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MINERAL WOOL AND ITS PRODUCTS: MANUFACTURE AND USE 1/

by

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SUMMARY

MINERAL WOOL AND ITS PRODUCTS:
MANUFACTURE AND USE[1]

by

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USSR production of mineral wool and mineral wool products amounted to 400,000 tonnes[2] in 1958 and 840,000 tonnes in 1967.

On the basis of the volume of items, measured in cubic metres, the manufacture and utilization of mineral wool-based thermal insulating materials in building in the USSR increased over the same period more than 2.5 times.

The figures below show the evolution of the production of mineral wool and mineral wool products in a number of countries over the last few years:

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[1] The views and opinions expressed in this paper are those of the author and do not necessarily reflect the views of the secretariat of UNIDO.

[2] From information published by enterprises for 1968.

id.69-5701

Table 1

Volume of production in thousands of tonnes 1/

Country	[illegible]	[illegible]	[illegible]	[illegible]
United States	[illegible]	[illegible]	[illegible]	[illegible]
USSR	[illegible]	[illegible]	[illegible]	[illegible]
Scandinavia	214	234	[illegible]	[illegible]
Federal Republic of Germany	[illegible]	[illegible]	[illegible]	[illegible]
German Democratic Republic	-	24	-	-
United Kingdom	72	71	76	80
[illegible]	70	72	72.5	71
[illegible]	24	23	23	27
Switzerland	11	11	12	14
Czechoslovakia	-	13.5	-	-
[illegible]	-	15.8	-	-
Other countries	24	[illegible]	30	[illegible]
[illegible]	[illegible]	[illegible]	11	[illegible]

In recent years the following developments have taken place in the production of mineral fibre:

- The use of primary cast slags from steel works for the production of fibre. These slags are fed directly from the slag buckets into the slag processing furnace, which is heated by gas or natural gas. Several factories using this process are operating in the USSR;

- More extensive use of minerals as the main raw material and as additives to slags where there are higher requirements for acid number and durability of the fibre;

- Introduction of a process for the production of heat-resistant fibre 1-4 microns thick, involving the use of new combined processes of fibre formation and high-melting-point raw materials such as kaolin, silica and alumina.

1/ From information published by enterprises for 1968.

Electric arc and gas-fired furnaces are used to melt such raw materials.

According to available information, heat-resistant mineral wool [illegible] can be used at temperatures of [illegible] °C [illegible] countries [illegible] United States, [illegible] company in the United Kingdom, [illegible].

Development of the production of [illegible] types of [illegible] and [illegible].

The production of heat-resistant fibre and [illegible] is not dealt with in the present paper.

[illegible], the [illegible] and thermal [illegible], [illegible], and [illegible] of [illegible] heat-insulating [illegible] and [illegible] fibre production.

Mineral wool produced by the [illegible] method must satisfy the following requirements:

- [illegible] weight under specific loading of [illegible] not more than [illegible] kg/m[illegible];
- Content of non-fibrous inclusions with diameters of more than [illegible] not more than [illegible] per cent;
- average fibre diameter not more than [illegible] microns;
- Coefficient of thermal conductivity, [illegible] (m.hour.°C), at following mean temperatures, [illegible] kg/m[illegible] and [illegible] kg/m[illegible], respectively:

Temperature, °C	[illegible] kg/m³	[illegible] kg/m³
[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]
1[illegible]	[illegible]	[illegible]

- Acid number: not less than [illegible]

Investigations carried out in the USSR and other countries have shown that reduction of the diameter of the individual mineral fibres increases their strength and their resistance to the effect of various factors arising in the course of their utilization, such as vibration, temperature, humidity, etc.

[illegible]

[illegible] durability of mineral wool is affected not only by the thickness and strength [illegible] individual fibres of which it consists, however, but also by the chemical [illegible] (acid number), the method of fibre formation, and the content of non-fibrous [illegible].

[illegible] resistance of mineral wool is increased by raising its content of acid [illegible] Al_2O_3, SiO_2 and (within limits [illegible]). According to data of the "Jungers [illegible] firm [illegible] other [illegible], the total content of SiO_2 and Al_2O_3 should be [illegible] 56–60 per cent [illegible] the production of fibre by the centrifugal process).

[illegible] normal fibre production processes (the centrifugal roller process and the [illegible] air draught process), it is possible to obtain fibre not less than 4–7 [illegible].

[illegible] compaction of mineral wool achieved through these methods lies within [illegible] kg/m³. Lesser or greater compaction increases the coefficient of [illegible] conductivity.

[illegible] insulation is an inherent element of modern industrial activity. A [illegible] industrial processes would be technically impracticable without thermal in[illegible] the equipment and pipework.

[illegible] insulation [illegible] in fuel consumption, maintains more [illegible] conditions, and improves equipment servicing conditions.

[illegible] the construction of residential, industrial, agri[illegible], administrative and other buildings.

[illegible] advisability of using thermal insulation is now beyond doubt.

[illegible] construction [illegible] a number of special problems in connexion [illegible] thermal insulation:

[illegible] the planning stage, the areas [illegible] where thermal insulation is to [illegible] determined, and the most effective insulating materials must be [illegible];

[illegible] the building stage, the insulation material requirements of the areas to [illegible] must be determined.

Depending on actual conditions, a firm can either arrange to produce insulating material and insulating items itself, or it can obtain them from specialized home or overseas firms.

In order to take a sound decision on these matters it is essential to have a wide range of information and data on the production conditions of insulating materials, the resources required for their production, the cost of production, the magnitude of the capital investments involved, and so forth.

The production conditions of thermal insulating materials vary considerably from one country or area to another, so it will not be possible in the present paper to make recommendations which take all the possible actual conditions into account.

On the basis of the information given here, however, it is possible, by means of straightforward calculations taking into account the actual conditions of a given area, to determine all the necessary technical and economic characteristics regarding the production of insulation materials and take economically and technically justified decisions on the advisability of building a thermal insulation factory, its type, capacity and product range, and its main operating conditions.

It is not necessary, at any rate for the first approximate decisions, to call on the services of thermal insulation production specialists.

The use of thermal insulation in buildings and installations must be economically justified.

The use of such insulation on industrial equipment and piping, however, is dictated not only by economic considerations, but also by technical requirements. The construction of the overwhelming majority of industrial enterprises and power stations without thermal insulation would be technically out of the question.

The thermal insulation used for industrial purposes accounts for some 15 per cent of the total amount of thermal insulation used in building.

The requirements which have to be satisfied by thermal insulation work, materials and products for use in industry far exceed, both from the point of view of quality and compliance with a wide range of technical and physical requirements, as well as from the point of view of availability of an extensive range of different types and qualities, the requirements which must be satisfied by such materials for general building applications.

[illegible] SUMMARY

[illegible]ermal insulation for buildings is only called upon to withstand a relatively [illegible] range of temperatures from [illegible] upwards, while in more temperate areas the [illegible] only extends from about [illegible].

[illegible] temperature range of hot and cold [illegible] used in industrial and power genera[illegible] equipment and piping, however, is extremely wide, extending in [illegible] cases [illegible], to [illegible] where [illegible] temperatures may [illegible] -[illegible] or as high as [illegible] for higher temperatures, [illegible] lined [illegible] used.

[illegible] thermal insulation [illegible] buildings is not normally subjected to significant [illegible] loads. [illegible] industrial [illegible], however, [illegible] subject to [illegible] shocks and vibration, [illegible] severe. [illegible] insulation is [illegible] temperature [illegible], [illegible] slowly. [illegible] temperature [illegible] or power [illegible] frequently [illegible] rapidly, however.

[illegible] thermal insulation of industrial equipment which is located out of doors is [illegible] attack by the atmosphere and to the direct action of the sun's rays.

[illegible] cases the insulation of equipment located indoors is [illegible] to attack by [illegible] active agents.

[illegible]lation used in buildings is not subject to the requirement that it should be [illegible] being dismantled [illegible] permit repair or maintenance work.

[illegible] industrial or power generation equipment, on the other hand, and [illegible] times also [illegible] work [illegible] periodically be dismantled, [illegible] with its insulation, so that the possibility of dismantling and reassembling such [illegible] is of great importance.

[illegible]lly, only thermal insulation for buildings is only used in the form of slabs [illegible]. The complicated shape of pieces of equipment needing to be insulated and [illegible] different diameters of pipes which must be covered with insulation, however, make [illegible] to produce a wide range of heat insulating materials, products and [illegible], in an extensive selection of types and [illegible], for industrial use. It is [illegible]arly important to produce insulation material in the form of hollow cylinders [illegible] cylinders of various thicknesses and diameters for the insulation of piping.

The most effective types of products for the insulation of piping and equipment [illegible] those which are already provided, in the factory where they are manufactured, with protective coverings of sheet aluminium, thin galvanized steel sheet, [illegible] or [illegible] polymeric sheeting, and which are delivered complete [illegible] fittings for their attachment. The [illegible] for insulation purposes will depend [illegible] to be used.

Because of the wide variety of [illegible] characteristics, [illegible] operating conditions of process and power generating equipment and piping, a wide [illegible] of thermal insulating materials and products [illegible] addition to mineral wool, [illegible] insulation [illegible] silica, perlite, asbestos/vermiculite, asbestos cement, [illegible] and [illegible] are also [illegible].

The technical characteristics, production technology, production cost and whole sale prices of these materials and products differ [illegible].

At the same time, however, [illegible] from the point of view of their [illegible] properties, [illegible] the many [illegible].

The correct choice [illegible] tion material for a given application [illegible] will [illegible] the availability of [illegible].

A group of specialists [illegible] tions for making the best possible choice [illegible] for groups of applications [illegible] technical characteristics.

In view of the fact that the technical [illegible] in different branches of industry are extremely varied, investigations were carried out in a number of the main branches of industry: metals, mechanical engineering, chemicals, oil refining, power generation and food manufacture.

A considerable number of large representative enterprises were investigated in each branch.

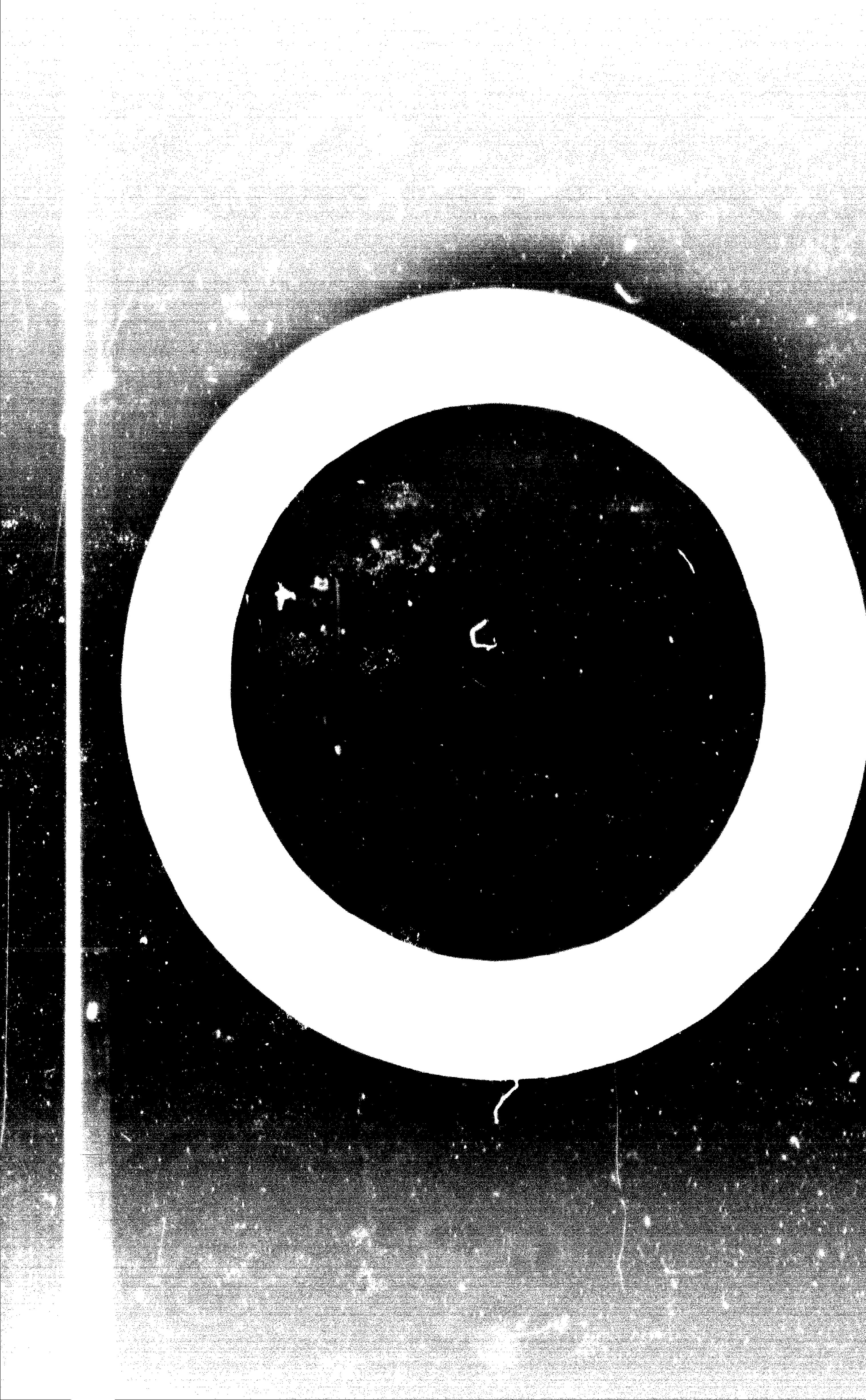
The results of the investigations made it possible to determine the relative frequency of the items of different shapes and sizes needing to be insulated and of the different temperatures of hot or cold fluids involved.

The selection of the [illegible] insulating [illegible] for a particular group of applications is [illegible] characteristics of the items to be insulated [illegible] the insulating materials [illegible], but also [illegible] basis of the relative [illegible] of [illegible] material for [illegible] given type of industrial [illegible].

[illegible] heat insulating materials [illegible] characterizing these materials, [illegible] thermal conductivity, the temperature range [illegible], the [illegible] heat [illegible] or per [illegible].

[illegible] insulation materials and products [illegible] thermal conductivity, their relative [illegible], the [illegible] investments involved, and the [illegible].

* * * * *



CONTENTS

Introduction

Mineral wool is made up of artificial fibres produced through blowing a liquid silicate melt of slags and rock into fine glassy filaments which harden when being cooled. Mineral wool is a shapeless mass with filaments arranged in different directions.

Methods of manufacturing artificial mineral fibres from slags and rock was already known over 100 years ago[x]. Fibre formation was occasionally discovered for the first time in a blast-furnace process: gases squeezing out molten slags through leaky joints in the walls of a blast furnace made lumps of filament like wool. In 1864 George Parry, of Wales, obtained slag fibres by playing a steam jet on molten slags escaping from the blast furnace.

In 1870 John Player from the USA was given a patent for manufacturing mineral wool from slags and glass waste.

In 1870 the firm of Parrot erected the first industrial enterprises in Greenfield, and in Germany nearby Osnabrück the firm of George Marienhütte did the same at a metallurgical works. The latter demonstrated in 1873 at the Vienna Internati-onal Exhibition its pipes insulated with mineral wools, by which a great interest in the new production was roused.

In 1897 Hell Ch.W. discovered in Alexandria /Ind., USA/ limestone from which mineral wool was obtained, and since then its production began.

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x) See point 15 in the List of Literature to be recommen-ded.

During World War I the manufacture of slag wools was greatly developed in Germany because in connection with the blocade there formed a deficit of such insulating materials as natural cork and asbestos.

The highest output of mineral fibres during the period from the First to the Second World War was in the USA where it increase from [illegible] thou.tns in 1928 up to 1[illegible] thou.tns in 1939.

In Russia mineral wools were obtained from blast-furnace slags for the first time in 1[illegible]. In the USSR there manufacturing began in 1[illegible] in the Urals.

The construction industry in progress, the production of mineral wools in the USSR was growing papidly every year running. If the 1[illegible] output of mineral wools in the USSR was 350 tons, in 1[illegible] it increased already up to 5000 tons.

In the post-war years the manufacture of rock- and slag wools began to develop rapidly in the Soviet Union and almost in all countries of the world. The cause was that we were badly in need of [illegible] and of developing such industries as chemistry, energetics, oil & gas processing, metallurgy, etc.

Use of thermal insulating materials based on rock- and slagwools in constructing apartment houses, industrial and civil buildings allows to save main building materials - cement, metals, brick and wood, - to reduce labour consumption and construction terms fixed, and to cut down fuel consumption in maintaining buildings.

Use of thermal insulating materials in industry also permits to reduce heat losses and fuel consumption. Thermal insulation of equipment and pipings favours in many cases to intensify technological processes and provides for safety engineering and labour protection.

The availability of source materials everywhere, simple and inexpensive production, resistance to molding and rotting, incombustibility, high thermoinsulating and sound-proof characteristics, capability of manufacturing various products with a leather-volume weight for different purposes, and of using them to insulate surfaces heated up to 300-700°C - all these factors have predetermined a wide application of mineral wools and their products as the most useful thermoinsulating material in many countries of the world.

In 1958 the USSR produced [illegible] thou. tons, and in 196[illegible] - 840 thou. tons of mineral wools and their products.

The output of insulating materials based on mineral wool and its use in the construction industry was an over-3.5-time increase in the USSR during this period, counting the production volume in cubic metres.

The following figures show the development of manufacture of mineral wools and their products in a number countries for the last few years. Production volumes are given in Table I in thousand tons.x)

Table I

Countries	1964	1965	1966	1967
USA	1750	1800	1800	[illegible]
USSR	740	840	900	[illegible]
Scandinavia	214	234	248	[illegible]
FRG	207	209	227	[illegible]
GDR		24		

x) According to prospects of "Jungers Verstad A.B."

xx) Conventional conversion coefficient is 10, i.e. [illegible] cu. m in 1 tn.

Table I (cont.)

Countries	1964	1965	1966	1967
Great Britain	72	71	76	80
France	70	72	72.5	73
Italy	24	23	23	27
Switzerland	11	11	12	14
Czechoslovakia		13.5		
Romania		35.8		
Benelux	24	29	30	32
Spain	4.6	6.8	11	13

The manufacture of mineral wools is also conducted in Japan, Canada, Yugoslavia, Iceland, the Netherlands, Portugal, Poland, South America and India.

According to information available the main manufacturers of mineral fibres are the following firms:

USA:

American Rockwool Co.; Boldwin-Hill Co.; Prenton N.Y.; Philipp Corly Co.; Eagle Picher Co.; Porty-Eight Insulation; Johns-Mauville; Armstrong; Gold-Bond; Refractory Insulation; H.I. Thompson Fiber Glass Co.; Babcock & Wilox Co.

Canada:

Johns-Mauville Co. Ltd.; Douctar

Great Britain:

Stillite Products Ltd.; Rudders & Paynes Ltd.

Japan:

Khittobo

FRG:

Grunzweig und Hartmann; Dortmund-Horder Huttenunion A.G.; Isola-Minerawolle-Werke; Deutche Rockwool Mineralwool; Erste Deutche Basaltwolle K.G.; August Messler; Rheinstahl Eisenwerke A.G.

France:

Stillite francaise, Fransicol

There have recently appeared new trends in the manufacture of mineral fibres:

- use of primery flame-liquid slags at metallurgical works, with isertion of such slags from slag-carrying ladles into a slag catcher which is heated by coke gases; in the USSR this method is employed at some plants;

- enlarging the use of rock muck as the main raw material and as an addition to slags in keeping with high requirements to the acid modulus and to the useful life of fibres;

- mastering of the processes on the production of thermo-stable filaments 1 to 4 microns thick which favoured the use of new combined methods of fibre formation, and use of refractory raw materials: kaolin, silica, alumina. In order to melt theses materials electric arc and gas furnaces are necessary. As is known[x] thermostable wools, with a temperature for use up to 1200°C, are manufactured by 8 US firms, one British company (Cape Insulation & Asbestos), and others.

- production development of acoustic slabs of different kinds.

Problems of the manufacture of thermostable fibres and acoustic slabs are not a subject of our study in the present paper.

Below we are considering some questions of the technological production, physico-mechanical and heat resistant properties, productional economy and use of mineral wools and their products as effective thermoinsulating materials in the construction industry.

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[x] See point 9 in the List of Literature to be recommended

CHAPTER I

NOMENCLATURE AND CHARACTERISTICS OF MINERAL WOOLS AND THEIR PRODUCTS

At first mineral fibres were being manufactured like wool , and which were called, depending on source materials, slag, stone, rock and basalt wools.

Later "mineral wool" became the most generally used term. This term will be henceforth used in the present work, regardless of any kind of raw material.

The manufacturing of various products from mineral wools is effected to facilitate construction and thermo-insulating works. Organization of production of mineral wools dates back to the beginning of the thirties. First experiments on the processing of ~~rock~~ mineral wool resulted in obtaining granular wool and felt. At present, out of ~~rock~~ mineral wools we can make a great variety of products for different purposes, and it can be subdivided into the following main groups of materials according to their structure and assignment.

Type of material	Assignment
Friable materials	
Raw ~~rock~~ mineral wool in stacks rolls, or packed in sacks;	Filled-up and stuffed insulation, insulation of oxygen installations.
granular wool packed in sacks.	
~~Pliant~~ Flexible, rolled materials.	
Felt (soft slabs), mats and ~~bands~~ strips stitched with a facing of paper, glass fibre, crimped card-board, metal ~~grids~~ mesh	Insulation for pipes of big diametres, vessels and apparatus; insulation for walls, ceilings, floors in building low-story houses.
Semi-rigid materials	
Slabs ~~on adhesive base~~ with binder, mats stitched in form of mattresses.	Insulation for protecting structures in buildings, and for equipment surfaces.

Type of material	Assignment
Half- and cut cylinders	Insulation for pipes 21 to 400 mm in diameter.
Rigid materials	
Slabs, blocks [redacted] with binder	Heat and sound insulation for walls, ceilings, roofings, floating floors in industrial and civil buildings; insulation for refrigerators and stoves.

The main factors of mineral wool and its products determining their quality as a material for heat and cold insulation are heat conductivity, volume weight, temperature, strength factors (for semi-rigid and rigid products).

Below are given characteristics of mineral wool according to the SU Standard.

1. Mineral wool produced by centrifugal-blowing and centrifugal-roller methods:

	Types '75'	Types '100'	Types '125'
Volume weight in kg/cu.m under rated load of 0.02 kg/sq.cm., (not more)	75	100	125
Content of non-filament inclusions in size of over 0.25 mm, in per cent (not more)	12	20	25
Heat conductivity in Cal/m.hr.$^{\circ}C$ (not more) at an average temperature of:			
$25\pm5^{\circ}$	0.036	0.038	0.040
100°	0.050	0.050	0.052
300°	0.092	0.088	0.084
Average fibre diameter in microns (not more)	6	8	8
Temperature for use, in $^{\circ}C$	600	600	600
Oxides total ratio $\frac{SiO_2 + Al_2O_3}{CaO + MgO}$ (not less)	1.2	1.2	1.2

Mineral wool is not subject to moulding and rotting and is non-combustible material.

The mineral wool heat conductivity in structures with different packing will depend on temperature as follows:

Volume weight, in kg/cu.m mineral wool pliant	in structures	Heat conductivity, Cal/m.hr.°C
65–70	75	$0.032 + 0.00033 t_{av}$
	100	$0.035 + 0.00022 t_{av}$
	125	$0.038 + 0.00019 t_{av}$
	175	$0.040 + 0.00016 t_{av}$
90–100	100	0.035 + 0.0002[illegible] t
	125	$0.038 + 0.00017 t$
	150	0.040 + 0.000[illegible] av
	200	0.042 + 0.000[illegible] t_av

Dependence of the mineral wool heat conductivity "φ" at a temperature of 20°C in structures on the volume weight can be expressed by the formula (for technical calculations):

$$\varphi = 0.031 + \frac{0.075\,\gamma_0}{100} \text{ Cal/m.hr.}^{\circ}\text{C}$$

where: γ – volume weight in kg/cu.m. under rated load of 0.02 kg/sq.cm.

2. Mineral wool manufactured by the drawing – blowing method, should meet the following requirements:

Volume weight under rated load of 0.02 kg/sq.cm (not more)	75 kg/cu.m	
Content of non-filament admixtures by size of over 0.5 mm (not more)	4 %	
Average filament diameter (not more)	8 microns	
Heat conductivity in Cal/m.hr.^{o}C at an average temperature of:	with γ=75 kg/cu.m	with packing up to 125 kg/cu.m
0^{o}C	0.030	0.032
50^{o}C	0.044	0.040
100^{o}C	0.058	0.048
Acid modulus (not less)	1.5	

Studies made in the USSR and other countries have shown that by reducing the diameter of common mineral filament its strength and resistance to various factors arising from the process of exploitation such as vibration, temperature, moisture. etc., increases. However, the longevity of rockwool does not only depend on its thickness and strength of elementary filaments, but also on its chemical composition (the acid modulus), methods of filament formation, content of non-filament admixtures.

A higher content of the oxides Al_2O_3 and SiO_2, and also FeO, (up to a certain level) increases heat resistance of mineral wool. The firm of Jungers Verkstads A.B. and others indicate that the total content of $SiO_2 + Al_2O_3$ should not be less than 53 to 57% (using the centrifugal method).

Filament not less than 4 to 7 microns thick can be generated by usual methods of fibre formation (centrifugal, centrifugal-blowing). Optimum packing made by these methods ranges from 90 to 110 kg/cu.m. The heat conductivity increases with softer or more solid packing. This dependence is shown graphically in Fig. 1 (according to the Jungers Verkstads A.B. firm's figures on mineral wool generated by the centrifugal- roller method). The higher solid packing the less the so-called angular coefficient characterizing dependence of the mineral wool heat conductivity on temperature in Fig. 2 (according to the Jungers Verkstads firm's figures).

In order to manufacture products of certain shapes and of specified dimensions, mineral wool is soaked in cohesive resins, placed into a moulding installation and is treated with heat.

Depending on the properties of resins used and on the packing of mineral wool soaked in resin we can get products with different volume weights and for various purposes.

Mineral wool products are also obtained by washing mineral wool placed in lining materials: metal mesh, glass

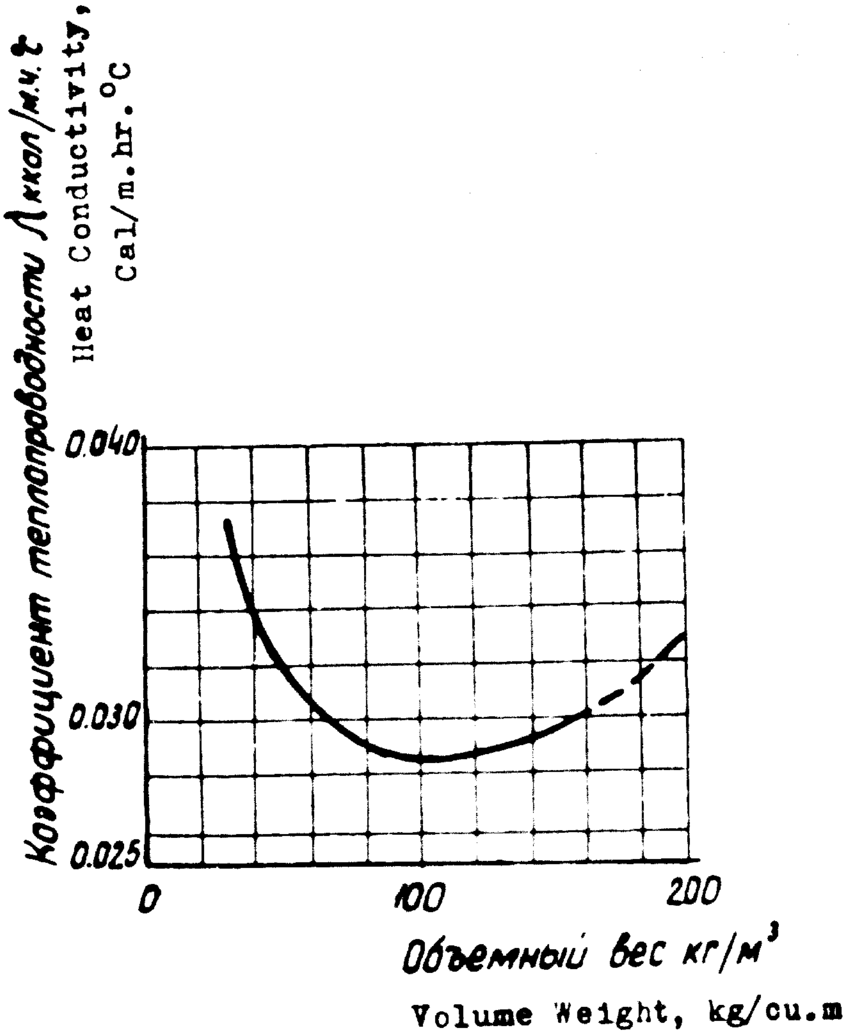

Fig. 1. Dependence of Heat Conductivity of Mineral Wools on Volume Weight (centrifugal-roller fibre formation method)

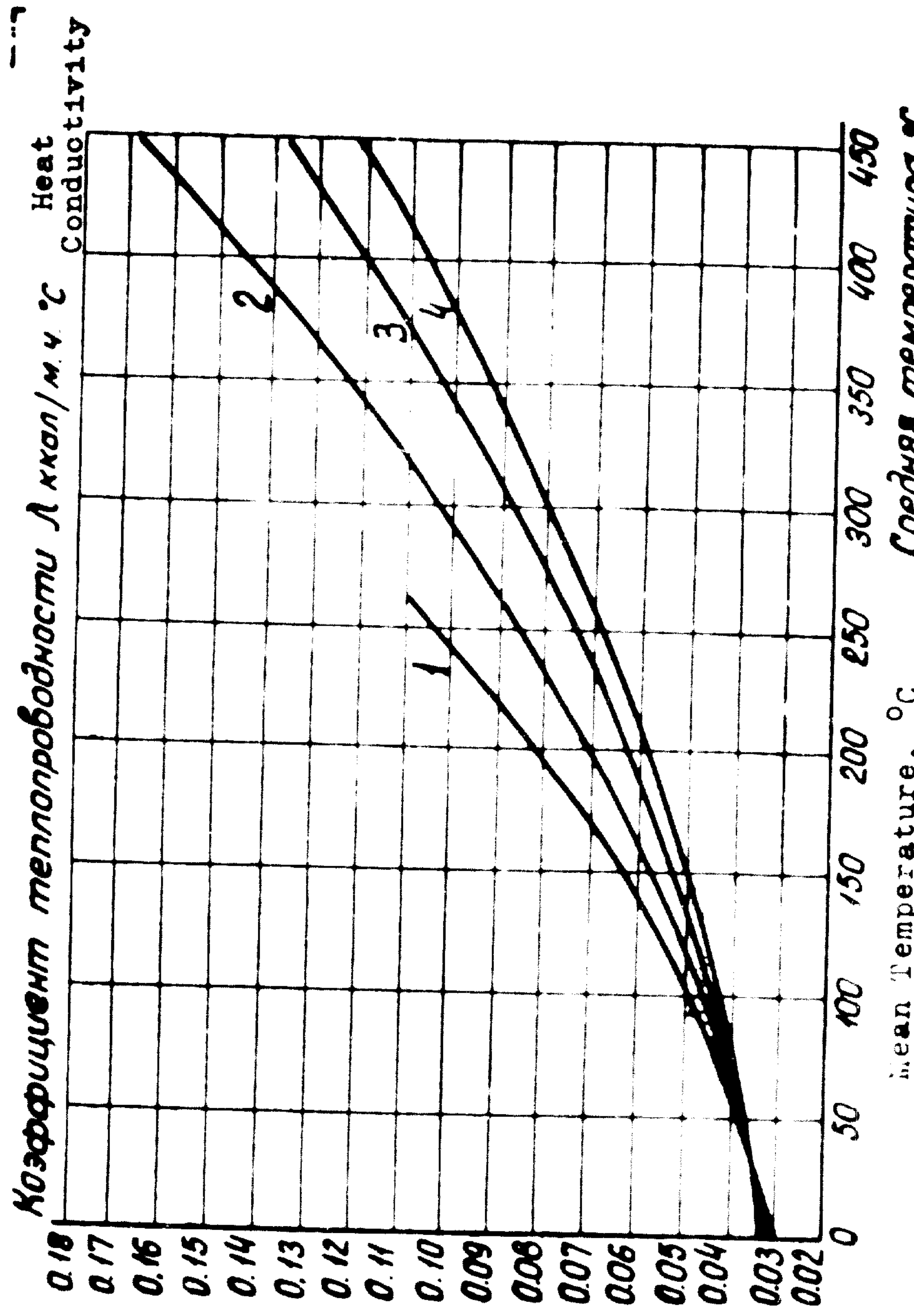

Fig. 2. Dependence of Heat Conductivity of Mineral Wools on Temperature

1. Volume weight = 45 kg/cu.m
2. Ditto = 70 kg/cu.m
3. Ditto = 100 kg/cu.m
4. Ditto = 150 kg/cu.m

fiber glass, waterproof paper, crimped cardboard and others.

Every year the output of friable (and granular) mineral wool decreases because of its remaking, on a growing scale, into products of various kinds.

The ratio of volumes for use of friable (and granular) wool and its products is defined, for example, by the following figures:

- in 1963 the output of mineral wool in the USA[x)] was 443 cu.m per one million dollars' cost of construction and erection works, including:

friable and granular mineral wool - 25.6 cu.m

products for construction industry - 252.1 cu.m

products for equipment - 141.8 cu.m

others - 23.5 cu.m

During the period from 1958 to 1967 the production of slabs, mats and other products was an over 7-fold increase, and the output of friable mineral wool for this period increased by 25%.

The FRG's[xx)] output of slabs and mats from 1958 up to 1964 increased by 242%, while the output of commercial raw mineral wool increased by 42%.

Besides, slabs and mats, were produced half cylinders and insulating cord.

The main types of mineral wool products for a great number of firms are as follows:

a) Rigid slabs (including acoustic ones) 1 x 0.5 m or

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x) Report of "Jungers Verstads AB" in the USSR, 1967

xx) Census of Manufactures, 1958-1964.

1 x 1 m in size, 9 to 70 mm thick, and volume weight 170 to 500 kg/cu.m;

b) Semi-~~hard~~ rigid slabs 100 mm thick, 1 x 0.5 m or 1 x 1 m in size, and volume weight 80 to 150 kg/cu.m;

c) soft products in form of mats stitched with various linings, ~~bands~~ strips, mattresses, felt, cloth, with volume weight from [illegible] to [illegible] kg/cu.m.

d) ~~Shells~~ Half-cylinders and cylinders for insulation of pipes from 16 mm up in diameter, volume weight 100 to 220 kg/cu.m.

The further enlargement of the variety of heat insulating products is following now the next main trends:

a) creation of multi-layer structures and structures of big sizes capable to perform not only a function of heat insulation but also a function of space division;

b) strengthening of semi-~~hard~~ rigid products (slabs and ~~shells~~ half-cylinders) and enlargement of a variety of products for pipe insulation;

c) manufacture of a greater range of acoustic products.

Table 2 shows the variety and characteristics of ~~rockwool~~ mineral wool products in compliance with the USSR Standards.

Dependence of heat conduction on temperature is represented for various products in Table 3.

Table 2

Characteristics of Mineral Wool Products According to the USSR Standards

Type	Volume Weight, kg/cu.m	Heat Conductivity, Cal/m.hr.°C at t_{av}=25°C	Packing under Rated Load of 0.017kg/sq.cm, in %, (not more)	Content of Cohesive Materials, in % (not more)	Temperature for Use, °C	Dimensions, mm		
						Length	Width	Thickness
		Flexible, soft products						
Soft slabs (of felt) on bitumen-bonded cohesive base	100	0.4040	Under load of 0.02 kg/sq.cm 55	5	60°C- indoors, 200°C- outdoors	1000; 1500 and 2000+_20	450;500 and 1000+10	50 - 100 +7 -2
Mats rolled with synthetic cohesive binder base	30-50	0.034	60	4	up to 300°C indoors	2000 3000 4000 ±100	500 and 1000 ±50	40;50;60; 70;80;100 ±5
	50-75	0.037	50	4	up to 400°C outdoors			
Soft slabs with synthetic binder	60-100	0.036	35	4	- " -	1000	500	40,50,60, 70,80,100 ±5

Table 2 (cont)

1	2	3	4	5	6	7	8	9
Mats stitched	100 125 150 200	0.036 0.038 0.040 0.042	Not specified	Not more than 1	600°C- with liming, 400°C- glass fibre glass, 150°C- card-board, bitumi-nouse paper, glass cloth	1000 to 2500 ±50	500 to 1500 ±20	40 to 100 ±5
Insulating cord	200 250 360	0.052 0.055 0.060	-	not spe-sified	600°C- braiding of wires, 400°C - glass fibre glass, 200°C - synthe-tic fibre (kapron),	Weight of one coil=50 kg		Diame-ter 20,35 and 60 ±6

8

1	2	3	4	5	6	7	8	9
					150°C cotton			
Semi-rigid and rigid products								
Slabs with synthetic binder: types: ПП	100–150		15	5	300°C indoors	500 and 1000	500±	30 to 100
ПЖ	100–175		5	6	400°C outdoors			30 to 70
Semi-rigid slabs starch-bonded	125 150 200	0.040 0.045 0.050	15 10 4	3±0.5	400	100±10	100,450,600 and 900 ±5	40,50,60 ±3
Semi-rigid slabs bitumen-bonded	150 200 250 300	0.045 0.050 0.055 0.060	27 24 17 12	20	60	500,1000 ±20	450,500 ±10	50 to 100 +7 −2
Half cylinders with synthetic binder	125 175	0.044 0.046	15 5	6 6	300°C indoors 400°C outdoors	500 &1000 ±20	Internal diameter 52,67,77, 95,116,137, 161,222,282, ±3	40,50,60 ±3

Table 2 (cont.)

1	2	3	4	5	6	7	8	9
Hollow cy-	175	0.046	8	6	-	500 1000	Internal diameter 52,67,77, 116,137,161, 222,282 ±4	40 to 1000 ±3
linders with	225	0.048	6	6				
synthetic binder (half-								
cylinders)								
Rigid slabs	250	0.055	15	6	70	1000 ±10	500 ± 5	40,50,60 ±3
	300	0.060	special	5				
bitumen-	350	0.065	20	4				
bonded	400	0.070	ordinary	3				

Table 3

Dependence of Heat Conductivity on Temperature

Name	Volume Weight kg/cu.m		Rated Heat Conductivity Cal/m.hr.°C		Use, °C
	Standardised products	In structures	Positive Temperature	Negative Temperature	
1	2	3	4	5	6
Mineral wool	75	120	0.038+0.00025 tav		-200 to 600
	100	150	0.040+0.00020 tav		
	125	190	0.042+0.00018 tav		
	150	230	0.046+0.00016 tav		
Mineral wool slabs with synthetic binder					
soft	100	150	0.042+0.00017 tav		
semi-rigid	150	180	0.044+0.00017 tav	0.06–0.07	-30 to 300 indoors
rigid	175	175	0.046+0.00017 tav		-30 to 400 outdoors
Cylinders and	130–170	130–170	0.042–0.00017 tav	0.05–0.06	-30 to 300 indoors
half-cylinders with synthetic binder	180–220	180–220	0.046+0.00017 tav	0.06–0.08	-30 to 400 outdoors

Table 3 (cont)

1	2	3	4	5	6
Insulating cord	200	–	0.048+0.00016 tav		600 – braiding of wires
	250	–	0.050+0.00016 tav		
	300	–	0.052+0.00016 tav		150 – braiding of cotton yarn
Mats stitched	100	130	0.040+0.00018 tav		60 to 600 depending on lining
	150	200	0.046+0.00016 tav		
	200	260	0.050+0.00016 tav		
Semi-rigid slabs starch-bonded	200	240	0.048+0,00016 tav		up to 400
BΦ slabs with synthetic binder:					
ПМ-50	45–55	70–85	0.036–0.00030 tav		-40 to 300
ПП-100	70–110	110–130	0.040–0.00018 tav		-"-
Rigid slabs bitumen-bonded	200–300	200–300	–	0.07–0.08	-60 to 70

where: t_{av} – temperature of surface to be insulated.

Chapter II

Technology of Mineralwool Manufacturing

1. Raw Material

Natural silicate and carbonate rock can serve as raw material for the manufacturing of mineralwools as well as the same materials processed and which are by-products in other industries: ferrous and non-ferrous slags, ceramic rubble and rejections, etc.

The main criterion determining the adaptability of raw material for producing mineralwool is the acid modulus "Mk" which is used to define the ratio of a silica and aluminia percentage to a percentage of calcium and magnesium oxides.

According to the SU Standard the acid modulus of rockwool must not be less than 1.2, that is:

$$M_k = \frac{SiO_2 + Al_2O_3}{CaO + MgO} \geq 1.2 \quad (1)$$

Yet, rock muck and industrial by-products can rather seldom be used for production without any chemical admixtures to correct their chemical composition.

If the acid number of source materials is high carbonate rock (dolomite, limestone, dolomitized limestone and others) is added; if the acid number is low acid rock muck, red and silicate brick rubble as well as ceramic rubble and others are added.

Raw material having a big acid modulus usually have a higher viscosity and a higher melting temperature. Still, though the basalt acid modulus is much higher than that of blast furnace slags, the yield (fluidity) of both melts is the same at a temperature of 1320 °C. Good yield of a basalt molten mass at a temperature of 1300 to 1320 °C is due to the presence of ferric oxides in basalt.

Basalt, diabase, gabbro, amphibolite, syenite, peridotite, trachyte, and others belong to natural raw material having a higher content of ferric oxides and alkali metals which are usually called fluxes.

Average chemical compositions of raw mineral materials that can be used to manufacture mineral wools are recorded in Table 4 where the most typical characteristics are given.

Lump raw material can be melted in cupola furnaces. But those materials not having enough strength to be melted in cupola furnaces should be crushed (granulation, milling) up to a required size and can be melted in furnaces of glass and cyclone types.

The universal availability of raw materials to produce mineral wool was favourable to the fact that mineral wools became predominant among other thermoinsulating materials in the heavy and construction industries.

The main oxides determining the quality of a melt from which mineral wool is being obtained are silica, alumina.

Typical Average Chemical Compositions of Raw Materials for Manufacture of Mineral Wools (in %)

Table 4

N A M E	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	CaO	MgO	R_2O	S	SO_3	Calcination loss	Acid modulus
	S i l i c a t e R o c k												
phibolite	46.88	2.13	11.44	2.95	13.5	0.28	10.51	7.02	2.82	0.4		0.25	3.3
salt	51.15	0.62	13.7	6.26	9.22		9.14	6.06	2.11			1.74	4.2
bbro	46.8		16.96	5.5	8.08		[illegible]	6.34	3.59			2.72	3.9
abase	48.14	0.96	12.74	4.01	11.97	0.22	8.54	4.56	4.09			0.19	4.6
anite	68.05		13.95	4.22			5.18	0.23	5.58		0.08	2.71	15.1
ellostonite	51.08		0.9	0.4			44.[illegible]	1.00			0.45	1.35	1.17
ay slate	47.43		19.9	2.19			15.14	3.34			0.99	11.19	3.64
	C a r b o n i t e R o c k												
olomite	1.07		0.23	0.41			30.4	[illegible]			[illegible]	47.0	[illegible]
olomitized limestone	5.14		0.34	1.21			41.89	[illegible]			[illegible]	42.55	0.105
imestone	1.1		1.89	0.91			52.4	1.95			0.34	40.41	0.055
	M e t a l l u r g i c a l b y - p r o d u c t s												
last-furnace slags	38.6		5.1	0.5		2.7	49.0	[illegible]		1.3			[illegible]
upola-furnace slags	50.42		13.33	3.17		4.46	24.9	3.47		0.25			[illegible]
artin slags	30.22		15.12	12.34		7.8	25.07	8.28		0.17			1.3
ickel slags	40.46		4.66	29.54		1.2	13.0	10.52					1.74
	O t h e r i n d u s t r i a l w a s t e												
ed brick rubble	69.82		[illegible]	4.91			5.61	3.62	2.37		0.91		8.9
ilicate brick rubble	84.92		[illegible]	1.15			[illegible]	0.54	2.25		0.34		14.2
eramic rubble	[illegible]		[illegible]	[illegible]			[illegible]	[illegible]	3.05	0.55			17.1

calcium and magnesium oxides.

Silica is always present in mineral wool. Wool used in the construction industry is obtained from melts having a temperature of 1300 to 1400°C.

As is seen from Table 4, the content of the four main oxides ranges within considerable limits. Despite it mineral wool produced meets the requirements of the Standard.

One of the most important characteristics of a melt is its viscosity at the moment of drawing it out into filaments.

If the temperature of a melt being extracted out of a cupola furnace does not exceed 1400°C the viscosity required is achieved by selecting a chemical composition of the charge.

Fig. 3 show graphs of the viscosity of three-component melts ($SiO_2 - Al_2O_3 - CaO$) at the temperatures of 1400°C and 1500°C.

In order to calculate the viscosity of silicate melts at a temperature of 1400°C the following empirical formula is used:

$$\eta = \frac{4.9}{K_2 - 0.45} \text{ poise}$$

$$K_2 = \frac{CaO+MgO+FeO+MnO+TiO_2+R_2O+S}{SiO_2+Al_2O_3}$$

where: CaO, MgO, FeO, etc - content of corresponding oxides, in %.

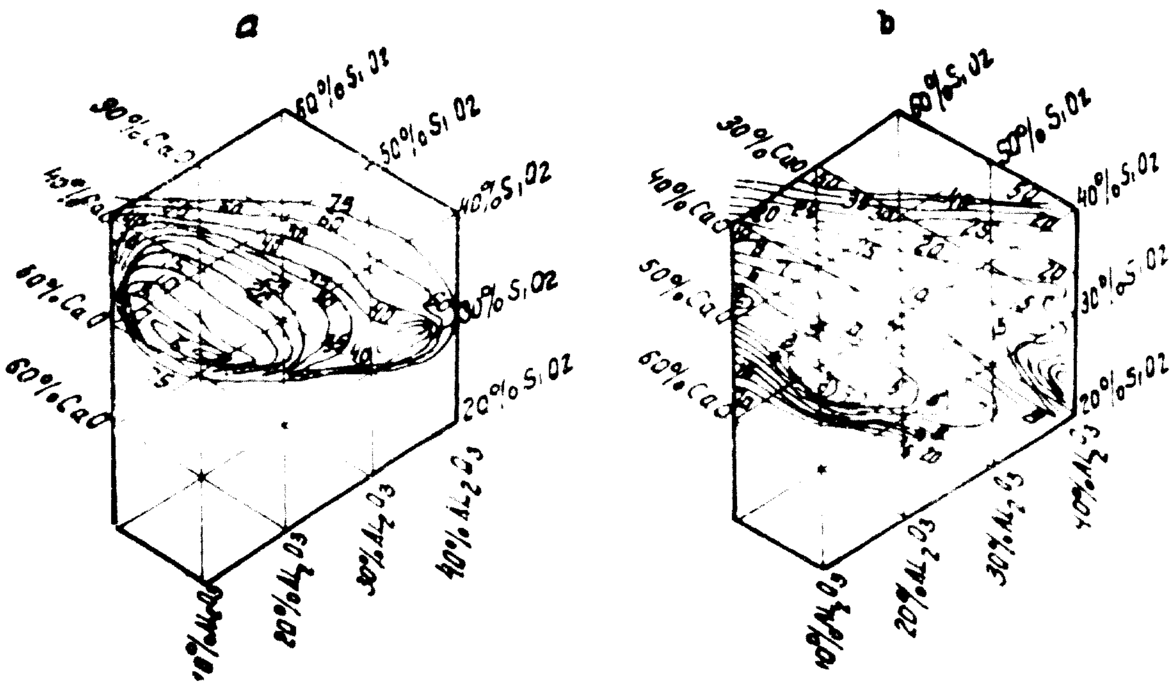


Fig. 3. Viscosity of Melts (in poise)

a. at 1400°C

b. at 1500°C

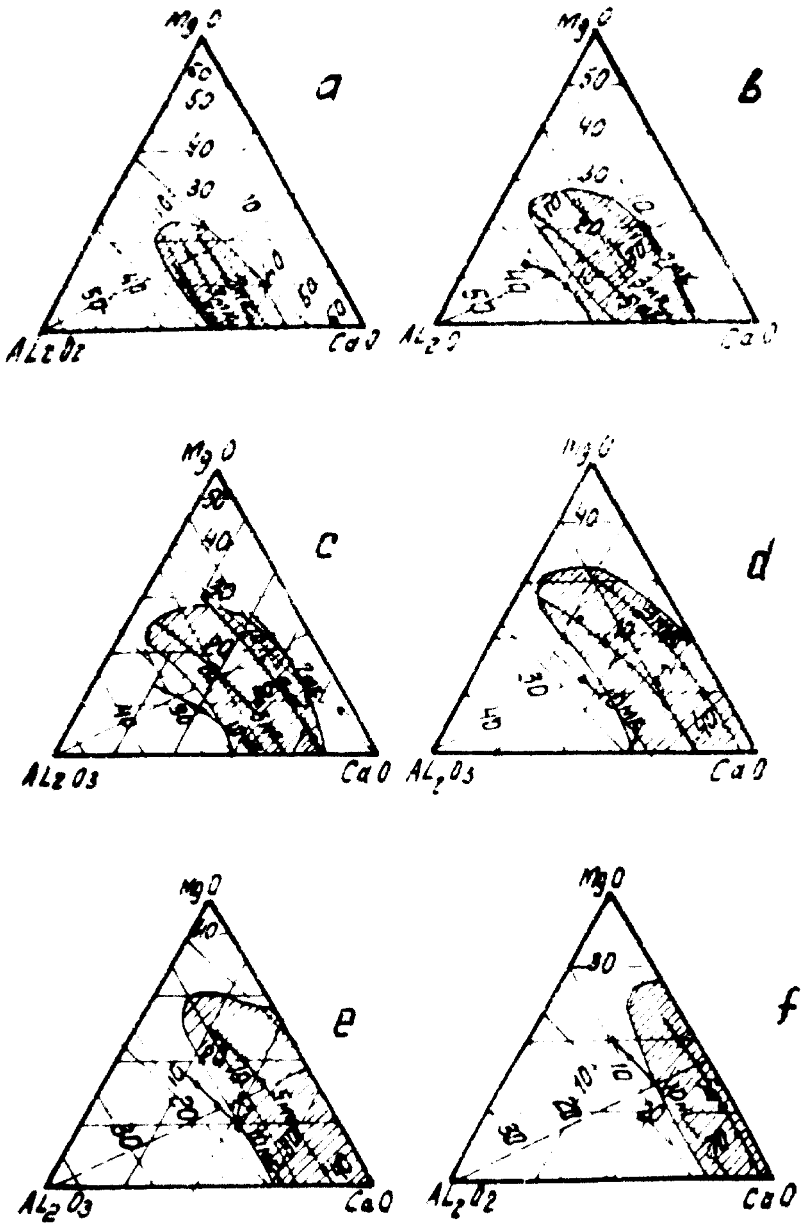


Fig. 4. Limits for Compositions with the Content of SiO_2 (in %):

a. 35
b. 40
c. 45
d. 50
e. 55
f. 60

Fig. 4 represents diagrams worked out by C. Frylingstone giving possible chemical compositions of mineral wool with a content of silica of 35,40,45,50,55 and 60%, and with varying contents of aluminia, calcium and magnesium oxides.

Areas crosshatched within a triangle indicate a range of possible mineral wool chemical compositions. In the crosshatched areas are drawn curves on which lie compositions of melts enabling to obtain mineral fibres 2 microns and more in diameter at the fusing temperature of 1500°C, and with the blowing of a molten stream by overheated steam at a pressure of 5 to 7 atm.

Knowing the chemical composition of silicate rock or slag and using the above mentioned diagrams, one can determine, with a certain degree of approximation, an adaptability of given rock muck or slag for the manufacture of mineral wool. On the other hand, in order to produce fibres 3 microns in diameter and with a content of silica of 45%, any point in the crosshatched part of the triangle is taken on the fibre dispersity curve in the diagram (Fig. 4c). Assume that we choose a point on the curve crossed with the first line parallel to the base of the triangle. This point corresponds to a content of 10% MgO, 10% Al_2O_3 and 35% CaO. It follows that the mineral wool chemical composition desired will be: SiO_2 - 45%, Al_2O_3 - 10%, CaO - 35% and MgO - 10%, and the wool acid modulus as follows:

$$\frac{SiO_2 + Al_2O_3}{CaO + MgO} = 1,22 \qquad (20)$$

However, while calculating the acid modulus on the basis of the four main oxides (SiO_2, Al_2O_3, CaO and MgO), contents of other oxides which can sometimes considerably influence over melting temperature of the charge and over the quality of a ~~fusion~~ melt to be obtained, are not always taken into consideration.

If raw material assigned to produce ~~rock~~ mineral wool has a higher content of FeO, MnO, K_2O and Na_2O, it is expedient to use the acid modulus found in the Standard together with the saturation coefficient "K_H" which is ratio of a percentage of silicic acid and aluminia to a percentage of other oxides:

$$K_H = \frac{SiO_2 + Al_2O_3}{CaO+MgO+K_2O+Na_2O+FeO+MnO}$$

The saturation coefficient for charges to be melted in a cupola furnace can be 1.5 to 2. K_H can be even more than 2 if charges are melted in bath or cyclone furnaces.

Selection of raw materials and calculation of charges are made on the basis of a chemical composition found. In choosing raw material and in calculating charges, it is necessary to consider the individual influence of a separate oxide over the characteristics of ~~fusions~~ melts and products obtained from them.

A higher content of silica favours to increase a temperature viscosity range (a very valuable characteristic especially needed in processing a ~~fusion~~ melt by centrifugal and centrifugal-blowing methods), chemical resistance of manufactured ~~filament~~ fibres and to reduce an aptitude towards recrystallization.

Alumina as well as silica increases the viscosity of a ~~fusion~~ melt and, simultaneously, temperature resistance of ~~rock~~ mineral wool produced; for instance, ~~rock~~ mineral wool from melted kaolin and containing about 46% alumina endures a temperature up to 1100°C without any change ~~of~~ in physical characteristics whereas usual standard wool begins to noticeably change its physical characteristics at a temperature of 600 to 700°C.

Calcium and magnesium oxides are fluxes reducing the melting point of aluminosilicates. However, if a CaO content is over 45% the viscosity of ~~fusions~~ melts rises, which is explained by crystallization of a two-calcium silicate $2CaO{-}SiO_2$.

~~Fusions~~ Melts containing the two-calcium silicate are apt to decomposition when being cooled. Ferrous and manganese oxides (FeO and MnO) reduce considerably the viscosity of ~~fusions~~ melts.

Sulfur is contained in ~~fusions~~ melts used to manufacture ~~rock~~ mineral wool, in chemical compounds such as ferrous sulfide, calcium and manganese. The higher a content of sulfides the less chemical resistance of ~~rock~~ mineral wool. That is why the Standard sets a limit of 1.5% to the content of sulphur in ~~rock~~ mineral wools

2. Calculation of the charge

From the point of view of production organisation and simple exploitation it is most advisable to manufacture ~~rock~~ mineral wools from an one-component charge, that is from rock muck of one deposit, or from one slag. But such cases are rare. ~~Rock~~ Mineral wools ~~is~~ are produced much oftener from a two-component ~~ch~~ charge one component of which has an acid character, and another the main character.

Many components complicate considerably the manufacture and are used in exceptional conditions.

Below is represented the simplest method of calculating a two-component charge if a chemical composition is designated as shown in the given table.

Table 5

Charge Components	Chemical Composition, in %							Acid Modulus
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	R_2O	Calcination Loss	
1st component	S'	A'	F'	C'	M'	R'	П'	M'_k
2nd component	S''	A''	F''	C''	M''	R''	П''	M''_k
~~Rock~~ Mineral wool from these charge components	S	A	F	C	M	R	-	M_k

The proportion of charge components necessary to obtain mineral wool of the desired acid modulus can be calculated by deciding the following equations:

$$1)\quad \frac{(S'+A')K'x + (S''+A'')K''y}{(C'+M')K'x + (C''+M'')K''y} = M_k \qquad (2)$$

(3) 2) $x + y = 100$, where $K' = \frac{100}{100-\Pi'}$ is a conversion factor containing an amendment for calcination losses of the first component (Π');

$K'' = \frac{100}{100-\Pi''}$ is the same for the second component;

x - portion of the first component in the charge, %.

y - portion of the second component in the charge, %.

Example:

Chemical composition of charge components

Table 6

Charge Components	Chemical Composition, in %							Acid Modulus
	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Others	Calcination Loss	
Red Brick rubble	69.82	12.7	4.91	5.61	3.62	3.34	-	8.93
Dolomitized limestone	5.14	0.34	1.21	41.89	8.78	0.09	42.55	0.108

Let's assume that ~~rock~~ mineral wool should have the acid modulus $M_k=1.3$.

In order to define in what proportion components should be taken to compose a charge it is necessary to introduce into formulas 4 and 5 relevant values:

$$1)\quad \frac{(69.82+12.7)\,x+(5.14+0.34)\,\frac{100}{100-42.55}\,y}{(5.61+3.62)\,x+(41.89+8.78)\,\frac{100}{100-42.56}\,y}=1.3;$$

$$2)\quad x + y = 100$$

On deciding the given system of equations we get:

$x = 60\%$

$y = 40\%$

That is, in order to obtain from components the desired chemical composition of ~~rock~~ mineral wool with the acid modulus $Mk=1.3$ the charge must contain: 60% of red brick and 40% of dolomitized limestone.

The correctness of calculations made may be checked by determining a chemical composition of ~~rock~~wool to be produced. (Table 7)

Table 7

Charge Components	Conversion factor	Chemical Composition, %					
		SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Other
1	2	3	4	5	6	7	8
Red brick rubble	$\frac{X K'}{100} = \frac{X}{100} \cdot \frac{100}{100-\Pi'} = 0.60$	41.87	7.61	2.93	3.33	2.17	2.00

Table 7 (cont)

1	2	3	4	5	6	7	8
Dolomitized limestone	$\frac{y-K''}{100} = \frac{Y}{100} \cdot \frac{100}{100-\Pi''} =$ 0.39.174=0.697	3.55	0.23	0.84	29.27	6.14	0.[illegible]
Chemical composition of mineral wool		45.42	7.84	3.77	32.60	8.31	2.06

Now we receive the acid modulus by formula 1:

$$Mk = \frac{SiO_2 + Al_2O_3}{CaO + MgO} = \frac{45.42 + 7.84}{32.60 + 8.31} = 1.3$$

The above calculations are preliminary because only the main chemical compounds are taken into account in calculating a charge composition.

Calculation results are usually checked by making laboratory melts of raw material and obtaining mineral fibres from a melt received.

In order to define a productivity possible when using chosen raw material, experimental melts are made on industrial installations available, similar to those which are being designed.

3. Methods of Obtaining Melts

Melts are obtained by melting raw material in special furnaces. Currently employed methods of manufacturing mineral wools require a continuous inflow of mineral melts to a fibre formation unit. Therefore furnaces used for this kind of production are of a continuous operation type. At present the following furnaces are used to manufacture mineral wool; shaft furnaces like cupola ones, bath furnaces like glass ones, electric furnaces, cyclone furnaces (now being assimilated). Slag catchers are used to produce mineral wools from flame-liquid metallurgical slags.

Cupola furnaces

At present the main type of furnaces used in the USSR to melt raw material is a shaft or cupola furnace. They are practised on a large scale due to a high coefficient of fuel heat utilization, a big productivity, small dimensions, simple design, lower investments, simple maintenance.

Thanks to high technical characteristics and efficiency cupola furnaces have the advantage over furnaces of other types especially when using lump materials not containing carbonate ingredients, e.g. slags and rock muck of volcanic origin, as raw materials.

A cupola furnace consists of two main parts: a hearth and a shaft with a spark extinguisher.

Fuel is burned and raw material is melted in its lower part, the hearth. The highest temperatures are obtained here. Therefore the hearth is protected with a water jacket. Air for burning is fed through tuyeres.

A ~~fusion~~ melt produced in the cupola furnace flows out of special tapping holes cooled with water.

The bottom is made up of two folds which open downwards to facilitate discharging the furnace.

In the shaft part of a furnace the charge is being heated and melted by ~~transferring~~ exchanging heat ~~to~~ with combustion products that go up.

Above the filling opening, the shaft turns into a pipe outletting end products into the atmosphere.

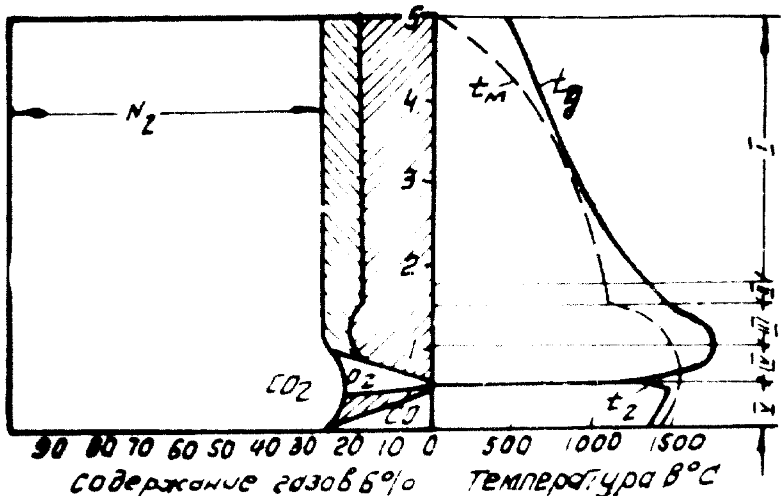
~~Fig. 11. Zone temperature and gas component distribution in a cupola furnace.~~

~~t_m and t_g - temperatures of material and gases respectively~~

The spark extinguisher is assigned to catch red hot particles of raw material and fuel being taken away with flue gases. Particles are caught due to a sharp change in the direction of passing flue gases when they enter the spark extinguisher, and due to their losses in speed in its widening part.

It is desirable to divide the cupola furnace into five zones from top to bottom to facilitate the consideration of its processes(see Fig 5).

I - heating zone;



Content of gases, %   Temperature, °C

Fig. 5. Distribution of Temperatures and Contents of Gases in Zones of the Cupola Furnace.

t_m and t_g - temperatures of materials and gases respectively

II - melting zone;

III - reduction zone of the bed charge;

IV - oxygen zone of the bed charge;

V - ~~fusion~~ melt overheating zone, the hearth.

The following processes occur in the gas medium. Air supplied for burning through tuyers (in the graph, the inlet corresponds to the line dividing zones IV and V) meets incandescent fuel and is heated. Atmospheric oxygen reacts with the carbon of the fuel.

The reaction of the fuel burning in a layer results in obtaining at the first stage CO_2 as well as CO. The presence of free oxygen allows for CO to burn in CO_2, the combustion process being so rapid that, at this stage of burning, it is impossible to fix the availability of CO in combustion products in carrying out gas analyses by ordinary methods. Passing gases lose their oxygen, and a deoxidating reaction starts: carbon in the coke reacting with the formerly received carbon dioxide, forms carbonic monoxide. The higher a temperature of the medium the quicker the reduction process.

The following processes occur in the zones.

Zone V is located lower than the tuyer belt - from it up to the hearth. The presence of free oxygen supplied with air through tuyeres permits to maintain the oxidizing capacity of the medium in its upper part. Here, the bed charge coke burns intensively. The oxidizing capacity of the medium is less below, and is equal to zero at a level of the fettings.

Carbonic monoxide is absent in the upper part of the zone, it appears only in the middle zone and at its end, its content is the highest at the hearth. The medium in this zone has a high temperature close to a maximum because heat is consumed here only to cover thermal losses through the side walls and the hearth, and also to heat a little the fustenx melt.

Zone IV is located above the tuyere belt-from the tuyere axis up to a conventional line where, practically, a content of free oxygen is equal to zero.

There is an oxidizing medium in this zone as in the upper part of zone V, and the combustion of coke is intensive here.

The reaction of carbon burning in the oxygen medium can be practically calculated as follows:

$$C + O_2 = CO_2 + 97650 \text{ cal/mole} \qquad (4)$$

This reaction proceeds in giving off all heat that can be generated by burning carbon. The content of oxygen in the zone decreases while moving upwards, and the content of CO_2 rises. At the end of the zone the content of oxygen is practically equal to zero, a temperature reaches its maximum, and CO begins to appear in small quantities.

A shape of the oxygen zone depends on the fuel quality, sizes of its lumps and temperature of the medium. The higher the reaction capability of fuel lumps the quicker the combustion reaction and the narrower the oxygen zone. The oxygen zone is considered equal to 5-6 diameters of an average coke lump.

Zone III is located above the oxygen zone conventional line, up to the top of the bed charge.

A deoxidating reaction is developped in the reduction zone:

$C + CO_2 = 2CO - 38790$ cal/mole (5)

This reaction proceeds with taking away heat, and as a result of it temperatures in zone III are a little lower compared to those in zone IV.

The higher the amount of CO_2 passing into CO (and the latter depends in its turn on two factors: fuel reaction capability and sizes of fuel lumps) the bigger a temperature decrease for combustion products in zone III.

The fuel reaction capability means a capability of fuel to regenerate the formerly produced carbon dioxide into carbonic monoxide according to reaction formula (5). This reaction decreases the heat efficiency of a cupola furnace by reducing the fuel combustion coefficient.

CO-to-CO_2 ratio ranges from 0.6 to 0.05 in the end of the bed charge, depending on an air temperature and intensity of its supply. The more intensive air supply the less this ratio, but at a higher heating temperature it goes up too.

Dr. Mariyenbakh L.M. advises that the cupola fuel should have a low reaction capability, within a range of

15 to 20%, and besides - should meet the following requirements:

1. Must have such a mechanical strength that could withstand strains in coke when being transported, charged into the shaft of the furnace, and also because of the pressure of a charge column in the cupola furnace itself;

2. Be thermostable, that is not to crack at high temperatures.

3. Contain sulfur not more than 1.5%.

4. Contain cinders within a range of 8 to 9%.

5. Meet the condition that the ratio between the furnace diameter and sizes of coke lumps to provide for blowing and atmospheric oxygen for getting to the centre of the cupola furnace, is as follows:

$$D_B = (10 \div 12)\ d_k \qquad (6)$$

Approximate dependence between the furnace diameter and sizes of fuel lumps is given below:

Furnace Diameter in Light D_B, mm	Recommended Size of Fuel Lumps d_k, mm
750	60 - 75
1000	80 - 100
1250	100- 125

Unsorted coke chocked with fines must not be used. Use of such coke results in uneven fuel combustion because of an unproportional gas flow through the furnace profile.

6. Contain moisture not exceeding 3-4%.

7. Contain volatile matters within a range of 1 to 1.25%.

Coke filled into the cupola furnace getting to the high temperature zone, loses its volatile matters. They go upwards and burn over the charge surface. Heat from their combustion is not used. In addition, emission of volatile matters is favourable to coke porosity which results in a higher coke reaction capability, i.e. in deteriorating its quality as a cupola fuel.

8. Contain carbon not less than 85-90%. The carbon content defines the calorific power which depends, in its turn, on a content of cinders, sulfur and volatile matters in fuel. The calorific power desired in good cupola coke ranges from 6800 to 7200 Cal/kg.

Zone II is located directly above the bed charge. Incandescent combustion products escaping from the bed charge get into touch with fuel particles and impart them heat necessary to melt. Since the speed of a CO_2 deoxidation reaction depends on temperature, the process of CO formation in the melting zone slows down and ends at a temperature of 725 to 750 ^{o}C.

Special attention should be payed to a height of the bed charge. In melting a bed charge level should be constant and such that combustion products passing from the bed charge into the melting zone should have a maximum temperature and a minimum amount of carbonic monoxides. A higher bed charge level enables to: widen the reaction zone, increase an CO amount in combustion products, reduce their temperature in the melting zone and, therefore, the output of a cupola furnace, and increase heat losses with chemical incomplete combustion. Such an increase of the level occurs in case of extending the size of a fuel section of the bed charge, and of using very big coke lumps. A periodical change of the output of a furnace is the main factor in high coke consumption. In order to stabilize melting processes it is necessary to minimize the bed charge fuel section in size.

In lowering the bed charge level as against the optimum one, at first the output increases a bit but later on, when some unmelted raw lumps appear in sight of tuyers, melting is stopped and "bear" is formed. On finding out in good time signs of a lower bed charge level, it is possible to remedy the situation by filling an extra coke portion, a so-called "overfill", into the cupola furnace. Overfills must be used only on emergency. They cannot be recommended as a constant preventive means since use of overfills without any need gives a rise to the bed charge level, with all ensuing consequences: coke overheating (and its overconsumption) and decrease in the output.

In observing the technological requirements towards

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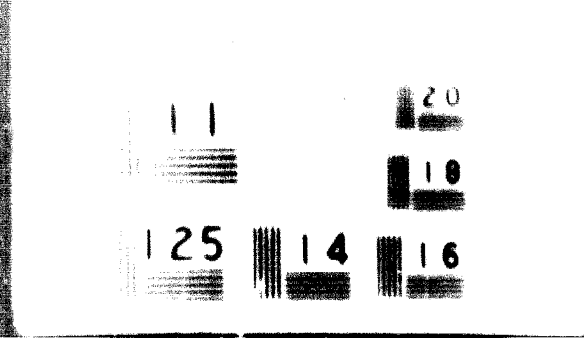


We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards, even though the best possible copy was used for preparing the master fiche raw material and coke (quality, fractional composition etc.), the bed charge level is stabilised by selecting correctly the ratio of raw to fuel components in the bed charge.

Zone I is located between the melting zone and the upper charge level. In this zone heat exchange occurs between coke combustion products and the charge being filled. The composition of combustion products in this zone changes because volatile matters are emitted from coke being heated, moisture is vaporised out of raw material and coke, and gasiform components are liberated.

Fuel volatile matters as well as carbonic monoxide burn principally when they come out onto the charge surface because of the presence of atmospheric oxygen fed through the filling opening.

Heat obtained in the cupola furnace is spent, coke being burnt, to heat raw material and to produce a mineral fusion melt - which is the main purpose of the entire cupola process, it is also spent on unavoidable heat losses: with water to cool the furnace, into the ambient medium, with escaping gases, and with fuel products incompletely burnt.

Raw material can be divided into the following two groups from the point of view of cupola processes:

1) Raw material not containing carbonate components and moisture and for this reason not requiring additional

heat consumption to vaporize the moisture and to decompose carbonates. This type includes metallurgical slags and some kinds of rock muck.

2) Raw material containing moisture and carbonate components and requiring additional heat consumption to vaporise the moisture and to decompose carbonates. This type includes, for example, marl, dolomite, limestone.

It would be more convenient to divide the heat exchange process in the cupola furnace between combustion products and raw material into two stages. The first stage is heating the charge from a temperature at which it is filled into the furnace, up to the melting point; the second stage is melting raw material and overheating the ~~fusion~~ melt from the melting point up to a temperature at which the ~~fusion~~ melt leaves the furnace.

Melting of raw material and overheating of the ~~fusion~~ melt. It is possible to melt raw material only there where coke combustion products have a temperature higher than the initial temperature for melting raw material. Melting is impossible if the temperature of combustion products does not exceed the temperature of raw material being melted.

Thus, in order to melt raw material and to overheat the ~~fusion~~ melt produced, the heat of combustion products can be consumed, only within a range from their maximum temperature t_1 to a temperature t_n^g at which they leave the melting zone, and which is always a little higher than the initial raw material melting temperature t_2^p .

Let us calculate what amount of fusion (melt) can be obtained by using the heat emitted from burning 1 kg of coke provided that raw material passes into the melting zone heated up to the melting temperature t_2^p , and that it is overheated up to t_1^p at which the fusion (melt) leaves the furnace. This value is called specific fusibility and is assigned a letter "p" and is calculated by the following formula:

$$p = \frac{Q_H^p \left(1 - \frac{q_3}{100} - \frac{q_5}{100}\right) \frac{t_1 - t_2^p}{t_1}}{m + c\left(t_1^p - t_2^p\right) + (1 - U) \cdot q_k} \quad \text{kg/1 kg of coke} \qquad (7)$$

where: Q_H^p - lowest operating heat power of raw material, in Cal/kg

q_3 - heat losses due to chemical incomplete combustion, in %

q_5 - ambient heat losses and heat by-passed with cooling water, in %.

m - latent heat to melt raw material, in Cal/kg.

C - average heat capacity of a fusion (melt), Cal/kg.°C

U - coefficient characterizing a degree of decomposition of carbonates in raw material in the melting zone

Σq_k - total consumption for decomposition of carbonates contained in raw material per 1 kg of ~~fusion~~ melt, in Cal/kg.

In this formula, the maximum temperature of combustion products in a cupola process under concrete conditions is a value practically invariable and is equal to about 1690°C in ordinary (not hot) blasting; actual temperature of combustion products t_n^g at which they leave the melting zone also rises if the initial temperature for melting raw material t_2^p increases. The more t_2^p the higher t_n^g, and therefore the less the temperature difference $t_1 - t_n^g$. In order to allow for production of a ~~fusion~~ melt out of the furnace and for its transfer to a ~~filament~~ fiber formation unit, with the optimum viscosity for ~~filament~~ fiber formation, t_1^p should not exceed t_2^p by 200 to 300°.

Considering the above-mentioned one can arrive at the following conclusions:

a) If raw material having a high initial melting temperature is used, the amount of heat to be used to melt raw material and to overheat the ~~fusion~~ melt, decreases (the value $\frac{t_1 - t_n^g}{t_1}$ becomes less), and certainly the specific fusibility of such raw material decreases too. In addition, the output of a cupola furnace drops as well.

b) If raw material containing carbonate components is used the specific fusibility of raw material drops, and by the way, the less a degree of decomposition of carbonate components in the raw material heating zone the quicker. A portion of heat in the melting zone that could be used for melting is spent to decompose carbonates.

For use purposes it would be more convenient to modify a little formula 7 to define the specific fusibility of raw material, as follows:

$$p = \frac{\varphi Q_н^р \left(1 - \frac{q_4}{100} - \frac{q_5}{100}\right) \frac{t_1 - t_н}{t_1}}{m + c\,(t_1^р - t_2^р) + (1 - U)\sum q_п} \qquad (8)$$

The following changes were made in the formula: there was added coefficient φ taking into account heat losses with gases escaping through the tap holes. The value of the coefficient φ depends on a tap hole diameter, gas pressure and temperature at the hearth. $\varphi = 1$ (usual tapping holes, if tap hole diameters are small), the fusion [melt] occupying all, or almost all, the sectional area.

The φ value should be calculated if it is necessary to use special tap holes with a big sectional area for utilising the heat of combustion products to maintain a high temperature of the melt in the distributing cradle. In some cases $\psi = 0.8$.

There are new values in formula 8: t_1' - maximum temperature at which the melt is produced, and t_n - temperature of combustion products escaping from the melting zone, it is conditionally equal to the initial raw material melting temperature: $t_n = t_2^p$. In addition $t_1 - t_1' = t_n^g - t_n$ and $t_1 - t_n^g = t_1' - t_n$; therefore such a change does not modify the value of the specific fusibility "p".

The initial melting temperature t_2^p being equal to the maximum temperature t_1', the specific fusibility is equal to zero ($p=0$) because $t_2^p = t_1' = t_n$, and that is why: $t_1' - t_n = 0$.

Charge heating. It is possible to make up a formula for the amount of the charge in the heating zone, as was done for the melting zone, which can be heated by combustion products emitted from burning 1 kg of coke. This formula is as follows:

$$p_w = \frac{Q_H^p \left(1 - \frac{q_3}{100} - \frac{q_5}{100}\right) \frac{t_1 - t_1' + t_n - t_{yx}}{t_1}}{C_w (t_2^p - t_w) + U \sum q_s + q_w} \qquad (9)$$

where: p_w - amount of a charge to be heated in the heating zone by burning 1 kg of coke, in kg.

t_{yx} - temperature of combustion products escaping from the heating zone, in °C.

C_w - average heating capacity of the charge, in Cal/kg °C.

t_w - temperature of a charge being filled into the cupola furnace, in °C.

q_w - heat consumption to vaporise moisture, in Cal/kg.

Proportion of materials contained in a charge is defined by formula 18 since it shows what amount of raw material is to be taken per 1 kg of coke, and then $p_w = p + 1$, i.e. amount of a charge to be heated in the heating zone by burning 1 kg of coke is equal to the raw material fusibility pelus one (1 kg of coke).

In order to determine whether heat proceeding into the heating zone with combustion products is sufficient to preheat the charge, to remove moisture from it and to decompose carbonates, it is necessary to decide equation 9 in regard with t_{yx}.

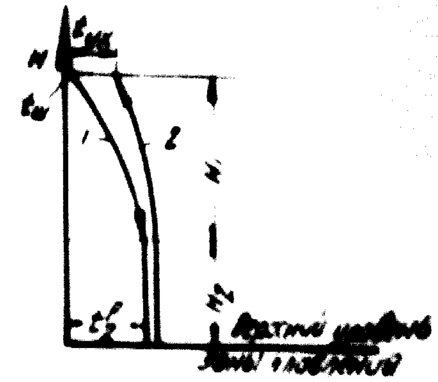
As a rule, heat proceeding from the melting into the heating zone is more than enough to heat up the charge (raw material and fuel), to remove moisture, to decompose carbonates contained in raw material, and to sublimate volatile matters from coke. For this reason the temperature of combustion products escaping out of the heating zone t_{yx} is always high - 500 to 700°C.

Mind that a higher charge level, i.e. artificial widening of the heating zone over that required to heat the charge, will not reduce the temperature of combustion products escaping from the cupola furnace. It is clearly illustrated in Fig. 6a. Temperatures of the charge and gases approach each other practically at a height H_1. A higher charge level leads to increasing height H_2 where heat exchange between the gas medium and the charge is in essence absent. The charge cannot absorb all the heat from combustion products, for the charge heat capacity is less than an amount of heat in combustion products.

Fig. 6a. Diagram of heat exchange in the charge heating zone.

Now let us consider the main factors on which depend the speed to heat up raw material lumps, to melt them, and to overheat the [illegible].

Specific surface of lump raw material. The wider the specific surface of raw material the quicker its heating because there is a larger surface, through which heat exchange is effected, per each volume unit of material.



Lower level of melting zone

Fig. 6. Diagram of Heat Exchange in the Charge Heating Zone.

1. Charge

2. Gases

With finer raw material, a charge height may be lower - in proportion to sizes of raw material lumps.

Moisture and carbonate components. Their presence in raw material retards heating and melting of raw material not only because it requires an additional heat consumption but also because moist vapours produced in the beginning of heating and carbon dioxide emitted, when carbonates in the end of heating are decomposed and raw material is melted, proceed from the centre of a lump to its periphery, towards a heat flow. When heated, they carry some portion of the heat retarding thereby the heating of the central part of a raw lump.

That is why raw material containing carbonate components is recommended to be filled in form of smaller fractions than raw material not containing carbonates, or to increase a charge height.

Moisture being present in raw material as well as in fuel, it is necessary to increase the charge height in the cupola furnace, other equal conditions being equal.

Amount of air for burning. The amount of air being raised, the amount of combustion products in the furnace and, therefore, their movement in regard to raw material increase. An increase in the speed of a heat carrier leads, to a certain degree, to a higher heat transfer coefficient, and for this reason, to accelerate heating and melting of raw material.

If heating and melting are retarded, the amount of air for burning is reduced.

Uniformity of charge lumps. Combustion products moving upwards pass through a charge layer making their way between raw lumps. The value of these ways and their character depend on the arrangement of lumps in regard to each other, on the amount of free, unoccupied by raw material, space and on the amount of voids formed.

A wrong opinion is widespread concerning a dependence of the total void volume on sizes of charge material lumps. The volume of voids depends on a charge packing degree, i.e. laying of a charge, but not on sizes of lumps.

Surveys of the volume of voids in a charge containing lumps of irregular shape have shown that voids are noticeably reduced if the difference in sizes of lumps to be mixed is considerable. But if this difference is not great, voids even increases a bit sometimes.

It if known that an admixture, for example, of only 10% of carbon dust in a fraction of 1+4 mm will rise several times the resistance of a layer, the height and the air inflow speed being the same. An attempt to raise air supply results in such cases in carrying all the dust and partially fuel fines out of the layer, this can always be observed in forced procedures. Thus, sizes of granules in a charge being more equal to each other, it is easier to attain the stationary performance of a furnace, and therefore its higher efficiency.

Working ~~with~~ on fractionated charges provides for simultaneous filling of only one fraction of raw material and fuel to be used. Fractions being different, they should be alternated and not be used simultaneously.

Researches carried out by various authors have shown that gas permeability of materials comparatively a little depends on the character of lump surfaces since the influence of the latter is insignificant in comparison with the resistance of a charge layer.

However, reducing the average size of lumps in a charge will increase to a certain extent its total resistance, for even ~~vacuum~~ voids being retained, the friction surface, the number of ~~turns~~ revolutions and the number of gas jets per unit of a way length will increase.

<u>The output of a cupola furnace</u> can be determined by the following generally used formula:

$$\Pi = \frac{V}{K\ L}\ 100 \qquad (10)$$

where: Π - furnace output, in kg/hr

V - air consumption per hour, in cu.m/hr

K - coke consumption coefficient, in %.

L - rated consumption of air necessary to burn 1 kg of coke, in cu.m/hr.

In order to use this formula the value of air consumption V should be defined taking into account the efficiency of blasting devices and providing that air from 50 to 70 cu.m/min is to be supplied per each square metre of the cross section of a cupola shaft.

The output of a cupola furnace is directly proportional to the amount of air supplied for burning and therefore to the amount of coke to be burnt.

The value of rated consumption of air necessary to burn 1 kg of coke is easily determined regarding a coke chemical composition by the formulas generally used in heat engineering.

The following formula could be advised for approximate calculations:

$$L = \frac{1.1 \cdot Q_H^P \cdot \ell}{1000} \quad \text{cu.m/kg} \qquad (11)$$

Fig. 18. Nomogram for determining specific fusibility of raw material at various melting points.

The coke consumption coefficient K is taken on the basis of practical data and ranges from 15 to 40% in relation to the quality of raw material, fuel and cupola procedure.

Rated coke consumption is inversely proportional to the rated output of a cupola furnace, being a quantity factor of its performance. The rated output characterises a cupola process from a qualitative side, i.e. how rationally heat obtained from coke burning is used.

The rated output of a cupola furnace, or as it was called above - raw material specific fusibility "p", depends on a chemical composition of raw material, its melting temperature and its melting procedure as well.

On the basis of the above - said:

$$K = \frac{100}{p}$$

Making a substitution in formula 10 we receive:

$$\Pi = \frac{V}{L} p \qquad (12)$$

The output of a furnace is directly proportional to the coke consumption $\frac{V}{L}$ and to the specific fusibility "p".

The specific fusibility of raw material can be determined by using curves (in Fig. 70) calculated by formula 18. Below are given values that were taken in calculations: they were obtained as a result of the processing of balance tests of cupola furnaces 1250 mm in diameter carried out by the Institute "Teploproyekt" ("Heat Project") during the period from 1955 to 1961:

$Q_H^p = 6800$ Cal/kg; $q_3 = 30\%$; $q_5 = 15\%$; m = 75 Cal/kg;

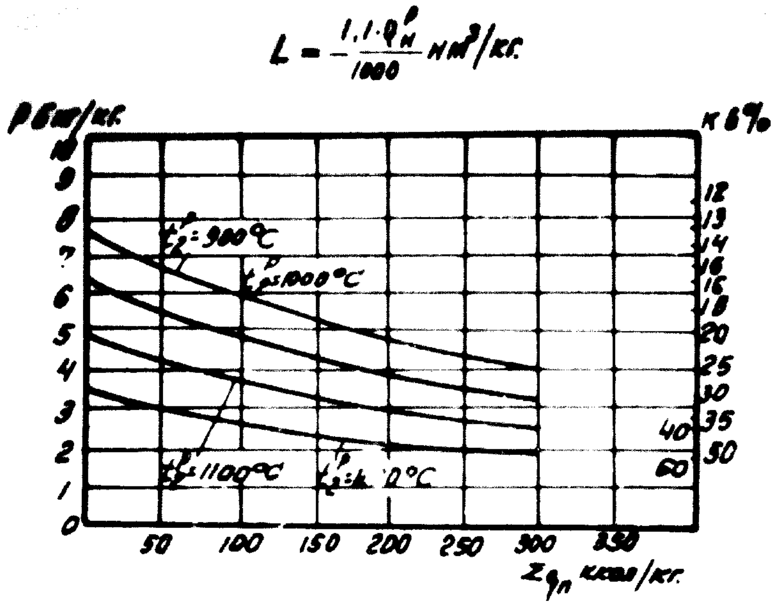


Fig. 7. Nomogram for Determining Specific Fusibility of Raw Material at Different Melting Temperatures.

$C=0.19\,(1+0.00039\ t^P)$ Cal/kg °C; $\psi=1$; $U=0.5$; $\sum q_x=0$; 50; 100; 150; 200; 300 Cal/kg of fusion; $t_1=1650°C$; $t_1'=1450°C$; $t_1^P - t_2^P = 300°C$; $t_w=20°C$; $t_2^P=900$; 1000; 1100; 1200°C.

The above-given method permits to determine the output of a furnace in relation to a chemical composition of raw material and its initial melting temperature.

Curves in Fig. 76 show that the output of a furnace is higher if the initial melting temperature and the content of calcium and magnesium carbonates in raw material are lower.

Examples of calculating the output of a cupola furnace

1. Determine the output of a furnace 1250 mm in diameter operating ~~with~~ on blast-furnace slags having the initial melting temperature of $t_2^P=1050°C$; fuel is coke; $Q_H^P=6800$ Cal/kg; rated air consumption U per 1 sq.m of the hearth = 50 cu.m/min.

a) Specific fusibility of raw material is determined. In the fusibility nomogram (Fig. 76), $\sum q_x$ being equal to zero (slag without carbonate components), p will be 5.6 kg/kg coke.

b) Amount of air supplied for burning in the furnace:

$$V = \frac{\Pi d^2}{4} \cdot U \cdot 60 = 1.25^2 \times 0.785 \times 50 \times 60 = 3390 \text{ cu.m/hr}$$

c) Amount of air necessary to burn 1 kg of coke is roughly calculated by the formula, as follows:

$$L = \frac{1.1\ Q_H^P}{1000} = \frac{1.1x6800}{1000} = 7.48\ cu.m/kg$$

d) Output of the furnace:

$$P = p\frac{V}{L} = \frac{3390}{7.48} x 5.6 = 2540 \quad kg/hr$$

2. Determine for the same furnace under identical conditions the output by using marl as raw material of the following chemical composition (in %):

SiO_2	- 41.5	Cao	- 31.1
Al_2O_3	- 6.7	MgO	- 15.5
Fe_2O_3	- 6.0	SO_3	- 0.2

a) Calculate the amount of air to be consumed to decompose carbonate components in the melting zone:

$$(1 - U) \Sigma_{qk}$$

$$\Sigma_{q_k} = q_{CaCO_3} + q_{MgCO_3}$$

where: q_{CaCO_3} and q_{MgCO_3} represent consumption of heat to decompose calcium and magnesium carbonates contained in 1 kg of raw material.

Decomposition of calcium carbonate is made by the following equation:

$$CaCO_3 = CaO + CO_2 - 42500 \text{ Cal/mole}$$

Admitting that the molecular weight of $CaCO_3$ is equal to 100 the amount of heat to decompose 1 kg of $CaCO_3$ will be:

$$\frac{42500}{100} = 425 \text{ Cal}$$

When recalculated in relation to the end products from burning CaO having the molecular weight of 56, the heat consumption will be:

$$\frac{42500}{56} = 759 \text{ Cal/1 kg of CaO}$$

Decomposition of magnesium carbonates is made by the following equation:

$$MgCO_3 = MgO + CO_2 - 26150 \text{ Cal/mole}$$

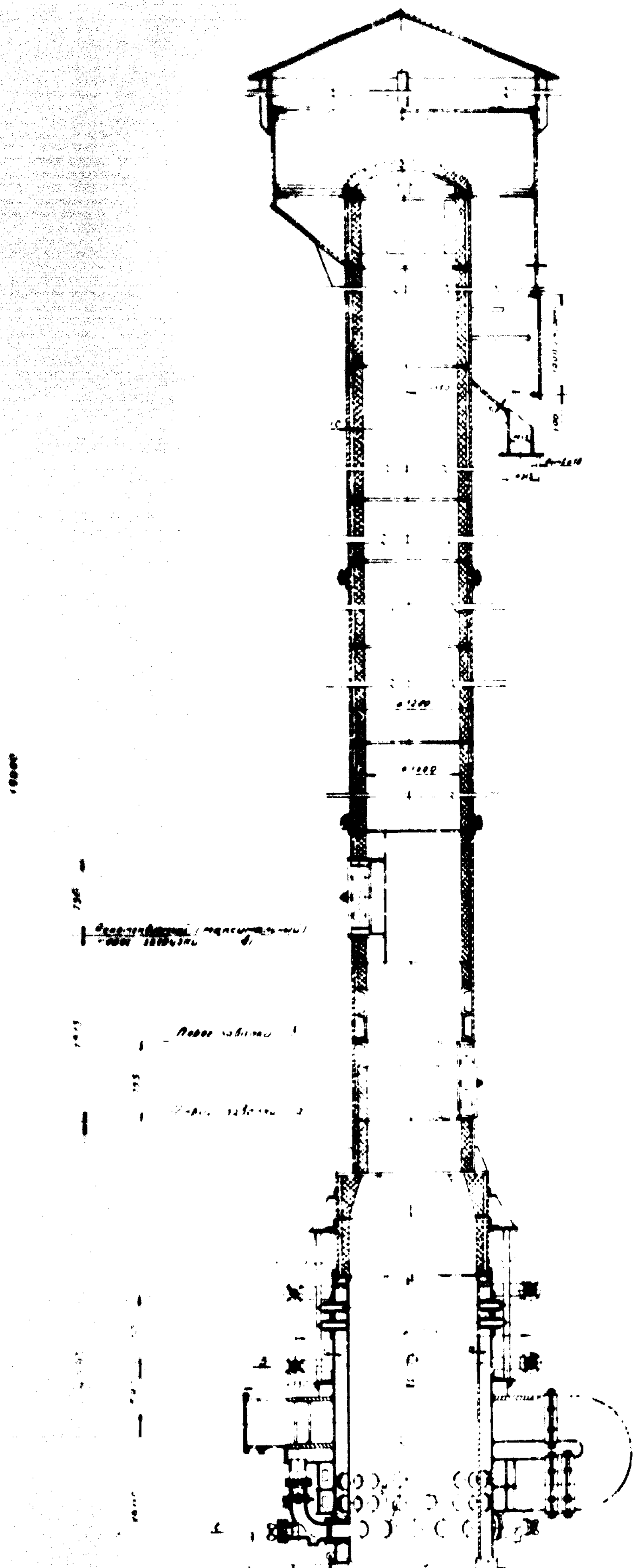
Admitting that the molecular weight of $MgCO_3$ is equal to 84 the amount of heat to decompose 1 kg of $MgCO_3$ will be:

$$\frac{26150}{84} = 311 \text{ Cal}$$

When recalculated in relation to the end products from burning MgO having the molecular weight of 40, the heat consumption will be:

$$\frac{26150}{40} = 654 \text{ Cal/1 kg of MgO}$$

The total heat consumption for decomposition of carbonate components per 1 kg of melt will be as follows:



$$\sum q_{x} = \frac{729 x 31.1}{100} + \frac{624 \ x \ 12.2}{100} = 339 \ Cal/kg$$

Using the nomogram in Fig. I we determine, at $t^{p}=1050^{o}C$, the specific fusibility of raw material $p=3.7$ kg/kg.

b) Output of the furnace:

$$p = \frac{1.25^{2}x0.785x50x60x3.7x1000}{6800 \ x \ 1.1} = 1420 \ kg/hr$$

Alongside with advantages a cupola process has its shortcomings too. The main drawbacks are as follows: some non-uniformity of a melt obtained from the furnace especially when a combined charge containing several components is used; impossibility to use without any special preparation loose or free - flowing material for heating; necessity to use as fuel expensive coke difficulty available.

These shortcomings make us search other furnace units suitable for melting mineral raw material.

Bath furnaces have a lower (compared with cupola furnaces) coefficient of heat utilization, and for this reason they were rarely used in the mineral wool industry. At present the manufacturing of mineral wools in bath furnaces has become expedient in connection with the development of the gas industry and with the availability of cheap natural gases.

Complex exploitation of such furnaces is payed off by a very high quality of a melt produced and by a possibility to use local raw material unsuitable to be used in cupola furnaces. The melt is kept in a bath furnace for a long time, and this provides for its more thorough boiling and uniformity.

A possibility of all-out automation and reliability to control all heat as well as technological processes allows for obtaining a molten stream to be transferred to a fibre formation unit with constant parameters on consumption and temperature as well as on chemical uniformity, and this is what is impossible to achieve in cupola furnaces.

Therefore, the bath furnace is an obligatory smelting unit when a melt of a higher quality must be generated to manufacture mineral wool. The drawing and blowing method of fibre formation widely used by the firm of Grünzweig and Hartmann (FRG) and the centrifugal drawing - blowing method used by the firm of San Gobin (France) require constant chemical compositions of melts and their temperatures for without this it is impossible to get fibres of a high quality. The melt should not contain metals or sulfur compounds. Their presence in the melt destroys the material from which draw plates are usually made, the main component of this material being expensive platinum.

A cupola furnace cannot provide for producing a melt of a required quality for these methods of filament formation. That is why bath furnaces are used for these two methods - drawing-blowing and centrifugal-drawing blowing.

Electric furnaces

Electric furnaces are not used to manufacture common types of mineral wools because of a relatively high cost of electric energy.

But it is impossible without electric furnaces to obtain special types of mineral wools resistant to high temperatures. Difficultly fusible material, from which temperature - resistant mineral wool is produced, can be melted only in electric furnaces.

For the above-mentioned reasons electric furnaces are not widely practised to manufacture mineral wools.

Cyclone furnaces.

A cyclone furnace is usually made in form of a vertical metal cylinder cooled with water. Gas or fluid fuel is fed tangentially inside this cylinder into its upper part, by special burners. Dust-like raw material is blasted in there by special devices. Dust-like material is quickly heated and melted thanks to a high heat tension, and therefore to a high temperature.

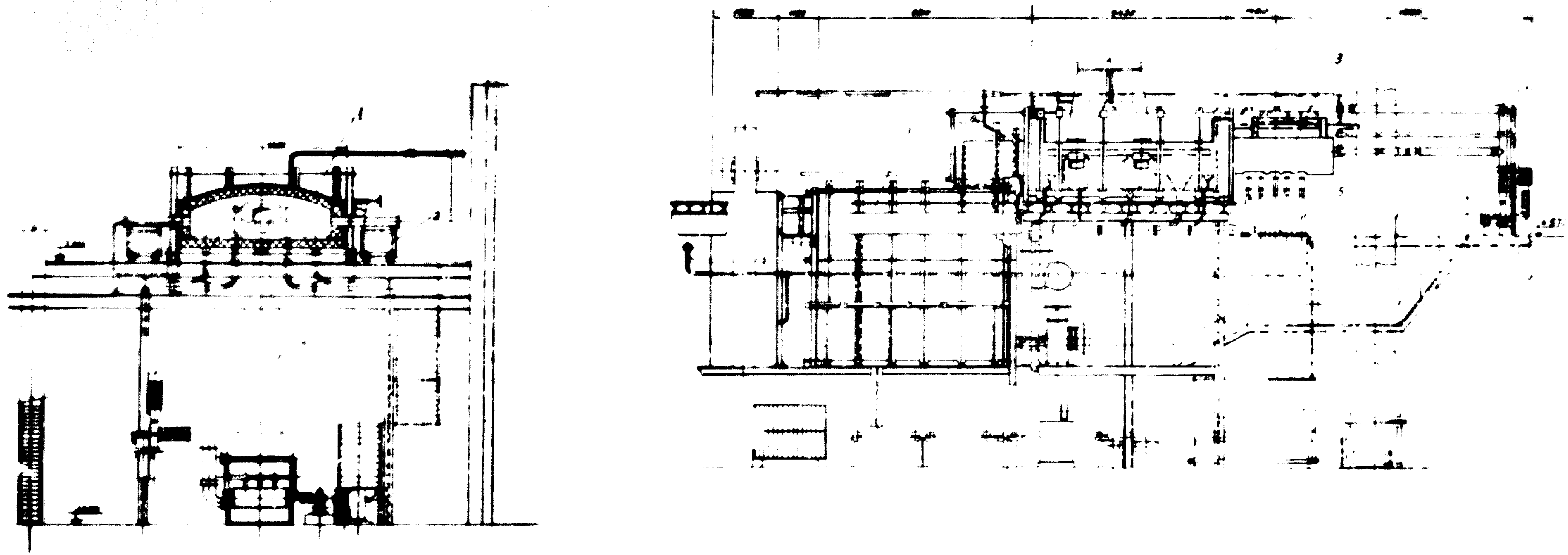


Fig. 9. Bath Recuperative Furnace.
1. Bath with recuperator. 2. Charge loader.
3. Feeder. 4. Shaft fibre settling chambre.
5. Fibre formation unit (vertical drawing-blowing)

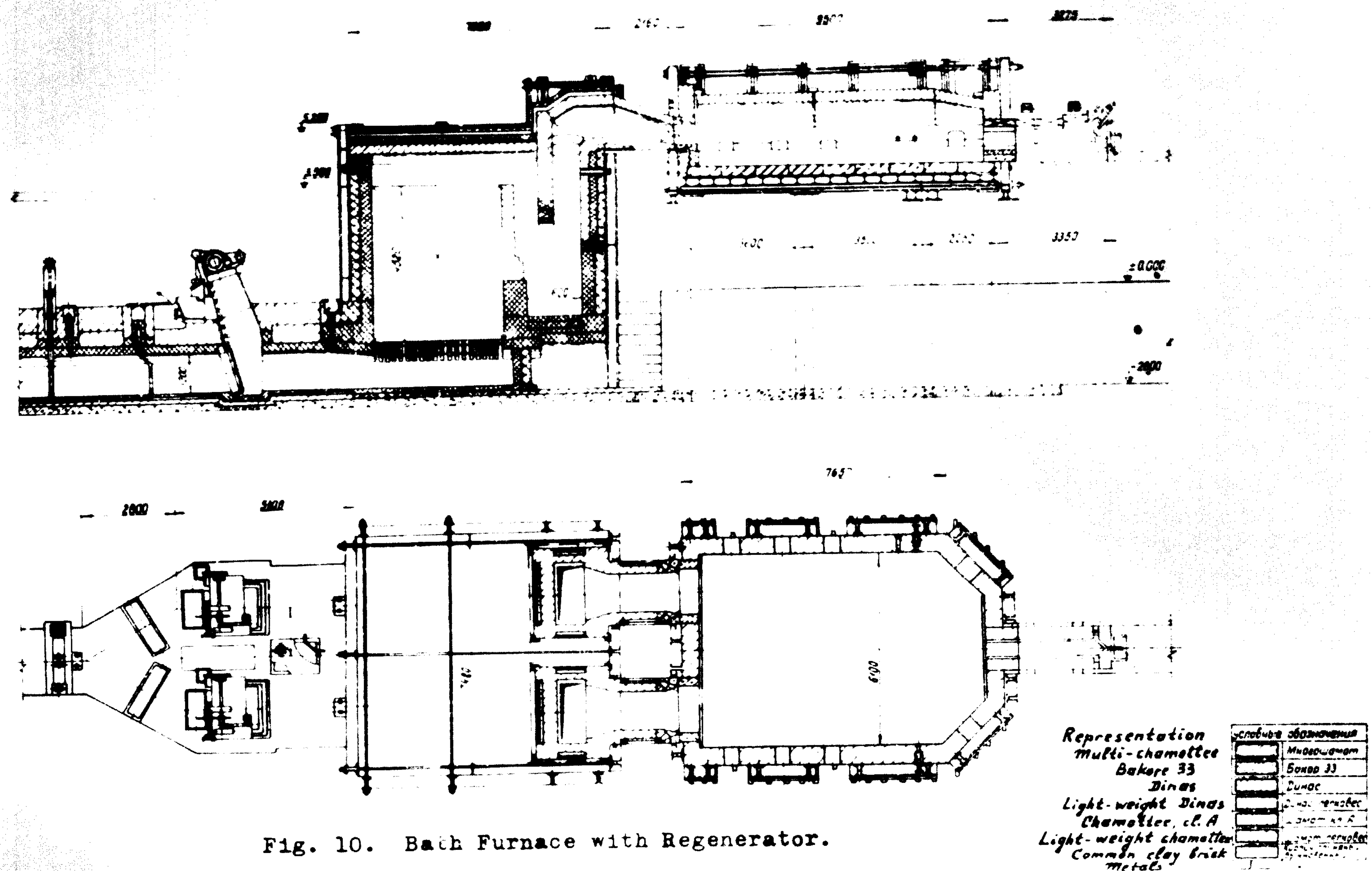


Fig. 10. Bath Furnace with Regenerator.

Drops of a melt are thrown onto the walls of a furnace as a result of flame rotation under centrifugal forces. Drops form on the walls a melt film to which unmelted particles of raw material stick, and they are easily melted in this thin film. The melt obtained on the walls drips little by little down into a bath placed under the cylinder. In the bath, the melt is neutralized and boiled up. A desired temperature is maintained in the bath by combustion products escaping from the cyclone. The melt is outlet and guided from the bath up to a fibre formation unit in an incessant stream through tapping holes.

Cyclone furnaces are not yet used to manufacture mineral wool, but the first experiments have shown that furnaces of this type will be used in the near future especially when other industrial dust-like waste fit by its chemical composition is available. For example, dust-like waste of various concentrating mills, dust from electric filters at heating and power plants, from cement works etc.

<u>Slag catchers.</u>

Creation of slag catchers permitted to begin using flame - liquid slags of the ferrous and non-ferrous industries in manufacturing mineral wool. Use of flame-liquid slags to produce mineral wool is beneficial economically, for it allows to considerably reduce its cost. This

Light-weight chamotte
Common clay brick
Metals

Fig. 10. Bath Furnace with Regenerator.

can be achieved by decreasing fuel consumption, by excluding expenses on slag dressing in refuse dumps, on its grinding and sorting. In addition, use of flame-liquid slags is favourable to use gasiform and cheap fluid fuel to heat slags, and not expensive coke necessary to operate a cupola furnace.

A slag catcher is a regenerating bath or a recuperating furnace with a feeder equipped with special tapping holes for letting the melt out of the furnace, taking a change in its level into account.

Metallurgical flame-liquid slags are transferred to a slag catcher in ordinary slag ladles. Transfer of slags in ladles provides for the normal operation of a mineral wool factory situated in a slag dump area of some metallurgical works, i.e. at a distance of 3 to 5 km from the blast furnace plant. Correction of slag chemical compositions is effected by adding necessary admistures. A design of a slag catcher is shown in Fig. 11. Installations of a similar type function at six plants in the USSR.

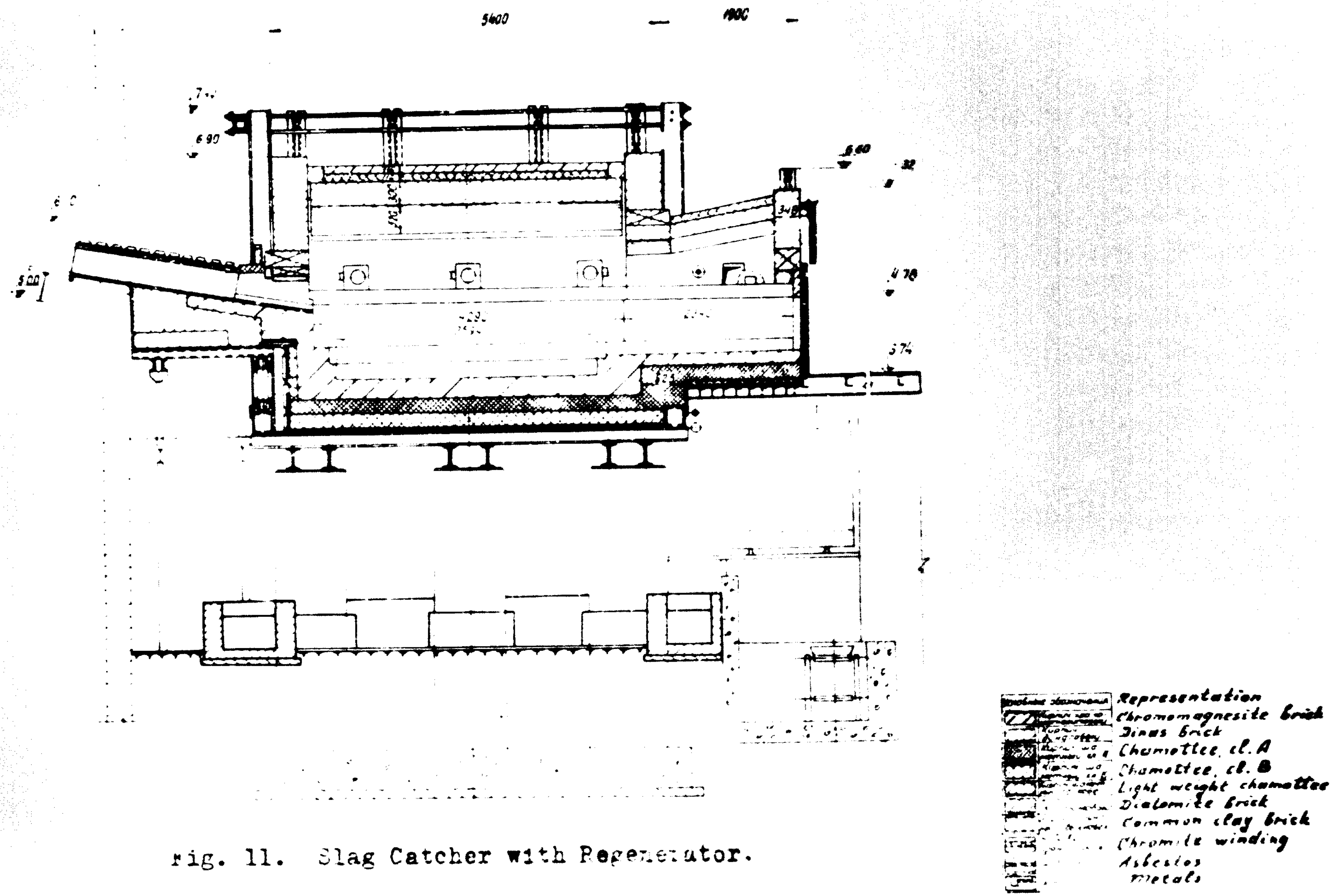


Fig. 11. Slag Catcher with Regenerator.

Technical Characteristics of Furnaces Used to Obtain Melts in Production of Mineral Wools

Table 8

Characteristics	Cupola Furnace 1250mm	Bath Furnace 48 sq.m	Bath Furnace 18 sq.m	Slag Catcher
1	2	3	4	5
Type of furnace	Shaft furnace	Regenerative furnace	Recuperative furnace	Regerative furnace
Output, kg/hr	up to 3000	1600	500	2000 and more
Furnace mirror area, sq.m	-	48	18	17.5
Specific output of melt from 1 sq.m, kg/sq.m.hr	up to 2450	30-40	25-30	114
Furnace heat efficiency, Cal/hr	-	6.0×10^6	2.25×10^6	1.75×10^6
Conventional heat tension of mirror, Cal/sq.m.hr	-	125×10^3	125×10^3	100×10^3
Rated fuel consumption,	1000-1950	3 500	4500	880
Nozzle heating surface of regeneration sq.m	-	1070	-	-
Ditto per 1 sq.m of surface mirror, sq.m/cu.m	-	22.3	-	-
Fuel consumption: mazut, kg/hr (Q^p_H=9500 Cal/kg)	-	$\frac{630^{x)}}{97}$	$\frac{250^{x)}}{93}$	-
Natural gas,cu.m/hr (Q^p_H = 8800 Cal/cu.m)	-	$\frac{680^{x)}}{105}$	$\frac{275^{x)}}{100}$	$\frac{200^{x)}}{110}$
coke,kg/hr (Q^p_H = 6800 Cal/kg)	400-700	-	-	-

Teble 8 (cont)

1	2	3	4	5
Electric power consumption per 1 hr,kw	-	60	20	10
Steam sonsumption for mazut spraying, kg/hr	-	150	70	-
Water consumption in cooling system, cu.m/hr	10-25	3-4	-	10-15
Air consumption for combustion,cu.m/hr	3000-5000	8500	4000	3500
Air consumption for blowing over furnace cooling surfaces, cu.m/hr	-	76000	25000	-

x) Note: numerator-fuel consumption in bath furnace; denominator-fuel consumption for heatig up the feeder

4. Methods of Fibre Formation

Current methods of industrial processing of a mineral melt into filaments can be divided into three main groups: blowing, centrifugal and centrifugal-blowing fibre formation methods. Each of them in its turn includes some other forms which can be traced in Fig. 12.

Mineral fibre formation blowing methods include a blowing-horizontal bulge proper (see Fig. 12a) and a drawing-blowing-vertical bulge (see Fig. 12b).

The essence of this or that method is that an energy carrier (steam, air or combustion products, liquid or gasiform fuel) reacts on vertical molten streams flowing out of a cupola furnace or out of the sieve-like bushings of a bath furnace feeder.

The difference between these forms of blowing is that when using the blowing method proper an energy carrier flow is headed onto a molten stream 7 to 15 mm in diameter and at an angle of 15 to 20° to the horizon, while using the drawing-blowing method it is headed onto streams up to 3 mm in diameter from top to bottom and from two sides at an angle of 7 to 10° to the vertical.

The energy carrier splits a stream into finest particles speeding them up. At the moment when particles break away from the main stream they are drawn and instantaneously cooled, i.e. they are converted into filament. Calculations as well as researches made by scientists from different countries have shown that the durability of a fibre formation process is counted in ten-thousandth fractions of a second (10^{-4}). Molten particles not drawn into filaments tend to take on a spherical shape under surface tension forces. Such non-drawn spherical solidified molten particles are called "beads" and they are always present in a certain quantity in fibres obtained by the blowing method.

The above-given principle of fibre formation by the blowing method can be equally referred to the drawing-blowing method. But in this case the energy carrier reacts on separate molten streams flowing out of sieve like bushings, and this improves conditions of fibre formation; for this reason a number of "beads" in fibres is insignificant and they are even smaller.

<u>When using centrifugal methods</u> a melt is drawn into filaments, as is seen from the name itself, by centrifugal forces acting on molten particles. There are one-disk (Fig. 12 c) and multiroller centrifugal (Fig. 12 d, e) methods of fibre formation.

The principle of fibre formation is as follows: the melt getting onto rollers (Fig. 12 d,e) sticks to their surfaces. Under a centrifugal force and in certain temperature conditions, the melt begins to flow off in many points on the surface of a roller, as if forming a variety of "fountains". Molten streams of these "fountains" having a speed equal to the roller rotation linear speed and tending to escape from their surfaces, are still more drawn and thinned.

Peripheral streams getting into an air jet headed across the roller rotation plane, are cooled, converted into a fibre settling chambre. Non-draw molten particles ("beads") having a less sailing capacity and moving on the roller rotation plane, are separated from fibres and are selected under the centrifuge from where they are periodically or continuously transferred to a waste collecting place by special mechanical devices.

"Fountain" streams directed to adjoining rollers get onto their surfaces, stick to them and are again processed. The cavity between rollers is protected from the air jet, therefore there are no conditions to intensively cool the melt there. The melt transfer from one roller onto another allows for its distributing on roller surfaces (in width) and therefore for increasing the output of a centrifuge.

A centrifuge of the type shown in Fig 12 d can produce 3 to 3.5 tons of fibres per hour, an average fibre diameter being 6 to 8 microns.

Centrigues having an arrangement of rollers as shown in Fig. 12 e can produce 2 to 2.5 tons of fibres per hour, and fibres are obtained of a higher quality with an average diameter of 4 to 5 microns.

By using the disk method (see Fig. 12 c) an incessant molten stream is headed into one of the grooves made on the surface of a rotating disk. The melt fills in a groove and flows off in thin streams across its external edge under centrifugal forces. These streams are drawn in flight and, being cooled, are converted into filaments. Fibre is very long. Filaments are 10 to 12 microns in diameter. The output of a disk is 250 to 300 kg of fibres per hour.

This method is not widely practised at present because of a low output.

Out of centrifugal as well as other fibre formation methods the most widely spread now is the centrifugal - roller method shown in Fig. 12 e.

When using combined methods, fibre formation is effected in two stages: first, a molten stream is presplit into separate streams under centrifugal forces, and then fiber is finally formed by processing these streams with a strong steam or air jet if you use the centrifugal-blowing method;

second, the melt, under centrifugal forces, is pressed out through sieve like bushings on the walls of a rotating bowl, and molten streams flowing out of the bushings are additionally processed by hot gases escaping from a ring nozzle.

In order to split the melt and to draw fibres it is

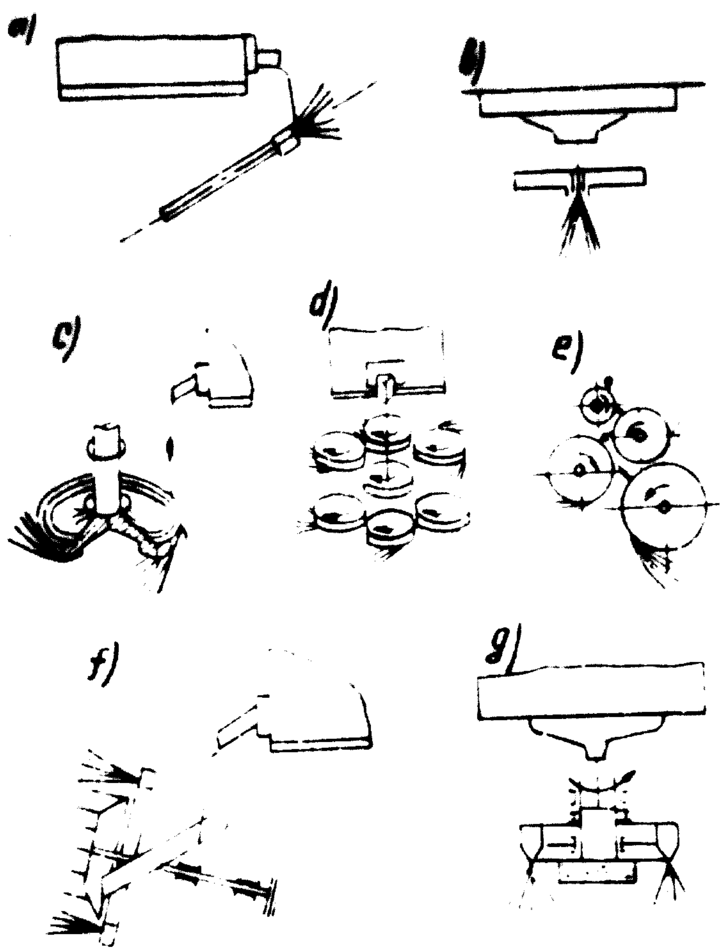


Fig. 12. Fibre Formation Methods.

a. Horizontal blowing

b. Vertical drawing-blowing

c. One-disk centrifugal

d & e. Centrifugal multi-roller

f. Centrifugal-blowing

g. Centrifugal-drawing-blowing

necessary to consume a certain amount of energy. When using blowing methods, an energy source is the kinetic energy of an air, steam or gas jet escaping out of a nozzle; when centrifuging the melt, the power of electric motors rotating the functioning organs of a centrifuge is used.

The two kinds of energy are used at different stages of making fibres of a molten stream, if combined methods are employed.

The following below table gives amounts of power consumption for fibre formation by the main industrial methods. In addition, in order to compare and to determine the efficiency of utilization of energy to be consumed for fibre formation, it is given in heat units (Cal/kg of wool) to be spent to obtain an energy carrier to be used in manufacturing 1 kg of wool.

Table No.9

Technical Characteristics of Filament Formation Methods

Name	Filament Formation Methods					
	Unit	Blowing (horizontal)	Drawing blowing (vertical)	Centrifugal roller	Centrifugal blowing	Centrifugal drawing blowing
1	2	3	4	5	6	7
1. Normal productivity of a technological line	kg/hr	from 500 to 2000	500	from 1500 to 2500	from 1500 to 2500	

Table 9 (cont.)

1	2	3	4	5	6	7
Producti-.ty of one .lament for-ation unit (blowing head, drawing boat, centrifuge)	kg/hr	500	100	up to 2500	up to 2500	
b) Number of working filament formation units usually installed in a technological line	pc	1 to 8	5 to 6	1	1	4-5
2. Energy carrier consumption to obtain 1 kg of mineral wool with use of:						
a) Steam	kg/kg	1-1.4	2.5	-	1	-
b) Compressed air	cu.m/kg	1	2.5	-	1	-
c) Hot gaseous combustion products	cu.m/kg	-	-	-	-	5 to 8
Heat from burning gases	Cal/kg	-	-	440	-	910 to 1470

Table 9 (cont.)

1	2	3	4	5	6	7
d) Electric power	kwhr/kg	-	-	0.01 / 0.06	0.001	0.02
3. Total heat consumption for filament formation with use of:						
a) Steam	Cal/kg	860 to 1210	2600	22	862 to 868	-
b) Air	Cal/kg	135 to 198	1980	132	135 to 198	954 to 1514

Note: in centrifugal-roller method: numerator-power consumption only for filament formation; denominator-power consumption for filament formation and for blowing off fibres.

The above-given comparative table shows that the most rational filament formation method is centrifugal-roller regarding use of power, then comes centrifugal-blowing, blowing with horizontal bulging, centrifugal-drawing-blowing, and at last drawing-blowing.

Besides, the table indicates that use of compressed air as an energy carrier is more preferable than steam from the point of view of the efficiency of utilization of power to be applied. However, practically, steam was oftener used than air for blowing. It can be explained by the fact that a boiler station is simpler to maintain than a compressor house.

As to the quality of fibres produced methods can be arranged in the following order: fibres produced by the centrifugal-drawing-blowing method has the best quality factors, then - by the centrifugal-roller one, drawing-blowing, centrifugal-blowing, and at last - by the blowing (horizontal) method.

Quality Factors of Mineral wool Produced by Different Filament Formation Methods

Table 10

Quality Factors	Filament Formation Methods					
	Unit	Blowing (horizontal)	Drawing blowing (vertical)	Centrifugal-roller	Centrifugal-blowing	Centrifugal-drawing-blowing
1	2	3	4	5	6	7
		(Fig. 12 a)	(Fig. 12 b)	(Fig. 12 c)	(Fig. 12 d)	(Fig. 12 e)
1. Average filament diameter	micron	3–5	5–8	4–5	7–8	3–4
2. Filament length	mm	2–7	5–15	a few cm	5–15	a few cm
3. Content of "beads"	%	40–50	up to 5	7–10	15–25	practica ly ab- sent
4. Heat conductivity, at 20°C	Cal/ m.hr.°C	0.042 to 0.044	0.038 to 0.040	0.038 to 0.040	0.040	0.036

Table 10 (cont.)

1	2	3	4	5	6	7
5. Volume weight under load of 0.02 kg/sq.cm	kg/cu.	150-200	75-100	75-100	100-125	50-75

Note: 1. In determining bead contents only beads having a diameter more than 0.25 mm are taken into account.

2. Mineral wool fibre lengths are not standardized in view of the absence of methods to determine them. The given fibre lengths do not claim absolute precision and are input here only to have approximate, comparative data.

Concerning complexity of equipment used to manufacture mineral wools the fibre formation methods in question can be put in such an order: The blowing-horizontal method is the simplest one as to equipment used as well as very simple in service. This is the oldest industrial method to produce mineral wools. It was known since the middle of the last century and was practised on a large scale till the middle of this century. At present this method is almost stopped to be used because of a low quality of fibres obtained.

Then come centrifugal-blowing, centrifugal-roller and drawing-blowing methods, and at last the most complex, as to equipment and service, is the centrifugal-drawing-blowing method.

The first three, i.e. blowing, centrifugal-blowing and centrifugal-roller methods, are used in any furnace unit that can provide for incessant transfer of the melt to a filament formation unit on condition that no high requirements are made to the chemical composition of raw material and to the temperature of a melt being transferred for filament formation, because some deviations from the made requirements will influence over the quality of filament but will not destroy the equipment in use. Centrifugal-drawing and centrifugal-drawing-blowing methods are used only in furnace units which can provide for producing a strictly fixed amount of melts not containing sulphur compounds and metal and having a strictly fixed temperature.

Non-observance of these requirements will result in quick wear or in complete destruction of sieve-like platinic radium bushings. Service of bushings is aggravated, if the centrifugal-drawing-blowing method is used, because they are under considerable centrifugal forces.

Hereabove were described the main industrial filament formation methods and furnace units used now in the production of mineral wools.

Option of a filament formation method can be made very simply when organizing a new production. At present the centrifugal-roller method is most advisable for industrial and construction insulation needs. This method permits to get high-quality fibement with the lowest expenses for its manufacturing. When employing the centrifugal-drawing-blowing method platinum is used and in this connection high requirements are made to raw material. Concerning expenses it does not justify a minor improvement in the quality of fibres, in comparison with the centrifugal-roller method.

But option of a furnace unit for producing mineral wools is not very simple. It depends on properties of raw material as well as on the availability of fuel.

If the selected raw material is lumpy, hard, stone-like, e.g. metallurgical slags, rock muck of volcanic origin, and if coke is available to be used to generate mineral wools then cupola furnaces can be employed as furnace units.

A technological scheme of production might be the following: autoroads and railways for transferring raw material and coke; raw material and coke dumps (usually the volume of a dump is taken per one month's needs of a plant); transport means and necessary mechanisms for transferring raw material and coke to discharge hoppers. Discharge hoppers are usually of a volume enough to meet 24-hour need of raw material and fuel for a furnace unit, and transport and charging mechanisms at raw material dumps of such a power so that they could charge discharge hoppers per one shift. Such a decision favours to reduce the personnel. Weight dosers should be installed under hoppers. It is recommended to equip hopper chutes with vibrofeeders which provide for even filling of the material to be dosed into a weight doser thus increasing the precise performance of the latter, and creating a reliability in operating such dosers in an automatic cycle. Then the dozed raw material and fuel are filled, in turn, into a cupola furnace by means of a skip hoist or conveyor. The cupola furnace is equipped with: a radio-active level indicator which shows a charge level and gives pulses to fill a next charge into the furnace; a thermoregulator by which a constant, fixed temperature of the cooling water is maintained in the furnace water jack; a system of regulating devices that can provide for supplying a certain, fixed, amount of air to the furnace for blowing. Such equipment of the cupola furnace provides for, while operating in an automatic cycle, its stable output and the constant ~~fusion~~ melting temperature. The ~~fusion~~ melt flowing out of the furnace is guided onto rollers of a centrifuge by means of regulating devices. Filament generated by an air inflow passing through the roller rotation plane are carried into the filament settling chambre where it settles on a latticed conveyor. The air sucked from under the chambre conveyor is relieved by a ventilator into the atmosphere. If this is a phenol spirit adhesive which is dispersed in the settling chambre then the air before being relieved into the atmosphere should be cleaned particularly from phenol and formaldehyde vapours. A layer of mineral wool settled on the chambre conveyor is continuously taken out and guided for further processing. The ventilator sucking air from under the fibre settling chambre conveyor should be of such an efficiency as to suck air through the roller rotation plane with a certain speed to remove the air supplied into the chambre from blowing-off devices which evenly distribute fibre, and to remove the air entering the chamber through its leaky joints.

If raw material is fine, loose, dust-like or sticky it cannot be melted in a cupola furnace. Therefore when using marl, different clays and the like as raw material to obtain mineral wool it is necessary to use bath furnaces of a glass type taking at the same time as fuel-gas or liquid fuel. Regardless of the lower heat utilization coefficient compared to that of a cupola furnace, bath furnaces can be economically justified because of a lower cost on gas and liquid fuel than on coke.

A technological scheme may be as follows: Raw material is supplied to a dump equipped with mechanisms for taking it to the dump from transport means and for putting it into production. From the dump raw material components are carried to a preparation section where they undergo preliminary processing, that is grinding and drying. The prepared components are taken into discharge hoppers, from which, by dosers, into a mixer where they are carefully mixed to obtain a uniform mass. The mixed raw material is transferred by special transport means to discharge hoppers of the furnace from where it is filled, when required, automatically by feeders into the furnace for melting. A ready melt is outlet uninterruptedly from the furnace through a feeder and is guided onto centrifugal rollers; then the scheme is analogous to the first one.

A bath furnace is equipped with automatic devices to conduct all heating procedures and to keep a constant melt level in the furnace.

When using flame-liquid blast furnace slags or some others to produce mineral wool a technological scheme may look as follows. A slag ladle with flame-liquid slags is installed under an acidifying installation cover where a special burner is put into the ladle and an acidifying admixture (mostly sand) is supplied in a certain quantity. The acidifying admixture is quickly mixed up and melted, due to the operating burner, with submerged flame. Slag acidification is over, the slag ladle is transported to a chute for discharging the fusion out of the ladle into a slag catcher. The melt is overboiled in the catcher. Through tapping hole with a regulating level the ready melt is guided incessantly onto centrifugal rollers; then the technological scheme is similar to the first one.

Since flame-liquid slag is transferred periodically but its discharge from the slag catcher is continuous, the melt level in the furnace is variable. In order to continuously outlet the melt with a constant debit the furnace feeder is equipped with a special tap hole which can move uninterruptedly or periodically regarding changes of the melt level in the furnace.

CHAPTER III

Manufacture of Mineral Wool Products

1. Bonding Materials

The following binders are used in the manufacturing of mineral wool products:

- synthetic resin;
- bitumen and emulsified bitumen;
- starch;
- bentonite;
- cellulose derivatives.

These adhesive materials can be used separately as well as in different compositions with other resins or with various admixtures imparting to products such features as waterresistance, flexibility, heatresistance, etc.

Synthetic resins such as phenolformaldehyde, carbamide, urea-formaldehyde and others are most widely practised in all the countries. Phenolformaldehyde resins are very wide spread in the USSR, the USA, Great Britain, France, the FRG, the GDR, Sweden, Finland, Canada, Bulgaria, Czechoslovakia, Yugoslavia, India, Japan, etc.

In the USSR the following binders are used: phenol-formaldehyde resin (phenol spirits), carbamide, bitumen-clay or bitumen-diatomite suspension, and starch. In order to raise the elasticity of mineral wool products, cutting emulsion and rosin compositions are added to resins. A composition of phenoformaldehyde and polyvinylacetate emulsion is also used.

There can be used various ~~adhesive~~ bonding compositions, for example:

- The FRG's firm "Grünzweig und Hartmann" uses compositions of phenolformaldehyde and polyvinylacetate emulsion or cutting emulsion. The firm's products have a trade mark "Sillan".

- The American and British firms use urea-formaldehyde combined with ethylene-glycol, phenolformaldehyde, melamine.

- The French firm "Fransicol" uses compositions of phenolformaldehyde, starch and heat-resistant admixtures; starch-paraffine-mazut compositions; phenolformaldehyde with mineral oil admixtures.

A number of firms use ~~adhesives~~ binders on the oellulose derivatives base. Thus, e.g. the Norwegian joint-stock oompany "Kureholnes Aktiebolad" has a patent to obtain products on the base of carboxylmethyl-cellulose.

Some US firms and firms of other countries use ~~adhesives~~ binders on the base of starches (corn, maize, potato) with admixtures of bentonite, asbestos and other inorganic materials for obtaining ~~hard~~ rigid, heat-resistent and acoustic ~~rock~~wool slabs.

Resins used for manufacturing ~~rock~~ mineral wool products should meet the following main requirements:

- high adhesiveness;
- capacity to generate water emulsions stable in time;
- lowest content of toxic admixtures and free alkali;
- good adhesion to mineral fibres;
- capacity not to harden at temperatures of 50 to 60°C in fibre formation chambres;
- capacity to completely harden in heat treatment chambres at temperature of 140 to 200°C within a few minutes;
- low hygroscopicity.

Below are given technical characteristics of some binders used in the USSR for manufacturing mineral wool products:

Phenol spirits: phenolformaldehyde resin of the resol type is a primary product of condensation of phenol (C_6H_5OH) with formaldehyde (CH_2O) at the presence of alkaline catalyst (NaOH); it is transparent liquid dark-cherry - or brown - coloured.

Dry remainder content - not more than 50%.

Dissolution in water (stable solution transparency)	- not less than 1:2
Hydrogen factor pH	- 7.5 to 9
Ostwald viscosity at 20°C	- 10 to 20 centipoise
Specific weight at 20°C	- 1.14 gr/cu.cm
Freezing temperature	- 6°C below zero
Free phenol content	- not more than 9%

Optimum hardening point	**- 160 to 180°C**
Storage temperature	**- -3 to 15°C**
Storage time	**- up to 2 months**

Phenol spirits do **not generate explosive concentrations and** do not burn.

Urea-formaldehyde resin KC-II is a product of condensation of urea with formaldehyde; this is syrup-like liquid of white to light brown colour.

Dry remainder content	- not less than 60%
Dissolution in water	- not less than 1:5
Hydrogen factor pH	- 7.5 to 9
Viscosity at 20°C	- 10 to 60 centipoise
Specific weight	- 1.27 to 1.29 gr/cu.cm
Free formaldehyde content	- not more than 5%
Optimum hardening point	- 160 to 170°C
Storage time at 25°C	- not less than 2 months

Polyvinylacetate emulsion (П.В.А.) is a product of polymerization of vinylacetate in a water medium at the presence of an emulgator and initiator; in apperance it looks like a tough homogeneous liquid white-coloured.

Oil bitumen is used as a ~~rock~~ mineral wool dust removing means and as an ~~adhesive~~ binder in the manufacture of ~~rock~~ mineral wool soft (felt), semi-~~hard~~ rigid and ~~hard~~ rigid slabs for heat insulation of surfaces having a temperature of not more than 200°C (outdoors).

Bitumen БН-Ш, БН-Ш-У is used for wool dust ~~removing~~ catching and for manufacturing felt, semi-rigid and rigid slabs; bitumen БН-IV or БН-V - for semi-rigid slabs.

A Sample Composition of Different Bitumens

Table 11

Bitumen	Bitumens Composition Contents, %				Softening Temperature, °C
	Oils	Resins	Asphaltenes	Carbenes & Carboids	
БН-Ш, БН-Ш-V	52.84	45.25	1.46	0.45	45-50
БН-IV	52.80	28.84	8.70	9.66	70
БН-V	42.76	25.76	12.81	16.36	90-95

Cutting emulsion is used as a mineral wool dust catching means and as a plasticizer in a composition of synthetic resins in the production of flexible mats and soft slabs, and is a colloid solution of mineral oils and high-molecular organic acids in a concentrated water solution of alkaline oils (mostly naphthenate). Cutting emulsion, when mixed up with water, generates another emulsion.

The USSR produces three types of cutting emulsion: Э-1; Э-2 and Э-3.

Э-1 and Э-2 are transparent homogeneous liquid of light to dark-brown colour; Э-3 is homogeneous liquid of dark-brown to black colour.

Kaolin (levigated), diatomite and bentonite are used in the USSR in combination with bitumen in form of emulisified bitumens in production of rigid mineral wool slabs.

When screening levigated kaolin through screen No.0085, the remainder should not exceed 0.4%.

Ground (scutched) raw diatomite

This is ground settled rock muck mostly containing amorphus silica, and must meet the following requirements:

Filled-up volume weight in dry condition - not more than 500 kg/cu.m

Maximum granule size - 5 mm

Moisture should not exceed 45%.

2. Methods of Manufacturing Mineral wool Products

Regarding methods of mineral wool processing there are the following types of technological processes for manufacturing mineral wool products:

1. Conveyor - line production based on incessant transfer by conveyors of a soaked in some adhesive rockwool layer (blanket) supplied directly from the fibre settling chambre conveyor, and on its heat treatment with obtaining products during its transfer. Soft, semi-rigid slabs as well as moulded half cylinders are manufactured by this method.

2. Conveyor - non-line production based on obtaining products out of preliminarily taken from the fibre

settling chambre conveyor half-finished produots: rolled ~~rock~~ mineral wool stock, packs and packages. Subsequent ~~rock~~ mineral wool processing into products is effected on equipment installed aloof from the main line, and stitched mats, wound cylinders, ~~shells~~ half-cylinders and others are produced there.

3. Non-conveyor - line production based on mixing loosened granules or ~~rock~~ mineral wool flocks with some ~~adhesive~~ binder in form of a water suspension, on moulding products out of the hydropaste obtained, and their heat treatment. More solid, so-called ~~hard~~ rigid, slabs, blocks, stock for acoustic slabs based on bituminous, starch or other ~~adhesives~~ binders are manufactured by this method. Below is given a desoription of technological procedures for manufacturing main types of ~~rock~~ mineral wool products.

3. Manufacture of Products ~~on~~ with Synthetic ~~adhesive~~ Binder ~~Base~~

3.1. Slabs (soft, semi-~~hard~~ rigid and ~~hard~~ rigid)

Technological processes of manufacturing slabs ~~ones~~ with synthetic ~~adhesive~~ binder include:

- Obtaining mineral ~~filaments~~ fibres.
- Preparation of ~~adhesive~~ bonding water emulsion.
- Coating fi~~brement~~ with ~~adhesive~~ binder.
- Pressure moulding and heat treatment of ~~rock~~ mineral wool blanket ~~carpets~~
- ~~Blanket~~ cooling and its cutting into slabs.
- Products packing.

The following production methods differ by a procedure of coating fibres with some binder:

- Binder spraying into the filament settling chambre at the moment of fibre formation.

- Binder dispersion on a mineral wool blanket produced with subsequent sucking off its surplus at a special installation.

Bonding emulsion spraying in the fibre settling chambre is made by sprayers, special dispersers, rotating disks, and steam or air nozzles.

Commercial resin is usually diluted with water up to a concentration of binder in the emulsion from 12 to 17%. In order to disperse the adhesive evenly on mineral wool filaments the emultion should be sprayed fog-like and cover fibres forming thin films on them.

Mineral wool blanket moisture at the output from the settling chambre should range from 2 to 8% to avoid premature binder hardening.

Coating fibres with adhesive by its spraying permits to treat the mineral wool blanket with heat at a minimum time and with the lowest fuel consumption; that is why this method is wide spread. But there are certainly shortcomings: considerable losses (up to 20-25%) of the binder settled on the conveyor and the settling chambre walls or partially carried with air being sucked out of the chambre.

Blanket binder dispersion with subsequent sucking off the bonding emulsion surplus is less practised though it allows to cut bonding losses, to process the blanket more evenely, and to obtain slabs of a better structure. Carpet moisture after sucking-off is 50-55%, and to dry it, a considerable fuel and electric power consumption, a longer heat treatment and consequently bigger dimensions and weight of technological equipment are required. This method of manufacturing semi-rigid slabs and stock for acoustic slabs is used by the FRG's. firm "Grunzweig und Hartmann", "Sillan", and at some factories in the USSR.

Binder consumption for obtaining products is determined by the formula:

$$C = \frac{Q\left(1 - \frac{c}{100}\right)}{K_c \cdot K_n \cdot K_o} \quad \text{kg/hr}$$

where:

- Q - productivity of a line, kg/hr
- C - commercial resin consumption, kg/hr
- c - binder contents in slabs, %
- K_c - dry remainder in commercial resin content, %
- K_n - resin losses coefficient, $K_n = 1 - 0.01\Pi$
- Π - resin losses during dispersion, %
- K_o - coefficient of losses during blanket cutting and slabs waste, coefficient.

Concentration of the working emulsion "Kp" received as a result of dissolving the binder in water is defined by the ratio:

$$Kp = \frac{K_c}{1 + P} \%$$

where: P - water volume to resin volume ratio taken on the base of practical data.

Pressure moulding, heat treatment, cooling and blanket cutting into slabs are effected on equipment installed on a conveyor line with a fibre settling chambre.

An equipment line includes:

- Transfer or distributing conveyor.
- Chambre for heat treatment.
- Chambre or zone for cooling.
- Dividing conveyor equipped with knives for blanket cutting.

Moreover, some lines may include installations for slab papering and packing and for felt rolling.

When obtaining slabs by binder dispersion on the blanket the line also includes an installation for soaking which is set up before the heat treatment chambre.

The most important unit on the line is the heat treatment chambre where a mineral wool blanket is pressed up to a given volume weight and thickness, is dried and heated, and where the binder is hardened.

The heat treatment chambre is made up of welded structures with walls hanged in form of doors of panels insulated with mineral wool, and is equipped with two couples of perforated apron conveyor covered with mesh slivers. The lower conveyor is for transferring, and the upper one for pressure moulding. The mesh coverage provides for a necessary texture of products. Cells of a mesh conveyor are 50x4 mm in size. Lower and upper moulding conveyors are in the chambre body and operate at a present temperature in the chambre of 170-200 ^{o}C; the back sections of mesh conveyors are outside and are continuously cleaned by driving brushes. Of course, other conveyors are quite possible: of special rod and braided mesh, of perforated plates, etc. Conveyors should have a strength for blanket pressure moulding of 0.06 - 0.08 kg/sq.cm.

A mineral wool blanket formed of thin filaments has a high heat exchange surface achieving 2000 sq.m. per one cu.m. Thanks to this effect, the blanket is heated and its moisture is evaporated very intensively, especially by the binder spraying method when the blanket moisture does not exceed 8%. Duration of the blanket heating and moisture vaporizing processes directly depends on the amount of a heat carrier passing through a layer, that is on the speed of air or gas-air mixture infiltration.

Time for synthetic binder hardening depends on the binder properties and temperature. Optimum hardening temperature for most of synthetic resins used is 140-180^{o}C. Time for binder hardening at optimum temperatures is 1 to 2 minutes.

The total heat treatment duration is composed of time necessary for blanket heating, moisture vaporizing

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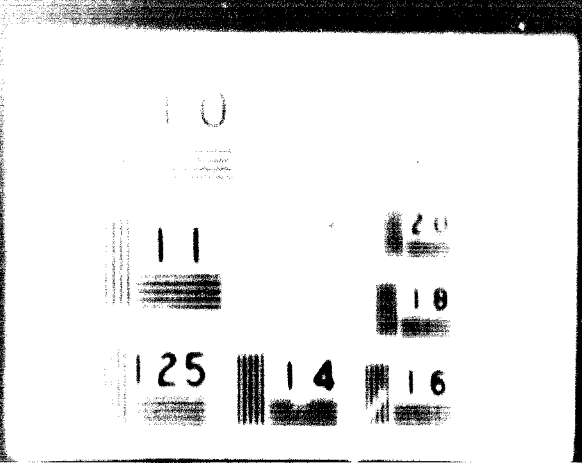

and binder hardening. These processes pass to a great extent simultaneously and the total heat treatment duration can be determined only experimentally and on the base of practical data.

In order to reduce time for blanket heating and drying, the speed of the heat carrier infiltrating through a layer must be increased, and it is calculated by the formula:

$$v = \frac{V}{L \quad b \quad 3600} \text{ m/sec}$$

where: V - heat carrier amount, cu.m/hr

L - chambre working sone length, m

b - blanket width, m

Yet increasing the heat carrier amount makes increase the power of ventilators for its transfer, fuel consumption and blanket hydraulic resistance. The latter requires use of high-pressure ventilators. Furthermore, in heat treatment conveyor chambres the heat carrier passes in between the blanket and chambre walls, and then some air is sucked through the carpet input and output ends. As a result the actual amount of the heat carrier passing through a blanket layer is much less than the rated and depends on a chambre structure.

Practice has shown that the most advisable infiltration speed of any heat carrier should be 0.5-0.7 m/sec, the binder spraying method being employed. In this case the heat treatment duration can be from 2 to 12 minutes regarding the binder properties, chambre structure, thickness and volume weight of slabs produced.

The binder dispersion method being used and blanket moisture being [illegible]-55%, the infiltration speed is 1.8-2.2 m sec and the heat treatment duration 15-25 min.

Increasing the slab volume weight and thickness makes increase the heat treatment duration because carpet hydraulic resistance rises and the actual amount of the heat carrier passing through a layer decreases. This requires either an additional heat carrier amount or line productivity reduction.

Line productivity is determined by the heat treatment duration and by length and width of the chambre, and is defined by the formula:

$$Q = \frac{L\ b\ h\ \gamma\ 60}{t} \quad kg/hr$$

where: Q - line mineral wool productivity, kg/hr

L - chambre working zone length, m

b - blanket width, m

h - slab thickness, m

γ - slab volume weight, m

t - heat treatment duration (as to practical and experimental data), min

The heat treatment chambre length is determined by the formula:

$$L = \frac{Q \cdot t}{B \cdot h \cdot \gamma \cdot 60} \; m$$

The heat treatment chambre length can be 12 - 18 m, conveyor productivity 1000 to 2200 kg/hr (conveyor 2 m wide), if the adhesive (binder) spraying method is used. The firm "Grunzweig und Hartmann" uses chambres [illegible] m long, 1 m wide, productivity being [illegible] kg/hr, if the adhesive (binder) dispersion method is effected. The heat carrier is usually a mixture of air and flue gases obtained in furnaces from burning liquid or gas fuel. As a rule chambres are divided into zones 5-7 m each, and each of them has a separate fire-chambre equipped with a ventilating installation. Heat carrier amount is determined by the formula:

$$V = v \cdot L \cdot b \cdot 3600 \text{ cu.m/hr}$$

where: v - rated infiltration speed, m/sec

L - chambre or zone length, m

b - carpet (blanket) width, m

Supply and infiltration of the heat affected carrier having a temperature of 160-180°C are effected by centrifugal ventilators alternately in each zone from top to bottom and from bottom to top, through the carpet blanket moving between the two perforated conveyors - the upper one for transferring and the lower for pressure moulding. Conveyor perforation degree should be a maximum.

Necessary slab thickness and volume weight are fixed by a position of the upper conveyor and its speed.

Depending on the chambre structure, heat carrier transfer scheme and temperature for heat treatment reference fuel consumption is 50-70 kg per 1 ton of material, if the binder spraying method is used.

Reference fuel consumption increases up to 290-320 kg per 1 ton of fibres, if the second method is used.

Blanket cooling after heat treatment is made by blowing cold air at a temperature of about 40°C through the blanket. Cooling time is 2-4 min.

Blanket cutting into slabs is effected by disk or guillotine knives on a dividing conveyor. Finished products are packed into packages, boxes and boards, or are rolled (felt).

Fig. 12 shows a general outline for slab production by the binder spraying method on an automated conveyor line in case of obtaining the melt in the cupola furnace and of fibre formation by the centrifugal method.

3.2. Manufacture of mineral wool products in form of hollow half-cylinders.

In this respect the following production methods are known:

- Winding a mineral wool layer on bars.
- Incessant pressing.
- Rolling.
- Cutting of slab stock.
- By-the-piece pressing.

The first two method – winding and incessant pressing –

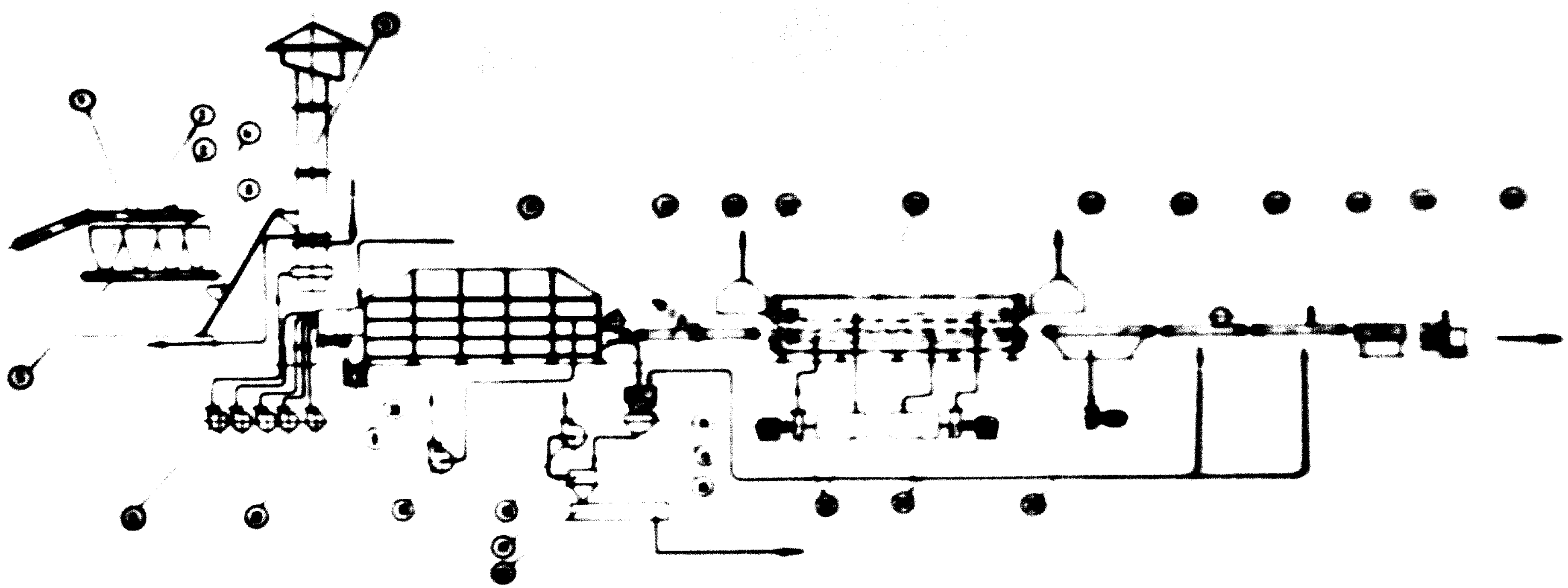

Fig. 13.

are most wide practised. By the winding method are obtained hollow cylinders which are then cut into half-cylinders.

Fig. 13. Technological outline of slab production with on synthetic binder. 1 and 2 - Belt conveyor with plough ejector. 3 - Raw material hopper. 4 - Coke hopper. 5 - Dosing conveyor. 6 - Skip hoist. 7 - Cupola furnace. 8 - Blowing ventilator. 9 - Roller contrifuge. 10 - Fibrous blowing-off ventilator. 11 & 12 - Fibrous settling chambre with fluegas exhauster. 13 - Installation for rolling. 14 - Granulator. 15 - Cross conveyor. 16 - Hopper. 17 - Cyclone. 18 - Pneumotransport ventilator. 19 - Installation for sack packing. 20 - Transfer conveyor. 21 - Heat treatment chambre. 22 - Fire-chambre with ventilating installation. 23 - Hood. 24 & 25 - Cooling chambre with ventilator. 26 - Length blanket cutting knife. 27 - Cross chopping knife. 28 - Installation for slab packing. 29 - Electric loader. 30 - Conveyor for fusion melt refuse. 31 - Transfer of bonding emulsion for spraying.

Winding includes the following technological processes:

- Winding a thin mineral wool layer on bars whose external diameter is equal to the internal diameter of products.
- Calibration and rolling.
- Heat treatment (drying, heating and binder hardening).

- Removal from bars and cooling.
- Cutting in sizes required.
- Packing.

Winding of mineral wool on bars can be effected directly from a thin wool blanket, soaked in the binder passing from the fibre settling chambre conveyor; from a thin blanket layer cut off from a mineral wool roll earlier obtained on the settling chambre conveyor; from a rockwool roll with subsequent soaking in the binder

Heat treatment is carried out by blowing the heat carrier through a blanket layer wound on perforated bars, or by blowing in kiln or continuous dryers. There are some different production methods for winding mineral wool on bars.

Their production is as follows. Mineral wool coated with the binder is wound on carton bars into tight rolls 700 to 1000 mm in diameter which are transferred on a truck or conveyor to an installation for manufacturing cylinders. Wool rolls are taken into the rear part of this installation where there are a receiving device and a machine for cutting. The cutting machine by means of a belt saw cuts off (in circumference) from rolls a wool layer of a fixed thickness. Then at the winding machine placed in the front part, mineral wool is wound on bars which are put into the machine and are automatically fixed there. As soon as the layer thickness preset is achieved winding is automatically stopped and the blanket obtained is cut by means of a quillotine. The transfer part of the machine stops, cylinders are taken manually out of the machine and put into a device for surface calibration where they are processed until receiving the exact size, and the surface is glued over with paper or fabric.

After that, cylinders are put onto a truck and placed into a kiln dryer. Dried cylinders are discharged from the truck, liberated from bars and filled into a machine for length, cross and edge cutting. Finished products are collected in the delivery installation, then are manually packed into boxes. Bars in the machine are lubricated with oil heated up to 150°C.

Now the USSR organises automatic production lines to manufacture cylinders with an internal diameter of 97-273 mm, and the productivity of 160 lin.m/hr.

A line is set up right after the fibre settling chambre and includes winding and calibration machines, continuous dryers, mechanisms for taking out bars, their lubrication and transfer, machines for cutting products.

In the last years there appeared installations in which winding, calibration and heat treatment are combined in one unit. Therefore bar steaming and some dryers are not necessary.

An equipment line includes a [illegible] transfer conveyer; incessant winding [illegible] with bars and fast-removable mouthpieces of different diameters, with perforation for supplying direct steam and hot air;

installation for cutting edges by belt saws;
installation for length cutting of cylinders by disk saws. Only piling of mineral wool blanket stock onto the transfer conveyor and packing of finished cylinders or half-cylinders into carton boxes are made manually. The output of such a line is 90 lin.m/hr for cylinders 100 to 800 mm in external diameter and 21 mm in minimum internal diameter.

The continuous pressure moulding method is that the moving blanket soaked in the binder is moulded into wave-like form by means of rollers arranged across the conveyor, then it is treated with heat and further cut into half-cylinders (shells).

Production can be made in line with the fibre settling chambre, or from rolled mineral wool stock. One of these methods used in the USSR is lamination of half-cylinders from the incessant mineral wool blanket processed with a synthetic binder on a conveyor line with the output of 300-400 lin.m/hr. The line consists of a transfer conveyor, heat treatment chambre and dividing conveyor. The heat treatment chambre is equipped with perforated trays in form of half-cylinders and profiled pressure rollers for moulding shells. Heat treatment is effected by blowing hot air through the blanket. Production technology by this method does not differ from that of manufacturing slabs.

4. Manufacture of Mineral Wool Products Bitumen-Bonded

4.1. Rigid slabs

Production includes the following processes:

- Preparation of emulsified bitumen.
- Mixing mineral wool loosened into flocks with emulsified bitumen.
- Slabs moulding.
- Charging of drying trucks.
- Slabs drying.
- Slabs cooling.
- Discharging of drying trucks.
- Slabs packing.

Emulsified bitumen is prepared by dispersing melted bitumen with clay or diatomite suspension heated up to 90-95°C, with subsequent diluting with water up to a concentration of 3-4% (diatomite to bitumen proportion is 1:2.5).

Wool from the fibre settling chambre conveyor is transferred onto a belt balance and then into a scutcher where it is loosened. Wool flocks are taken then into a hydromixer where they are mixed with emulsified bitumen in a weight proportion of 1:10-12. Hydropaste obtained (pulp) is transferred into a volume doser.

The moulding installation functions as follows. Empty trays are put onto the delivery board of a chain conveyor and are lowered along a cheek on its chains. Then the conveyor drive and the pneumocylinder of sliding guides to stop trays exactly under a vacuum shield are turned on simultaneously. At the same moment the shutter of the volume doser is opened by means of the pneumocylinder, and a portion of hydropaste 250-380 litres in volume fills up a movable pressmould. Then, after 8 sec., in order to drain the pressmould the latter is transferred on rollers by means of a hydrocylinder under the vacuum shield which presses and vacuumizes two slabs while lowering into the pressmould. Slab thickness is regulated by special regulating bolts on the vacuum shield. After pressing (3 sec.) the vacuum shield extracts slabs from the pressmould. The vacuum shield moving upwards, the pressmould simultaneously comes back into the initial position under the doser. Then the vacuum shield is lowered for a full stroke of its cylinder, vacuum is turned off and slabs 55-60% moist are discharged on trays.

The vacuum shield going upwards,the tray guides are lowered at the same time, the chain conveyor is turned on, and the trays piled are transported to a slab loader at a pace of 3000-4000 mm (visually) until new empty trays are transferred under the vacuum shield. Then the entire cycle of pressing is repeated. Piled trays, on reaching the slab loader, are stopped by a constant limit stop on the loader. Now chains can slide under trays. By pressing a button the hydrocylinder of a pace-ratchet gear of a rack loader is turned on (rise at a pace of 125 mm). On composing a stack of 24 trays the hydrocylinder of a pusher - is turned on to charge trays from the loader racks into a drying truck. The truck is charged twice. When charged the truck is put into the dryer by means of a transborder. Drying takes 10-16 hours at a temperature of 130-150°C.

When taken out of the drying oven, trucks are cooled up to 40-45°C and are transferred to an installation for discharging. This installation operates as follows:

A truck piled with dried slabs is rolled by the traverse transfer of an electric transborder onto rails of a hydrohoist platform. At this moment the console part of a stationary chain conveyor passes between the lower row of trays with slabs and the truck frame. By pressing a button the hydrohoist platform with the truck on it goes down at the first pace of 40 mm, and the first row of trays with slabs on them is put out onto hauling chain of the conveyor for unloading. Then the truck is lowered for 11 paces (125 mm each). The truck is hoisted in a reverse order.

Slabs on trays are either taken manually from the chain conveyor or transported on an inclined conveyor to a board for sorting slabs and trays. The output of such an installation is 180-200 slabs 1x0.5 m per hour.

A production outline is given in Fig. 14.

4.2. Semi-rigid and soft (felt) slabs

They are produced by spraying

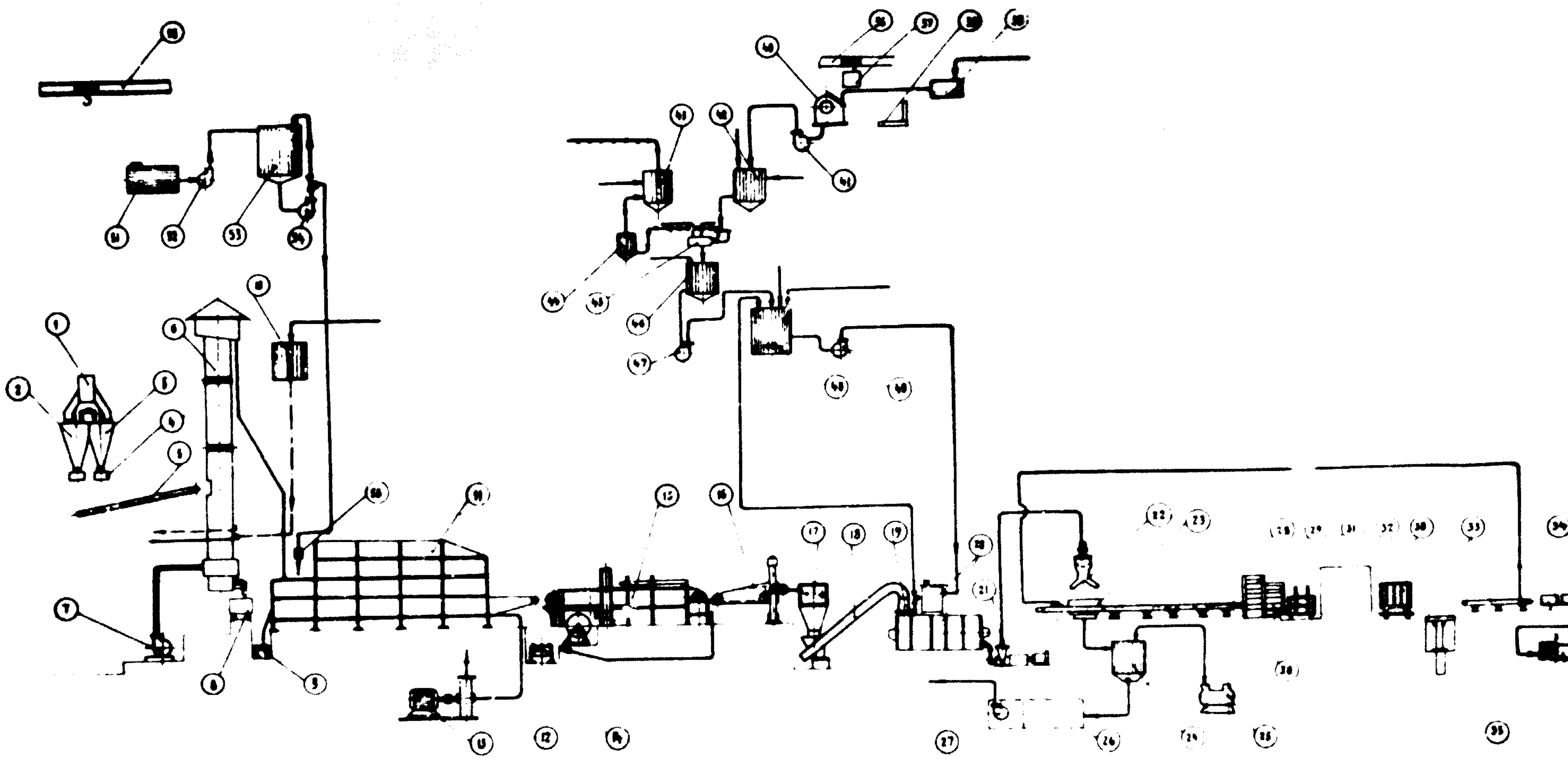

Fig. 14.

mineral wool, with molten bitumen pressure moulding, cooling and cutting of the soaked blanket on a conveyor line which includes a centrifugal installation, fibre settling chambre, pressure moulding installation, cooling zone with a ventilator, and dividing machine.

Bitumen molten and overheated up to 130-150°C is sprayed by means of the steam ring nozzle of a centrifugal-blowing installation.

The bitumen softening temperature for soft slabs is 45-50°C; 70-85°C for semi-rigid ones.

Fig. 14. Technological outline of production of rigid slabs bitumen-bonded.

1 - Conveyor with ejector. 2 - Raw material hopper. 3 - Coke hopper. 4 - Automatic weight doser. 5 - Belt conveyor. 6 - Cupola furnace. 7 - Blowing ventilator. 8 - Roller centrifuge. 9 - Conveyor for waste. 10 - Water tank. 11 - Fibre settling chambre. 12 - Fluegas exhauster. 13 - El.motor. 14 - Conveyor for mineral wool. 15 - Belt balance. 17 - Scutcher. 18,19 - Inclined conveyor. 20 - Hydromixer with emulsion doser. 21 - Centrifugal pump. 22 - Pulp doser. 23 - Moulding machine. 24 - Water intake. 25 - Vacuum pump. 26 - 27 - Drained water tank with pump. 28 - Chain conveyor. 29 - Installation for charging trucks. 30 - Drying truck. 31 - Transborder. 32 - Kiln dryer. 33 - Installation for discharging trucks. 34 - Slabs stack. 35 - El. loader. 36 - 37 - Monorail. 38 - Balance. 39 - Water doser.

40 - Mixer. 41 - Pump. 42 - Tank with mixer and steam heating system. 43 - Tank for melted bitumen. 44 - Bitumen doser. 45 - Disperser. 46 - Concentrated emulsion tank. 47,49,58 - Pump. 48 - Working emulsion tank. 50 - Monorail. 51 - Oil receiver for mineral wool dust separation. 53 - Oil discharge tank. 54 - Oil pump. 55 - Oil sprayer.

The productivity of a line is determined by an output of mineral wool. The volume weight and thickness of products depends on the packing factor and conveyor speed, The latter being defined by the formula:

$$T = \frac{Q}{B\ h\ \gamma\ 60}\ \text{m/min}$$

where: Q - mineral wool output of a line, kg/hr.

b - blanket width, m

h & γ - thickness and volume weight, m & kg/cu.m

5. Manufacture of Mineral wool Slabs Starch-Bonded

5.1. Rigid slabs and blocks

Production includes the following main processes:

- Preparation of the adhesive in form of water emulsion.
- Obtaining granulated mineral wool (from packs or rolls).
- Mixing granules with the binder.

- Moulding of slab blanket on continuously moulding machine.

- Carpet cutting into slabs of required sizes.

- Drying in kiln or continuous dryers.

- Packing.

5.2. Semi-rigid slabs

Semi-rigid slabs are manufactured on a conveyor line. Technology includes:

- Preparation of the starch bending agent with admixtures of paraffine, mazut, bitumen.

- Obtaining mineral wools on centrifugal-blowing installations.

- Binder spraying by steam through a ring nozzle, and producing, a blanket.

- Blanket moistening with steam and heat treatment with hot air by blowing through a layer.

- Cooling and blanket cutting into slabs.

6. Manufacture of Mineral wool Mats Stitched

Manufacture of stitched mats with different linings is effected by a mechanized method on conveyor or non-conveyor lines, or on machines.

Most wide practised are non-line stitching machines on which mineral wools in form of rolled stock taken out of the fibre settling chambre conveyor are processed.

Such production includes the following technological processes:

- Unwinding rolls into strips, or cutting off from them a layer of required thickness.

- Lining rockwool layers with coating material from one or two sides.

- Stitching rockwool layers with wire or thread lining.

- Cutting into mats of required length.

- Mats rolling.

Coating materials are paper, crimped carton, bitumen-impregnated paper, metal grids, rugs of lath or cane.

The output of different machines depends on mat thickness and type of lining, and is 100-800 sq.m/hr. If the line production method is used, the mineral wool blanket is transferred to a lining installation directly from the fibre chambre conveyer, then to a stitching machine and to an installation for rolling.

7. <u>Manufacture of Insulating Cord</u> (fluffy cord)

Fluffy cord is produced from mineral wool waste. Production includes the following operations:

- Waste loosening into flocks.

- Transferring flocks into machine.

- Cord generating.

- Cord braiding on braiding machine by means of bobbins.

- Cord winding on arbors.

Braiding is effected with zink-coated or brass wire

0.2 mm thick, asbestos or other threads.

The productivity of a braiding machine is 120-140 lin.m/hr depending on cord thickness (30-60 mm).

8. Shops for Manufacture of Mineral wool Products

As a rule technological equipment is placed in an engineering building which must include the following shops:

1. Charge preparation shop.
2. Cupola or other furnace shop.
3. Binder preparation shop.
4. Products manufacturing shop.
5. Packing shop.

Dumps for raw material and warehouses for finished products can be blocked with the building or may be located separately, regarding local conditions.

Besides, some auxiliary premises are in the engineering building, such as a laboratory, repair shop, compressor station, etc.

According to a required production volume and variety of products there can be set up a necessary number of technological lines including: manufacture of mineral wool and its products desired.

In the last years most wide practised were specified sets of installations including a conveyor line of equipment for manufacturing soft and semi-rigid slabs, and non-line machines for stitching mats, for producing half-cylinders for pipe insulation.

Such sets of installations are supplied by firms: "Jungers Verstads AB" (Sweden), "Fransicol" (France), Grunzweig und Hartmann (FRG), and others. These installations provide for obtaining a necessary variety of insulating products for construction and other industries.

The USSR is preparing at present new automated sets of installations for manufacturing mineral wools.

In order to meet needs for products a set of installations can be modified. Thus, for example, if products for pipe insulation and stitched mats are not required, a conveyor line for manufacturing felt and slabs is ordered.

The main technical data on installation sets of some firms are given below.

Main Technical Data on Specified Sets of Installations for Production of Mineral Wool Products by Some Firms

Table 12

Name	Jungers Verstads AB (Sweden)	Grunzweig und Hartmann (GFR)	Fransicol (France)	
			Type A	Type C
1	2	3	4	5
Installation output tn/yr	14400	5640-6850	15000	15000

Table 12 (cont.)

1	2	3	4	5
Products	Flooring felt γ=25-55 kg/cu.m Semi-rigid slabs γ=60-80 kg/cu.m Rigid slabs γ=80-120 kg/cu.m ~~Independent~~ Self-bearing slabs γ=150 & 200 kg/cu.m. Mats stitched γ=50-150 kg/cu.m ~~Shells~~ Half-cylinders (Ø25-400 mm) γ=150 kg/cu.m Insulating cord γ=200 kg/cu.m ~~Rock~~ Mineral wool in sacks	Felt γ=25-50 kg/cu.m Semi-rigid slabs γ=80-120 kg/cu.m Mats stitched γ=55-125 kg/cu.m ~~Shells~~ Half cylinders (Ø17-426 mm) γ=100-150 kg/cu.m. Insulating cord γ=200 kg/cu.m. Acoustic slabs γ=130 kg/cu.m	Felt γ=35-50 kg/cu.m Felt "Stillizol", semi-rigid slabs γ=50-120 kg/cu.m Rigid slabs γ=140-170 kg/cu.m Mats stitched γ=110 kg/cu.m ~~Rock~~ Mineral wool	Semi-rigid & hard slabs γ=60-8[illegible] kg/cu.m ~~Shells~~ Half cylinders γ=150, 1[illegible] 220 kg/cu.[illegible] Slabs self bearing "Alupan" γ=100-3[illegible] kg/cu.m
Raw material	Slags with admixtures of rock muck and silicate refuse	Rock muck like marl	Slags with admixtures of rock muck or silicate refuse	Ditto
Furnace unit type	Cupola furnace	Bath recuperating furnace	Cupola furnace	Cupola furnace
Number of units	1	2	1	1

Table 12 (cont)

1	2	3	4	5
[illegible] formation methods	Centrifugal-roller	Vertical drawing-blowing	Centrifugal-roller	Centrifugal-blowing (steam)
Bending agent	Phenolformaldehyde resin	Phenolformaldehyde resin, polyvinylacetate emulsion	Phenolformaldehyde resin	Composition of starch with admixtures
Fuel:				
for melting	Coke	Natural gas or mazut	Coke	Coke
for heat treatment	Natural gas or mazut	- " -	Natural gas or mazut	Natural gas or mazut
Heat carrier for heat treatment	Mixture of air with flue-gas	Ditto	Ditto	Steam; mixture of air with fluegases
Number of working people per shift	32	43 (without the acoustic slabs shop)	21	15

CHAPTER IV

ECONOMIC FACTORS IN PRODUCTION OF MINERAL WOOL INSULATING MATERIALS, PRODUCTS AND STRUCTURES

1. Development of Optimum Decisions to Meet Needs of Construction Industry in Thermoinsulating Materials and Products

Heat insulation is now an intrinsic feature of modern industrial enterprise. A number of technological processes cannot be effected at all technically without any thermoinsulation of equipment and pipes.

Heat insulation provides for big economy of fuel, for stability of technical processes, for improving conditions to serve equipment.

It is also practised on a large scale in constructing apartment houses, industrial, agricultural, administrative and other buildings.

It goes without saying that the expediency of use of the heat insulation is quite evident at present.

Every construction firm must, in this connection, decide a number of special problems:

1) Determine when designing, rational spheres and volumes for the heat insulation, choose the most effective thermoinsulating materials.

2) Determine, when constructing, sources to meet needs in for thermoinsulating materials.

A firm, under concrete conditions, may either develop its own manufacture of thermoinsulating materials and products,or acquire them from specialised home or foreign firms.

In order to resolve these questions most fully it is necessary to have much information data on conditions of manufacturing thermoinsulating materials,on material resources required on the prime cost of products abtained,on capital investments, etc.

3) Production conditions are in essence different in various countries and parts of the world. Therefore it is impossible,in the present study,to work out recommendations with due regard for all concrete conditions possible.

However,on the basis of information given here it is possible,proceeding from concrete conditions of any area, to define all necessary technical and economic production factors by means of simple calculations and to take technically and economically founded decisions about an expediency to construct a plant about its type,output and nomenclature of products and also to choose main technological decisions. Yet anyhow when taking first rough decisions,specialists in the field of thermoinsulating materials will not be required.

Calculations on the basis of procedures and information data given in this study can be made by any trained engineer or economist.

2. Choice of Optimum Type of a Plant. Influence of Plant Type over Technical and Economic Factors.

Manufacture of mineral wool thermoinsulating materials products and structures can be conducted at autonomous plants as well as in shops of certain plants and factories for thermoinsulating and building materials,ferro-concrete structures plants and house-building factories.

The optimum output of a plant for production of mineral wool materials is comparatively low thus scalling down the plant itself. These reasons are discussed in the section "Choice of Plant Optimum Output". In case of constructing an autonomous enterprise the specific weight of capital investments in erecting auxiliary shops and services as well as in establishing on-site and non-site communications-electric transmission lines, steam and water mains, branch lines, highways, etc. is extremely great.

These expenditures may considerably exceed investments in construction of main industrial shops under especially unfavourable conditions.

A high cost of auxiliary industrial units and communications gives a sharp rise to specific investments per yearly production unit and makes increase considerably its cost.

Taking the above-mentioned into consideration, it can be advisable to construct shops for production of mineral wool thermoinsulating products as part of plants under way or in operation, in other industries. Most effective is construction of a shop as part of a big plant whose power and transport facilities have substantial reserves for its output and can meet needs in exploitation of this new shop without commissioning auxiliary capacities.

3. <u>Principles of Territorial Siting of Plants for Manufacture of Mineral Wool Thermoinsulating Materials and Products</u>

Principles of territorial siting of plants for manufacture of mineral wool thermoinsulating materials and products differ radically from conventional principles of siting of plants in the building materials industry. It is explained by some specific features of thermoinsulating materials and in this connection, by particular conditions of their transportation.

Thermoinsulating materials have a minute volume weight. Weight of mass mineral wool materials ranges from 75 kg/cu.m to 150 kg/cu.m.

Only some special products-cylinders, rigid slabs with synthetic and bituminous binder-have the volume weight of 150-225 kg/cu.m.

When transporting these materials, only 15-22% of the load-carrying capacity of railway transport is used. This explains rather high transport expenses per production unit. But at the some time when transporting source material and fuel for manufacture of thermoinsulating materials and products, the load-carrying capacity of transport can be used fully since the volume weight of raw material and fuel is 10 times and more bigger than that of thermoinsulating materials.

Therefore if plants in the building materials industry are to be sited nearby raw material and fuel sources, factories of the thermoinsulating industry should be sited right in areas where products can be consumed.

4. Choice of Optimum Duty of a Plant and its Influence over Technical and Economic Factors

Optimum duty of a plant for manufacture of mineral wool thermoinsulating materials and products is three-shift work in a continuous week, with an annual stoppage for capital repair of 30-35 days.

Work in an interrupted week entails a considerable increase in the prime cost of products and a reduction of their output. Reducing the production volume will accordingly rise expenses per production unit because of overhead expenses.

Besides, an increase in expenses per production unit because of overhead expenses, work in an interrupted week will also lead to some increase in direct expenses per production unit.

Kindling, a cupola furnace the first day of a working week and stopping it its last day will result in an increase of raw material and fuel consumption.

Higher consumption of technological fuel per production unit will also occur as a result of a worse duty of heat treatment chambres if they are cooled and heated every day.

Thus due to all the above-enumerated factors work in an interrupted five-day week compared to that of a continuous one results in reducing the output volume by 30-35% and raising its cost by 15-20%.

Operation of main shops in two or, moreover, in one shift with hot processes (raw material melting) would entail such a sharp deterioration of all technical and economic production factors that, practically, it is unrealizable. And auxiliary shops and services can work in two or one shift, a continuous or interrupted week all the same.

The duty of each auxiliary shop or service must be chosen proceeding from concrete conditions of operation of a given plant.

5. Specialisation of Plants on Manufacture of Wool Materials, Products and Structures

Mineral wool materials and products, regarding what purpose t they are assigned for can be divided into two large groups:

A. Materials for heat insulation of buildings and installations.

This group includes almost only slab insulants-soft semi-rigid and rigid slabs with synthetic binder as well as semi-rigid and rigid slabs with bituminous binder which are widely used for heat insulation of stationary refrigerating installations. Besides it embraces a comparatively small number of shaped products, cylinders, half-cylinders or structures on their base for insulation of steam or hot water conduits in buildings as well as pipings coming from buildings to central heating mains.

B. Materials for heat insulation of pipes, technological and power equipment at industrial plants, power stations and heat mains (erection insulation).

This group includes a great variety of materials, products, and structures-half-cylinders, slabs and stitched mats with different linings.

Besides, mineral wool insulating cord is widely used for insulation of steel frame-works and complex pipe bends.

It is advisable to realize precise specialisation if the volume of thermoinsulation works is considerable.

In order to obtain an erection insulation it is recommended to construct a shop with two or three technological lines, with the productivity of 100-150 thou.cu.m of structures, products and materials per year.

Usually it is better to manufacture cylinders and half-cylinders on two lines and slab material with synthetic binder on the third. Equipment for producing stitched mats and insulating cord is installed aloof from the line.

But mineral wool for manufacturing stitched mats is obtained either on the main technological lines or during repair of heat treatment chambres,or by specially stopping periodically to manufacture products on with synthetic binder in order to select mineral wool obtained. Insulating cord should be as a rule produced from slab and half-cylinder waste (ends).

When it is necessary to obtain a wide variety of shaped products of specified types and sizes,equipment for manufacturing cylinders may also be installed aloof from the line. It is dictated by considerations to raise the output.

As a rule cupola furnaces and fibre formation equipment have a higher productivity than production lines for obtaining cylinders,and therefore have to operate on deferred duties.

Installing equipment to manufacture cylinders aloof from the line will permit to process completely all half-finished products and to obtain simultaneously a big variety of products of specified types and sizes without any reequipping. And it is quite posible to select half-finished mineral wools for stitched mats.

There is a number of projects pertaining to plants for production of the erection insulation. In particular,the Soviet Union has worked out,for all-out applications,projects of a plant with theree technological lines as well as a variant of the project with two lines specialised for manufacturing products and materials for the erection insulation.

At this plant there is a special shop designed to produce metal parts for protective coatings and a conveyor line to completely assemble thermoinsulating structures right at the plant.

In order to obtain the erection insulation it is recommended to construct a shop with two technological lines with cupola and bath furnaces of the output of 100–140 thou.cu.m.designed to manufacture mostly soft,semi-rigid and rigid slabs with synthetic binder.Aloof from the line can be installed equipment to obtain stitched mats,wound cylinders or half-cylinders.

The question about specialization can also be resolved so that plants for the erection insulation will produce only shaped products,stitched mats and insulating cord,and necessary slab materials for industrial units will be produced by plants realizing mass manufacture of such products for general construction needs.

And in turn, a certain number of shaped products for heat insulation of pipings in buildings,and from buildings to heat mains,are supplied to general construction organizations by heat insulation plants.

Most effective economically is to construct a shop with one or two technological lines directly as part of a large house-building,factory or a ferro-concrete structures plant so that the plant should consume all, or a bigger portion of, products of this shop, the remaining portion to be supplied to some others.

Liquidating the necessity in stowage and transportation of thermoinsulating materials will raise considerably the economic efficiency of a plants.

Shops and factories for manufacturing thermoinsulating structures, materials and products as part of a metallurgical works, flame-liquid slags being used, with four technological lines must, having a big production volume (200 and more than cu.m per year), manufacture as a rule general-purpose products expected to be supplied to general construction as well as to spevialized erection firms.

6. Choice of Optimum Raw Material. Influence of Raw Material Type to be Used over Technical and Economic Factors

Technical and economic factors depend essentially on a choice of raw material. It can be stipulated by the following:

- different cost of slag rubble and rock muck,
- different slag rubble and rock muck consumption per production unit;
- different fuel consumption necessary to melt raw material;
- different raw material fusibility degree;
- different outputs of cupola furnaces if different kinds of raw material are used, and corresponding changes in the output.

In order to obtain rock muck it is necessary to organise special quarries, often to carry out baring works, to make special spur tracks.

Slag dumps processing or obtaining slag rubble from special casting metallurgical basins requires as a rule much less investment and operating expenses. Therefore the cost of slag rubble is 1.5-3 times less than that of rock muck. Thus for example, the cost of 1 cu.m of blast furnace slag rubble being about one rouble 50 kopecks, the cost of 1 cu.m. of rock muck will range from 2 roubles 20 kopecks to 4 roubles 70 kopecks.

The rated rock muck consumption is 40-45% higher than that of slag rubble. But practically the difference in raw material consumptions at plants in operation is much greater and reaches 200%.

It should be noted that matching consumptions of different raw materials at various operating plants is to a great extent conditional because the raw material consumption level depends not only on types of raw materials but on a number of other factors such as nomenclature, output of products by types actual weight of raw material and products, main technological production decisions, level of production organisation, and especially strict observance of technological duties.

Absolutely convincing would be comparative data on consumptions of different raw materials, other conditions being identical. Yet if a large number of plants are compared then such comparison gives rather convincing results confirming in general the rated data.

Consumption of technological fuel to melt raw material is directly proportional to the fuel consumption per production unit as well as to the melting time. Thus, increasing fuel consumption, when using rock muck as raw material, will also increase raw material consumption and its refractoriness, It is established by special calculations tahat coke consumption per 1 ton of the melt, working on slag rubble, is 160 kg; working on rock muck - 285 kg, i.e. higher by 78%.

Similar data were received by calculations carried out during the development of projects for plants on production of mineral wool thermoinsulating materials. The difference was 82%.

The difference in factual consumptions at plants in operation is far greater. It is characteristic that the lowest consumption of coke per production unit occurs at plants operating on slag rubble and by the way it is close to the rated consumption.

Coke expenses for mineral wool production are up to 25% of the total. In can be explained by a very high coke cost - tens of times exceeding that of raw material.

The coke cost can fluctuate considerably depending on its grade and sort as well as on a given production area. On the average it can range from 23 to 58 roubles per 1th.

In regard to the fact that plants are sited most oftener in areas where products can be consumed, fuel and raw material are transported by railway. But increasing raw material and fuel consumptions per production unit will entail some additional transport expenses.

Thus coke expenses, when using rock muck insted of slag rubble as raw material, are increased by average 20% of the total expenses on production of one cu.m. of mineral wool fibres.

The duration of raw material melting depends directly on the coke consumption per 1 ton of the melt. Therefore increasing the coke consumption in melting rock muck means a corresponding decrease in the mineral wool output.

But the total expenses on manpower as well as overhead expenses are invariable and for this reason such expenses per one cu.m of mineral wool, the output being on the decrease, go up respectively. A degree of decrease in the productivity of equipment when operating on rock muck depends not only on raw material characteristics but also on a number of other factors such as a type and output of a smelter, power of technological equipment, etc.

Therefore comparing the productivity of equipment in different projects and at various plants in operation is to a certain extent conditional.

Most significant are comparisons on the basis of special calculations made for operations on different raw materials, other conditions being equal. Such calculations were carried out when technological design norms were being worked out, and in some projects designated for frequent use ("standard" projects).

These calculations have shown tahat the productivity of technological equipment when operating on rock muck compared to that when working on slag rubble with correcting admixtures is less by 45% on the average.

Accordingly go up "constant" expenses per production unit of mineral wool fibres, i.e. wages shop and plant expenses, - by 60%.

The above-numerated data indicate the advantage of use of slag raw material over rock muck from the economical point of view. Use of flame-liquid blast furnace slags as raw material is most effective.

7. Production Funds of Plants.

Main Funds.

Capital investments in construction of plants for manufacturing mineral wool thermoinsulating products are comparatively small but their efficiency is great. Rated investments per 1 cu.m of products are 10 to 39 roubles regarding the production volume, nomenclature and main technological decisions. The lowest investments occur in constructing a shop with 4 technological lines as part of a metallurgical works, using flame-liquid slags as raw material.

Low investments are possible thanks to a plant's high output and also to low capital investment in construction of objects of plant an non-plant character.

Especially big investments are put in construction of a small autonomous plant with one technological line under highly unfavourable conditions and operating on carbonate raw material. In this case high investments are because of a plant's low efficiency and because of comparatively high investments in construction of objects of plant and non-plant character.

Construction of such plants can be justified in areas where needs in thermoinsulating materials are small.
for

But minimum investments should not be followed sonce it is far from always possible to erect a shop as part of a metallurgical works, and the need in mineral wool thermoinsulating materials in an area where a shop is planned to be built is not always great enough.

Construction of plants with two technological lines and operating on slags with admixtures, the output being 136 thom.cu.m and more of thermoinsulating materials for general construction works per year, is more economic.

In this case investments per production unit are 14-15 roubles when erecting a shop as part of a building materials factory or other industrial plant, and 16 roubles when constructing an autonomous plant. If slag raw material is not available and operation is effected on rock muck the capital investments will go up to 20-22 roubles accordingly. When constructing a plant, with three technological lines and with the output of 160 and more thom.cu.m. per year for manufacturing mineral wool materials and products for the erection insulation, investments will be 16 to 21 roubles regarding the type of an enterprise (plant, shop) and types of source material.

Rated capital investments can vary essentially depending on a plant's variety of products. In this connection, Tables 13-18 show rated investments in regard to the plant's efficiency, its type and character of raw material as well as to the production volume and nomenclature of products.

CAPITAL INVESTMENTS IN CONSTRUCTION OF PLANTS FOR MANUFACTURE OF MINERAL WOOL THERMOINSULATING PRODUCTS (per 1 cu.m.of wools)

Table 13

NAME	Plant Power	Rated Investments, in roubles Including				
		Total	Construction and erection works	Equipment	Other expenses	Expenses on tying, out from the total
1	2	3	4	5	6	7
Mineral wool products						
A. For general construction works						
Working on blast-furnace slags with admixtures.	1 line	29.15	18.30	9.18	1.67	9.70
	2 lines	16.29	10.52	4.90	0.87	4.60
Working on flame-liquid slags, being part of metallurgical works in operation	4 lines	10.37	6.93	2.91	0.53	0.40
As part of new metallurgical works under construction	4 lines	11.89	7.94	3.35	0.60	1.80
Working on carbonate raw material	1 line	38.89	24.43	12.26	2.21	12.9
	2 lines	21.61	13.95	6.49	1.17	6.10
B. For erection insulation						
Working on blast furnace slags	3 lines	17.32	10.51	5.93	0.88	3.80
Working on rock muck	3 lines	20.53	12.49	7.02	1.02	4.50

Notes: 1. When building shops to manufacture the general construct insulation as part of a building materials factory or bases of the construction industry, the present norms are corrected with the coefficient = 0.9.

Table 13

2. Rolled and slab products are obtained at plants manufacturing materials for general construction works; slab and shaped products: cylinders, half-cylinders, segments - at plants manufacturing materials for special orection works. Rated invesments were estimated per 1 cu.m.of produots,proceeding from the following production pattern for different products given in Table 14.

Production Volumes and Nomenclature of Mineral Wool Products in Estimating Rated Capital Investments (thou. cu. m)

Table 14

Technological Lines	Products with Synthetic Binder: Semi-rigid slabs γ=150 kg/cu.m	Soft slabs γ=100 kg/cu.m	Cylinders γ=150 kg/cu.m	Half-cylinders γ=150 kg/cu.m	Rigid Slabs with Synthetic Binder γ=150 kg/cu.m	Mats Stitched γ=200 kg/cu.m: on mesh	on fibre glass	on paper	Insulating cord: γ=200 kg/cu.m	Total
One line:										
operating on blast-furnace slags	18	27.4	18							63.4
operating on rock muck	13.5	20.5	13.5							47.5
Two lines:										
operating on blast-furnace slags	54	82								136
operating on rock muck	41	61.5								102.5
Three lines:										
operating on blast-furnace slags	54		54	32		8	3	2	4	157
operating on rock muck	41		54	24.4		6	2.5	1.5	3.3	132.7
Four lines:										
operating on flame-liquid slags	81	41	54		54					230

Distribution of Rated Investments (in roubles & kopecks) per 1 cu.m of Products for Shops to Manufacture Mineral Wools with Synthetic Binder, Operating on Blast-Furnace Slags with Admixtures

Table 15

EXPENSES	Total investments per 1 cu.m of products	Including			Types of Products from Mineral Wools with Synthetic Binder							
					Soft Slabs γ =100 kg/cu.m				Semi-Rigid Slabs γ =150 kg/cu.m			
		Constr and Erect. Works	Equipment	Other Works	Total investments	constr. & erec. works	equipment	other works	Total investments	constr. & erec works	equipment	other works
1. On shop objects	10.44	6.74	3.14	0.56	8,66	5.59	2.60	0.47	13.14	8.48	3.95	0.71
2. On all-plant objects, 20% (conditional)	2.09	1.35	0.63	0.11	1.73	1.12	0.52	0.09	2.63	1.70	0.79	0.14
3. On non-plant objects, 30% (conditional)	3.76	2.43	1.13	0.20	3.11	2.11	0.93	0.17	4.73	3.06	1.42	0.25
Total:	16.29	10.52	4.90	0.87	13.50	8.72	4.05	0.73	20.50	13.24	6.16	1.10
Operating on carbonate raw material	21.61	13.95	6.50	1.16	18.00	11.63	5.41	0.96	27.00	17.42	8.12	1.46

Distribution of Rated Investments (in roubles & kopecks)
per L cu.m of Products in Shops to Manufacture Mineral Wools for Heat
Insulation of Equipment & Pipings, with the Output of I50 thou. cu. M
per year (operating on blast-furnace slags with admixtures)

Table I6

Expenses	Investment per Icu.m of products	Construct. and Erect Works	Equ-ipm.	Other Work	Types of Mineral Wool Products: Semi-Rigid Slabs γ =I50 kg/cu.m				Rolled Half-Cylinders γ =I50 kg/cu.m				Hollow Cylinders γ =I50 kg/cu.m				Mineral Wool Mats Stitched γ = 200 kg/cu.m				Insulating Cord γ =200 kg/cu.m			
					Investment	Construc and Erec Work	Equ-ipm.	Other Work	Investment	Const and Erect Works	Equ-ipm.	Other Work	Investment	Const and Erect Works	Equ-ipm.	Other Work	Investment	Construc and Erec Work	Equip.	Other Work	Investments	Construc and Erec Work	Equipments	Other Works
I. On shop objects	I2.I5	7.37	4.78		I065	6.9I	3.74		I6.27	I0.94	5.33		I2.II	7.4I	4.70		8.49	2.I7	6.32		II.80	I.50	I0.30	
2. On all-plant objects	2.28	I.39	0.I6	0.73	2.28	I.39	0.I6	0.73	2.28	I.39	0.I6	0.73	2.28	I.39	0.I6	0.73	2.28	I.39	0.I6	0.73	2.24	I.36	0.I6	0.72
3. On non-plant objects, 30% (conditional)	2.89	I.75	0.99	0.I5	2.59	I.66	0.78	0.I5	3.72	2.47	I.I0	0.I5	2.88	I.76	0.97	0.I5	2.I6	0.7I	I.30	0.I5	2.8I	0.57	2.09	0.I5
Total	I7.32	I0.5I	5.93	0.88	I5.52	9.96	4.68	0.88	22.27	I4.80	6.59	0.88	I7.27	I0.56	5.83	0.88	I2.93	4.78	0.78	0.88	I6.85	3.43	I2.55	0.87

Distribution of Rated Investments (in roubles & kopecks) per I cu.m of Products in Shops to Manufacture Mineral Wools from Flame-Liquid Slags, with the Output of 200 thou. cu. m per year (Shops as Parts of Metallurgical Works in Operation)

Table I7

Expenses	Total Investment per Icu.m of Products	Construct. and Erect Works	Equipment	Other Works	Types of Products from Mineral Wools with Synthetic Binder															
					Semi-Rigid Slabs γ=I50 kg/cu.m				Soft Slabs γ=I00 kg/cu.m				Rigid Slabs γ=I50 kg/cu.m				Hollow Cylinders γ=I50 kg/cu.m			
					Investment	Construct. and Erect. Works	Equipment	Other Works	Investment	Construct. and Erect. Works	Equipment	Other Works	Investment	Construct. and Erect. Works	Equipment	Other Works	Investment	Construct. and Erect. Works	Equipment	Other Works
I. On shop objects	9.43	6.30	2.65	0.48	8.89	6.38	2.03	0.48	7.23	4.83	I.92	0.48	9.42	6.67	2.27	0.48	II.84	6.93	4.43	0.48
2. On all-plant objects, I0% (conditional)	0.94	0.63	0.26	0.05	0.89	0.64	0.20	0.05	0.72	0.48	0.I9	0.05	0.95	0.67	0.23	0.05	I.I8	0.69	0.44	0.05
Total:	I0.37	6.93	2.9I	0.53	9.78	7.02	2.23	0.53	7.95	5.3I	2.II	0.53	I0.37	7.34	2.50	0.53	I3.02	7.62	4.87	0.53

Distribution of Rated Investments (in roubles & kopeoks)

per I cu.m of Products in Shops to Manufacture Mineral Wools from Flame-Liquid

Slags, with the Output of 200 thou. cu. m per year (Shops as Parts of New

Metallurgical Works under Construction)

Table I8

Expenses	Total: Investments per Icu.m of products	Construct. and Erect Works	Equipment	Other Works	Types of Products from Mineral Wools with Synthetic Binder: Semi-Rigid Slabs γ=I50 kg/cu.m				Soft Slabs γ=I00 kg/cu.m				Rigid Slabs γ=I50 kg/cu.m				Hollow Cylinders γ=I50 kg/cu.m			
					Investments	Construct. and Erect Works	Equipment	Other Works	Investment	Construct. and Erect Works	Equipment	Other Works	Investment	Construct. and Erect Works	Equipment	Other Works	Investment	Construct. and Erect Works	Equipment	Other Works
I. On shop objects	9.43	6.30	2.55	0.48	8.89	6.38	2.03	0.48	7.23	4.83	I.92	0.48	9.42	6.67	2.27	0.48	II.84	6.93	4.43	0.48
2. On all-plant objects, 20% (conditional)	I.90	I.26	0.54	0.I0	I.77	I.27	0.40	0.I0	I.45	0.97	0.38	0.I0	I.83	I.33	0.45	0.I0	2.36	I.38	0.88	0.I0
3. On non-plant objects, 5% (conditional)	0.56	0.38	0.I6	0.02	0.53	0.38	0.I2	0.03	0.43	0.29	0.II	0.03	0.57	0.40	0.I4	0.03	0.70	0.4I	0.26	0.03
Total:	II.89	7.94	3.35	0.60	II.I9	8.03	2.35	0.6I	9.II	6.09	2.4I	0.6I	II.87	8.40	2.86	0.6I	I4.90	8.72	5.57	0.6I

8. Wholesale Prices on Mineral Wool Thermoinsulating Materials, Products and Structures and Their Prime Costs.

Wholesale prices and the prime cost of mineral wool thermoinsulating materials products and structures are analysed on the basis of industrial practice and wholesale trade in the Russian Federation of the Soviet Union as well as in some other Union Republics.

Planned prime costs at new plants to be built are analysed, taking into account use of modern equipment and up-to-date technology.

The RSFSR's current wholesale prices on mineral wool thermoinsulating materials, products and structures as well as on commercial mineral wool have been established proceeding from the weighted average cost of these products in 1965 at the plants situated in the Russian Federation's territory.

When defining wholesale prices rather a high level of profitableness should be specified from 16 to 24% regarding types of products (19% on the average).

The Russian Federation's current wholesale prices are given in Table 19.

It should be taken into consideration that the cost of products on which these prices are based is much higher than the rated cost according to earlier projects. For lower must be the cost of products at newly built plants which will be operating on modern highly efficient equipment.

WHOLESALE PRICES OF MINERAL WOOL STRUCTURES, PRODUCTS AND MATERIALS

(per 1 cu.m)

Table 19

NN	Name	Type	Volume weight kg/cu.m	Price roubles an
1	2	3	4	5
1.	Mineral wool	75	75	7.90
		100	100	7.60
		125	125	7.40
		150	150	7.10
2.	Mineral wool drawn, rolled "ВФ"	75	75	12.00
3.	Structures in set of mineral wool half-cylinders with phenol binder with protective coating from aluminum-base alloy sheet (coating 1 mm thick)	Half cylinder inner Ø, mm	Insulating layer thickness, mm	
		57	60	138.00
		76	60	121.00
4.	Structures in set of mineral wool hollow cylinders with protective coating from aluminum-base alloy sheets (coating 1 mm thick)	116	60	111.00
		161	60	102.00
5.	Mineral wool mats glued to lining with bitumen	100	100	11.00
6.	Mineral wool mats stitched: 1) with linings of metal mesh, mats 80 mm thick	150	150	22.00
		200	200	24.00
		250	250	26.00
	2) ditto, mats 60mm thick	150	150	26.00
		200	200	28.00
		250	250	30.00

Table 19 (cont)

1	2	3	4	5
	3) ditto,mats 40mm thick	150	1[illegible]	35.00
		200	200	37.00
		250	250	39.00
	4) with linings of crimped paperboard from one side and kraft paper from the other,mats 80mm thick	150	150	17.00
		200	200	19.00
		250	250	21.00
	5) ditto,mats 60mm thick	150	150	19.00
		200	200	21.00
		250	250	23.00
	6) ditto,mats 40mm thick	150	150	25.00
		200	200	27.00
		250	250	29.00
	7) with lining of metal mesh from one side and fibre glass from the other,mats 80mm thick	150	150	29.00
		200	200	31.00
		250	250	33.00
	8) ditto,mats 60mm thick	150	150	35.00
		200	200	37.00
		250	250	39.00
	9) ditto,mats 40mm thick	150	150	48.00
		200	200	50.00
		250	250	52.00
	10) with lining of paper from two sides,mats 80mm thick	150	150	14.00
		200	200	16.00
		250	250	18.00
	11) ditto,mats 60mm thick	150	150	15.00
		200	200	17.00
		250	250	19.00

Table 19 (cont)

1	2	3	4	5
	12) ditto, mats 40mm thick	150	150	19.00
		200	200	21.00
		250	250	23.00
7.	Mineral wool mats stitched on metal mesh:	МП/С	100	
	mats 100mm thick			18.00
	" 90 "			19.00
	" 80 "			20.00
	" 70 "			21.00
	" 60 "			22.00
	" 50 "			24.00
	Mats stitched on bituminous paper:	МП/Б	100	
	mats 50mm thick			16.00
	" 40 "			17.00
	" 30 "			18.00
8.	Common rigid mineral wool slab bitumen-bonded	250	250	45.50
		300	300	41.50
		350	350	38.50
		400	400	35.50
9.	Semi-rigid mineral wool slabs bitumen-bonded	250	250	21.50
		300	300	19.50
		350	350	18.50
		400	400	17.50
10.	Soft mineral wool slabs bitumen-bonded	100	100	8.40
		150	150	7.40
11.	Rigid mineral wool slabs bitumen-bonded	ПЖ	175	28.50
12.	Semi-rigid mineral wool slabs bitumen-bonded	ПП	150	24.50
13.	Soft mineral wool slabs bitumen-bonded	ПМ	100	17.50
14.	Semi-rigid mineral wool slabs starch bonded	125	125	17.00
		150	150	19.00
		200	200	24.00

Table 19 (cont)

1	2	3	4	5
15.	Mineral woo slabs "Вф" with syntheric binder	ПМ-30 ПМ-40 ПМ-50 ПП-80 ПП-100	30 40 50 80 100	8.50 11.00 14.00 23.00 29.00
16.	Mineral wool half-cylinders with synthetic binder	150 200	150 200	25.50 32.50
17.	Mineral wool hollow cylinders with synthetic binder	150 200	150 200	31.00 40.00

Table 20 gives data on the actual cost of products as to plants operating in the Soviet Union (for the year of 1967). It is clear from the data how considerable are reserves to reduce the prime cost and to raise economic efficiency of the manufacture of mineral wool thermoinsulating structures, products and materials.

Prime Costs of Mineral Wool Thermoinsulating Structures, Products and Materials as to Plants Operating in the USSR (in roubles and Kopecks)

Table 20

NN	Products and Materials	Prime Cost	
		Average	Minimum
I.	Minearal wool structures, products and materials with synthetic binder		
	1. Soft slabs	11	8.60
	2. Semi rigid slabs	16	10.30
	3. Rigid slabs	18	-
	4. Half-cylinders: a) rolled	19	16.70
	b) moulded	42	-
	c) cut	39	-
	5. Cylinders	43	37
	6. Structures completely plant-made of cylinders with metal protective coatings	104	-
II.	Mineral wool slabs bitumen-bonded: a) soft (felt)	5	4.00
	b) semi-rigid	12	10.00
	c) rigid	35	20.00
III.	Mineral wool mats stitched	18	9.00
IV.	Mineral wool slabs starch bonded	8	-
V.	Commercial mineral wools	6	3.60

The prime cost of products at plants newly built in the USSR owing to standard projects and having a higher technical level of production is about 1.5 times lower than wholesale prices, and those plants operate very profitably.

Thus, use of highly efficient up-to-date equipment must allow for further reduction of the prime cost of products compared to the cost at those plants. The level of profitableness of manufacturing mineral wool materials and products is shown in Table 21.

Profitableness of Manufacture of Mineral Wool Thermoinsulating Materials, Products and Structures

(in % per the total prime cost of products)

Table 21

Products	Profitableness Level	
	Branch Industry Average	Maximum
I. Mineral wool structures, products and materials with synthetic binder:		
1. Soft slabs	40	100
2. Semi-rigid slabs	,40	127
3. Rigid slabs	46	46
4. Half-cylinders:		
a) rolled	25.7	40
b) moulded	19	40
c) cut	24	24
5. Cylinders	16 3% loss	16 3% loss
6. Structures completely plant-made of cylinders with metal protective coatings	6	6
II. Mineral wool slabs bitumen-bonded:		
a) soft	38	64
b) semi-rigid	34	59
c) rigid	26	112

Table 21 (cont)

III.	Mineral wool mats stitched	36	121
IV.	Mineral wool slabs starch bonded	52	52
V.	Commercial mineral wools.	13	16

The latest data for the year of 1968 on the manufacture of these products by a number of plants in the Soviet Union being partners of a large specialised construction erection firm are most significant in estimating economic efficiency of the manufacture of mineral wool thermoinsulating materials, products and structures.

Thus the prime cost of soft slabs with synthetic binder is 10 roubles, i.e. is lower by 10% than the branch industry average cost, the cost of semi-rigid slabs is 15 roubles that is lower by 6% than the 1967 cost; cut cylinders- 35 roubles, or less by 20% than the 1967 cost (this plant is unique):

- wound cylinders-34 roubles, i.e. less by 8% than in 1967;
- rolled half-cylinders- 18 roubles, or lower by 6% than the 1967 cost;
- rigid slabs with bituminous binder-28 roubles, i.e less by 20% than the 1967 cost

Distribution of actual costs (i.e.costs of products) as to expenses for different types of products is far from being even, and this depends on objective conditions of their production as well as on attendant occasional factors.

Tables 22-25 represent specific technological consumptions of raw and other materials, fuel and electric power necessary for the manufacture of various kinds of products. These consumptions were taken according to the projects in regard with which plants are being erected in the Soviet Union.

E X P E N S E S
on Manufacture of Mineral Wool and its Products (in % as to I967)

Table 22

NAME	Mineral Wool	Mineral Wool Slabs: Bitumen-Bonded: Soft	Bitumen-Bonded: Semi-rigid	Bitumen-Bonded: Rigid	With Synthetic Binder: Soft	With Synthetic Binder: Semi-rigid	With Synthetic Binder: Rigid	Shaped Mineral Wool products with Synthetic Binder: Cylinders	Shaped Mineral Wool products with Synthetic Binder: Half-cylinders
I. Raw material	I5-I8	I6	22	22	45	48	58	49	45
2. Technological fuel	25	31	24	11	16	16	14	7	10
3. Technological el.power	7	6	6	6	4	4	1	1	15
4. Wages of industrial workers serving main technological lines	12	11	10	15	6	6	8	12	5
5. Maintenance of equipment	9	9	14	11	7	7	6	-	-
6. Shop expenses	16	7	12	23	11	11	7	27	18
7. All-plant expenses	7	6	5	9	5	4	3	2	4
8. Non-production expenses	7	13	7	3	6	4	1	2	3

Rated Consumption of Material & Power Resources by Shops with Two Technological Lines for Manufacturing Products from Mineral Wools with Synthetic Binder (per 1 cu. m of products)

Table 23

N A M E	Unit measure	Blast-Furnace Slags with Admixtures as Raw Material					Rock Muck as Raw Material				
		Types of Soft Slabs		Types of Semi-rigid Slabs			Types of Soft Slabs		Types of Semi-rigid Slabs		
		75	100	125	150	200	75	100	125	150	200
Raw material:											
blast-furnace slags	cu.m	0.052	0.070	0.087	0.104						
rock muck (rubble)	kg	47	63	78	94	126	150	200	250	300	400
or brick rubble	"	33	44.5	55.4	66	89					
phenolspirits of 50% concentration	"	10	13.5	16.7	20	27	10	13.5	16.7	20	27
Technological fuel:											
coke KA-II when operating on rock or blast-furnace slags with admixtures of rock muck	"	16.7	22.2	27.9	33.4	45	30	40	50	60	80
coke KA-II when operating on slags with admixtures of brick rubble	"	15.5	20.3	25.9	31	41.5					
or mazut	"	3.73	5	6.25	7.45	10	4.65	6	7.55	9.1	12
or natural gas	cu.m	4.3	5.8	7.2.	8.6	11.6	5.4	6.9	8.75	10.5	13.9
Technological steam (operating on mazut)	kg	3.7	5	6.25	7.45	10	4.65	6	7.55	9.1	12
Technological water	cu.m	0.235	0.318	0.396	0.47	0.64	0.38	0.51	0.64	0.77	1.02
Technological el.power:											

Table 23 (cont.)

	Unit	75	100	125	150	200	75	100	125	150	200
operating on mazut	kwhr	10	13.4	16.8	20	26.8	17.3	23	28.8	34.6	46
operating on gas	"	9.8	13.1	16.4	19.5	26.2	16.9	22.4	28.2	33.8	45
Wages of industrial workers	roubles & kopecks	0.23	0.30	0.38	0.45	0.61	0.39	0.53	0.65	0.78	1.01
Shop prime cost:											
operating on liquid fuel (mazut)	"	6.03	8.10	10.64	12.06	16.22	7.36	9.89	11.38	14.71	19.74
operating on natural gas	"	5.99	8.06	9.98	11.98	16.12	7.31	9.82	11.29	14.60	19.68

Rated Consumption of Material & Power Resources and Prime Costs at Plants for Manufacturing Mineral Wool Products for Heat Insulation of Equipment & Pipings (per 1 cu.m of products)

Table 24

NAME	Unit measure	Blast-Furnace Slags with Admixtures as Raw Material							Rock Muck as Raw Material						
		Products with Synthetic Binder, type-150			Mats Stitched with Linings, type-150			Insulating cord	Products with Synthetic Binder, type-150			Mats Stitched with Linings, type-150			Insulating cord
		semi-rigid slabs	rolled half-cylinders	holl. cylinders	on mesh	on fibre glass	on paper		semi-rigid slabs	roll. half-cylinders	holl. cylinders	on mesh	on fibre glass	on paper	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Raw material:															
blast-furnace slags (rubble)	kg	120	134	120	160	160	160								
rock (rubble)	"	56	63	56	74	74	74		250	276	250	332	332	332	
phenol spirits of 50% concentration	"	17	19	17					17	19	17				
petrolatum	"			0.5							0.5				
cutting emulsion	"	2	2.2	2	2.6	2.62	2.6		2	2.2	2	2.6	2.6	2.6	
braided mesh [redacted]	"				21.5							21.5			
hexahedral mesh Nr 20	"				6.4							6.4			
wire steel, black 0.5mm in diameter	"				0.725							0.725			
wire zinc-coated 1.2mm in diameter	"							5							5

Table 24 (cont.)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Fibre glass 0.2mm thick	sq.m					50							50		
Binding paper twine 0.4mm thick	kg					0.5	0.5						0.5	0.5	
Crimped paper board 260 gr/sq.m heavy	"					6.5	6.5						0.5	6.5	
Paper for sacks 80 gr/sq.m heavy	"						3.2							3.2	
Technological fuel:															
coke KA-II	"	42	46		55	55	55		72	80		96	96	96	
mazut	"	15.8	18	53					21	24	53				
Technological water	cu.m	0.85	0.95	1.1	0.8	0.8	0.8		1.1	1.2	1.1	1.3	1.3	1.3	
Technological steam	kg	6	6.6	20					9	10	20				
Technological electric power	kwhr	54	60	60	32	32	32	100	71	79	60	42	42	42	100
Wages of industrial workers	roubles & kop.	0.40	0.60	0.60	1.33	1.26	1.25	5.15	0.40	0.78	0.60	1.78	1.56	1.60	6.24
Shop prime cost: operating on mazut	"	11.25	12.90	12.22	13.29	36.65	8.10	21.70	12.86	15.07	12.48	16.08	38.88	11.07	25.17
" on natural gas	"	11.03	12.77	11.56	13.29	36.65	8.10	21.70	12.60	14.73	11.77	16.08	38.88	11.07	25.17
Plant prime cost: operating on mazut	"	11.56	13.37	12.70	14.33	37.60	9.10	25.70	13.27	15.68	12.91	17.46	40.15	12.27	30.02
" on natural gas	"	11.33	13.22	12.02	14.29	37.55	8.94	25.57	13.00	15.32	12.23	17.42	40.08	12.19	29.87
Total prime cost: operating on mazut	"	11.73	13.57	12.89	14.54	38.16	9.24	26.08	13.47	15.91	13.10	17.72	40.75	12.45	30.47
" on natural gas	"	11.50	13.44	12.20	14.50	38.11	9.07	25.95	13.19	15.55	12.41	17.68	40.68	12.37	30.32

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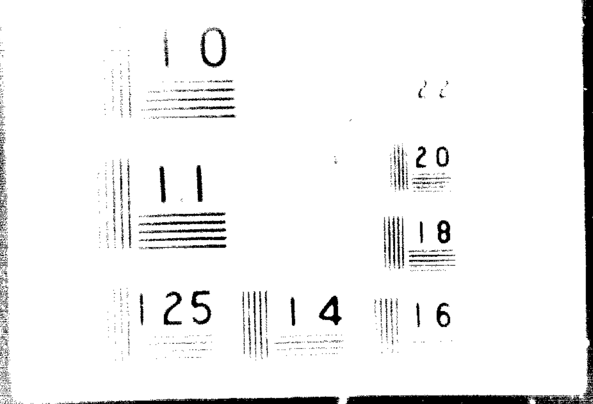


Rated Consumption of Material & Power Resources for Manufacture of Mineral Wool Products with Synthetic Binder from Flame-Liquid Slags, with the Output of 200 thou. cu. m per year

Table 25

NAME	Unit Measure	Semi-Rigid Slabs, Type 150	Rigid Slabs, Type 150	Hollow Cylinders: Type 150	Soft Slabs, Type 100
Raw material:					
flame-liquid slags	kg	170	170	170	113
QUARTZ sand	"	32	32	32	21.5
phenol spirits of 50% concentration	"	17	9	17	11.3
polyvinylacetate emulsion of 50% concentr.	"		22		
cutting emulsion	"	2	2	2	1.35
petrolatum IIK	"			0.5	
Technological fuel:					
natural gas (Q_p^H=3000 Cal/cu.m)	"	38	38	29	25
coke gas (Q_p^H=4000 Cal/cu.m)	"	81	81	62	53
MAZUT (Q_p^H=9300 Cal/kg)	"	34.5	34.5	25.2	22.6
Technological water	cu.m	1.05	1.05	0.9	0.7
Technological steam (for mazut)	kg	12.4	12.4	9.2	[illegible]
Technological electric power	kwhr	52.5	52.5	57	34.6
Wages of industrial workers	roubles & kop.	0.46	0.46	0.57	0.30
Shop prime cost:					
operating on natural gas	"	10.88	29.55	11.39	[illegible]
operating on coke gas	"	11.44	30.11	11.83	7.59
operating on mazut	"	11.36	30.[illegible]	11.73	[illegible]

CHAPTER V

HEAT INSULATION OF PIPINGS, TECHNOLOGICAL & POWER EQUIPMENT AT INDUSTRIAL AND POWER PLANTS

Use of heat insulation for buildings and structures is conditioned by economic expediency.

Use of this insulation for equipment and pipes at industrial objects is dictated by not only economic expediency but also by its technical necessity. Construction of a great number of industrial and power plants without any heat insulation is technically impossible.

The volume of use of the heat insulation for industrial objects is 15% from the total volume of its use in the construction industry.

Besides, technical requirements to thermoinsulating structures, materials and products either in regard to their quality and wide range of physical and technical characteristics or to a large nomenclature, incommensurably exceed requirements to heat insulating materials for general construction purposes.

The heat insulation of buildings operates within a comparatively narrow temperature range - from 50°C below zero up to + 50°C, und in the zone of the temperate climate this range narrows down up ± 20°C, ±30°C.

The temperature range of heat and cold-carrying agents 15
in industrial and power equipment and pipings is extemely large and reaches in many cases temperatures from 70°C below zero up to + 600°C, needless to mention special objects whose surface temperature can range from 170°C below zero up to

+ 1000°C (at higher temperatures refractory fettlings are used).

The heat insulation of buildings operates in conditions where considerable mechanical loads are absent. The heat insulation of industrial units is subject to hydraulic impacts and vibrations, sometimes very intensive. The general construction insulation is exploited within a narrow temperature range: besides, its temperature changes gradually. The surface temperature of technological and power equipment and pipings can often change, and if so, it changes for a very short time.

The industrial insulation of objects outdoors is subject to atmospheric forces and sunbeams.

In some cases the insulation of objects indoors is intensively subject to a chemically aggressive medium.

During exploitation of buildings their repair does not necessarily entail dismantling of the insulation.

Technological and power equipment and often pipings too, are periodically repaired with obligatory dismantling of the heat insulation what emphasises an importance of the question about assembliness of thermoinsulating structures.

Finally, in order to insulate buildings only slab material is used. But complex configuration of equipment to be insulated and various pipe diameters make it necessary to manufacture a wide nomenclature of thermoinsulating materials, products and structures, with a big number of types and shapes. Especially important is the manufacture of structures and products in form of hollow cylinders and half-cylinders of different thicknesses and diameters for all-over insulation of pipings.

Thermoinsulating structures with protective coatings of sheet aluminium, thin-sheet zinc-coated steel, fibre glass plastics and reinforced polymeric films supplied in sets with fastening parts, are most effective for insulation of pipes and equipment. Choice of this or that material for protective coatings of mineral wool thermoinsulating structures depends on conditions in which these structures are to be exploited.

Regarding a great variety of technical characteristics, configuration and conditions of exploitation of technological and power equipment and pipes there is a large number of thermoinsulating materials and products to insulate these objects. Equally with mineral wool products are used fibre glass, sovelite, asbestos-cement volcanite and diatomite products as well as porous plastics.

Technical characteristics of these materials and products, technology and prime cost as well as wholesale prices on them are distinctly different.

But at the same time, owing to their technical properties, many of these materials are interchangeable, and, technically, insulation of many objects with various materials is possible.

Correct option of most effective from the technical point of view and most economic thermoinsulating materials for a certain object, or a group of objects, is very important and requires as much information data as possible.

In this respect a group of specialists has conducted investigations and worked out recommendations on the optimum choice of thermoinsulating materials and products for various groups of objects combined together by similar, within certain limits, technical characteristics.

volume weight and heat conductivity, comparatively low expenses on their production, small specific investments and large temperature range for use.

The heat conductivity of materials and products from mineral wool is 0.040 to 0,055 Cal/m hr°C (at a temperature of 25°C); the heat conductivity of sovelite, perlite, asbestos--vermiculite, lime-silicic products is 0.068 to 0.080 Cal/m hr °C, i.e. higher on the average by 55%. It means that in order to achieve an identical thermal resistance a layer of these products must be over 1.5 times thicker than that of mineral wool.

When insulating pipings the production volume has an increase not proportional to products thickening but to a far greater extent. The volume weight of mineral wool materials and products is as a rule 100 to 200 kg/cu.m, that of sovelite, perlite and other products is 250 to 400 kg/cu.m, i.e. more than two times as much what makes structures much heavier.

Wholesale prices are also much lower than those on other materials and products. They range from 11 to 46 roubles, prices on sovelite and other products from 39 to 69 roubles, i.e. average 85% higher.

As a result, expenses on a thermoinsulating structure from sovelite, perlite and other materials of this group exceed those on a structure from mineral wool materials and products 1.5-2.2 times as much.

In addition, expenses on thermoinsulating structures from mineral wool materials and products being comparatively low, they are far more effective than structures from other

Table 41 shows values of total thermal resistance of panels KOTI-25, 30, 35 and 40 heated with haydite and mineral wool in field along the axis of voids and in joint of a [illegible] width 40 to 50 mm.

Table 41

Heat insulator / Panels	Haydite		Mineral wool [illegible] cm		Mineral wool [illegible] cm		Mineral wool [illegible] cm		Mineral wool [illegible] cm	
	R	Ro	Ro	[illegible]	[illegible]	R	R	Ro	Ro	Ro
KOTI-2[illegible]	1.09	0.66	[illegible]	[illegible]6	.65	[illegible]	–	–	–	
KOTI-30	1.37	[illegible].80	1.2	.20	1.0[illegible]	[illegible]	2.14	0.8		
KOTI-35	1.65	0.95	–	–	1.65	0.80	2.34	0.88		
KOTI-40	1.93	1.11	–	–	–	–	2.14	0.[illegible]	3.00	1.70

Notes: 1. When heating with haydite the voids are filled completely

2. Ro-thermal resistance along the axis of voids

3. Ro-thermal resistance in joint.

Allowed winter temperatures outdoors (in °C) for panels KOTI-30, KOTI-35, KOTI-40 and KOTI $\frac{[illegible]}{60}$ (per room) heated with haydite and mineral wool inserts are given in Table 42.

Heat insulant packages may have various dimensions regarding panel and opening dimensions. An example of rigging a wall panel 2HC2-50уш for an apartment house of series 1-464D with packages of mineral wool is given in Fig.30 and in Tables 38 and 39.

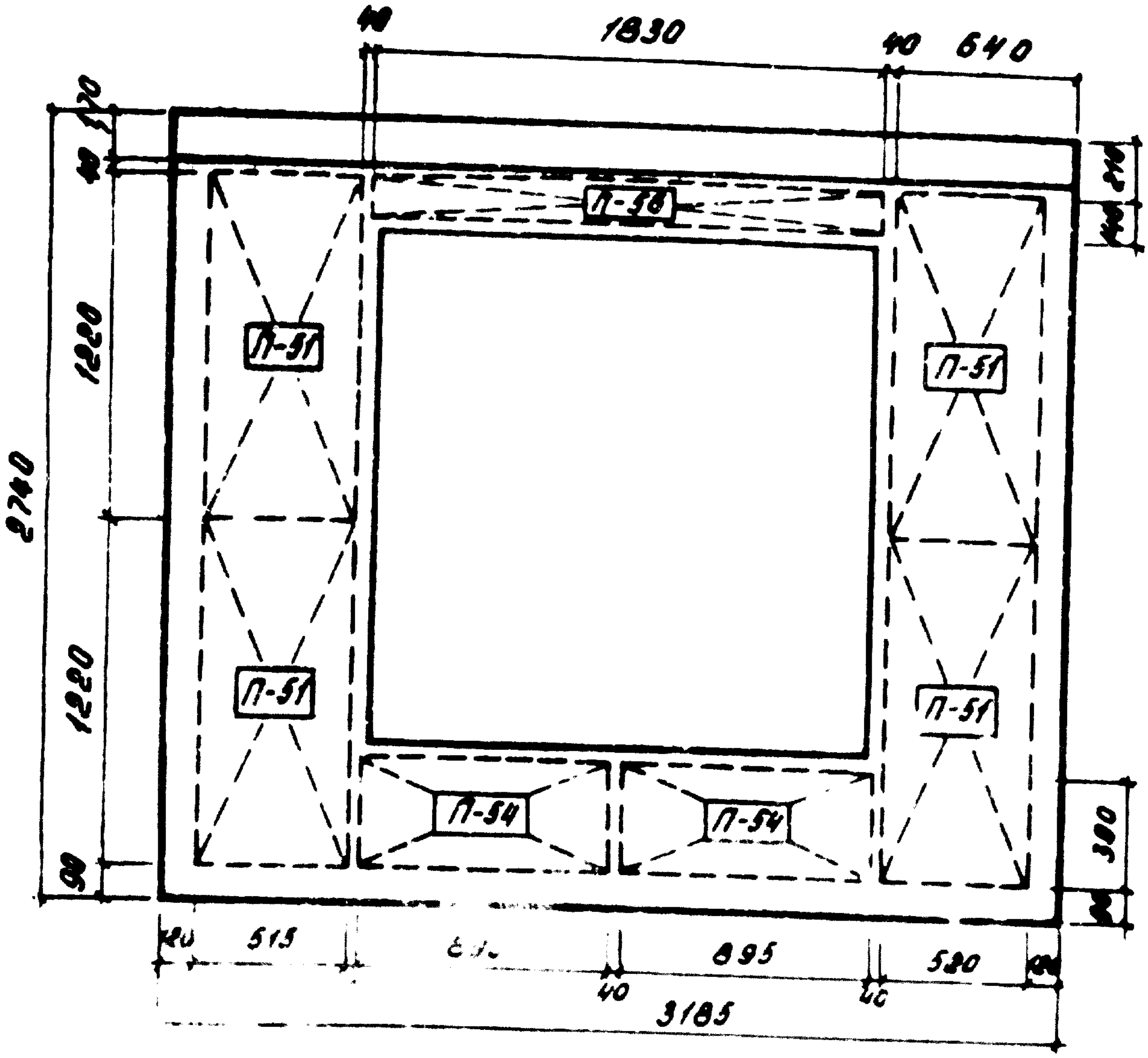
Table 38

Package types	Dimensions, in mm		Amount
	Length	Width	
ФП-51	1220	515	4
П-54	895	390	2
П-56	1830	140	1

Technical and economic characteristicks of three-layer panel heated with mineral wool slabs are illustrated in the table which gives the values of the same panel 2HC2-50 у for an apartment house ~~of series~~ of series 1-464D.

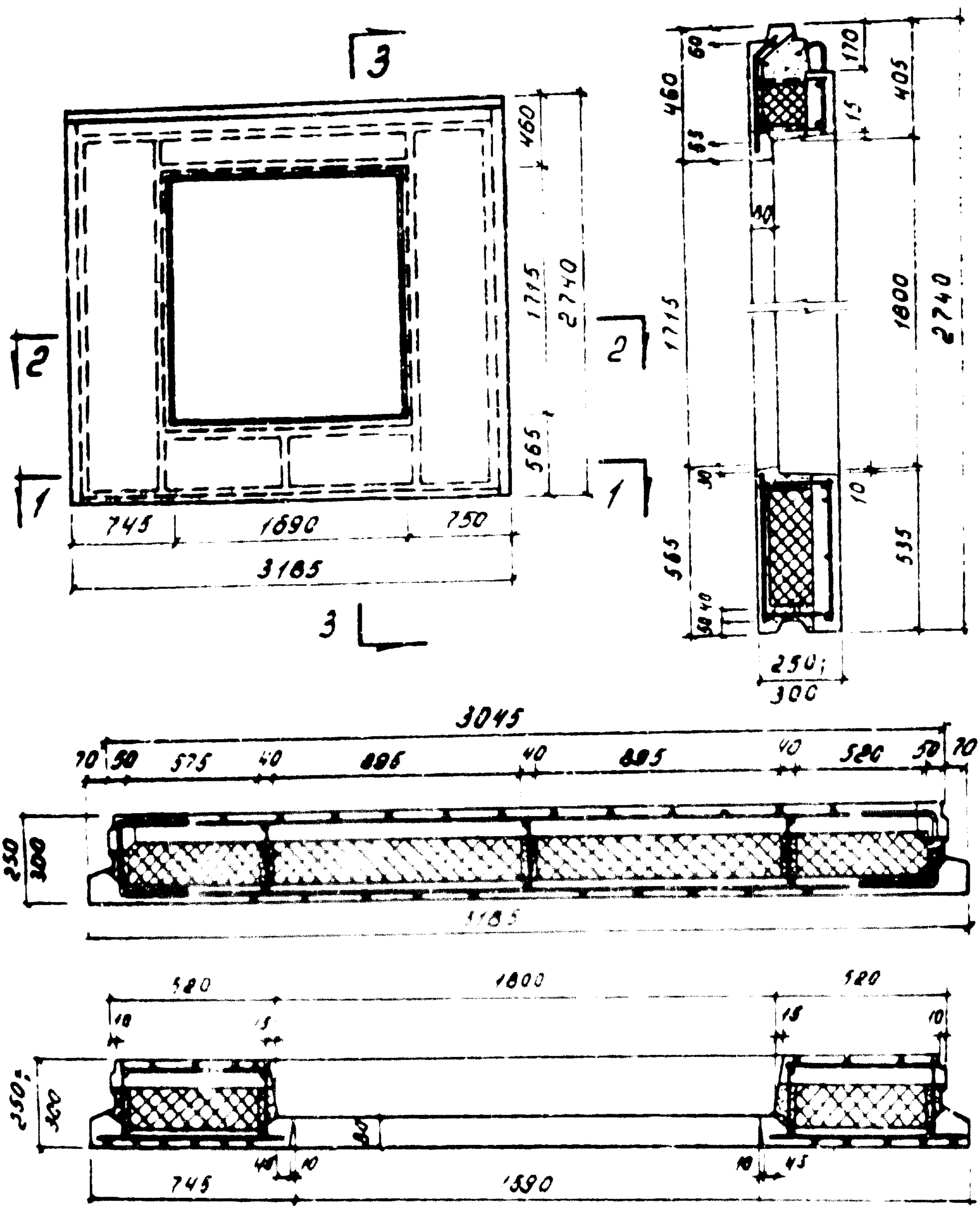
Table 39

Values per 1 panel	Panel Thickness, in mm		
	250	300	350
Weight, tn	2.05	2.40	2.65
Weight of steel, kg	37.26	37.86	38.73
Volume of heavy-weight concrete, cu.m.	0.75	0.75	0.75
Volume of light-weight concrete, cu.m.	0.12	0.18	0.24
Volume of heat insulant, cu.m.	0.34	0.51	0.68



Марка панели. Panel Type	Марка пакета Package	Размеры /мм/ Dimensions				Кол. шт.	Объем утеплит. м³ Heat Insulant Volume, cu.m	
		[illegible]	[illegible]	[illegible]			250	300
2НС2-50У	П-51	1220	515	100	150	4	0.2[illegible]	0.37[illegible]
	П-54	885	390	100	150	2	0.06[illegible]	0.10[illegible]
	П-56	1830	140	100	150	1	[illegible]	0.037
	Total. Итого					20.	0.34	0.51

Fig. 30. Arrangement of Heat Insulating Packages in Outer Wall Panels



Марка	Показатели на панель values per 1 panel	250	300
2НС2-5С1	Вес панели, weight, tn	2.05	2.40
	Вес [illegible] steel kg	37.26	37.88
	Объем тяжел. бетона [illegible] m³	0.15	0.15
	Объем легк. бетона [illegible] m³	0.12	0.18
	Объем утеплителя [illegible] m³	0.34	0.51

Fig. 30. (2nd sheet)

Together with panels of a room's size are also used vibrobrick length- out panels principally of the same structure. They are employed as hinged wall structures for industrial and public buildings. In connection with such a character of their static operation in a building their outer and inner walls are made 1/4 of a brick thick.

To 3-layer panels with mineral wool heat insulants can be referred panels of 2 reinforced concrete elements manufactured by continuous rolling. Thin-walled ribbed slabs of reinforced concrete were used for obtaining so called rolled panels.

A three-layer rolled wall panel consists of two ribbed rolled elements between which there is a thermal insulating layer of mineral wool slabs 100 mm thick (Fig.30). Reinforced ~~shells~~ half-cylinders 30 mm thick are manufactured of concrete of type 200. The size of shells is 300 x 300 mm, height of ribbs - 70 mm. Ribbs are armoured with frameworks of wire 3 mm in diameter. Panels are made of 1 or 2 rooms in size.

In order to obtain panels shells are preliminarily rolled on a rolling mill and then are assembled on a stand by fixing window or door blocks. So as to connect rolled half- cylinders with each other and with conjugated structures special metal embedded parts welded to framework bars are used. These parts are made of sheet steel 4 mm thick amd 40 mm wide. It is possible to fix vibrorolled shells on bolted joints.

Divided manufacture of shells for rolled panels with mineral wool heat insulants and their further assemblage increase the labour - consuming character and cost of such panels. Besides, in cooling rolled shells there can appear cracks.

Manufacture of shells requires an increased consumption of steel. All these drawbacks limit use of rolled panels. Yet due to lack of thermal inclusions and technological moistening of the heat insulant these panels as to their thermal and technical factors considerably outdo panels with connecting ribs where the heat insulant is moistened in the course of moulding and thermal treatment. Thus, a panel 26 cm thick heated by a semi-rigid mineral wool slab with the volume weight of γ= 100 kg/cu.m, 100 mm thick has a total thermal resistance Ro= 1.90 sq.m.hr °C/Cal, what considerably exceeds similar values and use range of 3-layer panels described above. Thermal stability of such a panel in summer is sufficient to be used as a main element of a wall structure for apartment houses, the rated summer temperature being up to 30°C.

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5. Use of Mineral Wool Heat Insulants in Asbestos-Cement Wall Panels

A pier wall insert-panel of asbestos-cement consists of a wood framework, heat insulant and coating (outer and inner) of flat asbestos-cement sheets.

A. Wood framework.

A framework is assembled of 2 vertical blocks 100 x 60 mm placed in the middle and three couples of horizontal blocks 50 x 60 mm fastened from outer and inner sides to the vertical b blocks. In points of intersection each block overlaps the plane of the perpendicular block by 10 mm to permit arranging in each intersection 4 nails 4 x 90 mm to be hammered into preliminarily drilled holes 3.5 mm in diameter and which are taken as steel pegs. It is also stipulated to glue the blocks in crossing points with phenolformaldehyde moisture-proof glues of type C-4 intended for construction purposes. In order to join haydite concrete panels and the insert there are embedded wooden bars to be inserted in required points and which are fixed to the main framework by nails. Framework blocks and bars must be manufactured planed from 3 sides, rectangular cross sections are obligatory.

B. Asbestos-cement coating sheets.

Asbestos-cement coating sheets 1365 x 1250 (inner) and 1355 x 1250 (outer) mm, and γ being equal to 1.6 gr/ cu.cm are cut out from flat larger sheets (2800 x 1640 x 10 mm).

Such sheets are characterised by a high strength and resilience.

The outer surface of an outer sheet is painted two times with waterproof facade paints of type and ЦПХВ ПХВ of a number required.

C. Heat insulant.

As a heat insulant mineral wool slabs with synthetic binder, with the volume weight being not more than 100 kg/ cu.m and the heat conductivity 0.045 Cal/m hr C are employed. Slabs 50 mm thick are placed into the panel cavity in two layers. From the outer side are laid vertical (for rated position) strips of the heat insulant from the same slabs to form an air layer between the strips. Heat insulating slabs overlap the end facets of the panel by 20mm for joints packing. Slabs are laid thrust-wise between wooden blocks to prevent settling of the heat insulant in some time.

Experimental panels were manufactured at a wood-working factory of the "Cherepovetsmetallurgstroy" trust.

The asbestos-cement insert-panel is 1385 x 1220 x 220 cm.

Characteristics of Products Table 40

Products	Unit	Amount	Weight,kg
Asbestos-cement Sheets	sq.m	3.34	58.3
Wood	cu.m	0.055	27.5
Heat insulant	cu.m	0.22	13.5
Galvanized screws	pcs	24	0.15
Nails 4 x 100 mm	pcs	75	0.75
Formaldehyde glue	kg		0.20
		Rated pannel weight	100.2

A necessity in differentiated approaches, taking into consideration the branch specificity, is quite obvious from the analysis of the given table.

E.g., the average volume of the insulation for apparatus beig 27%, this percentage in metallurgy is reduced to 0°C, or 2%, [illegible], and at food factories and power plants it is half of the total volume - 44 to 46%.

According to temperature zones distribution of volumes of woorks is characterized by the presence of mass objects, the insulation operating within the limits of + 10°C to 300°C, i.e. 74%; zones lower than 10°C and higher than 300°C make up only 13% of the total volume.

In this case branch specificity should be taken into account together with the obove-given average values. Thus, at power plants the volume of the insulation for objects with a temperature higher than 300°C rises up to 38%, and with a temperature lower than 10°C it drops to zero. In the food industry the volume in the temperature belt of over 300°C drops to 0%, and all the volumes of works ~~range~~ lie within the limits from + 10°C to 300°C.

The recommensations worked out in detail by this group of specialists have shown that 85% of the volume of heat insulation works require mineral wool and fibre glass materials and products, 10% - high temperature hard-moulded products and 5% - foam porous plastics, and by the way the whole volume of works with foam porous plastics is carried out at plants of the chemical, petroleum and chemical and oil processing in dustries. The need ~~in~~ for high temperature hard - moulded insulating materials is twice as much at power plants.

It is worth pointing out that from the point of view of a large specialised firm conducting its works only at power plants, the rational range of use of the high temperature hard-moulded insulation, mainly lime-silica and perlite products, reaches even 35-40% of the total volume of insulation works at the equipment of power plants and heat mains.

Mineral wool materials and products are mass thermoinsulating materials practised on a large scale.

RATIO OF HEAT INSULATION VOLUMES ON APPARATUS AND PIPINGS IN BRANCHES OF INDUSTRY (in %)

Table 26

Objects to be insulated	Branches of Industry: Power Plants	Chemical, Petroleum & chemical, Oil Processing Industries	Metallurgical Industry	Food Industry	Weighted Average
1	2	3	4	5	6
Diameters of pipes, mm:					
15-18	0.2	0.2	0.1	0.2	0.2
22-25	0.1	0.3	0.2	0.5	0.3
28-32	1.2	1.0	1.1	0.2	1.0
38	0.2	0.5	0.1	-	0.3
42-45	0.1	1.1	0.4	0.3	0.9
60	1.6	4.2	2.2	1.5	3.6
75	2.0	2.4	0.8	2.5	2.1
89	0.7	3.7	1.2	0.8	3.0
108	3.0	5.2	3.1	5.7	4.9
133	3.9	3.3	1.3	3.9	3.4
159	4.7	6.2	2.5	12.2	6.0
194	0.2	0.2	0.1	-	0.2
219	2.2	6.1	6.2	14.3	8.3
273	6.0	4.7	6.3	4.1	5.1
325	3.6	3.4	6.9	3.0	3.9
377	2.4	3.3	6.2	1.5	3.3
428	2.5	3.4	0.1	0.7	2.7

Table 25 (cont.)

1	2	3	4	5	6
478	0.1	0.2	10.8	0.8	1.6
529	0.2	2.4	13.0	0.8	3.4
631	2.6	1.7	5.1	0.2	2.1
720	0.4	0.9	5.7	-	1.4
820	4.4	0.1	8.6	-	1.6
920	0.2	0.2	0.6	-	0.3
1020 & more	5.7	0.7	4.5	-	1.3
Bundles, pipings with satellite	5.8	12.4	4.0	-	9.9
Equipment, apparatus, combustion chambres	44.3	28.3	2.0	48.8	27.8
Frameworks	1.7	4.0	3.0	-	3.6

RATIO OF HEAT INSULATION VOLUMES AS TO TEMPERATURE ZONES IN BRANCHES OF INDUSTRY

(in %)

Table 27

Temperature of Heat Carrying Agent, °C	Branches of Industry: Power Plants	Chemical, Petroleum & Chemical, Oil Processing Industries	Metallurgical Industry	Food Industry	Weighted Average
Lower than 10, and temperatures below zero	-	18	1	-	13
From 10 up to 100 inclusive	12	34	25	77	35
From 100 up to 300 inclusive	50	38	61	23	39
Over 300	38	10	13	-	13

Ratio of Applications of Various Insulating Structures at Plants of Chemical, Petroleum & Chemical and Oil Processing Industries (in %)

Table 28

Insulating Structures	Temperature Zones for Heat Carrying Agents																Total
	Less than +I0°C, and Temperatures below Zero				From +I0°C up to 300°C				From 300 up to 600°C				Over 600°C				
		Pipe Diameters, mm				Pipe Diameters, mm				Pipe Diameters, mm				Pipe Diameters, mm			
	Apparatus	up to: 57 includ	from 57 to 273 includ	over 273	Apparatus	up to: 57 includ	from 57 to 273 includ	over 273	Apparatus	up to: 57 includ	from 57 to 273 includ	over 273	Apparatus	up to: 57 includ	from 57 to 273 includ	over 273	
I. From cylinders & half-cylinders of mineral wool with synthetic binder		0.8	4.0			4.5	2I.5										30.8
2. From mineral and glass wool slabs with synthetic binder	I.3	0.I	0.2	I.7	22.5	0.3	I.5	I4.0									4I.6
3. From mineral wool mats stitched									2.0	0.I	0.3	2.0		0.0I	0.02		4.43
4. From glass wool strips and mats stitched	0.7	0.I	0.4	0.3	I.0	0.2	0.5	0.5									3.7
5. From mineral wool cords						I.0	I.0			0.2	0.3						2.5
6. From asbestos-vermiculite, lime-silicic, asbestos-cement and sovelite products									0.5	0.7	3.4			0.0I	0.02		4.63
7. From diatomite products					0.5	3.0								0.0I	0.03		3.54
8. From perlite ceramic products													0.I	0.02	0.I6	0.I2	0.4
9. From rigid mineral wool slabs bitumen-bonded	I.3			0.8													2.I
I0. From porous foamed plastics	I.2	0.5	3.8	I.0													6.3
Total:	4.5	I.5	8.2	3.8	23.5	6.5	27.5	I4.5	2.5	I.0	4.0	2.0	0.I	0.05	0.23	0.I2	I00

Ratio of Applications of Various Insulating Structures at Metallurgical Works (in %)

Table 29

Insulating Structures	Temperature Zones for Heat Carrying Agents: Less than +10°C, and Temperatures below Zero				From 10°C up to 300°C				From 300 up to 800°C				Total
	Apparatus	Pipe Diameters, mm: up to 57 includ.	from 57 to 273 incl.	over 273	Apparatus	Pipe Diameters, mm: up to 57 incl.	from 57 to 273 incl.	over 273	Apparatus	Pipe Diameters, mm: up to 57 incl.	from 57 to 273 incl.	over 273	
1. From cylinders & half-cylinders of mineral wool with synthetic binder		0.1	0.2			2.4	18.9						21.6
2. From mineral & glass wool slabs with synthetic binder	0.1		0.1	0.4	2.6	0.2	1.9	55.0					60.3
3. FRom mineral wool mats stitched									0.3		0.3	8.3	8.9
4. From mineral wool cords						0.6	0.9			0.1	0.3		1.9
5. From asbestos-vermiculite, volcanite, lime-silicic, perlite-cement and sovelite products									0.1	0.4	3.2		3.7
6. From diatomite products						0.2	3.3						3.5
7. From rigid mineral wool slabs bitumen-bonded				0.1									0.1
Total:	0.1	0.1	0.3	0.5	2.6	3.4	25.0	55.0	0.4	0.5	3.8	8.3	100

Ratio of Applications of Various Insulating Structures at Power Plants and in Heating Systems (in %)

Table 30

Insulating Structures	Temperature Zones for Heat Carrying Agents								Total
	From +10°C up to 300°C				From 300°C up to 600°C				
	Apparatus	Pipe Diameters, mm			Apparatus	Pipe Diameters, mm			
		up to 57 includ.	from 57 up to 273 includ.	over 273		up to 57 includ.	from 57 up to 273 includ.	over 273	
1. From cylinders & half-cylinders of mineral wool with synthetic binder		2.5	10.9						13.4
2. From mineral and glass wool slabs with synthetic binder	29	0.2	1.0	14.9					45.1
3. From mineral wool mats stitched					9.2	0.2	0.8	9.2	19.4
4. From mineral wool cords		0.3	0.5			0.5	0.8		2.1
5. From asbestos-vermiculite, volcanite, lime-silicic, perlite-cement, asbestos-cement and sovelite products					8.5	1.3	7.5		17.3
6. From diatomite products		0.2	2.5						2.7
Total:	29	3.2	14.9	14.9	17.7	2.0	9.1	9.2	100

RATIO OF APPLICATIONS OF VARIOUS THERMOINSULATING STRUCTURES IN THE SOOT INDUSTRY (in %)

Table 31

Insulating Structures	Temperature from $10^{\circ}C$ to $300^{\circ}C$				Total
	Apparatus	Diameters of pipes, mm			
		Up to 57 inclusive	from 57 up to 273 inclusive	Over 273	
1. From mineral wool cylinders and half-cylinders with synthetic binder	-	2.1	30.0	-	32.1
2. From mineral and glass wool slabs with synthetic binder	47	-	2.0	7	56.0
3. From mineral wool insulating cords	-	0.5	3.0	-	3.5
4. From diatomite products	-	0.4	8.0	-	8.4
Total:	47	3	43	7	100.0

ESTIMATE OF WEIGHTED AVERAGE PERCENTAGE OF APPLICATIONS OF VARIOUS THERMOINSULATING STRUCTURES FOR ERECTION WORKS ON HEAT INSULATION OF TECHNOLOGICAL EQUIPMENT AND PIPINGS

Table 32

Insulating Structures	Branches of Industry				Weighted Average
	Chemical, Petroleum & Chemical, Oil Processing Industries	Power Plants	Food Industry (Sugar Refineries)	Metallurgical Industry	
1	2	3	4	5	6
1. From half-cylinders and cylinders of mineral wool with synthetic binder	30.8	13.4	32.1	21.6	28.2
2. From mineral and glass wool slabs with synthetic binder	41.8	45.1	56.0	60.3	45.2
3. From mineral wool mats stitched	4.43	19.4	-	8.9	5.8
4. From glass wool strips and mats stitched	3.7	-	-	-	2.5
5. From mineral wool cords	2.5	2.1	3.5	1.9	2.4
6. From asbestos-vermiculite, volcanite, lime-silicic, perlite-cement, perlitegel and sovelite products	4.63	17.9	-	3.7	5.9
7. From diatomite products	3.54	2.1	8.4	3.5	3.7

Table 32 (cont.)

1	2	3	4	5	6
8. From perlite ceramic products	0.4	-	-	-	0.3
9. From rigid mineral wool slabs bitumen-bonded	2.1	-	-	0.1	1.5
10. From porous foamed plastics	6.3	-	-	-	4.5
Total:	100	100	100	100	100

VOLUMES OF INSULATING STRUCTURES PER 1 MILL. ROUBLES OF COST OF HEAT INSULATION WORKS

Table 33

Insulating Structures	Weighted average volumes of Structures per 1 mill roub.[x] (in cu.m)	Coefficient of Transition from Structures to Materials	Weighted Average Norms of Consumption of Insulating Materials per 1 mill roub. (in cu.m)[x]
1	2	3	4
1. From cylinders and half-cylinders of mineral wool with synthetic binder	2330	1.0	2230
2. From mineral and glass wool slabs with synthetic binder	3570	1.65	5000
3. From mineral wool mats stitched on mesh	460	1.30	610
4. From glass wool strips and mats stitched......	200	1.2	240
5. From mineral wool cords	190	1.05	200
6. From sovelite, volcanite, lime-silicic, perlite-cement, asbestos-cement products	460	0.93	430
7. From diatomite products (half-cylinders)	290	0.93	270
8. From perlite ceramic products	20	0.93	20
9. From rigid mineral wool slabs bitumen-bonded	120	0.8	90
10. From [illegible] foamed plastics	360	1.2	410
Total:	7900	-	9500

x/ Note: Norm corrected with the cost per 1 cu.m. of structures equal to 127 roubles.

Comparative technical and economical effectiveness of interchaugeable thermeinsulating materials is characterized by the fellowing.

Fibre glass products ara very clese te mineral weol ones by their technical,technologioal aud ecomemic characteristics. They are a little better in quality and appearance than those from mineral wool. But technology of their production is much mere complex: a multi-component batch is required fer their manufacturing, and sieve-like platinum bushings are necessary. All this provides for a higher quality of products but at the same time results in their higher cost. Besides, mineral weol products can be used fer objects havina a higher surface temperature than that of fibre glass, and therefore are more universal.

In this connection mineral wool products are preferable for objects with a very big velume of heat insulation works. Mest effective mineral wool materials are products with synthetic binder-soft, semi-rigid and rigid slabs,as well as shaped products-cylinders and half-cylinders - Phenolspirits of 50% concentration are practised on a large scale as a bonding agent.

The temperature range of use of products with this binder is very wide: from 70°C below zero up to 300°C. Mineral wool products are not used for objects having a temperature of lower than 70°C below zero; objects having a temperature of over 300°C are recommended to be insulated with mineral wool mats stitched with different linings such as on metal mesh, fibre glass, glass cloth,paperboard, paper,etc.Besides, mats can have two kinds of linings: the metal mesh from the side directly adjoining to a hot surface of equipment, and fibre glass, glass cloth, paperboard or paper from the other side-what cuts down their cost.

In view of a considerable improvement of the mineral wool quality for the past few years, stitched mats without linings have become possible to be manufactured-what reduces sharply their cost and labour-cousumning character and widens considerably the field of their application.

As is mentioned above, the most important question is about industrial production of completely plant-finished thermoinsulating structures with efficient protective coatings supplied in set with fastening parts. Practice has shown that manufacturing structures of thermoinsulating materials "on the spot", right on the erection site, does not provide for heightening the speed of works and for their quality required, and is very labour - consuming and expensive.

Out of the researches carried out by the leading specialised institution, it is established that use of completely assembled structures permits to:

- stabilise heat and physical properties of the heat insulation, and in this connection - reduce heat losses by 15-20%;

- increase the heat insulation useful life 3-4 times as much, and consequently cut labour and material consumption for current and capital repairs of the heat insulation;

- cut material losses by 8-10 %;

- reduce labour consumption on erection 3 times as much;

- reduce terms of performing heat insulation works 2 times as much;
- maximize mechanization of heat insulation works;
- minimize moist processes (plastering) in carrying out heat insulation works-what excludes their seasonal prevalence and extra material expenses because of double scaffolding;
- save up to 7 roubles per 1 cu.m.of the heat insulation;
- basically improve working conditions of workers.

------oooOOooo------

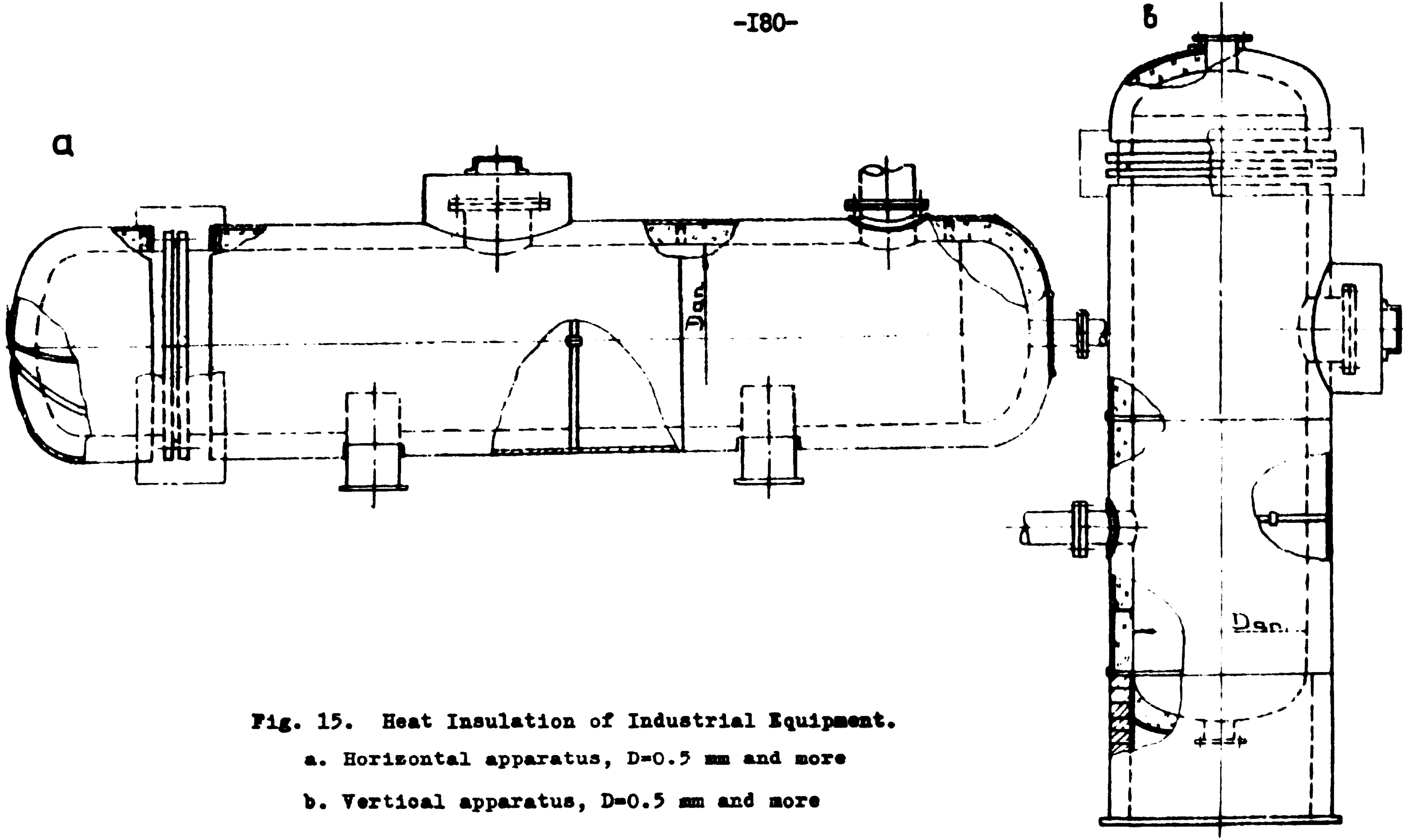


Fig. 15. Heat Insulation of Industrial Equipment.

a. Horizontal apparatus, D=0.5 mm and more

b. Vertical apparatus, D=0.5 mm and more

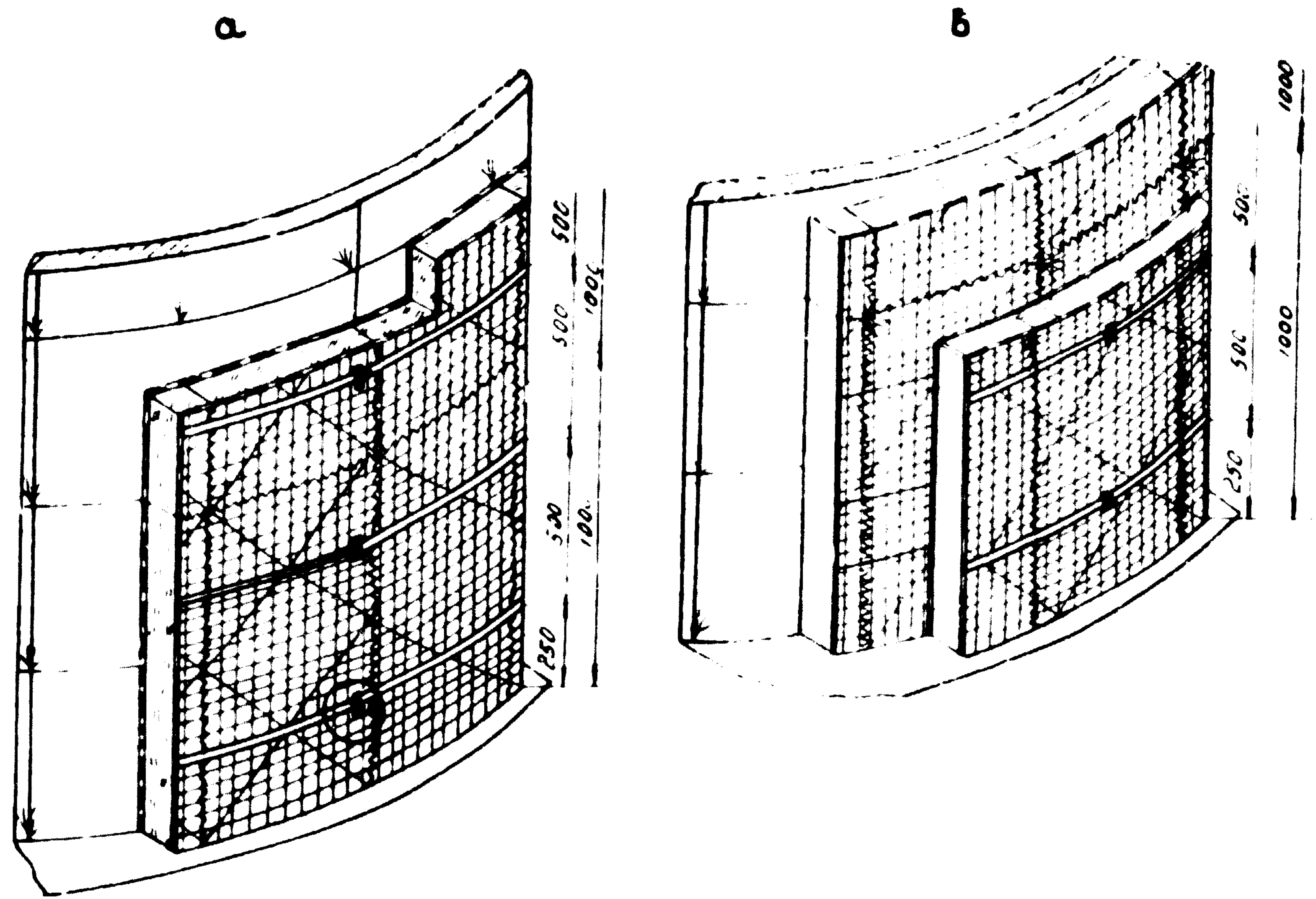


Fig. 16. Insulation of Vertical & Horisontal Apparatus with Stitched Mineral Wool Mats by Fastening them with Tie Pieces and Pegs.

a. One layer up to 100 mm thick
b. Two layers up to 200 mm thick

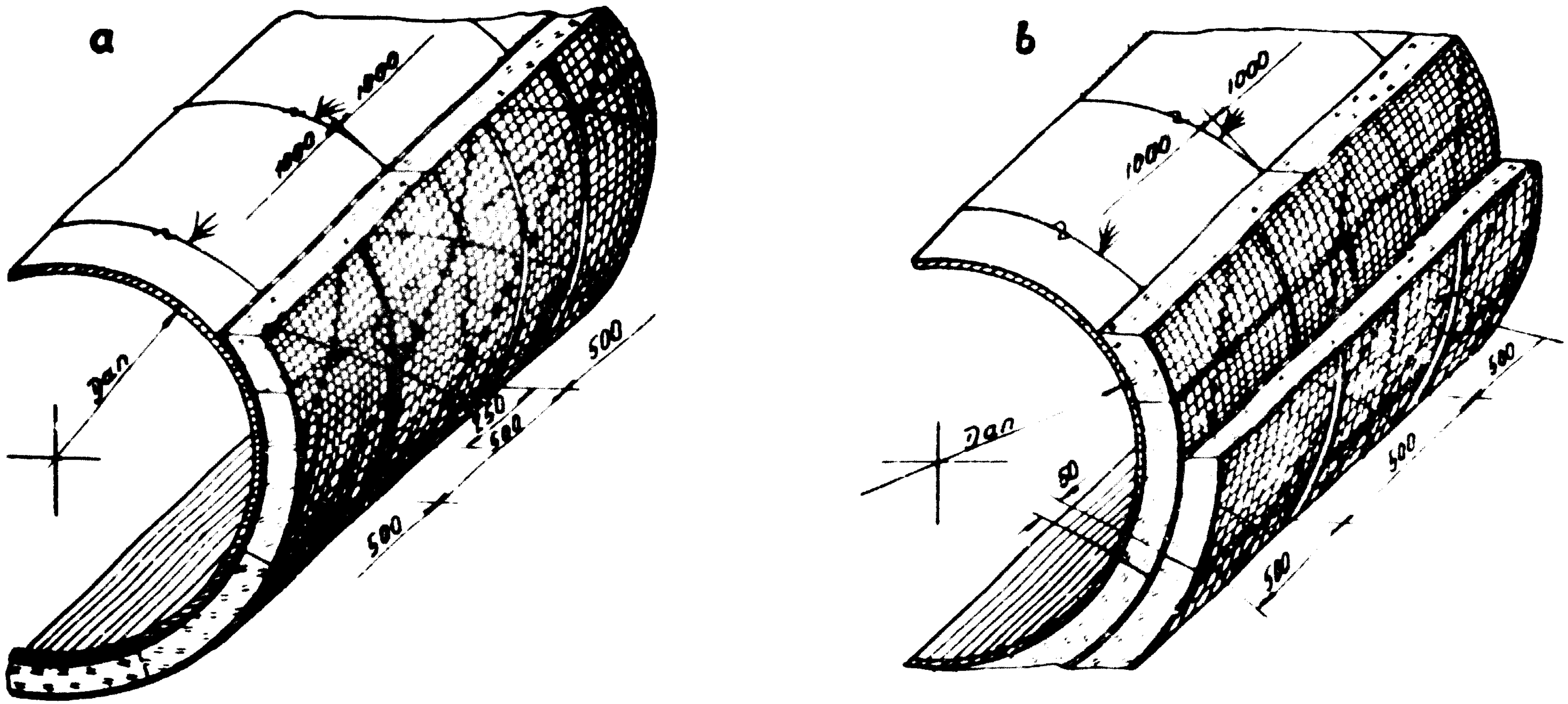


Fig. 17. Insulation of Horizontal Apparatus 0.5-1.5 m in Diameter with Stitched Mineral Wool Mats by Fastening them with Tie Pieces

a. One layer up to 100 mm thick
b. Two layers up to 200 mm thick

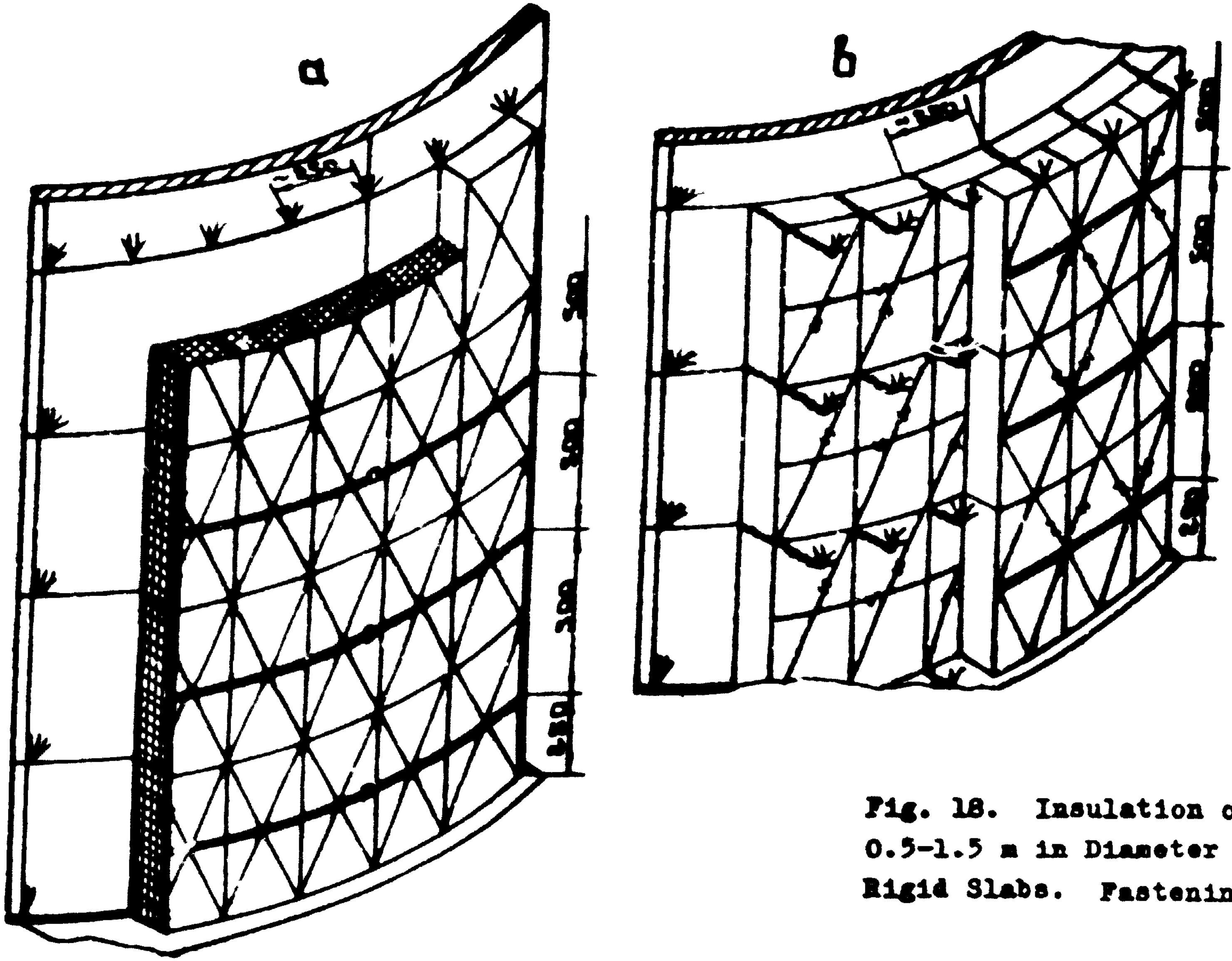


Fig. 18. Insulation of Vertical Apparatus 0.5-1.5 m in Diameter with Segments from Rigid Slabs. Fastening with Tie Pieces.

a. One layer
b. Two layers

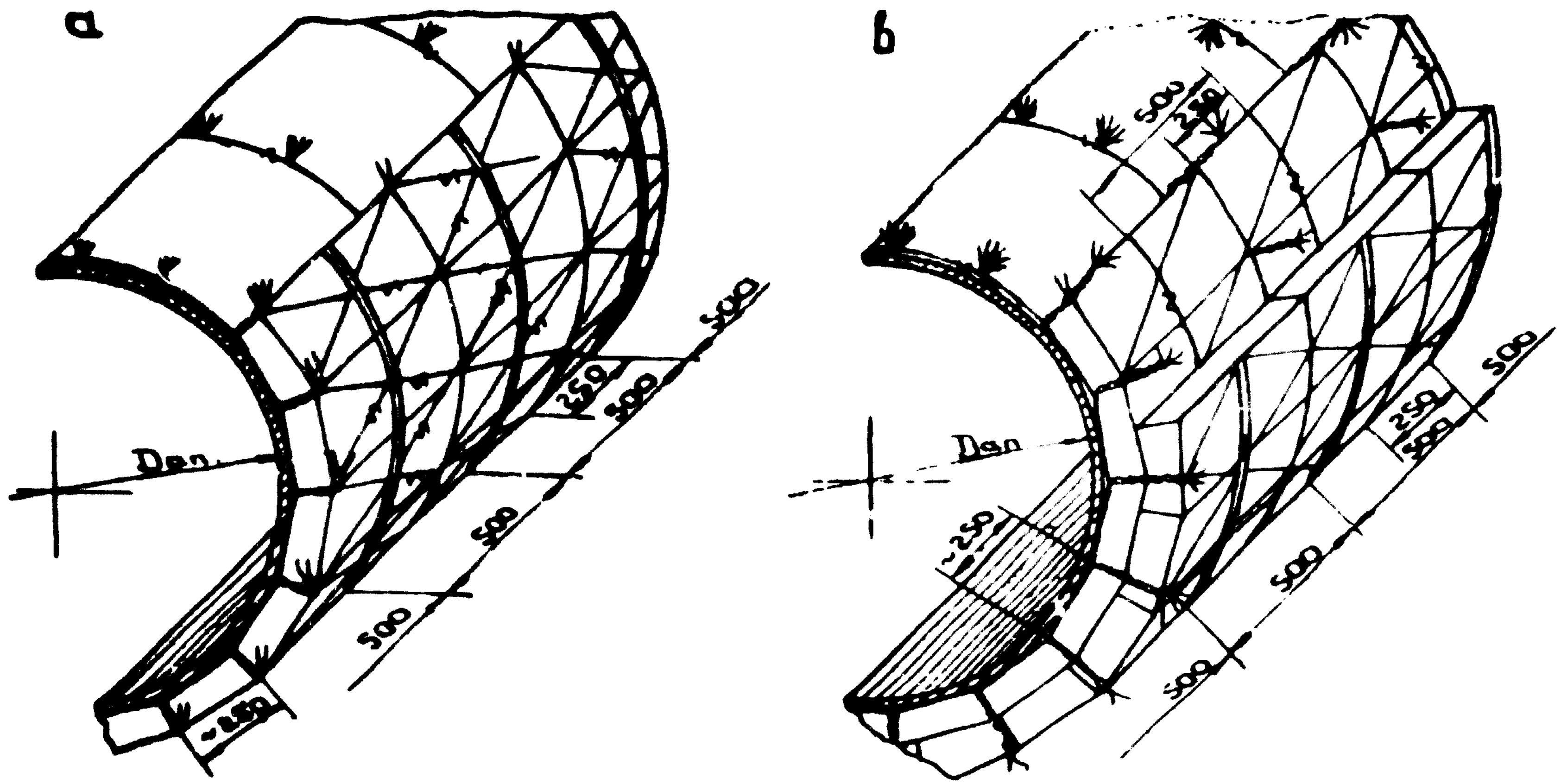


Fig. 19. Insulation of Horizontal Apparatus 0.5–1.5 m in Diameter with Segments from Rigid Slabs. Fastening with Tie Pieces.

a. One layer
b. Two layers

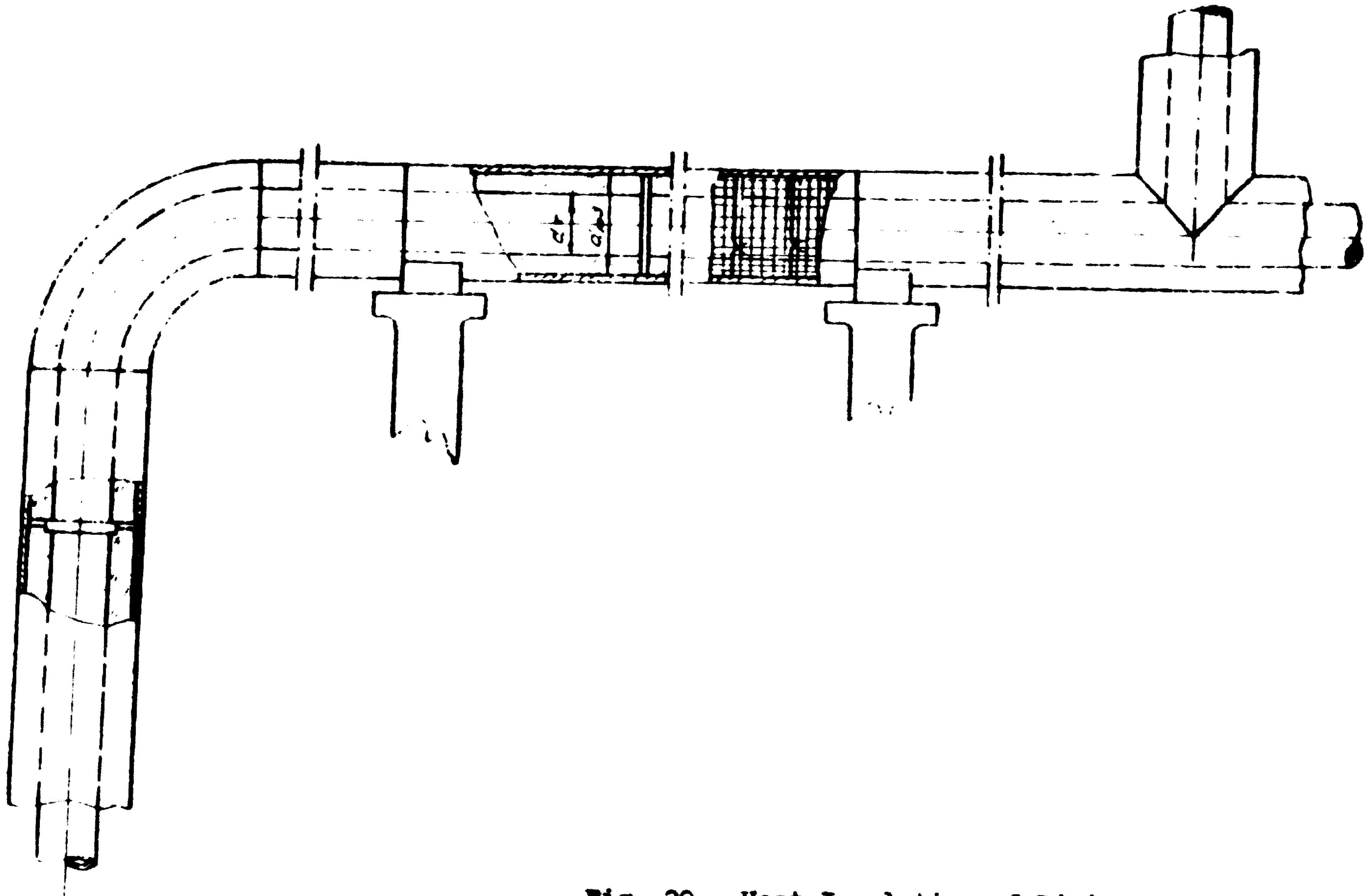
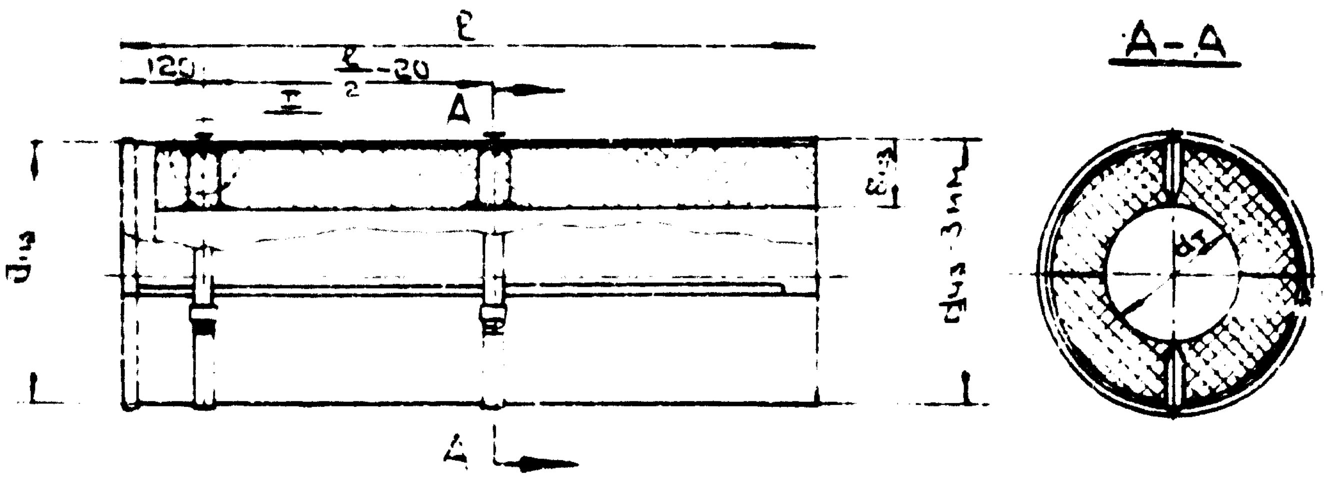


Fig. 20. Heat Insulation of Pipings.



a

Fig. 21. Insulating Structure from Half-Cylinders with Synthetic Binder, with Metal Catings for Pipes 57-273 mm in diameter.

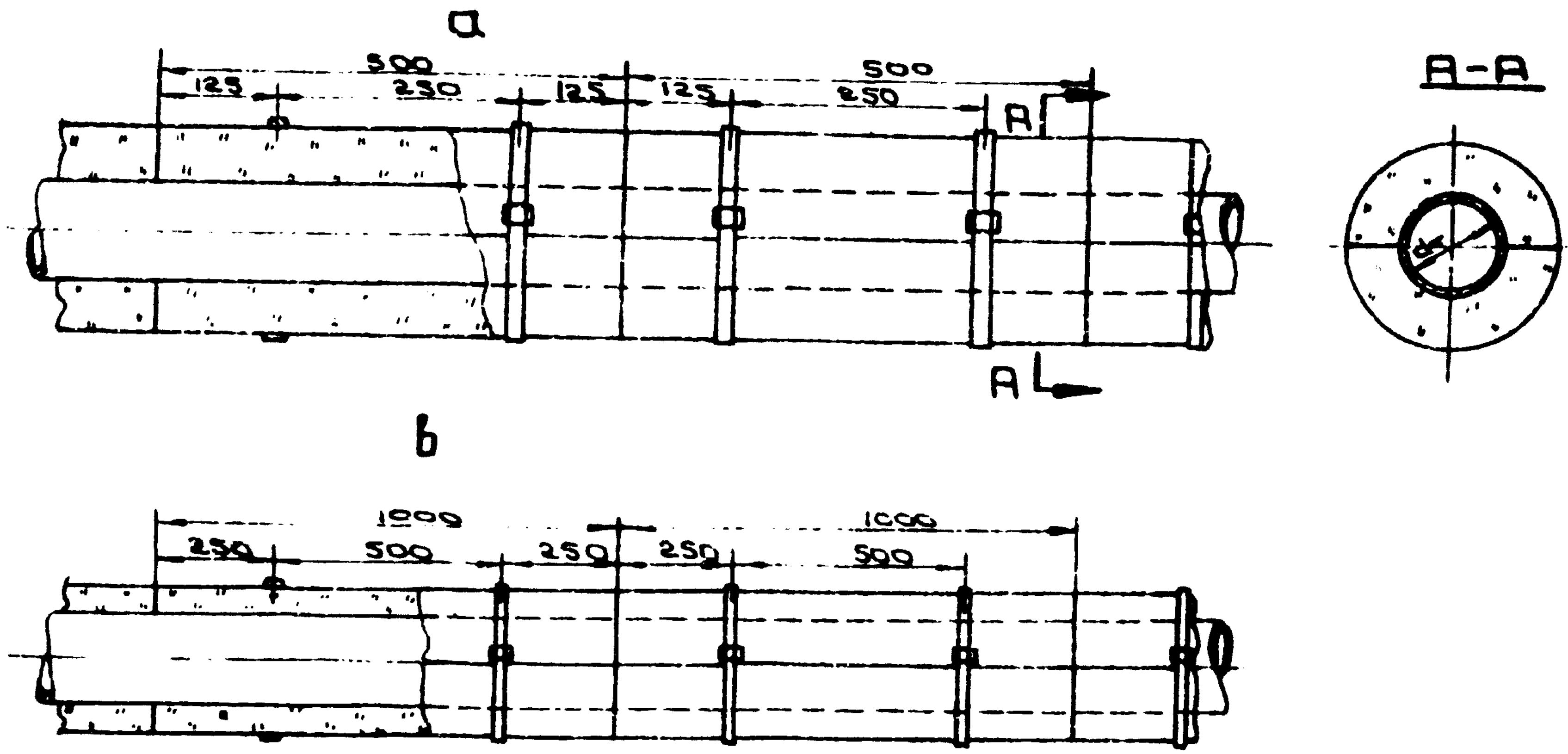


Fig. 22. Insulation of Pipes 18-273 mm in Diameter with Mineral Wool Cylinders and Half-cylinders

a. Insulation with half-cylinders
b. Insulation with cylinders

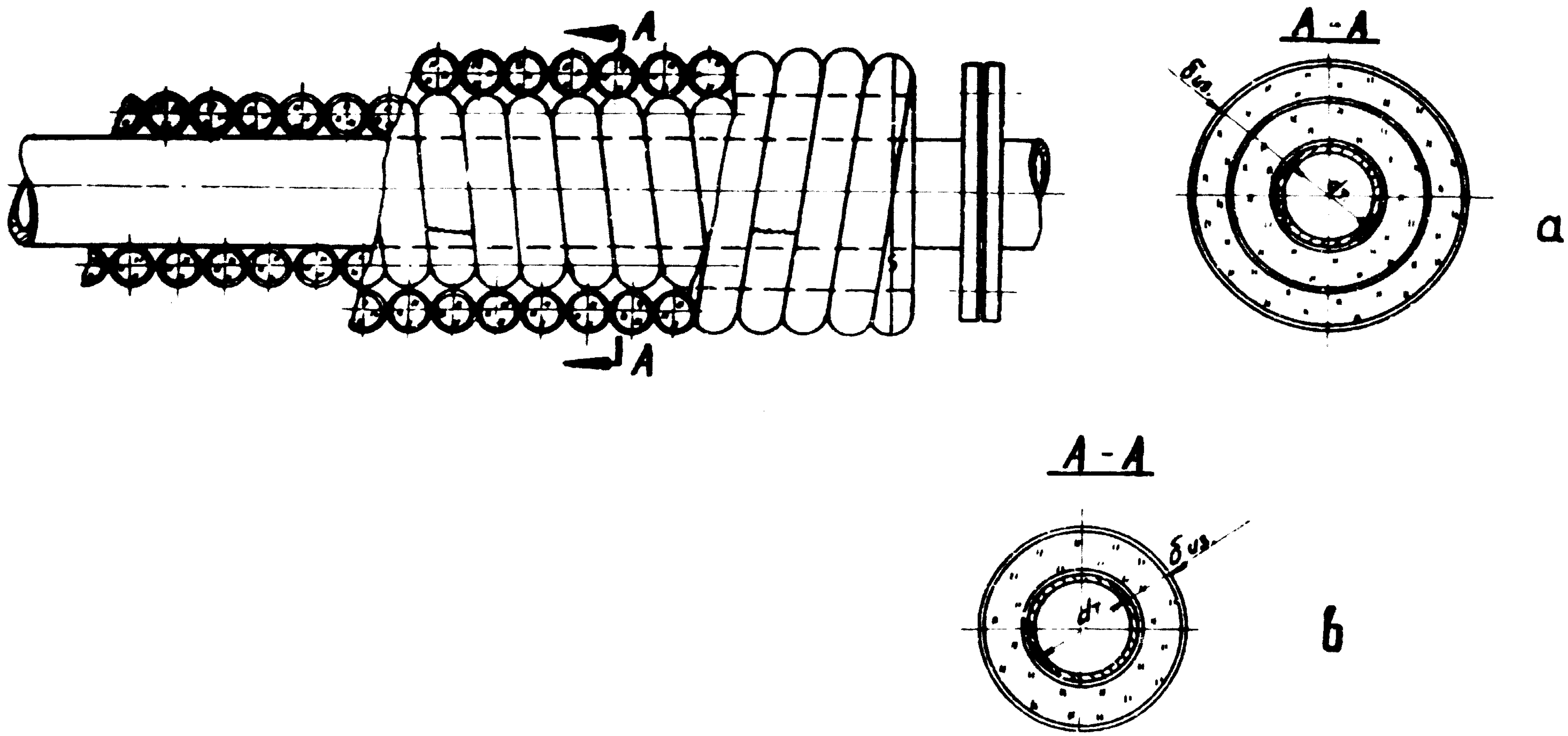


Fig. 23. Insulation of Pipes 14-108 mm in Diameter with Cords.

a. Two layers
b. One layer

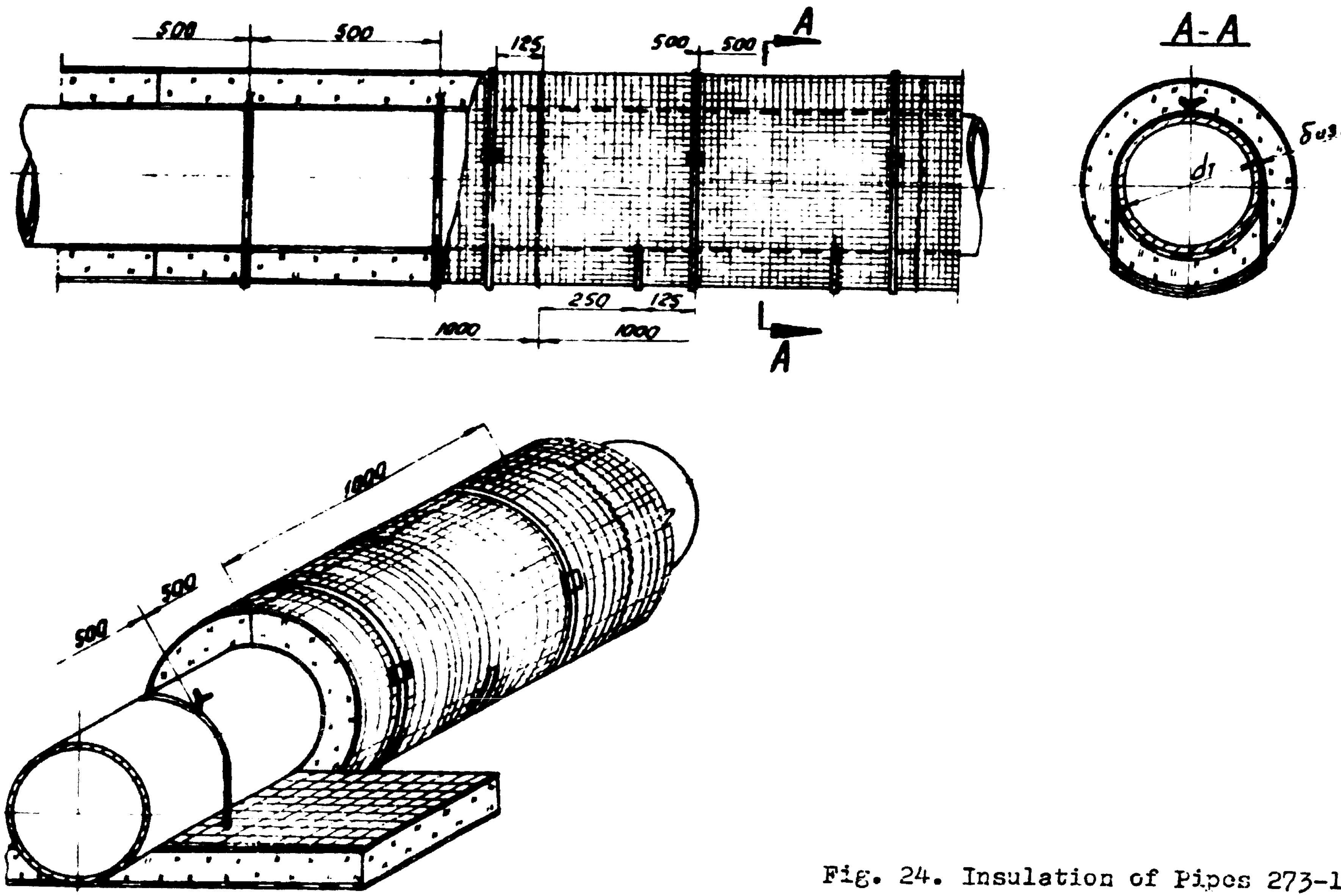


Fig. 24. Insulation of Pipes 273-1220 mm in Diameter with Mineral Wool Mats Stitched with Linings of One Layer.

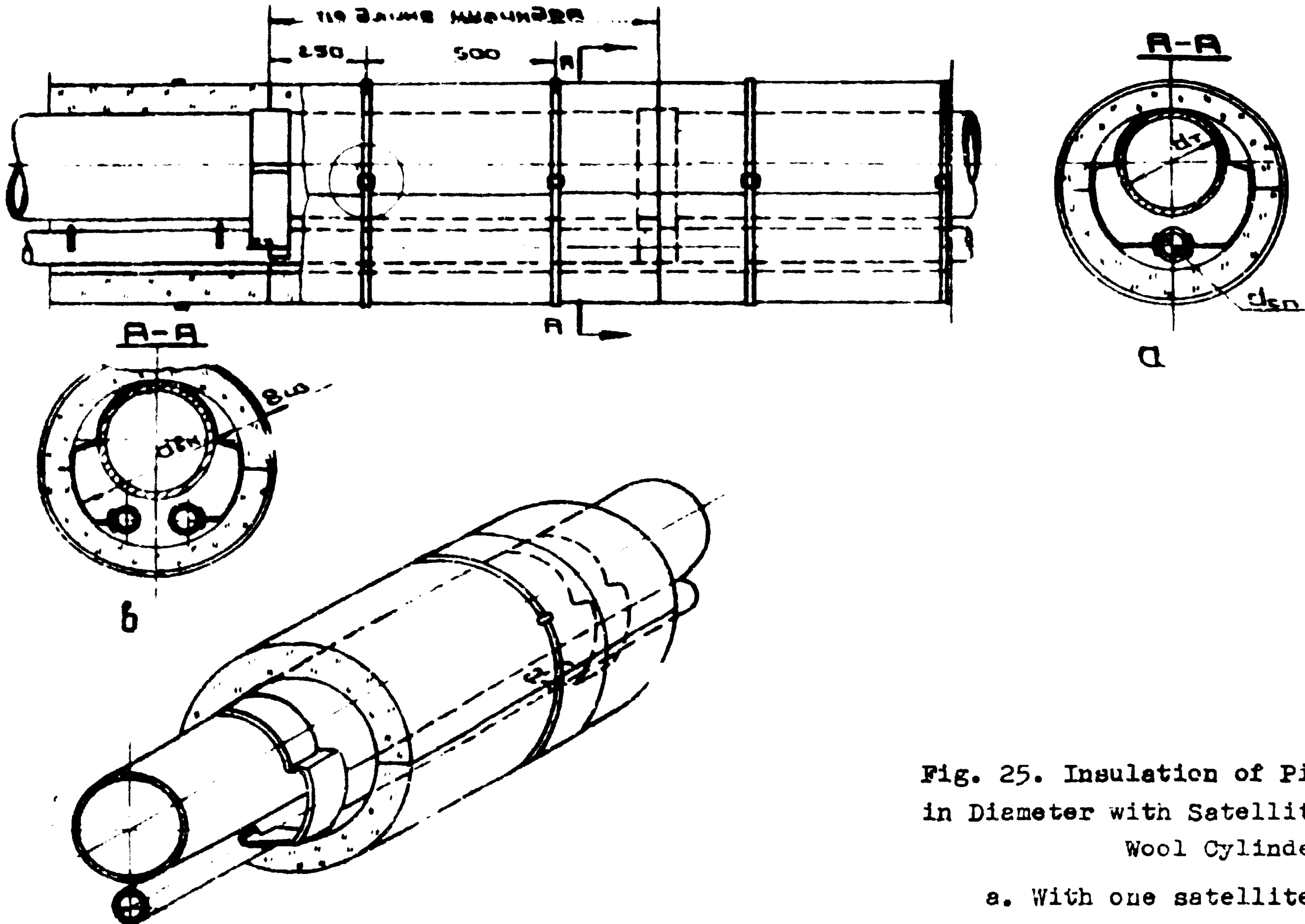


Fig. 25. Insulation of Pipes 45–219 mm in Diameter with Satellites with Mineral Wool Cylinders

a. With one satellite

b. With two satellites

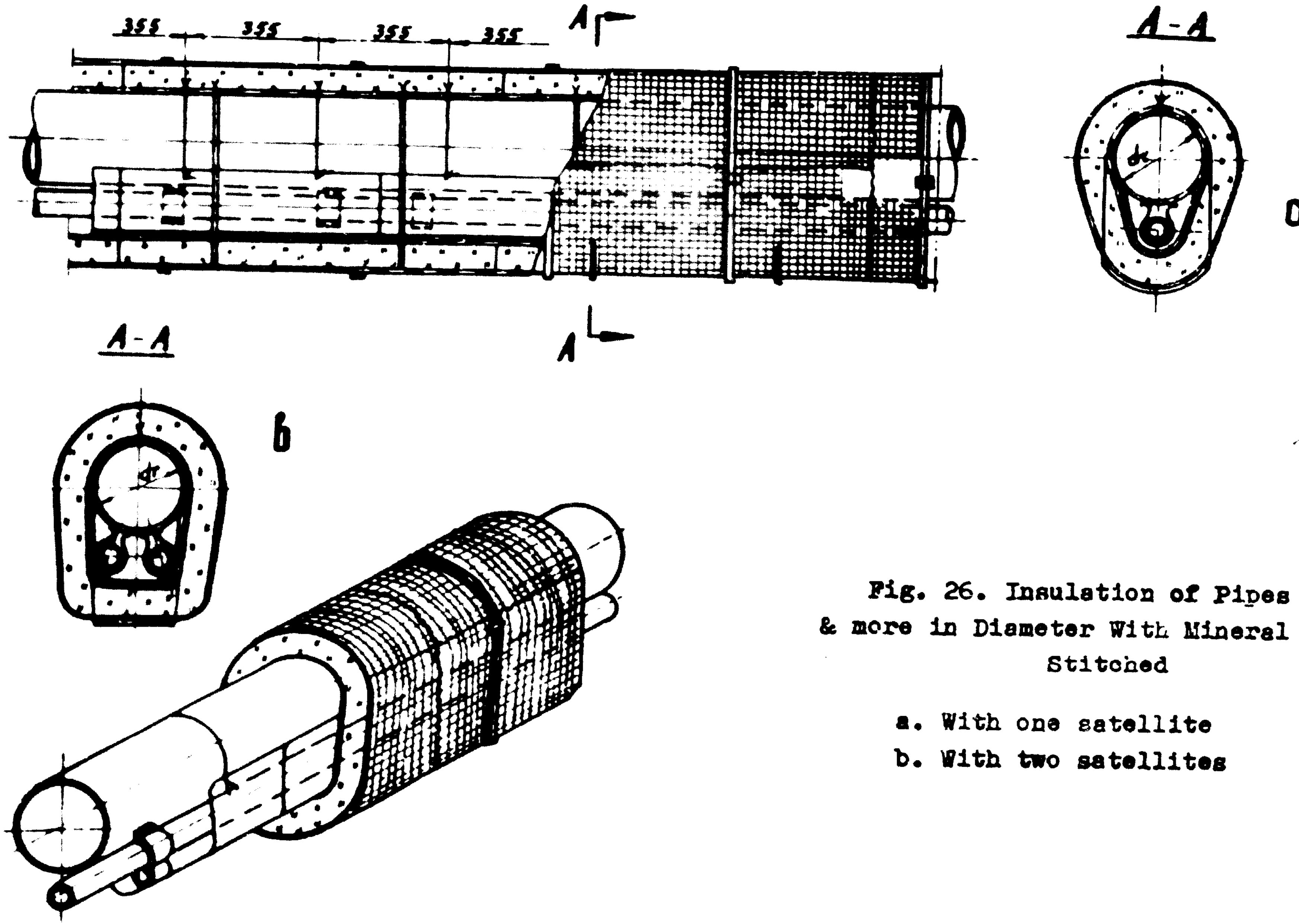


Fig. 26. Insulation of Pipes 219 mm & more in Diameter With Mineral Wool Mats Stitched

a. With one satellite
b. With two satellites

CHAPTER VI

MINERAL WOOL APPLICATIONS IN ENCLOSING STRUCTURES

1. Comparative Efficiency of Mineral Wool Heat Insulants

Expences on construction, weight, term of service and expences on maintemance of buildings, as it is known, depend to a considerable degree, upon ouater enclosing structures. This predetermines the necessity of developing and raising an economic effect of the latter what can be achieved first of all owing to use of their efficient thermal insulating materials of which mineral wool products are most widely spread.

Technical expidiency and economic efficiency from use of mineral wool products in enclosing structures of buildings designated for various purposes is caused by the intensive development of manufacturing those products in many cauntries of the world, especially after the end of World War II. (See data given in the INTRODUCTION).

The development of mineral wool production technology and use of synthetic binders resulted in a considerable improvement of the quality and in a sharp decrease of the volume weight of mineral wools with a simultaneous rise of their thermal insulation properties. Rising the quality of mineral wools reduced noticeably their cost and this was one of the most important factors stimulating the further development of production and use of these heat and sound insulating material in the construction industry. Use of mineral wool structures for buildings exceeds as a rule 50% of the total volume of its output.

The most important feature of mineral wools high is its high thermal insulating characteristics. The heat conductivity of flexible mineral wool slabs with synthetic binder of the volume weight of 75 and 100 kg.cu.m is equal accordingly to 0.050 and 0.055 Cal/m, hr. °C, semi-rigid slabs with the same binder of the volume weight of 125 and 150 kg cu. m - 0.06 Cal/m hr.°C; heat insulating haydite concrete M-21 with the volume weight of 600-700 kg/cu.m - approximately o.25 Cal/hr.°C, i.e. 4 to 5 times as much; and cellular (foam concrete) with the volume weight of 500 kg/cu.m - 2.5 to 3 times more (o.15-0.17) than that of mineral wool semi-rigid slabs with synthetic binder. Accordingly the volume of a haydite concrete heat insulant is 5 to 6 times and cellular concrete 3 to 4 times more than that of a mineral wool heat insulant, the rated values of temperature and moisture being the same. The more striking picture is when weight facters of mineral wool heat insulants are compared with these of heat insulants of light concrete.

If the volume weight facters and volumes of heat insulants are taken into account the weight values of mineral wools will be 30 to 40 times less than these of haydite concrete heat insulants and 20 to 25 times less than these of ~~heat these of~~ heat insulants of cellular concrete. Even if compared to such effective heat insulants as these from fibrelite wool slabs have the advantage by their weight values 5 to 6 times as much.

As to the labor-consuming character of manufacture per protective surface unit mineral wool heat insulants have also a multiple advantage against haydite concrete heat insulants

(15 to 20 times as much) and against foam concrete ones - 7 to 10 times as much. Finally, when comparing prime costs one may find out that even in this respect mineral wool heat insulants are advantageous against haydite concrete insulants 6 to 8 times as much and against foam concrete insulants - 4 to 5 times as much (See table N 34).

Furthermore, mineral wool heat insulants due to their small volume weight, high thermal insulating characteristics and comparatively low cost have an overwhelming advantage over heat insulants of light and cellular concretes, fibrolite and other effective thermal insulating materials.

It should be added to the above-said, that mineral wool and its products have high fire-resistance, bioresistance, and sound proof quality and they give-off moisture to the atmosphere rather quickly.

In recent years on the basis of science and technology technological processes of production of heat insulating materials, including mineral wools, were radically improved. At present new constructive forms and methods of panel manufacturing were being established and tested in laboratories and by practise what enables to employ at best important heat insulation characteristics of thermal insulants.

An essential development of roofing structures, roofs and outer walls of buildings may be achieved on the basis of production and use of thin - foliated box-like and hollow panels with atmosphere-resistant, supporting coatings (of heavy and structural light-weight and cellular concretes, asbestos-cement and other sheet materials). inside of which there is a highly efficient heat insulant performing only heat insulating functions.

Effectiveness of Use of Mineral Wools as a Heat Insulation for Outdoor Enclosing Structures for Building Instead of Light-Weight and Cellular-Concretes

(per 1 cu.m)

Table 34

Name	Unit measure	Haydite Concrete				Cellular Concrete		Mineral wool slabs with synthetic binder	
		M-15 γ=600-700 kg/cu.m	M-25 γ=700-800 kg/cu.m	M-35 γ=800-900 kg/cu.m	M-50 γ=900-1000 kg/cu.m	γ=400 kg/cu.m	M - 10-15 γ=500 kg/cu.m	γ= 75 kg/cu.m	γ=100 kg/cu.m
Heat conductivity	Cal/m.hr.°C	0.21	0.24	0.26	0.29	0.12	0.170	0.050	0.055
Layer thickness	cm	25	27	35.5	39.5	14.5	19.5	7.5	8.5
Weight	kg	160	200	290	340	58	107	6.0	9.0
Consumption of bonding agents	kg	38	46	68	88	15	20	0.3	0.4
Cost	Conditional units	5.3	5.7	7.2	8.0	3.0	4.0	0.7	1.0

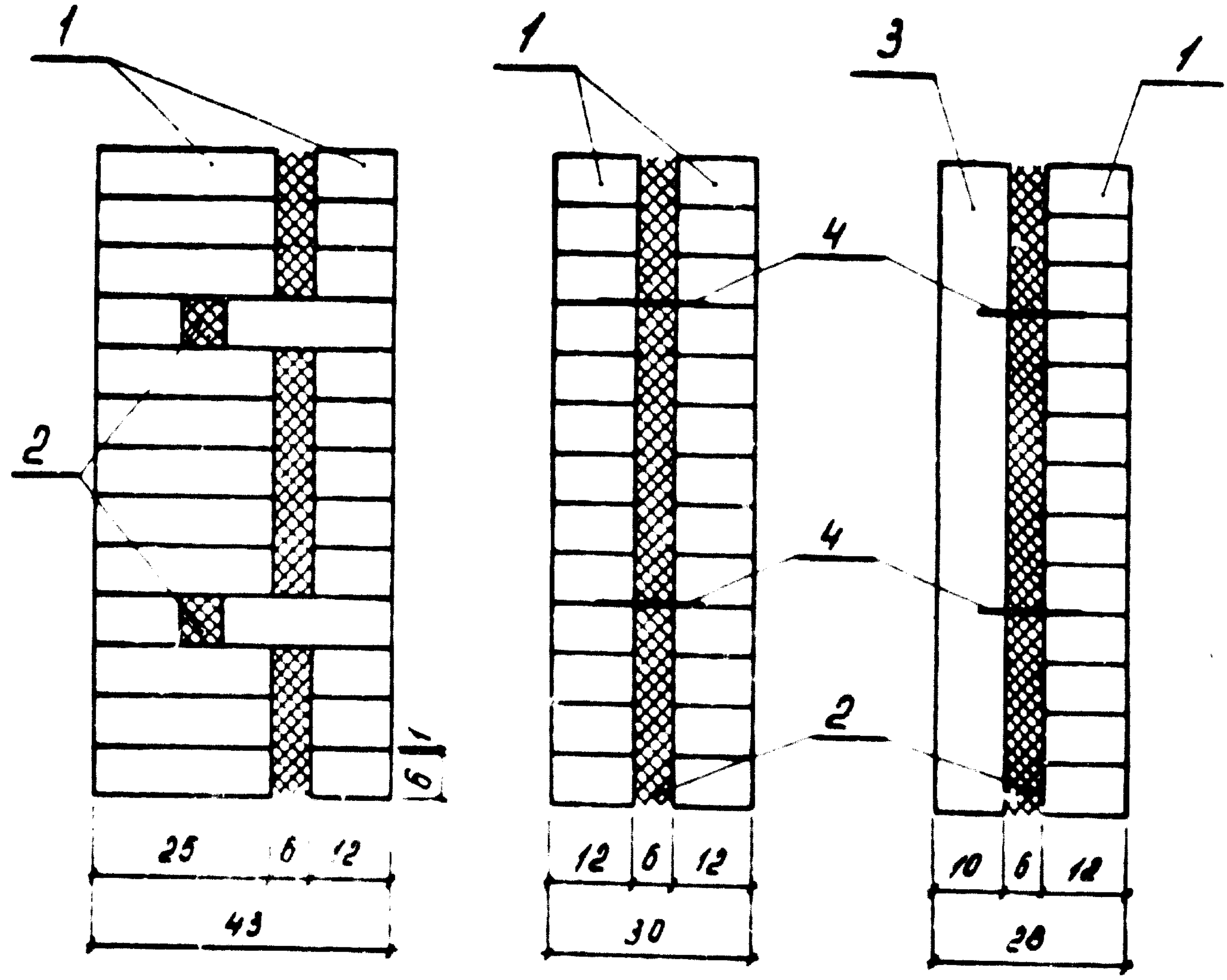
2. Use of Mineral Wool Heat Insulants in Brick Walls

Use of mineral heat insulants in brick walls is rather an effective measure which is spread on a certain scale in construction practice of such countries as Sweden, Denmark, the FRG and also in the USSR'S Baltic Republics. For example, in the Estonian Soviet Socialist Republic brick walls with mineral wool heat insulants are used in one-storey and multistorey apartment houses and public buildings and in one-storey agricultural buildings. In the Luthanian SSR similar strucrures are used for construction of five- and nine-storey buildings and some other types of public buildings.

Brick walls with mineral wool heat insulants are named relieved brick walls. Thickness of relieved brick walls is determined depending on height and temperature duties of buildings, and also on climatic and other conditions. Thus for multi-storey buildings there can be used structures of relieved supporting walls (see Fig.27) consiting of an inner supporting layer of one brick and an outer lining layer of half a brick. The outer lining layer is connected with the inner one by one binding brick row made at an interval of 5 or 6 rows in height.

Between brick layers there is a layer of semirigid mineral wool slab 60 mm theck and equivalent, by its heat insulating characteristics, to a wall of 1.5 brick on light mortar.

The total thermal resistance of the given structure taking into account compressability of the mineral wool heat insulant, is 1.4 sq. m. hr ^{o}C/Cal, what is approximately equal to the insulating capacity of a blind wall 3 bricks thick. And the weight



(размеры в сантиметрах)
(dimensions in cm)

Fig. 27. Structures of Brick Walls with Mineral Wool Heat Insulants

1. Bricking. 2. Mineral wool slabs.
3. Assembled element.
4. Metal tie piece.

of this relieved structure heated with mineral wool semi-rigid slabs is only a little over 50% of the weight of the 3-brick structure. Thermal resistance of relieved brick structures in summer is a bit less than that of the equivalent blind brick structure. Yet even relieved structures have sufficiently large reserves of heat resistance and they to a great extent exceed standard requirements at specified summer temperatures of 30°C and more.

It should be pointed out that the arrangement of layers in the given relived structure - the thicker inside and the thiner outside - is favourable to the moisture duty of the structure thus hightening its resistance to steam in filtration from premises into the wall and, on the contrary, facilitating to relieve steams from the structure.

In one-storey houses outer as well as inner layers can be in form of partitions of one brick thick (Figure 27), connected in 3 or 4 places in height with metal tie pieces with corrosion resistant coatings or with asbestos-cement sheet strips. Tie pieces are set up at interval of 1.5 to 2 mm.length. Crosspieces over doorway and window openings rested upon outer and inner layers of a relieved wall can also serve as tie pieces.

Instead of inner brick partitions there can be used reinforced concrete, light-weight, silicate concrete and the like industrially produced panels and slabs, connected with the outer layer of the wall by metal tie pieces. Resistance to heat conduction of the wall with 2 layer of one and a half bricks and with a mineral wool heat insulant 6 cm thick is equivalent to thermal resistance of a wall of 2.5 -bricks thick, and in case of using an inner layer of assembled rein feroed concrete elements - a wall of one fourth of a brick thick.

Thermal stability of such a structure in summer is also sufficient at rated summer temperatures of 30°C and higher.

The technical and economic factors of blind and relieved brick walls are given in Table 35, which shows that, insulation properties being identical, relieved structures, as to their weight and cost values, have considerable advantages over blind ones, namely: weight - 1.75 to 2.5 times as much, cost - 1.26 to 1.87 times as much. But as for the labour - consuming character blind and relieved brick structures are approximately equal to each other.

Technical and Economic Factors of Blind and Relieved Brick Walls with Mineral Wool Heat Insulants

(Per I sq. m of Wall)

Table 35

Factors	Blind			Relieved			Notes
	77cm	64cm	51cm	1	2	3	
Structure weight, kg	1232	1024	820	600	410	470	1. Cost values and labour consumption factors are calculated according to the Luthanian SSR's standards.
Labour consumption for erection (man-hb)	3.60	2.97	2.36	3.52	3.08	1.72	
Cost, roubles	16.05	13.37	10.70	9.81	7.14	8.48	2. Cost of 1 cu. m of heat insulant in structure as 30 roubles

Thus, use of mineral wool heat insulants in brick walls gives a certain number of evident technical and economic advantages over blind structures. It may be expected that for construction of low - storey houses especially in rural areas, relieved brick wall structures with mineral wool insulants will proove to be most applicable and will be practiced on a large scale in many regions. In case of a wider development of standard projects on building with use of relieved brick structures there will appear a necessity in more detailed designing of certain structural units including first of all structures of tie pieces between outer and inner layers, substitution of the inner brick layer for assembled elements or sheet materials.

3. Use of Mineral Wool Heat Insulants in Vibrobrick Wall Panels

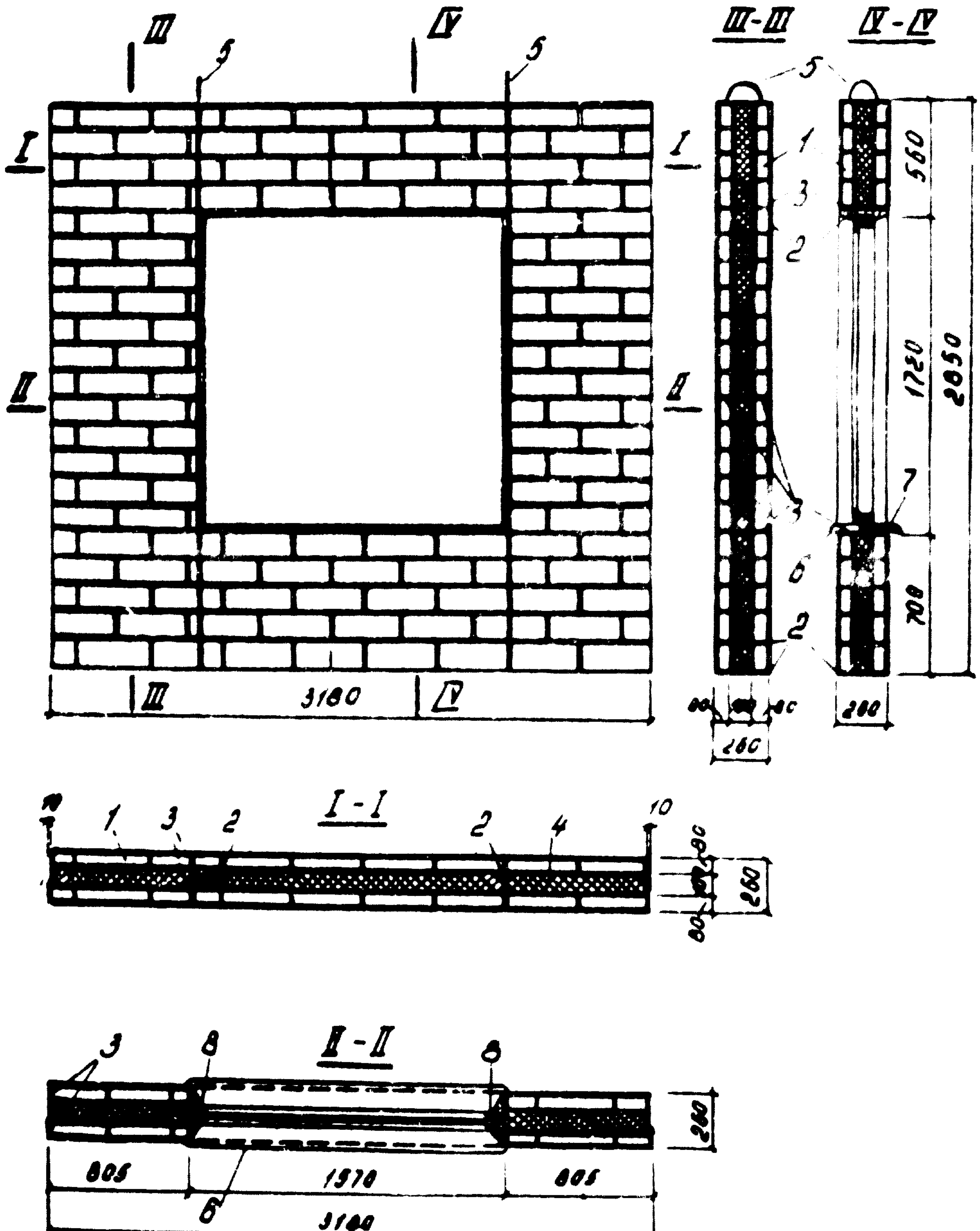
One of the ways to introduct industrial methods of erecting brick buildings will be use of brick blocks and vibrobrick panels. Economic effect of employing brick blocks is practically not significant because the thickness of walls made of such blocks is equal to the thickness of walls made of a common bricking. The main difference of vibrobrick panels from brick blocks is that they have an efficient heat insulant inserted between two outer layers of brick and reinforced concrete. And the total thickness and weight of walls, labour consuming character and cost of a structure are considerably reduced and there appears the possibility to mechanise the process of manufacture and erection of structures.

Vibrobrick panels for outer walls are produced of a room's shape in several variants. The bearing surface of panels is made of 1/2 or 1/4 of a brick thick and the thermal insulating layer is made of various kinds of efficient thermal insulating materials. When using soft or semi-rigid heat insulants panel are made of 3 layers, and if rigid heat insulants - of 2 layers. In case of employing mineral wool heat insulants panels are made of 3 layers.

A three-layer self-bearing panel with a heat insulant of mineral wool slabs connists of 2 outer layers of 1/4 of a brick (Fig.28) with finishing layers of cement mortar and inter-mediate layer of semi-rigid mineral wool slabs whose thickness is defined by calculations. Heat insulants being 10 cm thick, the thermal resistance of such a panel is Ro=2 sq-m hr ^{o}C/Cal, weight- - 240 kg per 1 sq.m. of wall taking into account the opening. Thermal Stability of panels in summer is sufficient at rated summer temperatures in the open of 30^{o}C and higher. Walls of 1/4 of a brick thick are connected by frameworks of cold-drawn wire 4 mm thick. Frameworks are arranged on the perimeter of a panel and window opening. Vertical bars of frame-works laid close the Window opening serve at the same time as lifting loops. They are made of round. Steel 10 to 12 mm in diameter.

A coupled window sash preliminarily coated with stand oil and stitched with tarred felt from the sides facing the bricking is placed into a form prior to moulding, wooden window- - sill boards and drains are placed after heat treatment of a panel.

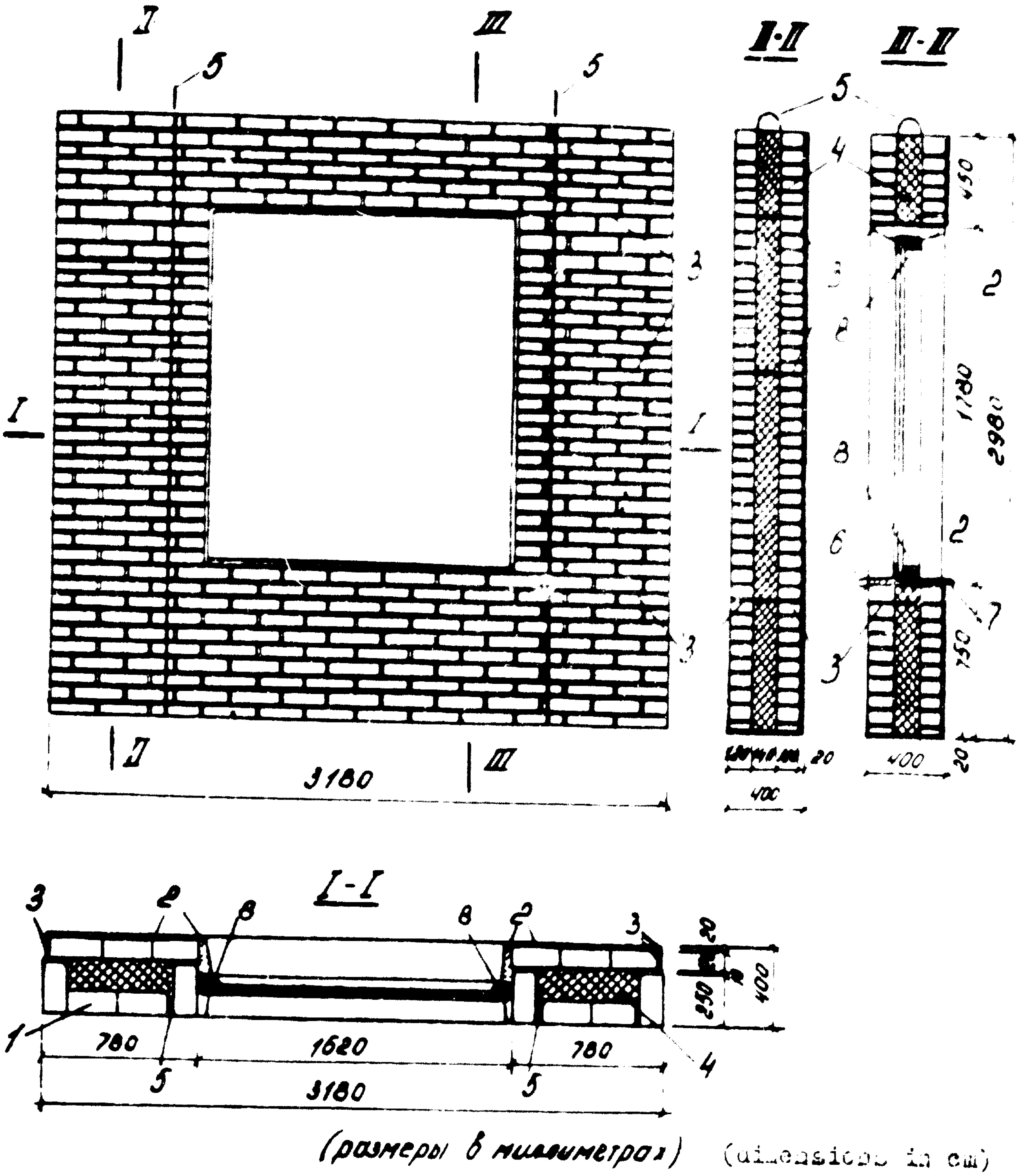
In 3-layer panels for bearing walls in multi -storey buildings vibrobrick layers are half a brick thick and are



(размеры в миллиметрах) (dimensions in cm)

Fig. 28. 3-Layer Panel Structure with Two Walls of 1/4 of a Brick and Mineral Wool Heat Insulants.

1. Brick wall of 1/4 of a brick. 2. Cement mortar.
3. Welded framework. 4. Mineral wool heat insulant.
5. Loop. 6. Drain of zink-plated steel.
7. Window sill. 8. Coupled window sash.



(dimensions in cm)

Fig. 29. 3-Layer Panel Structure with Two Walls of Half a Brick & with Mineral Wool Heat Insulants

1. Brick wall of half a brick. 2. Cement mortar. 3. Welded frameworks. 4. Mineral wool heat insulants. 5. Loop. 6. Drain of zinc-plated steel. 7. Window-sill. 8. Coupled window sash.

connected with each other by armature frameworks or reinforced ribs of light-weight concrete. (Fig.29). The heat insulant being 10 cm thick, panels will be 38 cm thick and weigh 320 kg.

Manufacture of vibrobrick panels is usually performed in horizontal plane facing downwards. Sequence of operations when manufacturing 3-layer panels is as follows. A window frame is placed on the bottom of a cleaned and lubricated mould. Its correct position is fixed with the help of a sweep. Then on the mould bottom around the window opening there is laid lining material (usually a roll of small ceramic slabs glued to paper) over which a layer of cement-sand mortar is applied, the outer- - brick layer with joints between at an interval separate bricks of 10 cm is embedded into the mortar flatwise or onto the rib. Joints where armature frames are placed can be at a distance from 30 to 40 mm.

In order to fill all the joints a mortar layer is applied over the lower (outer) brick layer, and then vibration is effected for 30 to 40 seconds. As practice has shown the strength of a brick wall after vibrating increases 2 to 2.5 times as much as compared to that of ordinary brickings. In order to avoid cold bridges the joints into which armature frames are set are filled with light-weight concrete mortar (e.g. haydite concrete). On finishing vibration of the lower brick layer onto it are placed semi-rigid mineral wool slabs whose thickness must be more than the rated by 15 to 20% because after applying the upper brick layer thickness of the numeral wool heat insulant with synthetic binder must be reduced by 15 to 20% of its original value.

It is advisable to cover the upper surface of the heat insulant with water-proof materials (building paper, Ruberoid, etc.) in order to prevent its impregnation with mortar. The heat insulant layer is coated with an upper (inner) brick layer over which is laid cement - sand mortar in order to fill all the joints and to form at the top a surface finish layer 15 to 20 mm. thick.

The upper layer is vibrated by a plane vibrator and the mortar upper layer is smoothed down by a vibrabatten and then by a levelling machine.

All operations to mould panels are carried out in one position but they can be transferred to another position for packing and finishing their upper surfaces. The panel moulded and timed for two hours is fed into a steam chamber for thermal and moisture treatment, its duty being determined by the plant laboratory.

Thermal treatment [illegible] is over, the panel is placed in a special position [illegible] slightly inclined plane, where its right side is cleaned from the paper of coating material, and other external defects are eliminated, and then the panel is transferred to a warehouse for finished products wherefrom - to construction sites.

4. Use of Mineral Wool Heat Insulants in 3 Layer Wall Panels of Reinforced Concrete.

Three-layer panels consisting of a coat of inner and outer layers between which a thermal insulating layer is applied are the most typical enclosing structures. The outer layer protects the heat insulant from atmospheric precipitations and mechanical effects, the inner layer is the bearing one and it partially prevents infiltration of steam from premises inte wall structures or coatings.

It is desirable to compare the three-layer structure with the socalled one-layer or blind structure. Some comparative data on one-layer and three-layer wall structures whose thermal resistance is equal to I sq.m.°C/Cal, are given in Table 36, which shows that a three-layer wall with mineral wool heat insulants as to its weight and cost calues has the overwhelming advantage over one layer panels.

Table 36

Wall structure	Weight of 1 sq.m. of wall, kg	Cost of 1 sq.m. of wall, roubles
1. One-layer of cellular concrete 25 cm thick.	209	11.92
2. Ditto - of haydite concrete with 32 cm thick.	330	12.39
3. Brick wall 51 cm thick.	937	18.84
4. Rein-forced concrete 3-layer wall with heat insulant of mineral wool slabs.	80	5.11

Three-layer panels have some other positive properties which are the result of high thermotechnical characteristics:

1. Due to high heat insulating qualities of the mineral wool heat insulant thermal resistance of panels can be rather easily raised by making the heat insulant a little thicker not making increase the thickness, weight and cost almost of a structure. This, in its turn, will enable to cut down operating expenses (fuel cost) and to enlarge the range of use of three-layer panels.

2. Small thickness and weight of three-layer panels with an efficient heat insulant enable to decrease expenses on their transportation and erection.
3. Due to small weights of three-layer structures with the mineral wool heat insulant there appears a possibility to erect multi-storey buildings of framed structures with hinge panels; use of one-layer panels of light-weight or cellular concrete for this purpose is difficult and not expedient.
4. For manufacturing foliated panels there may be used heavy-weight concrete on natural aggregates whose manufacture is not difficult since manufacture of structures made of light-weight or cellular concretes requiring special aggregates and mixtures is followed by considerable difficulties in some regions.
5. Outer walls of three-layer panels are dried much quicker than thick one-layer structures. Therefore original moisture of three-layer panels is for lower than that of one-layer panels and in the course of operation the difference in the moisture duty of these two types of panels grows more tangible for a short time.
6. When exploited three-layer panels are less subject to temperature deformations than one-layer panels. Therefore desolidification of jounts and corrosion of tie pieces in them are less probable than in structures of one-layer panels.
7. A concrete volume in 3-layer structures is 3 to 4 times less than in one-layer structures. Accordingly,

needs for cement and admixtures decrease as well as for plant equipment (concrete mixers, conveyors, etc.), cement warehouses and inert materials, etc.

8. Time for thermal of thin - walled 3-layer structures is much less than for one-layer structures.
9. Use of 3-layer panels allows in a number of cases to make outdoor ventilation structures what considerably improves their moisture duty and their heat stability in summer (no overheating).

When moulding 3-layer panels with mineral wool heat insulants there appear some difficulties, in the first place packing of mineral wool slabs under the pressure of a concrete upper layer. As experience in moulding shows, the compressibility of heat insulants reaches up to 15 to 20% of their thickness, therefore the thickness of unpacked heat insulants to be laid into moulds must be increased by 15 to 20% as compared to the rated.

While moulding 3-layer panels with mineral heat insulants there is some thickening of ribs connecting outer and inner (lower and upper) layers of the panel.

The main reason for this defect is the result of an incorrect arrangement of heat insulating slabs, and this can be easily eliminated under proper plant control.

Finally, in course of moulding and thermal treatment of foliated panels there occurs some additional moistening of heat insulants. This defect can also be eliminated by making mineral wool slabs hydrophobic or by wrapping them, or covering from top and from sides with water-proof materials (pergamyn or synthetic film) which at the same time serves as a steam insulating layer if moulded "facing dowuwards".

Thus, main technological defects of 3-layer panels with mineral wool heat insulants can be comparatively easily eliminated, and advantages of these panels will be better used in walls and coatings for buildings.

Three-layer wall panels of reinforced concrete cousist of two reinforced concrete layers and a heat insulating layer between them. Outer layers are connected with each other by armoured ribs of light-weight concrete. Outer and inner layers are moulded of heavy-weight concrete of 150-200 type. The outer layer together with the surface finish layer is usually 40 to 50 mm thick, the inner layer 50 to 100 mm thick, depending upon a character of wall operation.

Connecting ribs must have a thickness of not more than 40 mm in order to avoid "cold bridges". Connecting ribs are usually made of light-weight courete (haydite conerete) M-75 with the volume weight of not more than 1200 kg/sq.m. Heat insulants of semi-rigid mineral wool slabs 100 to 200 mm thick depending upon the rated temperature and moisture parameters, are placed between outer reinforced concrete layers. The outer finish layer may be made of:

- vibrated carbonate concrete M-100 on limestine rubble and sand, white and coloured cement of not lower than grade 400 or other concretes;
- small ceramic slabs;
- sea or river gravel;
- powdered crushed stone;
- concrete surface being painted with stable dyes.

Three-layer panels are armoured by welded nets and frameworks.

In the corners of panels there are anoher loops, two from top and two from bottom, to connect panels with each other and with other structures. Lifting loops are produced from hot-rolled flat armature steel of class, AI. The diameter of a lifting loop depends upon the fact that panels are lifted by special crosspieces in obligatory vertical direction of lifting strings.

Wall panels with mineral wool heat insulants can be made of various thicknesses, the most wide spread ones being 250 and 300 mm thick. The main values of thickness of elements, thermal resistance and ranges of applications of these panels in walls of apartment houses are given in Table 37.

Table 37

Panel Structures	Total Thickness mm	Thickness of layers, mm			Values of Ro		Allowed winter temperatures outdoors
		Heat insulant	Inner layer	Outer layer	in field	in rib	
1. 3-layer panel with insulant of semi-rigid mineral wool slags	250	120	80	50	2.276	1.17	-33°C
		100	100	50	1.957	1.02	-29°C
γ=150 kg/cu.m	300	170	80	50	3.106	1.51	-51°C
φ= 0.06		150	100	50	2.790	1.405	-46°C
2. Ditto	250	120	80	50	1.986	1.065	-31°C
γ=250 kg/cu.m.		100	100	50	1.706	0.966	-26°C
φ= 0.07	300	170	80	50	2.706	1.44	-49°C
		150	100	50	2.330	1-32	-42°C

Notes: I. Ro ~~trixxiex~~ calculated with coefficient 1.1

2. Allowed $t_н$ is calculated on heat conduction inclusion (in rib) $t_b - t_p = + 2.5°$, i.e. $t_b = 8.8 + 2.5 = 11.3$ and $\Delta t_н = 18 - 11.3 = 6.7°$.

3. Allowed summer temperature in the open is 40°C

Three-layer wall panels are manufactured in metal moulds in horizontal plane "facing downwards" or "facing upwards". When moulding "facing downwards" the outer surface becomes smoother, and the outer finish layer is included easier and more reliably into the total thickness of a wall. The drawback of moulding "facing downwards" is that the thicker inner layer is moulded from top, on the layer of the heat insulant, and due to this the latter undergoes considerable compressing forces but the inner (upper) layer itself is subject to less intensive vibration than the outer layer. Moulding "facing upwards" has contrary adventages and disadvantages. It should be pointed out that in this case the more compact inner layer serves as a more reliable steam insulation than in the previous case.

The order of manufacture of 3-layer panels for rooms when moulding "facing downwards" is approximately as follows. A window frame is placed into a cleaned and lubricated mould. Then are placed nets of the panel outer layer and frameworks of connecting ribs which are fastened to the outer layer nets and temporarily to the mould sides and window-frames. After that a concrete mixture is applied to mould the outer layer, and a vibrator is switched on for 30 to 40 seconds. Then semi-rigid mineral slabs preliminarily cut into pieces (packages) of such sizes so that that they would be accurately and tightly placed in positions arranged for them, are laid on the packed outer layer leaving holes for connecting ribs of rated dimensions.

26. 5. 72

Taking into consideration that technical characteristics of objects to be insulated in various branches of industry are quite different, investigations have been made in a number of industrial fields: metallurgy, mechanical engineering, chemistry, oil processing, power and food industries.

A number of big representative plants from each branch were taken as objects for investigations.

The research results permitted to define the proportion of volumes of objects to be insulated with different configurations and different temperatures of a heat carrier (or a cold carrying agent),

Use of this or that material for heat insulation of each group of objects can be decided optimumly not only proceeding from technical characteristics of objects on the one hand and of thermoinsulating materials on the other hand but also taking into account a comparative technical and economic effectiveness of use of this or that material for a given type of technological and power equipment or pipings.

Comparative technical and economical effectiveness of interchangrable thermoinsulating materials and products is determined by a number of factors characterizing these materials: heat conductivity, useful range of temperature zones, wholesale prices, total expenses on thermoinsulating structures (per 1 sq.m. of surface of equipment to be insulated, or per 1 lin.m of piping to be insulated), specific investments per 1 cu.m of products and per 1 structure commissioned.

A high technical and economic effectiveness of mineral wool materials and products is conditioned by their small materials and products, from the point of vi . of specific capital investments.

The optimum efficiency of plants for manufacture of mineral wool materials and products is rather higher than that of plants for manufacture of sevelite and other products. For example, the output of plants for manufacture of mineral wool products being 100 to 200 thou.cu.m.and more per year, the output of shops and plants for sevelite, perlite and other products is 20 to 30 thou.cu.m.,and technological processes being much more complex at that.

As a result of the influence of all these factors the rated investments in the manufacture of sevelite products,are 76 roubles per 1 cu.m,perlite products - 64 roubles,asbestos-- vermiculite ones - 74 roubles, the rated investments in the ~~temperature~~ manufacture of mineral wool materials and products ranging from 10 to 38 roubles, more typical 20 to roubles per 1 cu.m,i.e. 2-3 times lower. Taking into account that consumptions of sevelite and other products per pl cu.m of structures exceed these of mineral wool materials and products 1.5-2.2 times as much, the rated investments per 1 cu.m of structures commissioned are 3 to 6 times lower if mineral wool products are preferable to other materials and products.

All this made it favourable to use the abovegiven materials in all cases i if they can be applicable technically.

Data on technical characteristics of equipment to be insulated in metallurgy, chemistry,petroleum and chemical industry, oil processing and food industries as well as at power plants are given in tables, 26 - 31.

Average weighted proportions of insulating groups with similar technical characteristics are determined proceeding from the ratio of volumes of thermoinsulating works in the abovenumerated industries to be carried out by a large construction-erection firm.

The volume of these works in industries is as follows.

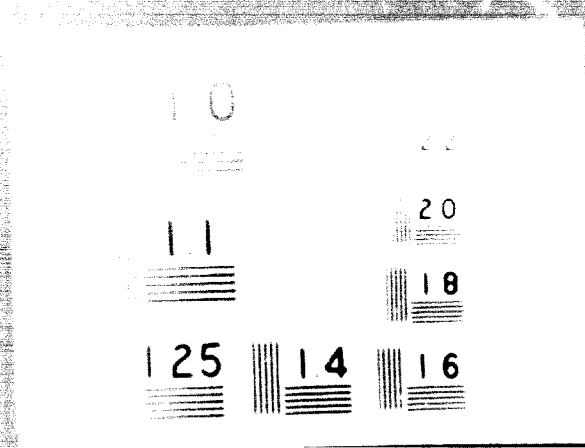
1. Plants of the chemical, petroleum and chemical and oil processing industries	-	53%
2. Power plants and heat mains	-	6%
3. Plants of the food industry	-	6%
4. Metallurgical plants	-	9%
5. Plants of other industries	-	26%

The ration of equipment groups at plants of "other" industries is directly proportional to the ratio of volumes of works in the first four industries. It should be noted that a character of works to be carried out by the firm, to which the data are referred, has a certain specificity:

1. The firm performs the insulation of power equipment only at comparatively small departmental power plants being a part of large industrial enterprises.

2. The food industry is represented by sugar refineries requiring insulation of hot surfaces, without taking into account the canning industry having considerable volumes of insulation of objects with low temperatures.

As is seen from the Tables, about 69% of the total volume of the heat insulation is for pipings, 27% for apparatus and about 4% for steel frameworks.


1.0
2.0
1.1
1.8
1.25
1.4
1.6

6. Use of Mineral Heat Insulants in Combined Coatings and Interstorey Floors.

Products of mineral wool for combined roofs and coatings as well as attic for floors are used as heat insulants in various structures. A structures of a combined assembled coating (Fig.31) consists of the bearing part, mineral wool heat insulant and upper ribbed slab on which a water-proof blanket (3 to 4 layers of ruberoid) is glued. Use of mineral wool heat insulants for attic and interstorey floors is shown in Fig.32. It should be noted that such structures have a low plant readiness and hence they require considerable labour efforts. Much better factors in this respect are embodied in light-weight concrete panels with voids filled with efficient heat insulants (panels of КОП type), which permit a wider application of mineral wool products not only in wall structures but also in combined roofs, coatings and interstorey floors.

Hollow panels for combined roofs and coatings are made of light-weight concrete 150 with the volume weight up to 1400 - 1500 kg/ cu.m and represent slabs with longitudinal holes (voids) where the heat insulant is inserted. Panels 6m long are moulded by continuous-aggregate or conveyer methods in horizontal position on standard (accepted for production of multi-hollow floorings made of reinforced concrete) or special installations with horizontal void-formers. Panels up to 4m long can be moulded in vertical position in cassette moulds with vertical formers.

Panels 1.5 m (1490mm) wide may be of three to four voids. In the first case the width of a void is 420mm, in

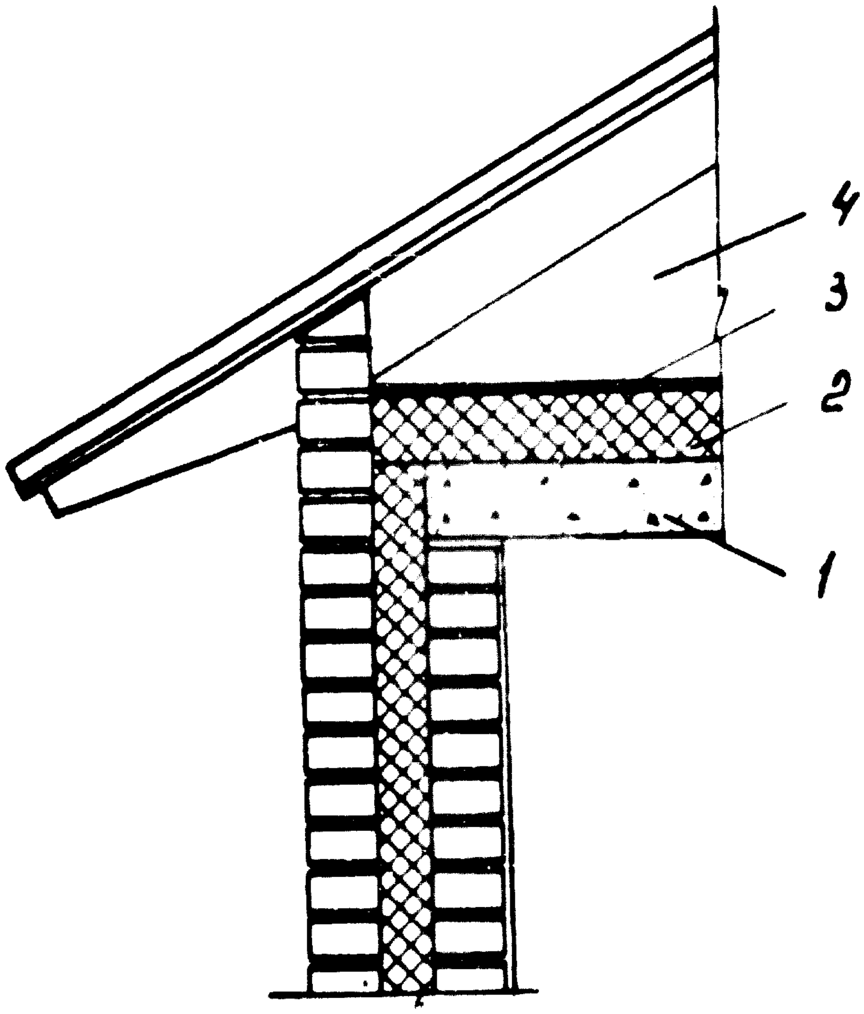


Fig. 31. Structure of Ventilation Pitched Roof with Mineral Wool Insulation

1. Foor of reinforced concrete.
2. Mineral wool slab.
3. Cement tie piece.
4. Ventilation attic.

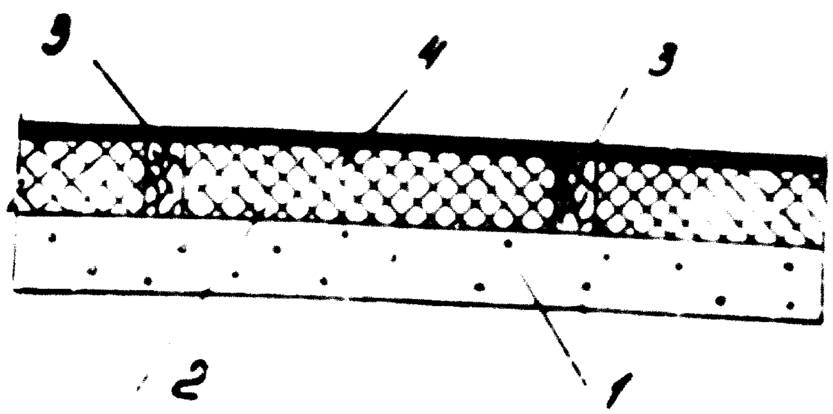


Fig. 32. Structure of Floor over Cold Rooms or Cellars

1. Floor of reinforced concrete.
2. Mineral wool heat insulant.
3. Sleepers.
4. Board floor.

the second - 290 mm. Ribs (between voids and the end ones) are 40 to 50 mm wide. It is adviseable to leave flanges along the end ribs in order to make a widened joint 120 to 140 mm wide filled with the heat insulant. Hollow panels for rooms may have 6 to 7 voids with their maximum allowed width of 460mm.

To heat panels there can be used charging heat insulants (haydite, perlite, volcanic slag, thermosite, etc.) or inserts of mineral wool semi-rigid slabs with synthetic binder as well as all kinds of sealing heat insulants. Mineral wool inserts with the volume weight of up to 150 kg/cu.m are made of the width similar to that of voids. Their thickness is defined according to calculations and is usually less than the height of voids so that over the layer of the heat insulant there should be a through hole (lengtwise) which is used to ventilate the panel.

Mineral wool inserts are necessary to be prepared in a coat of synthetic film or porgamyn, whose stripes are stitched widthwise from top and bottom of the latter, and lateral sides are left open to be better fitted to the panel ribs. The coat facilitated pulling inserts into voids and also forms from bottom steam insulating layer and from top it prevents infiltration of outdoor cold air (in ventilation structure) through the layer of the mineral wool heat insulant.

Special mechanisms are used for pulling thermal insulating inserts into voids. Heating of panel may be done with mineral wool inserts directly made at a plant on movable moulds. The bottom and sides of such a mould are covered with porgamyn and then a required layer of mineral wool is laid.

The mould is inserted in a corresponding void of the panel and then is pulled out leaving a mineral wool layer in the void and this layer is slightly pressed for better adjoining to the partition and bottom of the void. The thickness of a mineral wool layer in the mould must be by 10 to 15% more than the rated.

Panels 1.5m wide with end cornice consoles, or without them, can be used for combined roofs of apartment houses and public buildings with three longitudinal bearing walls (for example, brick buildings). The same panels can be used for combined roofs of buildings having a wide pitch of the bearing structures and also for ceilings of industrial and agricultural buildings if beams are employed as bearing structures. But if trusses whose upper belts are not designated for cross-bending are to be used then it is necessary to take ribbed and hollow panels or panels with local thickenings in fulcrums. Finally, in combined roofs of buildings having a narrow pitch of the bearing structures it is advisable to use hollow panels of a room's size with end cornice consoles.

It is clear from the given brief description of hollow structures that panels having a small width (1.5m) can be used in various kinds of buildings and with different bearing structures. In this connection such panels may be called unified or universal. In contrast to these kinds of panels wide panels have a use range limited by apartment houses with a narrow pitch of the bearing structures, and are panels for one room. Such panels usually rest on the contour and may have longitudinal or cross directions of voids.

When arraging [illegible] combined roofs and ceilings there [illegible] arise the necessity [illegible] than standard [illegible] is effected in the same [illegible] the same time [illegible] of inserting [illegible] into [illegible] it is possible to get one [illegible]

[illegible] panels can be [illegible] gradually changing heights of voids, leaving the thickness of shelves invariable.

A ventilation scheme of combined roofs and ceilings from hollow panels depends on an arrangement of panels, direction of dominant winds and other factors. In buildings with a cross arrangement of panels a cross ventilation is usually practiced, when each void or a group of voids is connected with the atmospheric air which enters air holes under the cornice and gets out into a longitudinal slit passing along the gable. If the longitudinal arrangment of panels is taken ventiligtion schemes can be more complex.

Thermal and technical qualities of hollow panels, naturally, cannot be the same (widthwise) because of the availability of heat conducting inclusions in form of ribs and joints.

Effect 1: When heating with haydite the voids are filled completely.

2: No thermal resistance along the axes of voids

3: Of thermal resistance in joints

Allowed winter temperatures outdoors (t = [illegible]) for panels KOII-30, KOII-35, KOII-40 and KOII $\frac{34}{35}$ for rooms heated with haydite and mineral wool inserts are given in Table 41.

Table 41

Panels	Heat Insulant	Apartment Houses	Industrial Buildings, tair 18°		
			Vair-50%	Vair-65%	Vair-70%
KOII-30	haydite	- 25	- 32	- 28	- 21
KOII-35	- " -	- 31	- 40	- 35	- 28
KOII-40	- " -	- 40	- 50	- 45	- 35
KOII-30	mineral wool 12cm "	- 22	- 29	- 26	- 19
ditto	- " 15cm "	- 26	- 32	- 27	- 21
KOII-35	- "-19cm "	- 35	- 42	- 39	- 30
KOII-40	- "-24cm "	- 45	- 52	- 48	- 37
KOII $\frac{34}{35}$	- "-18cm "	- 40	-	-	-

Thermal stability of KOII panels given in Table 41 permits their use at rated summer temperatures of 30°C and higher.

As compared to standard ventilation roofs the combined ventilation roofs from hollow panels have the following advantages:

total labour consuming character - by 25 to 40%.

steel consumption - by 30%;

cost - by 20 to 30%

weight - 1,5 to 2 times as much.

One of the most essential advantages of hollow panels is their low operating moisture while original moisture of coating structures of blind light-weight and cellular concrete is often 50 to 60%, the original moisture of hollow panels is for: coat - 6 to 8% mineral wool heat insulant - 2 to 3%. A thin coat of such panels promotes to quick removal of this small quantity of moisture.

Characteristics of some types of hollow panels are given in Table 41.

Table 41

Characteristics	КОГІ-35	КОГІ-35/40	КОГІ-35/20	КОГІ-35 with Widened joint
Weight, kg	2453/1803	4 600	1500	1700
Volume of concrete, cu m	1.17	2. 80	0. 94	1.10
Volume of heat insulant, cu.m	1.9/1.2	2. 00	0. 72	0.71
Reduced thickness of haydite concrete, cm	13. 2	-	10. 5	12. 30
Steel consumption per 1 sq.m, kg	6.24	-	-	-

Note: Numerator-heating of haydite γ = 400- kg/cum, denominator of mineral wool inserts.

7. Use of Mineral Wool Heat Insulants in Panels with Aluminum and Asbestos Cement Coats

Three-layer panels with aluminum outer coats are most widely used in remote and northern areas where a small weight of structures [illegible] is [illegible] is very [illegible] re-gions [illegible] requirements to these structures; cost, labour-consuming character [illegible] of deficit materials, etc., play a less important role. Such 3-layer structures are used for walls, ceilings and floors. Yet if cheap aluminum sheets for panel coats are available use of such panels is possible and expedient. Panels are lined with flat or corrugated aluminum sheets 1,5 mm thick. Paroloam, foam plastics and semi-rigid mineral wool slabs are used as heat insulants. Panel ribs are made of bakelisated plywood 10mm thick.

Panels for walls and roofs have the same structure and differ only in dimensions. Buildings with aluminum panels must be of a framework type. A Framework structures can be different. A method of hinging wall panels onto the framework is chosen according to the structure of the framework.

Panels are sheathed with flanges to which ribs from bakelisated plywood are fixed by rivets. Joints are sealed with non-hardening mastics (YMC-50 and YM-40). Panels are glued with rubber glues 88H and 88 HII.

Panels for floors do not have lateral flanges; instead, embedded parts are inserted in them.

The thickness of the heat insulant should be such so as to reduce the weight of the upper (inner) concrete layer. For this purpose the extra thickness of the heat insulant must be more than the rated on the average by 15 to 20%, and is checked up by test moulding. When moulding "facing downwards" the same operations are executed whereupon particular attention is paid to finishing of the upper (outer) surface.

The moisture coutent of the heat insulant after thermal treatment of the panel must not be higher than 5% in weight, and this can be achieved by its compulsory protection against moistening by one of the following methods:

- placing pergamyn or building paper on the top and sides of the heat insulant in positions of junction with connecting ribs; if a steam insulation is required a layer of rubereid is laid;
- packing up mineral slabs into water - proof coats from water-proof materials.

On having laid a heat insulant layer connecting ribs are moulded from a light - weight concrete mixture of 50-75 type, then inner layer nets are placed and fastened to the frameworks of connecting ribs. Upon compleetion of this operation the panel inner (upper) layer is moulded from a heavy-weight concrete mixture which is vibrated by surface vibraters and then is levelled by a vibrobatten.

When timed for two hours moulded panels are transfferred to steaming chambres for thermal treatment whose duty is determined so as to obtain not less than 70% of the rated type of concrete after taking out the panel from the chambre.

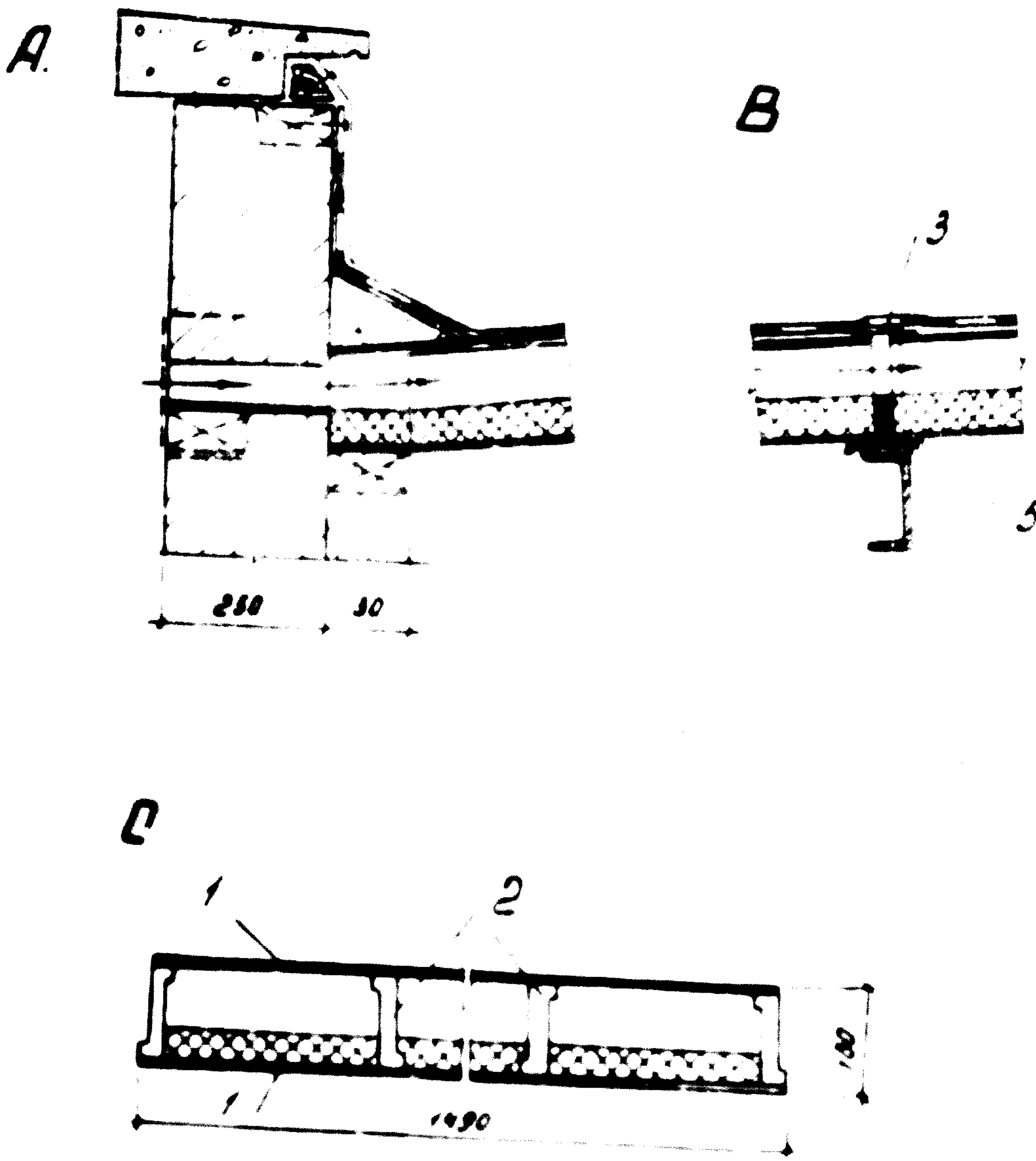


Fig. 33. Structure of Ventilation Coating From Asbestos-Cement Panels, with a Span of 3 m

A. Frieze unit with input ventilation hole.

B. Unit conjugation of asbestos-cement panels from short sides.

C. Panel cross section.

1. Asbestos-cement sheet. 2. Asbestos-cement blocks, or channel bars. 3. Compensator. 4. Steel girder. 5. Elastic pad.

Panels with asbestos-cement coats may be wall as well as roofing panels. Fig.33 shows a cross-section of panels for combined roofs with asbestos-cement coats glued to asbestos-cement blocks with epoxy glues. The lower slab is covered with a semi-rigid mineral wool slab whose thickness is defined by calculations. Space over the heat insulant is used for ventilation of a combined roof. One of possible variants of air input into the ventilation hole is shown in Fig.33 from which it is seen that the roof has an inner drain because its facade side is bordered with a parapet and not with a cornice.

Panels with aluminum and asbestos-cement coats have a small weight and sufficient strength in wall as well as in roofing enclosing structures. Their use is especially rational with efficient heat insulants to which mineral wool products belong.

Technical Values and Representations

Terms	Conventional Representation	Dimensions Unit	Definition
1	2	3	4
Value Weight		kg/cu.m	Weight of mineral volume unit in natural state, i.e. with streams.
Porosity actual		%	Ratio of total volume of pores to mineral volume.
Compression strength		kg sec / Sq.cm	Maximum tension under which material is destroyed from compressing forces.
Bending strength		"	Ditto, from bending forces.
Tensile strength		"	Ditto, from tensile or breaking forces.
Compressibility	C	%	Degree of compressibility of material from compressing efforts.
Gram calorie (small callorie)		cal	Amount of heat necessary to heat up 1 gr of distilled water by 1°C (from + 19.5 to + 20.5°C)
Kilocalorie (large calorie)	-	Cal	Ditto, 1 kg
Specific heat	C	Cal/kg°C	Amount of heat necessary to heat up 1 kg of material by 1°C
Heat conductivity	C	Cal/m.hr.°C	Amount of heat passing through 1 sq.m of material thick 1m for 1hr. with difference in temperatures on opposite wall sides equal to 1°C.

1	2	3	4
Water absorption (moisture capacity) of material		%	Amount of water absorbed per volume unit or weight unit of material through direct touch with water.
Hydroscope capacity of material		%	Ratio of moisture weight absorbed by material from atmosphere to its weight in absolutely dry state
Absolute moisture of material		%	Ratio of weight of moisture available in material to its weight in absolutely dry state
Relative moisture of material		%	Ratio of weight of moisture available in material to its weight in moistened state.
Fuel efficiency	Cal/kg Cal/cu.m.		Amount of heat released after complete burning of 1 kg of solid and liquid fuel or 1 cu. m. of gas fuel.
Conventional fuel	kg		Fuel with its efficiency of 7000 Cal/kg
Heat transfer coefficient	Cal/sq.m hr, °C		Amount of heat passing throught 1 sq.m. of wall 1m thick for 1 hr with difference in temperatures from opposite wall sides equal to 1 °C.

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