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IMPORTANT IMPROVEMENTS IN DENTAL FURNACES AND THE NECESSITY FOR THEM.

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THE strength of our porcelain, whether of inlays or crowns, varies through a range so wide that but few will believe it until they have seen the tests made by others or make them for themselves. Judging the work of other operators by my own in the past, I am satisfied that the strength of the porcelain inlays and office-made porcelain crowns is not over seventy per cent. of what it should be, due to error in baking. Here are three series of crushing strengths of the same porcelains baked at different temperatures. These small buttons were all the same size and baked alike at temperatures above and below and at their proper baking points.

Taking the crushing strength of a button baked at proper temperatures as one hundred per cent., Brewster's Body baked 85° C. too low the strength was forty-seven per cent. and 85° C. too high was fifty-four per cent. Brewster's Enamel baked 85° C. too low the strength was forty-two per cent. and 85° C. too high was fifty-two per cent. Jenkins baked 85° C. too low the strength was sixty-eight per cent. and 85° C. too high was eighty-one per cent.

(These tests were made with the help of Professor Cadwell, of the Case School of Applied Science.)

From these it will be seen that even this small variation of the temperature makes a very great difference in the strength, and the average bakes are in error as much or more than this, I think.

Dr. Le Cron, of St. Louis, has published similar results on this point in the November, 1903, *Dental Summary*. He found that Close's and White's inlay bodies with a maximum strength baked at 2288° and 2254° F. of five thousand six hundred and fifty and three thousand eight hundred pounds, respectively, crushed at three hundred to five hundred pounds less weight when underfused only 36° F., and gave way at sixteen hundred to two thousand three hundred pounds less when fused only 72° F. too high. He says, further, "The Jenkins body standing its highest test at 1580° F. crushed at three thousand three hundred and thirty pounds and at the temperature of 1544° F. crushed at two thousand nine hundred and ten pounds, and at 2616° F. crushed at one thousand and seventy pounds." "It is evident in my mind," he says, "that many failures in porcelain work can be attributed to improper baking and particularly to overbaking."

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The greatest source of failure in porcelain work to-day is not the recurrence of caries nor the loosening of the porcelain, but the breakage, which fault can be largely corrected by proper baking.

The writer has in the past used the gold fusing method and also watching the appearance of the glaze and the glow of the furnace, and the time on each button, but finds after careful testing that he cannot on the average tell the actual temperature within one hundred degrees. I have tested a number of other porcelain workers by having them state when the bake was correct without seeing the pyrometer, and find that they almost always are in error from fifty to two hundred degrees, and even more, which is probably as near as the porcelain workers of the country get to the proper baking point.

Because of this fact with its serious consequences and the fact that many operators' eyes, including my own, were being more or less seriously and even dangerously injured, and because none of us could correctly judge colors for some considerable time after staring into the furnace, together with the anxiety due to the uncertainty and the close undivided attention required for the old methods, I started many months ago to construct a thermometer attachment for our furnaces that would be constantly accurate under all conditions. For this it is essential that the part of the mechanism that shall receive the impressions of temperature shall be within the muffle and be subject to all the changing conditions to which the porcelain being baked is subjected. Owing to the conditions and the wide range of high temperatures only one principle of high temperature measurement is suitable,—viz., the thermo-electric pyrometer method, which consists of an electric couple made of platinum and rhodium, which, when heated at their junctures, produce a very mild electric current which is in constant and direct proportion to the temperature. But this requires an exceedingly delicate apparatus for the measurement and recording of this very small current.

Having successfully designed and constructed an exceedingly sensitive mil-ammeter for cataphoric work, the most sensitive portable mil-ammeter on the market we know of to-day, we had the problem already partly accomplished and have since so completely worked out the detail that I believe we have an instrument in many, if not in all respects, better than the famous German and French pyrometers which cost from $150 to $235, besides being designed for and adjusted to our work, and at a cost of about one-fourth that of the above instruments.

We have constructed it for the furnace of our design to which it is especially well and conveniently adapted, but can be attached to other dental furnaces. The meter indicating the temperature is connected to the furnace with small wires, but can be as far away or as near as desired.

The recording instrument has three scales. The temperature is recorded on both a Fahrenheit and a Centigrade scale, the former reading from thirty-two to two thousand seven hundred and thirty-two degrees, and the latter from zero to fifteen hundred degrees, the two scales being so adjusted to each other that their equivalents always coincide and are simultaneously under the needle. Both scales, which are eight inches long, are divided into subdivisions of ten degrees, which are easily read in smaller subdivisions. Above both of these scales, shown in Fig. 1, I have placed arrows passing through both scales, indicating the fusing point of many of the familiar metals and the proper baking point of all the principal porcelains and body's on the market, also the tooth body's of our principal makers. With this device any porcelain body or enamel can be properly baked without risk and secure its maximum strength without watching the glaring furnace or timing it or using any of the exacting and uncertain methods now in practice. The office girl can make as good bake as the best operator. With it I have made three bakes on a small inlay in ten minutes, about the time it takes to get the asbestos investment dried out in working the low fusing porcelains in a gas furnace. Of course large pieces cannot be baked so rapidly as small ones can with safety. The instrument has a third scale below the temperature scales, the divisions of which are millionths of amperes, or thousandths of milliamperes. This same meter is designed for three purposes by simply moving a switch: For recording the temperature of the dental furnace, recording the current used when applying cataphoresis, and for controlling the gold annealer (when the profession get educated up to it) by recording and indicating the correct temperatures for annealing the various filling golds. We have designed a special gold annealer with a pyrometer attachment, together with several other new features. The arrows on the scale indicate the proper annealing temperatures and time for most of the forms of filling gold and platinum. I have taken these records of proper annealing temperatures and time from the excellent work of Dr. John Callahan, of Cincinnati. The proper baking temperature for the various porcelains and tooth bodies have been taken from the careful determinations of Drs. W. A. Capon, Philadelphia, and Dr. O. M. Le Cron, St. Louis, with some slight additions. The melting points of the metals are taken from the latest determinations of the International Congress of Physics.

Until you see a furnace behave with a pyrometer attached to it, you will not conceive of the variations in its actual temperature. For example, with most furnaces the time required for melting pure gold is less than half for the second heat that it will be the first heat, starting from the cold furnace, and much less than half after several successive heats

These and all stages in between are encountered in regular work which cannot be corrected by allowing for them because they are never constant. Hence, a purely time method of regulating a furnace is never exact. Doubtless many operators will think they can make even and correct bakes until they try it or see it tried with a pyrometer attached. Another very deceiving factor is the varying condition of the eyes on light days or dark ones, in midday or in approaching twilight. What appears to be a red heat in bright midday will appear to be a white heat at night. A factor that has much influence in varying the temperature of the furnace is the door. Whether watching for the glaze on the porcelain or the color of the furnace, it is necessary to have a transparent door or have it open. Thin mica has served a good purpose, but is not clear and has to be frequently renewed. Opening the door when approaching the fusing point is very bad, as it lowers the temperature of the muffle from ten to thirty degrees, and much more than that near the front, and prevents an even baking. We have overcome this difficulty by making the door from a piece of specially prepared quartz which remains perfectly transparent as the clearest glass, and is not often affected by heat or the most sudden changes of temperature. It can be thrown into ice water at white heat and not check in the least. The door is pivoted at the side and with a slight touch is open or shut. For those working without the pyrometer this transparent door will be a great convenience and advantage.

There are several factors of quality that all good dental furnaces should possess, but which unfortunately but few of them do, it is a positive necessity for the best results that the dental furnace be capable of very close control, which is only done by the adjustable resistance or rheostat. It is impossible to evenly bake a large piece in a furnace that has but two or three stops in the rheostat, because the proper baking temperature cannot be secured for all parts of the piece, except by holding the temperature at just the proper point for some time by means of the rheostat, otherwise the temperature will advance away beyond the proper point and some parts of the piece will be overbaked before other parts have reached the fusing point. We have not realized this because we could not tell without a means of recording the temperature what was going on. Who that has done much porcelain work has not seen a crown come out of a finished bake with the enamel on the cusps whitish and even full of little bubbles and the same grade of enamel at the neck or some other part of the crown not even properly glazed. Simply the result of not checking the rise of temperature at just the proper baking point until the entire mass has acquired that temperature. A crown or an inlay can be kept at the baking temperature for a long time without injury,

but if allowed to go even a little too high is seriously injured. For this reason we have put on our furnace nine steps of resistance in the rheostat

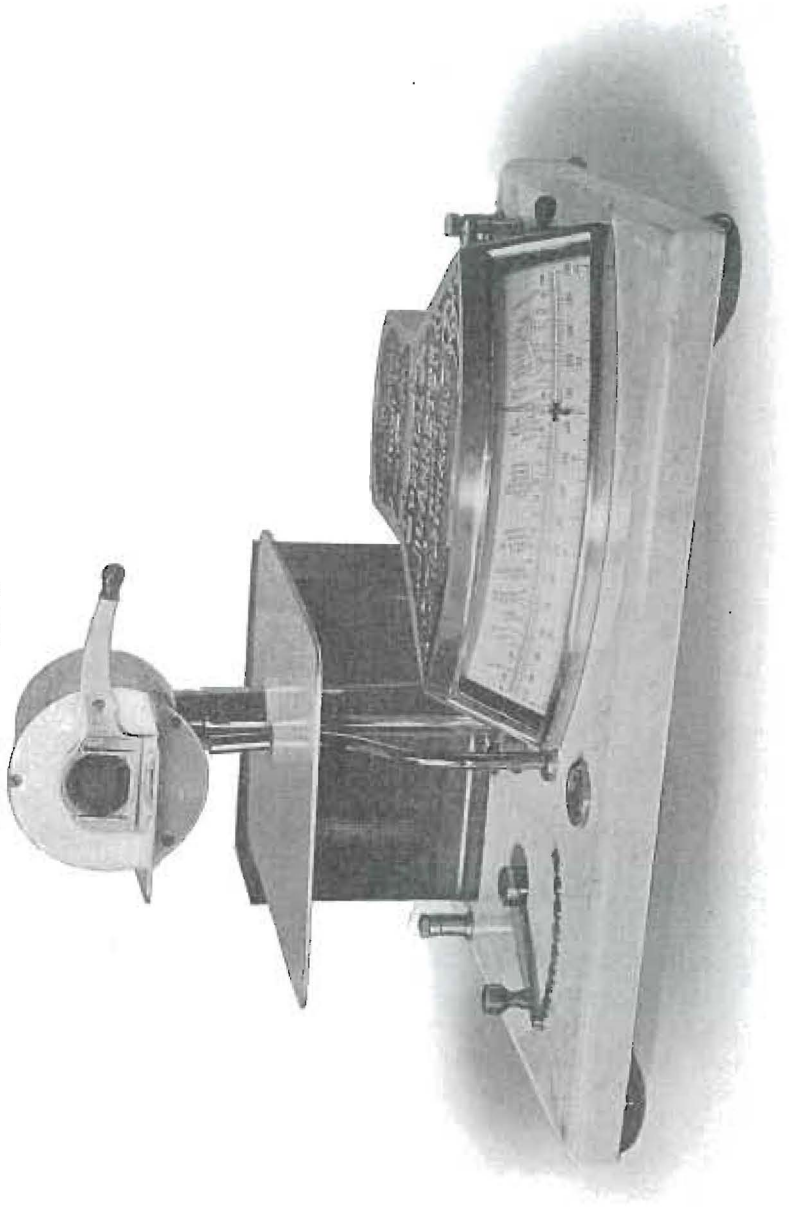

FIG. 1.

so that the temperature can be kept under perfect control. The comparison could well be made to a vulcanizer, the burner of which would

only allow of say two or three sizes of flames. For example, two similar buttons of Brewster Body were fused; the first stopped at the fusing point, and the other held for two minutes. The latter crushed at eight hundred and twenty-five pounds and the former at seven hundred and thirty pounds.

One of the most important factors of the dental furnace is the muffle, and its life and usefulness depend mainly on two things—the materials used and their arrangement. All the materials entering into the construction of the muffles have expansion on heating and contraction on cooling, and it is chiefly the uneven rate of expansion and contraction of the platinum in the muffle that in time causes it to weaken at some point and finally sever or burn out, as it is called. Several devices and schemes have been used to overcome this, chiefly by making frequent turns in the platinum so that the expansion and contraction would make a bend at a corner instead of stretching and condensing it. This requires tedious and expensive hand labor for the construction. We have accomplished this by putting the platinum into the shape of a fine sinusoidal wave, each wave about a sixteenth of an inch in length, including the two curves. In this form it can be wound onto the muffle in the lathe, thereby saving enormously in the expense and accomplishing the desired end in an ideal way.

To heat evenly, the muffle should be concave at the back on the inside and be heated throughout the back. Very few furnace makers have undertaken to heat the back of the muffle which we do by extending the circular winding in this shape in the back. With this shape and method of distribution the heat is very even throughout the muffle, as shown by testing with the pyrometer in various positions.

It has been suggested that there is less distortion of the matrix if the porcelain is heated mostly from beneath. To secure the condition we have devised a shell, the shape of the muffle, but without a bottom, which slides into the muffle and cuts off the heat from above, thus very simply and efficiently securing the condition.

There are very few finishes that will continue to look well on the outside of a dental furnace, for which reason we have used an alloy of pure nickle and aluminum for the entire furnace, which always looks clean and white and bright.

Owing to the difference in taste and available room these furnaces are made in six sizes and designs. Fig. 1 shows a compact outfit consisting of a large size nickel aluminum furnace mounted on a polished white marble base with the thermo-electric pyrometer, the nine point rheostat, the pivoted quartz door, and corrugated wound muffle with concave heated back, and large drying and working shelf, and a cooling

and annealing tray. This latter consists of a small covered tray lined with asbestos, into which the articles to be dried or cooled are placed. For drying it is set on the rheostat cover, which is warm enough, and for annealing or slowly cooling crowns and large inlays by placing them

FIG. 2.



in it away from the air and in which they are carried to the bracket and kept from sudden changes of temperature.

A very convenient arrangement is made of the large or smaller furnace on a slate base, with all the improvements except the pyrometer, which can be attached separately at any time. This arrangement is similar to Fig. 1 without the pyrometer. Fig. 2 shows a condensed form of either size, where space is a chief factor. It contains all the improve-

ments except the pyrometer, which can be attached and is designed to go inside the regular roll-top desks and gold-benches, etc.

The furnaces and muffles are made in two sizes and are interchangeable on any base. The muffles have the following dimensions: $1\frac{1}{4} \times 1^{1}/_{16} \times 2$ and $\frac{7}{8} \times \frac{7}{8} \times 1\frac{1}{2}$.

The pyrometers are practically indestructible and unchangeable in regular use. For those wishing it, the information, such as baking temperatures, can be had on a separate card and a plain temperature scale used on the meter.