International Fertilizer Industry Association

ISMA* Technical Meetings

Paris, France
25-27 September 1951

In 1982, the name of the International Superphosphate Manufacturers' Associations (ISMA) was changed to International Fertilizer Industry Association (IFA).

International Fertilizer Industry Association - Secretariat: 28 rue Marbeuf - 75008 Paris - France
Tel. +33 1 53 93 05 00 - Fax +33 1 53 93 05 45/47 - ifa@fertilizer.org - www.fertilizer.org

THE INTERNATIONAL SUPERPHOSPHATE MANUFACTURERS' ASSOCIATION

AGRICULTURAL COMMITTEE
11 AVENUE FRANKLIN D. ROOSEVELT
PARIS (8e)
TEL. BALZAC 57-25

SECRETARY:
R. M. COLLINS

CENTRAL OFFICE
32 OLD QUEEN STREET
LONDON, S.W.1.
TEL. WHITEHALL 7262

LE 297 September 1951.

TECHNICAL MEETINGS 1951

Paper No. 2. CONFIDENTIAL

This paper will be presented at the Technical Meetings in Paris on September 25th and 27th, 1951. It must not be published prior to that date and, in any case, it must not be published without the permission of the author.

NOTES ON THE FEEDING OF RAW MATERIALS IN THE CONTINUOUS PRODUCTION OF SUPERPHOSPHATE OR PHOSPHORIC ACID.

By P. Moraillon, (Manufacture des Glaces et Produits Chimiques de St-Gobain, Chauny et Cirey)

Although the continuous manufacture of Superphosphate has some real advantages which explains the fact that nowadays its adoption is making rapid progress, its realisation nevertheless sets certain problems of which the feeding of raw materials to the mixer is not the easiest to solve.

In order to obtain a product of good quality and uniform composition a precise control of the quantities of phosphate and of the acid introduced is imperative; such quantities have to conform at any given moment to a definite proportion, although a strictly constant discharge is not absolutely essential.

It goes without saying that, in addition, the composition of the raw materials must remain constant in the course of the same production.

There certainly exist some excellent types of continuous dens but experience has shown that the distributing devices for phosphate and acid with which these dens are mostly equipped leave much to be desired from the point of view of precision, maintenance and smooth running.

The study of the means to remedy those faults has led to the construction of different types of apparatus only to retain in the end those which in actual practice have shown themselves to have all the qualities of precision and sound construction which we regard as indispensable for Superphosphate works.

1. PHOSPHATE FEED.

Briefly, it is possible to distinguish two types of apparatus according to whether they control the volume or the weight of phosphate.

(A) VOLUMETRIC FEED.

The apparatus comprise, in the main, one or several buckets set in a rotor revolving at a constant speed about a vertical or horizontal axis.

The rotor is fitted very tightly in the interior of the carrier which is surmounted by a small phosphate hopper the level of which is kept constant by means of a continuous supply and an over-flow device. These buckets fill and empty themselves alternately, discharging, each time, a definite volume of phosphate, hence also a definite weight, provided that the bulk density remains the same.

In spite of the simplicity of the principle involved, these apparatus present many defects both from the point of view of mechanism as well as precision.

The presence of a very small foreign body in the phosphate, such as a nail for example, suffices to block the rotor by wedging itself between the outer casing and the carrier. In order to avoid in such a case the deterioration of the propelling mechanism it is necessary to introduce in the control a shear pin which acts as a fuse, but any breaking down of this device entails a considerable loss of time.

In addition, the close fitting of the rotor and the carrier decreases after a certain time of running due to the abrasion of the surfaces coming into contact with the phosphate. A portion of the latter enters in between the two parts and the volume discharged ceases to be controlled effectively.

Finally, experience shows that the bulk density of the phosphate is subject to considerable variations even if the grinding is perfectly even. The differences observed are due to the classification in the silos of particles according to their diameter and the irregular piling of the phosphate in the hopper surmounting the feed. The difference in size is particularly accentuated if a mixture of phosphates of various origin is used, owing to the imperfection of the mixture and to the variations in fineness due to differences in hardness and actual density. In addition, very finely ground phosphates (fineness 95% through sieve 100) are capable of retaining considerable quantities of air which vary according to the conditions of working and which render the notion of bulk density illusory.

The precision of a volumetric feed is very mediocre; the difference in discharge observed with identical speeds of revolution can be 5% which, to our idea, condemns this type of apparatus.

(B) GRAVIMETRIC FEED

This type of apparatus which is also called poidometer, consists in the main of a belt conveyor moving at constant speed on which the phosphate is placed and of which either a portion or the total quantity is weighed in a continuous manner by means of a weighing system. Any variation in weight controlled in this manner results in an increase or decrease in the quantity of phosphate admitted to the belt thus maintaining a discharge which is constant in weight.

(a) Figure I represents a diagram of the first type of apparatus functioning according to this principle. The phosphate contained in the hopper is removed in a continuous flow by a belt conveyor and passes over a weighing roller A attached by means of the lever AO'B and the rod BC to the beam of the scale DOE, kept in equilibrium by a box of tared weights F and the slider M. A sliding gate placed in front of the opening of the hopper, thereby limiting the quantity of phosphate passing, is attached by means of a rod, the length of which can be regulated, to the other end of the beam at E. In this manner any variation in the weight of the phosphate on the straight portion of the belt RS brings about a change in the equilibrium position of the beam and consequently a displacement of the gate in a manner which tends to compensate the initial variation.

The length of the rod BC should be such that with a horizontal beam the fixed rollers R and S and the weighing drum A equidistant from the preceding rollers should be tangential to the same horizontal plane. The tare in the box F is regulated initially in such a way that if the belt is empty and the slider in the zero position (in Mo) the beam remains in horizontal equilibrium.

In order to obtain the desired discharge one has to calculate beforehand - taking into account the speed of the belt - what should be the weight P of the phosphate on the straight portion of the belt RS; the slider weighing Q is then slid along to position M thus obtaining the following equation:-

$$\frac{P}{2} \times \frac{O'A}{O'B} \times OC = Q \times (OM - Mo)$$

or

$$MoM = \frac{P}{Q} \times \frac{O'A}{2 \cdot O'B} \times OC$$

It is also possible with the slider remaining at Mo to place in the box F a weight T thus obtaining the following equation:-

$$\frac{P}{2} \times \frac{O'A}{O'B} \times OC = T.OD$$

This done, it only remains for the apparatus to be set in motion and to regulate, by means of a winged screw I, the length of the rod EG in such a manner that the beam assumes a horizontal position.

In these conditions the pressure of the phosphate exerted on the weighing drum A is equal to half the weight of phosphate retained on the straight portion of the belt RS, as was admitted in the preceding calculation.

With this type of apparatus, where the displacements of the gate are brought about directly by the beam it is "a priori" evident that the corrections applied for the variations of bulk density of the phosphate are not complete: if the gate rises or descends it is because the equilibrium position of the beam has changed and therefore the weight of the phosphate on the length RS has ceased to be the same.

As a matter of fact, in the equation expressing the new conditions of equilibrium, the leverage of the [illegible] forces applied to the beam in relation to the axis C has changed and the tension of the belt comes into play, the straight portion RS having assumed a certain curvature.

The correction is, therefore, not complete and depends upon the characteristics of the apparatus but it can attain 90% of the variation which would have been observed if the gate had been fixed. Provided that the differences in bulk density of the phosphate does not exceed 5% the discharge will remain constant at about 0.5% which is quite adequate as far as accuracy is concerned.

On the other hand, even if the very pronounced variations in apparent density of the phosphate do not occur too frequently, the operator can readily remedy this state of affairs: it is sufficient for him to re-establish from time to time the horizontal position of the beam by turning the winged screw I. It is further possible to install in some part of the beam electrical contacts which set a bell ringing when the beam deviates, at a certain angle from the horizontal position.

By means of slight supervision it is possible for this apparatus to discharge a really constant quantity. It has the advantage that inertia is completely eliminated seeing that its reactions are spontaneous. In view of the simplicity of the apparatus its construction can be very strong; it is, however, essential that the friction caused by the sliding gate should be minimised which is attained by guiding it by rollers and by arranging a suitable fixed plate to eliminate the pressure of the product contained in the hopper on the sliding gate.

An apparatus of this type has been in use in our plant for twenty years and has given entire satisfaction.

(b) It is, however, easy to conceive apparatus on the same principle as the foregoing but still more precise and purely automatic and capable of correcting any variation in the bulk density of the phosphate. From what we have seen it is sufficient, as a matter of fact, to sever the mechanical connection between the two portions of which the poidometer is composed.

- the balance weighing the phosphate discharge.
- the gate regulating the quantity passing and making the gate act according to the indications of the balance through the intermediary of a servo-mechanism.

We have such an apparatus in use (fig. II) derived from the preceding type by adding a servo-motor driven by air, the distributor of which is regulated by the beam of the balance.

The method used is of the greatest simplicity: the servo-motor consists only of one cylinder 100 millimetres in diameter and 34 mm stroke and the air pressure employed does not exceed 500 mm of water, it is not necessary for the servo-motor to be fitted with a pressure gauge or that the piston should be adjusted in the cylinder with a clearance less than 0.25 mm.

The precision of this apparatus has been confirmed by approximately one thousand weighings. It has been ascertained that the quantity of material delivered in three minutes remains constant to the extent of + 2% even if the apparent density of the ground phosphate increases from 1.10 to 1.80 (the latter has been obtained by mixing green pyrites and phosphate).

(c) Another type of apparatus (fig. III) is equipped with an electric servo-motor. The two arms of the beam of the balance are equally long. The length of the rod supporting the weighing roller is regulated in such a manner that the empty belt is completely horizontal and rectilinear between the points of support R and S when the beam is horizontal. If the charge of the weighing roller is either insufficient or excessive the beam inclines and makes contact at either end with the mercury content of the vessels C or D. The contact closes an electric circuit which by means of a make or break (contacteur disjoncteur) determining the direction of rotation of the motor M. By means of a pronounced reducing gear this motor regulates the rise and fall of the gate E.

If the tare in the weight box is adjusted, so that the beam is horizontal when the belt conveyor is empty, the weight of the layer of phosphate between the supporting points E and S remains, under normal working conditions, equal to double the weight added to the box B.

An apparatus built according to the above description does not function altogether satisfactorily. It is observed that the beam oscillates continuously from one side to the other, and the gate is in perpetual motion, which causes fluctuations in the discharge and puts the motor to a severe strain.

The reason for this is as follows: when the gate is moving, the height of the layer of the product on the belt varies at any given moment from one end of the belt to the other. The moment the horizontal equilibrium of the beam is established, the electric contact is broken and the thickness of the layer of the product at the point of the weighing roller is that which would correspond to permanent equilibrium but the gate has already passed the corresponding position which at the end of a few second results in a renewed unbalance condition in the opposite direction.

It is possible to remedy this drawback by allowing the servo-motor to run intermittently in such a manner as to allow time for the phosphate layer to attain a uniform thickness and for the beam to become stabilised before permitting a fresh displacement of the recorder. Thus an equilibrium is obtained by a successive "button pushing" as a human operator would do.

The intermittent functioning of the motor is obtained by interposing in the power circuit a clockwork mechanism which can be regulated and which is set in motion by a cam at each revolution of the front roller of the poidometer.

With this improvement the functioning of this apparatus is very satisfactory and the precision excellent. The position of equilibrium of the beam is preserved for several consecutive minutes without the aid of the servo-motor.

Four apparatus of this type are in use at our works. Their behaviour is satisfactory in spite of the fact that they are worked very hard.

(d) In the preceding apparatus, the load of the product on the belt conveyor is controlled by making use of its suppleness. The principle is sound and the precision very great. This principle, is, in addition, embodied in the construction of certain continuous check-weighers used for the control of rubber belts.

There exist other apparatus where the entire belt conveyor including the motor rests on a fulcrum thus constituting a balance and that is why they are called pivoted belts (tapis-bascule). The pressure exerted by the phosphate is balanced by a counter-weight and the inclin... of the apparatus controls directly or indirectly the flow of supply. It goes without saying that, as in the foregoing, the conveyor is moving at constant speed.

In the apparatus represented in figure IV the pivoting of the belt conveyor about a horizontal axis regulates mechanically the opening or shutting of the gate valve at the base of the feed-hopper.

In another apparatus constructed and erected at one of our works, the regulation of the phosphate discharge controlled by a pivoted belt is carried out by the action of a servo-regulator on the speed of the chain-conveyor which removes the phosphate at the base of the hopper. This transporter is of the mesh type fitted with small scrapers and its arrangement at the base of the hopper is shown in diagram of Fig. V. It is set in motion by a motor the speed of which varies in the ratio of 1 to 4 according to the disposition (calage) of the brushes. The displacements of the latter in one direction or the other is ensured by auxiliary motor and by electric contacts (cliquets) which in their turn are regulated by a two-directional mercury circuit breaker attached to the beam of the balance.

This apparatus, in use for 16 years in one of our works for the continuous production of superphosphate, has shown itself very reliable. The only drawback is that it is more expensive to construct than the preceding apparatus, without ensuring a superior accuracy.

With the other apparatus of the same type the extraction device below the hopper is a worm-gear the speed of which is regulated by a speed regulator which is acted upon by a motor controlled by the balance.

Finally, it should be noted that there exist poidometers where the entire belt conveyor is mounted on a platform scale or attached to the weigher. The latter indicates the total weight of the apparatus when running, including the phosphate.

The feed is arranged in one of the manners mentioned above.

From the above it will be seen that there exists a great variety of poidometers all giving adequate precision provided that their construction is correct. Before choosing a poidometer it is advisable to verify in particular the constructional details. If entrusted to manufacturers who are not specialists the apparatus must be strong and fool-proof; all its parts must be accessible to facilitate cleaning and repairs. The beam must be visible and its equilibrium position indicated by a pointer to ensure the correct functioning of the apparatus.

It is advisable to equip the poidometer with a revolution counter fixed on the axis of one of the rollers of the conveyor or to fix on the latter a disc of known perimeter moved by the friction against the belt. As each complete turn of the latter transports a definite weight of phosphate, a measure of the total quantity of the material discharged is obtained. It is equally easy to record the speed of the belt by synchronisation of time and the revolution counter which would allow instant calculation of the discharged quantity which, in all cases, is proportional to the speed of the belt conveyor.

(c) Fluidity of phosphate.

Whatever the type of poidometer used it is evident that its accurate functioning is based on one essential condition i.e. that it is possible to govern and control effectively the running of the product when entering the apparatus. In this respect finely ground phosphate (fineness 95% through sieve 100) entails very considerable difficulties which at times appear to be unsurmountable. As a matter of fact, the very fine powder when in motion flows spontaneously on mixing with air, acquiring the properties of a liquid. It then cakes in an uncontrollable manner all over the apparatus which renders any control virtually impossible.

In order to avoid this disastrous caking it is necessary to study with great care the shape and dimensions of the hopper placed above the poidometer as well as the manner in which the phosphate enters the latter so as to avoid the formation of hollows and preferential channels and the introduction of air. Work is generally carried out with a constantly full feed hopper which requires continuous feeding and the recycling of the excess of phosphate to the lower silos.

II ACID FEED.

To our knowledge the acid distributors used in the industry are exclusively of the volumetric type. It would, in fact, not be easy to weigh the continuous flow of liquid.

A typical arrangement consists of a discharge by means of a nozzle calibrated below constant level of acid; this has the advantage of great simplicity but when used the precision may not be adequate due either to difficulties caused by a faulty arrangement (badly placed valves, badly designed elbow-pipes, eccentric orifice plates) or to varying viscosity or to mud sediments. To these drawbacks has to be added the fact that every time it is desirable to modify the flow, it is necessary to change the nozzle and to proceed to a new calibration; this lacks elasticity and entails a loss of time.

It is preferable to be able to modify at will the head of the liquid above the nozzle. The device shown in figure VII corresponds to this conception. The level of the liquid in the glass tube is regulated by acting on the valve and the flow obtained is proportional to h, h being the height of the column of the liquid above the nozzle. This flow can be calculated according to the following formula:

$$q = \frac{kd^2}{4} \sqrt{\frac{2gh}{1 - k^2 \frac{d^4}{D^4}}} \quad CM^3/sec.$$

or further:

$$Q = 125\, k\, d^2 \sqrt{\frac{h}{1 - k^2 \frac{d^4}{D^4}}} \quad \text{litres per hour}$$

by making d = diameter of nozzle in centimetres
D = diameter of the tube in front of the nozzle in centimetres
h = static pressure above the nozzle expressed in centimetres of the liquid (directly indicated by the level in the glass tube)
k = coefficient of flow, in the neighbourhood of 0.8 for a cylindrical nozzle and 0.6 for an orifice in thin material.

In order to obtain a constant acid level in the glass tube a suitable valve for the purpose of regulation has to be chosen. Plug cocks give good results.

In the U.S.A. a wide use is made of rotameter indicators and controls which control the opening of the valve by means of a servo-mechanism driven by compressed air. These apparatus give a precision of 2%.

Another apparatus which we would recommend especially because it can serve at the same time as integrating counter is the bucket-wheel which revolves at a pre-determined speed about a horizontal axis and where the buckets scoop up the liquid contained in a small receptacle fed continuously, allowing it to escape by means of a hollow shaft. In addition, this apparatus must be conceived in a rational manner. Certain installations comprise a bucket-wheel revolving at a constant speed where it is possible to regulate the flow by varying the height of the over-flow of the tank by means of a sliding tube. At first sight this principle appears to be sound but, unfortunately, the results are not satisfactory because any fluctuation of the feed to the tank causes a variation in the height of the liquid above the reservoir, hence in the discharge obtained.

In addition, it would be adviseable to study the shape of the wheel so that the buckets empty themselves completely on passing the highest point.

On the other hand, a bucket-wheel can give excellent precision (0.5%) when a special shape has been given to the buckets so that the normal fluctuations of the level of the liquid in the tank do not influence the flow obtained.

Such apparatus exist and give entire satisfaction to their users. One of them has been in use for twenty years in one of our works. It suffices to equip the apparatus with a revolution counter to constitute a total check. In order to vary the flow of discharge the speed of revolution is varied.

III. MECHANICAL REGULATION OF FEED APPARATUS

Among the above apparatus, those with mobile parts must be moving at a strictly constant speed in order to ensure a definite flow. From this point of view certain errors have to be avoided.

If, for example, the acid is regulated by nozzle whilst the phosphate is discharged by a single volumetric feed driven by the same motor as the mixer, any variation in speed due to the resistance of the mixer modifies the flow of phosphate although the flow of the acid remains constant.

Another cause for a possible variation in the flow obtained lies in the fluctuations of current frequency of the electric supply.

In certain regions oscillations are observed within a short space of time, between 48 and 51 cycles per second, i.e. a difference in value of 6% which corresponds to the same difference in the speed of revolutions of the motor.

That is why, if one is not absolutely sure of the frequency of the supply we are of the opinion that the use of a static flow regulator (nozzle or rotameter) is not to be recommended for an acid feed seeing that the phosphate distributor is, of necessity, of the mechanical type. On the contrary, it is advisable to use a poidometer and a bucket-wheel driven with preference by a common motor so that, although there are certainly temporary fluctuations of short duration in the discharge, the proportion of the two materials remains strictly the same.

In order exactly to regulate this proportion in accordance with the value desired several procedures are possible. One can regulate the tare of the poidometer. It is also possible to equip one of the apparatus with a speed regulator, the bucket-wheel, for example, the phosphate discharge remaining constant. In order readily to modify the whole speed of production without changing the proportion of the two materials, it is advisable to place in addition a speed gear behind the regulating motor.

Finally, it would be advisable to ensure an interaction between the poidometer and the bucket-wheel so as to stop the discharge of the phosphate if the acid is stopped and vice versa.

IV. CONTROL OF FLOW.

It is essential to be able to control rapidly and with precision the flow of material actually discharged by each apparatus. In order to obtain this, the quantity of discharged material corresponding to a number of revolutions determined by the revolution counter placed on the distributor should be measured (and not corresponding to a determined lapse of time which would introduce differences due to oscillations in frequency of the current). The knowledge of the relative speeds of the two apparatus will render it possible to calculate the ratio of the weights of the two products.

It is, therefore, advantageous to be able to calculate within a given period the flow of the material into a receptacle on a weighing machine or simply into a volumetric gauge for acid. For this operation the use of valves for the acid or of slides for the phosphate should be avoided as their manipulation is uncertain and requires too much time. A satisfactory device consists of a bent funnel swivelling round a vertical axis placed at the outlet of the distributing apparatus which allows of an extremely rapid movement to send the material towards the measuring receptacle (see figure VII).

In order to control the discharge of phosphate it is possible to collect and weigh the quantity of material present on a given length of the belt of the poidometer which has been stopped beforehand.

In some installations the measuring receptacle is placed during the normal transit of the material between the distributor and the mixer. The control of the discharge can thus be effected during manufacture by closing a valve or of the gate at the base of the receptacle. This process is very suitable but appears to us inaccurate in view of the duration of the shutting and the inevitable presence of an undetermined quantity of material in the receptacle at the zero point. In addition, for the duration of this manipulation the mixer is fed by a single constituent which is a disadvantage.

V. CONCLUSIONS.

The feeding of phosphate and acid in a modern continuous manufacture of superphosphate or phosphoric acid sets a problem of control and automatic regulation which is certainly intricate but which can be solved by means of a simple and serviceable apparatus giving a precision of about 1% as far as the constancy of the mixing proportion is concerned.

We hope that the foregoing indications, in spite of their general character, may be helpful when exploiting a continuous process either at present or in future, and serve as a guide for selecting an apparatus. We, on our part, have found that the use of rational apparatus with a satisfactory functioning is of inestimable advantage as far as the running of a works is concerned and allows of a distinct improvement in the quality of the product obtained.

June 1951.

----------oOo----------

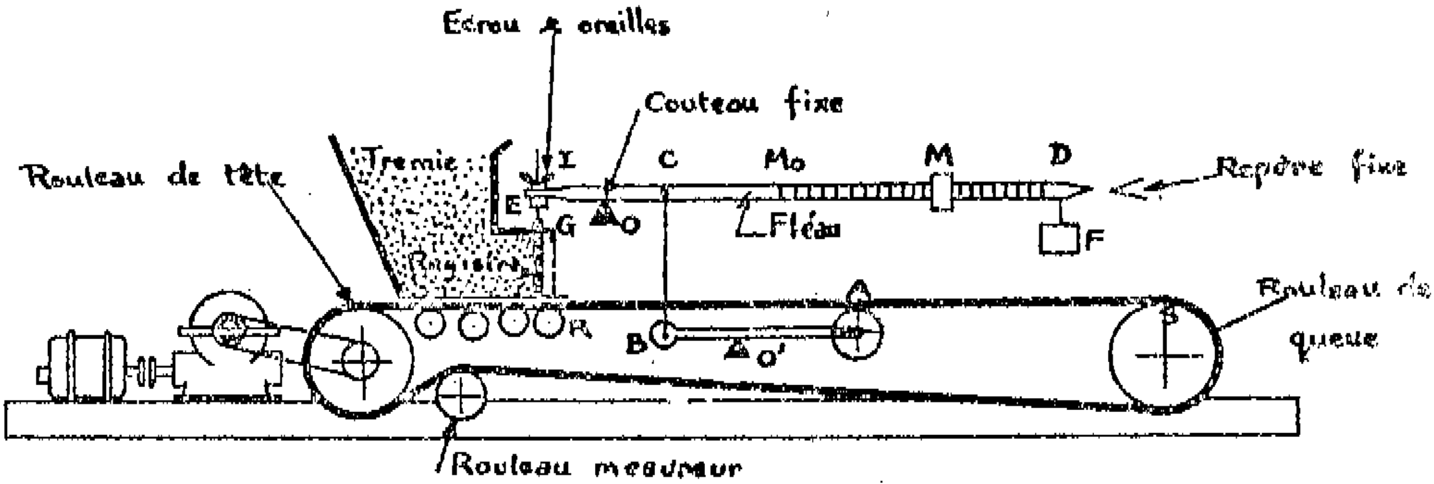

Ecrou à oreilles
Couteau fixe
Rouleau de tête
Tremie
I
C
Mo
M
D
Repère fixe
E
G
O
Fléau
F
Registre
R
B
O'
Rouleau de queue
Rouleau mesureur

Fig I

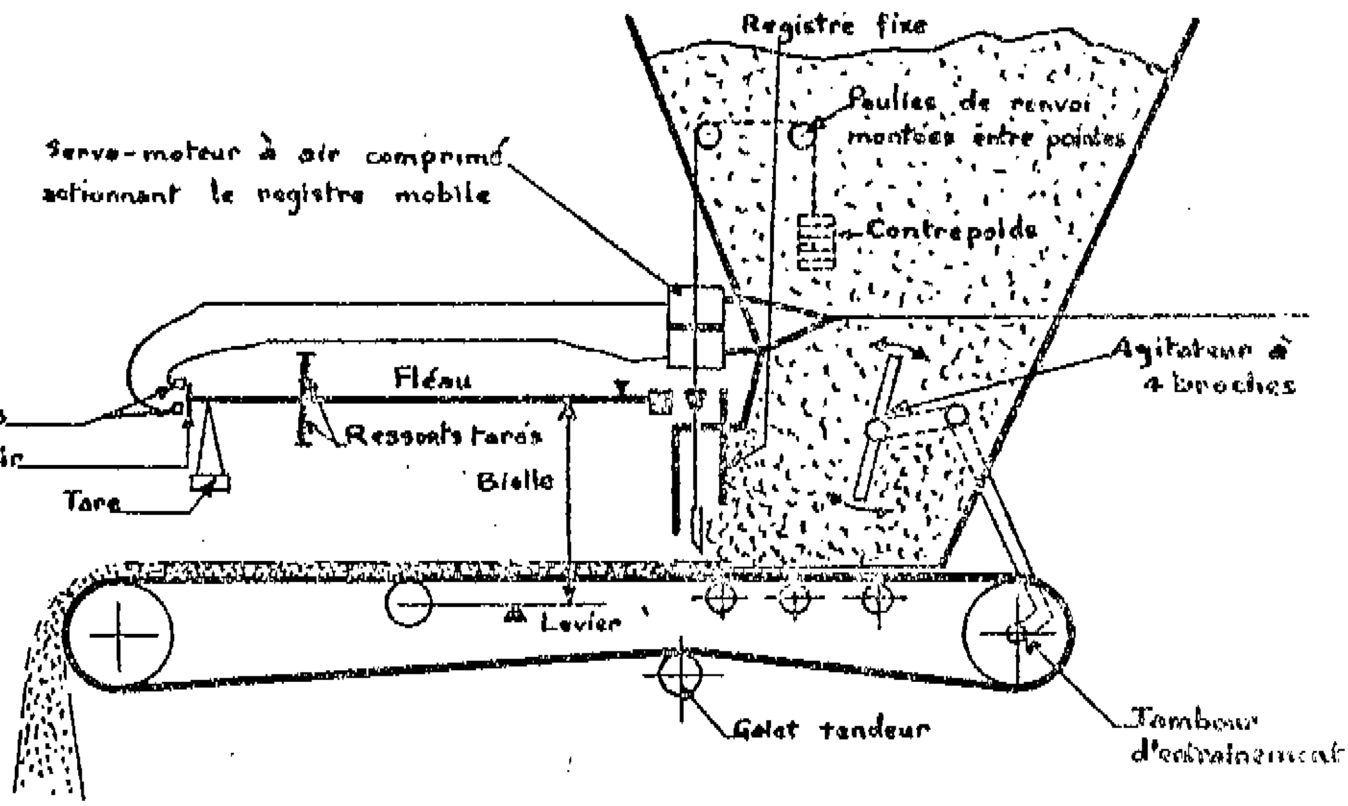

Registre fixe
Poulies de renvoi montées entre pointes
Servo-moteur à air comprimé actionnant le registre mobile
Contrepoids
Fléau
Agitateur à 4 broches
Tuyères
Tiroir
Tare
Ressorts tarés
Bielle
Levier
Galet tendeur
Tambour d'entraînement

Fig. II

FIGURE III

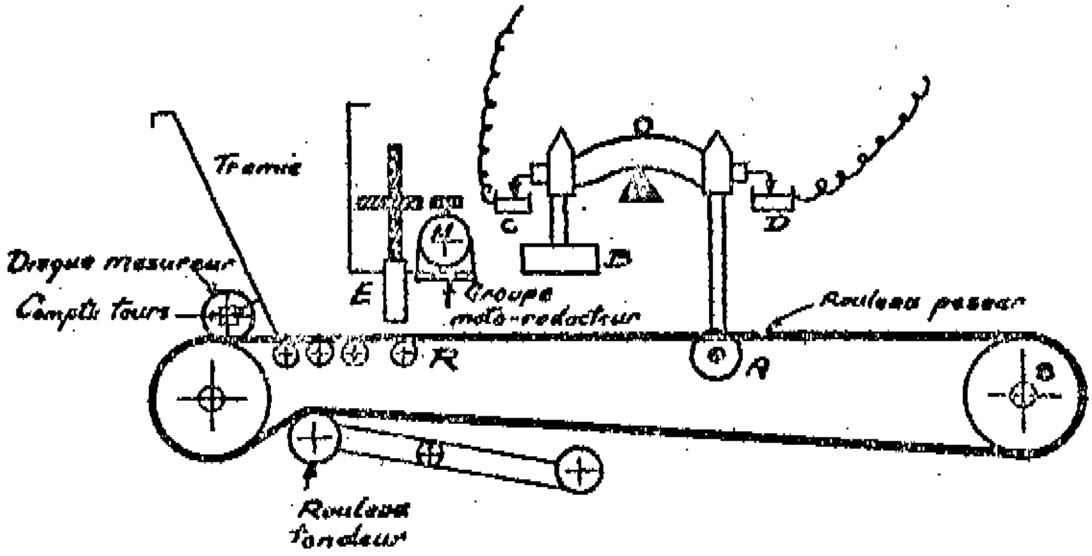


FIGURE IV

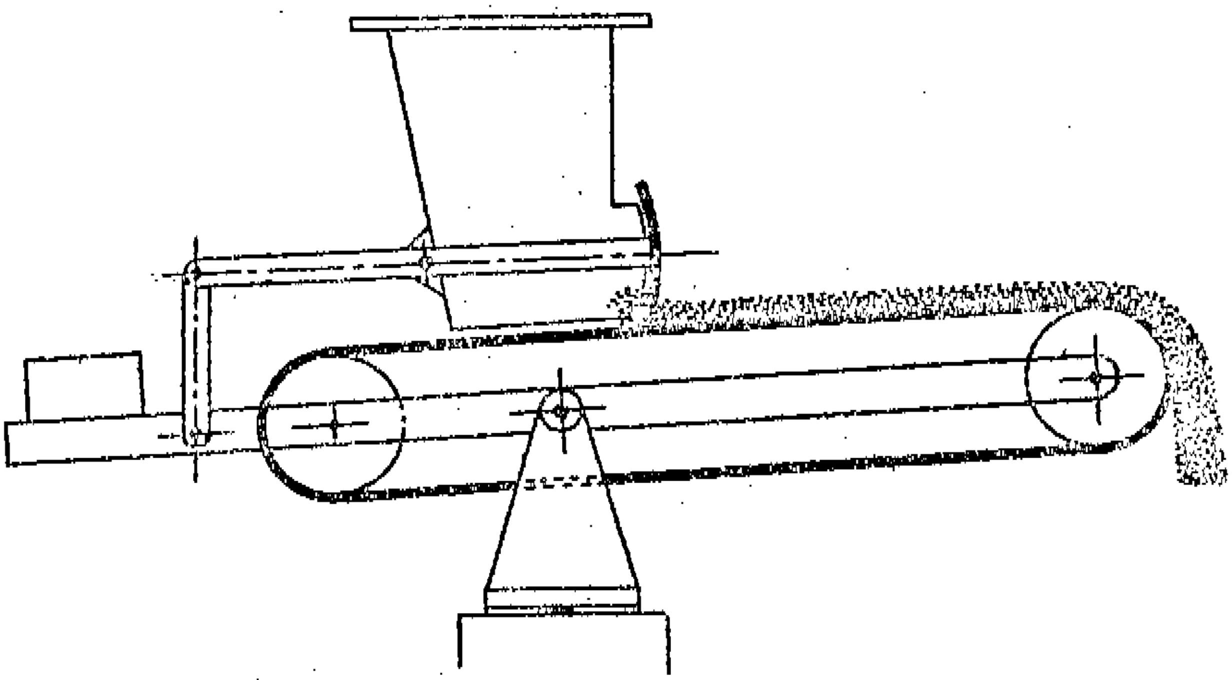


FIGURE V

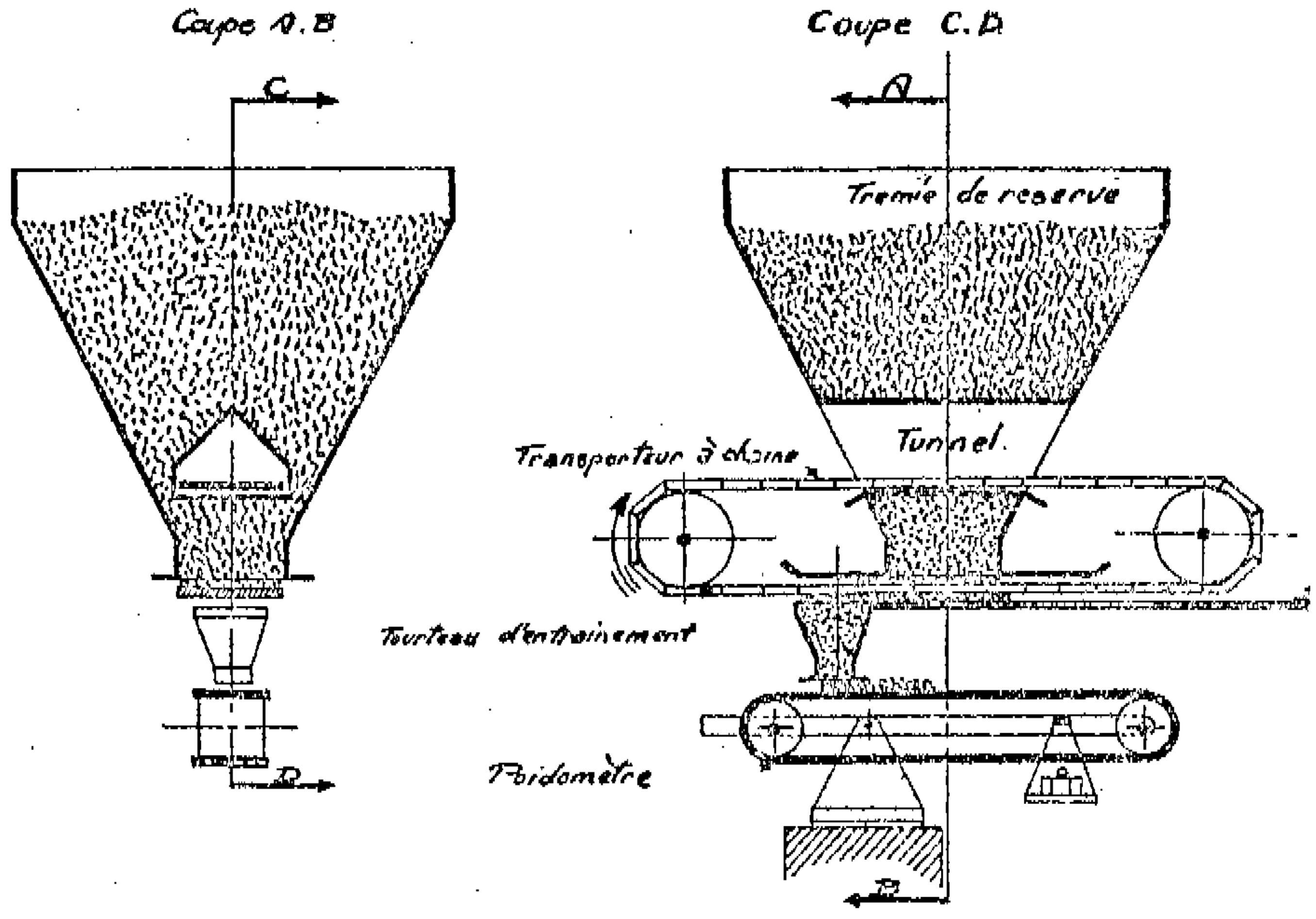
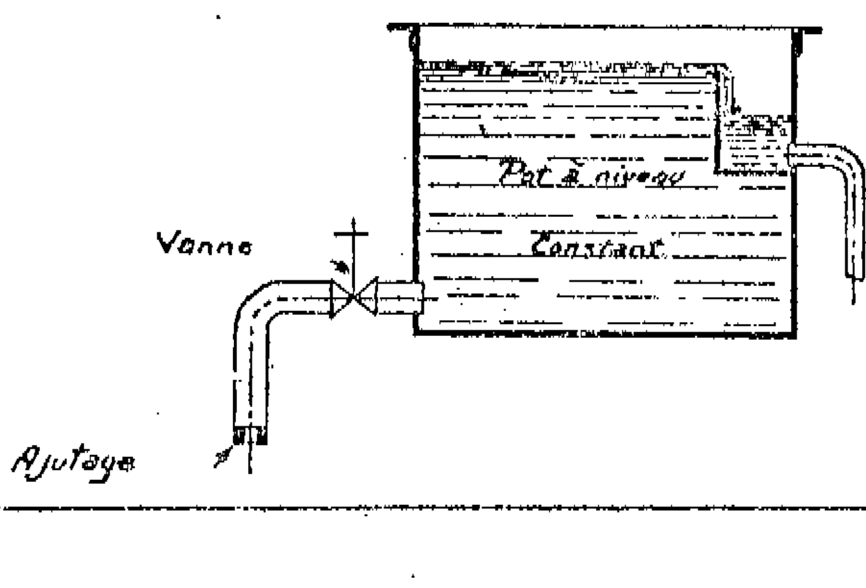


FIGURE VI



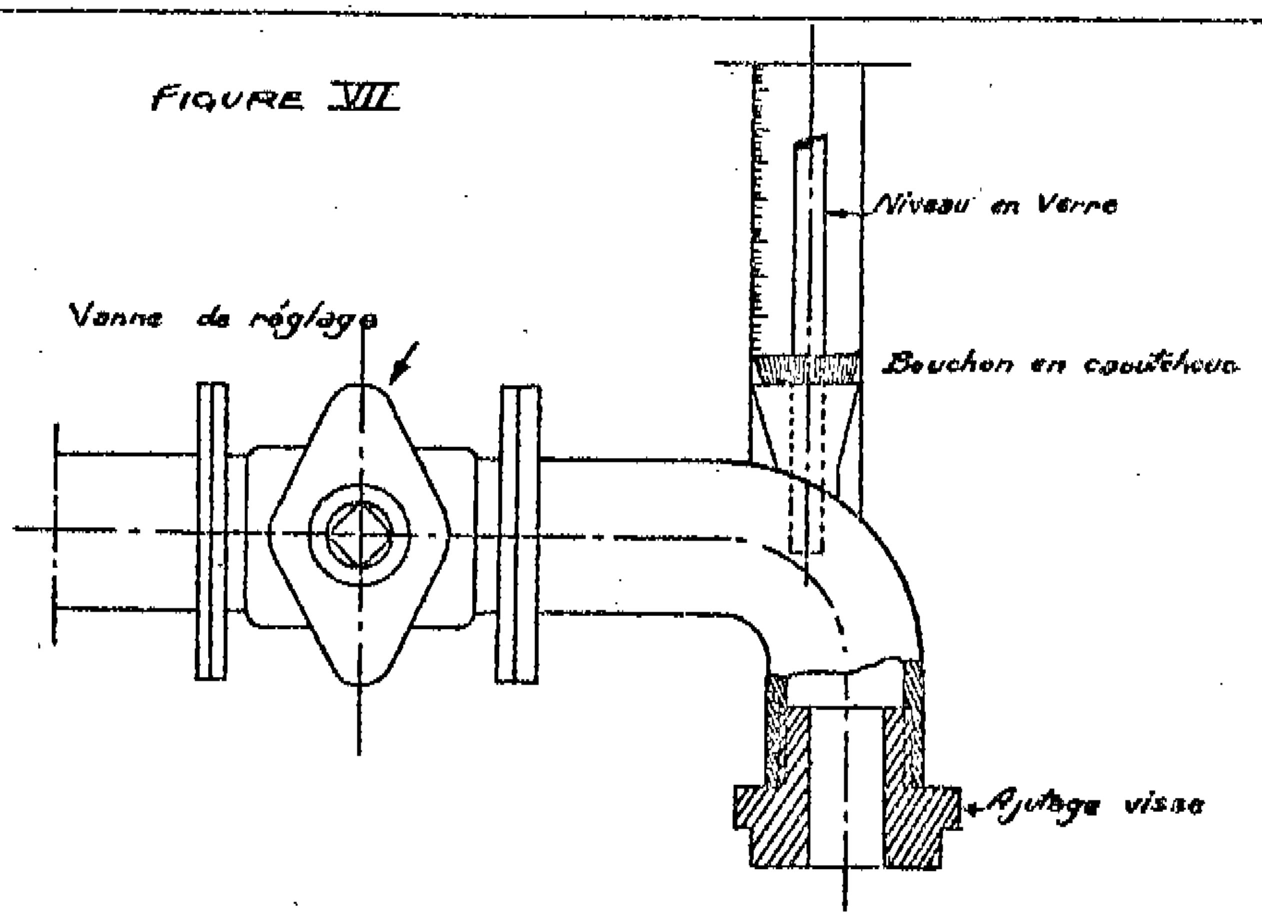


FIGURE VII

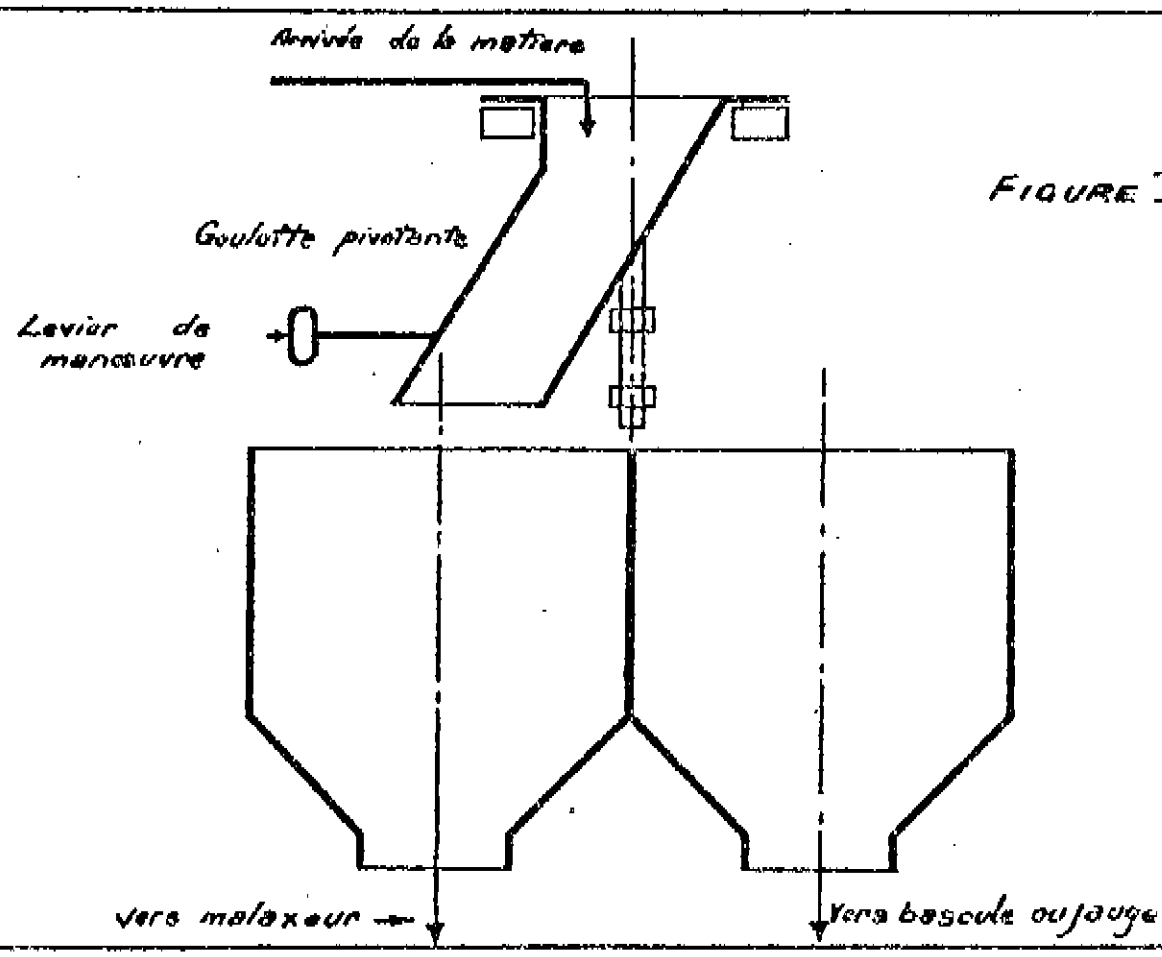


FIGURE VIII