OBSERVATIONS ON THE FACTORY CONTROL OF FISH-SCALING¹

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ABSTRACT

An analysis of fish-scaling, its causes and prevention, based upon observations and experience of practical work. Three principal causes of fish-scaling are: (1) Improper firing, either underfiring or overfiring, especially the latter since its effects are usually not evident until the ware is finished and marketed; (2) The use of a clay which does not give a free running uniform coat without the use of excessive amounts of flotation agents. Clays which, when stirred up with water give a persistent suspension are recommended. (3) Improper type of furnace for the firing operation. The author prefers the open type furnace for the firing of enameled ware.

To the uninitiated, the cause and control of fish-scaling seems of very easy solution, but to those familiar with enameling operations it is a serious question and a matter of vital importance; for unfortunate is the enameler whose ware is suffering from an aggravated case of this troublesome pest. So many causes have been attributed to it, and it occurs under so many different conditions and stages, that one is at a loss to know from what direction to attack it. Among the causes which have been advanced are the following: improper smelting, character of clay, improper milling, character of iron, lack of regulation of the acid bath, type of furnace, underfiring, relative coefficient of expansion of enamel and steel and such a host of other causes that upon investigation we rarely find two enamelers holding the same opinion.

Of the above causes, underfiring, character of clay and type of furnace, are the ones selected by the writer for a brief discussion. The remaining causes appear to be of secondary consideration. Still at times the writer is tempted to believe that the character of the iron may be an important factor. Nor can we ignore the fact that the established law of expansion and contraction holds an important place, being held by many as the

¹ Received August 18, 1921.

primary cause, not so much in its action alone but through other contributory causes that tend to rupture the enamel during the expansion and contraction of the ware. The glass maker has been successful in controlling this situation by the manipulation of materials and conditions until it is possible to expose certain glasses to extremes of heat and cold without fear of rupture. The enameler of cast iron has also been highly successful in this respect. But the enameler of sheet steel has not been as fortunate and his inability to definitely explain the phenomena has made him a target for criticism.

Taking up the first subject for discussion, that of underfiring, the writer believes that one of the principal causes of fish-scaling of finished ware is not so much underfiring as overfiring. An experienced burner can detect a piece of underfired ware quicker and with more certainty than he can tell a piece that has been overfired. For the writer knows of no rule to determine whether a piece, that to all appearances has been properly burned, will fish-scale or not until the trouble actually manifests itself.

This brings forth the question as to what change or action takes place from overfiring. If we should apply a uniform coat of enamel frit or glass that had been finely milled without clay to a piece of sheet steel and burn it, we would find upon withdrawing it from the furnace that its high luster and pleasing appearance apparently make an ideal coating; but after it is cooled we are not surprised to see the coating shivering off of the piece until the metal is bared, due to the absence of clay. On a second piece we repeat the operation but add clay in the mill and after burning and cooling the shivering has ceased or diminished according to the percentage of clay added. We will proceed to refire the piece containing the clay without recoating it and subject it to the intense heat generally used in ground coat burning and we find that if overfiring has taken place, one of three conditions are present—either the ground coat is sintered; the iron scale has forced its way through the enamel; or the ground is burned to a greenish brown color. Here the writer claims the damage is done, as the prolonged intense firing has destroyed or changed, either entirely or in part, that property of the clay that tends to regulate the gravity of the enamel until we find

after burning nothing is left on the ware but the ground frit or glass minus the clay, or essentially the same conditions we had on the piece that shivered off.

Fish-scaling from underfiring generally takes place upon the cooling of the ware or within a few hours after burning and it is the contention of the writer, based on factory observation, that the scaling from overfiring while not so conspicuous or prominent as the former is nevertheless just as persistent and does not occur until a few days up to two or three months after the ware is finished. As the ware is generally white coated the same day or the day following, it can be readily understood how very easily it is possible to overcoat a condition of fish-scaling that will not manifest itself until it is on the market. To white coat a piece of underfired ware that looks suspicious is simply inviting disaster from which the enameler cannot escape; but until some definite rule or means are discovered to also avoid the overfired piece we can only hope to follow the beaten path of taking chances.

There is no question but that pieces of underfired ware will at times pass unnoticed through the various operations and find their way to the market, but the amount of fish-scaling one sees in the display windows of various cities, both on stove, hollow ware and refrigerator works, is *prima facie* evidence that it is not all due to underfiring for the amount is too great to pass unnoticed if underfired. Therefore, we can reasonably suspect that it is due to the fact that the ware had been overfired and that the retarded scaling resulting therefrom did not manifest itself until after the ware was on the market.

In considering the second cause of fish-scaling, namely that of clay, the writer believes that herein lies the most important factor entering the enameling of sheet steel. The pride of every enameler is a reliable ground coat formula which he regards as his most treasured possession, and rightly so, for herein lies the secret of his success. We can expect that his ground coat, if properly used, will not fish-scale. The term "properly used" in this case simply means that the clay used is of the right character to make possible proper slushing and burning of the ware.

In discussing the effect of overfiring, we alluded to a particular

point at which the efficiency of the clay was destroyed; remembering this point, we must select a clay that will still retain its efficiency at the higher temperatures. Still another and more important requisite, is the selection of a clay that will hold the frit in suspension without the excessive use of flotation agents. An enamel ground coat applied too thinly, and fired too hard will fish-scale and enamel applied too heavily and underfired will do the same. On irregular shaped ware that has been dipped or shaken out, or on pieces on which the ground is required to flow from different angles, it becomes almost impossible to apply a uniform coating. Consequently upon firing we have two extremes to overcome at the same time. If we overfire the one part we underfire the other—hence, the importance of a free running clay that will insure a uniform coat on all parts of the piece. The non-uniform condition of the ground coat is very often the cause of fish-scaling on certain areas of the ware.

In selecting a clay the writer has used a very simple but satisfactory method of testing the ability of the clay to remain in suspension. Six one-quart Mason jars were procured, also samples of six of the leading well known American and foreign clays, regardless of their chemical analysis or prestige. Into each jar one pound of clay was placed and the jar filled with water. This was allowed to stand a few days until the clays were thoroughly saturated, after which they were all stirred by hand as quickly as possible and were then allowed to stand one week, after which the following data were noted. Four of the clays settled to the bottom of the jars in six hours, some more compactly than others. One, a washed clay, while not settling very fast, gave evidence of being held in suspension by the addition of some chemical agent. The remaining clay settled about one-half inch and remained so until the water was entirely evaporated from the surface, a matter of thirty days' time. This one showed no evidence of being chemically treated and was selected by the writer for further experiments for the reason that, if the other clays could not hold themselves in suspension, they certainly could not hold the frit. A batch of frit was then milled with ten per cent of this clay and the results were good. Suffice it to state that this clay was adopted.

The irregular shape and size of a refrigerator lining requires the entire immersion of the piece into a tank of ground coat of about one hundred and seventy-five gallon capacity. When the plant at which the writer is employed first started operation four years ago, it was very difficult to get a clay that would deposit the frit uniformly over the piece, consequently much fish-scaling appeared on the parts where the enamel was too thin or too heavy. With the changing of the clay and firing conditions corrected, this trouble has entirely disappeared. During the war the plant was obliged to shut down for a period of five weeks, the supply of fuel oil having been exhausted, and the writer was very much gratified upon returning to find the ground coat was still in a good state of suspension with very little precipitation at the bottom of the tank. Hence, we find from this that the flotation element of a clay holds a very important place in the occurrence of fish-scaling, as it not only makes it possible to apply a more uniform coat, but in a furnace of even heat distribution the firing is more uniform and more easily controlled.

The third and last cause of fish-scaling selected for discussion relates both to firing and the type of furnace used, and while it appears the last for discussion, it is by no means the least, for the results of our attention or our inattention to the details leading up to the firing operation will be indelibly engraven on the surface of the piece after firing. The old adage that "a poor workman will kick on the tools" is at times only too true. But after viewing some of the furnaces in different plants the writer is convinced that the workman often is justified in his "kicks." No matter how carefully details have been accounted for up to the firing operation, the labor will be in vain unless the means for proper firing conditions have been considered. The industry is awakening to this fact and as a consequence many new types of furnaces are being introduced, and while the intermittent firing open type furnace is not of recent origin it is now rapidly displacing the muffle type in many plants for the following reasons: It has a more uniform distribution of heat which insures the uniform firing of all pieces of ware, thus reducing the risk of over- or underfiring; as the firing is discontinued while the ware is at high heat, economy in fuel is obtained. Its solid construction

of standard fire brick minus special forms adds to its life thereby reducing the upkeep and making possible the firing of the ware without deformation of the muffle. Added to this advantage, its complete absence of gas makes it an ideal furnace. What relationship exists between fuel gas and fish-scaling, if such does exist, is not known. That its effects are injurious to the enamel cannot be doubted by the appearance of the disagreeable bluish color imparted to the ground when fired in a furnace containing gas. That there is a difference in ware burned in a muffle type of furnace and in the open type is beyond doubt. The fact that the muffle type is very seldom free from gas due to leaky joints or defective flues, while the open type is entirely free from gas gives strength to the opinion of many that the action of gas is a contributing cause of scaling.

Another important condition often overlooked in firing the ware is that the ground coat is applied too thinly and fired too hard. The fault does not lie so much in the length of time consumed but more in the severe high temperatures carried, no provisions being allowed the ground coat for the subsequent firing of the white. This is especially true of samples of hollow ware examined, for upon breaking through the white, one will find scarcely any traces of the ground. The result is that what anchorage the white depended upon from the ground has been destroyed by overfiring, a condition which later may cause fish-scaling or which will not permit the abuse to which the ware will be normally subjected.

The writer has long held the opinion that all sheet steel enamels could be so formulated as to lower their firing temperatures so that after firing, the ground remained intact. While this may not be possible on hollow ware, owing to the hard acid-resisting whites used, this rule can be applied to stove, refrigerator and kindred lines and would result in more shapely and durable ware.

In conclusion, the writer would state that the plant in which he is at present employed is in the fourth year of its production. During the first two years in which the muffle type of furnace was used the firm was about convinced that it had an unwelcome monopoly on fish-scaling and years of past experience availed naught in correcting the trouble. Every source from which it

might originate was thoroughly investigated and from the conclusive evidence of the results obtained the causes were traced to the three conditions under discussion, namely, overfiring, clay, and furnace construction. An open type furnace was installed, firing conditions corrected and the ground coat so formulated as to mature at lower temperatures. A clay was selected that would hold the frit well in suspension without the excessive addition of flotation agents, while a more uniform application of the ground coat was produced. In the last two years, since the change was made, with the exception of an occasional piece that could be readily traced to underfiring, all pieces have been free from fish-scaling.

Not on any one of the conditions alone depends success but on the three combined. A successful furnace will not produce satisfactory results unless the dipping or slushing conditions have been properly controlled and this in turn cannot be made possible without the use of the proper clay. Yet it is very evident that if the three conditions are carefully regulated the general result will promote success.

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