Issues related to rheology in the production process of thermal insulation products based on foamed waterglass

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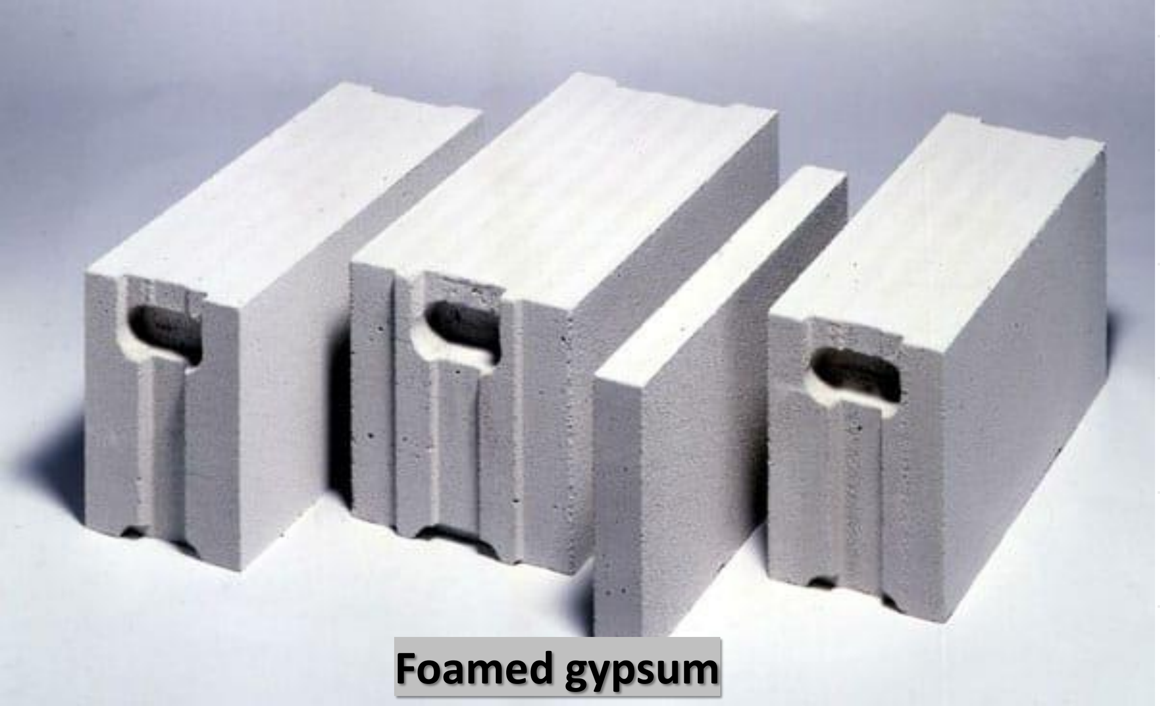
Effective non-combustible heat insulation based on foam compositions

Granulated Foam Lacquer Glass

Plate Foam Glass

Foam Glass gravel

Foam Glass rubble

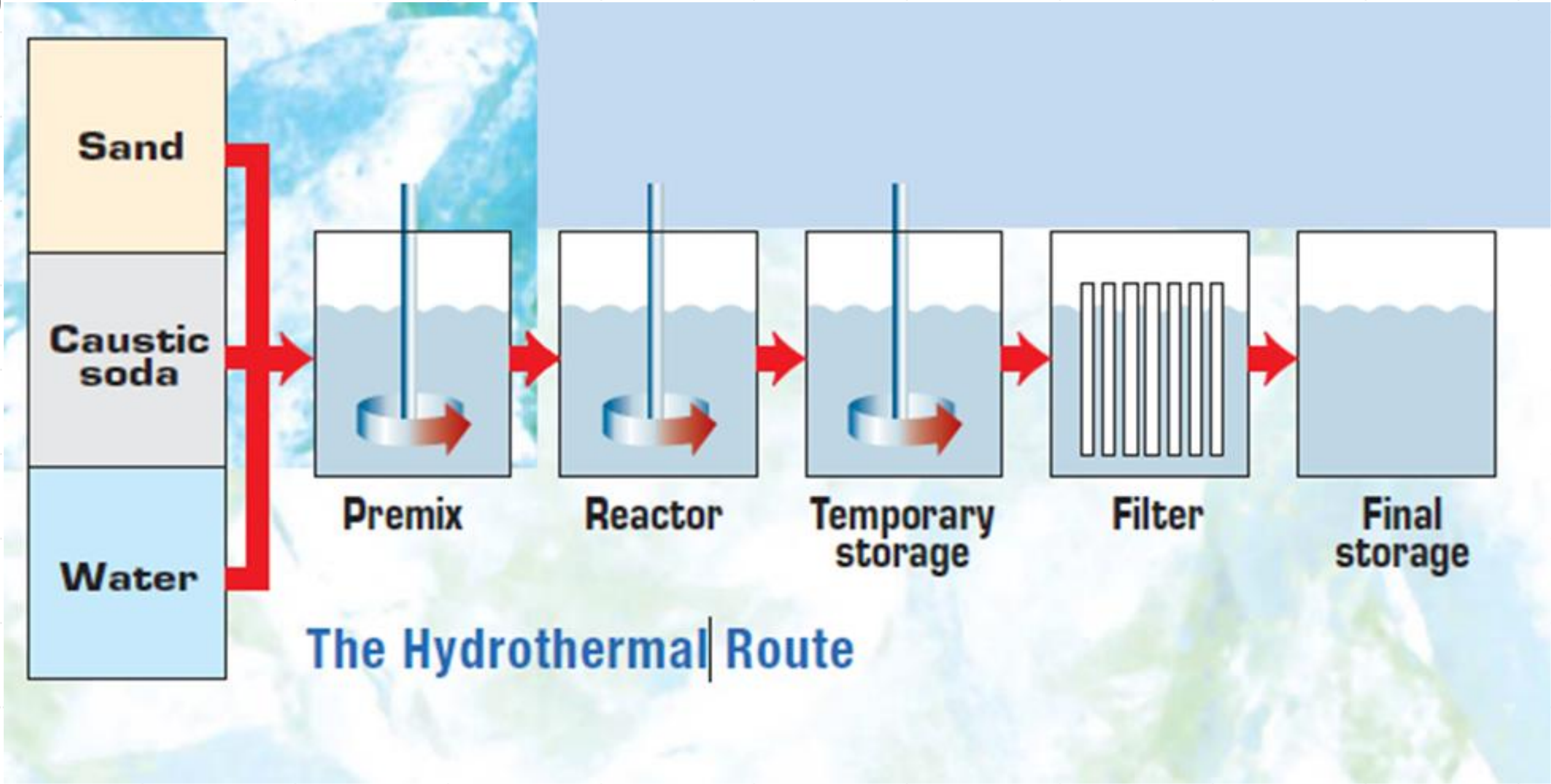


Foamed gypsum

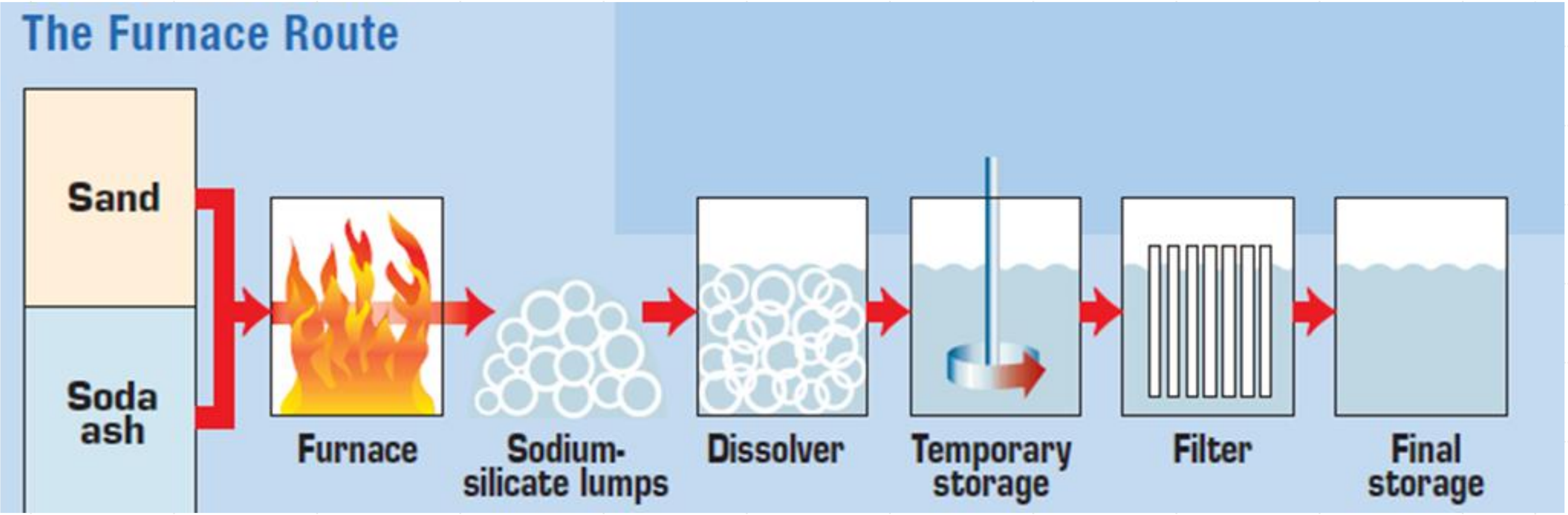
Foamed materials based on cold-cured waterglass

A solution of sodium silicate or its anhydrous variety, silicate block, is usually obtained in one of two ways:

1



2


The Furnace Route
Sand
Soda ash
Furnace
Sodium-silicate lumps
Dissolver
Temporary storage
Filter
Final storage

Technology of production of a material based on foamed liquid glass

The first version of the production technology consists of the following stages:

- mixing of pre-prepared raw materials in a continuous planetary screw mixer (liquid glass, hardener, fiberglass and foam obtained using a foaming agent through a foam generator);

- after loading the mixture, the molds are sent to the drying tunnel chambers of low temperatures, where the main processes of hardening warterglass, drying the material to remove excess moisture to make the formation of the final structure;

- after heat treatment in the chamber at a temperature of 50 C and a duration of 12 hours, the cooled cube of material is sent to the point of unforming and cutting by string method.

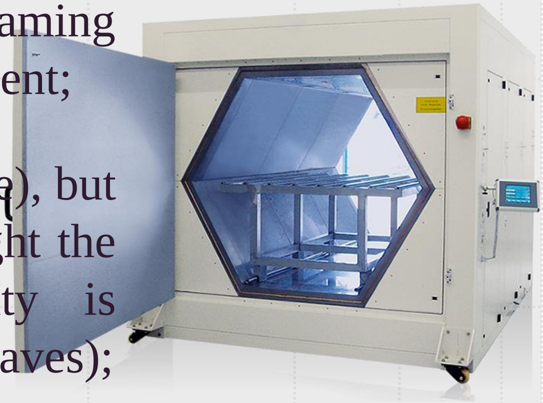
According to the second alternative experimental variant of processing a porous material based on waterglass, they were manufactured using microwave material processing technology. The technology involves volumetric processing by electromagnetic waves.

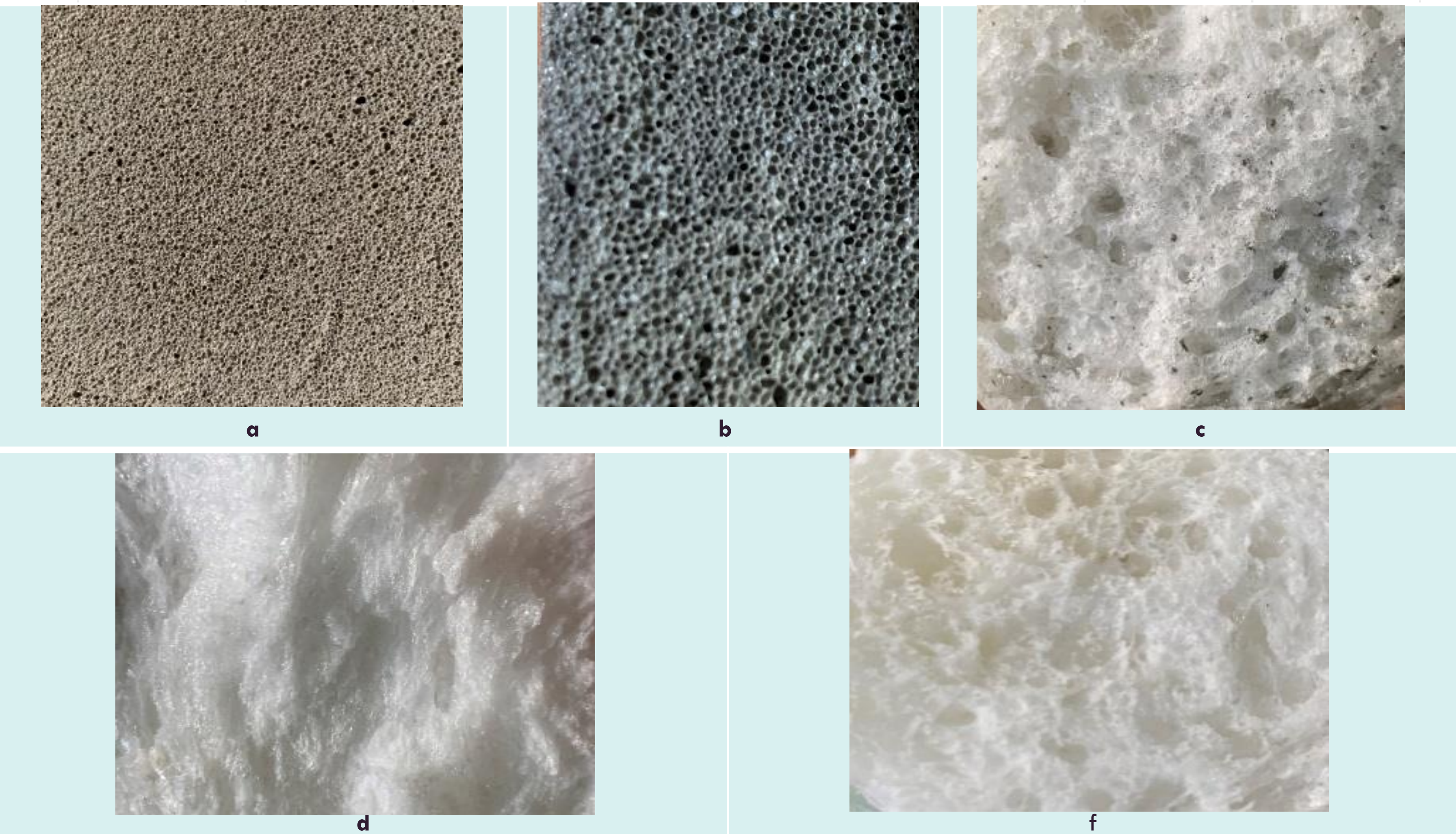
The main technological differences in the use of this method:

- it’s not necessary to use a foaming agent as a raw material component;

- molding not into a shape (cube), but onto a tape (only at a low height the necessary degree of porosity is achieved, by electromagnetic waves);

- the material is processed in a chamber vacuum microwave dryer.





Structure of various silicate compositions of porous materials:

a - foam glass; b - foam glass crushed stone; c - material based on liquid glass with the addition of Portland cement; d – material based on liquid glass and organosilicon additive; f - material based on liquid glass and additives - calcium hydroxide

One of the most important controlled parameters in the production process of a waterglass–based material is the ***viscosity*** of the waterglass composition, which affects the structure of the material.

Engineering rheology deals with the issues of structure formation of materials, including thermal insulation, the study of structural and mechanical (rheological) properties, the development of methods and devices for their determination. The devices developed and proposed for implementation in industry allow them to be installed locally or directly into technological equipment, including them in the technological process of processing raw materials.

Periodical operative collection of information on the quality of raw materials at the stages of its receipt, processing and release of finished products based on rheological characteristics using devices — all this provides the opportunity to control, regulate and manage the quality of raw materials and finished products. In the production of thermal insulation materials based on foamed waterglass, there is a need to control rheological characteristics (viscosity and fluidity of the mixture) raw materials such as waterglass (aqueous solution of sodium silicate) and additives.

Rheological properties of raw materials. Viscosity

The viscosity of a sodium silicate solution is a function of concentration, density, ratio and temperature. Figure 1 shows that the viscosity strongly increases with increasing ratio. High ratio solutions will increase in viscosity until they become semisolid. Comparison of viscosity at constant solids content at different ratios shows that silicate solutions are at a minimum viscosity at 2.00 weight ratio.

Viscosity increases as the weight ratio of the sodium silicate product becomes either more siliceous or more alkaline.

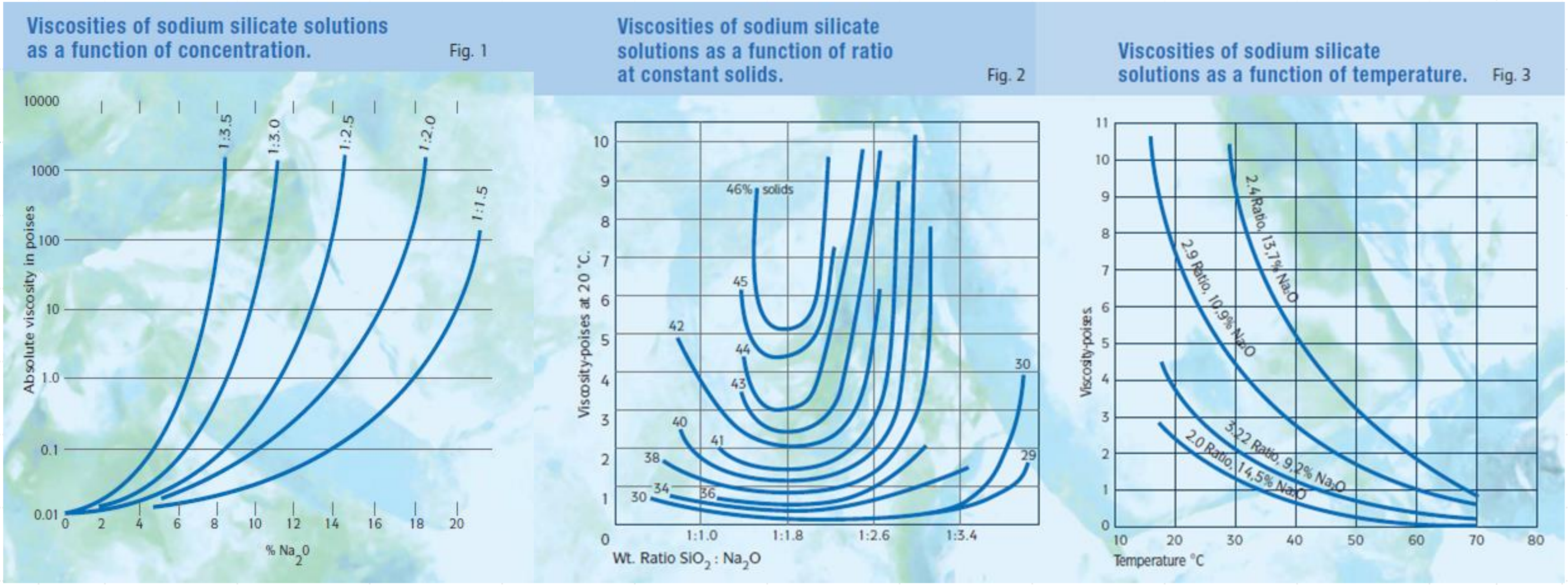


Figure 3 shows that viscosity of sodium silicate solutions at commercial concentrations can be decreased to less than 1 poise if heated sufficiently and if evaporation is prevented.

Potassium silicate solutions are similar to solutions of sodium silicate. One significant difference, however, is that potassium silicate solutions are somewhat more viscous than corresponding sodium silicate solutions at equal concentrations. But, like sodium silicate, the viscosity of solutions is affected by ratio, concentration, and temperature.

- The viscosity of the raw material mixture, consisting of a liquid–glass binder, foam and additives, affects the main parameters of the structure of thermal insulation materials - the type, size and distribution of pores in the thickness of the thermal insulation material. These structural parameters determine the main characteristic of the thermal insulation material - thermal conductivity resistance.
- In the pores of a relatively small material there is a smaller gas convection and a reduced influence of radiant energy of the heat transfer component.
- Let us compare the thermal conductivity of the materials based on foamed silicate compositions, which are similar in chemical composition but have different structure parameters due to different production technology and differ in type of main silicate raw material (cullet in the case of foam glass and sodium liquid glass in the case of a porous material based on foam based cold curing liquid glass)

Type of material	Porosity type	Mean density, kg/m^3	Thermal conductivity, $W/(m \cdot K)$
Foam based cold curing liquid glass	open-cell structure	130 - 195	0,049-0,068
Foam glass	closed cell structure	130 - 160	0,043-0,062

The thermal conductivity of porous materials is influenced not only by the size of the pores, but also by their structural parameters such as shape and location. Thus, the maximum porosity in a dense cubic pore formation is 52.5%, and in a hexagonal arrangement is 74%. Therefore, the aim is to obtain a structure with the most compact pore arrangement, which is achieved with an optimal combination of large and small pores.

Investigation of the dependence of the characteristics of water absorption of a material on its structure and composition. The influence of technological parameters on the rheology of the foamed mass

Composition number	Components	Content, % by mass
1	Sodium liquid glass $Na_2O{\cdot}2,7SiO_2$	85
	Organosilicon Hydrophobicator sodium ethyl sulfonate ($C_2H_5Si(OH)_2ONa$)	15
2	Sodium liquid glass $Na_2O{\cdot}2,7SiO_2$	87
	Hydrated lime $Ca(OH)_2$	13
3	Sodium liquid glass $Na_2O{\cdot}2,7SiO_2$	90
	Portland cement (main reactive phase - alite $3CaO{\cdot}SiO_2$ (C_3S))	10

Based on experimental data, it was found that the percentage of additive Portland cement indicated in the table provides optimal values for the edge wetting angle compared to other formulations.

The reason for the decrease in water absorption in the system «liquid glass - Portland cement» can be described in this way: when the components interact (free water in liquid glass binds to Portland cement) low-core calcium hydrosilicates are formed, as well as calcium hydroxide, which subsequently binds free sodium liquid glass cations into insoluble compounds.

Depending on the addition of a particular hardener (liquid additive or powdered), the rheological parameters of the raw material mass change during mixing. Therefore, it is necessary to control the viscosity of the mass during its transition from one technological point to another.

Proposals for the control of rheological parameters in the production process of a material based on foamed waterglass

- To fix the viscosity of the composition at each stage of hardening of liquid glass (the beginning is the stage of mixing raw materials, then heat treatment, the end is at the stage of drying the product).
- To consider the peculiarities of the heat treatment process, depending on the selected hardener.
- When using an alternative method of heat treatment – the microwave heating method, it is necessary to compare the rheological characteristics and characteristics that affect the formation of the structure of the material (viscosity of the semi-finished product mass, the rate of hardening, the total hardening time, the resulting structure). After analyzing the necessary characteristics that affect the performance of the finished product, select the controlled parameters of the mixture.
- Another rheological parameter is contraction. For example, after heat treatment of the material by cold curing, the contraction is 8 cm. How controlled rheology parameters can be involved in predicting shrinkage after heat treatment of the product.
- The role of rheology in this case lies in the fact that, using structural and mechanical properties of materials and instrumental (objective) methods and operational control devices as control indicators, we can ensure control, regulation and quality management of raw materials and finished products.

A question for the organizers and participants of the conference:

- *Have you ever faced the problem of controlling the rheological characteristics of a waterglass binder?*
- *Due to the technological differences with the cement binder, will there be differences in the laboratory equipment used to control the viscosity of waterglass?*
- *The question of the applicability of equipment designed for cement mortars to solutions of sodium, potassium silicates or fused cullet.*

THANKS FOR YOUR ATTENTION,
FEEL FREE TO EMAIL ME IF YOU HAVE ANY FURTHER QUESTIONS

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