July 16, 1940. G. A. RUBISSOW 2,208,230

METHOD OF TREATING MELTED MATTERS

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Fig. 1

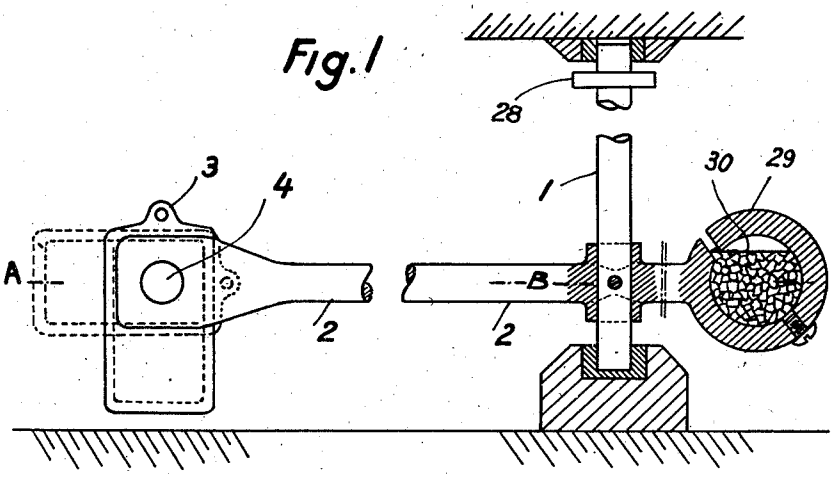


Fig. 2

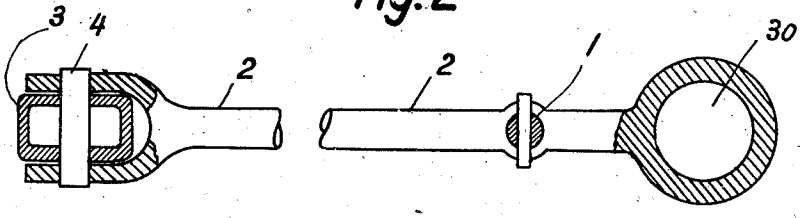


Fig. 3

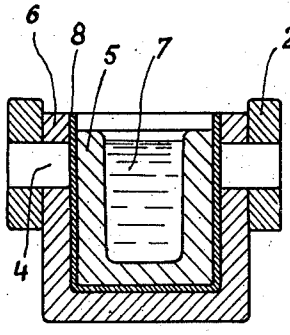
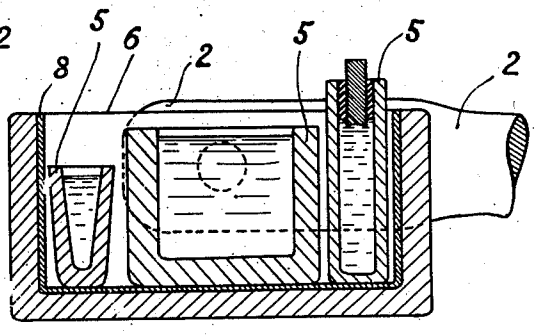


Fig. 4



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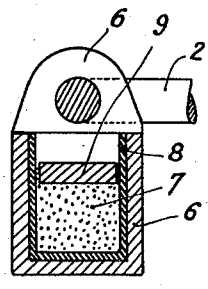
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METHOD OF TREATING MELTED MATTERS

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Fig. 5



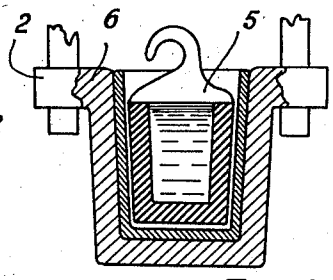


Fig. 6

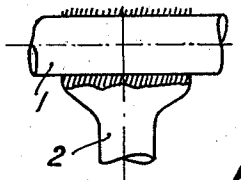
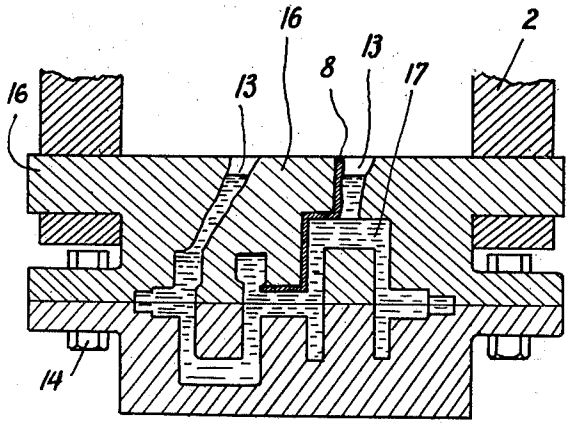


Fig. 7

Fig. 9



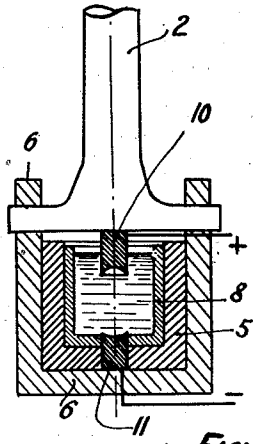


Fig. 10

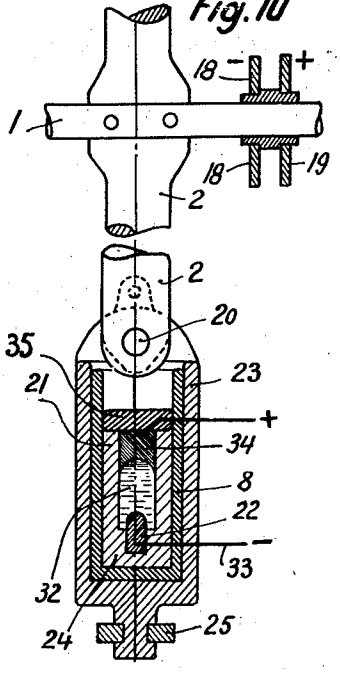


Fig. 8

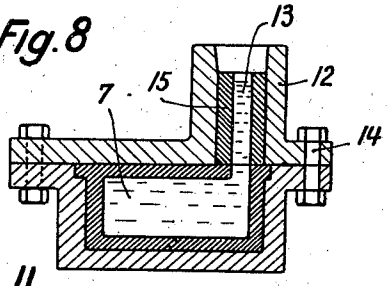


Fig. 11

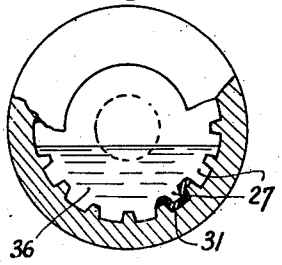
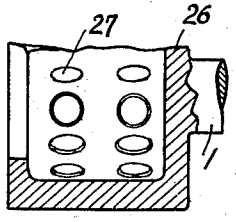


Fig. 12



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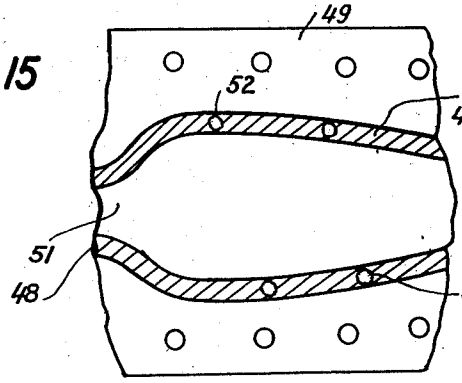
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METHOD OF TREATING MELTED MATTERS

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Fig. 15



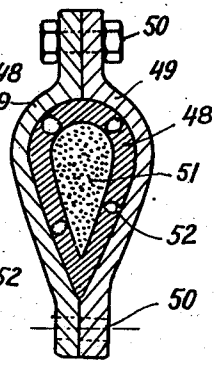


Fig. 16

Fig. 17

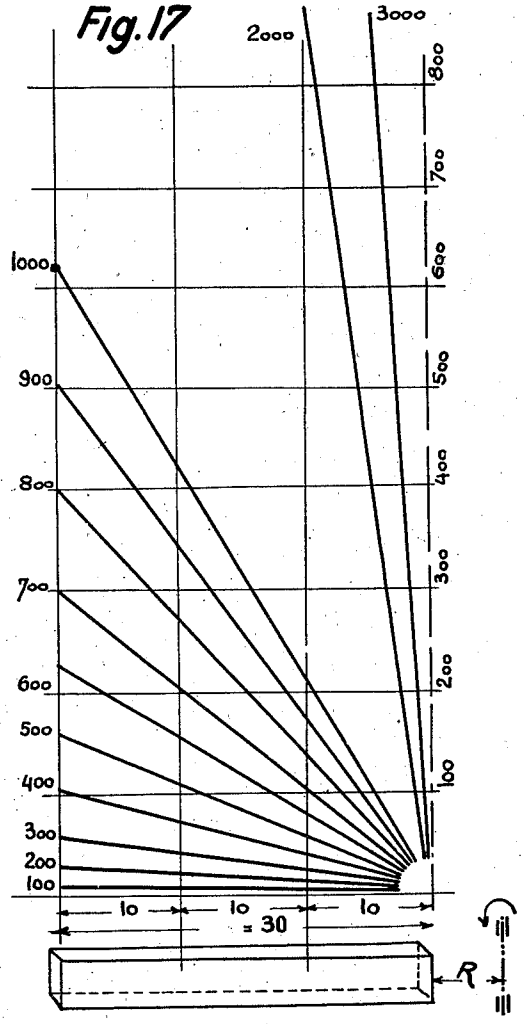


Fig. 13

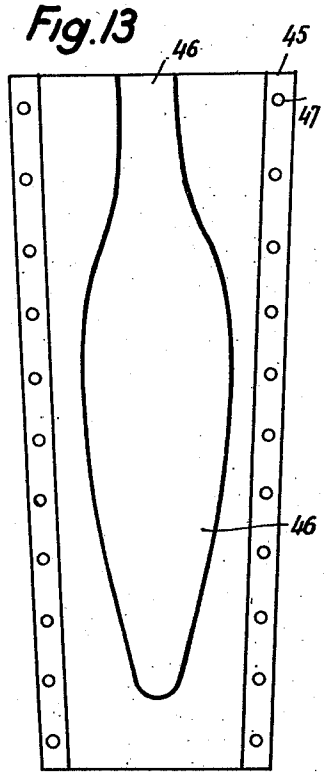
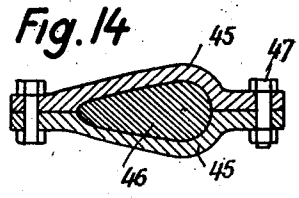


Fig. 14



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METHOD OF TREATING MELTED MATTERS

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Fig. 18

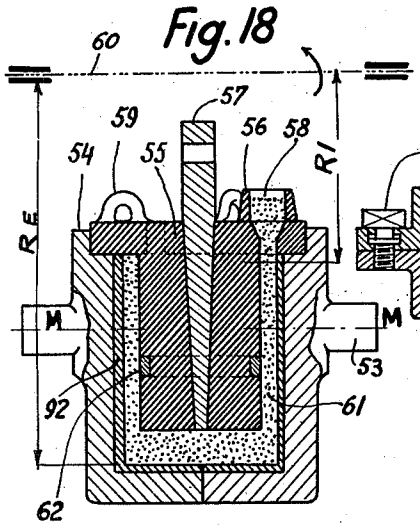


Fig. 21

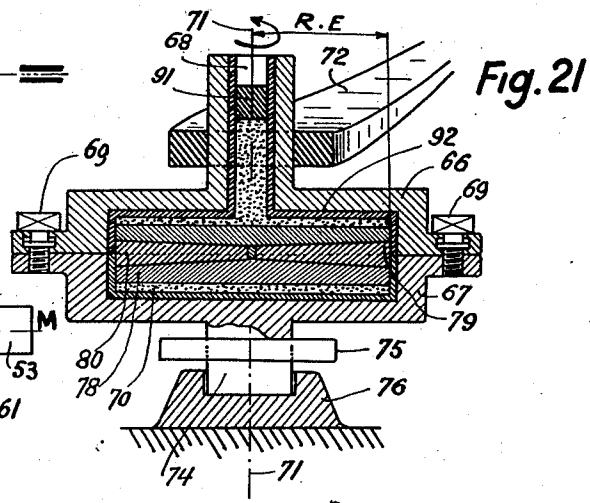


Fig. 19

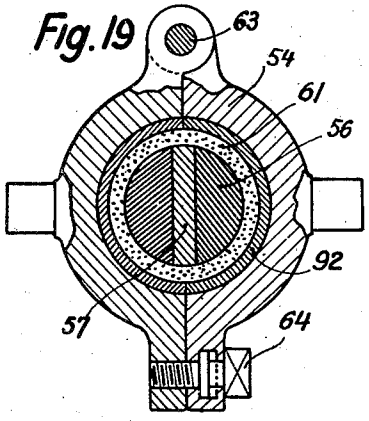


Fig. 22

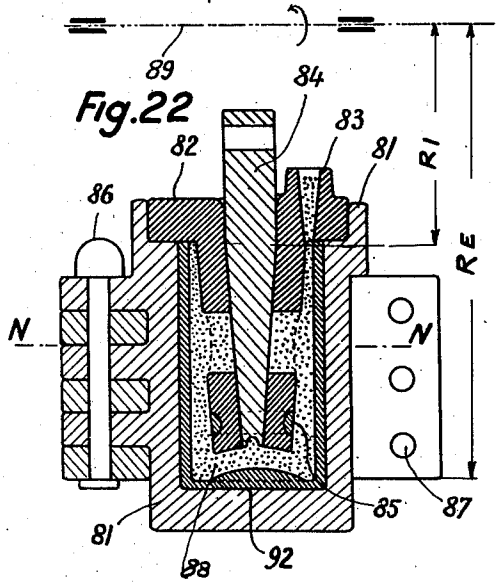


Fig. 20

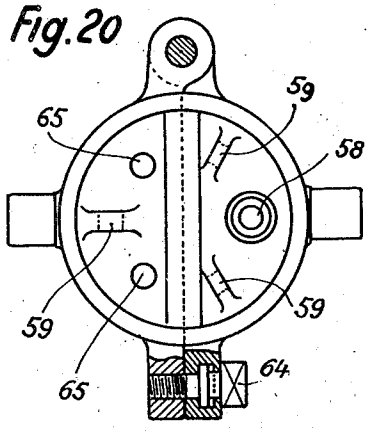
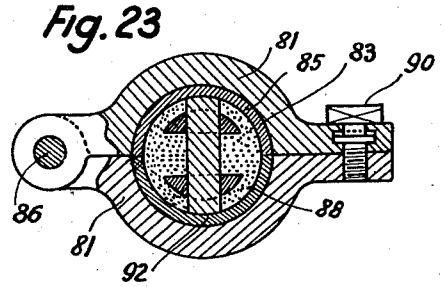


Fig. 23



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Patented July 16, 1940 2,208,230

UNITED STATES PATENT OFFICE

2,208,230

METHOD OF TREATING MELTED MATTERS

George A. Rubissow, New York, N. Y.

Application August 31, 1938, Serial No. 228,952
In Great Britain December 3, 1936

8 Claims. (Cl. 18—58)

The present invention relates to the production of solid bodies and materials, which are solid at room temperature and fusible (melt) under the influence of heat. It is more especially, although not exclusively, concerned with the treatment of metals and metallic alloys, but it applies also to the treatment of glass, stone, condensation products and the like.

It has already been suggested to subject such substances, when in the molten state, to a centrifugal treatment. But the results obtained by these methods were far from satisfactory, although advantages were obtained, especially as regards the filling of moulds and the elimination of bubbles.

The principle of mounting an electric furnace for die casting on an arm extending at right angles from a vertical shaft rotated by a motor is already known. Another principle which is known involves the moulding of hollow articles of concrete (not in molten condition) by rotating a mould about its longitudinal axis at a peripheral speed of from 1200 to 2500 or even more feet per minute for from 2 to 15 minutes. A third known principle involves the manufacture of hollow shapes from solutions of phenol and formaldehyde (not under the influence of heat) by rotating the mould about its longitudinal axis at a speed of 2000 to 3000 revolutions per minute.

The object of the present invention is to provide a novel method for producing materials which have better structural properties than it has been possible to give them up to now for a given composition.

In the accompanying drawings:

Figure 1 represents a side view partly in cross section of one of the apparatuses used for the application of the method.

Figure 2 is a top plan view partly in horizontal section of Figure 1.

Figures 3, 4, 5, 6, 7 and 8 represent side cross sectional views of the container in which molds with the material to be treated are placed.

Figure 9 is a cross sectional view of a mould for the manufacture of crank shafts.

Figure 10 is a cross sectional view of an apparatus—lever and container—for producing precious stones.

Figure 11 is a top plan view partly in cross section of a container for producing optical lenses.

Figure 12 is a side cross sectional view of Figure 11.

Figure 13 is a plan view of half of a propeller mold.

Figure 14 is a cross section of Figure 13.

Figure 15 is a plan view of a broken-out part of the mold and of the whole propeller.

Figure 16 is a cross sectional view of Figure 15.

Figure 17 is a schematical diagram of P_{icf} in relation to the revolution.

Figure 18 is a side cross sectional view of a container and mold for manufacturing cylinders.

Figure 19 is a cross sectional plan view of Figure 18.

Figure 20 is a top plan view of Figure 18.

Figure 21 is a cross sectional plan view of a container and mold for twin cylinders in line.

Figure 22 is a cross sectional view of a container and mold including a mold for manufacturing pistons.

Figure 23 is a cross sectional view of Figure 22.

The present invention relates to a method of treating and manufacturing solid fusible materials of the character referred to by subjecting them to the influence of centrifugal force, and this method is characterised by the fact that the material, which has been melted in any suitable manner, is subjected whilst in the molten state to the influence of centrifugal force by rotating the crucible, mould or the like in which the material is contained, about an axis which is substantially at right angles to the longitudinal axis of the mould or the like during its rotation, the material being subjected to the influence of centrifugal force for a period of time equal to at least five seconds for a radial thickness of 1 cm. of the material under treatment, to be increased substantially in proportion of the radial thickness, the centrifugal force being capable of creating in the interior of the material at a distance of 1 cm. from the inner surface thereof, a pressure which is not less than one-fourth the specific gravity of the material in kg./cm.^{2}. The material then continues to be subjected without interruption to the influence of centrifugal force until it at least commences to solidify, that is to say, just have acquired the plastic condition.

Advantageously, according to my invention, the centrifugal treatment is continued during the whole or a part of the solidification of the molten mass of material treated, and even after the end of said solidification, reaching the normal room temperature for additional cooling and ageing purposes.

According to my invention, the centrifugal treatment may be continued for the whole of the

solidification period, including the cooling period, down to the room temperature, or only a part of these solidification and cooling periods, for instance, only until the matter has cooled down from its molten state to red hot temperature (first case), or until it has grown cold enough (second case), or until it has grown quite cold, reaching room temperature (third case), the matter being in the first case (red hot temperature) either allowed to further cool down in its usual manner (without the centrifugal treatment), or immediately subjected to a mechanical treatment, and in the second or third cases—used as it is, or annealed in a known way before being subjected to a mechanical treatment. According to still another feature of the present invention, the matter subjected to the centrifugal treatment is, during the whole or a part of the time of solidification thereof, subjected to the action of vibrations.

Preferably, according to my invention, the melted matter is treated in a suitable mould, or the like, having as a rule a longitudinal axis of symmetry and the axis of revolution about which the centrifugal treatment is effected is at right angles to said axis of symmetry or makes a substantial angle therewith.

In some cases, according to my invention, I modify this angle during the treatment.

Other features of the present invention will result from the following detailed description and examples thereof.

A method of centrifugal treatment using a crucible, mould or the like, which is carried at the end of an arm keyed radially to a shaft driven directly or indirectly by a suitable motor; the arm may be balanced by a counterweight. Instead of arranging a single arm on the shaft a number of such arms may be provided and a crucible or the like carried at the end of each arm, in which case the various crucibles counterbalance one another so that counterweights are unnecessary. Instead of arranging crucibles or the like at the end of arms, a number of arms may form spokes which are connected together at their outer ends by a frame in the form of a rim, on which there are mounted, preferably at equally spaced distances, a number of crucibles and the like. The arm or arms may be of any suitable length.

Whilst it is preferred to arrange the arm or other rotary member in a horizontal position, it will be understood that this arm may be arranged to rotate in a vertical plane or in a plane arranged at any suitable angle to the horizontal.

Preferably the shaft is arranged vertically and the crucibles or the like are pivotally suspended with their filling openings at the top, the arrangement being such that the center of gravity of the crucible with its charge will be below the pivotal axis. As a result of the rotation of the shaft, the crucibles or the like will gradually move from a vertical into a horizontal position as the speed of the shaft increases, and as a result of this rotation, the molten charge in the crucibles or the like is subjected to the ICF, influence of the centrifugal force, whereby the charge in the crucible or the like is compressed and formed into a compact mass.

It will sometimes be advisable that a pivoted casing be attached to the outer end of the arm, into which casing all containers with the molten mass, such as crucibles, or the like are placed and submitted to the ICF.

Heating of the solids, under treatment, if required, may be effected by any suitable means, preferably electrically or by gas burners.

In the case of electrical heating the resistance wires may be arranged in the wall of the crucible or the like and connected by wires passing along the arms to slip rings provided on the shaft. Another method of electric heating may consist in connecting one of the wires to the molten mass, when this is an electrical conductor, whilst the other wire projects from the bottom or other suitable point of the crucible into the molten mass.

In the case of heating by gas burners, these are arranged inside or outside the crucible or the like.

The cooling of solid under treatment may be effected by removing all the heat in an accelerated, normal or slowed-down manner, and may be realized if necessary by application of suitable cooling media.

Another method of centrifugal treatment involves a loading member which may be placed, if desired, on the molten solid thus assisting the centrifugal force in compacting the solid under treatment. This loading member, which is preferably of lower specific weight than the solid under treatment, will be a solid, which has a higher melting point than the temperature used during treatment, and be made of metal, stone, or ceramic material or a combination of both. The loading member may, in certain cases, be fitted into the crucible or the like loosely, so that a space is formed between it and the inner wall of the crucible or the like, so as to allow a small quantity of the solid under treatment to pass through the space in question. The material passing through the space constitutes waste, but in spite of this the waste which occurs with this method is considerably lower than that which occurs with ordinary casting processes.

It is observed that whilst in connection with ordinary casting considerable waste occurs at both ends, the waste which occurs by the present method will be practically nil at the outer end and almost negligible at the inner end.

Another method of centrifugal treatment consists in having, if desired, the crucible or mould or the like closed at the inner end (nearest to the axis of rotation) in which case one or more pouring gates may be provided at this end; the gate or gates extend a sufficient distance upwardly so that they and the crucible or the like will be filled completely with molten material when subjected to the ICF. By the provision of the pouring gates the head of molten material in the crucible or the like is increased so that when the crucible is rotated the surface of material adjacent to the inner end of the crucible is also subjected to compression or pressure by centrifugal force. It will thus be seen that the longer the pouring gate or gates, the greater will be the weight of the head and consequently the greater the effect of centrifugal force.

The receiver or the like may be of any suitable cross-section according to the shape of the article to be produced.

The attached drawings show, by way of example, some of the various diagrammatical embodiments of this method and the devices to which this method can be applied.

Fig. 1 is an elevational view of an apparatus for carrying out the method, according to this invention, showing the shaft 1 rotated by means of a wheel 28; attached to the said shaft, an arm 2 on the end of which the pivoted axle 4 is fixed,

and on which a casing or crucible 3 is pivotally mounted, and the counterweight 30 is placed in the container 29.

Fig. 2 is a top plane view of Fig. 1, partly in horizontal section.

Figs. 3 and 4 are vertical views of a casing 6 pivoting on the axle 4 which is part of the arm 2 and a crucible 5 in which the molten solid 7 is placed. The crucibles 5 are of different shapes and filled with different melted material 7. Between the casing and the crucible there are insulating layers or walls 8 preventing rapid transmission of heat.

Fig. 5 is a cross section of a container 6 attached to the arm 2 in which the molten solid 7 is poured, and an additional weight 9 is placed on top to increase the ICF. 8 is the insulating material. The insulating material may be at the same time a means which will facilitate the removal of the already cooled solid, for which purpose it may be crushable.

Fig. 6 is a vertical section view of another form of the casing for carrying out this invention, in which a crucible or a mould 5 is put.

Fig. 7 is an elevational view, partly in vertical section of a casing 6 containing another crucible or container 55, with insulating walls 8, the container 5 being provided with heating electrodes 10 and 11.

Fig. 8 is a radial section of a container provided with the pouring gate 15 through which the molten solid 7 is poured into the mould including the pouring gate 15, and which latter material is indicated by 13 and may be considered as waste. 14 are the bolts, or other means, which hold the two parts of the container together. This container may then be put into another casing to be submitted to the ICF.

Fig. 9 is a casing or a mould 16 for production of crank shafts 17 having a pouring gate, and the material contained in the pouring gate is 13. Between the mould and the crank shaft may be introduced an insulating and/or crushable layer 8. This layer is shown partly only.

Fig. 10 is an apparatus especially intended for production of precious stones. 23 is the casing pivotally attached at the rotating arm 2. 8 is the first inner insulating case; 24 is the second inner insulating case; 32 is the precious stone. 33 is the negative pole of the electric current placed below the precious stone 32 and 34 is the positive electric pole placed at the top of the precious stone 32, and which during the rotation moves and presses under the influence of ICF against the molten stone 32. 35 is the additional weight on the positive pole 34 to increase the pressure. 18 and 19 are the arrangements for conducting the positive and negative currents whilst the shaft 1 is rotated.

Figs. 11 and 12 represent special rotating cases 26 for manufacturing in bulk optical lenses or any other glasses. This case 26 is rotated by means of the shaft 1. The molten glass 36 or the like is introduced when the casing 26 is at standstill and when rotated is poured automatically into the forms or moulds 27 which are cut out in the container 26. These moulds may be, if necessary, lined by special insulating material or metal 31. 31 may also be a separate inner mould to be put into each of the moulds of the container. 31 may be made of any substance which will facilitate the removal of the glasses.

Fig. 13 is a plan view of a two-parts mould 45 for making solid propellers 46. The two parts 45 are attached to each other by means of screws, or any other means 47.

Fig. 14 is a cross section view, corresponding to Fig. 13, of a mould 49 for making hollow propellers 48. The two parts of the mould 49 are attached to each other by any connecting means 50. In the mould is introduced a core 51 which must correspond to the inside hollow of the propeller and which may be made of such material that it may be taken out after the propeller is cast. 52 are the chaplets to keep the core 51 in the right position relative to the moulds 49.

Fig. 15 is a fragmentary view of a mold element for the manufacture of a propeller blade according to the present invention.

Fig. 16 is a cross sectional view corresponding to Fig. 15.

Fig. 17 represents by way of example a diagram, in which P_{icf}, the pressure created by ICF, is expressed in kilograms per square centimeter. R (the radius of the rotation, or the distance between the nearest surface of the treated solid and the axis of rotation) is regarded as constant and is equal to 220 cm. H is the length of the solid and in the example, is assumed to be equal to 30 cm. G is the specific density of the treated material, which in the example is assumed to be 7.5 (the approximate density of ordinary cast steel). The axis P_{icf} shows the pressures in kg./cm.^{2}, from 100 to 800. The lines marked 100 REV, 200 REV, 300 REV, 400 REV, 500 REV, 600 REV, 700 REV, 800 REV, 900 REV, 1000 REV, 2000 REV, and 3000 REV, represent the revolutions per minute of the treated solid. It is easily seen from the diagram that, for instance, at 1000 REV the treated solid 7—at the point farthest away from the axis of rotation—is compressed with 630 kg./cm.^{2}; at 10 cm. lower—420 kg.; at 20 cm. lower—210 kg. This is given only by way of example and approximately.

Fig. 18 is a diagrammatic radial sectional view of a pivotable mould for manufacturing of cylinders, pistons, and the like.

Fig. 19 is a horizontal sectional view of Fig. 18, taken on the line MM.

Fig. 20 is a top plan view of the Fig. 18.

Fig. 21 is a vertical section of a rotatable container including a mould for manufacturing twin-cylinders in line, adapted to undergo a centrifugal treatment about its own axis.

Fig. 22 is a vertical section of a container including a mould for manufacturing of pistons.

Fig. 23 is a horizontal section on the line NN of Fig. 22.

It is known that by centrifugal casting, better tubes are obtained than by the ordinary method.

It is well known that cylinders and pistons very soon become oval by wear—after which time the compression becomes defective, oil consumption too high and so forth. The general average engine for automobiles, motorcycles, boats, and so forth, has cylinders with a diameter from 2 to 7 inches. For this particular reason, manufacturers of tubes and/or cylinders by the usual centrifugal process cannot successfully apply their centrifugal method to the best advantage. For instance, to manufacture a cylinder of 4" diameter, it would be necessary to rotate the mould, containing the molten mass, about its own longitudinal axis at very high REV, for producing a pressure. For this reason, when such a cylinder is rotated around its own axis, the inner surface of the cylinder which is nearest to the axis of rotation (R_{int}) has no pressure applied thereto by the ICF, and only the exterior

surface has the maximum pressure applied thereto. Hence it is easily seen that such a method produces an improvement of the material, but at the wrong place, as the working surface of a cylinder is the inner one, and not the outer one. It may also be pointed out that as the wall thickness is generally about ¼ to 1 inch it is practically impossible to obtain considerable pressures even on the outer surface.

Just the contrary is offered by this invention. For producing the cylinder the molten material is placed in a mould having the shape of the required cylinder. For this purpose there is used a main cylinder mould (*m-c* mould), the inner diameter of which *m-c* mould is equal to the outer diameter of the cylinder to be obtained. Into the *m-c* mould there is then placed a core, the outer diameter of which is equal to the inner diameter of the cylinder to be obtained, the core being spaced from the bottom of the mould. When the *m-c* mould, containing the core, has been filled with the molten material, this *m-c* mould is placed in a receiver, with its closed bottom end on the bottom of the receiver. This receiver is pivotally attached to an arm, which arm is attached radially to a rotary shaft.

According to the present invention the mould is not rotated around its own axis, but around an axis which is substantially at right angles to the longitudinal axis of the *m-c* mould, at the required radius of rotation (R exterior) and preferably the axle of rotation should be exterior to the mold or at least exterior to the inner surface of the mold, i. e. exterior to the material to be treated therein. By this means, it is easy to apply any required ICF and any required pressure P_{icf}.

Observing now the result obtained in manufacturing the cylinder as described, according to this invention, it may be remarked that the cylinder so obtained will, at any point thereof, have the same pressure (P_{icf}) applied on its inner and outer surfaces. This pressure will increase up to the maximum, at the bottom of the *m-c* mould, which bottom is the cylinder head, treated at the exterior radius (R_{ext}) relatively to the axis of rotation. These pressures diminish proportionally and became equal to zero at the top of the *m-c* mould treated at the inner radius of rotation (R_{int}).

When such cylinder after machining and polishing is to be put in an engine, it must be so placed that its head (R_{ext}, P_{icf} max.) will be the compression chamber.

The same method is aplied when manufacturing any other tubular member.

According to this invention, the manufacture of cylinders, pistons, layers and the like, may be carried out in any suitable container.

The said mould or the like may itself be directly attachable pivotally on the arm fixed on the rotary shaft, provided that it is capable of resisting. Otherwise, the said mould is placed on the bottom of a receiver, and the receiver rotated as above described. A number of moulds or containers or the like may be placed in the same receiver.

In the Figures 18, 19, 20, I have shown a special receiver mould which consists of **53** a pivoting axis, of **54** the container or mould; **55** and **56** are the core segments between which the segment **57** is introduced, so that it can easily be removed after treatment. To the segments core **55** and **56** loops are attached. **58** is a pouring gate. **60** is the axis of rotation around which the entire mould is rotated. R_{int} and R_{ext} are the distances from the axis of rotation to the material which is to be treated. The material to be treated is **61** which has the form of a cylinder. **62** is a link which keeps together the three parts of the core **55**, **56**, **57**. **92** is the insulating material—sand, etc. **65** are the openings for allowing the outlet of the gases and air having the same height as **58**, but their upper parts are not shown. **63** are the articulations which permit the two parts of the mould to be separated. **64** is a screw to clamp the two parts of the receiver-mould together.

In the Figure 21 **66** is the upper part of the container or mould and **67** is the lower part of the container, both parts being lined with insulating material **92**. **68** is a pouring gate going co-axial with the axis of rotation. **69** are the screws for attaching the two parts of the mould together. **70** is a twin-cylinder in line to be obtained. **71** is the axis of rotation of the said receiver. **72** is a bearing of the upper part of the receiver. **73** is the upper part of **66** forming at the same time an axle. **74** is a lower part of **67** forming an axle, on which the wheel **75** is mounted to be connected with the motor force. **76** is the bearing in which **74** turns. **77** and **78** are the core segments between which two intermediate segments of the core **79** and **80** are introduced. **91** is an additional weight for increasing the pressure in the pouring gate.

In Figures 22 and 23 an arrangement to illustrate the application of this method is specially adapted for making pistons, where **81** is the mould consisting of two similar parts, **82** and **83** are core segments and **84** is the intermediate core between **82** and **83**. **85** is the ring for keeping together the three cores. **86** is the articulation element. **87** are the holes for the screws or some other means to keep the two parts together. **88** is the cast piston. **89** is the axis of rotation around which the whole mould moves.

This invention is also applicable to the casting of guns having parallel thickness or such which are reduced in wall thickness from the breech to the muzzle, or vice-versa. For casting such a gun, the breach of it is farthest removed from the axis of rotation.

The invention is also applicable for casting propellers or propeller blades, specially for aircraft and marine use, as the propeller or propeller blades may be cast under the same action of centrifugal force under which they will be used, that is to say, the propeller or propeller blades, during casting, is rotated at the average speed at which, approximately, it may rotate when in use (or a number of times that speed) for resonance purposes. In this manner, the fibres of the structure are caused to be directed in the required direction for withstanding the stresses to which the blades will be subjected when in use.

A propeller may be cast completely as a unit of two or more blades and a boss, or separate blades may be cast, or each blade cast in two or more portions which are subsequently welded or assembled by any known means (bolts, screws, etc.).

In the casting of a complete propeller, the boss is located at the middle and the mould rotated around the boss. Suitable cores are provided for making hollow blades.

For casting a blade in two separate portions, there is formed a casting of one half of a hollow blade, the division being taken along a plane

passing through the leading and trailing edges of the blade.

In casting blades or two separate portions for forming the blades, it will be understood that the tip of the blade must be at the point farthest from the axis of rotation (or vice-versa if the thickness of the blade is anti-proportional to the efforts) so that the blades or blade portions are cast under substantially the same conditions as those in which they will be used, and consequently will be exposed substantially to the same vibrations or stresses or in resonance to them.

Another application of the present invention is in the manufacture of precious stones, semi-precious stones, and the like.

When the chemical composition of such stones is known, the necessary substance can be provided; when the chemical composition is not known, or difficult to provide—waste or cheap qualities or dust, etc., of such stones is used.

New stones will be created, having the same characteristics and are most effectively compacted internally, without any irregularities, bubbles, vacuum, without any flaws, etc.

For this purpose, an electric furnace, which is itself a crucible, or includes a crucible, is used. There will now be described my way of example a method of producing precious stones.

The stone, for instance sapphire, etc., in the form of dust, or of small stones, or of a chemical composition, is placed in a crucible, made from a material which only melts at a temperature higher than the highest temperature used during treatment. This crucible may be enclosed in at least one receiver of heat insulating material, such as asbestos, fireproof stone, magnesia, charbon or mixtures of these materials. The receiver is then placed into a very strong container, preferably of steel having high resistance, and this container is submitted to rotation after its contents have been melted.

The inner dimension of the crucible itself may be, for instance, 20 millimeters high and 10 millimeters internal diameter, if it is desired to obtain a stone 10 millimeters in diameter and about the same height. Generally the crucible is at least twice as high as its internal diameter, as this is necessary when using the material contained in the crucible as the weight producing pressure.

The heat is produced by means of two electrodes, one of which may be, for instance, introduced through the upper part of the crucible and having more or less the same dimension, if desirable, as the diameter of the crucible. This electrode may even touch the material to be melted, or it may be provided with a spring arrangement to press it against the material, or it may be fixed, or it may be pressed against the material by the ICF. The other electrode is connected with the lower part of the crucible.

The cooling under the ICF of precious stones and some types of glass, must sometimes extend over many hours and even days.

Another application of my invention is in the manufacture of different glasses and particularly optical glasses for microscopes, telescopes, cameras, mirrors, prisms, etc., etc. It is known that in this industry considerable difficulties are met with in eliminating from the molten mass of glass substances or the like, the so-called glass bubbles, often microscopically small, caused by gas, air or impurities, etc., and also in eliminating all other irregularities. This invention eliminates all irregularities and enables perfect material to be obtained; furthermore, the materials (glass, quartz, or the like) may change their reflecting qualities.

The optical material, treated according to this invention may be cut and polished parallel or at a right angle or at any suitable angle in respect to the radius of rotation when the material was under treatment. By this means, the molecules or crystals which have been placed in good order under the ICF, are caused to reflect or transmit beams of light in an entirely new manner, and, therefore, if they are polished at a certain angle to their radius of rotation, they may offer the said polarisation effect as well as new reflecting characteristics.

In the case of water cooling, the water is supplied continuously through an appropriate device near, or around, the shaft and then forced through tubes or the like to the parts of the furnace, mould, receiver, or the like, to be cooled; and after passing the surfaces to be cooled, the water is then conducted to an outlet and rejected by the ICF. The efficiency of the circulation of water (which also means efficiency in cooling) may be controlled either by the cross-sections of the inlet and outlet, or the pressure in the supply pipe, or by the outlet being placed nearer or farther from the axis of rotation; the nearer it is placed to the axis of rotation, the slower will be the circulation of water.

The said appropriate device for connecting the rotating tubes or the like to the stationary supply pipe, may consist of a disc which is rigid and having a circular channel to which the water supply pipe is connected, and a second disc, which is fixed to the shaft and connected with the circulation tube or the like; the surface of the discs touching tightly and the circular channels covering each other substantially. A similar device may be provided at the water outlet.

An example will now be given to illustrate the variations of REV (speed of rotation), time and temperature which are possible when treating a solid under the ICF according to this method:

Assuming—

A=Treatment of the material under the ICF whilst in molten state

B=Treatment of the material whilst in molten state, without the ICF

AB=Treatment of the material whilst in molten state, partly with the ICF and partly without

C=Solidification including cooling down to room temperature, under the ICF

D=Solidification including cooling down to room temperature, without the ICF

CD=Solidification including cooling down to room temperature, partly with the ICF and partly without

E=Ageing of the material (after cooling) under the ICF, and

t=The temperature of the material under treatment (t1500° being a temperature of 1500° centigrade)

T=The time during which the ICF is applied (T17=17 seconds)

REV=The number of revolutions per minute (REV 0=0 revolutions=a rest, whilst

REV 100/2000 means from 100 revolutions up to 2000 revolutions per minute, and REV 100/2000 T17 means that the number of revolutions will be increased within 17 seconds, from 100 revolutions

up to 2000 revolutions)—Now, by way of example—

A—REV 1000.*t*1430°.T5.REV 0.T120.*t*1430°;
C—REV 1200.*t*1430/1200°.T600;
C—REV 1200/2050.*t*1200/20°.T700;
E—REV 2050.T7000.*t*20.

this will mean that the material is under ICF in molten state at 1000 revolutions per minute, at a temperature of 1430°, during 5 seconds; followed by a rest of 120 seconds at the same temperature (1430°); then cooled from 1430° down to 1200° under the ICF at 1200 revolutions per minute, which speed is then increased to 2050 and at the same time the temperature is decreased progressively from 1200° to 20°, within a time of 700 seconds; finally aged during 7000 seconds at 2050 revolutions per minute at 20°.

The foregoing is only one example, and all reasonable variations are within the present invention.

Another aspect of this invention is to carry out the rotation partly in one direction, and partly in the reverse direction ($\overline{REV}$) and ($\overline{REV}$).

According to another aspect of this invention, mechanical vibrations V may be applied to the solid under treatment, either by applying V to the shaft supporting the arm, to the arm supporting the crucible, or the crucible itself (or by the furnace, mould or the like), so that when such a device is rotating, it receives periodically or otherwise, one or more shocks or vibrations, or other kind of irregular movement.

Another aspect of this invention is the submitting of the solid at the same time to the influence of two different simultaneously applied ICF. One ICF is applied in one plane (e. g. horizontal) and the second ICF is applied in another plane (e. g. vertical), the two forces preferably being directed substantially perpendicularly to each other.

The application of two simultaneously applied centrifugal forces, as described, in two different directions, may be understood by the following: Imagine that a big cube is submitted to ICF, on the one side (a side approximately perpendicular to the radius of rotation) of which a man is hanging by his hands and his feet are hanging down along the side surface of the cube, and the centrifugal forces draw him towards the bottom of the cube. If the man has sufficient force, he can remain taut, continuing to hang. The same is true in regard to the solid treated under ICF, if instead of a man, we imagine a crystal or molecule or the like of the said material. Now imagine that our man hanging on the cube is at the same time not only drawn towards the bottom of this cube, but also another force will push his hands and his body sideways or horizontally or perpendicularly to the direction. Then our man could no longer maintain his position, but would occupy the place in which he will be able to remain resisting both of the said forces. In the example of the solid, the same will happen when the crystals, molecules, and the like, will under the simultaneous application of $(P_{icf})_b$ and $(P_{icf})_c$ occupy such a place where further compacting or compressing is no longer possible, under the given conditions.

This example shows that this method of application of two centrifugal forces simultaneously applied, is not only an invention which can be used for the particular application as described before, but also could be applied for many other chemical and medical applications.

Of course, it is also possible to apply centrifugal forces on three different planes.

The method of treating solids under the ICF produces a pressure inside the structure of the solid itself, and this pressure which has been applied while the solid was in a molten state or during solidification, is after the material has become solid, kept in the form of a potential or dormant pressure (which will be called ZW), and the greater the pressure that has been applied by the ICF, and the longer its application, the greater will be the potential or dormant pressure retained within the solid after solidification.

For the convenience of the further description of this invention, the following abbreviations will be used:

P_{icf} —Pressure created by the action of ICF (when its amount is indicated in this specification, it is measured in kg./cm.^{2}, at a distance equal to $(R+1)$ cm. If the radial thickness of the material h is greater than 1 cm., there exists really a surface at a distance of $(R+1)$ cm.; if h is smaller than 1 cm., the pressure will still be measured at the same distance, but on an imaginary surface.

T —Time of action of the ICF, in seconds.

$t°$ —Temperature of the material under treatment.

Q_{tm} —Number of calories supplied and/or lost for the maintenance of the material under the ICF in molten state and until solidification begins.

T_m —Time during which Q_{tm} is supplied and/or lost.

Q_{ts} —Number of calories which are lost by the material whilst it becomes solid and reaches the temperature of 20°±20° C. (room temperature).

T_s —Time during which Q_{ts} is lost by the material under treatment, under the ICF.

T_a —Time of ageing under the ICF.

R —Radius measured from the axis of rotation to the inner surface of the treated material, the inner surface being the surface nearest to the axis of rotation.

$(R+1)$ cm. —Radius measured from the axis of rotation to an imaginary surface located 1 cm. below the inner surface of the material.

pid —A pressure P_{icf} applied during a certain time. Therefore, *pid* is measured in

$$\frac{\text{kg. sec.}}{\text{cm.}^2}$$

pid_m —The amount of *pid* during T_m only while the material is molten.

pid_s —The amount of *pid* during solidifying T_s only.

pid_a —The amount of *pid* during ageing (time T_a).

ZW —The energy which is incorporated in the treated material in a form of a potentially kept quantity of *pid*.

ZW_m —A potentially incorporated quantity of *pid* during a period of time T_m.

ZW_s —A potentially incorporated quantity of *pid* during a period of time T_s, following after the material has been provided with ZW_m and until complete solidification of the material is reached (period of time T_s).

$\frac{ZW_s}{x}$ —An x part of ZW_s $\left(\text{period of time } \frac{T_s}{x}\right)$.

$\frac{T_m}{x}$ —An x part of the T_m.

$\frac{T_s}{x}$ —An x part of the T_s.

$\frac{Pid_s}{x}$ —An x part of the Pid_s.

$T_{s.y}$ or $Pid_{s.y}$—An y times of the T_s or the Pid_s.

When making use of containers pivoted on the rotating arm or the like, and when using different speeds of rotation, it is clear that each speed will move the container or the like into the angular position corresponding to the particular speed of rotation, that is in the direction of the resultant force-line. The centifugal forces, which have a definite direction, i. e. perpendicular to the axis of rotation, remain in this direction when the speed of revolution is modified, so that the molten material changing its direction on account of the charge of the speed of rotation, will be submitted to the said action of the ICF under different attacking angles.

It is clear that when the solid is in a molten state (T_m) and during part of the solidification

$$\left(\frac{T_s}{x}\right)$$

the change of the attack angle may act as a micro-mixer of the smallest particles of the solid under treatment. The use of change of force-line direction by means of changing the speed (REV) is another aspect of this invention, as this too may serve to modify the characteristics of the solid under treatment.

However, the change of speed of rotation (REV) will be done only as long as it is required and the micro-mixer action, if intentionally done, must not be continued indefinitely, but must be stopped at an appropriate moment during solidification.

Instead of changing the attack angle of the centrifugal forces by means of changing the speed of rotation, the same result can be obtained by devices controlling the inclination of the mould or the like, with regard to the axis of rotation. For this purpose, very simple mechanical or electro-mechanical devices may be provided, or more complicated arrangements may be made for sliding or rolling the moulds or the like, on guideways or guide surfaces.

Such devices are also necessary when it is desired to treat the solid to straight horizontal force lines. As it is preferred that the shaft to which is keyed the arm carrying the pivoting mould or the like be vertical, it is clear that such mould or the like could not under any speed of rotation take a straight horizontal position, as its own gravity will act against the centrifugal forces.

In case the mould or the like is not able to attain the desirable position (with a view to the desirable attack angle of the centrifugal forces) at the speeds of revolution prescribed for the particular treatment, than an additional weight can be attached to the bottom part of the mould or the like excentrically to its axis; if such additional weight is placed farther from the axis of rotation, the attack angle will be reduced; if nearer to the axis of rotation, the attack angle will be increased, allowing even a position of 180°, i. e., perpendicular to the axis of rotation.

In case of voluntarily changing the attack angles, it becomes sometimes necessary to provide closing devices in order to prevent the material from pouring out as the mould changes its position. Such closing devices are preferably made in the form of a "stopper" made of a material the melting point of which is higher than the melting point of the solid under treatment. This stopper closes the top of the mould or the like, and, if necessary, may be pressed against the surface of the solid under treatment by any mechanical means, or by springs, counterweights, and the like. This stopper may be, at the same time, a "loading member" as described before.

Proceeding with the question of attack angles, it is sometimes important, for the purpose of obtaining hardness, high tensile stress, utmost polishing capacities and fine grain character, to maintain substantially the same speed of rotation (REV) during (T_s) as was applied during the last part of (T_m), such solidification (T_s) following directly after (T_m), so that the attacking angles of the centrifugal forces will not be changed before solidification of the solid under treatment. Very good results are so obtained, and this was not known until the present, because the change of the force-lines or centrifugal forces in relation to the particles (such as molecules) of the treated material has not been taken into consideration previously. Instead of (T_s),

$$\frac{T_s}{x}$$

only may be employed.

Another advantageous form of this method of treatment, according to this invention, is that the moulds or the like, when they are pivotally attached to the arm of a drum or any other rotary member, are so made that their axle of pivoting is placed as near as possible to their center of gravity when filled with the molten solid, which will then allow the torque of the force (provided by the weight of the mould plus molten solid) to be as small as possible, and, therefore, when such molds or the like are pivoted by the action of the ICF, the attacking angle of the centrifugal forces will change much less in degree. It is sufficient to have the geometrical axis of pivoting of such moulds or the like, only a few millimeters above their respective center of gravity. The said moulds or the like may be provided with means for adjusting the position of the center of gravity thereof.

As to the choice of B_{icf}, which action on the inner structure of the solid provides the characteristics as above described, it is necessary to use P_{icf} (measured at $(R+1)$ cm. as explained) not less than ¼ of j (the specific gravity of the solid under treatment). This invention prescribes P_{icf} not less than $\frac{1}{4}j$ kg./cm.^{2} because, with this amount of pressure the results begin to be extremely important.

P_{icf} may be anything beginning from the said minimum and going so far as mechanically and economically possible. By way of example, some material may be treated with P_{icf}=2 kg./cm.^{2} to 20 kg./ cm.^{2}; or between 20 and 100 kg./cm.^{2}; or between 100 and 1000 kg./cm.^{2}. Also by way of example, steel having a density of 7.6—P_{icf} minimum will be $=\frac{1}{4}j=1.9$ kg./cm.^{2}.

Time T_m must be between 5 and 25 seconds at least, and it is always preferable to increase it as much as economically and technically possible within certain limits as hereinafter set forth as each increase of time renders the structure of the solid more orderly, more compact, more compressed; e. g. it eliminates also the smallest bubbles, free spaces, unnecessary gases and so forth, which require a certain time to travel through the molten mass to the outside thereof, as they must do so under considerable pressure which is produced by the action of the ICF. T_m depends substantially upon the radial thickness and the shape of the body to be made.

This invention recommends increasing T_m and this must not be misunderstood because after a certain time T_m maximum it must not be continued, as otherwise unnecessary energy is lost. Certain materials, such as iron, steel, metal alloys generally, do not require T_m for radial thickness of about 10 cm. any longer than 180—300 seconds for providing the maximum phenomena in the inner conception of the so treated solid.

During the time T_m the temperature must be so maintained, by any known means, that the molten mass of solid is capable of remaining in the molten state.

In some cases, it is sufficient to overheat the molten material before submitting to T_m so that such over-heated material will contain the necessary amount of Q_{tm} calories, which amount of calories it will lose during the time T_m. This method may be very economical if moulds or the like are provided with insulating means, so that the Q_{tm} will be sufficient to maintain the material in a molten state during all the time T_m. Generally speaking, each solid may be overheated about ¼ of its melting point in degrees centigrade, provided that it is not decomposed (as may happen with certain alloys).

Overheating of the solid may be combined with heating of the crucible, mould or the like (e. g. electrically or by any gas burner), or not overheated material may be charged into such a heated mould, or crucible or the like. The heatable crucibles, moulds or the like may also be provided with insulating means.

Special care must be taken with moulds, according to this invention, when the bodies to be treated have different thicknesses in different parts. Where the thickness is wide, for instance greater than 2 cm., the material poured in will conserve its heat longer than where the thickness is only a few millimeters. Therefore moulds and the like, for this invention, must be provided if and where necessary with heating means—electrical or otherwise—and/or insulating means, for regulating and heating conditions (increasing or decreasing).

As regards the centrifugal casting of tubes and of other circular members, the existing industries have never provided the necessary time T_m or even part of it. When the material was splashed over the walls, the molten material when contacting the walls of such centrifugal circular mould, became immediately pasty-like, which prevented the effects of the ICF as per this invention. Even if the moulds had been previously heated, the heat was not sufficient for keeping the material in a molten state even during the minimum amount of T_m required as claimed in this invention.

In the glass industries for making, for instance, glasses, lenses, and the like, it is easy to keep T_m as long as desirable, because the melting point of glass is low as compared to the melting point of iron.

A predetermined period of time is required by each material to pass from the molten state to solidification, which period of time depends only on the atmosphere in which the cooling is carried out and the cooling or heating means, if any, applied for this purpose. Any cooling means such as air draught, air fans, or water cooling, or the like, may be used when applying this invention. For some solids, it may be desirable to make the containers, mould or the like, of a very good heat conductor in order to accelerate cooling.

In some cases, the material just from the moment when it begins to solidify, is solidified by ordinary cooling without the ICF ($T_s=0$). The material so treated acquires some new characteristics, as its structure has been put in perfect order and all its particles compressed and compacted by the ICF during T_m.

T_s if not zero, may be any period of time from, for instance, one second up to several hours and even several days. Different results are obtained when, instead of the whole of T_s, only a fraction thereof is employed for applying the ICF. For instance, when steel after T_m is treated under the ICF during

$$\frac{T_s}{x}=250 \text{ seconds}$$

and after this is solidified and cooled in the ordinary way without the ICF, then the material obtained is different from the same steel but treated during

$$\frac{T_s}{x}=2{,}000 \text{ seconds},$$

and this steel is different from another treated for the full time of T_s (for example 10,000 seconds are necessary to reach the room temperature) and different from another steel treated during an increased $T_s=(T_s \cdot y)=1.5T_s$ or $3T_s$ and so on.

Iron, for example, is molten at about 1,500° C., and has already partly solidified (has acquired plastic condition) at about 900° C., but at this temperature it is too soft and cannot retain the incorporated pressure imparted by the ICF. Therefore, even such materials as iron, steel, metal alloys, or the like, must for some purposes be solidified under the action of the centrifugal forces at least until reaching 40° C. and preferably the ordinary temperature (20° C. ± 20° C.), when they will be employed or further treated.

The choice of T_s is very delicate in the case of glass and precious stones manufacture, according to this invention; some stones require that immediately after T_m, the T_s will be small, and that the stone or glass is then cooled in the ordinary way and during a very long period of time. Others require that

$$\frac{T_s}{x}$$

will be stopped at about 200° C. and further cooling done in the ordinary way; others that

$$\frac{T_s}{x}$$

will be stopped at about the moment when the temperature will become so long that the material is solid but still less hard, as compared to its normal hardness.

When ageing under the ICF (T_a) is required to

be carried on after solidification (t=20° C. ± 20° C.) in order to increase some of the characteristics of the material, then this invention foresees that T_s is followed uninterruptedly by T_s and the ageing fulfilled during the necessary time under the ICF. This may be of great importance for aluminum and some types of steel and their alloys, which require a long ageing.

In order to give an idea of the importance of the main features, the following figures are stated as minima for the general treatment under the ICF of metals and metal alloys.

For a radial thickness h less than 1 cm., the time T_m must not be less than 5 seconds, and the P_{icf} (pressure measured at a distance (R+1) cm. from the axis of rotation) must not be less than ¼ (one fourth) of the specific density j in kg./cm.². The time T_s must not be less than 180 seconds.

For h between 2 cm. and 3 cm., T_m must not be less than 7 seconds, P_{icf} not less that ¼ j kg./cm.², and T_s not less than 300 to 600 seconds, proportionate to the thickness.

For h between 3 cm. and 4 cm. T_m must not be less than 10 seconds, P_{icf} not less than ¼ j kg./cm.², and T_s not less than 600 to 800 seconds proportionate to the thickness.

For h between 4 cm. and 5 cm., T_m must not be less than 12 seconds, P_{icf} not less than ¼ j kg./cm.², and T_s not less than 800 seconds.

For h between 5 cm. and 7 cm., T_m must not be less than 14 seconds, P_{icf} not less than ¼ j kg./cm.², and T_s not less than 900 seconds.

For h between 7 cm. and 10 cm., T_m must not be less than 14 seconds, P_{icf} not less than ¼ j kg./cm.², and T_s not less than 1,200 seconds.

For h between 10 cm. and 30 cm., T_m must not be less than 20 seconds, P_{icf} not less than ¼ j kg./cm.², and T_s not less than 1,200 to 2,400 seconds proportionate to the thickness.

For h between 30 cm. and 50 cm., T_m must not be less than 20 seconds, P_{icf} not less than ¼ j kg./cm.², and T_s not less than 2,400 seconds.

For h over 50 cm., T_m must not be less than 25 seconds, P_{icf} not less than ¼ j kg./cm.², and T_s not less than 2,400 secs.

Instead of T_s,

$$\frac{T_s}{x}$$

or $T_{s.y}$ may be employed.

When using

$$\frac{T_s}{x}$$

only, that is when the action of the ICF has ceased at a stage when the solid just begins to solidify or is in a pasty state or red-hot, and so forth, and the remainder of solidification carried out without the ICF, the material so obtained will offer new characteristics on account of its having been ordered and compacted by the ICF during T_m, and whilst it will not be able to retain the total amount of Pid, it will, however, not lose the homogeneous structure imparted by the ICF.

Many metals treated with an appropriate

$$\frac{T_s}{x}$$

will offer the required qualities of very high malleability, high elongation, better tensile stress, sometimes also better hardness.

$$\frac{T_s}{x}$$

is a very interesting feature especially for solids to be worked. The solidification may, in that case, be completed under ordinary conditions without the ICF and the material worked later on; or the material is immediately passed on to a rolling mill, or presses, for instance, where it will be worked with a facility unknown hitherto. In both cases the solid may finally be heat-treated and/or hardened in the ordinary ways.

For treating precious stones, sapphires, emeralds, etc., of about 1 cm. in diameter, the T_m may be very small—3 to 5 seconds, but the maximum pressures are recommended to be very high—P_{icf} substantially about 17 kg./cm.². If smaller pressure is used, then the T_m is recommended to be longer, with a view to obtaining the most homogeneous nature of the precious stone.

For different plastic materials the melting points of which are generally very low, T_m may be as short as the minima fixed for metals; P_{icf} also the same as for metals, and T_s established according to practice.

There is no doubt that a solid containing

$$pid_m = \frac{35 \text{ kg. sec.}}{\text{cm.}^2}$$

and

$$pid_s = \frac{355 \text{ kg. sec.}}{\text{cm.}^2}$$

will be different from a solid of the same chemical composition and containing

$$pid_m = \frac{35 \text{ kg. sec.}}{\text{cm.}^2}$$

and

$$pid_s = \frac{1{,}000 \text{ kg. sec.}}{\text{cm.}^2}$$

and also different from a solid of the same chemical composition and containing

$$pid_m = \frac{200 \text{ kg. sec.}}{\text{cm.}^2}$$

and

$$pid_s = \frac{200 \text{ kg. sec.}}{\text{cm}^2}$$

and so forth.

Another aspect of this invention consists in a method subjecting the material to the ICF under the regulation of the corresponding determinations of amounts of the Pid_m and Pid_s or

$$\frac{Pid_s}{x}$$

It has been explained that Pid_m and Pid_s are measured in

$$\frac{\text{kg. sec.}}{\text{cm.}^3}$$

and this at a distance of one centimeter below the inner surface of the treated material. In reality the P_{icf} is growing with the growing of the distance from the center of rotation.

P_{icf_2} at the distance of (R+2) cm. is bigger than P_{icf_1} at the distance of (R+1) cm., etc. Therefore Pid_{m_2} is bigger than Pid_{m_1}, measured accordingly at (R+2) cm. and at (R+1) cm. distance. For the convenience of the interpretation of this invention the general total of the Pid_m and of Pid_s or

$$\frac{Pid_s}{x}$$

incorporated during the T_m or respectively during the T_s or

$$\frac{T_s}{x}$$

in the whole mass of the treated material may be designed by the integral of Pid, i. e.,

$$\int Pid_m, \text{ or } \int Pid_s, \text{ or } \int \frac{Pid_s}{x}$$

In order to convert, after its manufacturing, i. e., after cooling down to a suitable or even room temperature, a non-homogeneous material may be easily converted, according to another aspect of this invention, into a homogeneous material (speaking in the said sense) and this can be done by reheating or annealing this material to a temperature at which the material does not lose its plastic condition and still keeps in totality or in part the better structural properties acquired during the previous treatment under the ICF.

Such reheating or annealing will transform the non-homogeneous material into a homogeneous one (speaking in the said sense) and this method is extremely important especially for the treatment of metals and metal alloys.

Although certain forms of the present invention have been described in the application by way of illustration, it will be understood that these are not intended to limit the invention either in respect of the method used or in respect of the solid materials and articles so treated or so obtained.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:

1. A method of treating and manufacturing solid fusible material of the character referred to by subjecting it to the influence of centrifugal force, which comprises subjecting a mold or the like containing the material in a molten state to the influence of centrifugal force by rotating the mold and the material contained therein about an axis exterior to the mold for a period of time during which the treated material is in molten state, which period is substantially equal to at least five seconds for the radial thickness of the first centimeter of the said material under treatment, plus at least for two seconds for each additional centimeter of radial thickness up to the point where the same thickness substantially reaches ten centimeters, and not taking in consideration any radial thickness in excess of ten centimeters, the centrifugal force being sufficiently great and which speed of rotation is sufficiently great to create in the interior of the material at the distance of one centimeter from the surface thereof nearest the axis of rotation, a pressure which is not less than one-fourth the specific gravity of the material expressed in kilogram-per-square-centimeter, and thereafter permitting the material in the mold to cool while continuing uninterruptedly the rotation of the mold and thereby continuing the influence of said centrifugal force on the material during the cooling thereof until said material has at least cooled sufficiently to be incapable of flowing.

2. A method of treating and manufacturing solid fusible material of the character referred to by subjecting it to the influence of centrifugal force, which comprises subjecting a mold or the like containing the material in a molten state to the influence of centrifugal force by rotating the mold and the material contained therein about an axis exterior to the mold for a period of time during which the treated material is in molten state, which period is substantially equal to at least five seconds for the radial thickness of the first centimeter of the said material under treatment, plus at least for two seconds for each additional centimeter of radial thickness up to the point where the same thickness substantially reaches ten centimeters, and not taking in consideration any radial thickness in excess of ten centimeters, the centrifugal force being sufficiently great and which speed of rotation is sufficiently great to create in the interior of the material at the distance of one centimeter from the surface thereof nearest the axis of rotation, a pressure which is not less than one-fourth the specific gravity of the material expressed in kilogram-per-square-centimeter, and thereafter permitting the material in the mold to cool while continuing uninterruptedly the rotation of the mold and thereby continuing the influence of said centrifugal force on the material during the cooling thereof until the material is cooled down to not less than the room temperature.

3. A method as set forth in claim 1, wherein the mold is rotated at a greater speed during the cooling of material than when treating the material in its molten state.

4. A process as set forth in claim 1, wherein the material treated is metal.

5. A process as set forth in claim 1, wherein the material treated is glass.

6. A method as set forth in claim 1, wherein the mold or the like or the material contained therein are subjected to successive shocks during the rotation thereof.

7. A process as set forth in claim 1, wherein the melted fusible material is heated to such a temperature prior to the beginning of the rotation of the mold that the material remains in the molten state during said period of time, without additional heating of the mold or the like or the material during the rotation thereof.

8. A process as set forth in claim 1, wherein the mold is rotated simultaneously about two different axes both of which are exterior of the mold.

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