TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING AND METALLURGICAL ENGINEERS [SUBJECT TO REVISION]

Pyrometry Applied to Bottle-glass Manufacture

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I FEAR that my treatment of this subject may not, in all instances, meet the approval of those who read my opinion as to the utility and efficiency of pyrometers in the making of glass, or bottle-glass. It may be superfluous for me to add that this opening statement is based on over 15 years' experience in an endeavor to successfully apply pyrometers, or heat-measuring instruments, to glass-melting furnaces, particularly the type known as tank-furnaces, and that such endeavors have proved more or less futile. It is my desire, therefore, to herein set forth the problems encountered, hoping thereby to stimulate further effort in the successful application of pyrometers. It is my desire, also, to invite criticism of the methods used and suggestions from those who may have a wider experience, or who may have better methods.

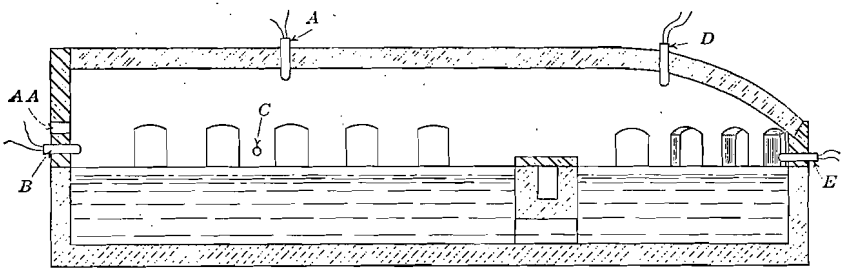

FIG. 1.—GLASS TANK FURNACE.

In general, I believe that the inefficient application of pyrometry to the melting of glass in tank furnaces is not due as much to the instruments as to the conditions under which they must be used and the character of the medium in which they must reside. Most of those present no doubt, are familiar, at least in a general way, with the methods and apparatus used in the melting and making of bottle-glass, or glass that is formed into containers of various shapes and designs. Most of this glass is made in what is known as a tank furnace, these furnaces vary widely in design and construction. In general, they consist of a rectangular tank-like form, built up of fireclay blocks, and range from 2 by 4 ft. (0.6 by 1.2 m.) to 24 by 140 ft. (7.3 by 42.6 m.) with a depth of glass from 2 to 5 ft.; or a capacity of from approximately 2 to 700 tons. Fig. 1 shows the general

design. The material is charged in at *A A*. It is pushed into the furnace by means of an iron tool and floats on the molten glass in mounds, or what might be relatively termed "bergs" of batch materials. Here it comes into contact with the fire and temperature, which effects a chemical combination of the batch material. As it melts the material flows forward and passes downward through the throat in the bridge-wall. This throat is a comparatively small opening, usually not exceeding 24 in. (61 cm.) in width by 18 in. (45 cm.) in height. The glass then enters what is known as "the refining chamber," or "working end" of the furnace. This chamber, above the bridge-wall, is in open communication with the melting end.

As no fire is introduced into the working end of the furnace, obviously its temperature is considerably lower than that of the melting end. Consequently the temperature of the glass decreases as the glass flows toward the ring holes, or working positions. If more glass is taken from any one working position, or ring hole, than from the opposite side, there will flow to this point a greater quantity of the hotter glass issuing from the throat. As a result, the workman working this glass, will be required to regulate his gathering or the machine he is operating. Accordingly, should he for any reason cease to operate his machine, or gathering, and the flow of glass to this point is checked, a change in the temperature of the glass will ensue. This necessitates a change in the working conditions when again starting up, also a further change when operations have been resumed until the normal flow has been produced.

It would seem that a simple answer to this would be to introduce into the glass at this point some form of temperature-measuring apparatus, or to sight upon the glass at this point a pyrometer working upon the optical principle, or the disappearing-filament principle. However, none of these have been found to be satisfactory. The thermoelectric pyrometer is absolutely unsuitable for this purpose, because we have not as yet been able to construct a sheathing or protecting tube for the element that will withstand the erosive action of the glass. The optical pyrometer is likewise unsuitable because the glass has not only light and heat transmitting properties, but is highly reflecting. As a consequence, the glass temperature at the surface is not measured but measurements are obtained of the underlying glass if it should be hotter than the surface, or possibly the temperature of the crown or side walls, or of the flame, which is reflected from the surface.

At the melting end of the furnace, the batch materials, which constitute the glass, are composed mainly of sand, soda ash, or salt cake, burned or raw lime, with possibly the addition of small amounts of borax, arsenic, antimony, nitrate, or soda. In some rare instances, barium carbonate, zinc oxide, etc. are being introduced in varying proportions and in a dry state. As they are injected into the furnace, the charges float on

the surface of the glass and come into contact with the fire, which plays across the funace. As a result more or less of these materials is entrained in the gases that pass across and are carried forward impinging upon the side wall, into the ports, checkers, and flues. To some extent this pervades the whole atmosphere of the furnace, producing a severe erosive action upon the whole interior lining, combined with the material forming the side walls, which effects a glaze that is more or less light reflecting.

Thermoelectric Principle

If pyrometers are introduced either through the crown at point *A*, Fig. 1, through the back wall at *B*, or the side walls at *C*, the protecting or sheathing tubes of the elements (if it is a thermoelectric equipment, are attacked by the entrained and volatilized alkali. It only requires a short time, in some instances a week or possibly a month or two, for this alkali to sufficiently dissolve and erode these protecting tubes as to expose and destroy the element itself. Therefore it is not only expensive, but extremely difficult, to keep these elements in an operative condition.

In order to minimize this erosive action, perforated silica block has been used as a protection tube, particularly where the element has been introduced through the crown, as at *A*. While this was satisfactory so far as reducing the erosive action and destruction of the element is concerned, it was not entirely satisfactory because it was necessary to make these blocks rather large in order that they would have sufficient mechanical strength. This results in there being considerable heat conducted through the block into the crown, consequently lowering the temperature readings below the actual temperature of the furnace, and also decreasing the sensitiveness of the instrument.

What has been said of the elements introduced at *A* is also true of those introduced at *B* and *C*. Those located at the two latter points, even where the same are protected by a silica block, do not resist the erosive action nearly as well as those at *A*.

Another great drawback to the use of pyrometers as a control medium for governing melting conditions when located in the melting end is the fact that they do not give readings that truly represent the temperature of fire conditions which perform effective work on melting the materials. To illustrate a pyrometer element located at *A*, Fig. 1, reads only the temperature produced at *A*, which is perhaps 3 in. (7.6 cm.) below the crown. Conditions can be produced in the furnace whereby, with a high stack draft and with gas and air valves adjusted, a perfect combustion can be obtained. A higher temperature can then be produced at the surface of the glass, or impinged upon the batch materials, than will be produced at the thermal element at *A*; but if the stack damper should be lowered, with other conditions remaining the same, the travel of the fire

across the furnace will be retarded and a greater quantity will be forced up to the crown. As a result, the temperature at *A* will be increased while the temperature of the furnace may be lowered, and at the surface of the glass will be very much lower than is found at *A*, or at least, melting will be retarded. This result I have been able to produce many times. For this reason it is my candid opinion that a pyrometer in the melting end of a tank furnace really does more harm than good, for where such conditions can be obtained the instrument must be misleading in its efficacy as a means for furnace control.

This is true to a greater extent, when the elements are located at *B* and *C*, for not only do the fire conditions have a pronounced effect on the element at *B*, but the quantity and proximity of the batch piles also affect it. While an element at *C* not only suffers from the two conditions mentioned, it also has the disadvantage that when the fire is traveling away from this side of the furnace, it receives that temperature only arising from the imperfect combustion as the stream of gas and air issues from the ports; while if the fire is approaching the element, the latter receives the greatest intensity of heat because of the impingement of the gases of final combustion.

A thermoelectric element introduced at *D*, Fig. 1, or in the refining end of the furnace, under certain conditions when correctly understood, is of considerable utility and value to the furnace operator. This element not only reads the temperature radiated from the glass immediately below, but it also indicates the temperature of the gases that surround the glass in the refining end of the furnace. This results indirectly in its being an indicator of the stack damper and air-valve settings that control the quantity of gases of combustion forced to this end, or the influx of air into the furnace. However, it gives but a secular indication of temperature, and cannot be accepted as any true guide of the temperature of the glass.

An element located at *E*, Fig. 1, is more efficacious, when properly installed, in giving the temperature of the glass immediately adjacent to it but as pointed out, this may be at a point where the glass is substantially quiescent, and consequently cooler than at any other point. If located between two ring holes from which relatively large quantities of glass are being taken, it will indicate a higher temperature than at other working points of the furnace.

As a means of furnace control, a pyrometer introduced in the flue, between the stack damper and air valve, and at *D*, in conjunction with an efficient type of draft gage, provides as good a means of regulating the furnace conditions and the requirements of adjustment as it is possible to obtain. However, so far as furnace control is related to the melting conditions is concerned, I have never found anything that affords as good a criterion as do the appearance of the melting batch, the flux line, and the

surface of the glass between the batch piles and the bridge-wall. Here we have indications that are directly the result of quantity, quality, and intensity of fire affecting the material to be acted upon.

Optical Principle

Some furnace men and operators have found that the optical pyrometer meets all their requirements in furnace control by using it as a criterion upon which to regulate their fire conditions, or the degree and speed of combustion. This is done by sighting through an opening in the rear wall of the furnace, at some convenient point, whereby the instrument may be focused upon some given point in the flame and the temperature read at this point. The readings are then empirically reduced to effect a criterion upon which to adjust or regulate valves and damper settings. I do not question but what after careful study and correlation of readings with the valve and damper settings, the optical pyrometer can be utilized to give valuable aid to the operator in governing furnace adjustments. However, I have never been able to obtain results that are as satisfactory as other means. Further, I have never been able to use an optical pyrometer of the Wanner type and obtain any satisfactory results in controlling the temperature of the glass, for, as before pointed out, the emissivity of the glass is dependent entirely on its composition, homogeneity, uniformity of temperature, and freedom from reflections of hotter or colder bodies.

As an example, if one will take out of the furnace in any convenient manner, a mass of glass of, say, 100 lb., having but a small part of its area exposed to radiation, and then attempt to measure the temperature of the surface, they will find that this surface temperature is very much lower, in some instances, 200° to 300°, than will be registered by the optical pyrometer.

Radiation and Disappearing-filament Principle

What has been said of the optical principle is, to a great extent, true of the radiation and disappearing-filament types of pyrometer. In the disappearing-filament and optical types, we also have the calibration factor to contend with, while in the radiation type we have the perfectness of focus and reflecting surface to maintain in order to obtain anything like accuracy.

It is indeed regrettable that some one cannot devise a means or material whereby an accurate temperature can be measured. However, it is not strictly essential and, in fact, I believe it is not wise to attempt to measure the temperature of the melting end of these furnaces, for the reason that the position at which such temperatures are measured is so small in proportion to the volume and areas involved that such measurements

do not give information of any practical value. If we could devise a means whereby the temperature of the glass as it is being worked, could be continuously and accurately measured, we would solve a problem that would be of inestimable value to the manufacturer.

In regard to this statement, let us consider some of the conditions wherein this temperature plays such an important part. Fig. 2 is a diagrammatic view of what is known as the Owens revolving pot, which consists of a furnace and a revolving clay vessel situated adjacent to the tank furnace, as shown in Fig. 1. A spout introduced in the refining end of the furnace, some inches below the surface of the glass, has a gate member arranged so that by adjusting the gate a quantity of glass flowing into the revolving pot marked *AB* can be regulated so as to maintain a constant level, or the gate can be lowered so as to completely shut off

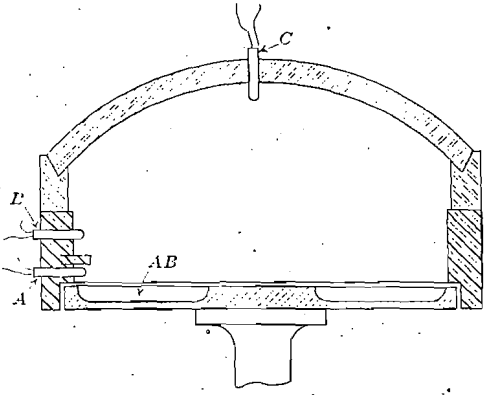

FIG. 2.—OVEN REVOLVING POT.

the flow of glass to the pot. A heating chamber surrounds this revolving pot and is entirely separate from the melting furnace and its refining chamber, and is supplied with auxiliary means for obtaining the required temperature therein; this is done by means of oil, natural gas, or producer-gas fuel. The glass that flows into this pot is formed into various articles, such as bottles of all sizes, fruit jars, packers' ware, etc., by means of what is known as the Owens bottle machine, the fundamental principle of which, briefly stated, is as follows:

A parison mold is lowered so that its opening and under surface just comes into contact with the surface of the glass; as a vacuum is created in this mold, the glass is forced up into it and around a plunger, which produces the required cavity within the parison blank. Subsequently, this parison mold is opened and removed from the blank, and the blow mold, or the mold that governs the shape of the article, is closed around the blank, the plunger is removed, the opening closed where the plunger passed through, compressed air is admitted into the cavity in the blank,

and the blank distended to fill the contour of the mold, after which the mold is opened and the article is ejected upon a suitable conveyor, or is removed manually.

The perfectness of the article depends, primarily, on the temperature of the glass as it is drawn into the parison mold. It is a serious and perplexing problem as to what this temperature should be, and after the temperature has once been determined, for a given size and weight of ware, its effect must also be determined as related to the condition of the molds, speed of operation, distribution of glass in the article, vacuum and air pressures, etc. and should be maintained uniform and constant. Numerous ways have been suggested, and I have tried nearly every suggestion, but I have not found any method for measuring the temperature of the glass at exactly the location where the mold takes up the glass, that has been entirely satisfactory or successful.

A pyrometer element introduced, at *C*, Fig. 2, is subject to the same criticism as the one introduced at *A*, Fig. 1, in the melting end of the furnace, as its registrations are susceptible to all the variations in temperature that may be produced by varying fire conditions, draft, and glass temperature. The same is true of an element introduced at *B*, Fig. 2. However, there is no flying flux or alkalies to attack the sheathing tube or element. An element introduced, at *A*, Fig. 2, as near to the glass as is possible, gives about as effective results and as satisfactory as any, by introducing the element through an open ended protecting tube so that possibly from ½ to 1 in. of the element proper, with just a thin coating of clay over the element wires, protrudes beyond the open end of the sheathing tube. This will bring the element about 2 in. above the surface of the glass. Over this I construct a composed tile shield about 2 in. thick and 6 in. long, to protect the element as much as is possible from the direct radiation from the flame or fire in the furnace. In this manner, a registration of the temperature radiated from the glass in the pot is obtained; and while the results obtained are fairly satisfactory, they are far from what might be desired, for the temperature of the glass must be measured to insure the best results.

We have made numerous attempts to use optical and radiation pyrometers to obtain the temperature of the glass in this pot at the required point, but these attempts have proved utter failures.

What has been said as to the difficulties encountered in applying pyrometers to the Owens pots is true of other modes of gathering or working the glass. In the Hartford-Fairmont process, the glass flows into a channel, is then paddled over a weir, discharged through an orifice, cut off by means of shears, and discharged into an open parison mold. Here it is essential, in order that a given weight of glass shall be discharged into the mold each time, that the glass is maintained at a definite and uniform temperature. In the Tucker-Reeves method, the

glass flows through a refractory channel to an orifice (as shown in Fig. 3) of a predetermined size and then through controllable periods of time of such flow is sheared off in a manner as to discharge predetermined weights and quantities of glass to the molds. In the Brookes device, wherein there is no means for regulating, with precision, the quantity of glass flowing through the orifice and the time period of shearing, by a gate in the channel, obviously the amount discharged is directly related to the temperature.

In all of these processes, *i.e.*, Hartford-Fairmont, Tucker-Reeves, and Brooks, numerous attempts have been made to use pyrometers as a means of controlling the temperature of the glass, but so far all attempts have been unsatisfactory. It has been found that to introduce the thermoelectric element in any part of this apparatus, it is necessary to keep the same out of contact with the glass. Therefore, the elements are usually introduced at some point approximating the position marked *A*, as shown in Fig. 3. Although I have used, in some experimental work, an element introduced at *B* and into the glass stream with satisfactory results, so far as indicating the true temperature of the glass is concerned, it is substantially impossible from a practical standpoint, to use this method of installation, because of the high erosive action of the glass upon the sheathing tubes, which necessitates the shutting down of the machine and serious damage to the spout if a new element is to be installed.

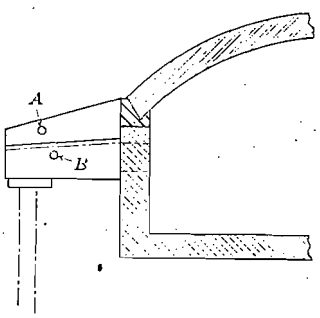

FIG. 3.

CONCLUSIONS

My conclusions on this subject are as follows:

That pyrometers applied to the melting of glass in tank furnaces perform no useful function in determining the regulations or control of fire conditions. To a minor degree, they do assist in keeping a check upon the furnace operation, and, more effectively, function to effect a psychological stimulus for the operator.

That they are woefully inadequate as a means for controlling the temperatures at the working, or refining, end of the furnace, although they are of great value in controlling the conditions at this point.

That the thermoelectric type is greatly superior to the radiation, optical, or disappearing-filament types, except in possibly special or isolated cases.

That the invention or design of a protecting tube that will withstand the erosive action of the glass, will give to the glass manufacturer a means whereby he will be able to utilize a pyrometer in a manner as to make it indispensable and of inestimable value.