NATIONAL BUREAU OF STANDARDS REPORT

6667

Progress Report

on

SURFACE ROUGHNESS OF DENTAL GOLD CASTINGS

by

Joseph J. Barone
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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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SURFACE ROUGHNESS OF DENTAL GOLD CASTINGS

Abstract

The effect of varying burnout and casting temperatures on the surface roughness of dental gold castings has been studied. Data relating the degree of surface roughness of various alloys to nominal temperatures of the mold as removed from the oven after burnout and that of the molten gold alloy when cast have been recorded for 273 dental gold alloy castings cast with burnout temperatures varying from 800°F to 1600°F and alloy casting temperatures varying from 1725°F to 2400°F. Extremely high mold and metal temperatures appear to increase surface roughness irrespective of alloy used. The effect of high temperatures seems to be an additive one. At burnout temperatures to 1300°F and metal casting temperatures to 2000°F and in some instances to 2100°F surface roughness appears to be constant at approximately 30 microinches. In repeat castings of one alloy, seventeen times, surface roughness was constant when burnout and alloy casting temperatures were held constant. Reusing the alloy did not affect surface roughness.

1. INTRODUCTION

The surface of a dental gold casting should be an accurate reproduction of the surface of the wax pattern from which the casting was made. In practice, however, most castings have a significantly greater surface roughness than do the corresponding wax patterns. Excessive roughness necessitates additional polishing of the casting and affects its dimensional accuracy. A general study of the surface roughness of dental castings has been made by Pomes, Slack and Wise [1]. In a paper on the reproducibility of gold castings Suffert and Mahler [3] concluded that the inherent surface roughness or texture of the casting will appreciably affect the subsequent fit. In this present report emphasis is placed on the relationship of surface roughness to burnout and casting temperatures.

Surface roughness is described as relatively finely spaced surface irregularities the height, width, and direction of which establish the predominant surface pattern [2]. It is this predominant surface pattern, the surface roughness, that has been measured in this study. Isolated surface irregularities due to improper technic are not discussed.

2. EQUIPMENT AND MATERIALS

The major equipment used for preparing the molds and making the castings consists of a Whip-Mix mechanical hand spatulator or mixer, a Jelenko Model A Vacutrol, a Jelenko burnout oven Type 13 AM, and a Jelenko Model D-2 Thermotrol casting machine.

The Whip-Mix Corp. 4 inch mechanical hand mixer consists of a 4 inch, rubber, plaster bowl and a four inch blade, hand driven by an egg beater type mechanism.

The Model A Vacutrol consists of a vacuum pump mounted inside a cabinet. The inlet of the vacuum line and a vacuum gage are located on the counter top of the cabinet. A bell jar is placed over the vacuum inlet and the rubber bowl containing the investment.

The Jelenko burnout oven is equipped with a percentage timer so that heating can be controlled by adjusting the relative percentages of time per minute that the oven is on and off. The temperature of the oven is indicated on a dial face below the oven door. Calibration data demonstrated that after a period of approximately one hour oven dial temperature readings corresponded to actual center of mold temperatures as measured with a thermocouple.

The casting equipment, the Jelenko Model D-2 Thermotrol is similar to a conventional centrifugal dental casting machine except that it contains an electrically heated oven for melting the alloy. The oven control box contains two dials which indicate the temperature and current within the casting oven and a rheostat which controls the current supplied to the oven heating element.

The temperature dial was calibrated in °F both before and after the 273 castings were completed. The data obtained indicated that in the range of casting temperatures used

(1750°F to 2400°F) the true temperature in the muffle was approximately 100°F below that indicated by the temperature dial at the beginning of the series of castings and approximately 100°F above the dial reading at the end of the series. The casting temperatures reported have been corrected on the basis of a uniform change in calibration (0.7°F per casting) over the series of castings.

The instrument used to measure the arithmetic average surface roughness of the dental casting is the Surfindicator Model BL-110 and an accessory Motor Drive, Model BL-110, manufactured by the Brush Electronics Co. of Cleveland, Ohio. The instrument functions very similarly to a phonograph pick-up arm. A diamond stylus, with a point of .0005 in. radius, exerting one gram pressure, and traversing 1/8 inch per second, was adjusted to travel 1/4 inch in a reciprocating motion over the surface of the dental casting. The up and down vertical displacements of the stylus as it moves over the surface are reproduced as a varying potential by a transducer. The varying potential from the transducer is then fed through an electronic amplifier and from there to the power output meter. A standard ruled block is used to calibrate the meter in arithmetical average deviation in microinches from the mean line.

Beauty-Cast inlay investment was employed. Kerr's pink casting sheet wax gage 22 was used for the pattern because the resulting casting afforded two extensive surface areas for measuring surface roughness. This wax is reasonably smooth as

manufactured. Its surface roughness was found to be 10 micro-inches when measured with a microinterferometer. Three casting gold alloys were used in the experiments. Ney-Oro A-1, Type II, Medium, casting gold alloy was used for 209 castings. Two Type III, Hard, white casting gold alloys manufactured by Julius Aderer, Inc. were also used in the experiments. These were Multicast a medium fusing Type III alloy used in making 33 castings and Procast a high fusing alloy used in making 31 castings.

3. PROCEDURE

In order to limit and control the many variables present in making dental castings, the same method of investing, wax elimination, and casting was used throughout the experiments. A thermal expansion technic familiar to dentists and dental laboratories was employed. Briefly it consists of using one brand of inlay dental alloy casting investment at a controlled W/P ratio; a half inch square of gage 22 (.025 in.) pink sheet casting wax sprued and invested similarly for all castings and one of three dental gold alloys.

The one-half inch square patterns were mounted on a 3/32 inch sprue as shown in Figure 1. The investment at a water to powder ratio of 51 cc of water to 150 grams of powder was mixed using the mechanical hand spatulator. Each mix contained sufficient investment for four inlay molds. After mechanical mixing, the investment was freed of air bubbles by using the Vacutrol machine. The dry, wax patterns were painted with investment and the molds were poured in conventional inlay rings lined with

a wet asbestos liner. After pouring, the molds were permitted to set at room temperature for approximately one-half hour and then placed in a 100% relative humidity container from which they were transferred to the burnout oven when required.

Two molds were placed in the burnout oven, brought to the desired temperature and held there until the time of casting. The entire burnout process lasted for at least an hour so that the center of the mold reached the temperature of the oven. The balance arm of the casting machine was wound three revolutions and set in place. The dental casting oven was heated using 5-1/2 amperes. When the oven reached a temperature of 400°F below the casting temperature 4 pennyweight of gold alloy was placed in the oven. Just prior to the time when the casting temperature was reached, the insulating ring was removed and replaced by a heated mold from the burnout oven. As soon as the casting temperature was reached the balance arm was rotated clockwise slightly so as to disconnect the oven and was released to make the casting. The oven was allowed to cool below the temperature at which the gold was inserted, reheated with the insulator ring in position and a second casting was prepared in a like manner. The time between the formation of the castings was about ten minutes. The castings were bench cooled until the disappearance of the redness of the heated alloy, quenched in water, removed from the molds, washed, pickled in 50% diluted, boiling sulfuric acid and washed again. Each of the prepared castings in turn was placed horizontally under the stylus of the Surfindicator

and roughness was measured in two directions at right angles to each other. This procedure was done on both sides of the casting.

4. RESULTS

Surface roughness measurements were made on a total of 273 castings made with burnout temperatures varying from 800 to 1600°F and with casting temperature from 1725 to 2400°F. Typical results for a series of castings made with a constant burnout temperature and with various casting temperatures are shown in Figure 2. The points plotted in the figure give an indication of the variation of individual specimens. In this instance all specimens fall within 10 microinches of the smooth curve drawn through the points. Larger variations were observed for castings with higher roughness values.

A statistical analysis of the results obtained on 48 specimens was made to evaluate the variability of the surface roughness values on the same casting and between castings. Each measurement is the average of a "high" and "low" reading of the power meter. It was found that the measurement is slightly more reproducible on the same side of a casting than on opposite faces. Also some additional variability is generally observed between replicate castings.

The components of variance (individual contribution to the total variability) for these sources of variation are as follows (in microinches squared):

Between directions on the same side of a casting --- 12

Between two sides of a casting --- 4.5

Between two castings --- 25

For each condition (given burnout temperature and casting) two castings are measured, each on both sides and in two directions. The average of the 8 measurements thus obtained has a standard deviation of 3.9 microinches. Thus, the uncertainty interval for such an average based on a 95% confidence coefficient extends approximately from 7.8 microinches below the calculated average to 7.8 microinches above this average.

To ascertain the accuracy of measurement of the Brush Surfindicator an independent check was done on 2 sample castings by using a model 3 Taylor Hobson Talysurf of known calibration. The average difference between surface roughness values obtained from the Surfindicator and the Talysurf amounted to 3 microinches. This difference was consistently in one direction, the Surfindicator values being lower than those of the Talysurf.

The effects of variations in burnout and casting temperatures on the surface roughness of castings made from the three alloys are shown in Figures 3, 4 and 5. In Figure 3 the curves for 1100°F and 1400°F burnout are based on 3 and 4 points, respectively, while the other curves represent 5 to 13 points.

Curves in Figures 4 and 5 are based on only 3 points, one at each end and one near the middle of the range of casting temperatures shown. Each point represents an average of eight measurements, four on each of two specimens.

With all of the alloys increases in either burnout or casting temperature tended to result in increased roughness. For burnouts below 1200 to 1300°F and casting temperatures below 2000 or 2100°F roughness variations were slight. Above these temperatures significant increases in roughness were observed.

To determine whether or not reuse of gold alloy affected the surface roughness of castings, one lot of alloy was melted and cast 17 times with a burnout temperature of 1200°F and a casting temperature of 2000°F. The results are shown in Figure 6. No significant differences in surface roughness were observed. Figure 6 also gives an indication of the reproducibility of the roughness determinations. Each point represents the average of eight values (2 measurements on each side of duplicate specimens). The standard deviation of the values is shown by the vertical lines through the points.

5. DISCUSSION

The difference between the surface roughness of the wax (10 microinches) and that of the castings made under optimum conditions (approximately 30 microinches) may be connected with the particle size of the investment and its inability to reproduce precisely the wax pattern surface in microinch detail. The increased surface roughness of the dental castings for temperatures above optimum conditions can probably be explained by deterioration of the investment surface and increased fluidity of the molten alloy at the higher temperatures. The increased fluidity probably causes the molten alloy to penetrate between the mold particles to greater depths than the same gold alloy does when cast at lower temperatures. At extremely high

temperatures the investment adheres tenaciously to the gold alloy. This was originally pointed out by Pomes and can be substantiated by the use of the microscope.

The relationship between roughness as described in this report and dimensional accuracy has not been determined. However, if it is assumed that the roughness consists of numerous uniform projections added to the surface of the casting, an estimate of the possible effect of roughness on dimensional accuracy can be made. The roughness values reported here represent the average deviation from a mean line. Assuming that maximum deviations extend a distance of twice the average both above and below the mean line, the overall distance from top to base of the projections would be four times the average roughness values. For optimum casting conditions this would amount to 4 x 30 microinches or 120 microinches. Since dimensional accuracy of a casting would usually be affected by roughness on two surfaces the total effect would be 240 microinches. Over a 1/4 inch distance on a casting this would be equivalent to 0.1% and would have little clinical significance. For the highest roughness values measured, approximately 160 microinches, the effect would amount to 0.5% and could be expected to have a clinical effect. Roughness of this magnitude would seldom be encountered in practice. Thus, it may be concluded that surface roughness as such is probably not a major factor in dimensional accuracy. This surface roughness should not be confused with surface irregularities caused by fins or bubbles which are characteristic of poor investing technics.

6. CONCLUSIONS

1. When using a thermal expansion technic as described, surface roughness is constant at approximately 30 microinches at burnout temperatures from 800°F to 1300°F and at casting temperatures within approximately 300°F above the liquidus temperature of the three dental alloys used.
2. At burnout temperatures above 1300°F and at temperatures more than 300°F above liquidus temperature of the three alloys used, surface roughness generally increases with temperature to a value approximately 5 times the 30 microinches obtained at optimum temperatures.
3. Remelting or reusing the same gold alloy over as much as seventeen times did not affect the surface roughness of the dental casting when cast under optimum conditions.

BIBLIOGRAPHY

1. Pomes, C. E.; Slack, G. L. and Wise, M. W. Surface Roughness of Dental Castings. J.A.D.A. 41:545, Nov. 1950.
2. American Standard Surface Roughness, Waviness and Lay. ASA B46.1, 1955.
3. Suffert, L. W. and Mahler, D. B. Reproducibility of Gold Casting Made by Present Day Dental Casting Technics. J.A.D.A. 50:1, Jan. 1955.

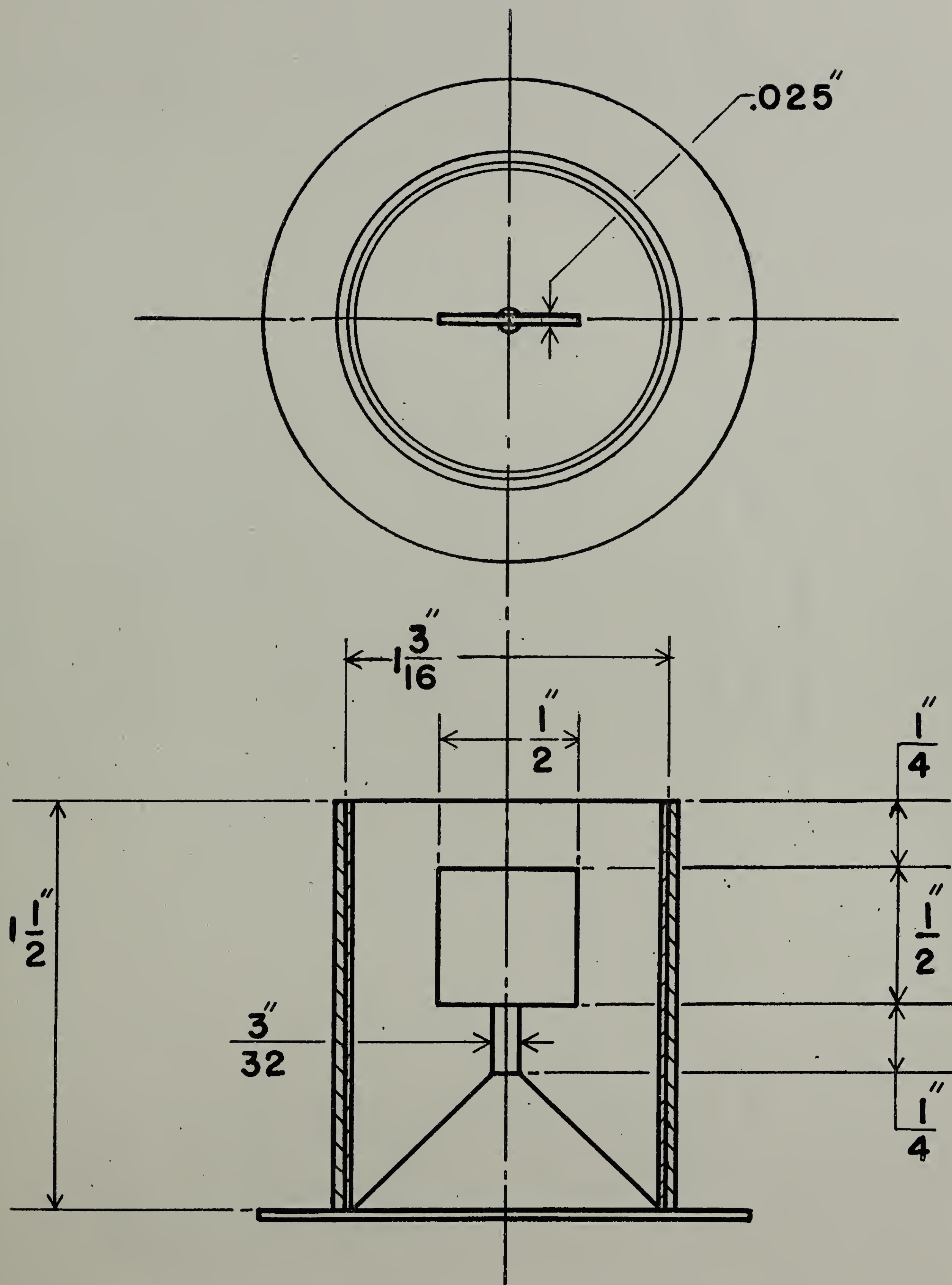

Figure 1. Dimensions of casting.

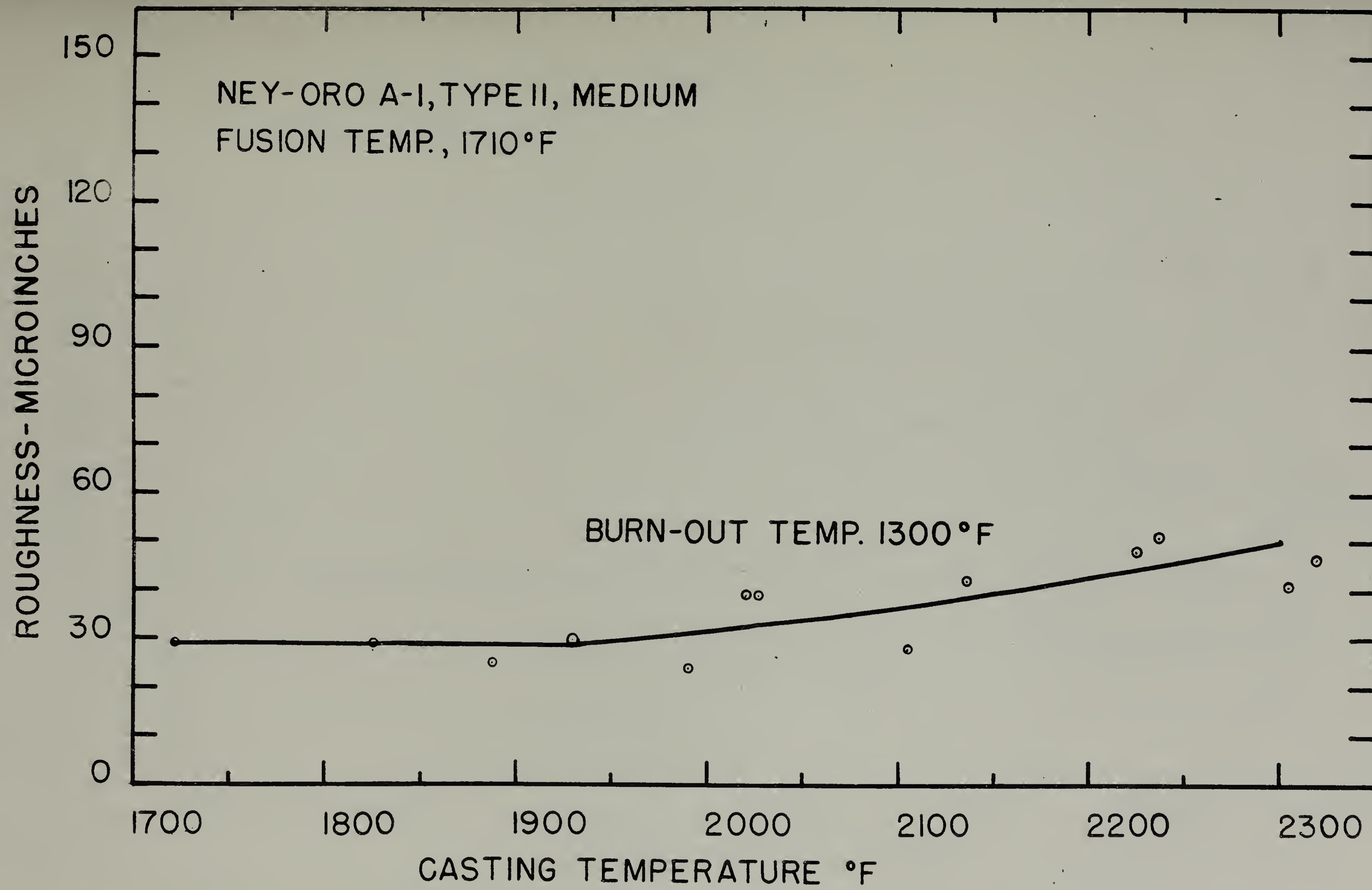

Figure 2. Typical distribution of surface roughness determinations.

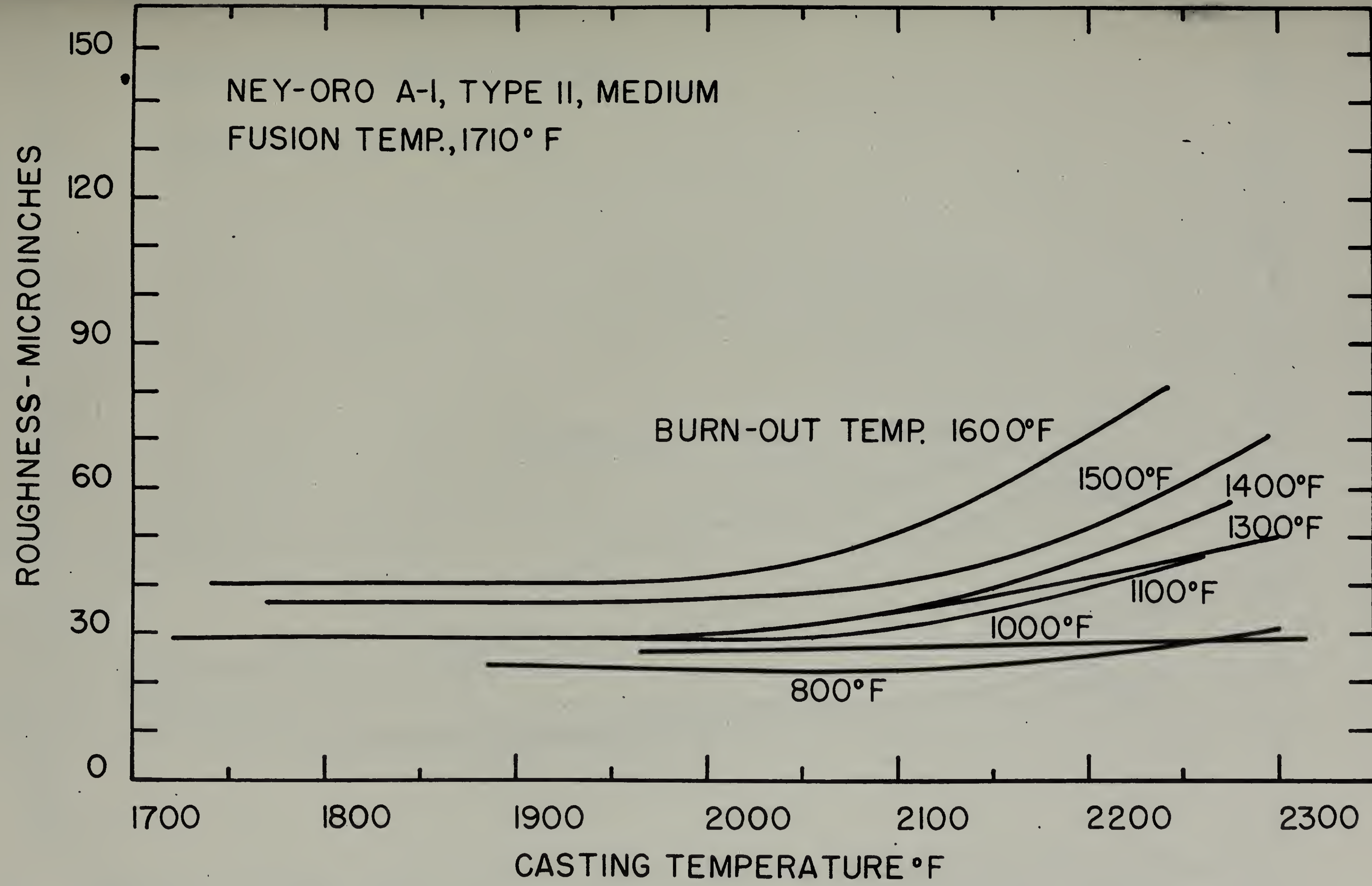

Figure 3. Effects of burnout and casting temperatures on the surface roughness of castings made with a Type II, Medium, gold alloy (Ney-Oro A-1).

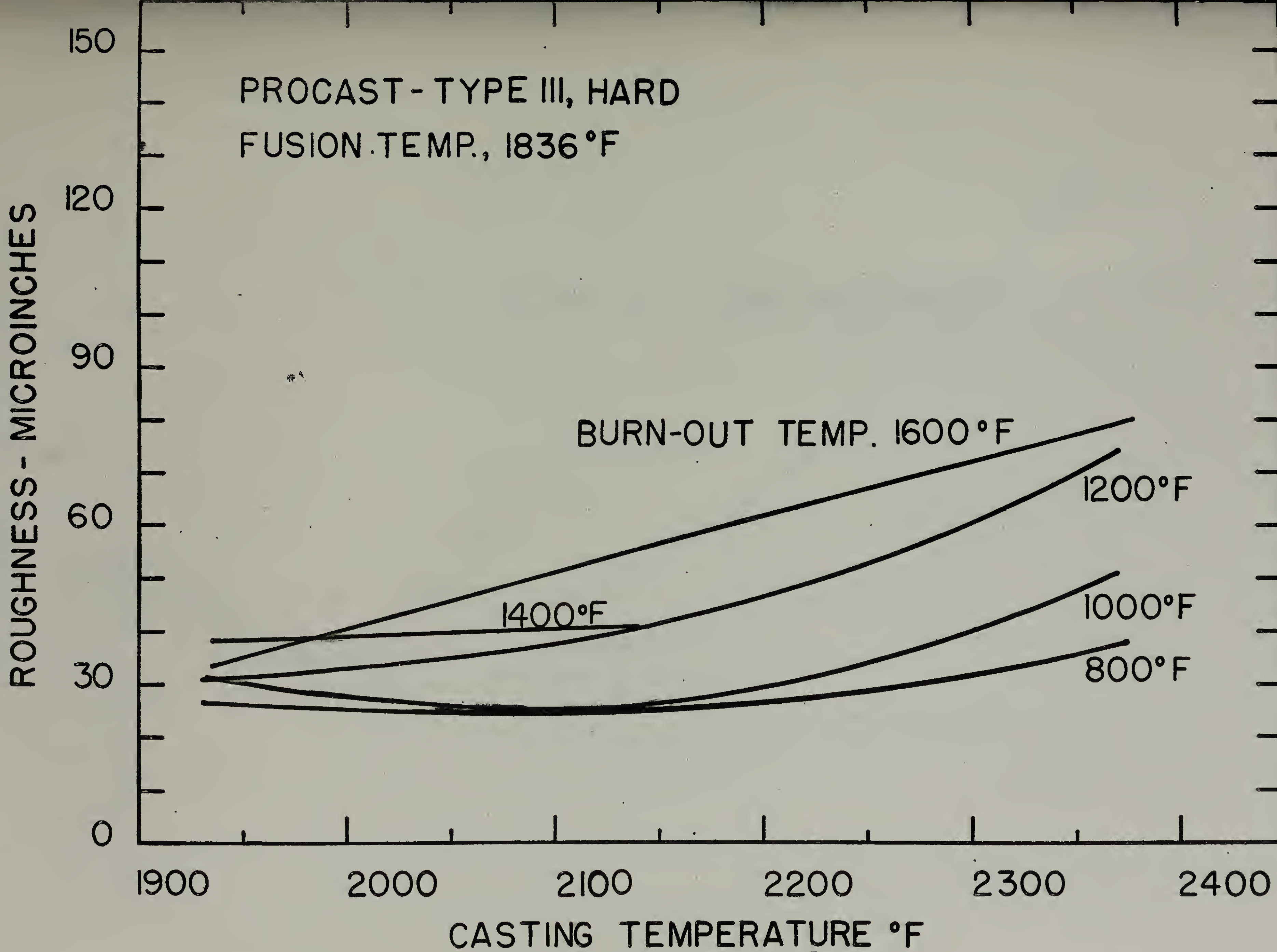

Figure 4. Effects of burnout and casting temperatures on the surface roughness of a Type III, Hard, gold alloy (Procast).

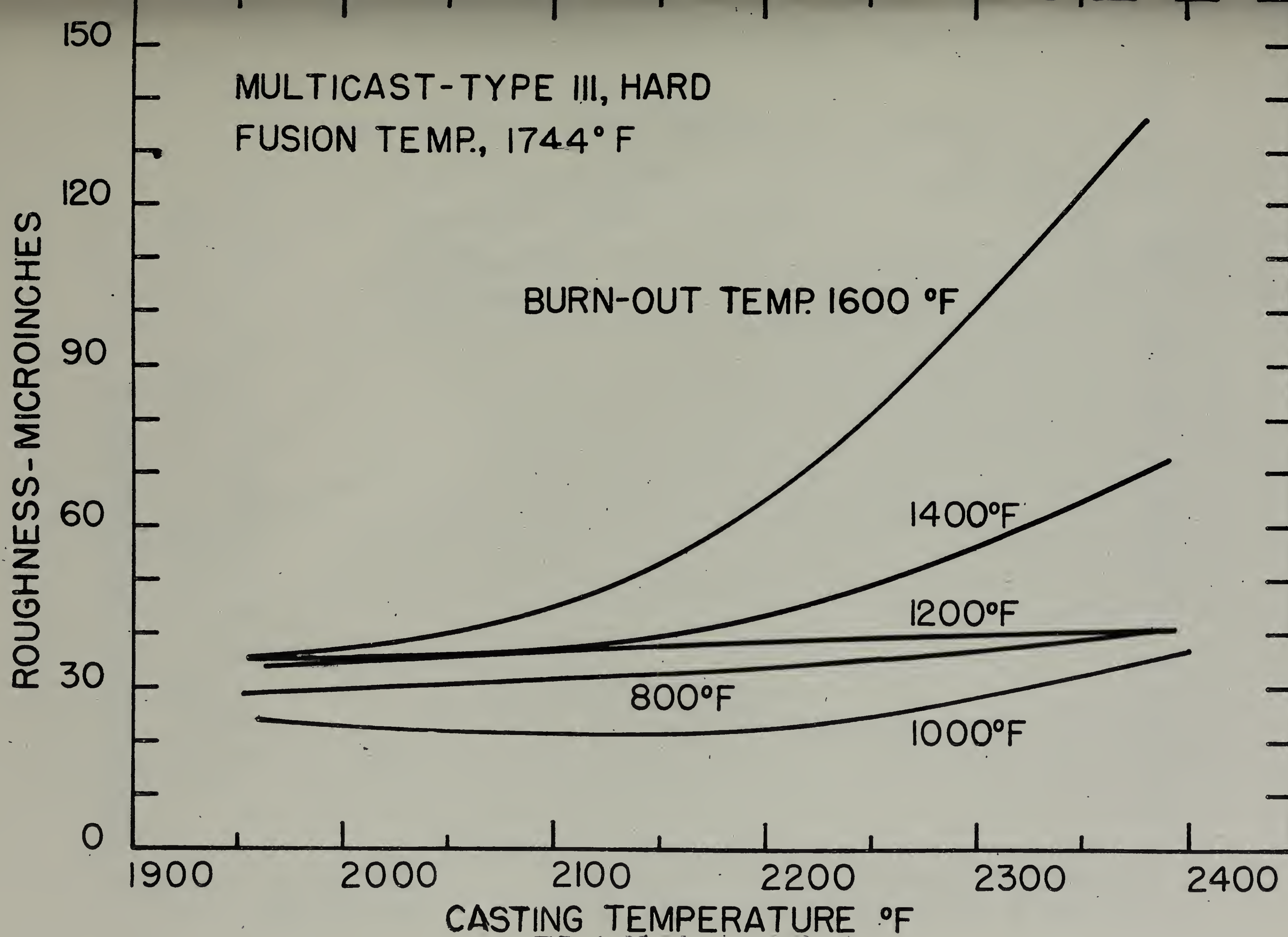

Figure 5. Effects of burnout and casting temperatures on the surface roughness of a Type III, Hard, gold alloy (Multicast).

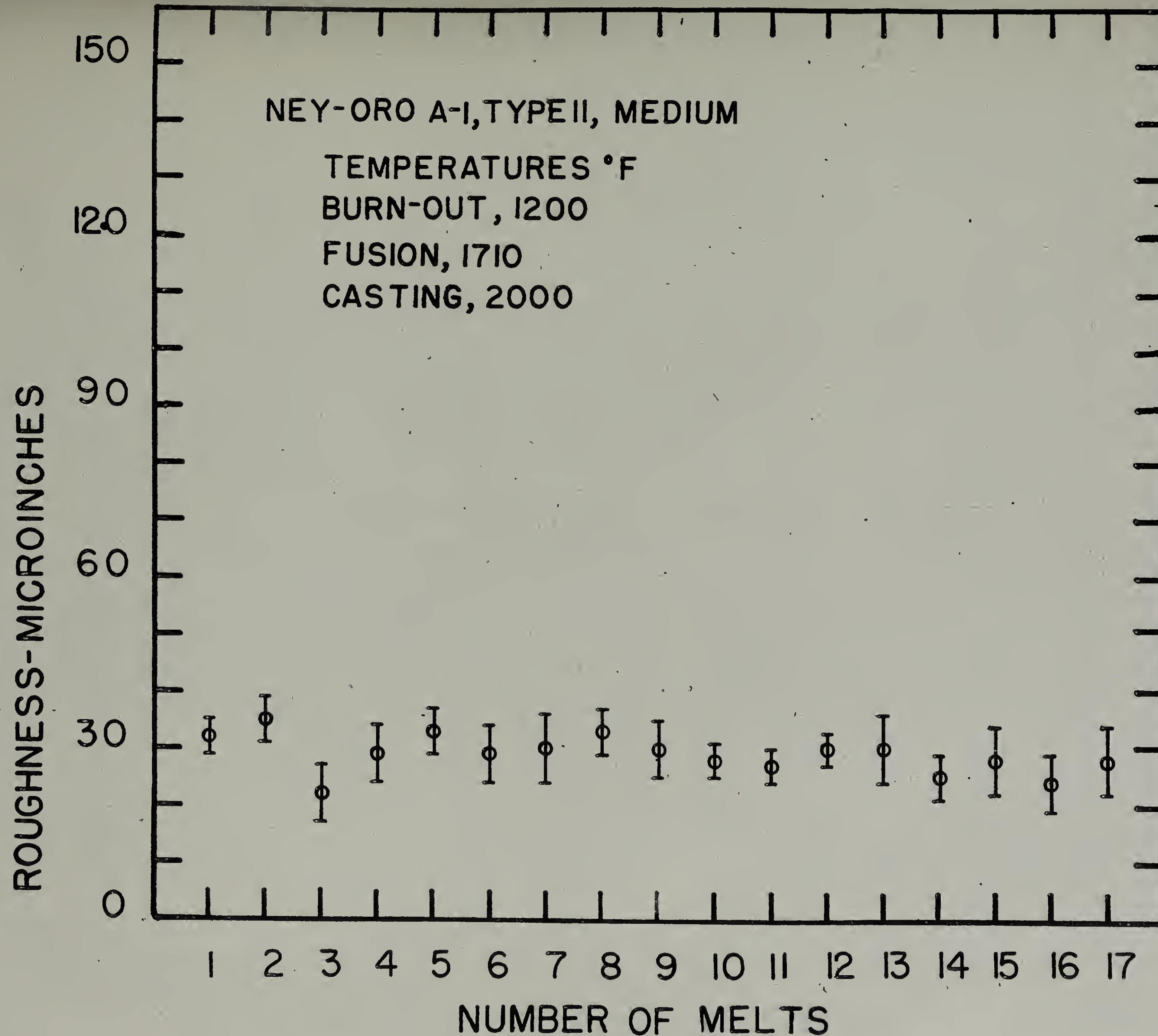

Figure 6. Effect of remelting on surface roughness. Vertical lines represent standard deviations.

U.S. DEPARTMENT OF COMMERCE
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THE NATIONAL BUREAU OF STANDARDS

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