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METHOD OF ENAMELING SHEETS

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This invention relates to enameling sheets having enhanced resistance to distortion and warping but which at the same time are readily cold formable.

Various steps have heretofore been taken to overcome the defect or problem of sagging and warping during the process of high temperature heating or firing to convert the enamel frit into a fused glass-like coating. However, trouble is still encountered with sagging, warpage or distortion during such firing due to relieving stresses resulting from prior shaping to the desired contour, and to the lower strength of the material at elevated temperatures and expansion and contraction of the material as it passes through its lower A_1 and upper A_3 critical temperature range.

We have discovered that prevention of distortion during firing does not depend on any single factor but primarily depends on the combined effect of improved steel composition and heat treatment thereof.

The improved steel of our invention contains phosphorus in the range of .05 to .10% and is otherwise the same as conventional enameling steel which is mild steel of the following analysis:

	Max.
Carbon	.03
Manganese	.10
Sulphur	.05
Silicon	.01

A major requirement of enameling sheets is that they be readily formable. If the sheets are too hard or stiff, forming thereof results in undue strains causing warpage during firing to complete the enameling. For this reason, the phosphorus content must be limited to .10% maximum. While a larger amount may be effective to prevent sagging during firing, it stiffens the sheet unduly so that forming strains are introduced therein which result in warpage during firing even though the sheets do not sag. Likewise, less than .05% phosphorus is insufficient to eliminate sagging.

The high temperature box anneal in the range of 1550 to 1650° F. has been found to produce very desirable results in the prevention of warpage. Below 1550° F. the sheets blister on firing and the desired softness is not obtained and over 1650° F. objectionable grain growth occurs. The desirable results obtained can be readily seen from the following comparison of lots of steels, one treated by a conventional 1250° F. box anneal and the other given the high temperature box anneal forming a part of our invention.

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Lot	C	Mn	P	S	Si
A	0.014	0.10	0.08	0.010	0.003
B	0.025	0.07	0.10	0.035	0.002
C	0.025	0.07	0.10	0.030	0.002

Lot A.—Steel was hot rolled, pickled, cold reduced to 18 gauge, box annealed at a temperature of 1240 to 1260° F. using a 14-hour soak, and was given one temper pass.

Lot B.—Steel was hot rolled, pickled, cold reduced to 18 gauge, box annealed in loose coils at 1575 to 1625° F. for four hours and was given one temper pass.

Lot C.—Steel was hot rolled, pickled, cold reduced to 18 gauge and was given conventional normalizing treatment.

These treatments developed the following average mechanical properties:

Lot	Yield Point lbs./in.²	Tensile Strength lbs./in.²	Elongation in 2", percent	Rockwell Hardness B Scale	Grain Size
A	43,450	62,000	25	69	7-8
B	26,150	47,150	33.2	47	6-7
C	32,150	52,350	28.5	55	5-7

Strip of these lots was cut into sheets and formed into architectural panels 31 by 93 inches which were given one ground coat of vitreous enamel being fired 4 minutes at 1580° F. and one finish coat fired at 1550° F. for 3 minutes. After cooling, the panels were measured for warpage by placing a straight edge through the center line of each panel midway between the sides and then across the width of the panel about 12 inches from each end.

The following table presents deviation from a true plane observed on the panels tested as above. Deviation is expressed in thirty-seconds of an inch, and when the deviation was less than $\frac{1}{32}$ of an inch, the term "no" is entered in the table. Positions on panel correspond to the above mentioned locations given in consecutive order.

Lot	Panel	Box Annealed at—	Position on Panel			
A	1	1,240-1,260° F.	1/2	2/1	3/2	4/1
	2	1,240-1,260° F.	No	5	1	No
	3	1,240-1,260° F.	2	5	No	1
	4	1,240-1,260° F.	4	2	3	1
	4	1,240-1,260° F.	5	5	2	3
	6	1,240-1,260° F.	4	2	No	No
B	7	1,575-1,625° F.	No	No	No	No
	8	1,575-1,625° F.	No	No	No	No
	9	1,575-1,625° F.	No	No	No	No
	10	1,575-1,625° F.	No	No	No	No
	11	1,575-1,625° F.	No	No	No	No
	12	1,575-1,625° F.	No	No	No	No

Lot C warped so badly upon firing that it was unsatisfactory.

These results conclusively demonstrate that mere addition of phosphorus to enameling steels is incapable of reducing distortion within acceptable limits, but a combination of phosphorus addition with an appropriately selected thermal treatment yields a product capable of meeting severest requirements of the trade. It may be noted in this connection that the composition, gauge of steel, forming operations, and firing practice for the samples were well within commercial variations, differing only in the annealing practice employed.

Further evidence of the difference between the treatments is exemplified by the microstructure of both types of material. Thus our material has a smaller and more uniform ferrite grain size than lot C. Also there is considerable difference in carbide size and distribution. Our material has much larger carbides than lot C and the carbides have a more favorable distribution in that the carbon has agglomerated toward the center of the cross-sectional area thus stabilizing the carbides to avoid enameling defects and keeping the carbon away from the surface where it could give rise to enameling defects.

In reducing the present invention to practice, we prefer to make steel of a conventional enameling-steel composition in any commonly used type of metallurgical furnace and follow the usual methods of steel making. The steel is alloyed with substantially 0.05 to 0.10 per cent phosphorus, and the molten metal cast into ingots. The ingots are reduced by hot rolling to substantially 0.080" strip and the strip cold reduced to the desired final gauge, following which the band is box annealed in loose coils in a protective atmosphere, to prevent oxidation of the metal, at a temperature of 1550° F. to 1650° F. and soaked for substantially two to four hours at this temperature followed by a slow cooling to room temperature. The desired final surface is imparted to the material by temper rolling, following which the material may be sheared to any desired length, the desired final shape of the articles to be enameled is imparted thereto by mechanical means, and the surface prepared by the application of cleaning media. The cleaned articles are then coated with enamel frit and heated at 1500 to 1600° F. for substantially 3 to 5 minutes to fuse the components of the frit into glass and to fuse the glass coating to the steel base.

Enameling sheets produced in the above-described manner possess an exceptional freedom from warpage and sagging, greatly improving the appearance of the finished articles and reducing cost of production.

We claim:

1. A method of making enameled articles comprising alloying .05 to .10% phosphorus with .03% maximum carbon steel, cold rolling bands of said steel to the desired gauge, box annealing said bands at a temperature between 1550 and 1650° F., cutting said bands into sheets, forming said sheets into the desired form, coating said formed articles with enamel frit and firing the coated articles to fuse said frit.

2. A method of making enameled articles comprising alloying .05 to .10% phosphorus with .03% maximum carbon steel, cold rolling bands of said steel to the desired gauge, box annealing said bands at a temperature between 1550 and 1650° F., cutting said bands into sheets, forming said sheets into the desired form, coating said formed articles with enamel frit and firing the coated articles at a temperature between 1500 and 1600° F. to fuse said frit.

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