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→ Marie Dietrich

14709

JP/181/84

UNIDO - CZECHOSLOVAKIA JOINT PROGRAMME
FOR INTERNATIONAL CO - OPERATION IN THE FIELD
OF CERAMICS, BUILDING MATERIALS AND NON - METALLIC
MINERALS BASED INDUSTRIES
PILSEN, CZECHOSLOVAKIA

GLASS PRODUCTION TECHNOLOGY IN DEVELOPING COUNTRIES

1984

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UNIDO-Czechoslovakia Joint Programme
for International Co-operation in the Field of Ceramics,
Building Materials and Non-metallic Minerals Based Industries
Pilsen, Czechoslovakia

Distr.
LIMITED

JP/181/84
April 1984

ORIGINAL: English

GLASS PRODUCTION TECHNOLOGY IN DEVELOPING COUNTRIES

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ABSTRACT

The paper deals with the production of utility glass. It gives an informative survey of the production technology of household glass including crystal glass, container glass and sheet glass. Chemical composition of industrial utility glass, glassmaking raw materials, glass batch preparation and batch plant equipment, suitable types of melting furnaces, technology of melting and forming are described. The entry-, operational and final inspections are mentioned, too.

The publication gives an information about limiting properties of raw materials which are usable in the production of different types of glass and about production equipment in connection with the production capacity and assortment of a plant in question.

The paper was initiated by the need of developing countries to establish and develop the glass production and, therefore, it respects the specific conditions of these countries.

LIST OF CONTENTS

-...-

INTRODUCTION

During the previous experience, the UNIDO-Czechoslovakia Joint Programme has met different non-metallic raw materials, some of which suitable for the glass manufacture. However, different developed countries present their national Standards for the classification of available glass sands. Those Standards reflect the purity and up-grading and refining methods in the relevant home countries and, therefore, do not respect different deviations from the requested quality which, in many cases, occur in the developing countries.

On the other hand, there are developing countries producing glass without respecting relevant permitable limits especially as far as the content of colouring oxides is concerned. As a result of that, glass of various shades is produced which does not enable the manufacturer to export the products to neighbouring countries.

Another reason for editing this paper is the attempt to assist the developing countries starting the crystal glass manufacture.

The crystal glass manufacture is not distinguished according to the decoration of products by cutting and engraving but first of all, according to its diffractive index which depends on the purity of raw materials and batch composition used. Therefore, following the requests from many developing countries, the UNIDO-Czechoslovakia Joint Programme has analyzed the practical admissible limits of the purity of raw material inputs, in connection with the manufacturing equipment applied, in order to show the possibilities of introducing cheaper and simplified refining processes of glass sands in developing countries.

The decision on the establishment of glass production in developing countries is to be based on a detailed analysis of local conditions. Geological and physico-chemical evaluation of reserves of raw materials, such as silica sands, limestones, dolomitic sands, dolomitic limestones, feldspar pegmatites and phonolites must be done since these raw materials form the basic constituents of the glass batch. Total reserves of glass raw materials of constant physical and chemical properties must give a chance of their perspective mining for at least 50 years. The accessibility and suitable quality of glass sands in the country is the most important factor with regard to their share in the glass batch which amounts up to 75%.

When classifying the natural raw materials, it is necessary to take into account the economy of upgrading methods, as grain size sorting (sieve preparation) of silica sands, grinding of siliceous raw materials, limestones and dolomites. These methods must be undertaken in order to fulfil the technological conditions of the successful melting process of glass in good quality and with good economy.

The total content of Fe_2O_3 in glass is the primary technological condition of usefulness of a raw material in the production of glass because Fe_2O_3 colours the glass into green. If the content of Fe_2O_3 in natural raw materials is low, they are usable for the production of luxury crystal household glass, if the content of Fe_2O_3 in natural raw materials is higher, they are usable for the production of colourless container and sheet glass, in case of high content of Fe_2O_3 they are usable merely for the production of coloured container glass (beer bottles). SiO_2 from silica sands is the main constituent of glass. Its share in a glass batch is up to 75% depending on the type of glass. The content of Fe_2O_3 in these sands is, therefore, decisive. If limestone, dolomite and dolomitic limestones are used, bringing into glass stabilizing oxides CaO and MgO - their share in glass is about 10%, their content of Fe_2O_3 is not decisive but also not negligible. The alkali constituents of glass Na_2O and K_2O are brought into the glass batch as synthetic raw materials, such as soda, potash, saltpeter, and their contamination by the oxides of iron is minimal. There is only one exception - technologically advantageous easy meltable natural raw materials, such as phonolites containing up to 15% of alkali oxides. Due to their high percentage of content of Fe_2O_3 and Al_2O_3 their use is limited merely to coloured container glass. The use of natural alkali rocks as a cheap source of alkali in container glass is economically feasible namely in developing countries.

The establishment of a glass production in a developing country and the choice of an assortment depends predominantly on local market requirements and availability of local raw materials. It is feasible if the market requirements are higher or at least the same as the break even point of the production.

This paper does not include the technology of production of special technical glass, such as the production of optical glass and borosilicate glass. These sorts of glass are produced in industrialized countries with developed glass industries as their production requires high qualification, specialization and developed other branches of industry.

It is to be mentioned that the export of glass sands for the production of optical glass into industrialized countries is advantageous and advisable for developing countries. It requires perfect up-grading methods and machines, eventually the selective mining, in order to gain the glass sands of desired size and of the content of Fe_2O_3 less than 5.10^{-3}. If the mining and up-grading of sands for the production of lower quality glass is already established, the improvement of up-grading methods for the production of glass sands for export will not require large investment costs.

The paper is limited to basic utility glass, i.e. household glass, container glass and sheet glass giving a general information about these branches of glass industry. Some practical compositions and the basic physico-chemical properties are described. Limiting concentrations of some oxides, e.g. Fe_2O_3 and Al_2O_3 in the final melted glass, i.e. including the influence of refractory materials during the process of melting,are mentioned defining the possibility of exploitation of these raw materials for certain sorts of produced glass. In surveys of typical compositions, the recommended ranges of substitutions for some glass-forming oxides, e.g. for alkali oxides Na_2O, K_2O, by the oxides CaO, MgO, BaO are presented. It will give orientation for the given raw material base of the country in question.

The paper provides orientation for managers and specialists in developing countries intending to start with or develop the existing production of glass, to exploit local raw material reserves and labour power.

Technicians in existing productions will find in the publication a useful information concerning production technology and production diversity.

I. CONCLUSIONS AND RECOMMENDATIONS

1. The establishment or expansion of the glass industry depend primarily on the market potentiality and suitable local raw materials availability.

2. More sophisticated types of glass, such as cut crystal glass, chemical or optical glass, need a lot of know-how and training for the successful manufacture.

3. Quality and quantity evaluation of domestic glass raw materials is the first prerequisite for the considerations on glass manufacture.

4. Glass siliceous sand, representing the bigger part of any glass batch, is to be available locally while the other batch components, depending on local situation, can be imported.

5. Up-grading and refining of siliceous sands or other raw materials are very common in order to make the raw materials suitable for the glass production.

6. Quality factors of glass raw materials are usually defined by national standards. Such standards reflect the nature of domestic raw materials and up-grading and refining methods of the respective country.

7. There exist practical limits of raw material permissible quality factors, kept by different world's manufacturers which do not correspond to relevant standards but which can be a base of the successful glass manufacture. Such limits are very important in considering the possibility of the establishment or expansion of the glass industry in developing countries as they can influence the economy very much.

8. At present, some developing countries produce different types of glass regardless the permissible limits. As a result, the produced glass shows various shades which can be accepted by local markets but such glass can hardly be exported.

9. The actual trend of producing crystal glass in developing countries wakes up the neccessity of setting out practical limits for the purity of glass raw materials for individual glass types as the crystal glass is not defined by different types of cutting, engraving and decorations but primarily by the diffractive index reached by the purity of raw materials and by the batch composition.

10. The presented paper does not show the general principles of glass manufacture which are described in many publications. The paper analyzes the permissible practical limits of quality factors of glass raw materials and it draws attention to the economic choice of the manufacturing technology and equipment.

11. Taking into consideration the foregoing theses, the following steps are to be respected in establishing or expanding the glass industry in a developing country:

    a) To conduct the geological research and evaluation of siliceous sands and raw materials including their technological evaluation.

    b) To test locally available siliceous sands or other siliceous raw materials.

    c) To develop an economical method of up-grading and refining siliceous sands or other siliceous raw materials in order to prepare the suitable glass sand for the batch composition.

    d) To evaluate the market potentiality and to determine main types of glass to be produced. Depending on the type of requested glass manufacture, to review the raw materials availability and refining and up-grading methods for the glass sands preparation.

e) To carry out the feasibility study for the venture taking into consideration the minimum economic plant capacity in relation to the market requirements.

12. Training of local engineers and technicians abroad is very essential from two different aspects' viewpoints:

- testing, refining and up-grading methods of glass sands
- manufacture of requested type of glass including various decoration possibilities, such as screen-print, stamping, cutting and engraving for glass containers and glass table ware manufacture.

13. Energy availability forms an indispensable condition to the establishment of glass industry. Average energy consumption in container glass production ranges from 5 to 9 GJ/t of produced glass.

14. The UNIDO-Czechoslovakia Joint Programme renders its assistance to developing countries in the following fields of activities:

- Fostering of twinning arrangements between the appropriate Czechoslovak organizations and similar ones in the developing and least developed countries
- Individual training of technicians and engineers
- Group training programmes and workshops
- Testing of raw materials together with the related technological research and pilot demonstration applicable in industry and selection of appropriate technology
- Technical assistance, exploratory and advisory missions
- Energy conservation
- Application of non-metallic sorbents to agriculture

Many countries turn directly to the Joint Programme requesting raw materials preliminary testing, technical publications and information.

In case of interest in a twinning arrangement with the Joint Programme, individual training of technicians, pilot tests of raw materials and selection of appropriate technology, advisory and exploratory missions or in energy conservation programme, the request for such an assistance is to be conducted through UNDP in the relevant developing country and through UNIDO Headquarters Vienna.

15. High skill of the UNIDO-Czechoslovakia Joint Programme in non-metallics reflects also to the glass industry, especially to the raw material testing, up-grading and refining. Direct assistance can be organized or intermediated with other institutions.

II. TYPICAL CHEMICAL COMPOSITIONS OF INDUSTRIAL UTILITY GLASS

Household glass - soda-potash crystal for hand made leadless glass, and following decorative techniques
- leadless soda crystal for the mechanized and automated production
- lead crystal containing up to 24% PbO
- luxury lead crystal containing more than 24% PbO for following cutting and chemical polishing

Container glass - colourless glass for preserving industry
- green and amber glass for bottles

Sheet glass - glass for drawing up from the level

Other technical sorts of glass as optical glass, borosilicate glass, glass to mechanical drawing of fibres, float glass (glass manufactured by floating on the batch of molten metal, are not included because their production is very difficult and requires high technical standard and co-operation with other branches of industry. Such glass manufacture is not recommended to be started with in developing countries.

A Household Glass

Soda-potassium crystal

The most common range of composition of this glass is presented in Table 1. When simplifying the matter, the basic components of the glass are SiO_2 from 70 - 77%, alkali oxides Na_2O, K_2O from 15 to 18% and alkaline earth oxides CaO, MgO from 6 to 10%. Due to the limited content of Fe_2O_3 in glass 0.015 - 0.03%, in colourless crystals relatively pure raw materials are used - glassmaking sand up to 0.02% Fe_2O_3, limesotne ev. dolomite up to 0.03% Fe_2O_3, calcined soda up to 0.005% Fe_2O_3, calcined or hydrated potash up to 0.001% Fe_2O_3. These glass batches have to contain refining agents accelerating the degasing of the glass melt during the melting process. In practice there are two possible variants of refining combinations: KNO_3 + Sb_2O_3 and Na_2SO_4 + KNO_3. The choice of the refining process depends on the type of the furnace. Whereas in gas fired melting pot and tank furnaces both combinations are admitted, in all-electric furnaces the sulphate refining is excluded or admissible to a limited extent only.

The resulting greenish tint of crystal has to be complementary decolourized into neutral grey by pink colouring compounds of selenium completed by minute amounts of cobalt and nickel. Corrections in charges of decolouring agents are to be done every day, at every furnace, according to colour tint of the crystal. The corrections depend on redox conditions during the melting process. In hand made crystals determined to consecutive raffination by grinding, cutting, painting, etc. the combination of alkali oxides Na_2O : K_2O in the ratio of 1 : 1 up to 2 : 1 is used. Where pure dolomites are available, it is possible to admix CaO and MgO but in the dolomitic ratio approximately 3 : 2. In the case that it is desirable to change the properties of glass during melting, accelerators of melting - borax up to 1%, fluorine compounds and newly lithium compounds up to 0.2% are added into the charge. For viscosity modifications during melting and forming some other glass forming oxides, such as BaO, ZnO, Al_2O_3, are added into the charge. The above mentioned modifications of composition of basic glass are used for optimization according to local conditions in individual glass works taking into account thermo-technical and technological functions of the melting furnace, technological conditions of forming, annealing and other following refining treatments. The materials for hand made glass are more expensive (higher content of K_2O) because the decolouring of crystals must be more efficient than that of soda glass. The portion of raw material costs in the price of decorated products is not decisive as the products are more expensive. But in the automated production of household glass with a small portion of decoration, e.g. by silk screen painting, the raw material costs are cogent and, therefore, these products are made of cheaper raw materials (soda glass), eventually with a small portion of K_2O. As the soda glass shows specific viscosity curve and a long thermal working range, the viscosity, surface tension and chemical durability are modified by adding Al_2O_3 in the amount up to 1%. MgO in the amount of 1 - 3% is often used, too.

Lead crystal

The top quality crystal with a high refractive index is used as a raw product for decoration by grinding or cutting or it is produced as a pressed glass with a complicated decoration imitating a rich cut. The cut or pressed articles are then chemically polished in acid bath containing 1 - 3% HF + 50 - 60% H_2SO_4 at the temperature of 55 - 65°C. As it can be seen in Table 1, lead crystals contain more than 24% PbO and have minimum refractive index n_D 1.545. In this case it meets all commercial standards defining the designation "lead crystal". The characteristic feature of these crystals is the potassium containing composition with minimum content of Na_2O from 2 to 3% because the decolouring of the remaining greenish tint is carried out by the compounds of nickel. In this potassium containing composition nickel brings in a blue - violet tint which is complementary to the green colour caused by Fe_2O_3. On the contrary, in soda containing glass nickel colours glass into dirty grey. That is the reason why lead crystals must not contain a higher percentage of Na_2O.

Also the selenium compounds are not usable as decolouring agents in lead crystals with high content of PbO because they colour the glass into yellow-brown. The typical blewish tint is the result of decolouration by nickel where the complementary combination of colours retains the excess of blue constituent.

The fundamental technological condition of successful melting and of good quality of produced glass is highly oxidizing atmosphere in furnaces; in gas fired furnaces 2 - 3% content of O_2 in vaste gasses . The glassmaking batch must also contain a sufficient quantity of oxidizing substances, e.g. 3% of KNO_3 which in combination with 0.2 - 0.5% As_2O_3 form an oxidizing refining agent. Oxidizing conditions in the batch and in the atmosphere of the furnace above the level of glass melt prevent from the reduction of elementary lead. If the reduction occurs, the elementary lead sinks to the bottom of pots in pot furnaces or to the bottom of the basin in tank furnaces and brings about a strong corrosion of refractory materials - the so called pitting corrosion - and releasing of small grains into the glass melt.

A perfect crystal appearance of a cut workpiece is conditioned by the use of purest raw materials, namely of glass-making sands (content of Fe_2O_3 maximum up to 0.015%). The pure hydrated sulphate-free potash is used as potassium containing raw material in addition to the above mentioned small quantities of KNO_3. The sulphates would not decompose in strongly oxidizing conditions during melting and a separation of liquid phase would occur. The oxide of lead is brought into glass in the form of minium Pb_3O_4 , less often in the form of litharge PbO or other lead containing raw material. An important condition is the use of arsenic As_2O_3 as a refining agent in combination with saltpeter KNO_3 as it retains Fe in little colouring form. The use of Sb_2O_3 does not give good results due to bad influence on the colour of crystal. If arsenic is used, it is necessary to control severely its contamination by CoO colouring crystal into blue. Other components of glass the limiting contents of which are given in Table 1, are not decisive and are added into glass in some cases as oxides influencing the mechanical properties (cutting, grinding) and chemical properties (chemical durability) of products.

The glass industries in some countries produce the so called halflead crystals where cheaper BaO or a small content of ZnO and B_2O_3 substitute for a part of PbO. The ratio of alkali oxides Na_2O and K_2O must remain in the above mentioned proportions, i.e. up to 2 : 1, if nickel is used as decolouring agent. The same counts for oxidizing conditions in the charge and melting furnace and for the use of refining agents. Most often these combination crystals contain 5 - 10% PbO and up to 10 % BaO. The technology of chemical polishing must be specifically adapted for this glass and the concentration of HF in the polishing batch is not usually higher than 1%.

B Container and Sheet Glass

The range of components in container and sheet glass is approximately the same (Table 1); the same raw materials are used with the exception of coloured container glass. Therefore, container and sheet glass is described jointly in this paper.

These sorts of glass are produced mostly by mechanized and automated forming. Their chemical composition is simple. The batch consists predominantly of cheap natural raw materials. The most expensive constituent of the charge is soda which is the cheapest of synthetically produced raw materials. Container and sheet glass consists mostly of four exceptionally of three basic constituents - SiO_2, Na_2O, CaO, eventually MgO (see practical example of container amber glass in Table 1). The other constituents, such as Al_2O_3 in the amount of 0.4 - 3% are added to influence the viscosity of the glass melt during forming and, above all, to enhance the chemical resistance against leaching in water. Most producers supply MgO into the batch together with CaO in the form of dolomite and dolomitic limestones and these oxides are regular components of container and sheet glass in the amount of 2 - 4%. These addicts impart to glass good chemical and mechanical properties. Moreover, when substituting for CaO, it favourably influences the viscosity of produced glass. Interval of workability of this glass is longer than that of soda - calcium glass. It favourably lowers the liquidus temperature and crystallization rate which is very important in the production of sheet glass. Even the better meltability of a glass containing MgO is not negligible.

A substantial parameter of the quality of used raw materials is the content of Fe_2O_3. In dependence on Fe_2O_3 content, it is possible to decide whether the natural raw materials are usable for colourless container glass and sheet glass (content of Fe_2O_3 in glass 0.05 - 0.1% by mass) or merely for coloured container glass (content of Fe_2O_3 0.3 - 0.7% by mass).

Al_2O_3 content is the next limiting factor of usability of raw materials in container and sheet glass production. The content of Al_2O_3 in a colourless glass is 0.4 - 1.5%, in coloured glass maximum up to 3%. Higher contents of Al_2O_3 negatively influence especially the melting conditions. The above mentioned limiting content of Al_2O_3 designates to what extent it is possible to use phonolites containing up to 15% of alkali .

Also feldspars, feldspar pegmatites, trachytes, nephelinic syenites and basalt are technologically advantageous and very cheap. Formerly, a large amount of phonolites was used for the production of coloured container glass due to their low price and the content of Al_2O_3 was 4 - 12%. With regard to the technological purposes these types of highly aluminious glass are not produced nowadays with the exception of coloured glass bottles where phonolite is the source of Fe_2O_3 and Al_2O_3. Al_2O_3 is brought into colourless container and pressed glass in the form of pure feldspars containing up to 0.2% Fe_2O_3. In Table 1 there are presented the ranges of constituents in compositions of all groups of container and sheet glass as mean values of analysed glass of a number of European glass producers.

The refining agents enhancing the degasing of glass during the process of melting may be practically the same as those used in crystal glass but in the mass production the combination KNO_3+ SB_2O_3,eventually As_2O_3 is too expensive and, therefore, nearly exclusively sulphates (sodium sulphate, Glauber salt) are used in the theoretical amount of 0.4% SO_3 in glass in gas fired furnaces . The contents of So_3 presented in Table 1 are residuary contents in glass. The sulphates are used as refining agents in electric furnaces but in the half amounts in comparison with the gas fired furnaces.

If the use of chemical intensifiers of melting and refining is necessary, then for the gas fired furnaces the most suitable combinations including the basic dosage of refining agents are:

Na_2SO_4 - 0.5% Na_2O brought into glass by sulphate , calculated proportionally to the mass of glass melted from the batch

CaF_2 - 0.7 - 0.8% CaF_2 of the mass of the batch

NaCl - 0.3 - 0.5% NaCl of the total mass of the charge ; NaCl is not suitable in the production of pressed and container glass formed in smooth metal moulds .

As decolouring agents of the greenish tint in colourless glass, similarly as in leadless crystal glass the compounds of selenium are used but the decolourization is not perfect due to higher content of Fe_2O_3 in this glass. The colourless container glass and sheet glass with lower content of Fe_2O_3 are not decolourized due to rising prices of selenium on the world market.

Another specific technological problem is the colouring of green and amber (brown) glass. Green glass is coloured, in addition to Fe_2O_3, by chromium which is brought into glass by chromium ore or other industrial finely granulated waste products containing chromium (chromium slags). The content of Cr_2O_3 in this glass ranges from 0.15 to 0.2% by mass. Amber glass is coloured by polysulphides. Their origin in alkali glass is the result of added sulphates - up to 0.3% SO_3 - together with the reducing carbon (graphite, carbon waste products) in the amount up to 5% in the batch. Iron and sulphur are brought into the glass batch with advantage in the form of pyrite in the amount of about 0.3%. In the production of container glass it is possible to use a relatively wide range of basic compositions especially as far as the ratio CaO : MgO is concerned. Table 1 shows the practical example of amber glass.

The basic composition range is very narrow in sheet glass production due to severe technological requirements on the properties of the glass melt during drawing (system Fourcault), such as the viscosity, liquidus temperature and the rate of crystallization. The composition is given by long technological experience. The fundamental condition is the MgO content in the range of 3.5 - 4% and a relatively small admitted deviations in the composition in the work of the batch plant.

An example of sheet glass composition is presented in Table 1. The condition of a prosperous technology of production of drawn sheet glass is a correct adjustment of the drawing machines and perfect homogeneity of glass melt based on precise work of the batch plant, granulometric size of raw materials (see recommendations in Table 2), homogeneity of the mixed charge and a correct function of the thermally-technical operation of the melting aggregate.

C Recommended Physico-chemical Properties of Individual Glass Sorts

The chemical durability - resistance against water at 98°C, classified into five grades according to the individual international standards ISO/DIS - is decisive from the point of view of functional use of any type of glass (household, container, sheet glass). The sorts of glass included in Table 1 must not exceed class 4 because these glass sorts when in use come into persistent contact with water : the washing and rinsing of household glass, preserve jars, bottles and weather influence exerted on sheet glass.

Other physical properties of container glass and sheet glass depend to a certain extent on the leachability, i.e. indirectly on their total alkalinity. The values in approximate ranges are mentioned in Table 1 and it is evident therefrom that they lie in the same areas. The desired improvement of leachability not influencing substantially other properties of the glass melt and products is practically carried out by bringing in Al_2O_3 in the range of 0.5 up to 3% where the influence of Al_2O_3 on the leachability is the most effective.

At luxury soda - potash and lead crystals in addition to required class 4 of leachability further commercial aspects come into question, above all the clarity and colour stability. In cut glass the refraction index n_D is of great importance. Sodium potassium crystals have refraction index about 1.515, barium-calcium and barium-lead crystals above 1.520 and lead crystals above 1.545. The aspect of colour at luxury crystals is the most important one. Further technologically limiting aspects are for example a low content of CaO in chemically polished glass, low content of MgO and ZnO influencing the cutting hardness and a relatively high content of potassium and low content of sodium enabling the decolourization of crystal by nickel as a substitute for instable decolourization by selenium.

III. GLASS RAW MATERIALS

A Raw Materials for Household Glass

The price of a household glass is very often, in case of a lead crystal exclusively, raised by cutting and other refinement techniques. The labour costs are high in comparison with raw material costs which are in this case not negligible but subsidiary ones. The decisive criterion for the choice of raw materials in the production of crystal glass is the content of colouring oxides, especially Fe_2O_3. Luxury glass is produced in relatively small quantities from relatively expensive, with the exception of sands, predominantly synthetic raw materials. This glass is very expensive.

In addition to natural purified sands, eventually selectively mined limestones and dolomites, synthetic basic raw materials are used.

Synthetic basic raw materials for glass production

Soda caustic ash	Na_2CO_3
Hydrated potash	K_2CO_3, K_2SO_4, KCl
Caustic, eventually molassy potash	K_2CO_3, Na_2CO_3, K_2SO_4
Saltpetre	$NaNO_3$
Barium carbonate	$BaCO_3$
Minium (red lead)	Pb_3O_4
Zinc oxide	ZnO
Antimonium oxide, eventually arsenic oxide, etc.	Sb_2O_3, As_2O_3

B Raw Materials for Container and Sheet Glass

These sorts of glass are produced in large quantities, mostly without further refinement and the value of final products is given by the costs of raw materials and that of the melting process. In the composition of the glass batch for the melting of these sorts of glass, maximum quantities of cheap natural raw materials are used. The alkaline compounds are brought in preferably by soda ash, the most expensive raw material of the batch. Therefore, there are efforts, especially in production of coloured container glass, to use all available natural rock raw materials containing alkaline constituents.

The most common raw materials for the production of container glass

glass sand	phonolite
dolomite	feldspar
soda ash	basalt

Refining and colouring raw materials

sulphate	graphite
Glauber salt	manganese ore
pyrite	chromium slag

Raw materials for the production of sheet glass

glass sand	soda ash
dolomite	feldspar
limestone	

As refining materials for sheet glass, sulphate and Glauber salt are used.

C Technological Requirements on Basic Raw Materials for Glass Melting

Technological requirements on basic glass raw materials from the point of view of their grain size distribution are presented in Table 2.

The sorts of limiting accompanying oxides classifying the raw materials from the point of view of their extent of technological applicability in individual types of glass are also mentioned in Table 2.

Two alternatives are presented in grain size distribution of basic raw materials:

a) optimum grain size distribution from the aspect of technology of the melting process, energy consumption and homogeneity of produced glass. This grain size distribution respects approximately the recommended industrial standards of quality,

b) in the adjacent column maximum (extreme) values are mentioned which occur in glass industry when imperfect upgrading methods are applied. In spite of this, these rough grained raw materials were industrially used in glass works without relevant changes in the quality of produced glass. Rough raw materials, namely with grain size distribution above 1 mm are not recommendable in the production of drawn sheet glass as the drawing process requires a highly homogenous glass melt. In this case it is not possible to achieve optimum economy in glass melting, maximum output of melting furnaces, correct melting temperatures and first class quality of the glass melt. This extreme alternative is mentioned because when applying natural raw materials for the melting of glass above all container glass, in developing countries, a situation may occur when the use of simpler upgrading methods will be economically more important than e.g. optimum melting rates of furnaces and the energy consumption.

D Raw Material Quality

The surveys presented in Tables 3 to 8 give practical examples of quality of natural and synthetic glass raw materials industrially used in the melting of glass from the point of view of their chemical composition and grain size distribution. The surveys include used extremely rough grained rock raw materials in the production of less demanding container glass.

Glass sands

The most slowly meltable raw material is glass-making sand (see Tables 1 and 3) the grain size of which must not exceed 1 mm. From technological reasons (degasing of the glass melt) the portion of grains under 0.1 mm should not exceed 5% from total. In some cases (luxury crystals) the portions under 0.1 mm and above 1.0 mm are removed and these sands are dried in glass works just before use.

In the mass production of container glass and sheet glass the damp glass-making sands are used without following sieving. The moisture content of sands in the batch plant before weighing should not exceed 4%. The moisture content of sands in wagon consignments directly from mines (natural deposits) should not exceed 7%.

Special cases may occur at sea sands which contain small quantities of Fe_2O_3 but they are often contaminated by calcareous compounds CaO + MgO , eventually by alkaline compounds. In general, these sands are usable in the production of luxury glass in case that calcareous fragments (cockle shells) do not exceed the grain size of sand, i.e. 1 mm. The sieved, eventually washed fragments of limestones may be ground and used as pure raw material bringing CaO into glass.

Table 4 presents practical examples of rough grained dolomites. These rough grained dolomites are usable in glass-making because they are more easily meltable then the glass-making sands. As to the up-grading of dolomites and limestones, there is one general condition that their grain size should not exceed the grain size of silica sand whereby then the portion of powder represents no deficiency.

Between the two examples there may exist a long row of interjacent dolomitic limestones in nature representing an equivalent glassmaking raw material.

The rock raw materials always contain a certain portion of alkaline components from 4 to 15% and are relatively easy meltable. From this reason even extremely rough grain size distribution e.g. of phonolites and basalts presented in Table 5 except feldspar do not cause operational problems during the melting of the charge. In optimum technological conditions of melting the grain size of rock raw materials should not exceed the grain size of sand, i.e. 1 mm. The usable rock raw materials are those containing higher percentage of alkaline components and limited percentage of Fe_2O_3 and Al_2O_3. Further examples of industrially applicable rock raw materials for the production of coloured container glass are feldspar pegmatites, trachytes and nephelinic syenites. The main reason for their use is the soda saving.

Potash which is often produced from various waste products of chemical industry may contain different amounts of impurities namely of sulphates and clorides. That is why in the production of lead crystals requiring oxidizing atmosphere during melting chemically purest hydrated potash is used. As alkali containing raw materials waste liquors are used, poured into the dry glass batch (dried sand and dolomite).

For luxury crystals with high content of lead above 24% PbO mostly minium is used, for crystals with lower content of lead from 3 - to 10% PbO, it is possible to use litharge, eventually lower oxidized lead products. In colourless crystals the content of Fe_2O_3 and of other colouring oxides is strongly limited. On the world market, granulated lead containing raw materials with low portion of dust are available - granulated minium and granulated litharge. In order to improve hygienic conditions in the preparation of glass batch, when using the powder lead raw materials, the batch is wetted with water up to the moisture content of 1 - 2%.

E Cullet

The cullet in the charge is to be taken for an important raw material forming over 50% of the mass of the newly melted glass. The cullet in the charge revaluates to a large extent the value of expensive primary raw materials and their content in the charge lowers the consumption of energy during melting since the cullet is easy meltable. For example, 100 mass units of cullet replaces cca 125 mass units of primary raw materials and every 10% of glass manufactured from cullet spares 2 - 3% of energy consumption in melting.

In the production of household glass with prevailing hand manufacture at normal conditions the own cullet, such as waste and moils of workpieces, usually forms 50% of the charge and even more. The cullet is to be perfectly pure and it must be crushed into pieces corresponding to the method of charging the furnace, as a rule of surface dimensions up to 10 cm^2.

In the production of sheet glass where the demands on homogeneity of glass melt are very high, the quality claims on cullet are similar to those in the production of household glass, i.e. the exclusive use of own cullet in the amount of 10 - 40%. The fundamental condition is the constant ratio of the batch to cullet.

In the production of container glass, mostly of coloured container glass, the field of application of cullet is substantially wider and not limited to own cullet but also waste container glass, excess of sheet glass, cullet from other glass productions are used. Constant portion of cullet of different chemical composition is admissible in lower concentrations but in this case the corrections in the composition of basic glass is necessary. In the melting of container glass it is possible to use 40% of cullet in the charge including 5% of cullet from other productions. In extreme cases it is possible to use 60% of cullet including 15% of cullet from other productions. Average portion of cullet in the charge is 20 - 30% which corresponds to 20% difference between the btto and netto production.

F Conclusions to Glass Raw Materials

In the foregoing chapters, all the decisive conditions of the choice of raw materials for the production of various glass sorts were discussed in detail, i.e. the choice of raw materials concerning the required composition of glass, chemical purity, recommended ranges of grain size distribution and final limiting components of raw materials enabling their practical classification. The following conclusions can be summed up:

1. The limiting condition of all raw materials is their content of Fe_2O_3 defining not only their applicability for the adequate sort of glass (see Table 1) but also the range of use of the raw material in the glass batch. At the rock raw materials further limiting component, Al_2O_3, comes into account. The limiting content of both these oxides in glass must not be exceeded from both the functional and technological points of view.

2. The upper limit of raw material grain size 1 mm is defined by the most difficult fusable raw material, i.e. in common glass the glass-making sand. As proved in practice (Tables 2, 4, 5) it is possible to exceed these values in the production of container glass at dolomites and alkali rock raw materials.

3. In the production of household glass and luxury glass, namely when glass is melted in pot furnaces, the grain size of raw materials, e.g. glassmaking sand, dolomite, is finer. These natural raw materials are, before consumption in batch plants, dried and sieved on control sieves mesh 1 mm^2. In some cases, the portion under 0.1 mm is removed.

4. Rocks used as raw materials are economically interesting in the first place in the mass production of coloured container glass. They bring a part of alkali into glasses as a substitute for expensive soda ash.

5. Cullet as a return raw material in the glass batch is economically advantageous as it revaluates the primary raw materials, raises the melting rates and saves fuels during melting.

IV. BATCH PLANT AND BATCH PREPARATION

The process of preparation of the glass batch, eventually glass charge, i.e. batch + cullet, consists of following working operations:

a/ transport of raw materials into the store and their storage
b/ treatment before use
c/ transport into storage bins in the mixing room
d/ dosing and weighing
e/ mixing (homogeneization) of the glass batch, eventually the wetting of the batch
f/ cullet storing and crushing
g/ dosing of cullet into the glass charge
h/ discharging of the mixer, eventually mixing the batch with cullet
i/ transport of the glass charge to the melting furnace

In this chapter the main technological principles and machine equipment for the homogeneization of the batch are described.

A Hand Operated Batch Plant

In small capacity production, e.g. in hand manufacture of blown and pressed glass, melted in pot furnaces, manual methods of feeding the charge into the melting furnaces are used. This occurs in the so called hand operated batch plants without automated systems of weighing and with a small portion of mechanized labour. The weighing is carried out manually in metal containers forming the bottom section of a drum (tumbling) mixer, e.g. type "Saxonia" (Figure 1). In these metal containers the batch is transported to melting furnaces and their content is fed manually by means of a shovel as a charge into the pots. In drum mixers the wetting of the batch may be done. For the homogeneization of the batch in the mixer 30 revolutions of the drum per minute are usually sufficient. The decolouring and colouring agents are added into the batch before mixing. The crushed cullet (crushed manually or in a jaw crusher with jaws made from manganese steel) is not mixed with the batch but fed into pot furnace separately according to the prescrit d procedure.

It is necessary to respect cleanness and use protecting aids (respirators) according to hygienic instructions during the work in a hand operated batch plant.

B <u>Mechanized and Automated Batch Plants</u>

For the preparation of large quantities of glass charges mechanized batch plants mostly with automatic system of weighing are used.

Former types of mechanized batch plants are represented by the so called horizontal batch plant (Figure 2) where the storage bins are arranged in horizontal rows. Under the storage bins automatic charging scales for individual components are situated. The weighed components of batch fall upon the collecting belt conveyor and therefrom into the feeding bin of the mixer. The homogenized batch is discharged into batch storage bins which are transported to the melting furnace and the charge is discharged into the charge storage bins of a mechanized charger of the continuous melting furnace. The arrangement of transporting lines of raw materials and of storage bins and above all the arrangement of the weighing system of raw materials, their transport into the mixer and the transport of the charge to the melting furnace may vary according to local conditions and the choice of the project designer.

More modern and now widely spread are the so called vertical batch plants where the storage bins with automatic scales, eventually one scale for more components, are arranged in circles. The transport of raw materials and batch including pneumatic transport and/or vibration offer many variations according to the stage of automation. In the demanding productions (crystal glass) magnetic separators of iron are used. The flow sheet of a modern vertical batch plant including pneumatic transport is presented in Figure 3

The arrangement of a mean capacity batch plant with prevailing manual handling of raw materials is shown in Figure 4. Sand, eventually other natural raw material, is unloaded from the wagon into the sand stock 1. It is dried in the sand drier 2 and transported by an elevator 3 into the storage bunker above the balance 4 . Other raw materials, such as soda and limestone, are usually supplied into the glass works in bags or barrels on pallets and are transported by the elevator 5 for packed raw materials into the space 6 above the storage bunkers. Therefrom they are transported on hand operated or electrical trucks into the bunkers 4 above the balance 7 . From the bunkers the raw materials are poured through vibration feeders into automatic balance 7 with indicators of weighed doses. The balance weighs the desired amounts of raw materials and these are emptied into the mixer 9 in which they are mixed into homogenous mixture (time of homogeneization 2 - 4 minutes). From the mixer the charge is supplied into transporting containers with bottom outlet in which the charge is transported on electric or petrol driven trucks to the melting furnaces. The above described batch plant (Figure 4) can prepare ca 40 t of charge per day and is, therefore, the most often used type in the production of utility glass.

The addition of cullet into the glass charge for the continual melting furlaces depends on the type of the melting furnace, on the method of feeding the charge into the melting furnace and on the type of mixer. At disc paddle mixers cullet may be supplied directly into the mixer. In planetary screw mixers cullet is supplied to the outlet of the mixer into the container. Cullet completely or partly mixed with the batch is convenient for piston batch chargers. In some cases cullet and the batch are dosed separately into the doghouse of the melting furnace and the batch is deposited onto the layer of cullet.

C Wetting of Batch

Dry sands are used mostly in luxury soda-potash or lead glass and they are cooled and sieved before use on a control sieve of mesh 1 mm^2. An additional wetting may be carried out mainly in the preparation of batch in the production of lead glass for hygienic reasons:

Moisture content of wetted glass batch

Type of glass	Moisture content
lead crystal	1 - 1.5 %
soda-potash glass	3 - 4 %

In the production of container glass and sheet glass where large quantities of sand in the batch are consumed, sand is used wet without control sieving. The optimum admitted moisture content of sand causing no problems in technology is up to 4%. The total moisture content of the batch when using sand containing 4% of water will be in the production of sheet glass 2.3%, the moisture content of the batch when using sand containing 5% of water will be 3.1%. The wet batch is to be stored in optimum conditions at the temperature above 35°C.

D Machine Equipment of Batch Plants

The arrangement of store spaces, bins, bunkers, system of weighing and the complex transport of raw materials from the storage up to weighing line depends on the whole project of the batch plant and on the transport of the charge to the melting furnace.

Following fundamental machinery equipment most often used in practice without frequent failures, with small requirements on maintenance and suitable for all types of batch plants for preparing charges of both dry and wetted batch is to be recommended:

a/ disc paddle mixer

b/ jaw crusher of cullet with plates made from manganese steel; it is not suitable for sheet glass production

c/ for manual charging of batch in small quantities (crystal glass or combination of coloured glasses) the mixer of Saxonia type (see Figure 1) is most suitable. For mechanized feeding of batch into small continual melting furnaces in hand operated batch plants a similar mixer analogous to Saxonia type mixer is used but the bottom section of the mixer has the shape of a cone including lower outlet of charge, serving as a transporting container of the charge above the batch charger of the melting furnace (Figure 5).

The handling equipment of the glass charge (batch + cullet) for its transport from the mixing room to melting furnaces is adapted to local space layout. The claims upon the transporting equipment of glass batch are higher than those laid upon the transporting equipment of raw materials because it is necessary not only to prevent the glass works hall from dusting during the discharge of the batch into the charger but also to eliminate demixing of batch particles during the transport.

In large batch plants the transport on belt conveyors is most often used. In smaller batch plants materials are transported in containers with lower outlets of the charge into the storage bins of the charger.

E Charge Feeding into Melting Furnace

Charge feeding means its supply into a continual melting furnace by horizontal pushing the batch and cullet onto the surface of the melt in subsequent portions. According to the shape of the charge on the surface of the melt various systems of feeding are distinguished:

a/ feeding in larger piles discontinuously into the forehearth (doghouse) of the furnace - obsolete method (see Figure 6)

b/ feeding in thin continuous blanket, applicable only for electric furnaces

c/ feeding in small lumps of charge with gaps (see Figure 7)

The last mentioned system is the most suitable one for gas fired melting furnaces. The following types of mechanized chargers are used according to the method of transport of the batch from the storage bunkers into the charger of the furnace:

a/ piston batch chargers

b/ screw batch chargers

c/ separate charging of cullet and batch in 2 layers

For smaller types of tank furnaces used in the production of household glass and container glass the piston batch chargers proved competent (see Figure 7). In the production of sheet glass in the giant melting furnaces the batch chargers feeding the batch and cullet in two separated layers are most suitable (Figure 8).

Correct function of the chargers requires maintaining the surfaces of the melt in continuous melting furnaces on constant values. The level of the surface is measured by means of glass-level indicators coupled to electric control of the charger. Various systems are at disposal:

a/ floater glass-level indicators with electrical output signal (Figure 9)

b/ pneumatic glass-level indicators based on the change of air pressure in dependence on the distance between air pressure tube and the surface of the glass melt

c/ contact electric glass-level indicators based on the principle of electric contact of a suspended or movable platinum probe with the glass melt (Figure 10)

d/ in the last time either optical glass-level indicators based on the principle of reflection of a light beam on the surface of the glass melt or glass-level indicators based on the principle of scanning the reflection of radioactive radiation.

The floater glass level indicators or contact electrical glass level indicators are recommended because they are simple in construction and operation.

V. TYPES OF MELTING FURNACES

The melting furnaces are generally divided into 3 groups:

1/ pot furnaces - periodical operation of melting and through-put (once in 24 hours)

2/ day tanks - periodical operation, method and technological conditions of melting and treating are analogous to put furnaces but glass is melted in the basin of the day tank. These furnaces are not suitable for the high quality production.

3/ continuous tank furnaces - continuous melting process and through-put, the surface of the glass melt in the basin of the tank is maintained on constant level and eventual changes in glass through-put are sensed by glass level indicators and compensated by the amount of the charge fed into the furnace.

Further classification of the types of melting furnaces according to various characteristic features is used, e.g.:

1/ the type of fuel used: gas fired furnaces, electric furnaces

2/ the direction of flame in the combustion chamber of the furnace: cross-fired furnaces, end-fired furnaces, longitudinal flame

3/ the system of recovering heat from flue gases: regenerative furnaces, recuperative furnaces

4/ the division of the furnace space: tank with one combustion chamber, tank with more combustion chambers, tank with a throat

5/ the sort of produced glass and the method of forming: furnaces with feeders, furnaces with manual off-take, furnaces for the production of container glass, furnaces for the production of sheet glass

The furnaces vary in their design to a large extent and, therefore, the chapter is limited to recommended types of furnaces corresponding to various sorts of production, including the aspects of low investment costs, general purpose of their use, available fuel basis and the reliability of operation without high qualification requirements, i.e. the real conditions of establishing glass production in developing countries in initial relatively small capacities.

A Recommended Minimum Production Capacities

A survey of recommended production capacities of outputs of glass-making shops and of forming machines for various sorts of glass including the types and melting rates of the furnaces are presented in Tables 9 and 10. The output of a hand-making shop in t/shift for blown and manually pressed glass on one press is taken for maximum, for medium size of workpieces and for thickwalled lead crystal. In the production of soda-potash glass, the outputs are about 20% lower, in the production of thin-walled workpieces, e.g. stemware, about 35% lower. Production capacity is to be installed in dependance on the market requirements.

At the operation of a periodical pot furnace the work-out changes are admissible and the desired amount of the worked-out melt is given by the content of the melting pots.

In the production of hand-pressed glass at one 6-pot furnace 4 press shops are situated because the output of one shop corresponds to the content of 1.5 pots of diameter 100 - 110 cm.

In the developing countries, the following melting furnaces may be used /simplified/:

a/ hand production in small series in 1 shift - a top flame 6-pot regenerative furnace with 6 working holes, gas- or liquid fuel fired, melting rate 3 t/day (see Figure 11)

b) hand production, semi-automatic eventually combined production in 2 - 3 shifts/day - a simple continuous channel furnace such as Bohemia Melter type - the Czechoslovak modification of Unit Melter adapted for hand production and mechanized production of high quality glass, e.g. lead crystal (see Figure 12). The maximum melting rate of these furnaces is 5t/24 hours, the furnace is provided with one throat and one circular working end with 3 - 4 working holes. A melting furnace with melting rate of ca 10t/24 hours is provided with two throats and 2 independent working ends each having 3 working holes. It is destined to universal use, for the production of wide assortment and for the combination of hand- or mechanized production. Feeder channels may be attached to these furnaces with melting rate 10 - 20 t/24 hours in the automated production of glass tableware.

c) production of container glass - a regenerative cross-fired furnace with four pairs of ports and melting rate of 40t/24 hours, which corresponds to the capacity of two modern automatic individual section machines, 1 - 2 feeder channels leading to the forming machines project out of the working end.

d) production of flat window glass - a cross-fired regenerative furnace adapted to the drawing of flat glass, provided with a cross shaped distribution space into 3 drawing compatments for 3 drawing machines system Fourcault. The melting rate of the furnace is 40 - 50t/24 hours. An example of a high capacity melting aggregate for 9 machines is presented in Figure 14.

3 basic types of melting furnaces (pot furnace, Unit Melter, regenerative tank furnace) are recommended for 3 different sorts of production - household glass, container glass, sheet glass, with alternatives in constructional arrangements according to local conditions, various capacities and chosen production assortment.

All recommended melting furnaces are fired with gas (natural gas, city gas), eventually with liquid fuel, e.g. light oil.

B Characteristic Features of Recommended Types of Furnaces

Some comparable characteristic features of the recommended types of furnaces are presented in Table 10.

Pot furnace

Top-flame furnace with direct conduction of the flame in the space between the top part of the ceramic melting pots and the arch of the furnace (Figure 11).

The vertical regenerators with checker chambers and the whole substructure are made of fireclay. The top structure of the furnace (the arch and the sidewalls) are made of silica. The melting pots are arranged on the oval bottom of the furnace under the working holes on the periphery. The ceramic burner jets are arranged in longer sides of the furnace so that the blast of gas, eventually of atomized oil, immediately at the orifice of the jet before entering into the furnace is mixed with the preheated combustion air inserted into the port mouth through vertical channel from regenerators. At the center of the furnace bottom is situated an orifice of a shaft for hearth glass (glass spilled on siege) which is collected in the so called cool glass pocket and taken therefrom. The regenerative system includes the connection of the channels from regenerators with a bricklayed chimney of the minimum height 30 m through the reversal device.

The technological function of the pot furnace is typically periodical, i.e. the work-out of glass melt during the morning shift and the melting of glass in afternoon and night shifts. Maximum melting temperatures are about 1450°C with holding time 4 - 6 hours according to the sort of glass and the amount of residue glass in the pots from the preceeding melt . The work-out temperatures are 1100 - 1250°C according to the production assortment.

The melting cycle includes following operations:

a/ preheating the furnace before the feeding of the charge

b/ 2 - 3 charges of batch and cullet

c/ process of melting down the solid phase

d/ homogenization of the surface layers of glass melt containing the residues of non totally melted cullet and batch by bubbling

e/ refining (degasing) of the glass melt at maximum temperatures 1450°C

f/ cooling down the glass melt from the melting temperature to work-out temperature.

The whole cycle of melting lasts 12 - 14 hours.

The pot furnace accessories are pot arches where the pots are dried and tempered up to the work-out temperature of the melting furnace 1200°C . The hot pots are transferred from the pot arch into the melting furnace by means of special shovels in combination with high lift trucks. The working life of a set of pots in the melting furnace depends on the sort of pots, on the corrosiveness of the glass melt and the method of melting, and as a rule amounts to 5 - 12 weeks. The pots handling and method of melting require high qualification and experience of the operating personnel. The quality of the worked-out glass melt depends on the quality of melting pots, their drying and sintering in the melting furnace, as well as on the treatment of the surface of glass melt in pots during the work by the glass makers. Technological disadvantages of pot furnaces are derived from the quality and behaviour of melting pots in the course of melting.

Local corrosion, breaking of pots and the leakage of glass melt into the glass pocket cannot be totally eliminated.

Melting furnace type Unit Melter (Bohemia-Melter)

Characteristic features of furnace system UM

1/ long and narrow melting compartment with the ratio of length : width from 4:1 up to 6:1
2/ counter-flow of the exhaust gases and fed charge, i.e. the doghouse and exhaust flues are situated at the charging end of the furnace
3/ short-flame high-pressure burners are situated in the sidewalls of the furnace above the glass level

The Czechoslovak variant of this type of furnace, patented abroad, called Bohemia-Melter (Figure 12):

1/ the shape of the basin of the melting compartment, location of burners in the sidewalls, counter-flow of exhaust gases, the flow of charge in the furnace are analogous to those in classic Unit-Melters.
2/ the combustion products are exhausted through flues on both sides of the doghouse according to local conditions and hygienic regulations:

a) upwards into a steel chimney above the roof of the plant hall, i.e. without heat recovery
b) upwards into metal recuperators and further as under a)

Variants a) and b) do not require either substructure below the level of the hall floor or high investment costs. The melting process is stable during the whole working life and does not require exacting service.

c) downwards under the furnace into metal recuperators or directly into a bricklayed exhaust flue channels connected through regulation valves to a bricklayed chimney. This variant is more expensive but more advantageous from the hygienic point of view (lower amount of exhalations into the atmosphere).

3/ the melting compartment is connected by a deep-subsurface throat with a working compartment. The throat and the shape of the basin bottom limit the return convection current of the glass melt between both parts of the basin which is required in lead crystal production

4/ the working compartment of the basin is circular in horizontal section and is provided with a ceramic screw stirrer for the surface homogeneization of the glass melt in the place of gathering, eventually in the place where the outflows into feeder channels are situated.

5/ on the periphery of the basin of every working compartment of maximum diameter 1500 mm, there are located 3 working holes or 1 - 2 outflows into feeder channels. The working compartment is provided with gas boosting enabling to regulate the viscosity of the glass melt according to varying assortment of produced workpieces.

6/ in the case that two circular compartments are used, the melting compartment is bifurcated into two short channels at the end of which two separate subsurface throats leading to individual working compartments with boosting are situated. In this case it is possible to work out simultaneously glasses of differing viscosity, e.g. hand working from the one working compartment and mechanized moulding from the other.

7/ other eqipment of the melting furnace, e.g. measuring and regulation are analogous to those used in classic tank furnaces

8/ the relatively high consumption of energy owing to the lack of heat recovery from exhaust gases or to lower temperatures of preheating the combustion air in metal recuperators, is partly compensated by higher specific melting rate from the surface of the melting compartment and by lower capital expenditures on the furnace construction in comparison with classic tank furnaces. The melting tank furnaces of Bohemia-Melter type are consequently advantageous in these cases where the fuel consumption is not the main viewpoint.

9/ the lining of the furnaces Bohemia-Melter is analogous to that used in classic tank furnaces, i.e. the basin of the melting and working compartments is of electrically fused cast refractory material and the superstructure of silica

10/ special construction of the basin of the furnace Bohemia-Melter enables to use them in discontinuous operation, i.e. without night shifts, without negative influence upon the glass quality. The combination of hand production in 2 shifts and mechanized production in 3 shifts is advantageous because it raises the melting efficiency. Another alternative is to use one working compartment for hand production and the other, provided with feeders, for machine production.

Regenerative tank furnaces for container and sheet glass

The classic type of a cross-fired regenerative tank furnace provided with a submerged throat and a working end with feeder channels for automated production of container glass is represented in Figure 13.

The tank furnace heated by gas or oil should be of minimum width 4 m owing to the length of flames . The minimum ratio of width to length is 1 : 1.7 and gives a melting area of about 28 m^2. At the specific melting rate ca 800 kg/ m^2. 24 hours the minimum melting rate is ca 22t/24 hours. In the recommended melting furnace for the production of container glass with 1 - 2 moulding machines, according to the production assortment, with the melting rate ca 40t/24 hours the melting area must be larger, about 50 m^2.

Vertical regenerators with section chambers for 3 - 4 pairs of cross burners are bricklayed with fireclay and lined with checkerwork of fireclay, eventually of magnesite . The port mouth arches are predominantly of silica, the port mouths are of fused cast materials or of refractories based on corundum or mullite. The side walls and the superstruction (arch) are of silica. The side walls and bottom of the basins of the melting and working compartnments are of fused cast refractory materials. The orifices of gas burners jets, eventually of atomizers of oil into the port mouths vary according to the sort of used fuel and the construction of port mouths. The sectional regenerator chambers for each pair of ports are very advantageous as it is possible to replace the checkerwork of the chambers during operation without difficulties.

The basins of the melting and working compartments are connected by a submerged throat. The working compartment is of small dimensions and of various shapes and serves to the distribution of glass melt into attached 1 to 2 feeder channels leading glass melt to moulding machines. If a glass melt of higher quality is required, it is possible to arrange homogenizing screw stirrers in the distributing working compartment or, with advantage, in the feeder channels. In special cases it is possible to provide the basin of the melting compartment with 2 throats each of them leading into independent working compartment, e.g. enabling the combination of a feeder channel and gathering a portion of glass and feeding the gob by means of a rod provided with a sphere at the end thereof.

A part of the melting tank is the so called "caisson", usually the basement of the glass works hall where the duct with reversal device attached across regulation valves to the exhaust flue of exhaust gases into a bricklayed chimney, further air line system, pumps, water recirculation system and other equipment to moulding machines are situated.

The feeding of the charge regulated by glass level indicator in these relatively small tank furnaces is carried out by means of piston chargers.

The shape of the working compartments, the system of attachement of feeder channels and their construction are recommended by contractors supplying the moulding machines and charging devices.

The regenerative tank furnace for the drawing of sheet glass (system Fourcault) in its functional part, i.e. melting compartment, arrangement of ports, is analogous to the furnace for the production of container glass but is is not provided with a throat and its conditioning is not heated; prolongated part leading to drawing chambers is separated from the melting part merely by surface floaters on the level of glass melt. An example of a large tank furnace for the production od sheet glass (system Fourcault) with the melting rate of ca 150t/24 hours with nine drawing machines is described in Figure 15. The recommended basic unit with three drawing machines is adequately smaller. The construction of a melting compartment for the production of 40 - 50 t of both container and sheet glass / 24 hours will be similar. Only the prolongated non-heated conditioning part of the tank for the production of sheet glass including channels and drawing chambers will differ totaly from the throat system of furnaces for the production of container glass.

Feeders

Feeder is a device preparing for automatic glass-making machines suitable portions of glass to the following moulding. This portion has the form of a gob of various shapes adapted to the type of the machine. A short and wide gob is suitable for pressing and press-and-blow machines, longer gobs for blow-and-blow in production of bottles.

The feeders must comply with the following conditions:

a/ the portions must be equal in mass and shape under equal circumstances

b/ the mass and shape must be changeable in the course of production

c/ the portion of glass must have uniform temperature in the whole mass

d/ the severing of the gob by shear cut must be exactly synchronised with the function of the moulding machine.

In order to fulfil the above mentioned conditions, the producers of feeders possess a row of constructional variants adapted to various production capacities. In general, a feeder consists of following functional and construction elements:

a/ a ceramic supply trough - feeder channel leading the glass melt from the distributional working part of the tank to the place above the moulding machine,

b/ heating and cooling, eventually homogenizing system by means of which the glass melt is thermally and physically homogenized so that the viscosity and temperature of glass in the feeder spout correspond to the required shape of gob.

c/ in horizontal section circular feeder spout at the end of the feeder channel provided with a portioning mechanism including a plunger and power shears for forming and cutting off the portions of glass

Older types of feeders are heated with refined gases by means of a set of shortflame burners so called collar burners, nowadays mostly electrically heated feeders are used. Figure 14 illustrates a side sectional elevation of a feeder of older type.

The producers of equipment for glass-making plants supply complete production lines of their own construction and with corresponding guaranty. This paper, therefore, does not deal with the problems of mutual relation between the construction of the distribution part of the tank furnace, feeders, feeding mechanisms and moulding machines. These problems are solved by the supplies of the production lines.

VI. METHODS OF FORMING GLASS

It is possible to form glass into final workpieces by means of various methods or eventually their combinations:

a) blowing (hollow workpieces)
   - mouthblowing on blowpipe in hand working
   - blow-and-blow process in automatic forming (thin-walled household glass, narrow neck container glass)

b) pressing (hollow and otherwise formed workpieces)

c) pressing with following blowing-press-blow process (thin-walled household glass, wide neck container glass)

d) drawing (sheet glass produced by Fourcault method)

e) rolling (flat glass)
   - rolling of patterned glass and wired glass
   - float glass floated on a bath of molten metal - Float-process

Survey of recommended forming methods, of production assortment and of types of forming machines is shown in Table 11. The development of new forming machines in recent years is very fast. For the short-run production of household glass and pressed luxury lead crystals in addition to low speed feeders a great number of construction variants of mallet feeders with a rod provided with a sphere at the end in connection with turret presses with small number of stations, e.g. 6 appeared last time on the market.

The basic principles of some moulding and forming methods that are applicable in the conditicns of developing countries are informatively mentioned in this chapter. All modern forming machines are equipped with complicated control systems - programming, electronic control including microprocessors, etc. Their use in developing countries would bring complete dependence on the service from foreign countries and could cause difficulties in the production so as failures, breakdowns and interruptions in continuous flow of production. Therefore, it is being recommended to give preference to machines of older types without electronic elements and with maximum proportion of mechanical drive and gear. On the other side, it is necessary to find out in advance whether the spare parts are available in sufficient quantities for the supplied older machines in the following years.

A Blow-and-blow Method

The turret and individual section machines based on blow-and-blow method of forming, i.e. both the blank and the finished shape are moulded by blowing, differ in the art of feeding the glass into the blank form. In older types, glass is sucked up into the blank form directly from the glass level and the charge is gripped in the neckmould by means of vacuum.

At modern wide spread individual section machines, glass is fed from the feeder and is blown down into the neck mould. The scheme of the molding process is illustrated in Figure 16.

B Press-and-blow Method

The press-and-blow method illustrated schematically in Figure 17 went through a number of evolutional steps and the result of this evolution is a set of various turret machines. The individual section machine type IS with adaptors for the press-and-blow method asserted itself in recent years. This arrangement seems to be the most perspective one because it enables to rebuild the basic blow-and-blow IS machine during operation by means of an adaptor into a press-and-blow machine. It is consequently possible to change over the production assortment to a limited extent from wide neck to narrow neck bottles. The mechanism of blow-and-blow plunger and its guide (thimble) is replaced by the mechanism of press plunger. The blank in the blank mould is pressed from down upwards similarly as in blowing the blank in the blow-and-blow method. The moulding in machines type M totally differs from classic methods and these machines may be taken for press-and-blow machines. Their operation is shown in Figure 18:

The gob 1 is guided by a cooled deliver chute 2 onto a pressing head 3 where it is caught and held in suitable position by the gob retainer 4. The pressing head 3 lifts the gob 1 upwards to the suction and transfer head 5 and presses into its cavity the cake (formed premoulding) that remains sucked in the head 5. The suction and transfer head 5 revolves and puts the cake on the ring 7. The blow head 9 with low air pressure is pushed over the ring holder 8 and the cake is reshaped by sagging into a blank (see Figure 19). The blank with the blow head 9 begins to rotate under the action of the ring holder 8 and the finish mould 10 is closed around the blank.

Using the described forming method it is possible to form by rotation smooth shapes of thin walled workpieces with a moil. By following burning-off the moil, grinding and edge-melting high quality workpieces, e.g. water goblets, stem ware goblets, with the downward convergent wall thickness may be manufactured. These machines were originally developed for the production of electric bulbs. They are turret machines usually with 12 - 18 forms.

Another commonly used press-and-blow method for the production of thinwalled workpieces blown out during rotation is illustrated in Figure 20.

C Machines for Glassware Handling and Rough Treatment

A number of accessory machines and manipulation machines, from the moulding machines over annealing lehrs up to burning-off and edge-melting machines, mainly the manipulators to take-off the workpieces from the moulding machines, their transport to the annealing lehrs, pushing mechanisms of workpieces into annealing lehrs, machines for rough treatment, namely machines for burning-off moils, edge grinding, rounding of the rim, edge melting, etc. form a part of each production line, above all of an automated one. These accessory machines are not dealed in detail as they are mostly supplied as parts of production lines for given production assortment and their grouping is specific in each individual case.

VII. SHEET GLASS PRODUCTION

The invention of smoothing the surface of the cast glass ribbon on the bath of molten metal, the so called "Float-process, presents revolutionary change in the production of flat glass all over the world in the last 10 years. The application of this technology enables to draw horizontally both thick and thin window glass of high quality and with high productivity. This glass with mirror surface of high brightness is widely used for glazing in building industry and for car windows.
Up to this time used classic methods of production of sheet glass are expiring and are being replaced by Float-process practically in all industrially developed countries.

Nevertheless, for the developing countries beginning with the production of sheet glass, the Float process is not advisable as it requires high investment costs, high degree of qualification and high level measuring and controling techniques.

Therefore, for local applications of window glass in developing countries the technically less exacting classic method of vertical drawing of sheet glass according to Fourcault (Figure 21) will fully be convenient. This system, still widely used mowadays, gives good reliable results and is technologically the least demanding of all classic methods. Energy requirements of this method are also favourable being lower than that of Float-process.

VIII. QUALITY CONTROL AND FINAL INSPECTION

The scope and standard of laboratory inspection methods of production are dependent to a large extent on the qualitative standards of the raw material base and the periodicity of individual supplies. This has reference mainly to chemical analyses identifying the content of Fe_2O_3 and basic components, such as CaO and MgO.

In all cases, the control of grain size distribution is inevitable, namely in the glass works in which no control sieves are applied and raw materials are consumed in original moist state (glassmaking sand, dolomite, phonolite, etc.) The moisture content control of natural raw materials and hygroscopic materials, such as soda, immediately before the weighing of the batch is also inevitable because if the moisture content differs from the prescribed value, correction in the weighed individual dose must be made.

The extent of interoperational quality control depends on the assortment produced and helps to keep good quality of production. The control of an annealing process consisting of the determination of the residual stress in glass by means of a polarizing apparatus is inevitable in all technologies of glass production. The density control is used in all automated productions as an individual indirect criterion whether the basic chemical composition is observed.

In the production of crystal glass in which the green tint caused by Fe_2O_3 is complementary decolourized by means of various combinations of selenium, nickel and cobalt, the colour tint is to be daily controled by comparison with a standard rod and, according to the results, the decolourizing agents are charged into the batch. In the production of flashed eventually cased glass, a quick control of the thermal expansion of fused glass is necessary, e.g. by the method of doubled thread.

In the production of container and sheet glass, further operational and final inspections are applied testing the functional properties of products, such as the pressure test of container glass, the thermal shock resistance proving indirectly the quality of annealing, the homogeneity of glass, optical properties of sheet glass.

Other defects in the products inflicted, e.g. by irregularities in the forming process, are determined immediately after the forming by operators of forming machines, or, predominantly, by subjective sorting after the annealing of products.

A survey of main recommended quality controls and final inspections is given in Table 12.

IX . FINAL NOTE

Glass production represents an important component of non-metallic industries. Some of its characteristic features, such as high demand for labour power, simple technology and relatively low capital expenditures necessary for the establishment of non-mechanized production make the glass manufacture suitable for conditions existing in the majority of developing countries.

The publication takes into account common conditions in developing countries in which slight or no tradition and experience exist in the industrial production of glass. The recommended production assortment is, therefore, limited to the most common sorts of household glass, container glass and sheet glass supplying local market, especially in the first phase of developing the glass industry. The technically demanding productions, requiring developed other industrial branches, such as production of optical glass, technical glass (refractory glass-boiling glassware, tubes, glass fibres) and Float glass are not included in this paper as they are not recommendable to start with in the developing countries.

The establishment of glass industry in a developing country requires mainly the following technical and economical conditions:

- sufficient reserves of suitable local raw materials forming the basic predominant components of the glass batch
- sufficient quantity of labour power usable in the technological process with relatively large amount of manual labour
- local market potentiality
- available energy sources.

The technologies, glass sorts, constructions and basic capacities of melting furnaces, methods of forming and basic types of moulding machines recommended in this paper were verified in production plants of many countries.

The aim of this publication is to assume basic technical and technological conditions and correlations in order to give initial orientation preceeding the establishment of glass industry in a developing country.

The UNIDO-Czechoslovakia Joint Programme for International Co-operation in the Field of Ceramics, Building Materials and Non-metallic Minerals Based Industries is ready to assist the developing countries in consultations, training programmes and evaluation of selected samples of non-metallic raw materials in order to promote industrial exploitation of local non-metallic natural resources and industrialization. Long tradition of high quality glass production in Czechoslovakia guarantees high level of technical assistance which can be offered within the scope of the UNIDO activities by the Joint Programme.

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ISO 718	Glass - Method for Thermal Shock Test - 1982
BS 2975	Sand for Making Colourless Glass - 1958
ČSN 708061	Utility Glass for Domestic Use - 1978
ČSN 708001	Utility Crystal Glass - 1974

ANNEX

List of Tables

List of Figures

Table 1: Chemical Composition and Properties of Typical Sorts of Glass

Chemical composition (mass %)	household glass					container glass							sheet glass	
	Na - K - crystal			Pb - crystal		colourless		green		amber			composition range	practical example (Fourcault)
	composition range	practical example: hand production	practical example: mechanized production	composition range	practical example	composition range	practical example	composition range	practical example	composition range	practical examples 1	practical examples 2		
SiO_2	70 - 77	75	73	58 - 60	60	71 - 74	73	70 - 72	71	71 - 74	72	72	72 ± 0.3	72
Na_2O	7 - 16	12	16	2 - 3	3	14 - 18	14.5	13 - 16	14.5	13 - 16	14	14	14.5 ± 0.5	14.5
K_2O	4 - 8	6	-	9 - 12	11	0 - 4	-	0 - 4	0	0 - 4	-	-	-	-
CaO	5 - 10	6	10	0 - 1,5	-	5 - 12	8	7 - 12	8	7 - 12	8	11	8 ± 0.3	8
MgO	0 - 6	-	-	-	-	0 - 4	3	0 - 4	3	0 - 4	3	0,4	3.5 - 4	4
PbO	-	-	-	24 - 30	24.5	-	-	-	-	-	-	-	-	-
ZnO	-	-	-	0 - 2	-	-	-	-	-	-	-	-	-	-
BaO	0 - 7	-	-	0 - 5	1.5	-	-	-	-	-	-	-	-	-
Al_2O_3	0.1 - 1	0.15	0.2	0,05-0,1	0,05	0.4-1.5	0.8	0,5 - 3	2	0.5 - 3	2	2	0,6 - 1,2	0.8
As_2O_3	-	-	-	0,2 - 0,5	0,4	-	-	-	-	-	-	-	-	-
Sb_2O_3	0.2 - 0.4	0.3	0.2	-	-	-	-	-	-	-	-	-	-	-
SO_3	0.1 - 0.4	0.2	-	-	-	0.2 - 0,4	0.25	0.2 - 0.4	0.3	0.1 - 0.15	0.1		0.2 - 0.3	0,25
Fe_2O_3	0.015-0,03	0.025	0.025	0.015-0.02	0.015	0.05 - 0.1	0,06	0.3 - 0.7	0.5	0.2 - 0.4	0,25		0.05-0.1	0.[illegible]5
Cr_2O_3								0.1 - 0.3	0.2					
MnO_2										0 - 4				
graphite										0.1-0.5	0.4			
pyrite										0.1-0.4	0.3			
Chemical durability - resistance against water at 98 °C (ISO/DIS 719)	class IV			class IV		class IV							class IV	
Linear thermal expansion α 20-300 °C . 10^{-6}	8.5 - 9.5			8.5 - 9.5		8 - 9							8 - 9	
Littleton softening point (°C)						cca 725							cca 720	
Density /g/cm³/	cca 2.5			2.9		cca 2.5							cca 2.5	

Table 2: Technological Requirements on Main Glass-making Raw Materials

Raw material	Chemical characteristics: Chemical composition of the basic constituent	Chemical characteristics: Oxides brought into glass (basic constituents)	Chemical characteristics: Limiting accompanying oxides determining the extent of the techological use	Granular size distribution — Recommendation (optimum): the main portion of the constituent, mm	Recommendation (optimum): other portions, mm	Recommendation (optimum): other portions, %	Operationally usable extreme values (container glass)	Operationally usable extreme values (container glass), %
Silica sand	SiO_2	SiO_2	Fe_2O_3	0,1 - 0,6	0,6 - 1 < 0.1 > 1	5 2 0		20 5 0
Limestone	$CaCO_3$	CaO	Fe_2O_3	0,1 - 0,6	0,6 - 1 < 0.1 > 1	5 40 0		15 0
Dolomite	$CaCO_3$ $MgCO_3$	CaO MgO	Fe_2O_3	0,1 - 0,6	0,6 - 1 < 0.1 > 1	5 40 0	0,6 - 1 1 - 3 mm	20 15
Phonolite	Na $[(Al,Si)_2O_8]$	SiO_2 Al_2O_3 Fe_2O_3 Na_2O	Fe_2O_3 Al_2O_3	0 - 0,6	0,6 - 1 > 1	5 0	under 2mm 2 - 3 mm 3 - 6 mm	50 30 15
Basalt		SiO_2 Al_2O_3 Fe_2O_3 Na_2O	Fe_2O_3 Al_2O_3	0 -0,6	0,6 - 1 > 1	5 0	under 2 mm 1 - 4 mm	40 60
Potassium feldspar	$(K,Na)Al_2Si_2O_8$	SiO_2 Al_2O_3 K_2O, Na_2O	Fe_2O_3 Al_2O_3	0 - 0.6	0,6 - 1 > 1	2 0	0,6 - 1 mm above 1 mm	15 0
Calcined soda	Na_2CO_3	Na_2O	-	0 - 1	1 - 2 > 2	2 0		
Calcined potash	K_2CO_3	K_2O	-	0 - 1	1 - 2 > 2	2 0		
Sodium sulphate	Na_2SO_4	Na_2O	-	0 - 1	1 - 2 > 2	2 0		
Arsenic	As_2O_3		CoO	0 - 0.2				

Table 3: Glass Sands

Classification of sands according to their contamination /% $Fe_2O_3 \cdot 10^{-3}$/	15	20	25	40	100
SiO_2	99.5	99.5	99.6	99.0	96.0
Fe_2O_3	0.014	0.018	0.023	0.034	0.11
Al_2O_3	0.1	0.1	0.2	0.3	0.9
TiO_2	0.03	0.03	0.03	0.04	0.06
CaO	-	-	-	0.1	0.2
MgO	-	-	-	0.1	0.1
K_2O	-	-	-	0.1	0.3
loss on ignition	0.1	0.18	0.12	0.2	0.6

Table 4: Limestones and Dolomites

Raw material	Limestone %	Dolomite %
CaO	55	30
MgO	0.5	21
Al_2O_3	0.3	0.5
Fe_2O_3	0.02 - 0.05	0.03 - 0.05
loss on ignition	43.5	47
grain size:		
2 - 3 mm	-	10
1 - 2 mm	-	13
0.6 - 1 mm	15	10
0.3 - 0.1 mm	80	35
under 0.1 mm	5	32
moisture content	0.5	5

Table 5: Rock Materials

Raw material	phonolite /%/		basalt /%/		feldspar /%/	
SiO_2	56		40		78	
Al_2O_3	23		18		11	
CaO	1		13		0.5	
MgO	0.2		8		0.2	
Na_2O	10		3		2	
K_2O	5		1.5		7	
Fe_2O_3	2		12		0.15	
loss on ignition	2		3		0.6	
grain size distribution	3-6 mm	18	4-8 mm	18	above 1 mm	0
	2-3 mm	30	1-4 mm	50	0.6-1 mm	13
	under 2	52	under 1	32	0.1-0.3 mm	35
					under 0.1	17
moisture content	2		5		1.5	

Table 6: Alkali Materials

Raw material	potash /%/			soda ash/%/
	hydrated	calcined	molassy	
K_2CO_3	82-85	96-98.5	80-85	
Na_2CO_3		0.6-1	2-14	97.5-98.8
K_2SO_4	0.2-0.5	0.2-0.5	2.5-4	
Na_2SO_4				0.02-0.06
NaCl				1-2
KCl	0.15-1			
Fe_2O_3	up to 0.001	0.002-0.005	up to 0.05	0.005-0.01

Table 7: Colouring Agents for Container Glass /%/

Raw materials	pyrite	manganese ore	chromium slag
Fe_2O_3	56	3	0.6
S	35	-	-
SiO_2	13	-	-
MnO	-	55	-
Cr_2O_3	-	-	5.5
moisture content	20	0.5	

Table 8: Lead Containing Raw Materials /%/

Raw material	minium	litharge
Chem. composition	Pb_3O_4	PbO
Pb as PbO	97 - 99	97 - 99
PbO_2	29 - 32	-
Pb	-	0 - 10
Fe_2O_3	0.001 - 0.005	0.001 - 0.002
CuO	max. 0.001	dtto
Cr_2O_3	max. 0.0005	
CoO	max. 0.0008	

Table 9: Recommended Minimum Production Capacity According to Production Assortment

Sort of production	Production unit	The output of the shop in one shift (in tons)	Number of shops, machines, ev.	Number of shifts in 24 hours	The melting rate of the furnace t/24 hours	The sort of furnace	The type of furnace	The furnace production t/24 hours
Household glass	manual glass working shop (4 workers)	0.5	6	1	3	pot furnace (6 pots)	top flame 6 pot regenerative pot furnace	3
	hand operated press (2 workers)	0.7	4	1	2.8			
	hand making shop	0.5	6	2 - 3	9	tank furnace (6 working holes)	recuperative furnace type Unit-Melter with 2 working compartments (Bohemia - Melter)	10
	hand operated press	0.7	6	2 - 3	12.6			
	combination 3 blowing shops + 3 presses		6	2 - 3	10.8			
Container glass	individual section machine (8 sections)		1 - 2	3	40	tank furnace + feeder	regenerative tank furnace with feeder channels	40
Sheet (flat) glass	drawing machine system Fourcault		3	3	50	tank furnace	regenerative tank furnace with working end for 3 drawing machines	50

Table 10: Characteristic Features of Recommended Melting Furnaces

Furnace parameters	Physical unit	Pot furnace	Furnace type Unit-Melter (Bohemia-Melter)	Cross - fired regenerative tank furnace
Melting rate	t/24 hours	3	5 - 15	40 - 50
Specific melting rate of the melting end of the tank	kg/m^2.day	6 pots Ø 100 - 110 cm	1 000 - 1 200	800
Surface area of the melting end	m^2		5 - 12	50 - 60
Characteristics of the working end	-	6 working (gathering) holes	1 - 2 circular working compartments Ø 1.5 m, with central airscrew stirrers, 3 - 6 working holes	container glass - 2 feeder channels sheet glass - 3 drawing machines
Melting temperatures	°C	1 450	1 440	1 440
Heat recovery of the flue gases	-	ceramic regenerators	a)without heat recovery (metal chimney above the hall roof b)2 metal recuperators	ceramic regenerators
Temperature of the preheating of the combustion air	°C	1 100	a) - b) 400	1 100
Fuel	-	natural gas,city gas, oil	natural gas, city gas, oil	natural gas, city gas, oil
Base structure undr the furnace and a bricklayed chimney	-	yes	no	yes
Outer dimensions of the furnace length/width without working platform and feeders	m	6/5	8/2.5 - 9/4.5	12/12 + feeders + machines container glass 16/12 (sheet glass)
Refractory material (main portion)	-	chamotte, silica	electro fused cast refractory material, silica	electro fused cast refractory material, chamotte, silica
Working life between complete overhauls	month	48	60	48

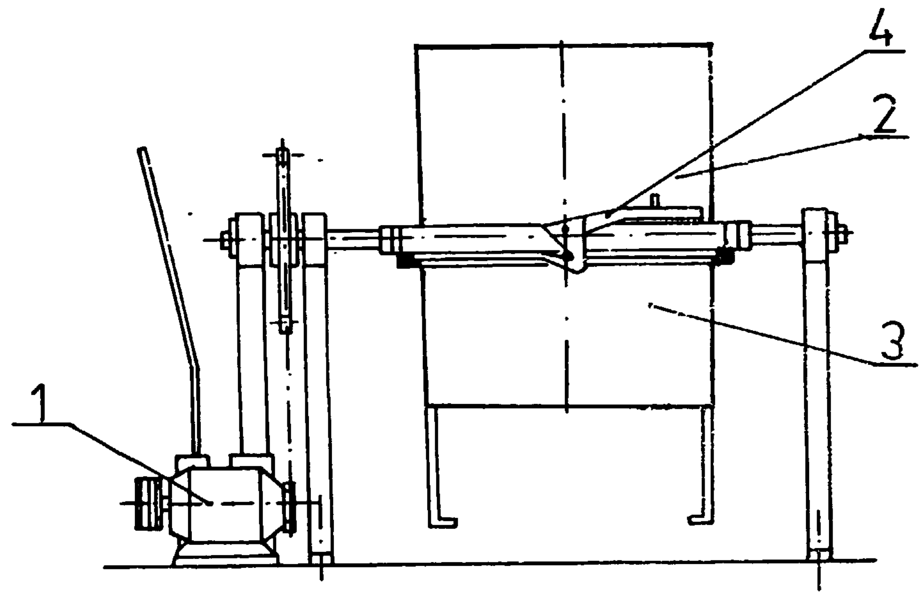
Table 11: Methods of Forming (Moulding), Moulding Machines and Production Assortment

Glass sort	Melting furnace	Method of moulding, forming	Production assortment	Moulding (forming) machines
hosehold glass	pot furnace	mouth blowing hand pressing blow-and blow process	blown tableware pressed tableware bottles of special shapes (short run production)	single station press with hand feeding semiautomatic presses with hand operation and hand feeding
	tank furnace (Bohemia-Melter)	dtto	dtto	dtto
		press-and-blow process- thinwalled workpieces	water goblets goblets (stemware)	press-and-blow turret machines system series M
		combination of hand- and mechanized methods	the entire assortment	hand shops and machines adjoined to individual working compartments of the tank
container glass	continuous tank furnaces + feeders	blows-and-blow process	narow mouth bottles	individual section machines IS
		press-and-blow process	wide mouth bottles (preservin jars)	individual section machines IS (with adaptors)
				turret machines (8 - 12 stations
sheet (flat) glass	continuous tank furnace	drawingupward through a debiteuse	window sheet glass	drawing machines system Fourcault

Table 12: Entry, Operational and Final Inspection

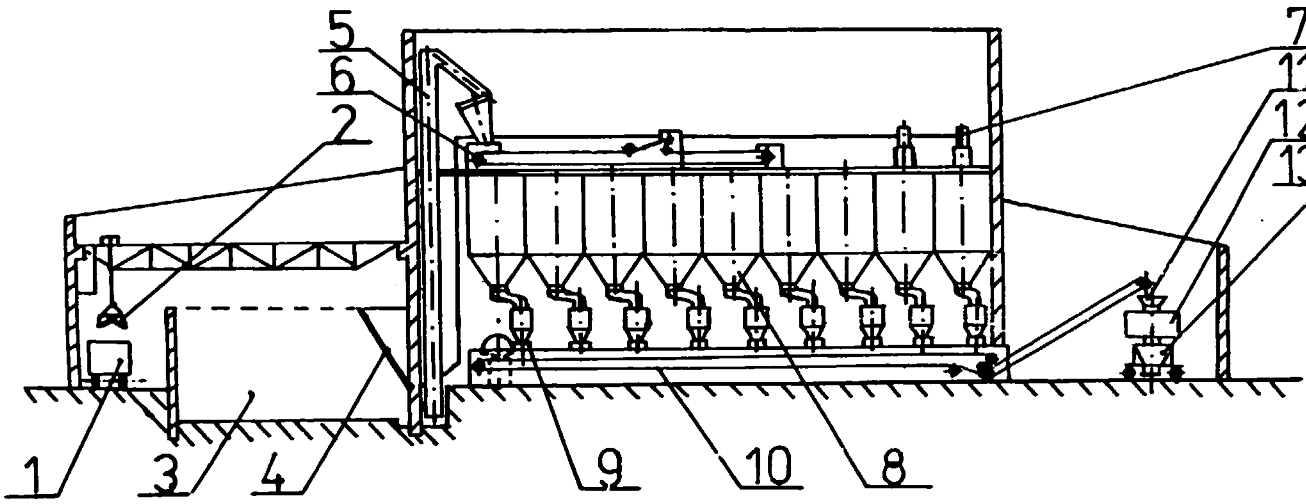
Sort of inspection	Range of application	Principle of the method	Note
Entry inspection			
Fe_2O_3 content	all natural raw materials	colorimetric determination of red colouring intensity of iron ions by means of difyridyl	subjectice comparison with a standard
grain size distribution	all natural raw materials	screen analysis by standardized system of control screens from 0,1 - 6mm, weighed out portions 100-200 g	manual sieving 30 minutes mechanical sieving 10 minutes
moisture content	all natural raw materials *soda (potash)	drying the specimen for 2 hours at 110°C ± 5°C	correction of the moisture content in the batch preparation
main component content	natural raw materials of inconstant composition	classical chemical anslysis	in the case of change of the supplier
Operational inspection			
rational batch analysis	batch homogeneity control	determination of insoluble residue of dried batch in acid	comparison with a standard
density control	control of constant composition of glass melt by measuring the density	floating of a glass sample in the liquid of defined density	laboratory apparatus available
glass homogeneity	for container glass	method of cut-off ring shaped samples of container glass (10mm) and evaluation of stress in the layers of glass immersed in liquid in a polarizing microscope	evaluation of lamination in the cut according a classification scale
thermal expansion (thread test)	flashed glasses in the handmade glass production	fusing 2 glasses, drawing of a thread, the difference of t.e. is evaluated from the radius od curvature of the thread	admitted difference is indirectly determined by curvature of thread
optical planeity of the surface	sheet glass	look through a sheet against a lined raster	classification of deflection of raster lines
number of bubbles determination	container and sheet glass	counting of bubbles at side lighting in a dark room and recounting to a comparable weight of glass	numberof bubbles in 1 kg of glass
colour of crystal	data for the charging of decolorants	subjective comparison of colour tint of rods of given length with a standard	daily control before the batch preparation
chemical durability	random control at all glasses	determination of water resistance at 98°C-int.standard DIS/DIN	class I-V of chemical durability
Final control			
stress (residual) in products	quality of annealing of final workpieces	phase delay at the passage of polarized light evaluated in nm/cm	operational polarization apparatuses available
pressure test	container glass for beverages containing CO_2	water overpressure test in an adapted apparatus	bottle resistance against breakage
resistivity against temperature changes	container and sheet glass	thermal endurance of workpieces heated in a drier to different temperatures and their sudden cooling % of beakage is determined in dependence on thermal shock	

Figure 1 Batch Mixer "Saxonia" Type



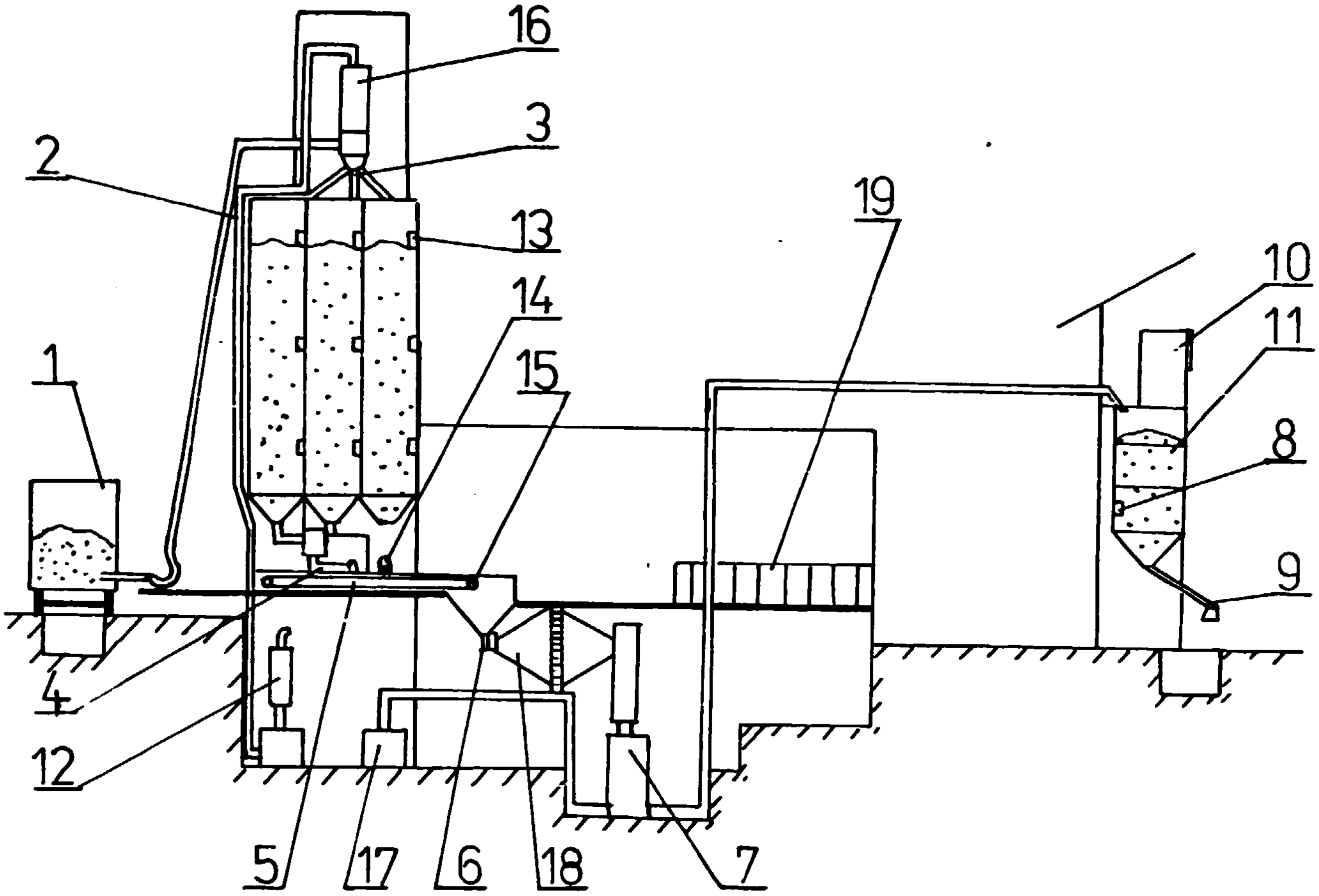
1 - driving device, 2 - stationary top section of the batch mixer, 3 - removable bottom section of the batch mixer (container), 4 - locking lever

Figure 2 Horizontal Batçh Plant



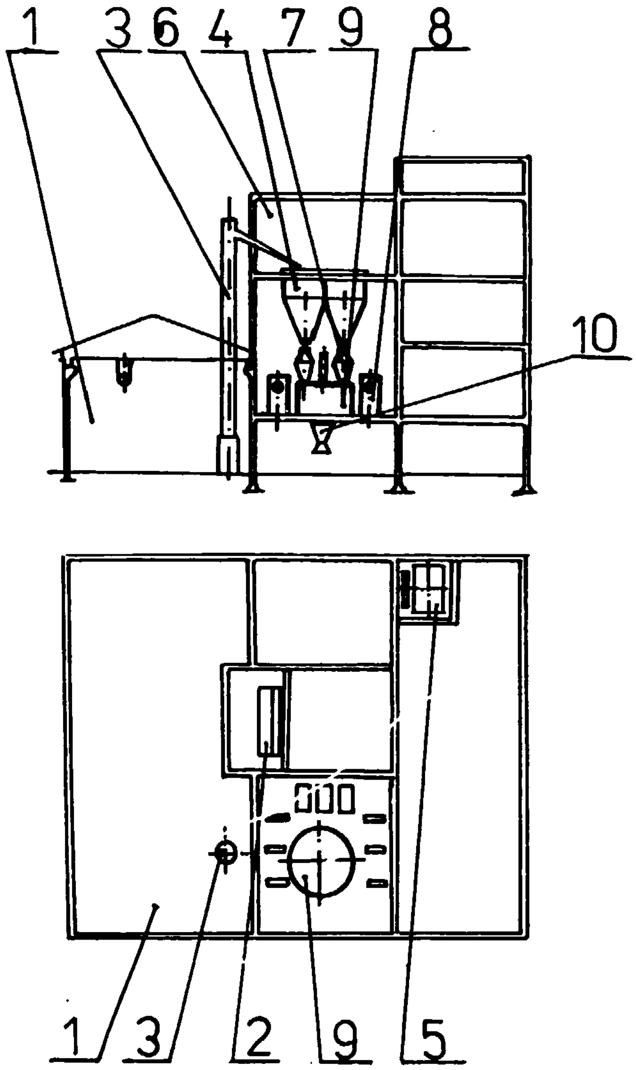
1 - unloading of raw materials in bulk, 2 - crane, 3 - raw material stock, 4 - feeding hopper, 5 - bucket elevator, 6 - belt conveyor, 7 - desintegrator of hygroscopic raw materials, 8 - raw materials storage bins, 9 - charging scales, 10 - collecting belt conveyor, 11 - feeding bin of the batch mixer, 12 - batch mixer, 13 - batch container

Figure 3 Vertical Batch Plant



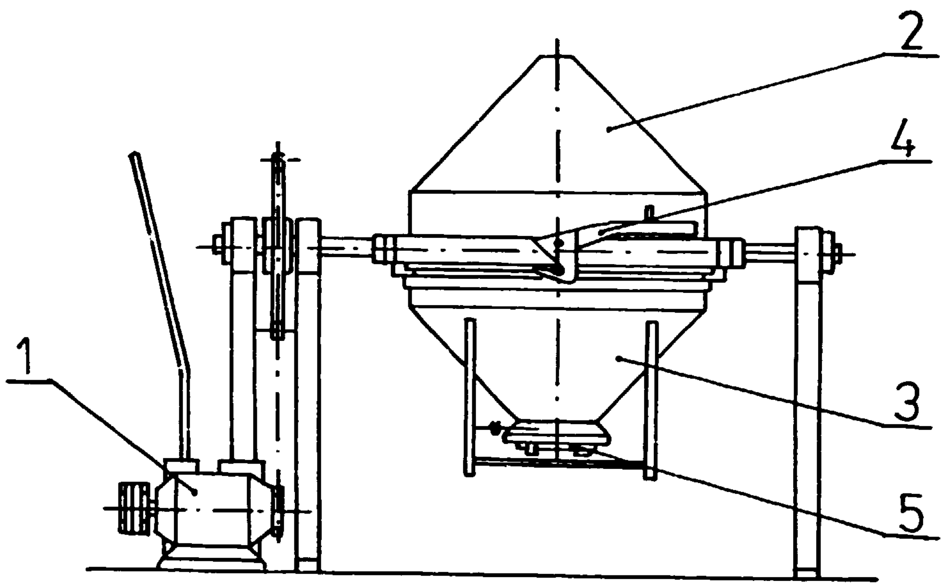
1 - unloading of raw materials in bulk, 2 - pneumatic transport device, 3 - distribution of raw materials into feeding bunkers, 4 - vibratory, eventually endless screw charging device, 5 - belt conveyor, 6 - outlet of the feeding hopper, 7 - storage bunker, 8 - signalization of the level of feeding, 9 - discharging of the batch, 10 - dust collector, 11 - batch container, 12 - vacuum pump, 13 - signalization of the level of feeding, 14 - automatic balance, 15 - electromagnetic separator, 16 - dust collector, 17 - blower, 18 - drum batch mixer, 19 - control panel

Figure 4 Spatial Arrangement of the Batch Plant Type "Middle"



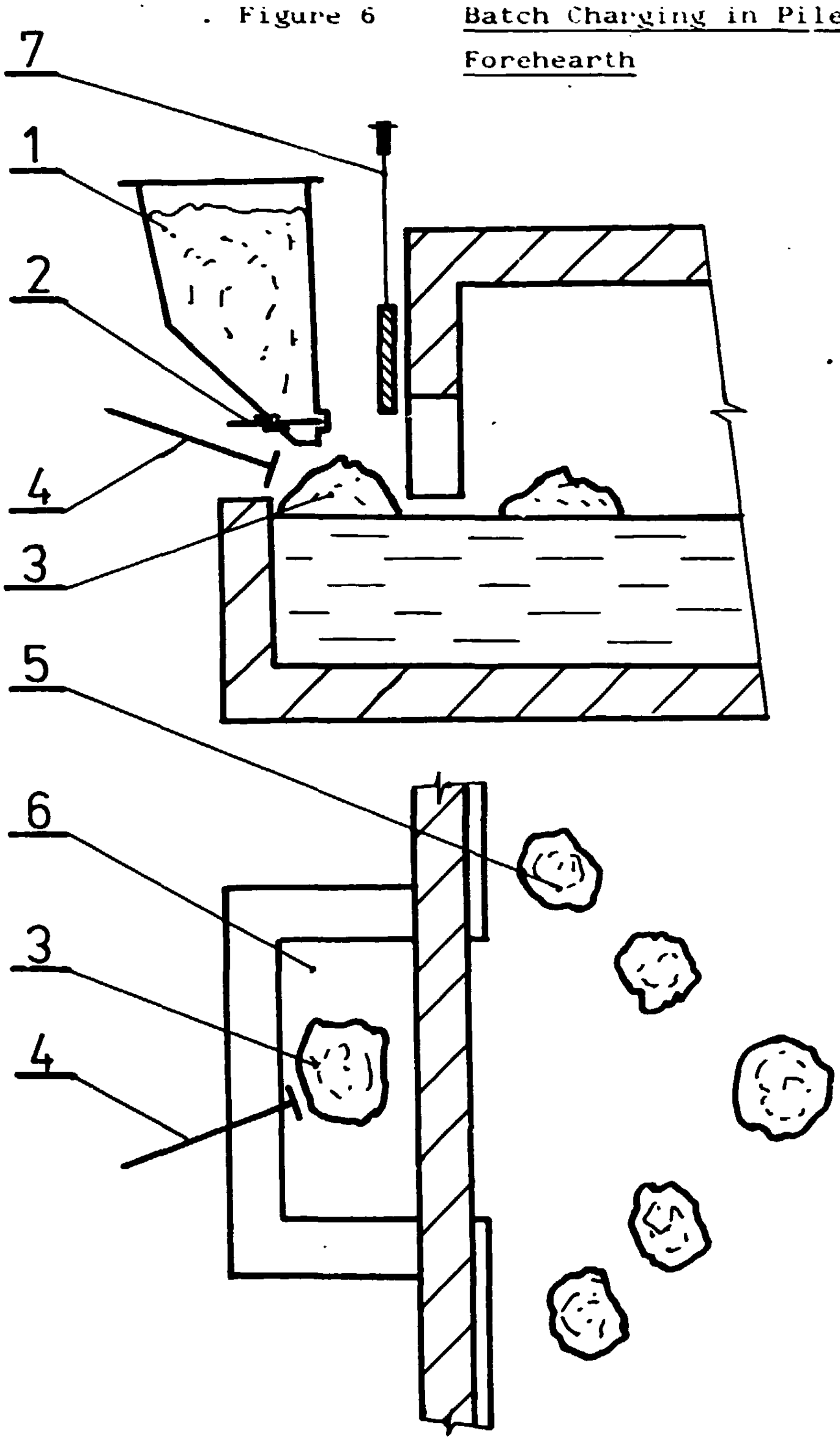
1 - stock of glass making sand, 2 - sand drier, 3 - elevator, 4 - storage bunker above the balance, 5 - elevator for packed raw materials, 6 - space for feeding the raw materials into storage bunkers, 7 - automatic balance, 8 - weighed doses indicator, 9 - batch mixer, 10 - batch container

Figure 5 Container Drum Mixer for Hand Operated Batch Plant



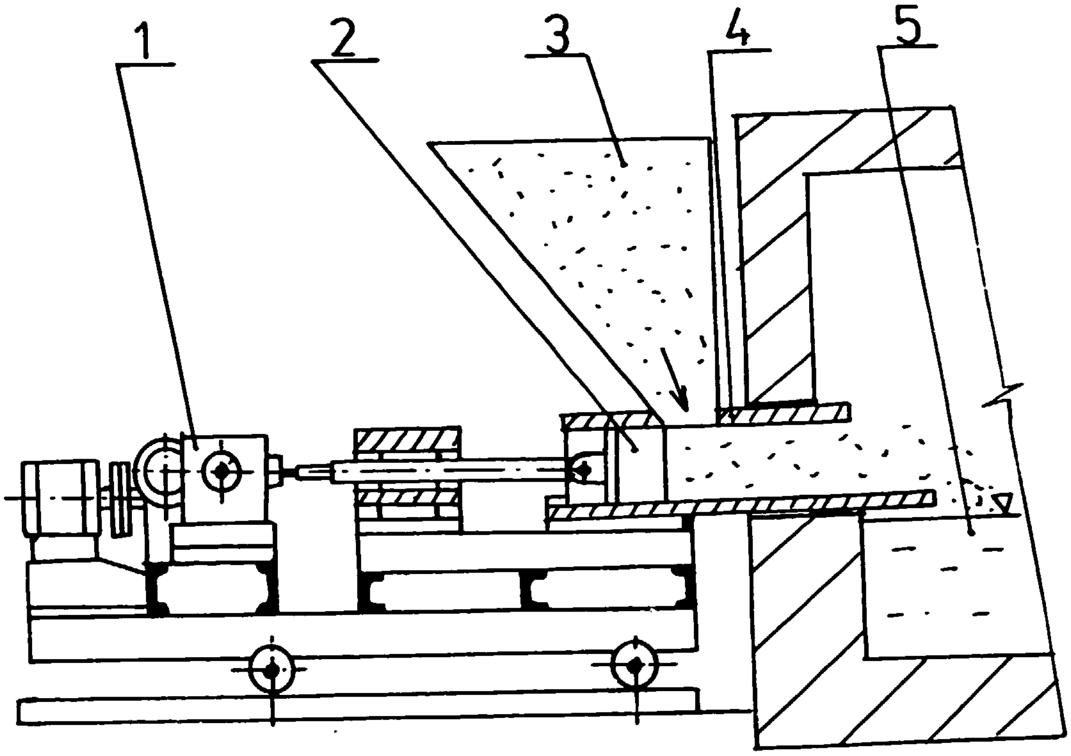
1 - motor, coupling, gear box, 2 - stationary top section of the batch mixer, 3 - removable bottom section of the batch mixer, container, 4 - locking lever, 5 - discharge closure of the container

Figure 6 <u>Batch Charging in Piles into Forehearth</u>



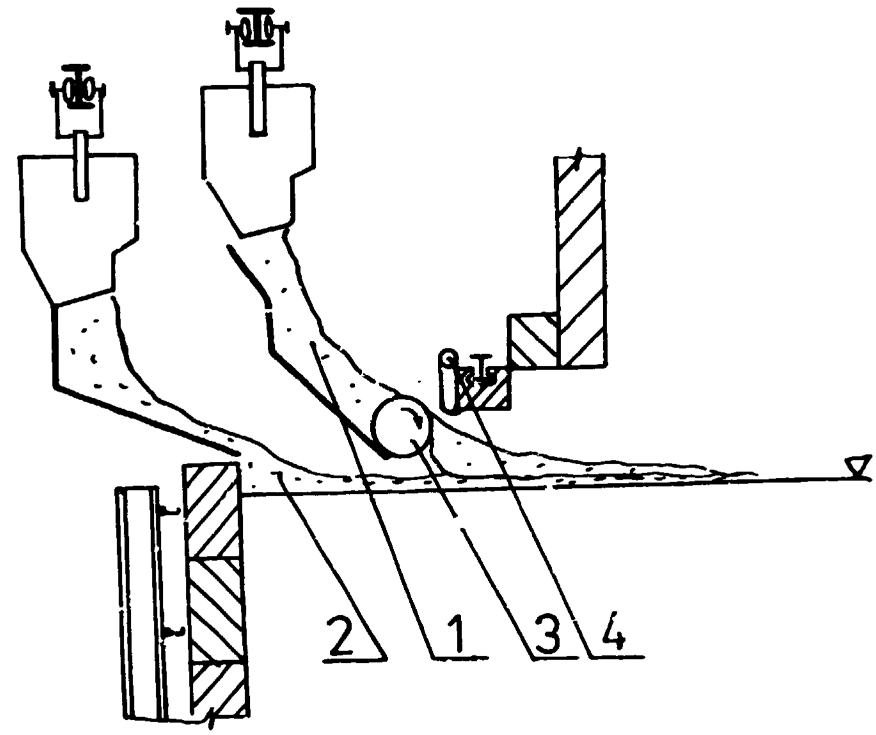
1 - batch storage bunker, 2 - closure and outlet of the batch storage bunkers, 3 - a pile of the batch charged into the furnace, 4 - rod for pushing the batch pile into the furnace, 5 - spacing of batch piles in the melting furnace, 6 - doghouse, 7 - suspending closure for the charging opening (outlet)

Figure 7 Piston Batch Charger



1 - drive unit (motor with a drive conversion unit), 2 - linear displacement piston of the charger, 3 - batch storage bunker, 4 - prolongated water cooled spout of the charger, 5 - doghouse of the furnace

Figure 8 Batch Charger System Univerbel



1 - batch, 2 - cullet, 3 - feed roller, 4 - water cooler

Figure 9 Functional Diagram of a Floater Glass - Level Indicator

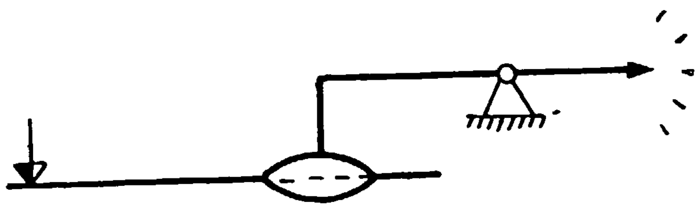


Figure 10 Functional Diagram of an Electric Contact Glass - Level Indicator

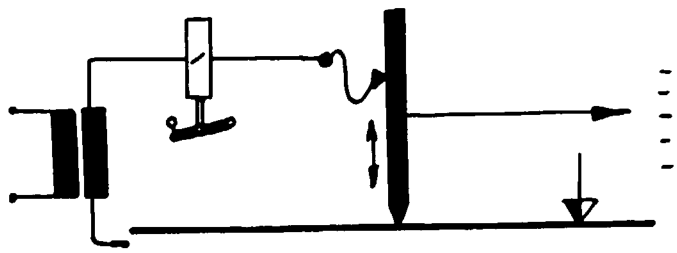
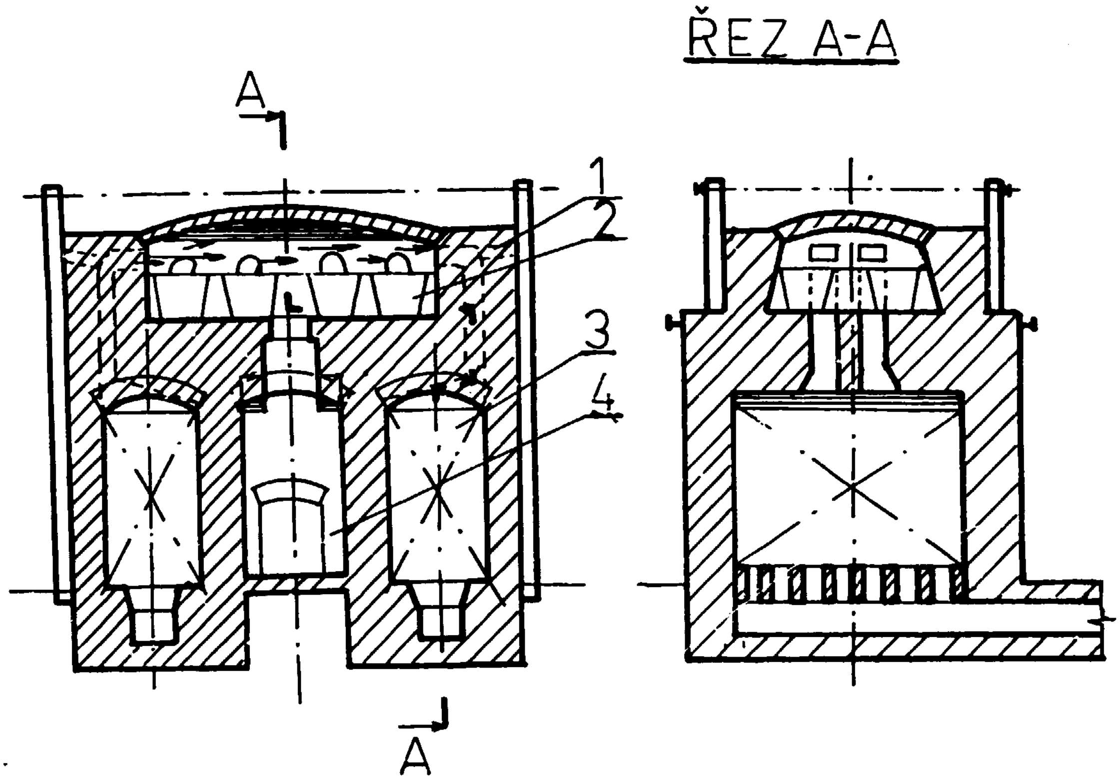
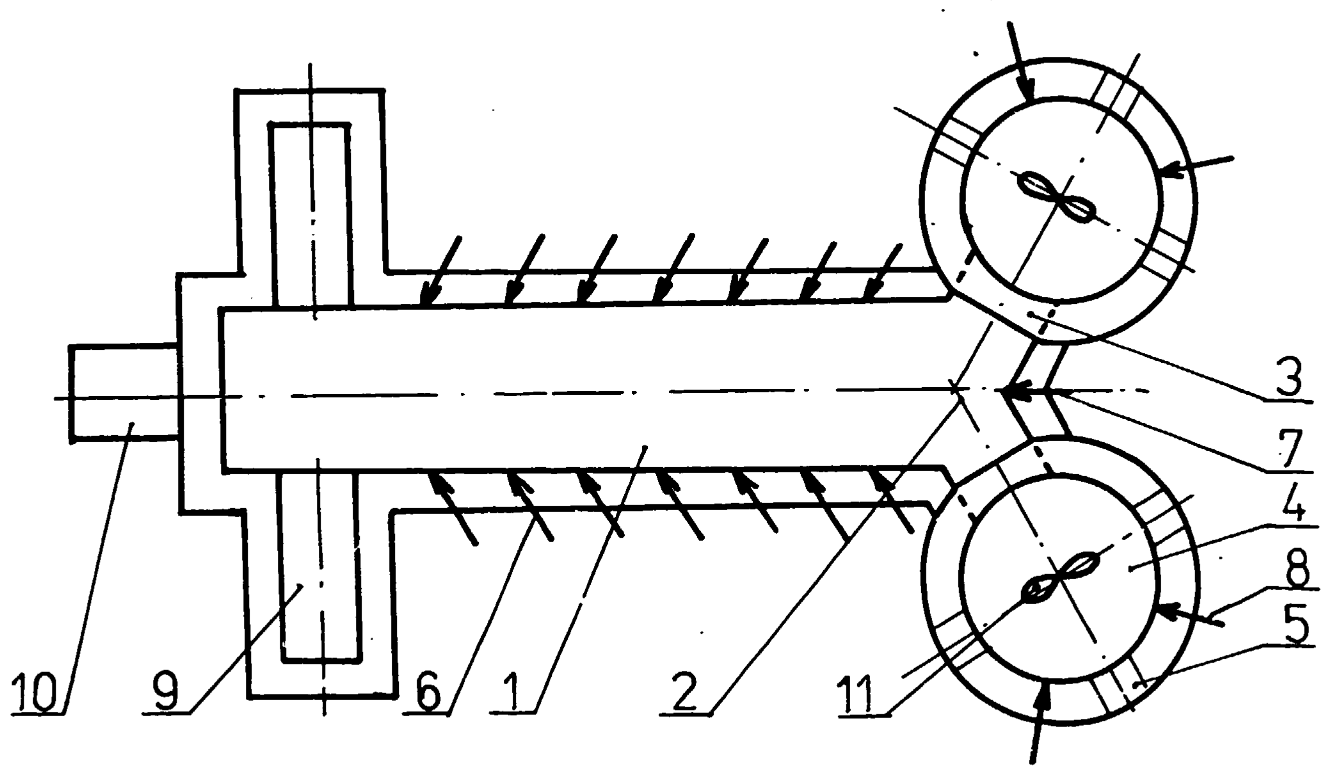


Figure 11 Top-flame Melting Pot Furnace



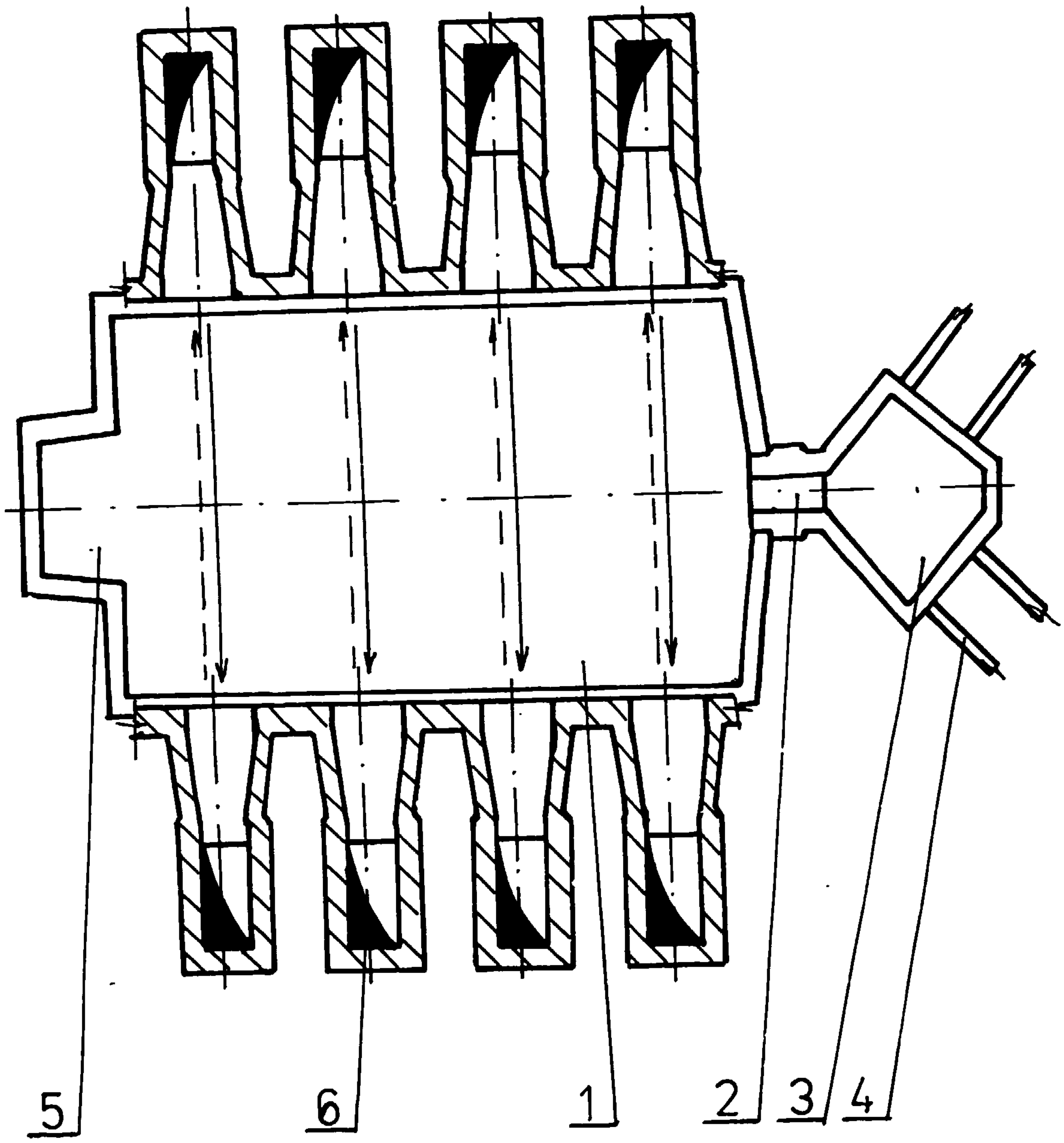
1 - spray nozzle for pure gas, 2 - melting pot, 3 - vertical regenerator chamber, 4 - glass pocket (for glass spilled on siege)

Figure 12 Long and Narrow Tank Furnace Type Unit-Melter for Hand-made Glass



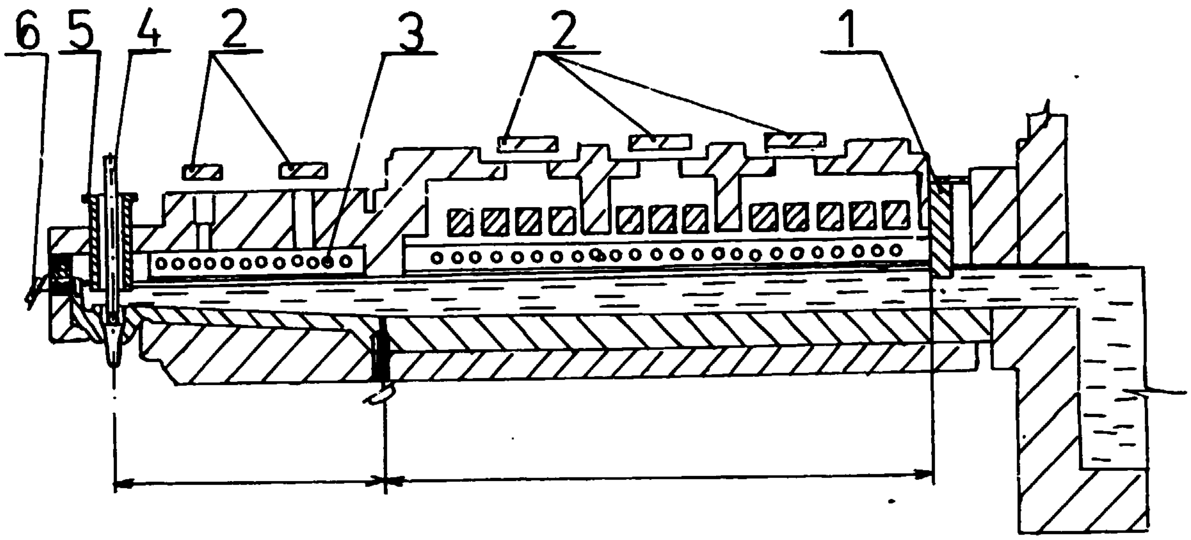
1 - melting end (compartment), 2 - bifurcation of the melting end, 3 - throat, 4 - circular working end (compartment), 5 - working holes, 6 - side wall burners, 7 - front face burner, 8 - burners in the working compartment, 9 - exhaust into a metal recuperator, 10 - batch charger, 11 - central air screw stirrer

Figure 13 Regenerative Cross-fired Tank Furnace with Throat



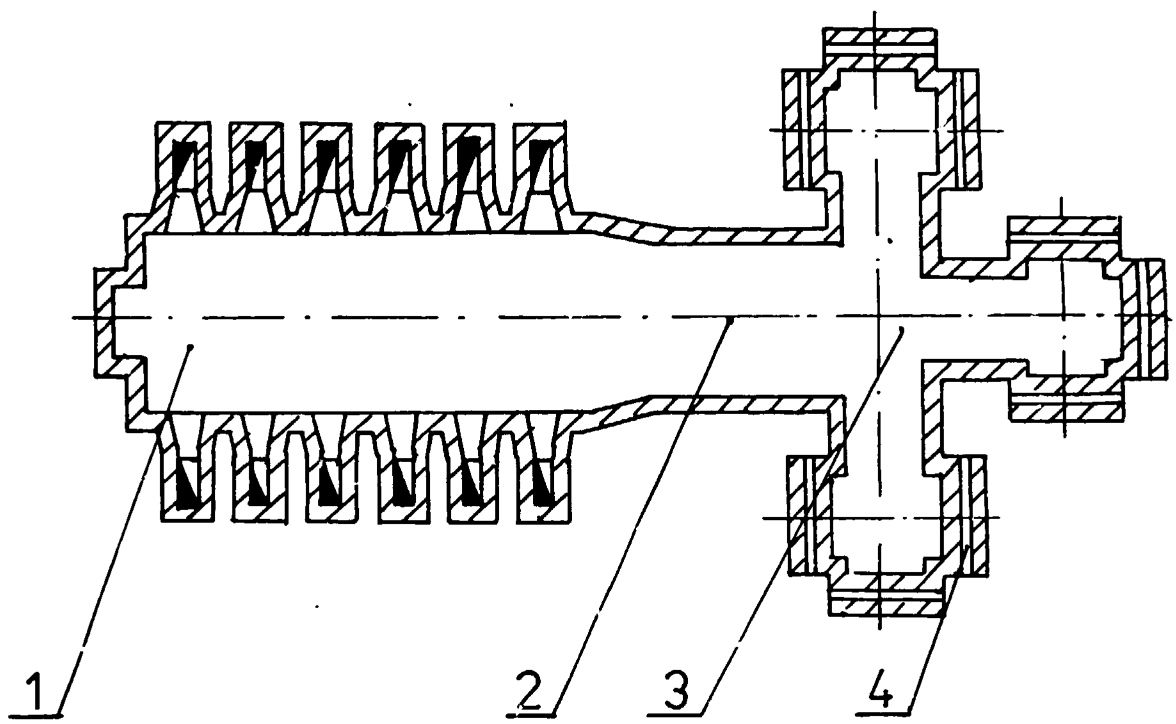
1 - melting compartment, 2 - throat, 3 - distributing working compartment, 4 - feeder channel, 5 - doghouse, 6 - uptake from the regenerator

Figure 14 Longitudinal Section of Feeder Channel and Feeder Bowl of the Gas-fired Feeder



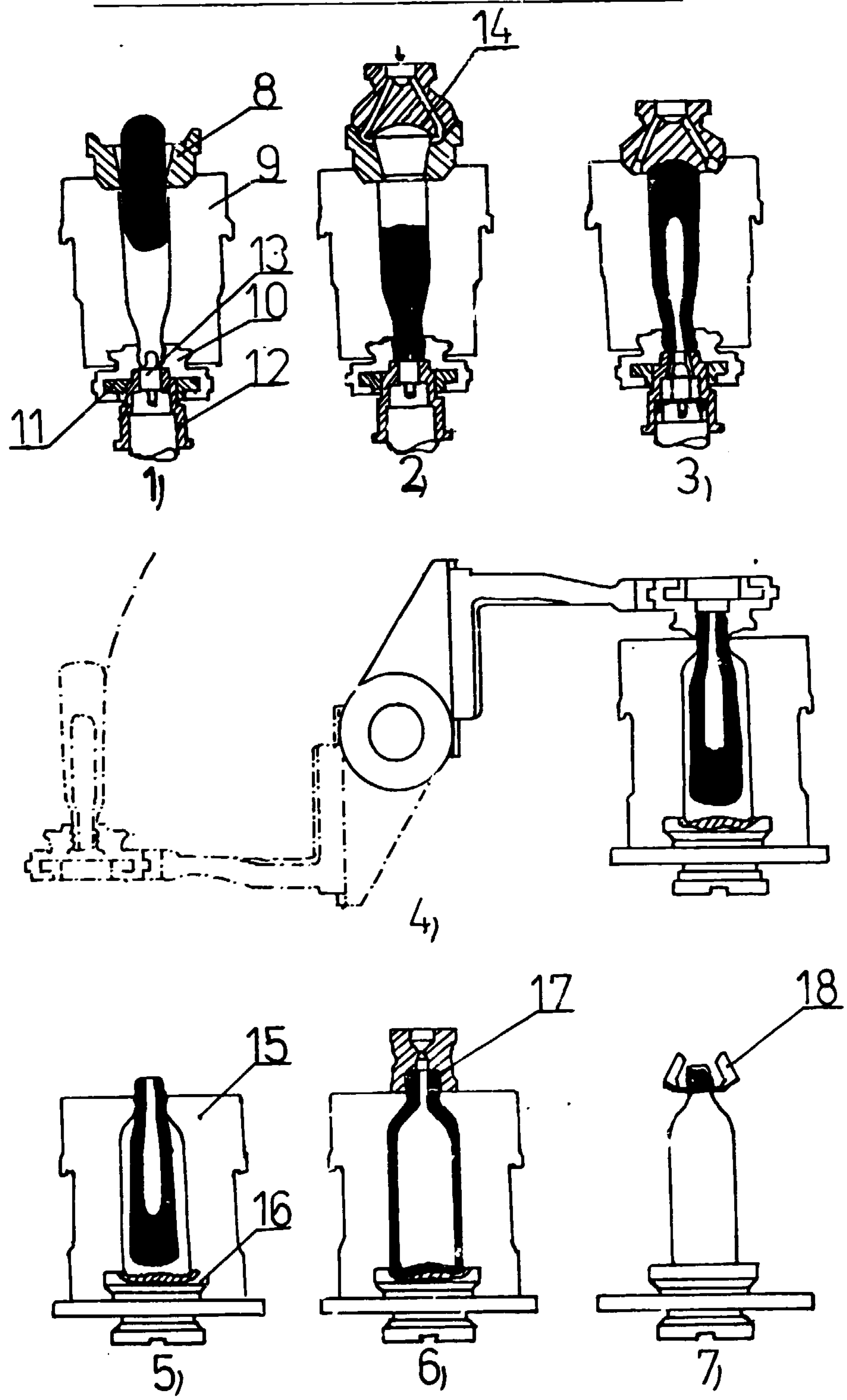
1 - siege block, 2 - ventilation block, 3 - burners, 4 - plunger, 5 - tube, 6 - submerged thermocouples

Figure 15 Regenerative Melting Tank Furnace for the Production of Sheet Glass



1 - fired melting compartment, 2 - not fired narrowed conditioning zone, 3 - distribution of glass melt to drawing compartments, 4 - drawing compartments

Figure 16 Blow-and-blow Process of Forming a Glass Bottle in an Individual Section IS Machine



1 - feeding a gob into the blank mould, 2 - settle blow in the neck mould, 3 - preblowing (first blow, puffing), 4 - transfer of the blank /parison transfer/, 5 - reheating and elongation of the blank /Parison/, 6 - second blow to final shape, 7 - take-out of the bottle, 8 - (guide) funnel, 9 - parison (blank) mould, 10 - neck mould (ring mould), 11 - guide plate, 12 - guide of the plug, 13 - plug, 14 - settle blow head, 15 - finish mould, 16 - blow mould bottom plate, 17 - blow head, 18 - jaws of the take-out tongs

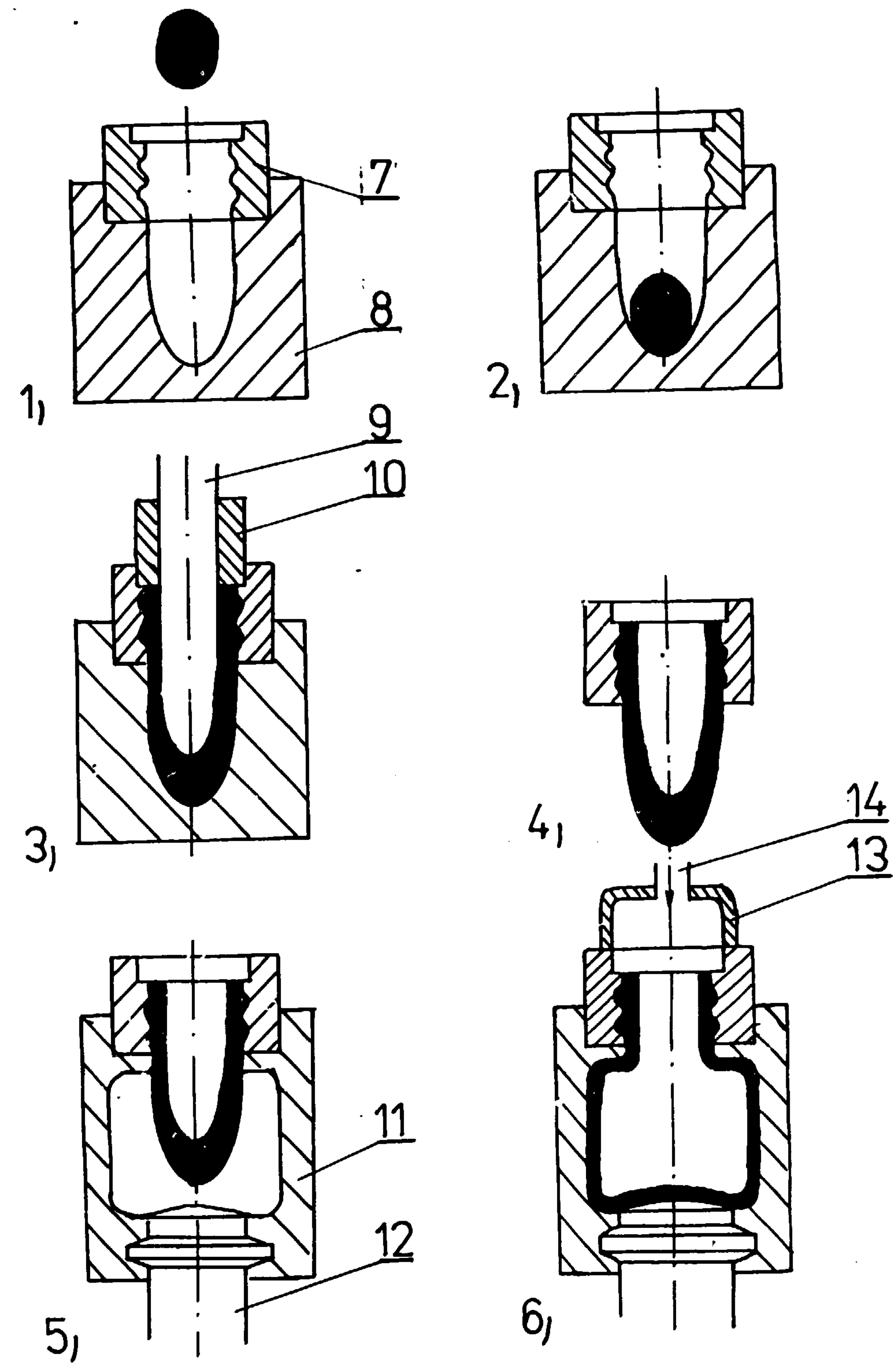
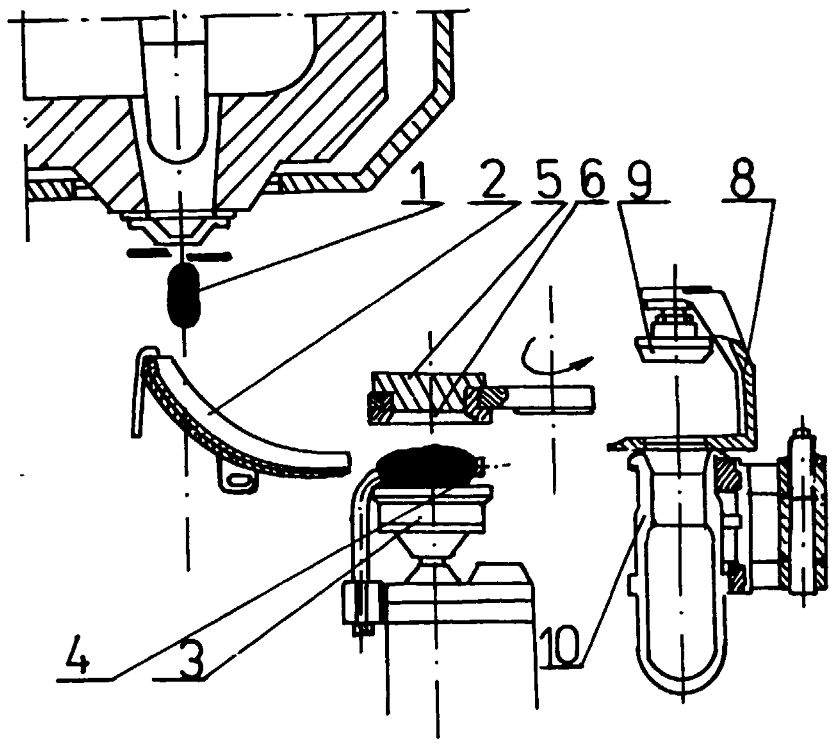


Figure 17 Press-and-blow Process of Forming

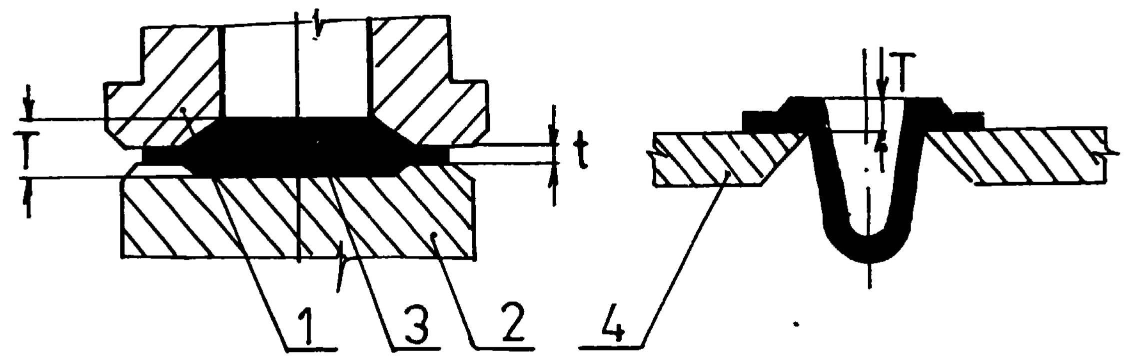
1 - pinch off the gob, 2 - filling the preform, 3 - forming the blank (parison) by pressing, 4 - reheating and transfer of the blank, 5 - reheating the blank and closure of the finish mould, 6 - blowing the final form, 7 - neck mould (neck ring), 8 - blank mould, 9 - pressing plunger, 10 - pressing plunger ring, 11 - finish mould, 12 - blow mould bottom plate, 13 - blowing head, 14 - copressed air inlet

Figure 18 Method of Moulding in a Machine M



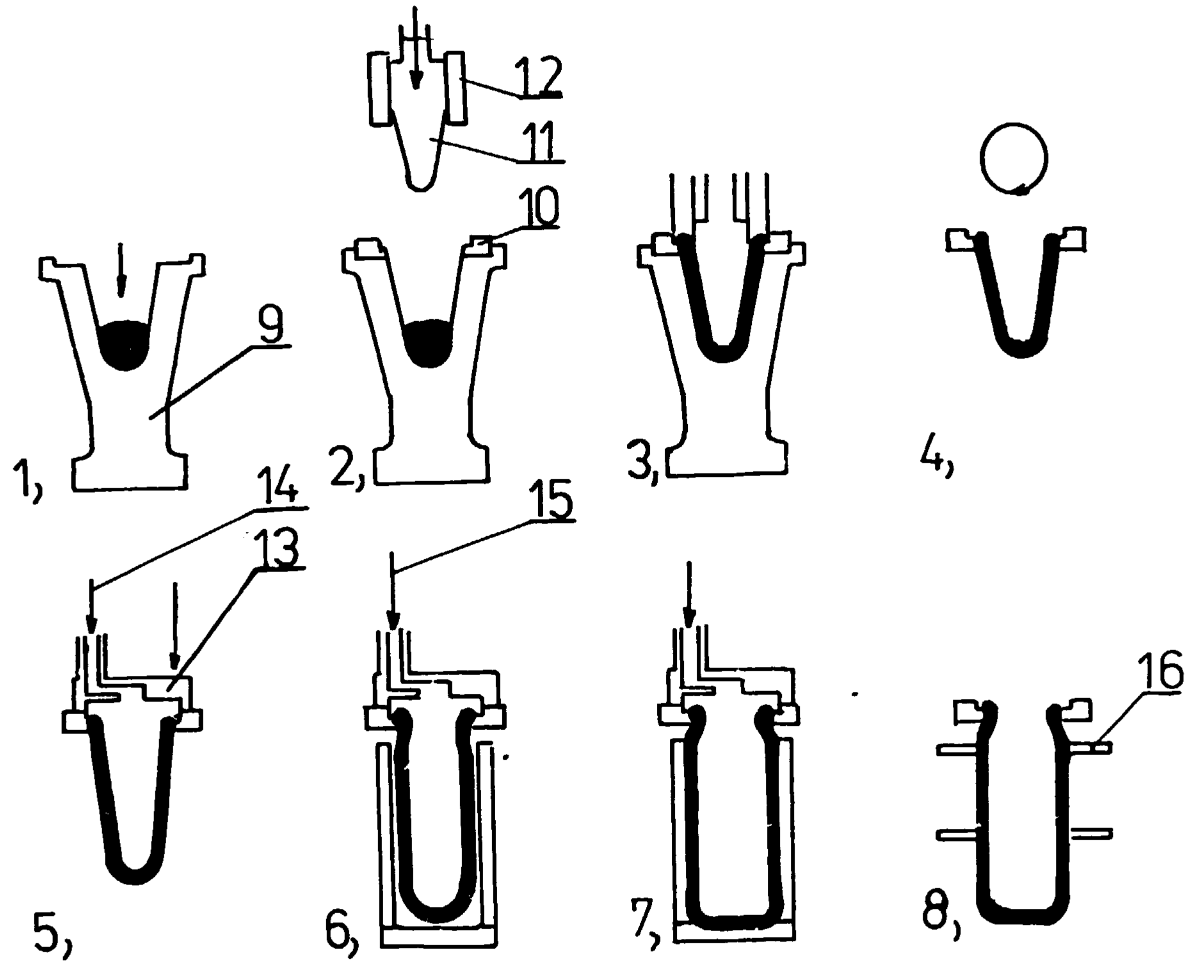
1 - gob, 2 - delivery chute, 3 - press head, 4 - gob retainer,
5 - suction and transfer head, 6 - suction head cavity,
7 - ring, 8 - ring holder, 9 - blow head, 10 - finish mould

Figure 19 Moulding the Blank by Sagging the Rough Pressing in a Machine M



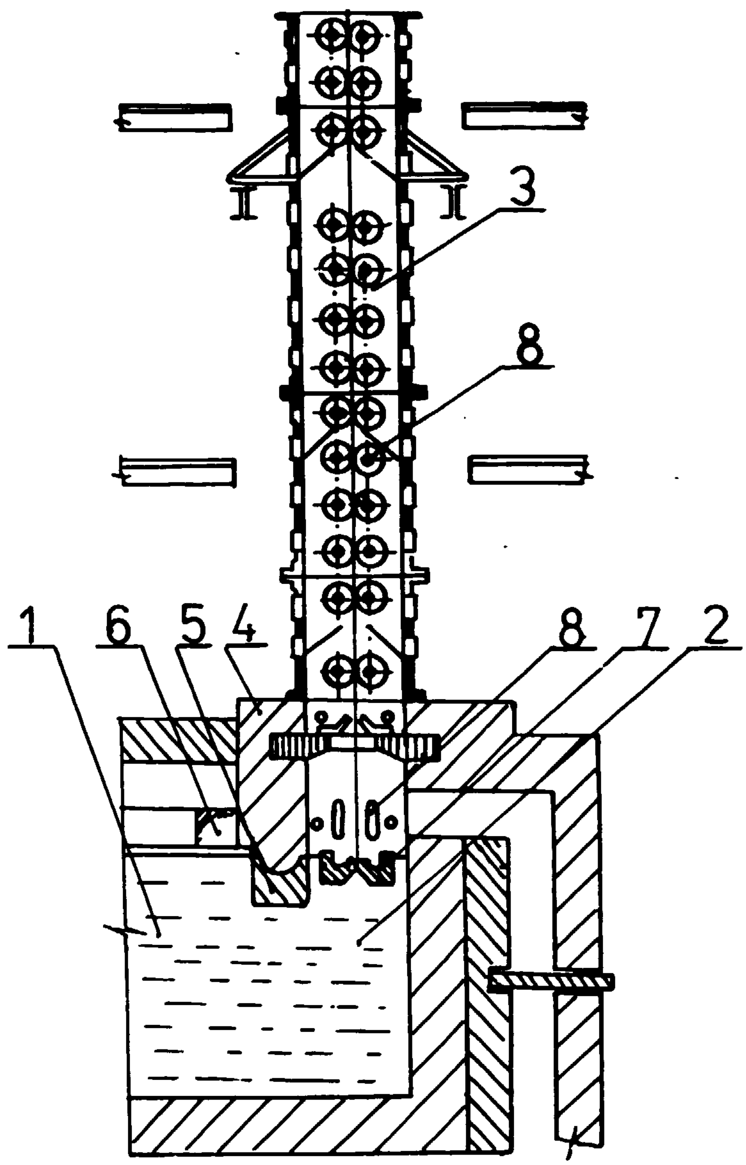
1 - suction and transfer head, 2 - press head, 3 - rough pressing, 4 - transfer ring

Figure 20 Press-and-blow Method of Moulding



1 - filling the mould, 2 - lifting the mould and making ready to pressing, 3 - pressing, 4 - revolving and reheating the blank, 5 - blowing the blank, 6 - closing the finish mould around the blank, 7 - blowing the final form, 8 - take-out of the product, 9 - blank mould, 10 - neck mould, 11 - plunger, 12 - plunger ring, 13 - blow head, 14 - pulses of low pressure air, 15 - low pressure air, 1 6 - take-out tongs

Figure 21 Vertical Drawing of Sheet Glass - system Fourcault



1 - inlet channel from the melting furnace, 2 - drawing compartment, 3 - vertical drawing machine, 4 - stationary bridge, 5 - movable floater, 6 - operation holes, 7 - ceramic debiteuse, 8 - water cooler