asbestos-cement manufacturing technology

based on work by Dr. I. I. Berney

In past years the attention of the manufacturers of machinery and equipment for the asbestos-cement industry, was mostly directed towards the increase f the productivity of the forming machines. It is important now to concentrate on the quality of the product and investigation of the technology of asbestos-cement which may lead to the improvement of existing machines and the design of new methods of manufacture, responding to the requirements. This series of articles appearing in the AC/M commencing with this issue are based on work on the investigation of the technological process of manufacture of asbestos-cement products. The experimental work, theory and calculations carried out, will be published in detail and it is hoped that they will assist engineers and technicians in factories throughout the world, in comparing their own observations of the conditions of operation of their machines and draw conclusions on the best methods to adopt for securing a qualitatively rational and quantitatively economical production.
In the course of the investigation of the processes making up the cycle of manufacture, particular emphasis was given to the influence of each of these processes on the productive capacity of the machines and on the physical mechanical properties of the asbestos-cement end product.
Considerable space will be dedicated to the methods and apparata used for the study of the process of filtration of asbestos-cement suspensions, filtration of water through the technical felt, dewatering of asbestos-cement layer, mechanical properties of felts — asbestos-cement layer — end product, plasticity of the end product. On the strength of the results obtained, recommendations will be given for the improvement of the design and technological process of operation of the machines.

Introduction.

Asbesto-cement as a new material was first used in 1892 although industrial production started only in 1900 when for the manufadture of roofing materials, the sieving process was introduced for the first time. Processes other than the sieving process were offered periodically but never got the wide application that the sieving process has known.
It is only later that the sieving process was applied for the manufacture of asbestos-cement pipes. A brief outline of the organisation and technology of the asbestos-cement factory is given hereunder. The binding characteristics of asbestos fibres and hardened cement stone represent the physical and chemical basis of the manufacture of asbestos-cement structural materials, asbestos fibre reinforcing the cement stone and thus increasing its strength. Apart from being expected to give an economic volume of production, the machines and the technological process should aim at increasing the reinforcing properties of asbestos-cement products.
The degree of fiberisation of asbestos, as delivered from the mines for consumption in the A/C industry, is not sufficient and its specific surface must be increased.
A number of relatively simple machines are conventionally installed in all factories for the purpose.

The next stage is the mixing of the treated asbestos fibres with cement in a water medium. Degree of fiberisation and the mixing of cement with the asbestos fibre suspension (aiming at maximum adhesion of cement on its surface) are perhaps the most important operations of the whole technological process of manufacture. Asbestos-cement stock in water is subsequently transferred from the mixing devices into what is mormally known as the Scoop Mixer where it is kept in agitation and from which the forming machine is fed. The detailed description of the forming machines will not be given in these articles but only the fundamentals necessary for understanding the principles of the process of manufacture of asbestos cement sheets and pipes.

The sieving part of the machines produces the asbestos-cement elementary layer formed by the filtration of the asbestos-cement suspension. The sieving part consists of one or more vats in each of which one sieve cylinder and as a rule 2 agitators operate.

Until recently only conventional type sieve cylinders were known and used. The total open area between the elements constituting the frame of a conventional sieve cylinder is 75 % which represents 36 to 40 % of the total surface area of the cylinders.

New types of sieve cylinders have been recently introduced, known as the « Wedge Wire Sieve Cylinders » which offer a considerably increased open area and which require no undercovers.

Conventional bronze sieve cylinders are first covered with an underwire No. 5 (4 openings per cm^2). This is in turn covered by a wire (No. 60 as a rule — 576 openings per cm^2 — 60 openings per linear inch). The openings of the undercover represent 40 % of the total surface area of the undercover and the openings of the cover 28 % of the total surface area of the cover.

Sieve cylinders of various diameters are used in the industry - 500 - 720 - 850 - 1000 - 1250 mms. The length of the sieve cylinder moulds and of the vats varies from 1350 mm to 6100 mm as the case may be.

The process of formation of abestos-cement pipes or sheets consists of the following: Asbestos Cement suspension (concetration 6-14 % as a rule) at a temperature of 25-35° C is fed into the sieve cylinder vat (s) from the Scoop Mixer: Agitators in the vat rotate independently at 140-160 rev/min. preventing the deposit of the solid phase of the suspension. The level of the slurry in the vats increases gradually while in the interior of the sieve cylinder, the filtrated water remains constant flowing freely from its sides into the special openings at the sides of the vats. As a result of this, the level of the suspension in the vat is always higher than the level of water inside the cylinder. This difference of levels creates the hydrostatic pressure which makes filtration possible. During the process of filtration of the suspension. the particles of asbestos-cement are deposited on the surface of the covering wire cloth.

The machine should be started only when the vat(s) have been sufficiently fed with asbestos-cement suspension. The technical felt which is pressed against the surface of the sieve cylinders by the couch rolls. is also the driving force that starts the rotation of the sieve cylinder and while doing so, it collects the elementary asbestos-cement layer formed on the surface of the sieve cylinder.

At the moment the elementary layer is picked-up by the felt, its moisture content is reduced from 68-70 % to 48-52 % as a result of the pressure. As the layer is conveyed on the technical felt towards the formation core, it passes over vacuum boxes and its moisture content reduced to 42-45 %. Further dewatering takes place by pressure when the elementary layer is deposited on the formation core and its water content is again reduced to 28-32 %. Every turn of the formation core causes an additional layer to depose on it until the end product is formed according to the requirements.

The level of the suspension in the vat should be kept at 0,6-0,8 of the diameter of the sieve cylinder: under such conditions, the level of the water in the interior of the sieve cylinder will not exceed 0,15 of its diameter. The thickness of the elementary asbestos-cement layer, is a much debated subject and it normally varies between 0,4-1,3 mms.

Many researchers have concluded that the increase of the thickness of the elementary layer leads to the reduction of the strength of asbestos-cement.

It is the Authors' belief, however, that incomplete research is the origin of this conclusion.

Many technologists obtain a good quality end product by building it up with a thin layer. This method of improving quality, is not the best however, as inevitably leads to a substantial reduction of the output of the plant and should therefore be considered as an uneconomical solution. The problem of obtaining an end product of high quality while maintaining a high rate of productivity of the asbestos-cement machines, can be satisfactorily solved.

The full investigation of the operation of the asbestos-cement manufacturing machines had to be undertaken as it was the absence of such research work that made impossible the coordination of the calculations obtained for the different processes of the cycle and the absence of data can also be explained by the technical imperfections of the machines. Incomplete investigation of the process of manufacture of asbestos-cement products, not only prevented the design of new machines but also prevented the improvement of the existing ones.

Sieving, pressure, felt speed, concentration of suspension, pressure of rolls are all questions which need an answer and the best parameters for different technological conditions must be established.

It is odd to note that the intensity and duration of the process of dewatering of the asbestos-cement layer by vacuum and the relation technology-technical characteristics of the machine have not been carefully investigated especially in respect to dimension and size of the sieve cylinder moulds.

Experience shows that the operation of asbestos-cement machines varies from factory to factory and that much depends on the skill and experience of the operators. Differences resulting from different methods of operation are as high as 30-50 %.

Another serious point is the lack of sufficient data in respect to composition and method of processing of the raw materials and their influence on the manufacturing process; this makes impossible the establishment of a method for determining the quality of asbestos-cement suspension and its influence on the operation of the machine. The same reasons account for the impossibility to assess with precision the output of the machines in relation to variations of asbestos and cement.

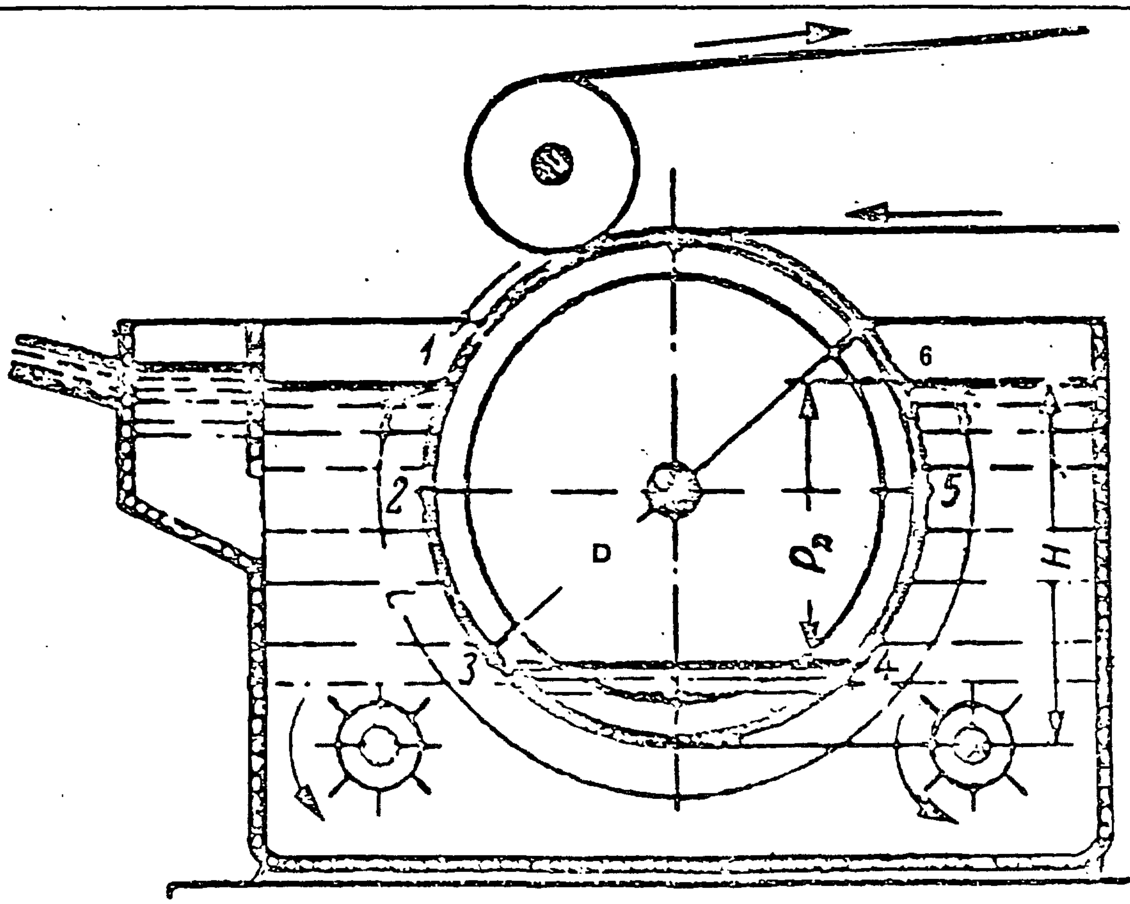

Fig. 1. - Vat and sieve cylinder of an A-C machine. D. = diameter of sieve cylinder. P_n = maximum hydrostatic pressure. L = perimeter of sieve cylinder immersed in the suspension. $H/D = K_n$ = coefficient of immersion.

All these factors explain the difficulties and complications met by different investigators and the reason why the entire technological cycle has not previously been investigated as such. Besides scientific knowledge had to be coupled with experience of the operating conditions in asbestos-cement factories.
The Authors in undertaking this work, believed that basic principles of manufacture could be established if attention was concentrated not only on the specific problems separately but on the general technological process as a whole.
In the series of articles that will follow, the results of the investigation of the main processes separately, will be published and also their study which has permitted to draw conclusions of a general character, not related to a special machine or raw materials of any special composition, but applicable to all machines of any construction and working under different technological conditions. In all cases when possible, the information obtained is generalised by mathematical equations which can be used for technological calculations.

Filtration of asbestos-cement suspension: the process of filtration and its experimental investigation.

The work of the sieve cylinder of an asbestos-cement manufacturing machine has a fundamental significance for the investigation of the technology of asbestos-cement manufacture. Of equal importance are furnish design and degree of openness of asbestos-fibres in relation to the productivity of the sieve cylinder, the temperature of suspension and its concentration, felt speed, size of sieve cylinder and the dependance of the physical-mechanical properties of the end product on the conditions of operation of the sieve cylinder.
The productivity of the sieve cylinder will be expressed in terms of the quantity of asbestos-cement delivered on the surface of the covering wire, per unit of time and this can be calculated by the following equation:

$$G_z = \gamma a_z \cdot \delta a \cdot uc \cdot B_z = G \cdot uc \cdot B_z \text{ gm/sec} \qquad (2\text{-}1)$$

where:

$G = \gamma a_z \cdot \delta a$ the weight of asbestos-cement delivered during the process of filtration on one cm² of the cover-wire cloth, during one full turn of the sieve cylinder, gm/cm².

uc Speed of felt, cm/sec.

B_z length of the sieve cylinder effectively working (filtrating), cms.

δa thickness of the asbestos-cement layer delivered on the cover-wire cloth, cms.

γa_z specific weight of the asbestos-cement layer (solid phase) delivered on the sieve cylinder, gm/cm³.

As the structure of the formula indicates, the productivity of the sieve cylinder can only be determined if the thickness of the layer is known. The formula cannot be applied for technological calculations if the thickness of the layer is not known and less for the determination of the thickness.
The thickness of the layer depends on the quantity and concentration of the asbestos-cement suspension and consequently, the productivity of the sieve cylinder is closely connected to the process of filtration.
Example: Considering an area of one cm² of the sieve cylinder (fig. 1) and volume V of the filtrated material which passes through that area, during its movement from points 1-6, the time taken in seconds is the rate of filtration.
If the concentration of the suspension is equal to « a » gm/cm³, then the quantity of asbestos-cement contained in the filtrated suspension would be equal to aV. However, all the particles contained in the suspension are not delivered on the face-wire, some passing through the openings of the cylinder and some being damaged and remaining in the bottom of the vat. The real quantity of the solid phase which is therefore delivered on the face-wire is the coefficient of delivery Ky (Ky will be explained later, in detail). Consequently, the weight of asbestos-cement delivered on the area under consideration, will be equal to:

$$G = Ky \cdot aV \qquad (2\text{-}2)$$

The volume of asbestos-cement is obtained by dividing the weight G by the specific weight and the thickness of the layer is equal to the volume divided by the surface of the area expressed in cm², or:

$$\delta a = \frac{Ky \cdot aV}{\gamma a_z \cdot 1} = \frac{Ky \cdot aV}{\gamma a_z} \qquad (2\text{-}3)$$

By introducing the weight of the layer in formula (2-1), we obtain in weight units, the equation for the calculation of the productivity of the sieve cylinder:

$$G_z = Ky \cdot aV \cdot u_c \cdot B_z, \quad \text{gm/sec.}$$

The last two equations indicate that for the determination of the thickness of the layer and the pro-

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ductivity of the sieve cylinder, it is necessary to establish only one unknown — volume V of the filtrated material through 1 cm^2 of surface area. The other factors, concentration of suspension « a », felt speed « u_c » and length of sieve cylinder B_c, are all known.

Consequently, the calculation of the productivity of the sieve cylinder will be possible if the relation between volume of filtrated material V and the basic technological parameters are established. In order, however, to establish this relation, it is necessary to investigate the process of filtration of asbestos-cement suspension.

In order to obtain data which would be characteristic of the different conditions of operation of the machines simulating factory production, the investigation of the process of filtration was carried out as follows:

a) *With different hydrostatic pressures.* The value of hydrostatic pressure in the sieve cylinder (see fig. 1) changes from zero at point 1 to maximum P_n at points 3 to 4. With a sieve cylinder of 1200 mms diameter, P_n would be 60 cms. and with cylinders of 850 and 500 mms, it would be 42 and 30 cms. respectively.

b) *With different rates of filtration.* The rate of filtration is equal to:

$$t = \frac{L}{u_c} \qquad (2\text{-}5)$$

where:

L is the circumferential section of the cylinder immersed in the suspension (points 1-6, fig. 1), in cms. The average value of L is equal to 0,62 πD (coefficient of immersion $K_n = 0{,}6$);

D is the diameter of the sieve cylinder.

u_c is the speed of the felt.

With a felt speed of 35 metres/minutes (58,4 cm/sec.), the rate of filtration will be: for a sieve cylinder of 1200 mms. diameter, 4 seconds; for a sieve cylinder of diameter 850 mms., 2,83 seconds and for a sieve cylinder of 500 mms diameter, 1,67 seconds.

c) *With suspensions of different concentration (from 5-14 %).*

d) *With different temperatures of the suspension (from 15-35° C).*

e) *With different raw materials (composition and degree of processing).*

The calculation of the productivity of the sieve cylinder, in consideration to the above variables, was a difficult task and hence work was divided in several parts, in the following order:

1) The process of filtration.
2) Investigation of the filtration of the suspension in the laboratory. This work was carried out by maintaining constant the composition, concentration and temperature of the suspension and the hydrostatic pressure. The only variable was the rate of filtration and the results gave the relation between the volume of filtrated material V and the rate of filtration t. Later the relation between the volume of filtrated material V and the rate of filtration t, was further investigated by introducing changes of hydrostatic pressure and composition, concentration and temperature of the suspension. Experimental work was also carried out, under actual factory conditions for checking the correctness of the equation for the calculation of the productivity of the sieve cylinder. Examples of application of the equation for practical calculations, will be given.

The influence of the conditions of operation of the sieve cylinder, on the quality of the end product was also examined separately.

The basic concepts of the process of filtration.

Filtration is the separation of the solid phase from the liquid phase by means of porous media which let pass the liquid while retaining the solid particles. The passage of the liquid through the porous screen, is the result of different pressures, on both sides. For the filtration of the suspension, metallic wire cloth has been used, the openings of which are greater than some of the particles of asbestos-cement.

Every unit of volume of the suspension which is filtrated through the wire, leaves on it a sediment, the quantity of which depends on the concentration of the suspension. The thickness of the sediment left on the wire during the process of filtration, continually increases while the passage of the suspension through the medium diminishes gradually and will eventually stop when the layer formed on the wire will have the required thickness for holding the thinnest particles of the solid phase of the suspension. It is only from that moment onwards that the real process of filtration begings. This period, will be referred to as « non stabilized ».

The layer of asbestos-cement formed on the surface of the wire, acts as a filter and therefore the quantity

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of water passed through the layer, determines the quantity of suspension filtrated per unit of time and as a consequence the productivity of the sieve cylinder.

It is important to note that the pores in the layer do not have definite forms nor equal sections; their size increases or decreases in conformity with the space between solid particles; it is therefore impossible to establish the rate of movement of the liquid through the pores of the layer; consequently, by rate of filtration we will understand the quantity of material filtrated per one unit of time through a unit of area of a transversal section of the layer which includes the section area of the pores and the area occupied by the solid particles.

The transversal section area of the layer is greater than the transversal section area of the pores and therefore the rate of filtration is necessarily lower than the real rate of movement of the liquid through the pores. The rate of filtration is higher at the beginning of the process and it gradually decreases as the thickness of the layer increases.

It is therefore necessary to know the average rate of filtration and its moment value.

The average rate of filtration equals:

$$u_f = \frac{V_n}{Ft} = \frac{V}{t} \text{ cm/sec.} \qquad (2\text{-}6)$$

where:

- V_n is the volume of filtrated material in cm³, obtained from the entire surface of the filter.
- $V = \frac{V_n}{F}$ is the quantity of filtrated material obtained from one unit of the surface of the filter, cm³/cm².
- F is the surface area of the filter, cm².
- t is the rate of filtration in seconds.

The moment value of the rate of filtration is expressed in differential form and equals:

$$\dot{u}_f = \frac{dV}{dt}$$

Experimental work was carried out for the investigation of asbestos-cement suspension and determination of the rate of filtration. The data obtained from the analyses of the results, enabled to establish the relation between the volume of filtrated material and rate of filtration, thickness (or weight) of the layer and pressure.

The following relation between rate of filtration, pressure and thickness of layer has been established by other investigators:

$$\dot{u}_f = \frac{dV}{dt} = \frac{P}{r\delta a} = \frac{P}{R_n} \qquad (2\text{-}7)$$

where:

- P is the constant pressure.
- r is the coefficient of proportionality.
- δa is the thickness of the layer.
- R_n is the resistance.

A similar relation can be observed in the movement of liquid through a sediment and in the capillaries. This analogy is useful in assessing the physical meaning of the values of the equation of filtration.

Filtration is the process of dewatering of a suspension of thin dispersion.

For a suspension of thin dispersion, the size of the pores in the delivered layer, and the size of the solid particles which compose the layer, are expressed by values of the same order. The asbestos-cement layer consists of 85 % by weight of cement grains, most of which and the pores which exist among them, have a diameter of less than 50 microns.

The volume of liquid V_k discharged from capillaries of such fine section, can be determined by the following equation:

$$V_k = \frac{\pi}{128} \cdot \frac{P d_k^4}{\eta l_k} t \qquad (2\text{-}8)$$

where:

- P is the difference of pressure at the two ends of the capillaries.
- l_k is the length of the capillary.
- d_k is the diameter of the capillary.
- t is the rate of flow.
- η is the dynamic coefficient of the viscous liquid.

In order to be able to apply the above equation for the calculation of the movement of the liquid through the asbestos-cement layer, we must assume that all the capillaries in the layer have an equal diameter. The calculation will be correct if the rate of filtration is not affected.

This theoretical equality of diameter will be indicated be the following symbols:

- d_t is the theoretically equal diameter of the capillaries in the layer.
- V_t is the volume of liquid passed through one capillary of theoretically equal diameter.
- Z is the number of capillaries of equal diameter, on surface F of the layer.

l_s	is the length of capillaries of equal diameter, in the layer.
F_k	in the sum of the section areas of the capillaries, on surface F of the layer.
$\frac{F_k}{F} = a_k$	is the relation between the section area of the capillaries and the section area of the layer, which depends on the porosity of the layer.

The surface area of the layer F in relation to the section area and number of capillaries, can be expressed as follows:

$$F = \frac{F_k}{a_k} = Z \frac{\pi d_s^2}{4 a_k} \tag{2-9}$$

If in equation (2-9) F is substituted with V_n (from equation 2-6 expressing the average rate of filtration), the result will be:

$$V_n = V_s Z = \frac{\pi P d_s^4}{128\, \eta\, l_s} t Z$$

where: V_s is the quantity of liquid passed through one capillary of equal diameter which can be determined by equation (2-8).

The simplification of the equation will give:

$$u_f = \frac{V}{t} = \frac{a_k}{32} \cdot \frac{P d_s^2}{\eta l_s} \tag{2-10}$$

An important relation has thus been established: the rate of filtration is proportional to the square of the diameter (equal) of the capillaries in the layer. If we assume that the average length of the capillaries l_s is proportional to the thickness of the layer δa and to the thickness of the sieving wire δm, then the following expression can be written:

$$l_s = \beta_1 \delta a + \beta_2 \delta m$$

where β_1 and β_2 are the coefficients of proportionality. If in equation (2-10) the length of the capillaries is substituted by the thicknesses of the layer and sieving wire, we shall get:

$$u_f = \frac{a_k P d_s^2}{32\, \eta} \left(\frac{1}{l_s} \right) = \frac{a_k}{32} \cdot \frac{P d_s^2}{\eta} \left(\frac{1}{\beta_1 \delta a + \beta_2 \delta m} \right) =$$
$$= \frac{P}{\eta (x_1 \delta a + x_2 \delta m)} = \frac{P}{\eta R_n'} = \frac{P}{R_n} \tag{2-11}$$

where:

x_1 is equal to $\frac{32\, \beta_1}{d_s^2\, a_k}$

x_2 is equal to $\frac{32\, \beta_2}{d_s^2\, a_k}$

and are the coefficients which characterize the size of the capillaries and porosity of the layer.

R_n is the total resistance to filtration including the resistance offered by the layer and the sieve wire, in gm.sec/cm³.

R_n' is the resistance due to viscosity, in cms.

If we consider the movement of the liquid only through the layer, without accounting for the influence of the wire, then the last formula will correspond to equation (2-7) which was established by experimental work. The resistance to filtration as shown by the last equation, depends on the diameter of the capillaries in the layer and on its porosity.