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INVESTIGATION OF RAW MATERIALS FOR THE PRODUCTION OF MINERAL WOOL

(Issledovanie Syriia dlia Proizvodstva Mineralnoi Shersti)

by

V.F. Zhuravlev and M.M. Sychev.

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Investigation of Raw Materials for the Production of Mineral Wool.

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The most important properties of mineral wool are: small weight per unit volume (from 30 to 160 kg. per 1 M^3) and a very small coefficient of thermal conductivity (from 0.05 to 0.07 k cal/M.hr. °C). The fact that mineral wool does not lose its heat insulating properties at fairly high temperatures, and it does not deteriorate from moisture is also of considerable importance.

Mineral wool finds wide application because of these properties. Thus, for example, mineral wool is used as a heat insulator in boiler installations, as a heat insulator and filtrating material in chemical apparatus and in refrigeration, but the building industry is the main consumer of mineral wool and its products.

The current methods in the building industry, which utilize prefabricated wooden constructions on a large scale, demand considerable quantities of heat insulating materials such as mineral wool. Because of this, it is necessary to ensure that the developing industry of mineral wool production has a sufficient supply of new raw materials.

The low cost of mineral wool and the possibility of utilizing raw materials of various and abundant types permit the organization of the industry in regions of greatest demand.

Literature sources indicate that a wide variety of raw materials can be used for the production of mineral wool. The use of the following materials is well known:

1. Schist dolomite containing clay (1)
2. Minerals of the pyroxene group, particularly wollanstonite (2)
3. By-products of bauxite (3)
4. Mixtures of clayey schist, sandstone, clay and lime (4)
5. Lime marl with an admixture of dolomite (5)

An analysis of various samples of mineral wool gave the following variations in the composition of the basic components (6,7,8)

SiO_2 from 35 to 46%

Al_2O_3 from 10 to 30%

Fe_2O_3 from 0 to 35%

CaO from 4 to 43%

MgO from 0 to 18%

In the United States quite often mineral wool factories are built beside Portland cement factories, so that they can utilize the by-products of the raw materials used in the Portland cement industry (9,10).

In the United States minerals which are suitable for the production of mineral wool without introducing any additions into the mixture are called "woolrock", but the rocks which

require the addition of a substance with either acidic or basic properties are called "subwoolrock".

The production of mineral wool is possible from various types of raw material and therefore the industry can be distributed throughout wide regions of the Soviet Union where such materials are available. The main problem in choosing the raw material is the selection of the proper mixture which will produce mineral wool of the necessary quality. The solution of this problem is in its turn dependent on the methods of evaluating the raw materials and the methods of selecting the mixture.

As is known, the production of mineral wool is based on the obtainment of a silicate fusion and the atomization of the stream of this fusion into very fine fibres. Hence, first of all, it is necessary to establish specifications for the properties and composition of silicate fusions suitable for the production of mineral wool.

The following conditions can be established on the basis of the data existing in literature:

1. The chemical composition of the mixture suitable for the production of mineral wool must be such as to ensure that the fusion upon cooling will become a glasslike structure without any tendency to become brittle.

2. The chemical composition of the mixture must ensure a sufficiently low viscosity of the fusion in the interval of 1250-1350°C. The viscosity of the fusion during the initial moment

of the fibre formation determines to a great degree the quality of the wool, and is mainly responsible for the fineness of the fibre.

3. The chemical composition of the mixture must be such as to allow the utilization of the presently existing melting apparatus. In cupola and bath furnaces, materials can be heated up to temperatures of 1500-1600°C. If we take into account that an overheating of the fusion up to 200-300°C (12) is required during the production, then temperatures of 1200-1250°C will be the optimum limits for the melting of the mixture.

When planning the mixture, it is good practice to correlate the ease of fusibility of the mixture with the minimum viscosity of the fusion.

The work of Pavlov (13) proves that the degree of liquefication of blast-slag is directly proportional to the ratio of the quantities of lime and silica to clay present in them. A predomination of $SiO_2 + Al_2O_3$ over lime makes the slag viscous, thick and slow-cooling, gradually becoming (passing through a doughy state) a glass-like mass. Slags in which the ratio $\frac{SiO_2 + Al_2O_3}{CaO}$ is close to unity liquefy more easily, cool more quickly, becoming a stone-like mass, which gives an ochreous fracture. If the quantity of lime is increased, these slags quickly lose their viscosity, become thick ("short" slags), and upon cooling disintegrate into powder.

TABLE 1

Lime content in slag - 30%

Al_2O_3 %	15	20	25	30	35
SiO_2 %	55	50	45	40	35
$\frac{Al_2O_3}{SiO_2}$	0.333	0.400	0.555	0.750	1.000
ηpoise	75	60	50	50	50

TABLE 2

Lime content in slag - 40%

Al_2O_3 %	5	10	15	20	25	30
SiO_2 %	55	50	45	40	35	30
$\frac{Al_2O_3}{SiO_2}$	0.10	0.20	0.33	0.50	0.62	1.0
ηpoise	20	15	15	20	35	60

TABLE 3

Lime content in slag - 45%

Al_2O_3 %	5	10	15	20
SiO_2 %	50	45	40	35
$\frac{Al_2O_3}{SiO_2}$	0.10	0.22	0.37	0.57
η poise	8	10	10	35

TABLE 4

Lime content in slag - 48%

Al_2O_3 %	6	8	10	12	14
SiO_2 %	46	44	42	40	38
$\frac{Al_2O_3}{SiO_2}$	0.13	0.18	0.24	0.30	0.37
η poise	7	6	min	8	10

It is also necessary to explain the effect of the ratio $\frac{Al_2O_3}{SiO_2}$ on the properties of the fusion.

From a study of McCaffrey diagrams on the viscosity of slags it is possible to explain the effect of the ratio

$\frac{Al_2O_3}{SiO_2}$ on the viscosity of the fusion for a given lime content.

Data expressing the effect of the ratio $\frac{Al_2O_3}{SiO_2}$ on the viscosity for fusions with various contents of CaO at a temperature of 1500°C are compiled in Tables 1, 2, 3 and 4.

The following conclusions can be made on the analysis of tables 1, 2, 3 and 4:

1. For low contents of CaO ($\leqslant$ 30%) there is a sufficiently wide interval in which a change in the ratio $\frac{Al_2O_3}{SiO_2}$ (from 0.5 to 1.0) has little effect on the viscosity of the fusions.

2. By increasing the content of CaO, this interval becomes considerably narrower (at CaO = 40%, ---- from 0.2 to 0.33, at 45% ---- from 0.1 to 0.37); at a content of CaO corresponding to the minimum viscosity (CaO = 48) this interval becomes a point. It must be noted, that although at the optimum content of CaO, this interval becomes a point the quantitative change in the ratio $\frac{Al_2O_3}{SiO_2}$ is very small.

3. At a content of lime less than 30%, and at an optimum content of lime (optimum from the point of view of obtaining minimum viscosity) a fairly wide deviation in the ratio $\frac{Al_2O_3}{SiO_2}$ is permissible.

It is possible to control the properties of a fusion, obtained from any raw material, in order to lower its viscosity. Thus at 1400 - 1600° the introduction of MgO up to 5% noticeably

lowers the viscosity. A greater increase in the content of MgO makes the fusion even more fluid, so that at 15-20% of MgO the viscosity of slags is 6 -- 8 times less than the viscosity of slags not containing MgO. It is also essential to note that with the introduction of MgO, the region of fairly fluid slags is widened (14). Therefore, in addition to the liquefying action, the presence of MgO makes it possible to widen the limits of the ratio $\frac{Al_2O_3}{SiO_2}$ without any essential change in the viscosity of the fusions.

There are indications that the presence of Fe_2O_3 in the fusion has even a greater effect on the viscosity than the presence of MgO, particularly if Fe_2O_3 is present in considerable quantities.

In order to lower the melting temperature of the mixture, 2-3% of alkali (recalculated on the oxide) are added. Sodium sulphate is generally used.

For the same purpose BaO may be introduced up to 6% (heavy spar may be used) at the expense of lowering the content of CaO. In this case the temperatures of fusion have been lowered to the order of 1000°. It must be pointed out that the temperature of fusion will again increase if the percent content of BaO is increased (14).

In order to regulate the properties of the fusion, a flux of the type CaF_2 can be introduced into the mixture which simultaneously lowers the temperature and the viscosity of the fusion (14).

According to Levinson -- Lessing (15) the halogen salts produce eutectics with silicate systems, and that these eutectics are displaced in the direction of the non-silicate components. From this point of view, sodium chloride can be used as a flux. The possibility of using this is explained in the work by Dilaktorski (16).

The above stated can be summarized as follows:

1. The ratio $\frac{SiO_2 + Al_2O_3}{CaO}$ should be greater than unity, which will ensure a glass-like structure upon cooling. Such a fusion will be a slowly cooling fusion, passing through a doughy state.

2. The value of the ratio $\frac{Al_2O_3}{SiO_2}$ considerably affects the viscosity of the fusion at a definite lime content.

3. Fluxes should be used (dolomite, heavy spar, fluorspar, sodium sulphate, sodium chloride) for the correction of the fusion.

4. The tendency should be to obtain compositions which possess minimum fusion temperatures. The fusion temperature of the mixture should not exceed 1200-1250°C.

Silicate fusions must possess a number of definite properties which determine their suitability for the production of mineral wool. Specifications for the raw material can be established by technological tests. The method of testing worked out by us includes the following:

(a) The determination of the chemical composition of the raw materials and fluxes.

(b) The planning of mixtures on the basis of above stated specifications regarding the chemical composition of fusions.

(c) The determination of the fusion temperatures for the selected mixtures.

The fibre quality of mineral wool is determined by the viscosity, the rate of cooling, "ductility", and, finally, by the value of the surface tension of the fusion. The total effect of the viscosity, rate of cooling, "ductility" and surface tension can be ascertained by a study of the phenomena of the so called flowability of the fusion.

Becuause of this, the testing method should also include:

(d) The determination of the flowability of the fusions from the selected mixtures.

(e) The production of mineral wool from the sample fusions.

(f) The study of the properties of the obtained mineral wool (composition of the fibres, weight per unit volume, coefficient of thermal conductivity, hygroscopicity).

(g) Correcting, when necessary, the properties of fusion by introducing fluxes and by repeating the investigations of the properties of the fusion and the wool.

(h) To establish the possibility of utilizing the raw materials under investigation.

(i) The selection of the mixture to be recommended to industry.

THE EXPERIMENTAL SECTION

Method of investigation

The temperature of fusion of the mixture was determined by the Seger cone in a Kryptol furnace.

The determination of the flowability of the fusions is carried out by the Selivanov method (17, 18). The method consists of the following: the fusion at some definite temperature is poured out onto a pouring gate located at an angle to the horizontal. The cross section of the pouring gate is uniform throughout its length. The length of the stream after cooling, and the weight of the cooled material are measured and the ratio of the length of the stream to the weight of the material is calculated. This ratio serves as a standard for the flowability.

An iron angle 25 x 25 planed along the inner surfaces was used as the pouring gate. The angle of incline was 16°.

In laboratory investigations the selection of the method for the production of mineral wool is very important and quite complex. The main lifficulty is the fact that it is not possible to obtain fusions of considerable quantities. For the laboratory investigations we have selected the mechanical method for atomization (English patent Buss (19), with modifications by Perkal and Epstein (12)). The laboratory apparatus for the production of mineral wool was constructed. The atomizer consisted of a rotating element, which produces the

scattering, and the necessary equipment for its installation and electrical connections.

The rotating element consists of a metallic propeller to which are attached metallic spokes of a special cross-section (see photograph). Two such rotating elements were prepared. One had eight spokes and the other sixteen. The propeller is mounted on a vertical shaft attached by two ball bearings. The shaft is also supplied with a pulley. The whole system is installed on a frame on which the electric motor is mounted. An A.C. motor of 0.5 Kw. and 1500 rpm is used. The ratio between the motor and the pulley on the vertical shaft is such that the element rotates at approximately 4000 rpm.

The wool is obtained in the following manner: a fine jet of the fusion at a definite temperature is poured onto the spokes of the rotating element. The spokes due to the high rotational velocity of the element (4000 x 16 = 64,000 blows on the jet per minute) break up the jet into minute drops which during the flight are drawn out into fine fibres.

In order to protect the worker from the spatterings of the fusion, a special coat was made from sheet iron. This installation proved very convenient for the experiment. It is particularly valuable because experiments with small quantities of fusion can be carried out.

TABLE 5

Name of Material	Chemical Composition (in %)						
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Losses at Heating	Σ
1. Marl	27.84	7.45	2.57	30.38	1.96	28.90	99.10
2. Dolomite	0.46	4.15	0.29	34.00	16.42	43.86	99.18
3. Speckled diatomite	80.16	4.57	2.35	1.92	1.27	8.88	99.15
4. Sand	99.58	0.26	0.08	0.80	0.15	0.26	100.63

For our experiments we used a Kryptol furnace.

The raw materials to be used in a new factory for the production of mineral wool have been investigated by this method.

Marl, dolomite, diatomite and sand were subjected tc these investigations. The chemical composition of the components of the raw material is given in Table 5.

Six mixtures were compounded. All mixtures contained approximately uniform amounts of Al_2O_3 and Fe_2O_3, which permitted to establish the effects produced by CaO and MgO on the properties of the fusion.

The chemical composition of the mixtures are compiled in Table 6.

TABLE 6

No. of mixture	Chemical Composition (in %)					
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Losses at heating
1	27.84	7.45	2.57	30.38	1.96	28.90
2	19.62	5.17	1.22	28.54	10.34	35.07
3	21.50	5.80	2.99	31.34	5.49	32.28
4	36.72	7.04	2.56	25.95	1.86	25.85
5	29.38	6.23	1.98	26.88	5.50	29.81
6	44.90	5.80	2.02	23.46	1.55	22.30

Table 7 gives the chemical compositions of the fusions and of the modulus:

$$\frac{SiO_2+Al_2O_3+Fe_2O_3}{CaO+MgO} \quad \text{and} \quad \frac{Al_2O_3}{Fe_2O_3}$$

The mixtures in this table are subdivided into two groups. From the first group (numbers 6, 4, 1) it is possible to judge the effect of the content of CaO on the properties of the fusion. The second group(numbers 1, 3, 2)explain the effect of MgO.

TABLE 7

No.	Chemical Composition (in %)					$\frac{SiO_2+Al_2O_3+Fe_2O_3}{CaO+MgO}$	$\frac{Al_2O_3}{SiO_2}$
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO		
6	57.70	7.46	2.60	30.13	1.99	2.1	0.13
4	49.50	9.49	3.45	34.98	2.51	1.66	0.19
1	39.20	10.58	3.61	42.60	2.75	1.18	0.27
1	39.20	10.58	3.61	42.60	2.75	1.18	0.27
3	32.00	8.65	4.45	46.30	8.19	0.83	0.27
2	30.21	7.96	1.86	43.95	15.92	0.67	0.38
5	41.80	8.86	2.82	37.40	7.84	1.18	0.21

The results of the determination of the melting temperature of the mixtures and the flowability of the fusion are given in table 8.

TABLE 8

Number of the Mixture	Melting Temperature (in °C)	Flowability of Fusion (k)			
		Temperature of the experiment (°C)	Length (l) of Stream (in mm.)	Weight (g) of the cooled material (in grms.)	k = l/g
1	1170	1400	130	20.50	6.35
2	1420	-	-	-	-
3	1230-1250	1400	138	20.00	6.90
4	1120	1400	107	19.25	5.55
5	1180	1400	117	16.85	6.94
6	1130	1400	65	17.90	3.64

From a comparison of the data given in tables 7 and 8, it is evident that an increase in the content of CaO from 30 to 40% makes the fusion more fluid; an increase in the content of MgO also makes the fusion more fluid; however, the increase in the quantity of MgO increases the temperature of melting. Mixture No. 5 gave the most fluid fusion with a sufficiently low temperature of melting.

A mineral wool with the following properties was obtained from mixture No. 5.

1. Thickness of fibre: maximum --106 μ, minimum --1.25 μ.
2. The composition of the wool by the fibre thickness (in percent): from 1.25 to 9.4 μ --30, from 9.4 to 19 μ--60, from 19 to 106 μ --10.
3. Length of fibre from 0.5 to 1.0 cm.

A comparison of the quality of the obtained wool with the standard specifications for slag cotton (standard 14--3915) shows that the obtained wool does not satisfy this standard.

From observations during the experiment, it is possible to conclude that the poor quality of the wool is due to the very high viscosity of the fusion during the time of its atomization.

The viscosity of the fusion can be lowered by three methods:

1. By increasing the reheating temperature of the fusion. This could not be done since the experiments were carried out at a very high temperature.

2. By an increase in the content of MgO; this increase was undesirable since the fusion already contained about 8% of MgO and a further addition of MgO would lead to a higher temperature of melting.

3. By the introduction of fluxes which would lower the viscosity, but which would not increase the melting temperature of the mixture.

Sodium sulphate in the amount of 6.58% (calculated so as to introduce up to 2% of Na_2O into the fusion) was used as the flux. The changed composition of the fusions due to the additions of the sodium sulphate are compiled in Table 9.

TABLE 9

No. of the fusion	Chemical Composition of the Fusions (in %)					
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O
1'	38.85	10.46	3.58	42.48	2.73	1.90
2'	29.54	7.10	1.87	43.10	15.60	2.06
3'	31.34	8.50	4.40	45.80	7.99	1.97
4'	48.60	9.35	3.40	34.39	2.46	1.80
5'	40.60	8.70	4.15	37.00	7.65	1.90
6'	56.73	7.35	2.56	29.68	1.96	1.72

The results of the determination of the melting temperatures of the mixtures corrected due to the addition of sodium sulphate, and the flowabilities of the new series of fusions are compiled in table 10.

TABLE 10

Number of the Mixture	Melting Temperature (in °C)	Flowability of Fusion (k)			
		Temperature of the experiment (in °C)	Length (l) of Stream (in mm.)	Weight (g) of the cooled material (in g.)	k = l/g
1'	-	1400	90	11.25	8.00
2'	1390	-	-	-	-
3'	1200	1400	172	14.40	11.95
4'	1100	1400	89	11.70	7.60
5'	1160	1400	118	9.97	11.84
6'	1100	1400	52	8.29	6.27

The introduction up to 2% of Na_2O into the composition of the fusions lowers the viscosity to a considerable degree. Moreover, the value of this decrease is not uniform for all fusions. The

introduction of Na_2O produces the greatest effect on fusions rich in MgO, since the introduction of Na_2O increases the liquefying action of MgO. If the addition of 1.97% Na_2O into the composition of the fusion number 1 increases its fluidity by 26%, then the addition of 1.97% Na_2O into the composition of the fusion number 3 (rich in MgO) increases its fluidity by 73%. Analogous results are observed for mixture number 5 (containing approximately the same amount of MgO as mixture number 3) the fluidity of which was increased by 70%.

The mixtures No.'s 5 and 3 possessing the greatest fluidity, were used to obtain mineral wool.

The characteristics of the properties of this mineral wool are compiled in table 11.

TABLE 11

Number of Mixture	Fibre Thickness in μ		The Composition of Wool According to the Thickness of Fibre (in %)			Length of Fibre (in cm)	Weight of Unit Volume under a load of 0.1 Kg/cm^2 (in Kg/M^3)	The Coefficient of thermal conductivity (in cal/M hr.°C)	Hygroscopicity (in %)	
	Min	Max	From 1.25 to 3μ	From 3.1 to 9.4μ	From 9.4 to 81μ				Moist Storage	Air Storage
3'	1.25	81	40	35	25	0.5-2.0	240	0.07	0.37	0.27
5'	1.25	37	25	48	27	1-10	240	0.07	0.42	0.31

The linear velocity of the atomizing element at the points of contact of the fusion jet with the spokes does not exceed 70M/sec. In industry atomization is carried out by steam, which has a velocity at the time of exit from the boiler of 300 to 800 M/sec. By atomizing mixture No. 5 with steam, it is possible to obtain a wool containing a larger percent of fibres having a diameter from 1 to 4μ.

We can recommend mixture No. 5 to industry, on the basis of the experiments which we have carried out.

In spite of the fact that mixture No. 3 produces a cotton which is more uniform in quality than mixture No. 5, we can not recommend mixture No. 3 to industry, since the fusion has the tendency to break up into powder upon cooling. This tendency is quite understandable, since the ratio $\frac{SiO_2 + Al_2O_3 + Fe_2O_3}{CaO + MgO}$ is less than unity for mixture No. 3.

Conclusions

A method for the investigation of raw materials to be used in the production of mineral wool has been worked out. It was also possible to obtain a mineral wool from the raw materials under investigation and recommend a composition of the mixture.

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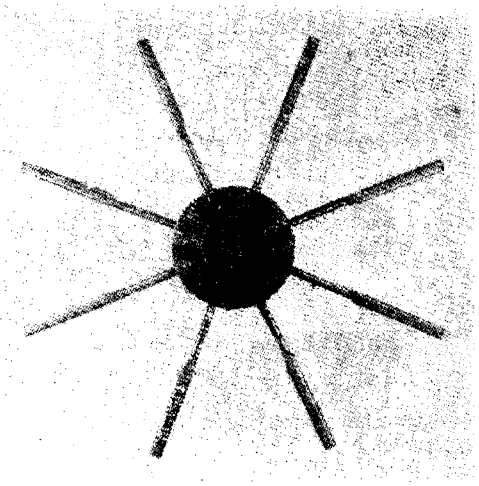

Atomizer