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MINERAL ASBESTOS SUBSTITUTES 1/

by

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United Nations Industrial Development Organization

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SUBSTI[illegible]1/

by

[illegible]

In Czechoslov[illegible] of [illegible] 15–20 [illegible]

[illegible]

1/ [illegible] UNIDO.

[illegible] used in the [illegible] of [illegible] coverings, lining plates [illegible] tubes. It [illegible] tubes [illegible] yet been [illegible] the [illegible] to be sub-[illegible].

[illegible] the [illegible] The addition of [illegible]. In fact, [illegible] with [illegible] [illegible].

[illegible] where [illegible] cement can [illegible] that it can [illegible] for [illegible]), it is [illegible]. In the [illegible] several [illegible] report [illegible].

[illegible]. It is [illegible], however, that we shall [illegible] cement, [illegible] certain [illegible] (In [illegible] would [illegible] stations.

[illegible]

1. Introduction

I was requested by the secretariate of UNIDO to prepare a paper on the problems of substitution of asbestos in the manufacture of asbestos-cement. I have tried to prepare this at our present level of knowledge [illegible] covering the whole wide field of this [illegible]. [illegible] too wide field prevented me [illegible] at desirable depth. Also some of our [illegible], [illegible] prevented me from mentioning concrete relations and numerical data. Then in the economic field it [illegible] short period which prevented to carry out thorough analysis on the basis of world prices. For these shortcomings I apologise.

The [illegible] in the paper are concerned with the main results of research projects, which we are just finishing, and are for the substitution of 15 - [illegible] asbestos mixture in the asbestos-cement by the special fibrous materials. To many, this percentage will [illegible] to be low. Still however, it is technically as well as economically attractive.

About the substitution of [illegible] of asbestos, I am mentioning only outwardly. It is the problem of future work and in my paper I wanted to confine myself only to the real position, which holds good for the present time.

2. Previous attempts about the substitution of asbestos in the asbestos-cement system

2.1 Asbestos is and will long remain the basic raw material for the manufacture of asbestos-cement goods. Significant occurrence of this mineral is very little. From this fact and from the necessity of its laborious separation from asbestos rocks, results the high price in world markets. It is not therefore surprising that attempts have been made relatively long ago either to manufacture artificially asbestos, or at least to partially substitute it by artificial fibres and that too also in the countries where asbestos is in abundance.

2.2 As our country obtains almost all demand of asbestos by its import, it is understandable that periodically we also attempted its partial substitution. However, gradually the whole scale testing of glass and mineral fibres was carried out, but till now really definite success has not been achieved. Once, really massive use of substitution was in the period of second world war, that is use of cellular pulping in the period of very great shortage of asbestos. For example, GEFA-discs were substituted upto 50% of asbestos (1). Cellulose however clearly deteriorated the quality of the products. Their strength gradually reduced, products lost the elasticity, from the effect of high absorbility of cellulose the frost resistance was reduced and roofing showed strong tendency towards warping and cracking (1,2). Immediately after the war, the addition of cellulose was dropped. Similarly unsuccessfully ended also the experiments with the addition of common glass fibres. All attempted types of fibres were so strongly corroded by alkaline cementing baths, that strength reduction of products for even relatively short period was quite significant (1,2). This revelation was [illegible] noticed with fibres, which complied with the module, claimed by [illegible] for the substitution of fibres (3,4,5), as also with [illegible], which contained low alkali (6,7). Little chemical resistance of commercial glass fibres eliminates the possibility of their use in asbestos-cement manufacture (1,2). Still less is the prospect of successfull substitution by mineral wool, manufactured on the basis of blast furnace slag. Here also low chemical resistance and low strength of fibres eliminates their extensive use (1,6,7).

Mineral fibres manufactured on the basis of some rocks or soils are considerably resistant mainly during short period effect of corrosive medium. For example Bulgarian fibre "Vergal" showed on the whole, hopeful results during short period tests at the Regional research station for asbestos-cement at Nitra (8). The analogous results were also later obtained by Bulgarian workers (9). Due to the lack of long period tests and the varying properties of this mineral wool, its use in mass production was not allowed in our country. In the following chapter we will show, that this restriction was well-founded. Unsuccessfully ended also the attempts of substituting asbestos by fibres with higher content of MgO, which was recommended in our country by Dr.F.Mothmann, owner of the firm MIFA-Chemie at Mannheim ([illegible]).

The basalt [illegible] is recommended as the most common substituting fibre for the production of asbestos-cement (1,2,7,10, 11). In our factories, the use of basalt wool as partial substitution of asbestos (10-15 % [illegible] mixture) was started in the middle of fifties. After a very short period however, its use was discontinued. The reason being the shortage of good quality basalt wool and [illegible] reasons, it is dusty and venting of too strong fibres (10-20 μm).

The artificial fibres are used at present in ČSSR only in little quantity for improving the filterability of asbestos-cement materials. This follows the increased output in the production links and no substitution of asbestos. About the tests with the new substituting fibres, the mention is being made later on.

2.3 Now at least in short about the problem of how much percentage of asbestos is possible to substitute by mineral fibres, so that properties of the mentioned products of asbestos-cement are not considerably deteriorate. In the literature it is shown, for example, that by basalt wool it is possible to substitute successfully 25 – 30% asbestos (1,11). Other sources are [illegible] realistic [illegible] show to maximum substitution of [illegible] ([illegible],12), or only 10–15% (13). In this context we will inform about our experience in the following chapters.

2.4 Partial substitution of asbestos in asbestos-cement goods seems however prospectively favourable to [illegible] workers. Continuous endeavour [illegible] carrying out in [illegible] our building industry to make cheaper construction. The development of the [illegible] walled and prestressed construction at that [illegible] is near the limits of technical possibilities, qualitative changes are only possible to realize in material, out of which steel supports were substituted by "microarmature" from fibrous material. This problem was investigated by workers in USSR (14,15,16). During the experimental production, the supporting was achieved by the [illegible] aluminated cement coupled by [illegible] or by setting alkali-free [illegible] "fibrous concrete" with strength in tension of 600–950 kp/cm², with the strength in bending about 250 kp/cm² and with modulus of elasticity of 2.10^5 – 3.10^5 kp/cm². The concrete of such properties for building construction was very attractive. For example large dimensioned cylindrical shell is possible to produce with about 5 times lesser weight than today. Later it was shown, that glass as well as mineral fibre in cement medium, were relatively quickly corroded and products lost strength. The use of lesser aggressive aluminated cement and excessively strong basalt fibres has not helped in any way. Therefore the next technical work was performed in the year 1964 and that till today, when the find was [illegible] of fibres, which are competent to resist the long period aggression of the products of hydration cement (17). No work to protect the surface of fibres from organic films ([illegible],18,[illegible]) was reached at realisation level. It is understandable, that similar to "micro support", the organic artificial fibre was also tested and [illegible] attractive by special [illegible] (19) and also retained here during laboratory experiments.

In recent years, the development of glass fibres to resist the effect of cement medium was carried out by A.A. [illegible] (20, 21,22) with others. The glass proposed for the production of fibres, containing SiO_2, Al_2O_3, CaO and Na_2O in such ratios, that melting corresponds to the region of primary crystallisation of [illegible]. Although [illegible] the more resistent glass, which [illegible] compositions mainly for good adhesion of fibres with cement stones.

I apologize for going out of the main problem of the paper. I considered this however to be very interesting.

3. Problems of substituting fibres for asbestos

3.1 History of attempts to substitute asbestos in asbestos-cement products, as stated in the previous chapter, seemed to be rather unsuccessful. It is [illegible] necessary to emphasise, that these attempts were made with fibres specified for other [illegible]. If we want to manufacture fibres specially for substituting asbestos, we must first of all examine the problems, which such fibres will have in asbestos-cement production. It is understandable, that during this we examine the function of asbestos in fresh as well as hardened asbestos-cement [illegible].

3.2. It is known, that commonly used chrysotile asbestos which consists of strip [illegible], regularly arranged, enormously thin and probably hollow elementary particles. Understably till now it is not possible to pulp these asbestos particles. However the technically obtainable softness is very well known. Fibres are then strong, elastic, sufficiently resistant against hydration products of cement, thus forming excellent microstructure cement-paste. Asbestic fibres are in addition "cemented". During stirring, the fibres bind themselves by their absorption forces to the surfaces of the cement particles in the cement bath. Ions Ca^{++}, freed by hydration are attracted to the surface of the fibres and form there crystalline centre for growth and later addition of hydration products. The binding of cement pastes with fibres is very strong /4/. Lately we have to review our opinion about very high resistant asbestos in cement medium. From the work of J. Butory (24) it follows, that ions K^+ disturbs crystalline lattice of chrysotile and frees from it Mg^{2+}. By higher concentration of K_2SO_4 in recirculating water which disturbs the surface of asbestic fibres, reduces their reinforcement capability and can bring about reduced strength of asbestos-cement upto about 30%.

Asbestos by now can be substituted in asbestos-cement production only by fibres, which would be cemented, sufficiently and long period resistant towards hydration products, would have good length and diameter would be strongest and most elastic possible, did not contain [illegible] non-fibrous ingre- [illegible] mass, [illegible] both [illegible] it [illegible] stirred the individual [illegible] to be hygienically defective. [illegible] possibilities of [illegible].

3.3. [illegible] with artificial [illegible]. [illegible], [illegible] have to be [illegible] ing [illegible] part of [illegible]. Artificial [illegible] substitution [illegible] rial [illegible] ment will [illegible] and [illegible] to [illegible] dey [illegible] d [illegible], we consider the [illegible] of [illegible] substitution.

3.4. Long period [illegible] of [illegible] products of cement:

We discuss in detail about this question in the following chapter. Here [illegible] will mention only that question of resistence of fibres is [illegible]. It is however necessary to realize, that [illegible], fibres lose their [illegible] strength of the products [illegible]. It is [illegible] of all [illegible] long period [illegible] fact, [illegible] with seasoned concrete ([illegible] years) after [illegible], the pH value above 12 was obtained [illegible].

3.5 Length and diameter of fibres:

Too long fibre creates trouble in production links and too short reinforces little. We consider [illegible] - [illegible] mm as optimum value. From hygienic point of view, too [illegible] fibre creates trouble. If fibre is [illegible] resistent, it will be possible to reduce its force to [illegible]. Such fibre will be elastic and will not be hygienically defective.

3.6 Strength and elasticity of fibres:

Well known [illegible] elasticity of fibres [illegible] or the [illegible] fibres. During selection of [illegible] fibres, it is [illegible] method, [illegible] to [illegible] select [illegible] of presence of surface defects of fibres. The [illegible] the strength of fibres [illegible] more than the [illegible] (6, 7, 8, 9).

3.7 Non-fibrous inclusions:

Fibres must not content particles of diameter more than 2 mm. Also the smaller particle content should be least possible.

3.8 Flotation of mineral wool:

Our tests showed, that with the [illegible] of correct procedure for [illegible] mineral wool [illegible] hydrophobic cleaning of fibres, it is possible to obtain with thin fibres also good distribution in [illegible] mixture.

3.9 Adhesion of fibres with cement stones and their hygienic [illegible]:

Reinforcement ability of artificial fibres is possible to improve by [illegible] surfaces, by suitable alkaline [illegible] of [illegible] material, small diameter of fibres and spraying them simultaneously [illegible] then solved hygienic problem during manufacture and [illegible] of mineral wool.

4. Testing of usefulness of mineral fibres for substituting asbestos

4.1 [illegible], [illegible] for judging the suitability of fibres for substitution of asbestos is their long period [illegible] in the [illegible] of the cement. Therefore at least briefly, [illegible] about the corrosion problems, [illegible] about the results [illegible] of the [illegible] of various types of mineral fibres.

4.2 With [illegible] fibres, which are subjected to the effect of stronger alkaline medium, brings the attraction and adsorption of OH^- ions on to the silicative group $-Si-O-Si$. This goes with the rupture of [illegible] bridge and consequently [illegible] the whole group of $-SiO_4$ with surface of fibre. [illegible] corrosion [illegible] alkaline medium (e.i. NaOH) [illegible] superfluous aggressive [illegible], [illegible] silicate group join with free alkaline ions to form orthosilicates, which pass into the solution. Like this stripping continues of the successive layers of the surface of fibre and corrosion continues.

In the solution of $Ca(OH)_2$ [illegible] originate also little mobile complexes of hydrosilicates of calcium, which settle down on the surface of fibres. During this period, from these originate new crystalline forms. However, [illegible] layers crystallize it does not prevent the successive penetration of aggressive ions to the undisturbed part of fibres. Besides the rising characteristics for corrosion of fibres in alkaline medium for specific [illegible] of fibres, other characteristics for corrosion of fibres in acidic medium can also be considered. During which diffusion of substituted cations K^+ and Na^+, in the superficial layers of fibres ions H^+ or H_3O^+ t[illegible]es. [illegible] H. [illegible] (30) considered there [illegible] in [illegible] higher concentration of [illegible] the [illegible] sive [illegible] ion. For [illegible] of corrosion, [illegible] is [illegible] determined for both [illegible].

In addition to [illegible] basic reactions, the [illegible] of corrosion is [illegible] of other factors, i.e. [illegible] etc. of fibres.

4.3 [illegible] fibres directly in cement paste is not [illegible] qualitative results, therefore we tested series of indirect methods, such as resistance of fibres in $Ca(OH)_2$ [illegible] solutions, in cement bath [illegible] in [illegible] solution, [illegible] of asbestos-cement [illegible]. After comparing with direct tests in cement [illegible], we [illegible] the conclusion, that for determining the [illegible] of the substituting fibres, it is sufficient to combine the test of long period resistance in $Ca(OH)_2$ solution with short [illegible] test in NaOH.

4.4 For test of fibre resistance [illegible] $Ca(OH)_2$, we processed a relatively simple method: to the polyethylene bottle 10 g of fibre [illegible], deprived of additional oily sprays and filled with 500 ml of $Ca(OH)_2$ solution of concentration 1060 to 1100 mg CaO/l, practically full bottle is closed airtightly and put on the temperature of 40 ± 2°C. Once a week the contents of bottle are stirred for a short time by the slow stirring machine. In agreement with the theoretical consideration about corrosion fibre, it is possible to expect, that reciprocal relation between $Ca(OH)_2$ and fibre will form the difficult soluble [illegible] products, containing calcium. Decrease in Ca^{++} ions [illegible] from solution will then determine the degree of corrosion of fibre. The direct determination of Ca^{++} is not [illegible] by the fact, that fibres with higher content of alkali forms soluble alkaline silicates. [illegible] it is [illegible] then possible to s[illegible] with [illegible] of observations of [illegible].

By this procedure we tested [illegible] representative of individual types of [illegible] fibres. [illegible] important results are tabulated in Table [illegible], given in the end [illegible] of the report.

Most important [illegible] are [illegible] in Fig.1. We [illegible] here, that [illegible] is that of [illegible] slag fibres. Also in first [illegible] with NaOH [illegible] high degree of corrosion. [illegible] and basalt fibres, the stronger corrosion starts [illegible] after [illegible] months, but then quickly continues. The corroded layers of fibres are clearly distinct on microphotographs of basaltic (Fig. [illegible]) and sintered (Fig.3) fibres. Gradually gel grows [illegible] distinct [illegible] grow (Fig.5). In the later period crystallization [illegible]. In Fig.1 is also included the effect of average diameter of fibres.

4.5 For determination of resistance of fibres against NaOH we used the method of [illegible] and [illegible] (21), modified such, that from it is possible to measure with the fibres, whose diameter is not constant along the whole length. Individual fibres are fastened [illegible] the measuring frame by three narrow slots [illegible] around these slots. The force on the fibre is then possible to measure by [illegible] always on the same points. We then heated the frames [illegible] with 10-15 fibres at 100 °C for 1,5 hours in NaOH. Difference in the diameter before and after leaching, expressed in percentage decrease in original diameter of the fibre, is the measure of its resistance towards NaOH. It is possible to measure fibre force from 6 - [illegible]. Because chemical resistance of fibres depends strongly on their diameter as well, it is always necessary to state, for which average diameter the [illegible] will [illegible] is the cal- culation of regression [illegible] in [illegible]

[illegible] F [illegible] fibre [illegible] For [illegible] figures of [illegible] method [illegible] in from the [illegible]

[illegible] in Appendix.

4.5 [illegible] one during [illegible] of [illegible] little [illegible] is [illegible] in [illegible] that [illegible] anticipate, [illegible] will [illegible] it is not possible to [illegible]. [illegible] for these [illegible] will have to be complied with [illegible].

5. Production of A-fibre

5.1 Development [illegible]:

Ostrava branch of [illegible] Institute for Construction [illegible] rials in Praha [illegible] research [illegible] connected with [illegible] of the [illegible], [illegible]. [illegible] beginning of [illegible] of Construction [illegible] to [illegible] possibilities of production of [illegible] to [illegible] partially the asbestos in [illegible] products.

Theoretical [illegible] of [illegible] fibre [illegible] line medium lead to the formation of [illegible] hypothesis, according to [illegible] new type of fibre, e.g. A-fibre was [illegible] out. [illegible] results of the resistance test of A-fibre in alkaline [illegible] moved the authors of the hypothesis to apply for patents first in ČSSR, later in other countries.

Economic aspect of partial substitution of asbestos [illegible] showed favourably, [illegible] the enterprise, which is chief producer of mineral fibres in ČSSR [illegible] our institute in the costs of research work, [illegible] in the development of special fibre, able to substitute [illegible] asbestos in asbestos-cement products. [illegible] work [illegible] started in the year 196[illegible] [illegible] scheduled for completion in middle of the next year, [illegible] mass production of A-fibre.

5.2 Principle of A-fibre

Theoretical considerations, which are supplementary to the proposed composition of A-fibre extend beyond the time limit of this treatise. [illegible] simple [illegible] say, that we came to the well known fact, that majority [illegible] high content of [illegible] with strong [illegible] (Zr, Zn, Ti) show increased resistance towards alkaline lye. First theoretically and then experimentally as well, we arrived the limits of chemical composition in such a way that ions increase the resistance towards $Ca(OH)_2$ as well, and in addition to it work so intensively that after reaching the required resistance, there very little addition is enough. I apologize, that Czechoslovakian patents regulation prevents me before completion of patents procedure, to define these limits numerically. These are not to hide and success depends upon prescribed combination of all elements and of melting.

We still increase the resistance of the fibres by creating in the surface of fibres a film of suitable organic-silicate material of strong bond. The material is selected such, that integrity and force of surface film is possible to regulate from the partial protection, used with substituting fibre for asbestos unto the perfect protection specified for other uses. Simultaneously, it is possible to make the surface of fibre rough by miniature filament of this material and thus increasing the cohesiveness with cementing paste in first few weeks of their hardening.

5.3 Scheme of production of A-fibre

A-fibre not only fulfilled the requirements prescribed for the successful substituting fibre, but is in addition economically advantageous, is produced from relatively cheaper raw material and that too with suitable process for mass production. One of the possible production scheme is being shown in Fig.7. It is simple and represents the recent state of technic in this field.

Raw material and fuel are fed to the furnace for melting (3) from the storage bunker (1) by skip (2). The granular materials from smaller bunker (4) are gently added direct to melting zone of the furnace via furnace conveyor by special nozzles (Czech Patent). During charging it is necessary to maintain prescribed ratios of the feed (Patent registration ČSSR, USA etc.). The melt at 1400-1500°C is pulped by four-cylindrical pulping machine (5). Waste from the machine is taken out by conveyor outside the hall. The fibres formed are conveyed by air through blowing slot from pulping cylinders to the [illegible] tanks (7).

The required [illegible] air is produced by ventilator. In the middle parts of settling [illegible] are installed spiral nozzles, by which while the fibres [illegible] pulping cylinders, spraying [illegible] emulsion of [illegible] with [illegible]. This liquid is conveyed to nozzles from storage [illegible]. Such modified [illegible] by air ventilators (10), on belt conveyor, [illegible] fibres elevated from settling tanks. From the [illegible] belt [illegible] to cleaning [illegible] (11,[illegible] patent [illegible]), where the unmelted [illegible] are [illegible]ted. These are conveyed back to the furnace [illegible] to its melting zone [illegible]. Cleaned A-fibres [illegible] bunkers [illegible] in pack [illegible], there [illegible] of production schemes. However, [illegible] the required [illegible] of A-fibres. At [illegible] the [illegible] production [illegible] to finish the chapter after [illegible] about the [illegible] and location for A-fibre production.

5.4 Raw material base:

For the production of A-fibre while using cupola furnace, [illegible] suitable [illegible] raw materials are those, basic basalt and basic rocks with plagioclase and foids, such as dunitic basalts, tefrity, basanite, [illegible], [illegible] etc. These should [illegible] basic [illegible] and their [illegible] it [illegible] to melt in such type of furnace and [illegible] by centrifugal machines. For preliminary consideration of suitability of raw materials according to these criteria, we [illegible] the tests tables. From these we can know how tested raw material will be for use in the production of A-fibre, by complete chemical analysis of raw materials with at least 60% reliable estimate. [illegible] it is possible to improve the melting index of basic raw material by the addition of slags, limestones or dolomites.

Suitability and [illegible] of such additions is possible to estimate [illegible] of the next tested tables. Final decision [illegible] after [illegible] laboratory tests.

At the base of melt [illegible] - 6% according to the type of raw material [illegible], at least 60% acidic metals, whose ions [illegible] strong electric [illegible].

In specific cases, it is possible to use some slags from metallurgy of non-ferrous metals as well. Also used for batch melting, the suitable new shaft furnace, developed in the field of use of basaltic rocks [illegible] to use also for some [illegible], clays or shales. With the use of furnace tank, this development is still wider and quality A-fibre can be used also for other uses than partial substitution of asbestos. While concluding this section I repeat, that requirements for chemical composition of A-fibre are precise. Here use can only be of raw material with sufficient chemical composition and during charging in the furnace, their mutual ratios should be maintained.

[illegible] Furnace and piping

The melting aggregate shown in technological scheme is cupola. Its economical advantages and technological deficiencies are generally known. Current type of cupola for production of A-fibre is usually [illegible] this, that closely below the melting zone provided with three special nozzles, equally placed around circumference of furnace. Nozzles blow the fine granulated [illegible] to the melting zone. These are conveyed to the blowers from small bunker located near the furnace. Charging is by small vibrating feeder having the 3 - 6 % of total capacity of furnace. Our experience with furnace of 1100 kg melting hour capacity showed, that by this procedure, fibres receive the practically full quantity of active constituent. It is advantageous, if the furnace is provided with the appliance for the periodical removal of reduced iron. About the possibility of use of other types of furnace as well, we mentioned in the foregoing section. For smaller production, these may be more advantageous. For pulping the melt, it is essential to use more the equipment working on centrifugal principle, enable to produce uniform fibres of average diameter 4,5 - 6 μm. During laboratory experiments, as also during semi-operational production, we verified the pulping machine with three to four vertical cylinders. Pulping by nozzles is not possible to allow. Fibres produced by these methods have so to say greater quantity of surfacial flaws, reduce their chemical resistance as also strength. We see this also in Fig.1, where A-fibre pulped by blowers with 500°C hot medium in Fig. represented by number 5 shows the smaller resistance towards $Ca(OH)_2$ than the analogous fibres (number 6) produced by pulping machine.

5.6 Settling chamber and surface finishing of fibres.

Settling chamber is of usual construction. With respect to the stickiness of clearing medium, it is recommended to obtain sufficiently wide regulability of the speed of belt, bringing out the settled mineral wool.

In the central portion of the settling chambers, the produced A-fibre is sprayed by strongly diluted emulsion of organicsilicate material.

For spraying purpose, 3-4 spiral nozzles are located such, that whole stream of fibres, blown out from rotating cylinders, was covered. Capacity of blowers, size of the spraying tubes of emulsion, dilution of emulsion and operational pressure of the pump should be harmonized so as to get the partial protection as well as roughing of surface of fibres.

The selected organic-silicate material in cement stone is sufficiently long time resistant and its slight remainders which were insufficiently coated, function in asbestos-cement production as skinner of carrying waters. Formation slips so quickly, that fibres after leaving clothing machine does not stick to itself. We solved the problems of combination with spraying the fibre and semi-operationally tested in one of our production of mineral wool.

5.7 Cleaning of A-fibre

As was stated, the A-fibre should not contain higher non-pulped portions and can have only specified maximum length. In the production chain, therefore it is necessary to equip cleaning aggregate. I would not like to prescribe directly the type of cleaning aggregate. However it should as completely clean, as also shortening the function and not damaging too much the surface of fibres. We developed the prototype of the machine, which suits these requirements. Not too big and is possible to move it in production chain within 40 secs. and goes on like this without disturbing the operation links in production of common mineral wool and reverse. The waste from cleaning machine is possible to return to melting zone of the furnace.

It is also necessary to mention, that during A-fibre production, it is not possible to use cleaning system working with pneumatic transportation of fibre. Little non-pulped portions, present in mineral wool are sprayed so much on the surface of the fibre that its chemical resistance and strength is reduced considerably. This is documented by the photograph from electrone microscope, which we have shown in Fig.9.

5.8 Packing and dispatch

A-fibre is possible to bag by any sufficiently precise equipment.

[illegible] in [illegible]ckets is not too advantageous for [illegible]. If the custom[illegible], the size of [illegible] to select, so th[illegible]-fi[illegible] [illegible] production of [illegible] [illegible]-ca[illegible].

6. [illegible]

[illegible] about the properties of A-fibre [illegible] state [illegible] briefly these in the [illegible] accessarily.

[illegible]

[illegible] That means that [illegible] substitution in asbestos-[illegible] fibre.

[illegible] towards hydration products of ce-[illegible]:

[illegible] towards $Ca(OH)_2$ [illegible] in Fig.1 and Table 1,[illegible] Fig.2 then we give the microphotograph [illegible]-fibre produced [illegible] (in [illegible] it is designated by [illegible] saturated $Ca(OH)_2$ [illegible], that fibre are practically no [illegible] and [illegible] of gelatine drops [illegible] formation.

[illegible] resistance is also shown by the fibre produced [illegible] in industrial equipments. In Fig.10 are [illegible] the average values and 95% reliability zone of de-[illegible] in concentration of $CaOH_2$ during the testing of A-[illegible] from our first semi-industrial experiment. Correspond-[illegible] numeric data are shown in Table [illegible]. These are fibre [illegible] surface finish. First results of test of surface finish-[illegible]-fibre from second big experiment are also good.

[illegible] of test for resistance of A-fibre direct in cement [illegible] are also good. During microscopic examination of thin [illegible] from [illegible] (20% asbestos + 50% A-fibre + cement), put on the terrace of our workshop for 1½ years, no corrosion was found on A-fibre. No change was also found on A-fibre in [illegible], heated for [illegible] at 20-80°C. [illegible] the reverse after 20 [illegible] heating in autoclave in series at 170 °C [illegible] 2,5 [illegible], the [illegible] distinctly corroded at the [illegible] of [illegible] [illegible] keeping [illegible] of [illegible] during autoclave [illegible] tests.

6.4. [illegible]

During our [illegible] experiences with [illegible] substitution of [illegible], [illegible] of average [illegible] of 2/[illegible] was confirmed. [illegible] of [illegible] not [illegible] to determine [illegible]. [illegible] measuring [illegible] the effect of [illegible] fibre. In determining the [illegible] of [illegible], therefore we use only our experience.

6.5. Strength and [illegible] of fibres

The [illegible] diameter and strength of fibre [illegible] the [illegible] fibres. This approximately [illegible] the [illegible], it is possible to [illegible] strength of at [illegible] elasticity of such thin fibres is sufficient.

6.6. Cohesiveness of [illegible] fibres with [illegible] and hygienic [illegible].

As was stated [illegible] of the fibre is [illegible] by organic-silicone [illegible]. This [illegible] is of [illegible] only of sub-microscopic size. We can only examine this by enormously big magnification. [illegible] using stereoscope. [illegible] with substituting [illegible].

In connection with [illegible], [illegible] attention [illegible] to [illegible] hygienic [illegible] of working environment. [illegible] strongly [illegible] settling chamber. [illegible] to keep [illegible] the central de-dusting system of production.

In the production [illegible] -cement goods, we did not had the trouble with [illegible] of A-fibre during our [illegible] proved fibre [illegible] in this direction enough effective. Supplement to this still [illegible] in the A-fibre specific [illegible]. This is [illegible] that it does not spoil the [illegible] in which A-fibre is packed, even during long storage, [illegible] sufficiently [illegible] the chosen diameter and elasticity of the A-fibre.

7. Use of A-fibre - partial substitution of asbestos

7.1. As it has been already said, the research for substituting fibre was started in our country at the request of one of the undertakings producing mineral wool. We were requested to develop such a fibre, which would be able to substitute 15–20% asbestos in asbestos-cement roofing and lining sheets. Quality of products with A-fibre should correspond to all the standards applied for these products. Simultaneously use of A-fibre in asbestos-cement products should not interfere with the management of building technology.

7.2. In connection with this work, besides laboratory experiments, full scale operational and semi-operational tests as well as industrial tests were carried out, working on HATSCHEK machine. Their purpose was to verify the usefulness of A-fibre not only from the point of view of properties of finished products, but also from the view of action of machinery arrangements, productivity etc. and their changes during normal plant operation.

First test which was carried out in August 196[illegible] was short period ([illegible]) and composed of [illegible] of preliminary verification of effect of [illegible] stimulating [illegible] of production process. In this, clean A-fibre without surface finish was used. During experimental operation usual production sequence was maintained. Ratio of asbestos and A-fibre was changed such, that in asbestos mixture, 10, 15, 20% of asbestos was gradually substituted by the same quantity of A-fibre. In all such production was over 2000 m^2 of corrugated sheets. Tests on finished products showed that absorbability, frost resistance and strength in tension while bending agreed with the requirements of ČSN 72 3101 "Asbestos-cement corrugated sheets". Against usual production, the strength of corrugated sheets (series with 20% substitution by A-fibre) was reduced at some amount. The mixture of 85% asbestos and 15% A-fibre showed after 28 days 240 kp/cm^2 and after 180 days 255 kp/cm^2.

[illegible] of strength [illegible] of products were a bit lower than [illegible].

During [illegible] in [illegible] 1967 some techno- logical [illegible] were [illegible] for surface [illegible] of [illegible]. [illegible] upto [illegible] in production of [illegible] asbestos mix- ture [illegible]. Out of the whole quan- tity of [illegible] phase of the experiment, 15% substitution [illegible] by weight, in the second phase [illegible] substituted 20% asbestos [illegible] of A-fibre. During [illegible] techno- logical [illegible]. On the contrary, [illegible] the influences were favourable: [illegible] of returning water showed the [illegible] the filtration station in [illegible] pro- duction. The filterability of [illegible] was improved due to [illegible] fibre. This was [illegible] gradual decrease of sediment content [illegible] returning water and by this, that gently re- duced number of revolution of circular sieve, necessary to [illegible] one sheet (from about [illegible] to [illegible]). First material continuously maintained sufficient plasticity and not even during 20% sub- stitution, on the edges of the wool there was not cracks. The dispersion of A-fibre in asbestos-cement suspension was so nice, that it was not possible do distinguish the [illegible] of arti- ficial fibre in [illegible] products. Increased filterability of the suspension, [illegible] increased also the output of the production arrangement [illegible] shift against the planned [illegible] shift. In all, in this experiment [illegible] of corru- gated sheets were produced, from which [illegible] pieces were selected for laboratory tests. After 28 days storage in a dry cellar, following strength in tension while bending were recorded (practically corresponding with usual production):

with 15% substitution: [illegible] kp/cm^2; s = [illegible] kp/cm^2

with 20% substitution: [illegible] = 25[illegible] kp/cm^2; s = [illegible] kp/cm^2.

Absorp-bility as well as frost [illegible] of the products [illegible] with [illegible]. [illegible] some [illegible] about the results of [illegible] [illegible] [illegible] [illegible] ex- [illegible] [illegible], [illegible] [illegible] of asbestos [illegible]

In addition to the [illegible] ages, [illegible] the technological [illegible].

The advantages of [illegible] [illegible] asbestos [illegible]. [illegible] in the year 1968 in [illegible] production [illegible] [illegible] [illegible] strength [illegible] [illegible] strength [illegible] by pure [illegible] mixture.

7.3. Our [illegible] in [illegible] [illegible] yet. By the end of this [illegible] of [illegible] in the next 4 [illegible] of [illegible] that [illegible]. We are planning [illegible] system. Next year we will carry out the [illegible] material, containing 50% asbestos and 50% [illegible]-fibre.

8. Economic effectiveness of production and use of A-fibre

8.1. [illegible] the extent of consumption of A-fibre

[illegible] between [illegible] [illegible] total [illegible] [illegible] 0,5 kg asbestos [illegible] and [illegible] consumption of [illegible] tons [illegible] substitution, [illegible] of 4 000 tons of A-fibre. And when [illegible], the consumption for [illegible], which will be [illegible] ing [illegible] production line. That [illegible], the A-fibre will be produced at one place in our country [illegible] will be [illegible] to consumers. [illegible], [illegible] its [illegible] in [illegible] country in [illegible] will [illegible] the tune of [illegible] – 5 000 tons yearly. [illegible] has not exceeded 20% of the [illegible].

8.2. [illegible] of savings in production costs

[illegible] in production costs, we will take the assumption, [illegible] of asbestos-cement roofing, Canadian [illegible] of the composition 30% [illegible].

Net price of [illegible] will [illegible] be about 320 [illegible]. Also [illegible] and specificness of the [illegible] countries importing asbestos, we can assume that price of 1 ton of A-fibre does not exceed [illegible] 5 [illegible] price of [illegible] asbestos. From which it [illegible] for one ton [illegible] when [illegible] yearly [illegible], it is possible to save [illegible] with [illegible] foreign trade balance, it is [illegible] foreign exchange savings. In [illegible], [illegible] 4 000 tons asbestos in Canadian dollars and can save yearly 1 200 000 Can.$.

In the foregoing records in our conditions I understandably took real preliminary assumptions verified by research.

As we have seen, that our asbestos-cement industry is placed in world scale on a very low percentage category. It is possible to assume, that consumption of substituting fibre would be very much higher in many countries. How approximately it looks, the global consumption of A-fibre and with it total savings in material costs is shown in Table 4 in enclosures.

8.3. Orientational data of A-fibre production

As was stated, basic production of A-fibre is on the whole obtained by the usual arrangements known from the production of mineral wool. Required supplementary equipments (mainly cleaning machines) are given in chapter 5. Their price form 5 - 15% of the price of usual production chain for mineral wool. It was also indicated, that for production of A-fibre, it is possible to modify relatively simply the large production of mineral wool as by its own or can have sufficiently modern pulping equipment. Because it is possible without disturbing the operation to pass from production of A-fibre to common production of mineral woll, the whole year's capacity would not be used for A-fibre. Nevertheless I give some informative figures.

We have plants for production of mineral wool with yearly capacity :

3 000 tons - 5 000 tons - 15 000 tons

All three types of plants can be used for producing A-fibre. For these following number of workers are counted:

Manufacture with production of 3 000	tons/yearly	...38 workers
5 000	tons/yearly	...49 workers
15 000	tons/yearly	...62 workers

Dealing with the worker's productivity. Their distribution is shown in Table 5.

[illegible] profitable for production of [illegible] is then shown in Table 6.

When the [illegible] were positively influenced by specific [illegible], it is possible to assume, that [illegible] economic categories [illegible], turnover etc. [illegible] express [illegible] economic effectiveness.

9. Summary

In CSSR was developed special fibre (i.e. A-fibre), able to substitute 15-20% of asbestos in asbestos-cement products. Basic raw materials for its manufacture are possible to find according to our opinion in majority of the countries. A-fibre is produced in the equipments, used for manufacture of mineral wool. Degree of mechanization and also the actual costs of production chain are to specific measure (mainly in the region of [illegible] in finished products) possible to change according to the specific ratios of producing country. Price of supplementary equipment does not exceed usually 15% of price of production chain. In no case, however the production costs of A-fibre will exceed double the costs of usual mineral wool production. That means, that except special cases, price of A-fibre does not exceed 50% of the price of average mixture with imported asbestos. [illegible] profits are here, in addition to the savings in costs of basic material [illegible] importing asbestos as well as considerable savings in foreign exchange. A-fibre is possible to use during manufacture of asbestos-cement roofing, filling sheets and pressure free cylinders. Use for the manufacture of pressure cylinders is not yet tried. It is likely, that A-fibre will not be possible to use [illegible] products [illegible] through autoclaving process.

Partial substitution of A-fibre in asbestos-cement manufacture does not require any modification in technological equipment. Addition of A-fibre does not cause any trouble in technological process. Movement of production or the contrary [illegible]. Quality of products with 15-20% substitution of asbestos by A-fibre corresponds to the standards for asbestos-cement goods. That means, that these products can be used everywhere in case of classical asbestos-cement.

Production of A-fibre is possible to set up, or adapted from the constructed set up for production of mineral wool wherever there is yearly sale assumed to be of 2 000 tons A-fibre, that is where at least 1 5000 m^2 of asbestos-cement is produced [illegible]early. With smaller scale it is necessary to manage the manufacture such that would produce alternatively A-fibre and common mineral wool for insulating purposes. Manufacture should be advantageously situated in the centre of the market area. With respect to the relatively low specific gravity of A-fibre [illegible], it is economically advantageous to transport [illegible] finished products. In developing countries that are producing A-fibre could stock it for smaller consumption of these countries. Low specific gravity of A-fibre would unquestionably make costly its transport by sea.

Work, which was ordered to us is near the completion. It is however likely that in the future we will continue to work and try perhaps for higher, up to 50% substitution of asbestos by A-fibre. These products however will probably have some technical characters different from standard asbestos-cement. For example, while using in climatically exacting regions, it would be necessary to calculate with cheaper, however efficient protection of surfaces of finished products (this problem in CSSR is being proposed for study). Big advantage of these products would be their low price. High percentage of substituting asbestos will also contribute to the solution of problems of silicosis diseases, which occurs sometimes in asbestos-cement industry. All these however are the subject of future work.

Table no.1 Resistance of fibre towards $Ca(OH)_2$.

Basic raw material	Production	Thickness in um	% decrease in concentration of $Ca(OH)_2$ in days				
			30	[illegible]	180	360	720
Basalt 1	Czechosl.-Hc	21,5	[illegible]	1,6	10,[illegible]	25,[illegible]	
Basalt 2	Czechosl.-Hc	14,9	0,0	3,5	21,[illegible]	40,8	
Basalt 3	Czechosl.-A	[illegible]	[illegible]	3,2	15,4		
Mergel	[illegible]-Hc	27,3	[illegible],7	4,[illegible]	42,[illegible]	[illegible],8	
Slag 1	Czechosl.-Hc	[illegible]	[illegible]	[illegible]	34,7	[illegible],0	
Slag 2	Czechosl.-B	4,[illegible]	[illegible],4	[illegible]	[illegible],2		
Slag 3	[illegible]-B	[illegible],6	28,5	40,7	44,4		
Glass	[illegible]-A	23,2	11,4	37,4	45,3		
A-fibre	Czechosl.-B	[illegible]	3,0	3,3	[illegible]	[illegible],7	[illegible],1
A-fibre	Czechosl.-Hc	5,0	1,0	1,[illegible]	1,[illegible]	4,2	

Hc=Horizontal cylinder, Sm=4-cylindrical pulping machine, B=Blower, A=other method.

Table no.2 Resistance of fibre towards NaOH.

Type of fibre	original diameter cm	reduced diameter after leaching, %
E-glass	[illegible]	[illegible]
Basaltic	12,7	43
G - [illegible]	12,7	42
A - fibre	12,7	26
PYREX	12,7	22
G - 2[illegible]	12,7	[illegible]

Table no.3 Resistance of industrially manufactured A-fibre towards $Ca(OH)_2$.

Decrease in concentration $Ca(OH)_2$	30	90	180	360	[illegible]
Arithmetic average $\bar{x}$	1,0	2,7	4,[illegible]	[illegible],1	[illegible]
Standard deviation s	0,3	0,4	0,5	1,6	[illegible]
u - 2	0,4	1,9	3,7	4,3	[illegible]
u + 2	1,6	3,5	5,7	11,9	[illegible]

Table no.4 Increase in savings with respect to increase in [illegible]

Yearly production of roofing 1000 m2/0,48 cm	Yearly consumption of asbestos in tons	Yearly consumption of A-fibre in tons	Savings on 1 t A-fibre £ Omd	Yearly savings costs £ Omd	Total [illegible] £ Omd
25 000	21 000	4 200		[illegible]	2 316 000
50 000	42 000	8 400		1 344 000	2 593 000
75 000	64 000	12 800	160	2 048 000	4 104 000
160 000	85 000	17 000		2 720 000	5 450 000

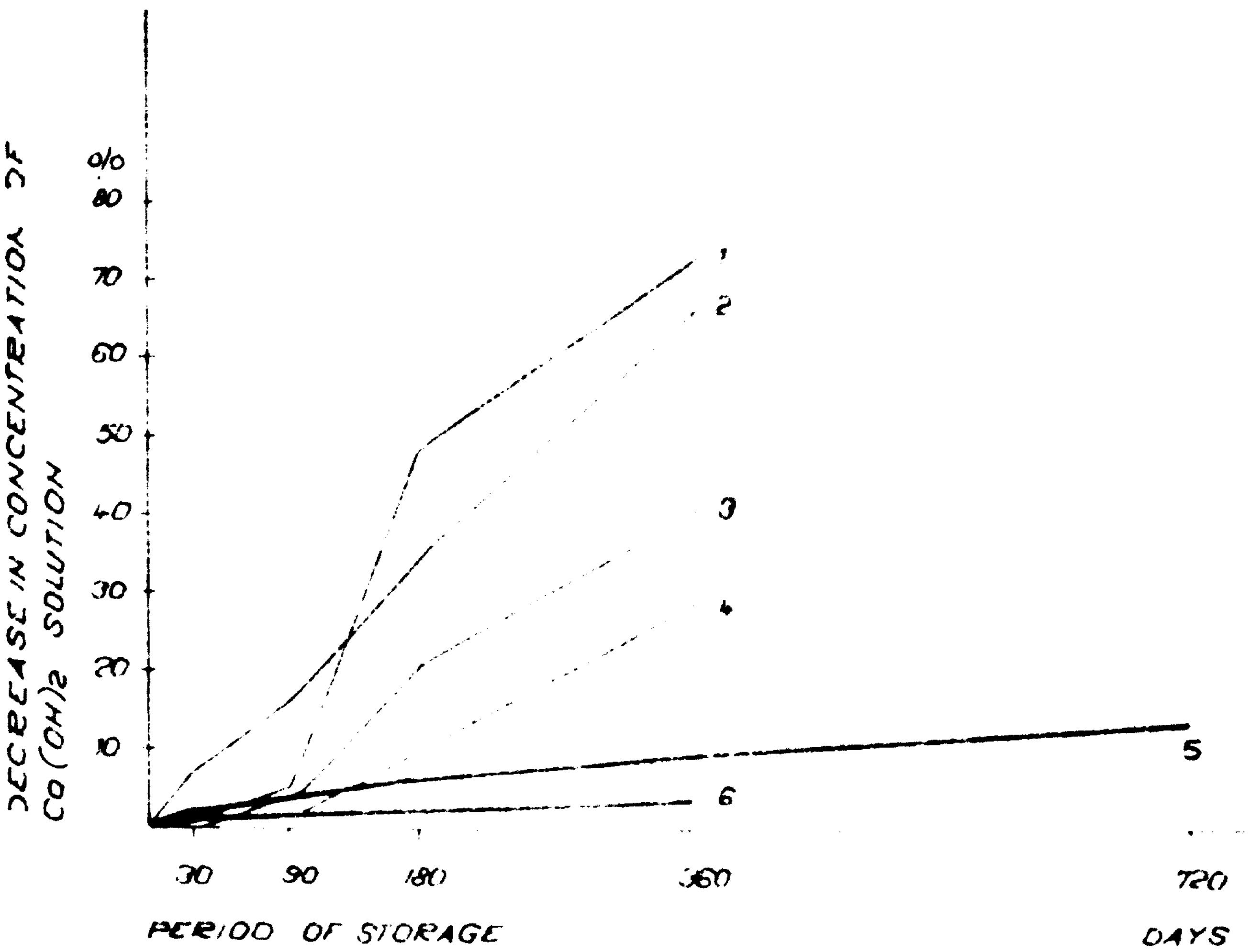
Table no 5 Survey of number of workers and their distribution in A-fibre manufacture

Working place	Yearly production 3000 t						Yearly production 5000 t						Yearly production 12 000 t					
	Number of shifts	I	II	III	IV		Number of shifts	I	II	III	IV		Number of shifts	I	II	III	IV	
Storage for raw materials	2	1	1	–	–	2	2	2	1	–	–	3	2	5	2	–	–	7
Feeding appliance	3	1	1	1	1	4	3	1	1	1	1	4	3	2	2	2	2	8
Melting and pulping	3	2	2	2	2	8	3	2	2	2	2	8	3	2	2	2	2	8
Supervision at production line	–	–	–	–	–	–	3	1	1	1	–	3	3	1	1	1	1	4
Packing	3	3	3	3	3	12	3	4	4	4	4	16	3	6	6	6	6	24
Expedition	1	2	–	–	–	2	1	2	–	–	–	2	2	4	3	–	–	7
Store of auxiliary raw materials	1	1	–	–	–	1	1	1	–	–	–	1	1	1	–	–	–	1
Purification of line	–	–	–	–	–	–	3	1	1	1	–	3	3	1	1	1	–	3
Maintenance	3	1	1	1	1	4	1	2	1	1	–	4	3	5	2	2	–	9
Maintenance of electric plant	3	1	1	1	1	4	3	1	1	1	1	4	3	2	1	1	–	4
Laboratory	1	1	–	–	–	1	1	1	–	–	–	1	3	1	1	1	–	3
Removal in storage	3	2	2	2	2	8	3	2	2	2	2	8	3	3	3	3	3	12
Works siding	2	1	1	–	–	2	3	1	1	–	–	2	2	2	2	–	–	4
	[illegible]	16	12	10	10	48	[illegible]	21	15	13	10	59	[illegible]	35	23	19	17	94

Table no.6 <u>Consumption of raw materials and fuel for A-fibre manufacture.</u>

	Yearly production		
	3 000 t	5 000 t	15 000 t
Melting raw materials	4 700 t	7 880 t	22 000 t
Metallurgical coke 6670 kcal/kg	940 t	1 550 t	4 950 t

FIG. 1 **RESISTANCE OF FIBRES IN $Co(OH)_2$ SOLUTION**



FIBRES: 1 - FROM CLAY, 2 - FROM BLAST FURNACE SLAG AND BASALT, 3 - FROM BASALT (15 µm), 4 - FROM BASALT (21 µm), 5 AND 6 A - FIBRE

Fig.2: Microphotograph of basaltic fibre after 8 months storage in $Ca(OH)_2$ solution, 620 x magnification.

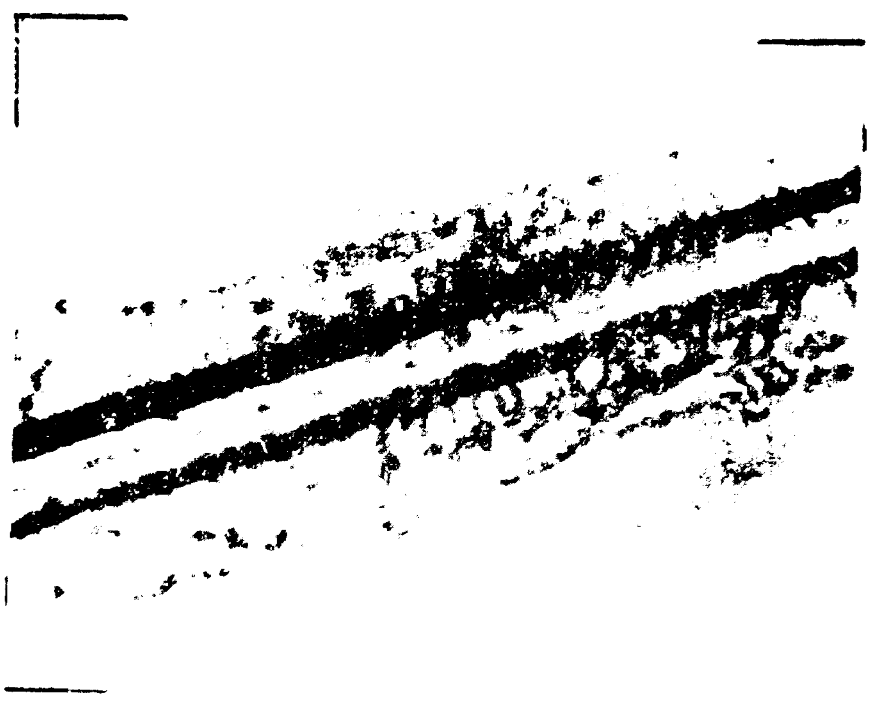


Fig.3: Microphotograph of fibre from clay after 8 months storage in $Ca(OH)_2$ solution, 620 x magnification.

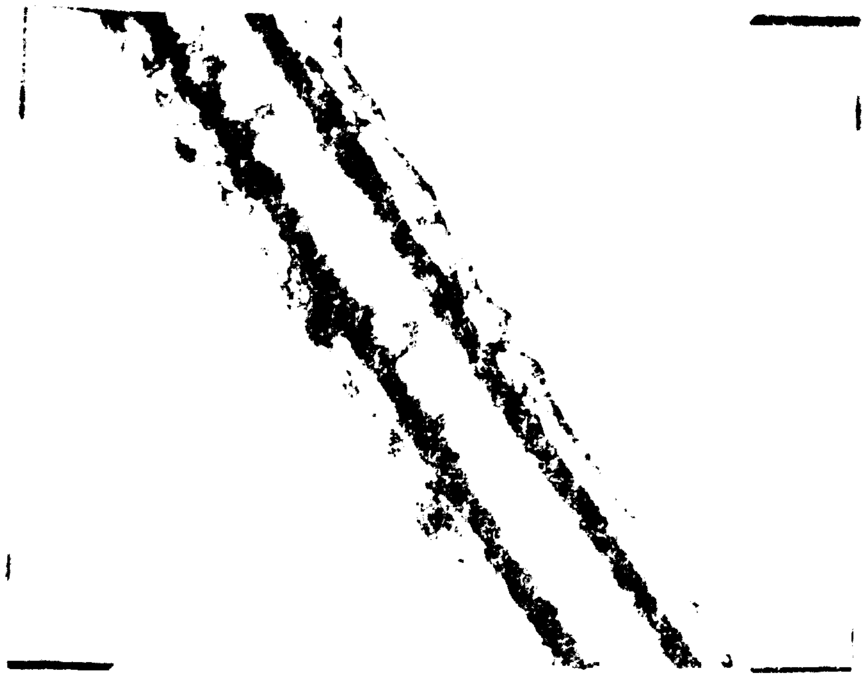
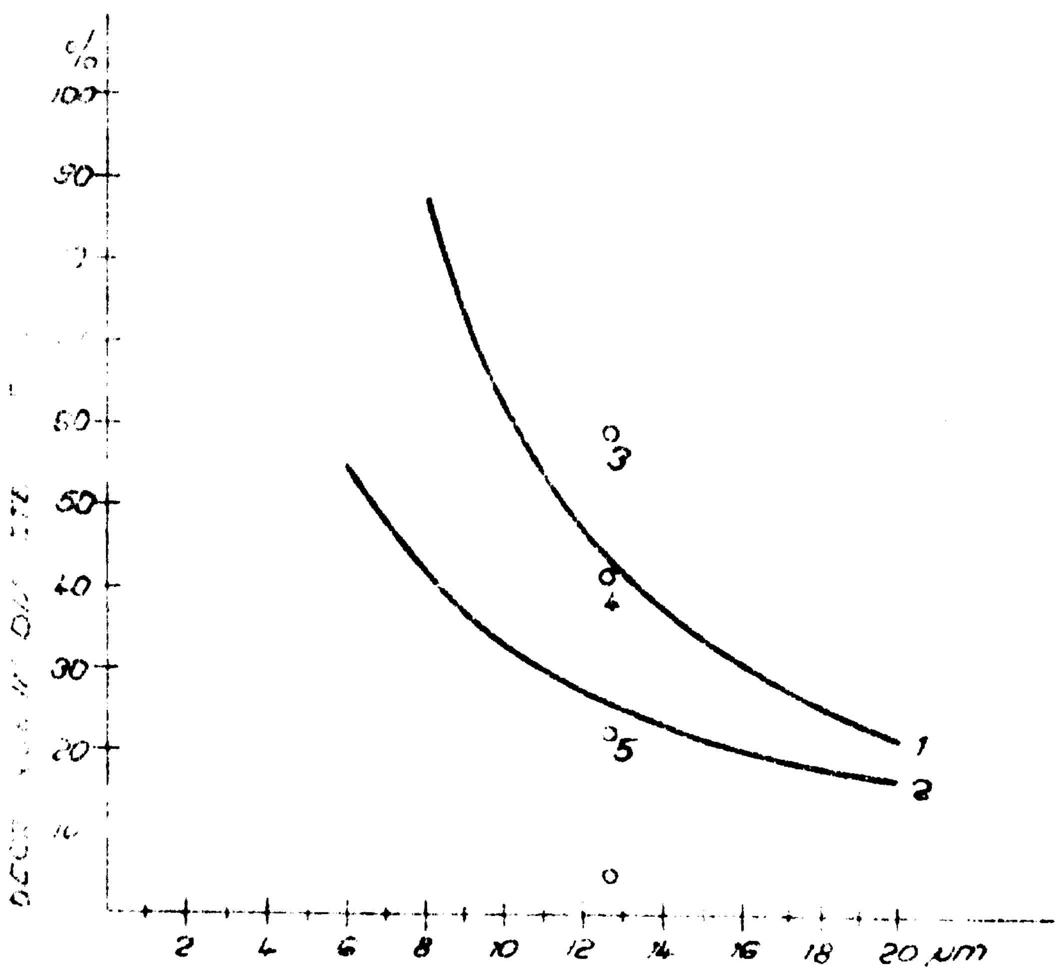


Fig.4: Microphotograph of fibre from clay **after** 15 months storage in $Ca(OH)_2$ solution, 620 x magnification. Direct light.

Fig.5: Same photo as in Fig.4. Polarised **light,** crossed nicols.

FIG. 6 **RESISTANCE OF FIBRE IN NaOH SOLUTION**

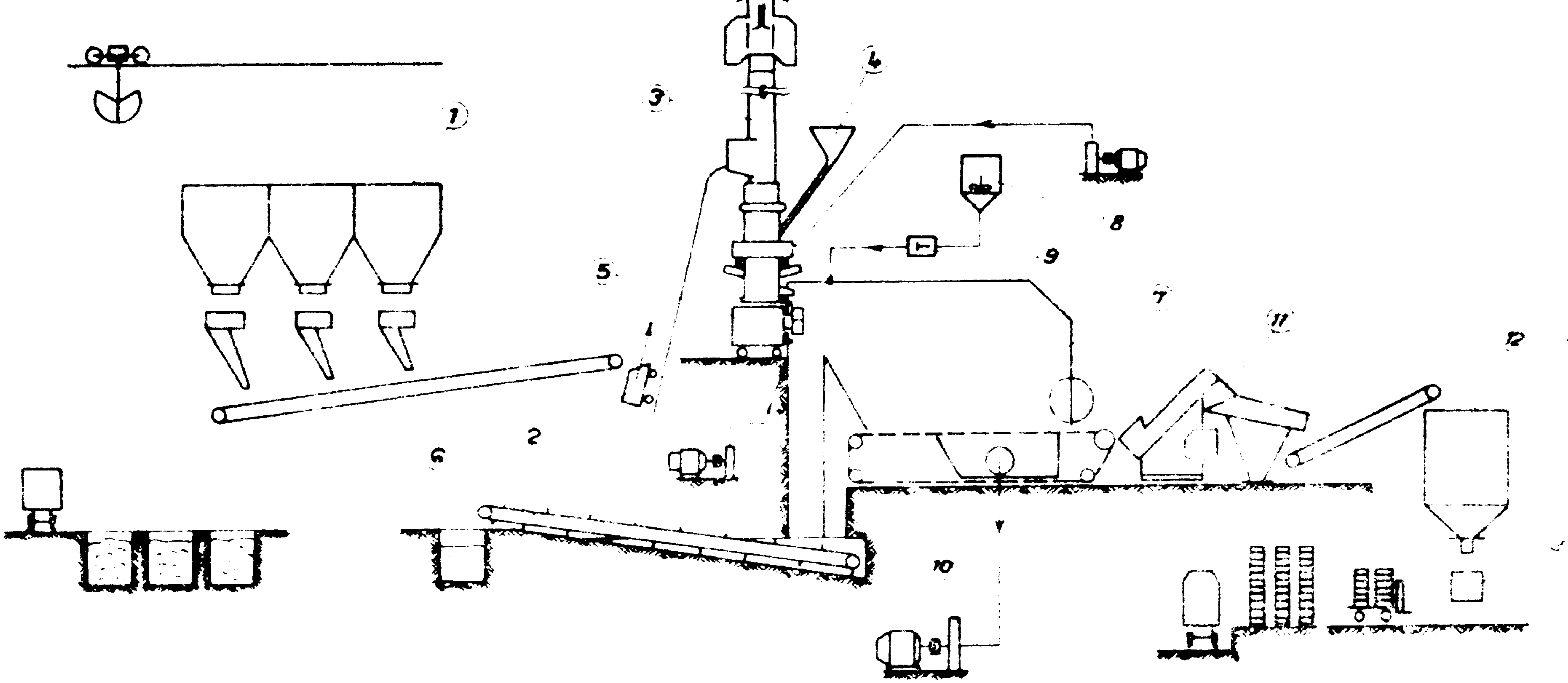


ORIGINAL DIAMETER OF FIBRES

1 - BASALTIC FIBRE, 2 - A - FIBRE, 3 - FIBRE FROM E GLASS

4 - G4, 5 - FIBRE FROM PREMOULDED PYREX

FIG. 7 : PRODUCTION SCHEME OF A - FIBRE MANUFACTURE



1 STORAGE FOR RAW MATERIALS AND COKE
2 FEEDING APPLIANCE
3 CUPOLA FURNACE
4 AUXILIARY STORAGE WITH CHARGER
5 PULPING MACHINE
6 BELT CONVEYOR
7 SETTLING CHAMBERS
8 STORAGE FOR EMULSION
9 HIGH PRESSURE PUMP
10 VENTILATOR
11 CLEANING MACHINE
12 AUXILIARY STORAGE
13 PACKING MACHINE

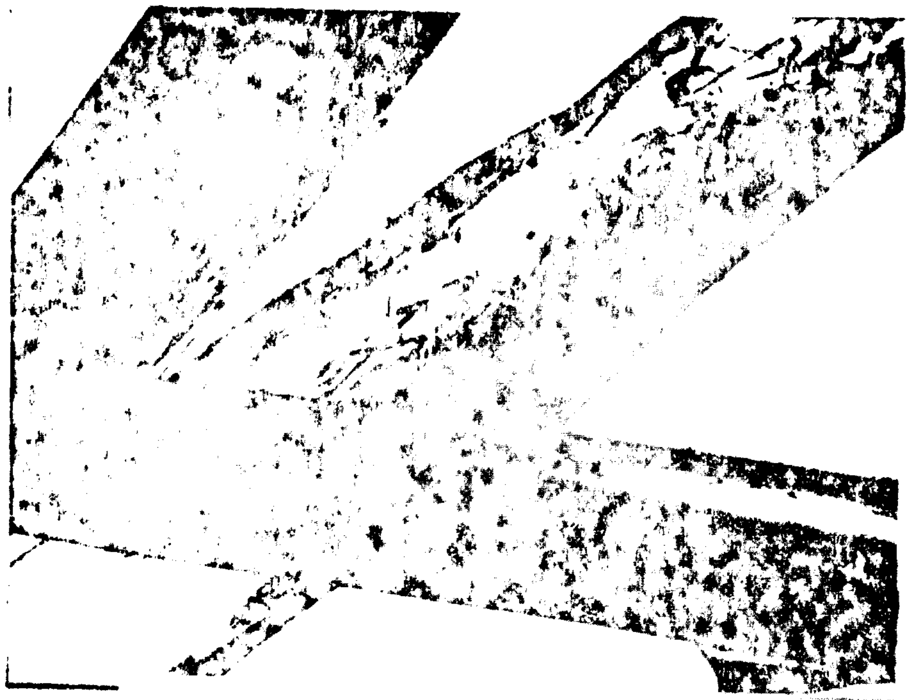


Fig.8: Photo of fibre surface, sprayed during pneumatic transport. Electrone microscope. Magnification 8 400 x.

Fig.9: Microphotograph of A-fibres after 15 months of storage in $Ca(OH)_2$ solution. Magnification 620 x.

FIG 10 RESISTANCE OF A - FIBRE IN Co(O SOLUTION

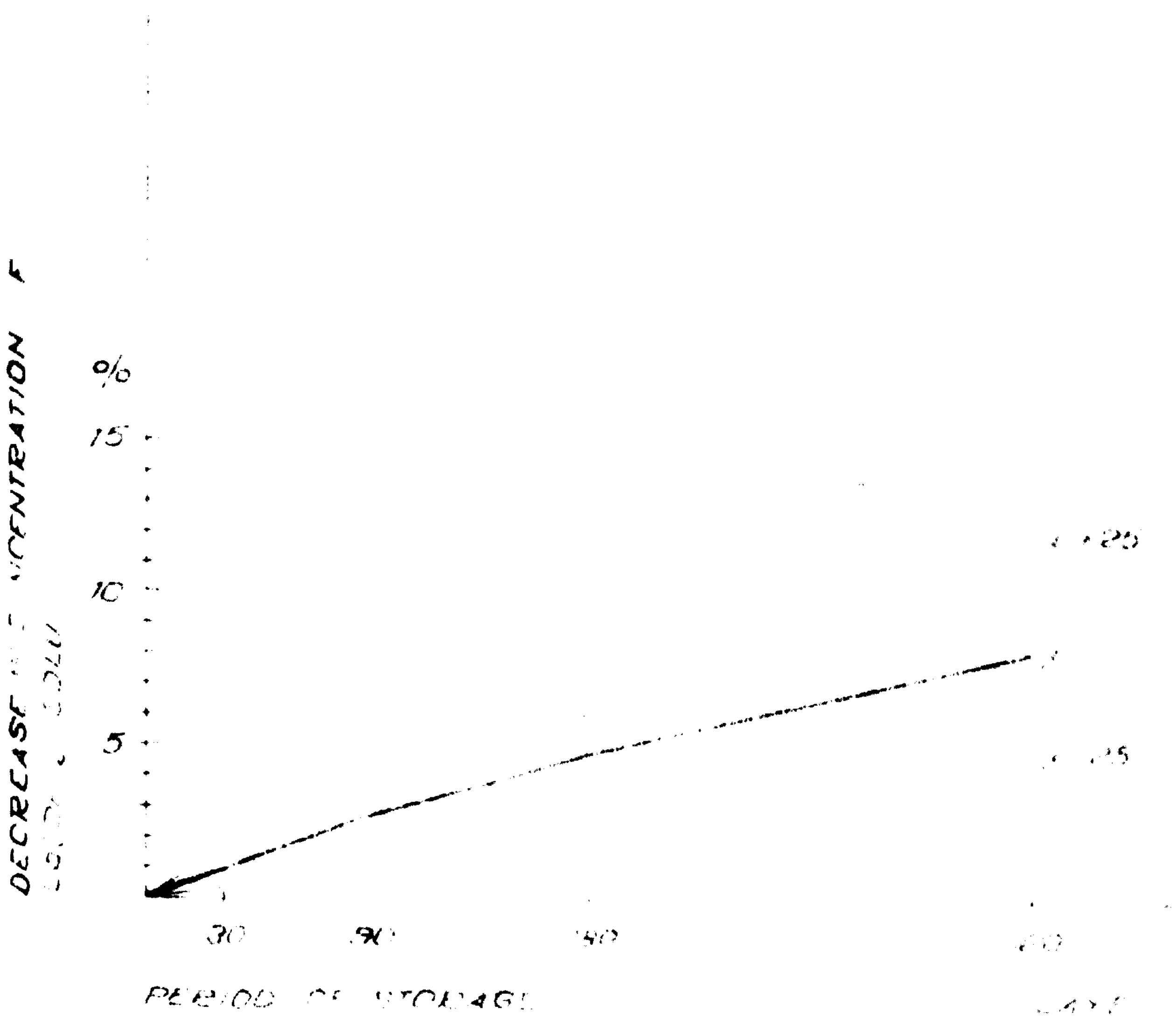


Fig.11: Microphotograph of A-fibre in asbestos cement after 18 months storage. Magnification 1[illegible]0x.

Fig.12: Surface [illegible] [illegible].
Magnification 7[illegible] x.

Fig.13: Surface of [illegible] fibre, stereoscan.
Magnification [illegible] x.

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