increase in rotor speed will increase the work input per pound of material.

Orifice Opening

With a fixed Rotor Speed and Production Rate, an increase in Orifice Opening will reduce the amount of work per pound of material.
Therefore it can be seen that by proper use of these three variables plus the machine temperature control it is possible to set the machine to produce the most desirable results and also to vary its output to match the requirements of subsequent processes.

Method of Operation

See Figure 10 on facing page

Motion of the material through the machine depends upon the material throughout the length of the mixing chamber changing in stiffness. The stiffer material at the feed end pushes the softer material forward through the rotors to the discharge orifice. The screws which feed the rotors are never run full but in a starved condition. The balanced design of the rotors eliminates heavy thrust loads.

Steadiness of Electrical Load

When the machine is mixing continuously, there are no pauses for loading and unloading. Therefore better use is made of the Electrical Driving Motor because it runs under steady load conditions.

Machine Temperature Control

The machine is divided into zones enabling the machine temperature to be set to suit the material being processed.

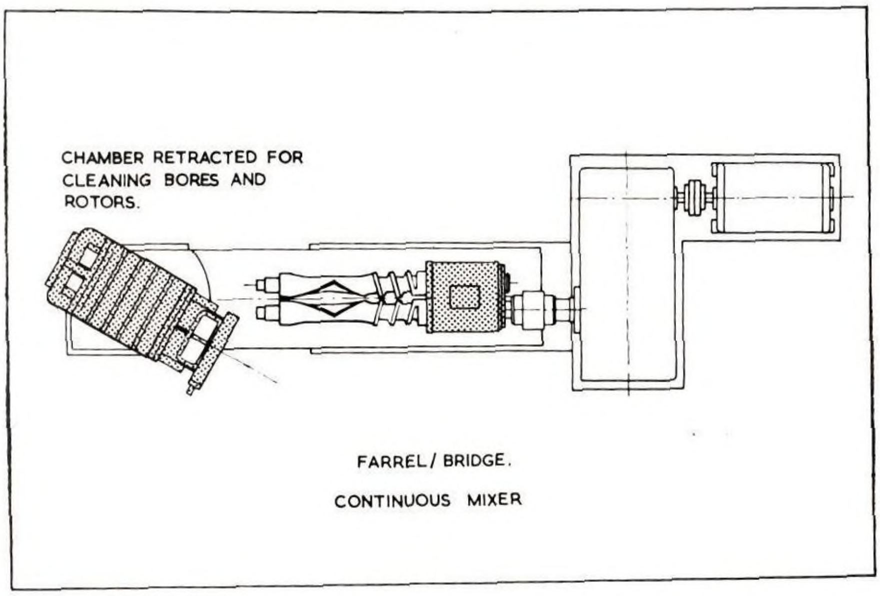

Figure 12.

Cleaning

The machine is designed so that the mixing chamber can be readily moved along the bedplate onto a turn-table exposing the mixing rotors and chamber cavity, so that both are completely accessible for cleaning.

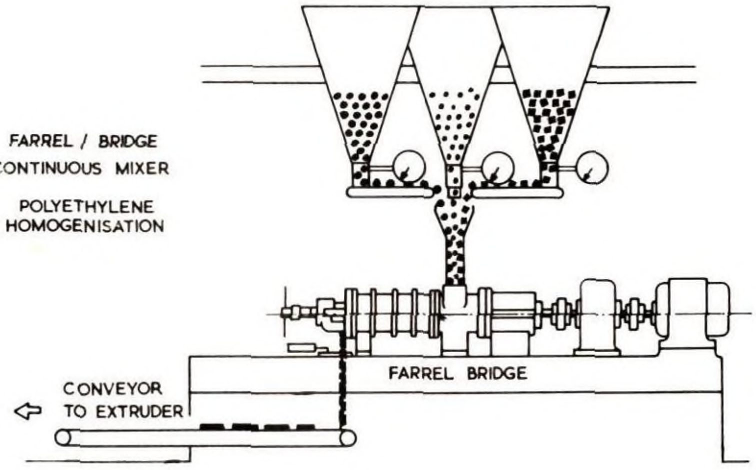

FIG. CM 4.

Figure 13.

Materials being Processed in the Continuous Mixer

The successful mixing of any material in the Continuous Mixer is dependent upon the ability to feed material continuously into the machine. It is permissible to feed materials in small increments at intervals not exceeding 15 seconds.

The machine has been very successful in the processing of plastics materials which are either in pellet or powder form, such as Polyethylene, Polypropylene and P.V.C.

Figure C.M. 4 shows a typical installation for the homogenisation and blending of polyethylene. There are feed hoppers with continuous weigh-scales for the proportioning of the materials. The output of the machine is arranged to feed an extruder with an underwater pellet head.

Whilst the Farrel-Bridge Continuous Mixer is comparatively new it has already made a great impact on the plastics field. It is only a matter of time before the technique of feeding the machine for rubber compounding is more fully developed.

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