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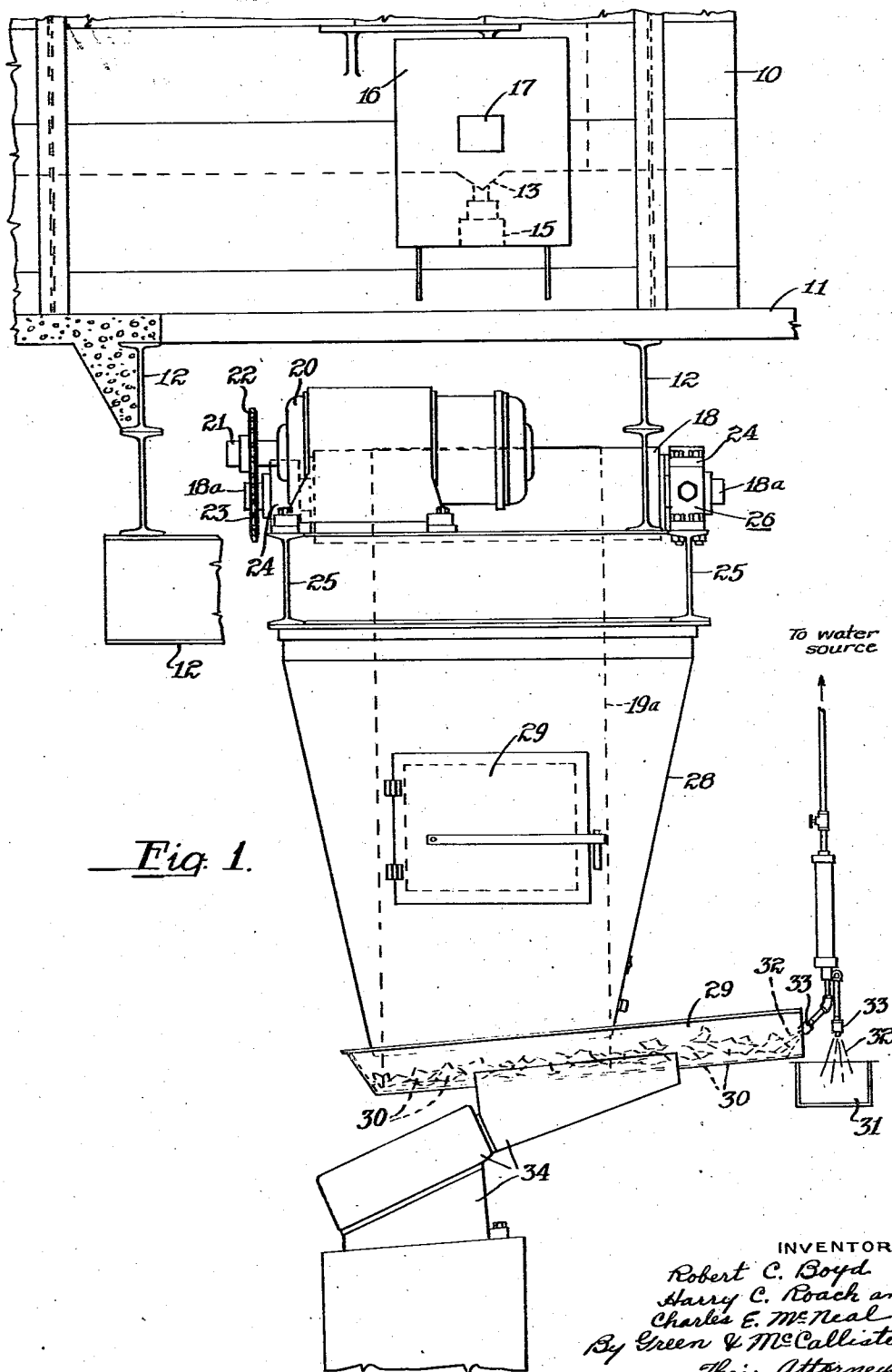
R. C. BOYD ET AL

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METHOD AND APPARATUS FOR PRODUCING VITREOUS ENAMEL

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UNITED STATES PATENT OFFICE

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METHOD AND APPARATUS FOR PRODUCING
VITREOUS ENAMEL

Robert C. Boyd, Harry C. Roach, and Charles E. McNeal, Louisville, Ky., assignors to American Radiator & Standard Sanitary Corporation, a corporation of Delaware

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7 Claims. (Cl. 83-91)

The present invention relates to the production of vitreous enamel directly from molten enamel but without the conventional quenching operations. The invention more particularly comprises procedure for producing such enamel and equipment by means of which the new procedure may be effectively carried out.

The important considerations which must be taken into account in the preparation of vitreous enamel from molten enamel and the conventional procedures therefor have been outlined in application Serial No. 254,424, filed February 3, 1939, of which this application is in part a continuation. In that application it was pointed out that the ordinary quenching procedure, although extensively practiced, has recognized disadvantages which could not be avoided by existing practices. In that application it was also pointed out that by following the procedure there set forth as constituting the invention of that application many, if not all, of the defects and disadvantages of prior practices could be eliminated and superior enamel produced at a very moderate cost. It has now been discovered that optimum results can be secured by following the additional practices described and claimed in the present application and that matters of control along with other special features still further improve the results.

It is, accordingly, one of the objects of the present invention to make it possible to produce vitreous enamel in pure, uncontaminated form at a relatively high rate and at a comparatively low cost.

Another object of the invention resides in making it possible to produce vitreous enamel by means of a novel procedure which involves simple but accurate control of the material and the product during all stages of production from molten to finished state.

A further object of the invention resides in the provision of equipment which makes it possible to carry out the new procedure in a highly effective manner and without manual attention.

An additional object of the invention resides in relatively rapidly cooling a stream of molten enamel while shaping it into strip-like form, in relatively slowly cooling such enamel in the form of a then plastic sheet to a temperature which is just above the annealing temperature thereof, then in suddenly or rapidly lowering the temperature of the enamel below its annealing temperature to place it in a highly strained brittle condition, whereupon it breaks up into self-drying plates and chips.

Other and further objects and advantages will be understood by those skilled in this art or will be apparent or pointed out hereinafter.

In the accompanying drawings,

Figure 1 shows a front elevational view of parts of the equipment constituting the present invention and fragments of associated equipment;

Fig. 2 is an end elevational view looking from right to left at the parts of Fig. 1; and

Fig. 3 shows a fragmentary sectional view through the rolls during operation.

Like numerals designate corresponding parts throughout the views of the drawings.

Describing the equipment with detailed reference to the drawings, it will be observed that we employ a continuous melting furnace 10 of any suitable or desired construction which per se forms no part of the present invention. This furnace rests upon the concrete or other flooring 11 which is suitably supported as by the metal beams and framework designated at 12 in any suitable or conventional manner, which likewise per se form no part of this invention. The furnace 10 is provided with a suitable discharge means such as the trough 13 which conveys molten metal from the melting chamber 14 of the furnace to the orifice or tap-hole 15 in the refractory fore-hearth 16 on the front of the furnace and which has a sight opening 17.

This furnace, while of the continuous melting type, may be, and preferably is, such as to provide a substantial molten body of enamel of the appropriate composition and character within the furnace so that a continuous stream of molten enamel may be withdrawn from such molten body and discharged to the apparatus constituting our present invention at a fairly constant temperature and viscosity. This prevents irregularities in production either with regard to continuity of the product or of variation thereof from a standard or mean which has been employed as the basis for the control factors hereinafter described and forming an important part of this invention.

The stream of molten enamel descending from orifice 15 is received in the bight between the rolls 18 and there forms a molten pool 19 hereinafter referred to. These rolls are so mounted that they are capable of being rotated in opposite directions at the same speed. These rolls are gear-driven from the gear motor 20, the shaft 21 of which is provided with a gear 22 which, through a chain drive or the like 22a, acts on gears or gearing 23 at one end of the rolls 18, thus driving said rolls at the desired rate of

speed. The bearings 24 of the rolls are mounted on the framework 25 so that the roll shafts or journals 18a rotate therein, as will be understood by those familiar with rolls and their mountings. Means, marked 26, is provided of conventional nature for varying the spacing between rolls 18 and consequently varying the deforming force exerted on material between the rolls as well as controlling the rolled thickness of such material.

The motor 20 is preferably of $7\frac{1}{2}$ H. P., 440 volt, three-phase and 60 cycle. The motor shaft 21 has a speed of 13 R. P. M. The rolls 18 are $12\frac{3}{4}$ inches in their outside diameter and are water-cooled, as is best noted at 27 in Fig. 3. The rolls are revolved by the motor at 10 R. P. M., and thus the calculated surface speed thereof is equivalent to approximately 32.3 feet per minute. The cooling water 27 is pumped to the interior of the rolls at the rate of approximately 60 gallons per minute and under average operating conditions there is approximately a 6° F. rise in temperature in the cooling water.

The stream of molten enamel issuing from the furnace and entering the bight between the rolls is rapidly cooled and deformed by said rolls. Whereas the temperature of the molten enamel as it enters the bight is in the neighborhood of 1800° F. ($\pm 50^{\circ}$), it will, of course, be understood that the precise temperature is dependent upon the composition of the particular enamel being handled. The temperature must be high enough so that the enamel is in the form of a readily flowable mobile liquid. For the various compositions ordinarily encountered the temperature of the molten enamel may range from about 1700° F. to about 2000° F. The temperature of any particular composition should be fairly closely controlled to within approximately 50° F.

In its passage between the rolls 18 the stream of enamel is rapidly and suddenly lowered in temperature by several hundred degrees and at the same time is converted into sheet-like plastic form. The rolls are preferably so set or adjusted as to produce a sheet which is of the order of $\frac{1}{4}$ " in thickness. In the conversion of the molten stream to the plastic sheet-like form it will, of course, be understood that a considerable width is imparted to the sheet. This width depends upon certain factors which will be understood or hereinafter referred to but we have found that a sheet approximately 18" in width is equivalent to a smelting rate of about 1000 pounds per hour.

The rate of rotation of the rolls, the spacing therebetween and the rate of discharge and temperature of the stream of molten enamel are all so correlated that a substantial pool of molten enamel, heretofore designated as 19, is formed and maintained in the bight between said rolls. This molten pool should be maintained of such size that its approximate depth at its center is not less than about 3" to 4". A pool of this volume and character not only has definite influences upon the subsequent operations and the character of the intermediate and final products but also improves and enhances the cooling action of said rolls upon said enamel as well as ensuring continuity of the sheet-like product and the reasonably constant or uniform temperature thereof. We have found that by operating under the conditions here outlined the sheet-like enamel is discharged from between the rolls at a temperature of approximately 1150° F. ($\pm 50^{\circ}$) but, as will be appreciated from what has

gone before, the precise temperature of the plastic sheet will vary somewhat depending somewhat upon the enamel composition. We have found that the temperature of the plastic sheet should range between approximately 1000° F. and 1400° F. for effective consistent results.

It will be appreciated, however, that the width and thickness of the sheet may be varied or controlled and that wide sheets as well as narrow ones can be equally well produced. The equipment must furthermore be correlated with the particular melting furnace which must be of adequate capacity to supply sufficient molten enamel for the purposes of our present invention.

The plastic sheet-like enamel now is in the form of a descending ribbon 19a, the speed of which is governed by the surface speed of the rolls 18. Therefore, under the conditions above recited it can be calculated that the descending enamel has an acquired speed of approximately 32.3 feet per minute. This descending ribbon of enamel gives up its heat in accordance with its temperature gradient with respect to the surrounding temperature and its speed of movement but this rate is relatively slow as compared to the abrupt reduction in temperature due to passage through the rolls and also with relation to the subsequent reduction in temperature hereinafter described. To protect the descending ribbon of enamel and to prevent contamination thereof, it preferably passes through a tapering stainless steel hopper 28, the larger end of which is directed upwardly to receive the enamel from the rolls. This hopper 28 is provided with a suitable inspection door 29 which may be opened for test or examination or may be provided with a transparent sight glass section (not illustrated) in order that the production may be observed at all times so as to check upon the appearance, continuity and dimensions of the product.

The vertical height of this hopper may be varied in accordance with the enamel composition or the circumstances of the installation. In its passage through this hopper the enamel relatively slowly becomes reduced in temperature until it approximates a temperature which is just above the annealing temperature of that particular composition. In the present instance this temperature is approximately 950° F. ($\pm 50^{\circ}$), but the temperature at this point should be within the range of approximately 800° F. to 1100° F., which range of temperature covers those compositions ordinarily employed. The movement of the enamel ribbon creates a flow of air around the same which is ample to secure the cooling effect desired and which is equivalent to a positive cooling but at a slower rate than the succeeding and preceding temperature reductions. Within the purview of this invention, however, we may introduce air or other fluid cooling medium (liquid, gaseous or both) into the hopper at such temperature and rate as to effect the proper amount of cooling. In other words, we may control the temperature and/or atmosphere of said hopper and its interior.

As the descending ribbon of enamel leaves the bottom or smaller end of said hopper 28, it is received by the vibrating pan conveyor 29. This is mounted at a slight angle of inclination, as will be noted from Fig. 1, and the enamel is received in the lower part thereof. As the enamel passes into such conveyor it breaks up into large flat plates 30 which roughly vary from about 4" to 12" in extent or diameter.

The vibratory action is of such nature as to cause these enamel plates to ascend in the pan conveyor 29 until they reach the upper end thereof, at which point they drop off the conveyor into the second vibrating pan conveyor 31 which, while also slightly inclined from the horizontal, is mounted substantially at right angles to the first vibrating pan conveyor 29.

As the plates 30 reach the upper end of conveyor 29 and as they drop into the lower end of conveyor 31, they are subjected to vigorous wetting and cooling action by one or more water sprays 32. These water sprays are discharged with the requisite force and direction by means of the spray nozzles 33 which receive cold water from a suitable supply or source and which discharge that water as sprays in the approximate proportion of 1 gallon of water to each 250 pounds of enamel. While a single spray has been shown for convenience and simplicity in connection with each conveyor, it will, of course, be understood that additional nozzles may be employed for producing the required cooling effect over the required area.

Under the conditions just set forth the enamel undergoes a relatively rapid reduction in temperature until that temperature is reduced below the annealing temperature or temperature range for the particular composition involved. For an enamel composition responding to the particular temperatures hereinabove specified, the temperature reduction by means of the spray nozzles should reduce the temperature to less than 750° F. but not below approximately 300° F. In this manner the abrupt or drastic cooling causes the enamel chips 34 which result to be in a highly strained and brittle condition and to retain sufficient internal heat to render the chips self-drying, thus eliminating the usual drying operation in connection with prior art procedures. The enamel chips which spontaneously form in the conveyor 31 are ordinarily from 1/2" to 3" in extent or diameter and are suitable for direct feed into a grinding mill which reduces them to the desired state of subdivision, preferably to a fine powdered form.

It will be understood that suitable equipment is provided for vibrating the conveyors 29 and 31 but in the drawings we have only illustrated fragmentarily conventional equipment 34 for vibrating the conveyor 29. The precise details of such are immaterial and form no restriction upon our present invention.

In describing the apparatus which constitutes a part of our present invention we have at the same time set forth the procedures which are carried out thereby and thus we have, in effect, also described our procedure. For convenience and clarity, we, however, point out that the procedure comprises a combination of steps involving predetermined changes in temperature under appropriate control with predetermined changes in physical form. This procedure commences with the discharge of a continuous stream of molten enamel from a suitable furnace and concludes with the spontaneous formation of the chips 34 in conveyor 31. The stream of molten enamel is acted upon by a pair of rolls which rapidly reduces the temperature thereof under the conditions noted to a temperature at which the material is in a plastic condition, i. e., is readily bendable or deformable but without cracking, breaking, etc. such as would occur with respect to a brittle or hard product. Simultaneously with the creation of the plastic condi-

tion the enamel is converted to sheet-like form. This plastic sheet is discharged continuously from the rolls and descends a certain vertical distance while being further cooled but at a relatively slower rate to a temperature which is just above the annealing temperature of that composition. The descending enamel impinges against a vibrating pan conveyor wherein it breaks up into plate-like form and from that conveyor it passes to a second vibrating conveyor where it spontaneously takes a chip-like form. During the transition the temperature is rapidly or abruptly lowered through the annealing range so as to place the enamel in a highly strained brittle condition. By annealing temperature or annealing range as herein employed, we mean that temperature or range of temperatures at or within which an enamel, glaze or vitreous composition is ordinarily heat treated to relieve strains and to put it in a tough, strong form in which it is not readily shatterable and in which it is substantially free of internal stresses.

The present invention comprises both apparatus and procedure, and within the spirit and scope of the appended claims we may make various additions, omissions, substitutions and modifications, and in any event the foregoing description is to be understood as being illustrative or exemplary and not as limitative or restrictive. Depending upon the particular composition and its critical temperatures, we may make such changes in the size, speed and nature of the equipment as will be designed to take care of material of the particular kind involved.

Having thus described our invention, what we claim as new and desire to secure by Letters Patent is:

1. A method of producing enamel chips directly from molten enamel which comprises discharging a stream of molten enamel which has been raised to a temperature of about 1700-2000° F., intercepting such stream and substantially simultaneously cooling and deforming it to lower its temperature abruptly and to convert it to plastic sheet-like form at a temperature of about 1000-1400° F., further cooling the sheet-like enamel at a relatively slow rate until it reaches a temperature of about 800-1100° F., which is just above the annealing range of the particular composition involved and then rapidly cooling the enamel to a temperature below its annealing range and below about 750° F. but not less than about 300° F., whereby the enamel spontaneously breaks up first into plates and then into chips which are brittle and highly strained and which are in a condition favorable for ready conversion into powder form.

2. A method of producing enamel chips directly from molten enamel which comprises discharging a stream of molten enamel, intercepting such stream and substantially simultaneously cooling and deforming it to lower its temperature abruptly and to convert it to plastic sheet-like form, further cooling the sheet-like enamel at a relatively slow rate until it reaches a temperature just above the annealing range of the particular composition involved and then rapidly cooling the enamel to a temperature below its annealing range by spraying it with a cooling fluid, whereby the enamel spontaneously breaks up first into plates and then into chips which are brittle and highly strained and which are in a condition favorable for ready conversion to powder form

and subjecting the enamel to the influence of vibration during the chip-forming stage.

3. Apparatus for producing enamel chips directly from molten enamel which comprises a pair of water-cooled rolls capable of being slowly revolved in opposite directions at the same speed, a tapering hopper-like receptacle below said rolls and the upper larger end of which is disposed to receive enamel discharged in plastic sheet-like form from said rolls, an inclined vibrating conveyor underneath the lower smaller end of the hopper-like receptacle and disposed to receive enamel therefrom, said conveyor being inclined upwardly from the receptacle, a second and similar conveyor angularly disposed with respect to the first conveyor and arranged to receive enamel in its lower portion from the first conveyor and means for introducing a cooling fluid into said conveyers.

4. Apparatus as set forth in claim 3 in combination with means for discharging a stream of molten enamel to the bight between said rolls and means for correlating the rate of discharge thereof with the rate of rotation of the rolls to form and maintain a substantial molten pool of enamel in the roll bight having a depth at the center thereof of about 3-4 inches.

5. A method of making vitreous enamel which comprises the steps of discharging a stream of molten enamel, at a temperature above the melting range thereof, into the bight between two cooling and forming rolls rotating at the same speed in opposite directions, withdrawing enamel from said bight, controlling such withdrawal so as to form and maintain in said bight a substantial molten pool of said vitreous enamel, said enamel being withdrawn in a plastic sheet-like form at a temperature in the neighborhood of 1300° F., further lowering the temperature thereof to about 1100° F., which is just above the annealing range of the particular enamel composition by bringing it into contact with a cooling medium and finally converting the enamel to a brittle strained condition by further reduction in temperature through the annealing range to about 750° F., by bringing it into contact with

another cooling medium whereupon it spontaneously breaks into fragments.

6. A method of making vitreous enamel which comprises the steps of discharging a stream of molten enamel into the bight between two cooling and forming rolls rotating at the same speed in opposite directions, withdrawing enamel from said bight, controlling such withdrawal so as to form and maintain in said bight a substantial molten pool of said vitreous enamel, said enamel being withdrawn in a plastic sheet-like form at a temperature in the neighborhood of 1300° F. due to rapid lowering of temperature by contact with said rolls, bringing the plastic sheet-like enamel into contact with a cooling medium which relatively slowly lowers its temperature to about 1100° F. which is just above the annealing range of the particular enamel composition and then converting the enamel to a brittle strained condition by quickly shock cooling it through the annealing range to about 750° F. by contact with another cooling medium, whereupon it spontaneously breaks up into fragments.

7. A method of making vitreous enamel which comprises the steps of discharging a stream of molten enamel into the bight between two cooling and forming rolls rotating at the same speed in opposite directions, withdrawing enamel from said bight in a descending, plastic substantially continuous sheet-like form at a temperature in the neighborhood of 1300° F., so correlating said discharging and withdrawing steps as to form and maintain a substantial pool of molten enamel in the said bight, contacting the descending sheet-like enamel with a cooling medium which reduces its temperature to about 1100° F. at a relatively slow rate compared with the initial cooling between rolls and then shock-cooling the enamel through its annealing range by bringing it into contact with another cooling medium which lowers its temperature rapidly enough to convert the enamel to a strained brittle condition, whereupon it spontaneously breaks up into self-drying fragments.

ROBERT C. BOYD.
HARRY C. ROACH.
CHARLES E. MCNEAL.