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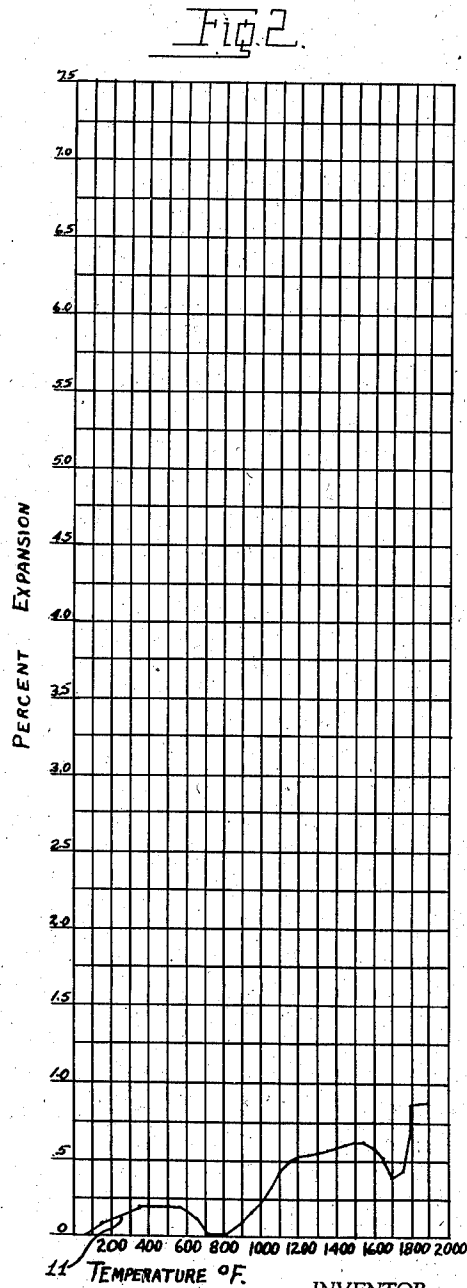
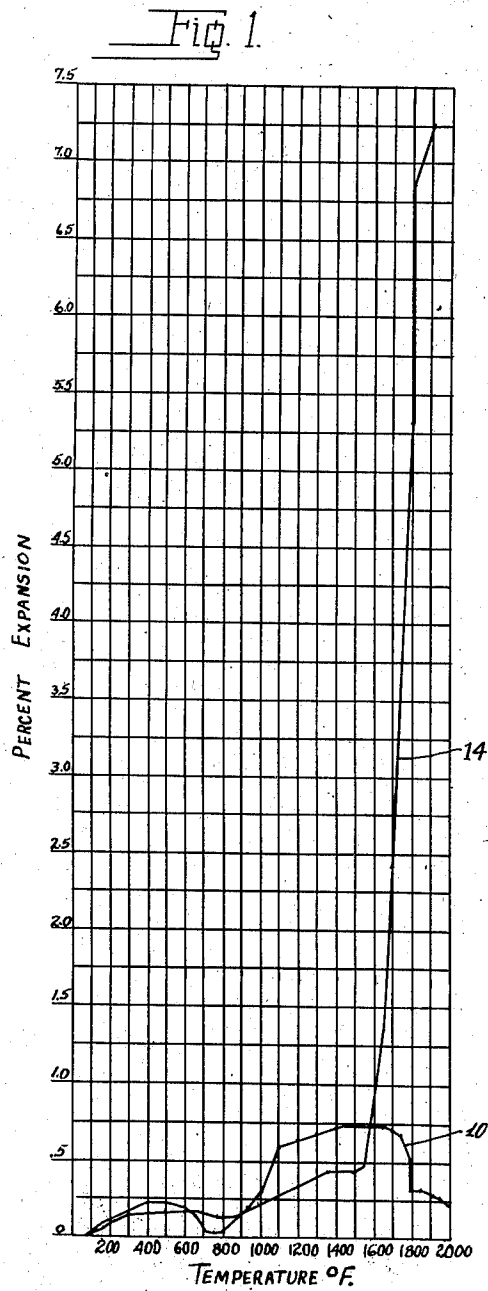
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2,263,586

INVESTMENT

Filed Dec. 18, 1939

2 Sheets-Sheet 1



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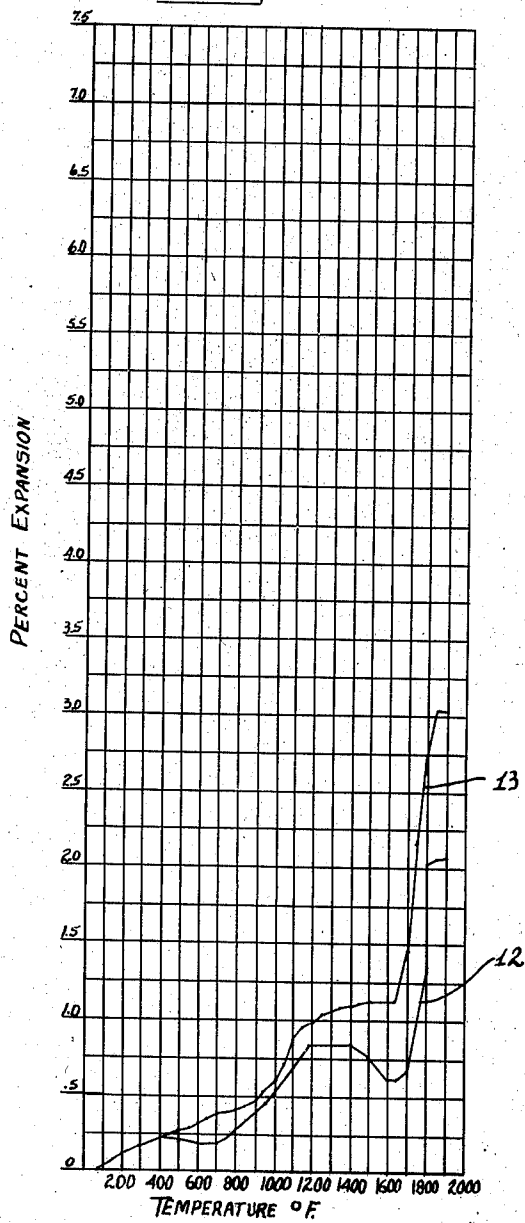
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Fig. 3.



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INVESTMENT

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This invention relates to investment compositions for use in making refractory molds into which metals or alloys may be cast into objects which must conform to a predetermined size and shape.

While the composition of this invention has general application in industry, it will be described in its use in dental casting work.

In making a dental inlay or a larger denture, the operator or dentist first makes a wax pattern of the exact size and shape to be cast of metal. This wax pattern is invested in a plastic mix, made from an investment composition which sets to form a hard mold. The investment mold, usually surrounded by a metal flask, is placed in a furnace, generally electric, and heated to a temperature to burn out the wax pattern, leaving within the mold an aperture or cavity from which extends an opening for the entrance of the metal to the cavity, and which opening is called the sprue hole. The mold is then further heated to a temperature at which the metal can be safely cast, and which additional heating, as will later be explained, causes the mold and its cavity to expand prior to the introduction therein of the molten metal. The flask containing the investment mold is then placed in a casting machine, whereupon the molten metal is forced into the cavity formerly occupied by the wax pattern. The mold is then cooled, the casting recovered, finished and then polished, ready for insertion in the mouth.

As was noted above, the mold is heated, after the wax pattern has been burned out, to the temperature at which the molten metal may be safely cast, this temperature being generally 200–500° F. below the melting point of the metal being cast, and, as further noted above, this heating causes the mold to expand, and which expansion is known as the thermal expansion of the mold. This thermal expansion of the mold is necessary to take care of the casting shrinkage of the metal. This shrinkage in most gold alloys, particularly as used in dentistry, is 1.25%, while the higher fusing alloys of precious metals, and the high fusing base metals and alloys, have shrinkages generally in excess of this, and values approaching 2% are not uncommon. The high fusing alloys of the precious metals, and the high fusing base metals and alloys must be cast in investment compositions which have a relatively large thermal expansion, and such investments should withstand heating temperatures to 1800° F., and sometimes higher, without breaking down or shrinking at these temperatures.

It is therefore one of the principal objects of the present invention to provide an investment composition which will withstand the high heating necessary for casting metals having high fusing points.

Another object of this invention is the provision of a high heat investment composition, which will have the proper thermal expansion at this heat, instead of breaking and shrinking, as do investments heretofore known and employed.

It is also an object of this invention to provide an investment composition which is capable of withstanding a relatively high heat, such as above 1800° F., and will have the desired thermal expansion at these heats, and, at the same time, is relatively economical to produce.

Other objects and advantages of this invention should be readily apparent by reference to the following specification, considered in conjunction with the accompanying drawings forming a part thereof, and it is to be understood that any modifications may be made in the exact proportions there shown and described, within the scope of the appended claims, without departing from or exceeding the spirit of the invention.

In the drawings:

Fig. 1 is a chart illustrating a pair of graphs, one of which was developed from a composition containing 30% alpha gypsum and 70% silica, while the other was developed from a composition containing 30% alpha gypsum, 69% spodumene and 1% potassium iodide, which depict the advantage of the invention.

Fig. 2 is a chart, similar to Fig. 1, depicting a graph showing the expansion of an investment, containing 30% alpha gypsum, 50% silica and 20% spodumene, and embodying this invention; and,

Fig. 3 is a chart, further depicting a pair of graphs, one of which was developed from a composition containing 30% alpha gypsum, 49% silica, 20% spodumene and 1% sodium chloride, while the other was developed from a composition containing 30% alpha gypsum, 49% silica, 20% spodumene and 1% potassium iodide, and illustrating the expansion of investments made in accordance with this invention.

Investment compositions, as known and utilized today, consist of a filler and a binder, together with some form of an accelerator or/and retarder, and sometimes a coloring agent.

The most widely used filler is pulverized quartz, commonly called silica, which has a thermal expansion of 1.5%. Other fillers consist of refrac-

tory oxides of aluminum and magnesium, as well as refractory silicates, which are also used. The highest expanding filler yet known is cristobalite (SiO_2), which has an expansion slightly over 2% when fairly pure and properly prepared, but has the disadvantage of being of such fine particle size that it requires a large amount of water to render its mix plastic. This high water content renders the investment weak and reduces its expansion.

It has been found that by substituting spodumene for the above fillers either in whole or in part, that unusually high expanding investments may be produced which are of greater expansion than any investment composition yet produced.

Spodumene is a mineral of the formula $\text{LiAlSi}_2\text{O}_6$, when pure. Commercial varieties contain various other elements, either as impurities or replacing some of the elements in the pure compound. Some varieties are known as hiddenite or kunzite. It is quite hard, brittle, variously colored, of specific gravity 3.13 to 3.20, having a refractive index 1.65 to 1.70 and optically positive. These values are those found in standard books on mineralogy for the fairly pure mineral. This mineral is known as the beta variety, and, upon heating to 690°C . (1274°F .) to 980°C . (1796°F .), inverts to the alpha form, having a specific gravity of 2.41 and an index of refraction of 1.521, and a melting point of 1380°C . (2516°F .). During this inversion, the material has a volume expansion of approximately 24%, which is equal to about 8% of linear expansion. The linear expansion is the one used and referred to throughout this specification. The inversion of the material is permanent (not reversible upon cooling), and the investment will not therefore show any sudden shrinkage if cooled somewhat in the casting process. The beta variety has not as yet been made artificially, but is believed possible. The low temperature form, as found in nature, we shall designate as the beta form; and the high temperature form as the alpha form, even though some books reverse the nomenclature. The inversion temperature varies in different specimens, and is most likely due to slight differences in composition, the presence of impurities acting as fluxes, and/or the time of heating. The use of fluxes, such as sodium molybdate and molybdic acid, along with prolonged heating time, decreases the inversion temperature. The lowest yet reached is 690°C . (1274°F .).

The binders most generally used in investments are calcined gypsum, aluminous cements, magnesia cements, silicates, silicic acid, phosphates, etc. The most desirable binder, from a standpoint of ease of manipulation, speed, strength and economy, is calcined gypsum. The hemihydrate, $\text{CaSO}_4 \cdot \frac{1}{2}\text{H}_2\text{O}$, is available in two commercial forms. The most desirable, from the standpoint of strength and low water carrying capacity, is alpha gypsum, the other form is plaster of Paris. There are also available two anhydrous forms of calcined gypsum (calcium sulphate) which set upon the addition of water, and these are known as second settle stucco and Keene's cement. The latter two products are inferior hower to alpha gypsum.

The cements and ceramic silicate binders may be used, and are sometimes more refractory, but are generally slow setting, difficult to manipulate and are not very strong before firing or heating. A mixture of binders may obviously be used as the binder.

Calcined gypsum, which includes the four

forms mentioned above, possesses a low thermal expansion of itself, and necessitates using a high expanding refractory filler, and even then the expansion is not very great, as illustrated by the graph indicated by the reference character 10 in Fig. 1. This graph was developed from an investment comprising 30% alpha gypsum and 70% pulverized quartz (silica). As will be seen in the graph or curve, however, this expansion is considerably less than 1% at a temperature of approximately 1400°F ., and when heated beyond this point shrinks rapidly, the shrinkage being rapid beyond 1650°F .

When alloys having a comparatively high fusing temperature are utilized, it is necessary to increase the mold temperature at the time of casting, in order to secure accurate reproduction of detail in intricate pattern shapes and thin cross sections. A mold that is too cool will chill the molten metal before the mold cavity is completely filled, and this comparatively cool mold necessitates superheating of the alloy, or a heating thereof considerably above its fusing point in order to prevent its being cooled below its freezing point before the mold cavity is filled. This superheating of the alloy is quite injurious to it, as it increases its affinity for impurities and causes rapid oxidation, as well as tends to scorch the investment mold when it first hits the mold. Investments containing calcined gypsum, even when in the form of alpha gypsum alone, are therefore unsuited for casting metals having a high fusing point, as they are not able to withstand temperatures much over 1500°F ., and, furthermore, do not have the required thermal expansion.

By using spodumene in place of a portion of the pulverized quartz, it is possible to overcome both objections to the simple investment composition just described. In other words, calcined gypsum or alpha gypsum binders may be used successfully when in the presence of, and mixed with, spodumene. The graph or curve indicated by the reference character 11 in Fig. 2 illustrates such an example. The investment composition which developed curve 11 was composed of 30% alpha gypsum, 50% pulverized quartz (silica) and 20% spodumene. As will readily be observed, this composition, while starting to break down when heated beyond 1500°F . had this break arrested at approximately 1700°F . and then caused the investment to expand to a point substantially above the maximum thermal expansion of the simple composition of curve 10.

The curves or graphs 12 and 13, shown in Fig. 3, are from compositions the same as that from which curve 11 was developed, except, however, the composition of curve 12 has 1% of sodium chloride substituted for 1% of the silica, while the composition from which curve 13 was formed has 1% of potassium iodide substituted for a similar quantity of the silica. It will be noted that the expansion of the investment represented by graph or curve 12 is more than double that illustrated by the graph or curve 11, while the graph or curve 13 indicates an expansion of more than treble that of curve 11.

The graph or curve 14, disclosed in Fig. 1, is a composition composed of 30% alpha gypsum, 69% spodumene and 1% potassium iodide. In other words, the composition for the curve 14 used all spodumene, instead of only 20% spodumene, and 49% silica, as in the composition which gave the curve 13. This investment, of the graph or curve 14, expanded 7.27% when the

temperature reached 1900° F., and which expansion is many times that of any investment composition heretofore produced or known.

In all of the investment compositions from which the curves of the drawings were developed, the binder was 30% alpha gypsum, and use was made of 30 cc. of water for each hundred grams of powder, except the investment from which curve 14 was developed, which used only 28 cc. of water for each hundred grams of powder. The water proportion is given, since the proportion of water to the powder has a great effect on the expansion, as an increase in water proportion will reduce the expansion, while a decrease in water proportion will increase the expansion.

It is interesting to note that the effective expansion, due to the spodumene in the composition from which the graph or curve 14 was developed, and beginning at about 1500° F., is exactly $3\frac{1}{2}$ times the expansion of the composition from which graph or curve 13 was developed, and beginning at about 1650° F., since the proportions of spodumene between these two compositions, and having the other ingredients the same, is $3\frac{1}{2}$ to one (70% of spodumene in the composition of graph or curve 14 to 20% of spodumene in the composition of graph or curve 13). This shows that in a given investment formula, the expansion due to spodumene is in direct proportion to the amount used. It should also be noted that the decrease in water proportion in the composition of curve 14 is barely noticeable, if at all, and the use of spodumene gives this further advantage, since, in investments as heretofore used, a change in water proportion was quite noticeable.

A further advantage derived from the use of spodumene is that calcined gypsum may be used advantageously for molds of high temperature, and that once the expansion of spodumene is completed, the mold will remain of constant size within a temperature range of approximately 100° F. This allows for error in pyrometers measuring the furnace temperature, as compared with the actual mold temperature, etc.

When using this investment composition, particularly in making dental casts, the mold will not shrink appreciably while cooling during the time it is moved from the furnace to the casting machine, and during the time required for melting the metal. It will readily be appreciated, therefore, that the investment containing spodumene, and not shrinking on slight cooling, is a special advantage in the dental art, since most investments containing calcined gypsum show a considerable shrinkage on cooling. The fact that spodumene inverts with tremendous expansion, and does not invert back upon cooling, is believed to be the reason for this constancy of mold size.

Spodumene is an inert refractory material, and permits the use of those agents generally used by those skilled in the art, such as accelerators, retarders, plasticizers, and graphite. Materials to prevent decomposition or other deterioration of the mold and similar effect on embedded pieces (such as inserts) as known in the art, may also be used, as may those agents which control the setting expansion.

Spodumene is of a high melting point (approximately 2500° F.), and it is therefore possible to use ceramic binders or cements which are more refractory than gypsum products, and pro-

duce molds which may be heated in excess of 2000° F.

Spodumene has an expansion of nearly 10% (linear), and is thus effective in much smaller quantities than siliceous materials, as only a fraction of the amount of these other materials is all that is necessary. It has been found that as little as 5% of spodumene will greatly increase the expansion of investment compositions when heated to the necessary point for casting metals and alloys having a high fusing point. Thus it is that only 20% of spodumene is necessary in the compositions from which curves 12 and 13 were developed to obtain quite high expansions. This is very helpful, as it allows the use of other fillers which may be even more refractory or otherwise desirable in large quantities, and, furthermore, permits the use of a greater percentage of binders, which increases the strength of the mold, especially desirable while being used and handled in making the pattern. Binders, such as calcined gypsum, have lower expansions than most fillers, and calcined gypsum or alpha gypsum are usually used in amounts of 30% to 50% of the total investment. This is not a limiting proportion, however. Spodumene is used in its natural low temperature form and is a dense solid, and, therefore, does not absorb a large amount of water as do such materials as cristobalite (a high temperature form of silica), and thereby produces a mold that is not unduly weakened, nor has its thermal expansion decreased.

For want of a better term at the present time, the term catalyst will be used to denote any material, or combination of materials, which, when used in small amounts, from a fraction of a percent up to about 5%, will increase the expansion of investment molds considerably, especially when calcined gypsum is used as all or part of the binder. The use of about 1% of certain catalysts will sometimes double the expansion of the investment. The exact reason for this phenomenon is as yet unexplained. Many of the catalysts will cause the investment to continue to expand, or prevent its shrinkage, at temperatures in excess of that which it would otherwise withstand.

Examples of such catalysts are potassium iodide, sodium silicate (such as SS-20 of Philadelphia Quartz Co.), lithium molybdate and molybdc oxide mixtures, sodium chloride, soluble inorganic iodides and bromides, especially those of the alkali and alkaline earth metals and soluble inorganic nitrates. Mixtures may also sometimes be used. The investment composition, from which the graphs or curves 12, 13 and 14 were developed, illustrates this effect when use is made of potassium iodide and sodium chloride. The exact amounts of these catalysts to be used, must be determined by experiment, as it depends on the composition of the investment. While this is a fairly comprehensive list of so-called catalysts, it is not to be considered as limiting the invention to these materials when used with spodumene, since they are not necessary to cause the spodumene to expand, but only to enhance the mold expansion.

Some materials, or mixtures of materials, have the effect of lowering the inversion temperature of spodumene and thus gives a greater expansion of the investment at a somewhat lower temperature, and which is an advantage in certain uses. Materials which have this property in the ceramic arts are termed fluxes and they will be so termed

in this application. Sodium molybdate and molybdc oxide have been found to do this in investment compositions using spodumene as the whole or part of the filler. Fluxes do not necessarily increase the amount of expansion, but merely lower the temperature at which this expansion occurs. As can readily be observed from the graph or curve 14, potassium iodide seems to be both a catalyst and a flux, and seems to act better in compositions having the greater percent of spodumene, which is readily evident in comparison with the graph or curve 13.

It should be noted at this time that the values of expansion in the curves were determined by slowly heating the investment for about two hours from room temperature to 1100° F., and thence more rapidly heating the investment at the rate of 100° F. per seven minutes, and then holding the investment at 1800° F. for about five additional minutes, in order to complete the inversion. It is believed obvious that the same expansion may be achieved at somewhat lower temperatures by slower heating, or by holding the investment at lower temperatures for a longer time, provided, of course, this temperature is within the inversion temperature range.

From the foregoing, it is believed now evident that an investment composition made in accordance with the foregoing will accomplish the objects initially set forth, and that an investment composition has been provided which will permit the casting of metals and metal alloys having a fairly high fusing point.

The foregoing description pertains to an investment generally referred to as an inner investment and may be called the mold. Since the mold, made by enclosing the wax pattern in the investment, is generally of various shapes and sizes, it is customary to place this mold inside the casting ring or flask, and to completely fill in the intervening space with another investment, commonly called an outer investment. This outer investment should permit the inner or casting investment to expand fully without hindrance. The outer investment should therefore possess an expansion equal to that of the inner investment, or else be so flexible as to "give" easily and thus not distort the full expansion of the said inner investment. It should be noted, however, that the casting ring or flask may be completely filled with the inner investment.

An investment found successful for use as an outer investment, consists of approximately 40% plaster of Paris and 60% "micronized" talc. This proportion may be varied within limits and the plaster may be replaced, in whole or in part, by other binders such as alpha gypsum or other forms of calcined gypsum. Obviously, other suitable binders may be used. The filler, or talc, may be replaced in whole or in part by other refractory materials especially of fibrous nature, such as asbestos.

Since these outer investments have quite low thermal expansion, it is found that the casting ring may expand away from the outer investment and may even cause same to fall out of the ring. It is therefore expedient to use expanding agents which will give great expansion when used in small amounts. Spodumene is quite satisfactory for this purpose, and furthermore, it expands at high temperatures where the expansion of the ring above that of the investment becomes most pronounced. The usual catalysts and fluxes, accelerators, retarders, plasticizers, etc., as known and used in the art, may be incorporated.

These outer investments are not generally suited for casting of metals requiring great accuracy of fit, they may be used on other occasions where great porosity is required, where rapid heating of the investment is necessary without danger of cracking, and as a soldering investment. It is necessary to compound a little differently for each specific use as is known in the art.

What is claimed is:

1. An investment composition comprising from 1 to 70% spodumene and the balance substantially calcined gypsum.

2. An investment composition comprising from 1 to 70% spodumene and the balance substantially alpha gypsum.

3. An investment composition consisting principally of a binder and spodumene, and having present in the composition a catalyst in the amount of .1 to 5%.

4. An investment composition consisting principally of a binder and a filler, said filler consisting in part of spodumene in the amount of from 1 to 69%, a catalyst being present in the composition in the amount of .1 to 5%, and a flux being present in the amount of .1 to 1%.

5. An investment composition consisting principally of calcined gypsum and spodumene, a catalyst being present in the composition in the amount of .1 to 5%, and a flux being present in the composition in the amount of .1 to 1%.

6. An investment composition consisting principally of alpha gypsum and spodumene, a catalyst being present in the composition in the amount of .1 to 5% and a flux being present in the composition in the amount of .1 to 1%.

7. An investment composition consisting principally of calcined gypsum and spodumene and having an amount of from .1 to 5% potassium iodide present.

8. An investment composition consisting principally of alpha gypsum and spodumene and having an amount of from .1 to 5% potassium iodide present.

9. An investment composition consisting principally of calcined gypsum and spodumene, and having an amount of from .1 to 2% sodium chloride present.

10. An investment composition consisting principally of calcined gypsum and spodumene, a catalyst being present in the composition in the amount of .1 to 5% and a flux being present in the composition in the amount of .1 to 1%.

11. An investment composition consisting principally of alpha gypsum and spodumene, and having an amount of from .1 to 2% sodium chloride present.

12. An investment composition comprising 30 to 50% alpha gypsum, and 70 to 50% filler, said filler consisting of spodumene in the proportion of at least 5% thereof to the whole.

13. An investment composition comprising 30 to 50% alpha gypsum, 70 to 50% filler, said filler consisting of spodumene in the proportion of at least 20% thereof to the whole, and a catalyst in the amount of .1 to 5%.

14. An investment composition comprising 30 to 50% alpha gypsum, and 70 to 50% filler, said filler consisting of spodumene in the proportion of at least 5% thereof to the whole, a catalyst in the amount of .1 to 5%, and a flux in the amount of .1 to 1%.

15. An investment composition comprising 30 to 50% alpha gypsum, 5 to 68% spodumene, 1 to 48% silica, and 1% potassium iodide.

16. An investment composition comprising 30

to 50% alpha gypsum, 5 to 68% spodumene, 1 to 48% silica, and 1% sodium chloride.

17. An investment composition comprising calcined gypsum 30 to 50%, talc 1 to 69%, and 1 to 69% of spodumene.

18. An investment composition comprising calcined gypsum 30 to 50%, talc 1 to 69%, 1 to 69% of spodumene, a catalyst, and a flux, said two last mentioned constituents being respectively present in an amount from .1 to 5%.

19. An investment composition comprising 1 to 98% of comminuted spodumene and the balance binder which, when gaged with a suitable fluid, will form a plastic mass that may be poured or otherwise formed into a desirable mold shape and thence set to a cementitious mass capable of retaining its general configuration, and of withstanding heating to such temperature as will

invert and expand the crystalline spodumene, and possess enough strength to permit successful pouring or casting of metals and alloys.

20. An investment composition consisting principally of a binder and a comminuted filler, said filler consisting in part of spodumene, in the amount of from 1 to 69% of the composition, said composition when gaged with a suitable fluid will form a plastic mass that may be poured or otherwise formed into a desirable mold shape and thence set to a cementitious mass capable of retaining its general configuration, and of withstanding heating to such temperature as will invert and expand the crystalline spodumene, and possess enough strength to permit successful pouring or casting of metals and alloys.

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