

Nov. 5, 1957

R. L. FOLSOM

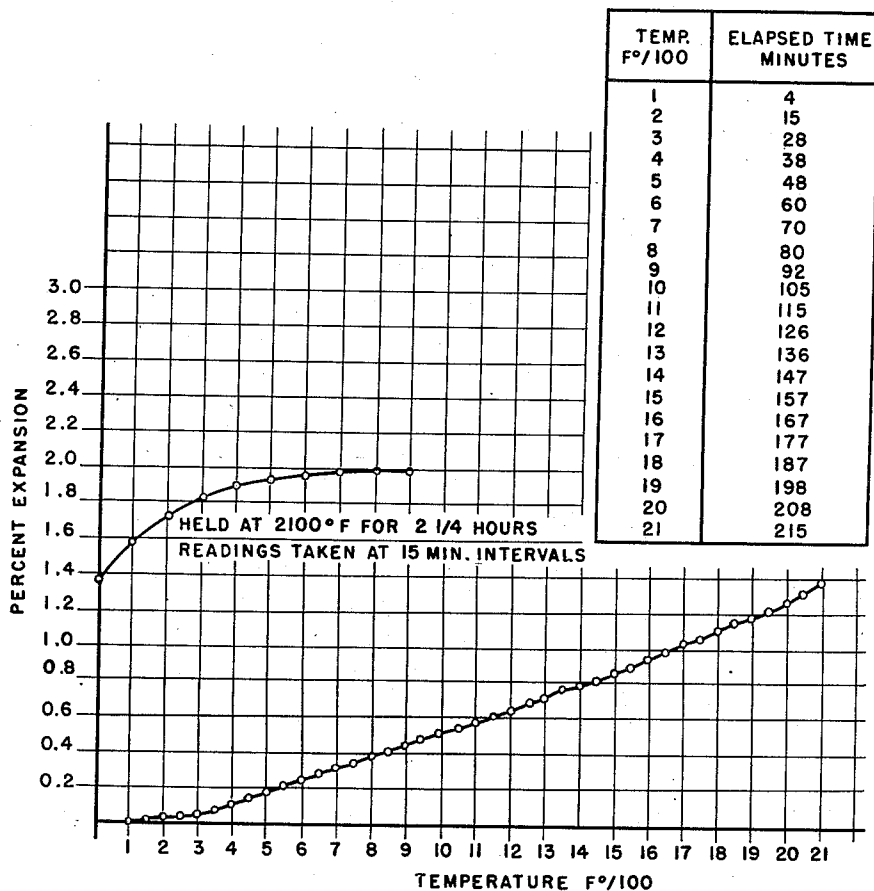
2,812,265

REFRACTORY MOLD MATERIAL

Filed Dec. 14, 1953

4 Sheets-Sheet 1

FIG. 1



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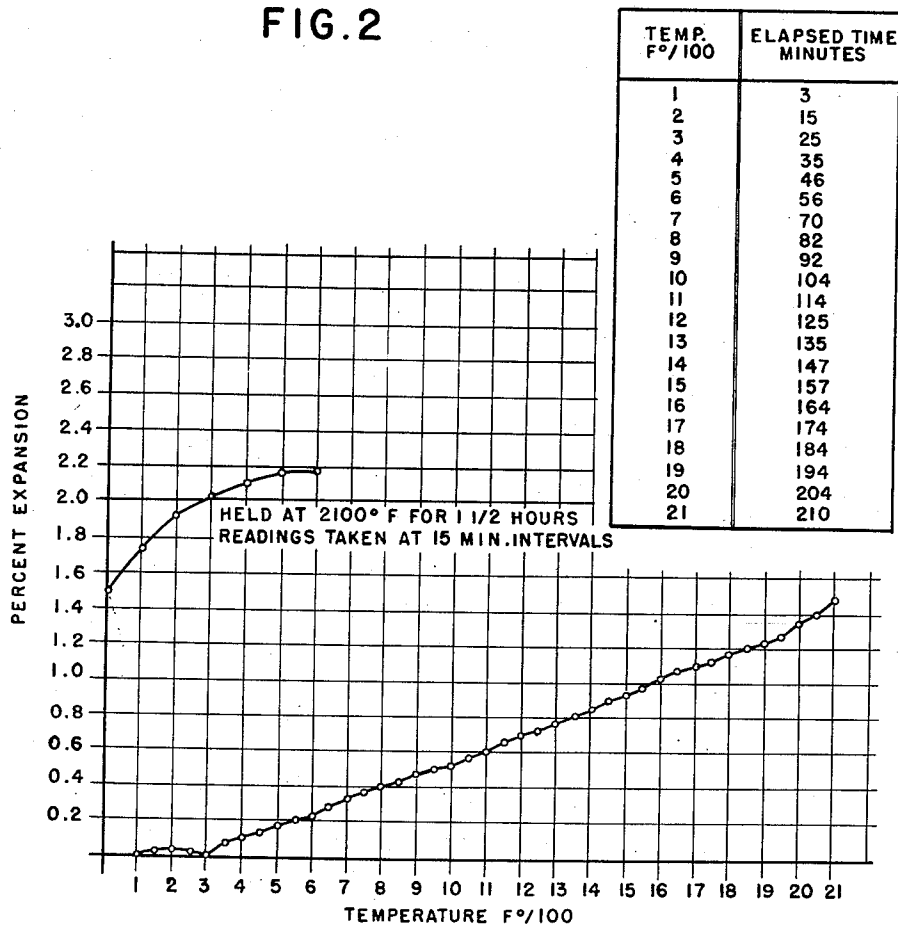
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REFRACTORY MOLD MATERIAL

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4 Sheets-Sheet 2

FIG. 2



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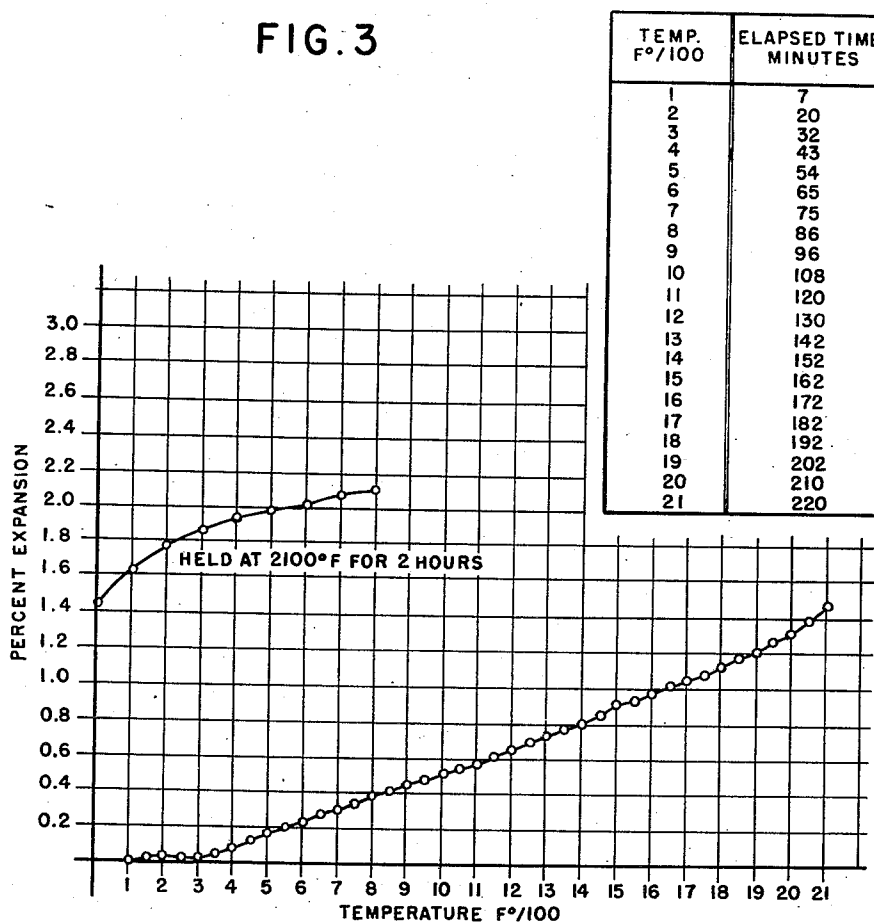
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4 Sheets-Sheet 3

FIG. 3



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4 Sheets-Sheet 4

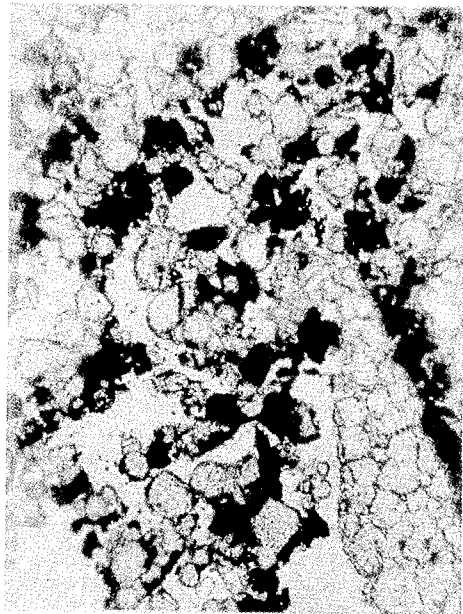


FIG. 4

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2,812,265

REFRACTORY MOLD MATERIAL

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Application December 14, 1953, Serial No. 397,856

13 Claims. (Cl. 106—38.9)

The present invention relates to a new investment composition which can be combined with a binder liquid into a mold material suitable for making refractory molds for the precision casting of high melting metals and metal alloys.

The invention also relates to the mold materials prepared with the aid of the new investment composition, to the method of making refractory molds from such mold material and to the novel refractory molds obtainable by this method.

More particularly the present invention relates to investment compositions and mold materials which are suitable for the production of refractory dental molds and of the refractory dental models forming part of such molds for use in the casting of partial or complete dentures, tooth inlays, crowns and bridges from high melting metal alloys, such as the cobalt-chromium-molybdenum alloys.

Investment compositions which are suitable for the preparation of molds for the precision casting of high melting metals and metal alloys must combine a number of desirable properties of which the most important ones are the following:

The investment composition should be a dry powder readily miscible with conventional binder liquid such as, for instance, the ethyl silicate binder liquids used extensively in the dental and precision casting arts.

The mold material resulting from a combination of the investment composition with a suitable quantity of binder liquid should be easily moldable or castable, and should set at ordinary or slightly elevated temperatures to form stable molds of high green strength.

The setting period of the mold material should be sufficiently long to permit formation of the desired refractory shapes, such as a model or a mold, but not so long that an excessive time must elapse before the model can be waxed up or the completed mold is ready for casting. Setting periods between about 15 minutes and 2 and 3 hours are preferred.

The mold material should have a minimum setting and drying shrinkage so that the dimensions of the completed mold conform exactly to those of the pattern on which the mold is formed.

The completed mold should be refractory in casting processes in which metals or metal alloys are cast at temperatures between about 2500° F. and 3000° F. The mold should also be chemically inert to the metals and alloys cast therein and to their oxides, so as to minimize formation on the metal parts of slag, scale and oxides, which would tend to reduce the accuracy of the castings.

High melting metals and metal alloys, such as, particularly, the alloys containing high proportions of cobalt, chromium and molybdenum which are used extensively in the precision casting of dental structures as well as in the manufacture of industrial precision castings, have casting temperatures above 1800° F. and frequently as high as 2500°–3000° F. and their linear shrinkage from casting temperature to room temperature is in the range of about 1 to 2% calculated on their room temperature

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dimensions. In order to compensate for this shrinkage of the cast metal, it is therefore desirable that the casting molds, when heated from room temperature to the casting temperature, undergo an equivalent linear expansion so that the castings made in these molds after cooling to room temperature will have final dimensions conforming exactly to those of the original mold and will thus constitute an exact replica of the pattern on which the mold was formed. Accordingly, the molds, upon heating, to casting temperature, should undergo a linear expansion of about 1 to 2%, corresponding to the cooling shrinkage of the metal or metal alloy to be cast.

The expansion of the mold during heating from room temperature to the casting temperature should proceed at a substantially uniform rate so as to produce a straight line curve because any sharp breaks in the expansion curve may result in the formation of internal stresses which may cause strains or fractures of the mold either during the heating or during the casting.

The expansion curve, however, should flatten out after the mold has been maintained at the casting temperature for a certain length of time so that the mold is in proper condition for casting at any time after it has reached the desired expansion.

The rate at which the mold is heated should not cause any substantial change in the expansion characteristics of the mold. Preferably, the mold should produce equally satisfactory results, regardless of whether it is placed in a cold furnace and slowly heated to the desired temperature or placed directly in a furnace preheated to the desired temperature.

A further desirable feature is that the mold surfaces are smooth and remain so during casting.

Finally, it is desirable that the molds have a relatively high porosity to permit the escape from the mold of the enclosed air and of gases which may be formed or released during the casting operation.

It is an object of the present invention to provide an investment composition from which mold materials and molds can be made combining all or at least most of the above enumerated desirable properties.

A further object of the invention is to produce an investment composition consisting of a small number of relatively inexpensive and readily available components, and which can be easily varied in its composition to produce molds the linear expansion of which at casting temperatures can be adjusted to the desired magnitude of between about 1% to about 2%.

A still further object of the invention is to provide an investment composition in which selected proportions of the ingredients in combination with predetermined quantities of suitable binder liquids yield consistently mold materials suitable for the production of molds of predetermined expansion characteristics and small variations in the proportions of the ingredients do not produce any appreciable changes in the expansion characteristics of the molds.

These and other objects which will appear more clearly as the specification proceeds are obtained according to the present invention by the use of a new investment composition which consists substantially of a refractory mixture of periclase and zircon.

The dry investment compositions according to the present invention contain between 30% and 85% by weight of periclase and 15% to 70% by weight of zircon. Outside of these limits some of the desirable properties, and particularly expansion characteristics of the desired type, are not obtainable under ordinary circumstances. Substantially inert refractory fillers, such as fused aluminum oxide, may be present up to a maximum of about 17% by weight of the composition without seriously impairing the desirable properties of the composition.

The term "zircon" as used in the present specification and claims includes natural and synthetic zirconium silicate. It is preferred, according to the present invention, to use a milled zircon substantially all the particles of which have a size less than about 50 microns.

The term "periclase" as used in the present specification and claims relates to a material consisting essentially of crystalline magnesium oxide which occurs naturally in aggregates of small cubes and which is also obtained synthetically by fusing of sea-water magnesite and milling of the fused material to small sizes. Small amounts of impurities such as SiO_2 , CaO , Fe_2O_3 and Al_2O_3 may be present, but the periclase used according to the present invention contains at least about 92% by weight, and preferably 95% or more by weight, of magnesium oxide.

According to a preferred embodiment of the invention, the periclase is used in the form of a graded periclase composed of coarse particles having a size larger than 175 microns, intermediate size particles having a size between about 75 microns and 175 microns, and fine particles having a size smaller than 75 microns. It has been found that in the investment composition according to the present invention, each particle size of periclase serves a specific function. The coarse particles form a basic crystalline skeleton and prevent drying and setting shrinkage; the fine particles constitute one of the principal reactants of the mold material; and the intermediate particles serve to strengthen the skeleton and also participate to some extent in the reaction.

Preferably, according to the present invention, the periclase is classified to contain at least 10% by weight of coarse particles having a size between about 175 microns and 830 microns, and at least 20% by weight of fine particles having a size smaller than about 75 microns. It is further preferred to use a classified periclase containing at least 45% of intermediate size particles having a size between about 75 and 175 microns.

It has been observed that, during heating of molds made from investment compositions according to the present invention to a desired temperature above 1800°F ., the linear expansion of the mold is substantially uniformly proportional to the temperature increase. Thereafter, when the molds are held at the desired temperature, expansion continues during an initial phase of the holding period at a rate substantially uniformly proportional to the elapsed time but at the end of this initial phase, which may be between less than 1 hour and several hours, the expansion rate gradually slopes off until the total linear expansion becomes constant at a desired value between about 1% and 2%, and the dimensions of the mold do not undergo any further change regardless of the length of time for which the holding period is extended beyond its initial phase. An expansion curve plotted against temperature and time thus follows a uniformly rising substantially rectilinear line during heating of the mold and in the initial phase of the holding period but flattens out gradually at the end of the initial phase indicating that no further expansion takes place.

It is therefore not necessary to remove molds, according to the present invention, from the heating furnace as soon as they have reached the desired temperature and expansion but the molds may be held in the furnace at the desired temperature until it is convenient to proceed with the casting operation.

While the applicant does not wish to be bound by any specific theoretical explanation of the advantages resulting from the present invention, X-ray examination of a fired test bar made from mold material according to the present invention has shown that magnesium silicate crystals, mainly in the form of forsterite, and zirconium oxide, are formed during the firing. It is believed that the forsterite forming reaction is one of the causes for the remarkably uniform high temperature expansion of the molds according to the present invention.

For the preparation of the mold materials, the invest-

ment compositions according to the present invention are mixed with a sufficient volume of a binder liquid to form with the other ingredients a moldable paste.

Binder liquids may be employed containing conventional binders, such as hydrolyzed ethyl silicates, but for the purpose of the present invention it has been found advantageous to use a tetra-ethyl-silicate binder hydrolyzed with an aqueous acidified alcohol, in a proportion of about 15 to 40 cc. of binder liquid for 100 grams of dry investment composition.

The invention will be more fully understood in the light of the following examples and the appended drawings, in which:

Fig. 1 is an expansion curve of the mold material according to Example 1.

Fig. 2 is an expansion curve of the mold material according to Example 2.

Fig. 3 is an expansion curve of the mold material according to Example 4.

Fig. 4 is a reproduction of a photomicrograph of a slice of a mold according to Example 4.

Example 1

An investment composition was prepared by intimately mixing 22.5 parts by weight of zircon milled to a particle size of less than 50 microns and 77.5 parts by weight of a tumbled, classified periclase containing about 3 to 3.3% SiO_2 , 1.6 to 2% CaO , 0.2 to 0.4% Fe_2O_3 and .25 to .45% Al_2O_3 , and the remainder crystalline magnesium oxide, and having about the following particle size distribution:

	Percent by weight
Particles larger than 830 microns.....	0.2
Between 380 and 830 microns.....	4.5
Between 240 and 380 microns.....	2.8
Between 175 and 240 microns.....	5.4
Between 145 and 175 microns.....	9
Between 105 and 145 microns.....	30.1
Between 75 and 105 microns.....	21.7
Smaller than 75 microns.....	26.3
	100.0

A test bar was made from this investment composition as follows:

A binder liquid was prepared from 40% by volume of tetra-ethyl-orthosilicate and 60% by volume of a thinner of the following formula:

	Cc.
Alcohol	31055
Water	6740
HCl concentrated CP.....	60

28 cc. of this binder liquid was intimately mixed with 100 grams of the investment composition for $1\frac{1}{2}$ minutes by hand followed by a 3 minute mixing in a mechanical mixer under vacuum. The resulting mix was vibrated into a test bar mold. The total vibration time was 3 minutes. The initial set occurred after 14 minutes. One hour after the start of mixing, the test bar was removed from the mold. It showed excellent green strength and uniformly smooth surfaces. No appreciable drying or setting shrinkage had occurred.

The test bar was then set up in a cold dilatometer furnace and the temperature was raised at the approximate rate of 10°F . per minute until a temperature of 2100°F . was reached in 215 minutes. The specimen was held at this temperature for $2\frac{1}{4}$ hours. The initial length was measured with a micrometer and the dimensional changes during firing with an Ames dial gauge. Fig. 1 shows an expansion curve of the test bar. It can be seen that during heating from below 100°F . to 2100°F . the linear expansion curve followed a substantially straight line rising at a rate approximately proportional to the rise in temperature. When the sample was held at 2100° expansion continued for the first 45 minutes at

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a rate approximately proportional to the time elapsed so that the expansion curve continued to rise along a straight line. Then during the next 45 minutes, the curve flattened out, and during the last 45 minutes the linear expansion remained constant at 2%. The expansion curve according to Fig. 1 may be considered as an ideal curve for the casting of alloys with high cobalt content to compensate for the shrinkage of such metals from a casting temperature above 2100° F. to room temperature.

In the production of a denture in a mold made from the investment composition described, the following procedure was adopted. A standard stone model duplicate of the patient's mouth was employed to prepare the usual flexible mold. A batch of mold material was prepared by mixing 200 grams of the investment composition with 63 cc. of binder liquid as described above. The resulting mold material was vibrated into the flexible mold during 3 minutes.

After about one hour, the refractory model was removed from the mold and waxed up, i. e., a wax pattern of the denture to be cast was formed on the model. The waxed up model was mounted on a plate and a ring was placed around the model and sealed to the plate. Thereafter a second batch of mold material was prepared from 200 grams of investment composition and 63 cc. of binder liquid, and the waxed up model was invested with this freshly prepared mold material by filling the space in the ring.

After setting of the investment the plate was removed. Then the mold surrounded by the ring was placed in a cold furnace and gradually heated to 2100° F. over a period of 3½ hours. When a furnace temperature of 2100° F. had been reached, the temperature was maintained constant at this temperature for a holding period of 4 hours. At the end of this period the mold was removed from the furnace and placed in a centrifugal casting machine. Immediately thereafter, a suitable quantity of a high melting alloy consisting predominantly of cobalt, chromium and molybdenum was melted in a crucible mounted in the centrifugal machine adjacent the mold by means of an oxy-acetylene torch. On spinning of the centrifugal machine the melted alloy was forced into the mold by the centrifugal force. The mold and casting were then removed from the centrifugal machine and set aside to cool. After cooling approximately to room temperature, the mold was broken up and the casting was removed. The casting had a very fine greenish oxide coating which was easily removed by light sand blasting. After removal of the oxide coating the casting surface was smooth and free of pits or scale. The casting itself was sound, non-porous, and free of inclusions and nodules. It fitted accurately on the original stone model without any adjustments or grinding.

Example 2

An investment composition was prepared by intimately mixing 20 parts by weight of zircon milled to a particle size of less than 50 microns and 80 parts by weight of a classified tumbled periclase having the same composition and particle size distribution as the periclase used in Example 1.

A test bar was made from this composition as follows: 30 cc. of binder liquid of the same composition as used in Example 1 were intimately mixed with 100 grams of the investment composition for ½ minute by hand, followed by a 1½ minute mixing in a mechanical mixer under vacuum. The resulting mix was vibrated into a test bar mold. The total vibration time was approximately 3 minutes. Initial set occurred after 17 minutes. About 1 hour after the start of the mixing, the test bar was removed from the mold. It had good green strength and smooth surfaces. There was no appreciable drying or setting shrinkage.

The test bar was set up in a cold dilatometer and the temperature was raised at the approximate rate of 10° F.

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per minute until a temperature of 2100° F. was reached in 210 minutes. The specimen was held at this temperature a period of 1½ hours. Initial length and dimensional changes during firing were measured as in Example 1. Fig. 2 shows an expansion curve of the test bar. It will be seen that, as the temperature was raised, expansion proceeded substantially in proportion to the increase in temperature along a straight unbroken line and thereafter continued to rise in proportion to the time elapsed also along a substantially straight line for about 1¼ hours. Finally, the expansion curve flattened out and expansion became constant at slightly under 2.2%.

Example 3

An investment composition was prepared by intimately mixing 15 parts by weight of zircon milled to a particle size of less than 50 microns and 85 parts by weight of a classified, tumbled periclase having the same chemical composition as the periclase used in Example 1 and about the following particle size distribution:

	Percent by weight
Particles larger than 830 microns.....	0.2
Between 380 and 830 microns.....	3.8
Between 240 and 380 microns.....	2.4
Between 175 and 240 microns.....	4.6
Between 145 and 175 microns.....	7.5
Between 105 and 145 microns.....	25.6
Between 75 and 105 microns.....	18.4
Smaller than 75 microns.....	37.5
	100.0

A test bar was made from this composition by intimately mixing 31.5 cc. of the binder liquid described in Example 1 with 100 grams of the investment composition for ½ minute by hand followed by a 3 minute mixing in a mechanical mixer under vacuum. The resulting mix was vibrated into a test bar mold. The total vibration time was 3 minutes. Initial set occurred after 10 minutes. About 1½ hours after the start of the mixing the test bar was removed from the mold. It had good green strength and very smooth surfaces. A negligible drying and setting shrinkage was observed.

The test bar was set up in a cold dilatometer furnace and the temperature was raised at the approximate rate of 10° F. per minute until a temperature of 2000° F. was reached in a little under 3½ hours. Initial length and dimensional changes during firing were measured as in Example 1. It was found that linear expansion during heating increased gradually along a substantially straight line to about 1% and thereafter continued to rise slowly for about 90 minutes to about 1.1% where it became constant.

A mold for a tooth inlay was made from this investment composition and an inlay was cast in this mold as follows:

A wax model of the inlay was invested with a mold material containing 200 grams of investment composition and 63 cc. of binder liquid by first vibrating a layer of mold material into a ring mounted on a plate, then placing the inlay model with a wax sprue attached thereto on this layer and filling the ring with vibration to a level above the wax model with additional mold material.

After setting of the investment the plate was removed. The mold surrounded by the ring was placed in a furnace preheated to 2000° F. and left in the furnace for 2½ hours. Thereafter the mold and ring were removed from the furnace and placed in a centrifugal casting machine. A high melting alloy was melted and forced into the mold as described in Example 1. After removal of the mold and casting from the centrifugal machine and cooling to room temperature, the mold was broken up and the casting was removed. The casting had a thin oxide coating which was removed by light sandblasting. The surface of the casting under the oxide coating was per-

fectly smooth. The casting was sound, non-porous and free of inclusions and nodules. It reproduced accurately the shape and dimensions of the wax model of the inlay.

Example 4

An investment composition was prepared from the ingredients described in Example 1 mixed in the proportion of 25% by weight of zircon and 75% by weight of classified tumbled periclase. A mold material was obtained by mixing 100 grams of this composition with 26 cc. of binder liquid substantially as described in Example 1. A test bar was formed from this mold material. Initial setting time was 15 minutes.

After setting, the test bar had excellent green strength and uniformly smooth surfaces. No drying or setting shrinkage could be observed. The test bar was set up in a cold dilatometer furnace and the temperature was raised at the approximate rate of 10° F. per minute to 2100° F. in about 215 minutes. The specimen was held at this temperature for 2 hours. Initial length and dimensional changes during firing were measured as in Example 1. Fig. 3 shows an expansion curve of this test bar. It will be seen that the expansion increased uniformly during heating and continued to increase after the temperature of 2100° F. had been reached substantially in proportion to the elapsed time until it tended to become constant at 2.1%.

Fig. 4 is a reproduction of a photomicrograph of a slice of the fired test bar taken under normal light, 100 power. The photomicrograph shows the reaction centers which had formed under the heating at high temperatures due to the reaction between zirconium and periclase. X-ray examination of the test bar showed that magnesium silicate crystals, mainly in the form of forsterite, and zirconium oxide were present in addition to some unreacted magnesium oxide and zircon.

Example 5

An investment composition was prepared by intimately mixing 25 parts by weight of zircon milled to a particle size of less than 50 microns and 75 parts by weight of a classified, tumbled periclase having the same chemical composition as the periclase specified in Example 1 and the following particle size distribution:

	Percent by weight
Particles larger than 830 microns.....	0.2
Between 380 and 830 microns.....	3.2
Between 240 and 380 microns.....	25.8
Between 175 and 240 microns.....	4.2
Between 145 and 175 microns.....	7.0
Between 105 and 145 microns.....	23.
Between 75 and 105 microns.....	16.
Smaller than 75 microns.....	20.6
	100.0

A mold mass was prepared from this investment composition by mixing 100 grams of the composition intimately with 30 cc. of the binder liquid described in Example 1. Various dental molds were formed from this mold mass substantially in the manner described in Examples 1 and 3. After setting, these molds displayed very high green strength and exact measurements failed to disclose any drying or setting shrinkage. Castings made in these molds had excellent metallurgical properties and conformed in every respect to the patterns used in making the molds regardless of the size, cross-section and dimensions of such pattern.

Example 6

An investment composition was prepared from the ingredients described in Example 1 mixed in the proportion of 30% by weight of zircon and 70% by weight of classified, tumbled periclase. A mold material was made from this composition by mixing 100 grams thereof with 26 cc. of the binder liquid described in Example 1 and a

test bar was molded in the manner there described. An expansion test conducted as in Example 1, and in which the test bar was heated to 2100° F. and held at this temperature for 1 hour, showed a rectilinear expansion during the heating to 1.3% and a further rectilinear expansion during the holding period to 1.5% at which value the expansion became constant.

Example 7

An investment composition was prepared from the ingredients described in Example 1 by mixing 40% by weight of zircon with 60% by weight of classified, tumbled periclase.

The mold material made from this composition contained 24 cc. of binder liquid per 100 grams of investment composition. A test bar formed from this mold material and tested under the conditions described in Example 1 by heating it to a temperature of 2160° F. at the rate of 100° rise in temperature per 10 minutes of time during 215 minutes, and holding it at this temperature for one hour, showed rectilinear expansion to approximately 1.2% during heating and after expansion to about 1.3% at which value the expansion tended to become constant.

Identical test bars heated to 2160° F. in 2 hours and 40 minutes, respectively, showed expansion curves substantially identical with those of the test bar heated to 2160° F. during 215 minutes when expansion was plotted against temperature during the heating period and against time during the holding period. Both also showed substantially rectilinearly rising expansion curves when expansion was plotted against time during the heating period. It was thus shown that the expansion characteristics of refractory shapes made according to the invention remain substantially the same regardless of the rate at which they are heated during firing.

Example 8

An investment composition was prepared by intimately mixing the same ingredients as in Example 1, using equal weight proportions of zircon and classified, tumbled periclase. The mold mass made from this composition contained 20 cc. of binder liquid as described in Example 1 per 100 grams of investment composition. A test bar made from this mold mass, heated in the manner described in Example 1 to 2100° F. and held at this temperature for 1½ hours showed a rectilinear expansion of about 1.2% during heating. The expansion rose during the holding period to above 1.6% and was still increasing at a slow rate when the test was completed.

Example 9

An investment composition was prepared by intimately mixing the ingredients described in Example 1 at the ratio of 60% by weight of zircon to 40% by weight of tumbled, classified periclase. A mold mass was made from this composition using 17 cc. of binder liquid and 100 grams of investment composition. A test bar cast from this mold mass and tested as described in Example 1, by heating it to 2000° F. and holding it at this temperature for 2¼ hours, showed uniform expansion during the heating to about .9% and after expansion in the initial phase of the holding period to about 1.1%. The expansion curve flattened out after 2 hours and the expansion then remained constant at 1.1%.

Example 10

An investment composition was prepared by intimately mixing the ingredients described in Example 1 at the ratio of 70% by weight of zircon and 30% by weight of tumbled, classified periclase. A mold mass was made from this investment composition using 15 cc. of binder liquid and 100 grams of investment composition. A test bar cast from this mold mass and tested as in Example 1, by heating it to 2100° F. and then holding

it at this temperature for 4 hours, showed expansion during heating to approximately .9% and after expansion during the initial phase of the holding period to slightly above 1%. The expansions became constant at 1% toward the end of the 4 hour holding period.

Example 11

An investment composition was prepared by intimately mixing 25% by weight of zircon milled to a particle size of less than 50 microns, 60% by weight of a classified, tumbled periclase having the chemical composition and particle size distribution specified in Example 1 and 15% by weight of an inert filler consisting of Alundum (crystallized aluminum oxide) having grain sizes between about 120 and 145 microns.

100 grams of this investment composition were mixed with 22 cc. of binder liquid as described in Example 1. A test bar made from the resulting mold composition and tested as described in Example 1, by heating it to 2160° F. and holding it at this temperature for 165 minutes, showed a substantially rectilinear expansion during heating to 1.7%. The expansion decreased slightly during the holding period and became constant at approximately 1.4%.

Example 12

An investment composition was prepared by intimately mixing 25% by weight of zircon milled to a particle size of less than 50 microns, 58% by weight of a classified, tumbled periclase having the chemical composition and particle size distribution specified in Example 1, and 17% by weight of an inert filler consisting of fused aluminum oxide having grain sizes between about 240 and 380 microns.

100 grams of this investment composition were mixed with 30 cc. of binder liquid as described in Example 1. Various dental molds and models were formed from the resulting mold material and showed, after setting, high green strength and complete absence of drying or setting shrinkage. Dental castings made in these molds were found to be sound, non-porous and free of inclusions and nodules. Such castings proved to be very accurate reproductions of the patterns used in making the molds regardless of the shapes, sizes, cross sections and dimensions of such patterns.

What I claim is:

1. Investment composition suitable for the production of refractory molds and models for precision castings and particularly for dental castings from high melting metals and metal alloys, said composition being a dry refractory mixture consisting of 30% to 85% by weight of a graded periclase containing at least 10% by weight of relatively coarse particles in excess of 175 microns and at least 20% by weight of relatively fine particles of a size smaller than 75 microns, 15% to 70% by weight of zircon, and up to 17% by weight of a substantially inert refractory filler.

2. Investment composition suitable for the production of refractory molds and models for precision castings and particularly for dental castings from high melting metals and metal alloys, said composition being a powdered refractory mixture comprising 30% to 85% by weight of a classified periclase containing at least 10% by weight of relatively coarse particles of a size between 175 and 830 microns and at least 20% by weight of relatively fine particles of a size smaller than 75 microns, the balance of the mixture consisting of milled zircon, having a particle size smaller than 50 microns.

3. Investment composition suitable for the production of refractory molds and models for precision castings and particularly for dental castings from high melting metals and metal alloys, said composition being a powdered refractory mixture comprising 30% to 85% by weight of a classified periclase of about the following particle size distribution:

	Percent by weight
Larger than 830 microns.....	0.2.
Between 380 and 830 microns.....	about 3 to 4.5.
Between 240 and 380 microns.....	about 2.3 to 25.8.
5 Between 175 and 240 microns.....	about 4.2 to 5.5.
Between 145 and 175 microns.....	about 7.0 to 9.
Between 105 and 145 microns.....	about 23 to 30.
Between 75 and 105 microns.....	about 16 to 22.
Smaller than 75 microns.....	about 20 to 37.5.
10 the balance of the mixture consisting of milled zircon, having a particle size smaller than 50 microns.	

4. Investment composition suitable for the production of refractory molds and models for precision castings and particularly for dental castings from high melting metals and metal alloys, said composition being a dry powdered refractory mixture consisting of about 70% to 80% by weight of a classified periclase containing at least 10% by weight of relatively coarse particles of a size between 175 and 830 microns, at least 45% by weight of medium size particles of a size between 75 and 175 microns, and at least 20% by weight of fine particles of a size smaller than 75 microns, the balance consisting of milled zircon, having a particle size smaller than 50 microns.

5. Investment composition suitable for the production of refractory molds and models for precision castings and particularly for dental castings from high melting metals and metal alloys, said composition being a dry powdered refractory mixture consisting of 77.5% by weight of tumbled classified periclase of the following particle size distribution:

	Percent by weight
35 Larger than 830 microns.....	0.2
Between 380 and 830 microns.....	4.5
Between 240 and 380 microns.....	2.8
Between 175 and 240 microns.....	5.4
Between 145 and 175 microns.....	9
40 Between 105 and 145 microns.....	30.1
Between 75 and 105 microns.....	21.7
Smaller than 75 microns.....	26.3
	100.0

45 and 22.5% by weight of milled zircon, having a particle size smaller than 50 microns.

6. Investment composition suitable for the production of refractory molds and models for precision castings and particularly for dental castings from high melting metals and metal alloys, said composition being a dry powdered refractory mixture consisting of 75% by weight of tumbled, classified periclase of the following particle size distribution:

	Percent by weight
55 Particles larger than 830 microns.....	0.2
Between 380 and 830 microns.....	3.2
Between 240 and 380 microns.....	25.8
60 Between 175 and 240 microns.....	4.2
Between 145 and 175 microns.....	7.0
Between 105 and 145 microns.....	23.
Between 75 and 105 microns.....	16.
Smaller than 75 microns.....	20.6
65	100.0

and 25% by weight of milled zircon having a particle size smaller than 50 microns.

7. Investment composition suitable for the production of refractory molds and models for precision castings and particularly for dental castings from high melting metals and metal alloys, said composition being a dry powdered refractory mixture consisting of 58% by weight of tumbled, classified periclase of the following size distribution:

	Percent by weight
Particles larger than 830 microns.....	0.2
Between 380 and 830 microns.....	4.5
Between 240 and 380 microns.....	2.8
Between 175 and 240 microns.....	5.4
Between 145 and 175 microns.....	9
Between 105 and 145 microns.....	30.1
Between 75 and 105 microns.....	21.7
Smaller than 75 microns.....	26.3
	100.0

and 25% by weight of milled zircon having a particle size smaller than 50 microns and 17% by weight of fused aluminum oxide having a particle size between about 240 and 380 microns.

8. Refractory mold material for precision casting molds, particularly for the production of dental castings from high melting metals and metal alloys, consisting essentially of zircon and periclase in a ratio of about .4 to 5.7 parts by weight of graded periclase to each part by weight of zircon and for each 100 parts of the combined weight of zircon and periclase up to about 20 parts by weight of a substantially inert refractory filler, and a quantity of a binder liquid to form with the other ingredients a moldable paste, at least 10% by weight of the periclase being relatively coarse particles in excess of 175 microns and at least 20% being relatively fine particles of a size smaller than 75 microns.

9. Refractory mold material for precision casting molds, particularly for the production of dental castings from high melting metals and metal alloys, consisting essentially of an investment composition consisting essentially of milled zircon of a particle size smaller than 50 microns and a classified periclase containing at least about 10% by weight of relatively coarse particles of a size between 175 and 830 microns, at least about 45% by weight of intermediate size particles of a size between 75 and 175 microns, and at least 25% by weight of fine particles of a size smaller than 75 microns, at the ratio of about 0.4 to 5.7 parts by weight of periclase to each part by weight of zircon, and for each 100 grams of dry investment composition from about 15 to about 40 cc. of a binder liquid comprising from about 40% to 50% by volume of a liquid ethyl silicate, hydrolyzed with dilute acidified alcohol.

10. Refractory mold material for precision casting molds, particularly for the production of dental castings from high melting metals and metal alloys, comprising an investment composition consisting of zircon of a particle size smaller than 50 microns and a classified periclase of the following particle size distribution:

	Percent by weight
Larger than 830 microns.....	0.2
Between 380 and 830 microns.....	4.5
Between 240 and 380 microns.....	2.8
Between 175 and 240 microns.....	5.4
Between 145 and 175 microns.....	9
Between 105 and 145 microns.....	30.1
Between 75 and 105 microns.....	21.7
Smaller than 75 microns.....	26.3
	100.0

at the ratio of 22.5 parts by weight of zircon to 77.5 parts by weight of periclase, and, intimately mixed with each 100 grams of said investment composition, about 28 cc. of a binder liquid consisting of about 40 parts by volume of tetra-ethyl-orthosilicate hydrolyzed with about 60 parts by volume of a diluted acidified alcohol thinner.

11. Refractory mold material for precision casting molds, particularly for the production of dental castings from high melting metals and metal alloys, comprising an

investment composition consisting of zircon of a particle size smaller than 50 microns and a classified periclase of the following particle size distribution:

	Percent by weight
Particles larger than 830 microns.....	0.2
Between 380 and 830 microns.....	3.2
Between 240 and 380 microns.....	25.8
Between 175 and 240 microns.....	4.2
Between 145 and 175 microns.....	7.0
Between 105 and 145 microns.....	23.
Between 75 and 105 microns.....	16.
Smaller than 75 microns.....	20.6
	100.0

at the ratio of 25 parts by weight of zircon to 75 parts by weight of periclase and intimately mixed with each 100 grams of said investment composition, about 30 cc. of a binder liquid consisting of about 40 parts by volume of tetra-ethyl-orthosilicate hydrolyzed with about 60 parts by volume of a diluted acidified alcohol thinner.

12. Refractory mold material for precision casting molds, particularly for the production of dental castings from high melting metals and metal alloys, comprising an investment composition consisting of zircon of a particle size smaller than 50 microns, a classified periclase of the following particle size distribution:

	Percent by weight
Particles larger than 830 microns.....	0.2
Between 380 and 839 microns.....	4.5
Between 240 and 380 microns.....	2.8
Between 175 and 240 microns.....	5.4
Between 145 and 175 microns.....	9
Between 105 and 145 microns.....	30.1
Between 75 and 105 microns.....	21.7
Smaller than 75 microns.....	26.3
	100.0

and fused aluminum oxide of a particle size between 240 and 380 microns at the ratio of 25 parts by weight of zircon to 58 parts by weight of periclase and 17 parts by weight of fused aluminum oxide, and intimately mixed with each 100 grams of such investment composition, about 30 cc. of a binder liquid consisting of about 40 parts by volume of tetra-ethyl-orthosilicate hydrolyzed with about 60 parts by volume of a diluted acidified alcohol thinner.

13. A shaped, bound investment composition which upon firing will form a refractory mold of substantially the same size, said composition consisting of a homogeneous mixture of solid and liquid phases, said solid phase consisting essentially of 30% to 85% by weight of a graded periclase containing at least 10% by weight of relatively coarse particles in excess of 175 microns and at least 20% by weight of relatively fine particles of a size smaller than 75 microns, 15% to 70% by weight of zircon, and up to 17% by weight of a substantially inert refractory filler, said liquid phase consisting essentially of about 15 to 40 cc. of a binder liquid for each 100 grams of solid phase.

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