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Detection of Velocity in High Temperature Liquid Metals

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Abstract

Various efforts have been made to measure velocity in liquid metals. All of these efforts, however, share the same inherent limitation, namely not being operative at the high temperatures required by liquid metals and liquid slags in an industrial application. In this paper the current methods used were reviewed, and a new technique was presented for the measurement of velocity in high temperature liquid metals. In using this technique there are two stages. Starting with the calibration stage and then moving to the actual measurement stage by making use of the data obtained from calibration stage.

Calibration proceeds in the following manner. Metallic spheres moving with a specific velocity are immersed in liquid metal held under isothermal conditions and at specific temperature. Their melting times are determined very accurately with a novel technique. These measurements are repeated for different metal bath temperatures and for different velocities of metallic spheres. In this manner it is possible to calculate the correlation between velocity and melting times for each metal bath temperature.

During the actual measurement stage, when the metal bath temperature is known and its velocity is unknown, the magnitude of the unknown liquid metal velocity can be derived as follows: Metallic spheres are immersed into the moving liquid metal and their melting times are determined. Using the above mentioned correlations, it will be shown that the magnitude of the unknown velocity in liquid metal can be deduced.

This new technique was applied to high temperature liquid aluminum and liquid steel and these results were presented. The potential applicability of this technique in other liquid metals and liquid slags was also be discussed.

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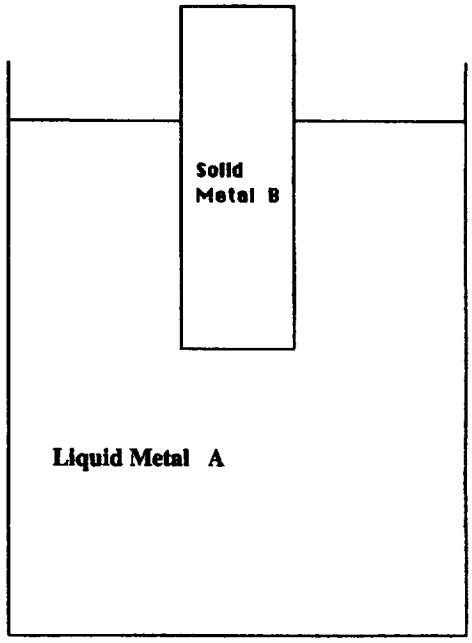
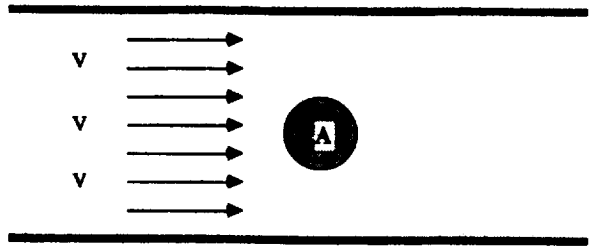
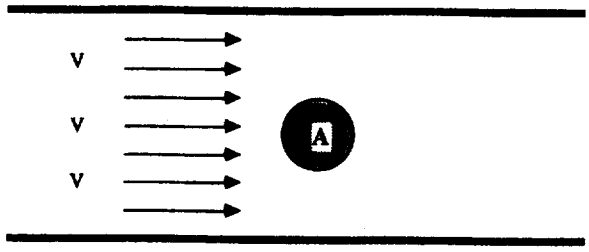




Liquid Metal A

Solid Metal A



Melting of Sphere = f (T, V)

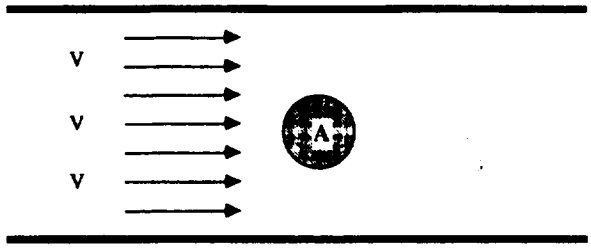
T: Metal Temperature

V: Metal Velocity

In isothermal Conditions where the flowing Metal is at constant temperature , T , then

Melting Time of Sphere = f (V)

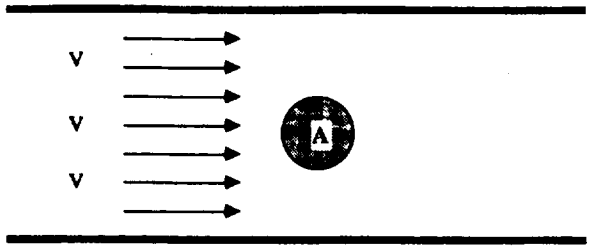
V: Metal Velocity



In using this technique there are two stages.

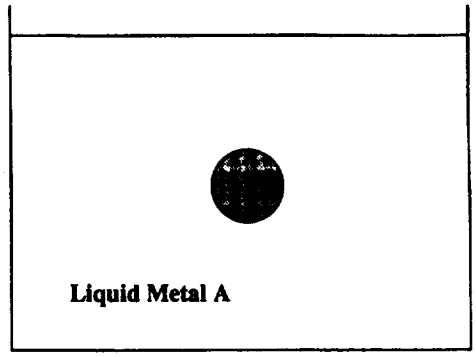
First the Calibration Stage

Second the Actual Measurement Stage

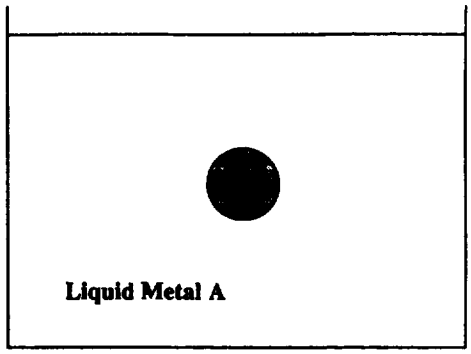


In the Calibration stage the Liquid metal is held in isothermal conditions T

The Solid sphere is moving with certain speed V



In the Measurement Stage the Sphere is held motionless and the liquid metal is moving with a velocity V



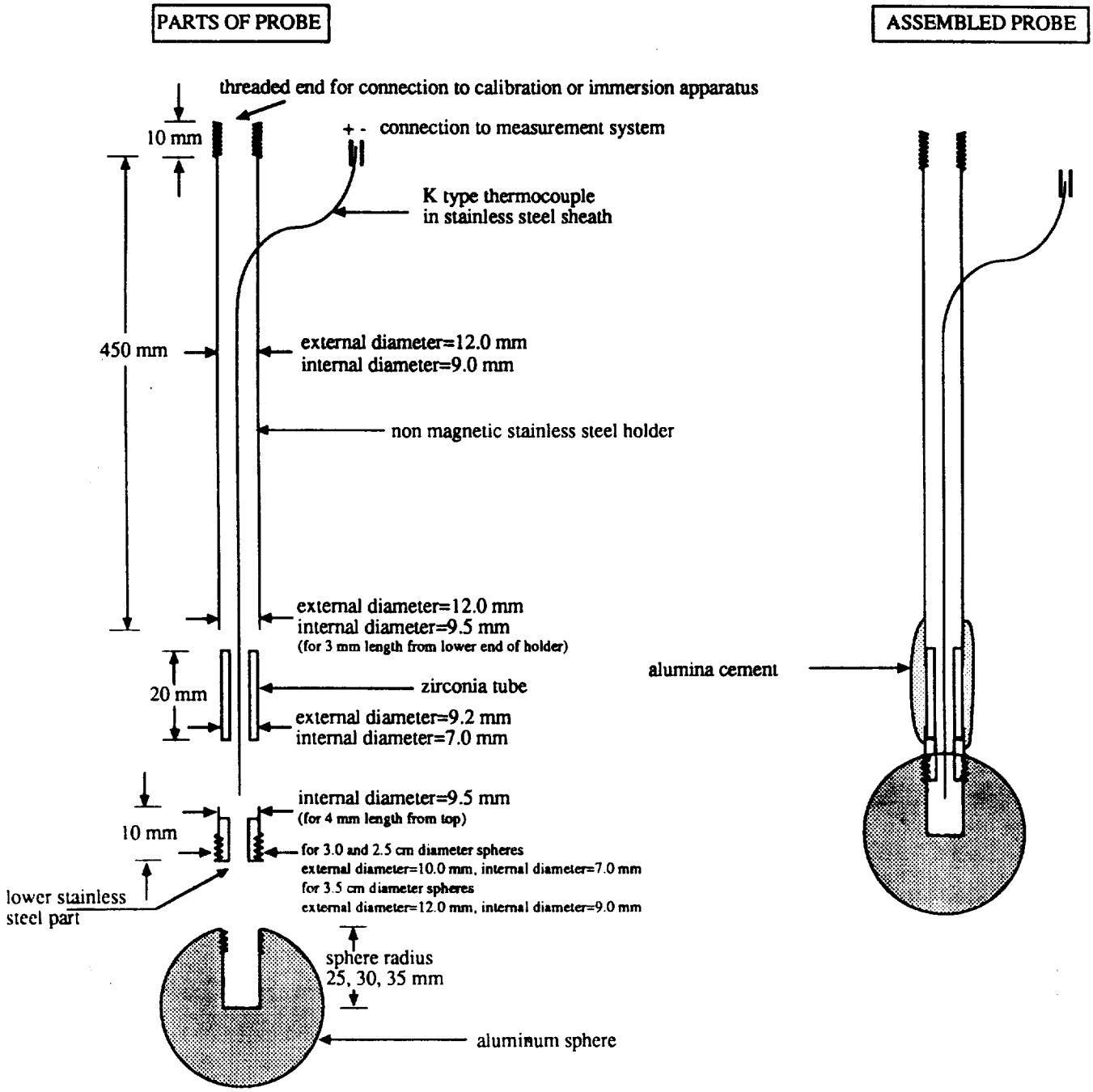


Figure 1 Schematic diagram of the probe employed in liquid aluminum baths.

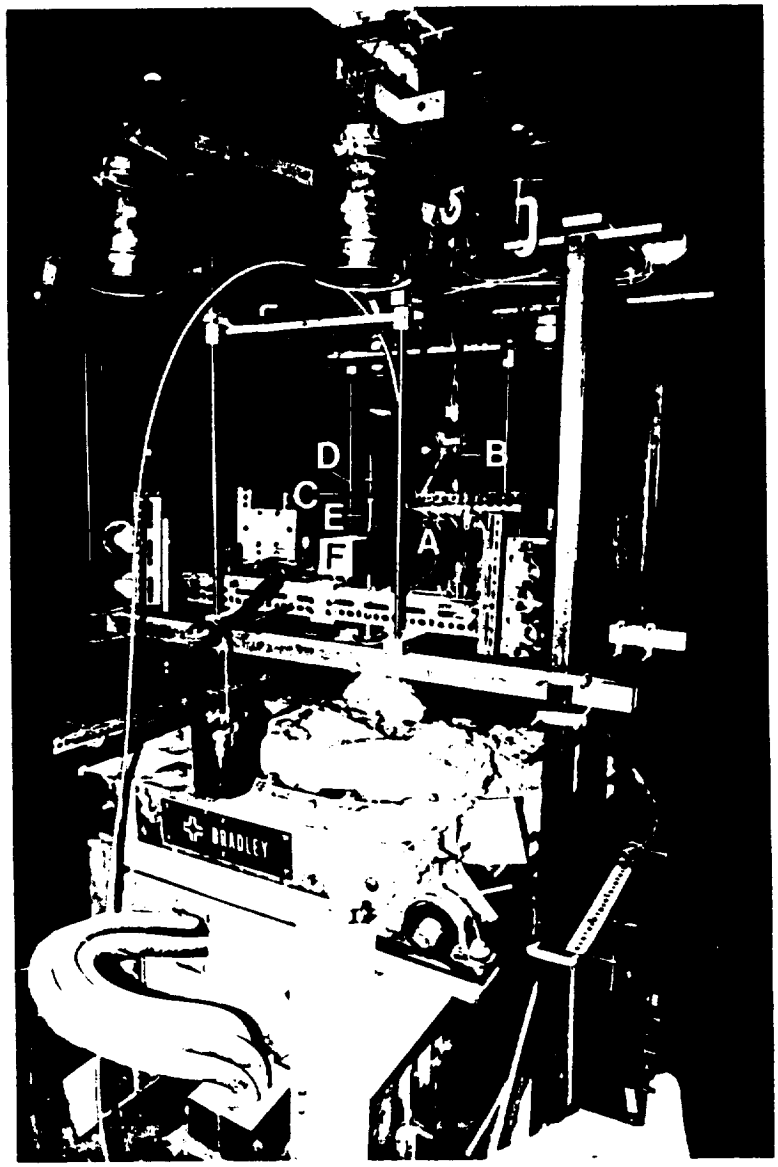


Figure 2 The experimental setup for stirring spheres in liquid aluminum. (A) motor (B) absolute encoder (C) chain (D) gears (E) hollow shaft (F) aluminum block.

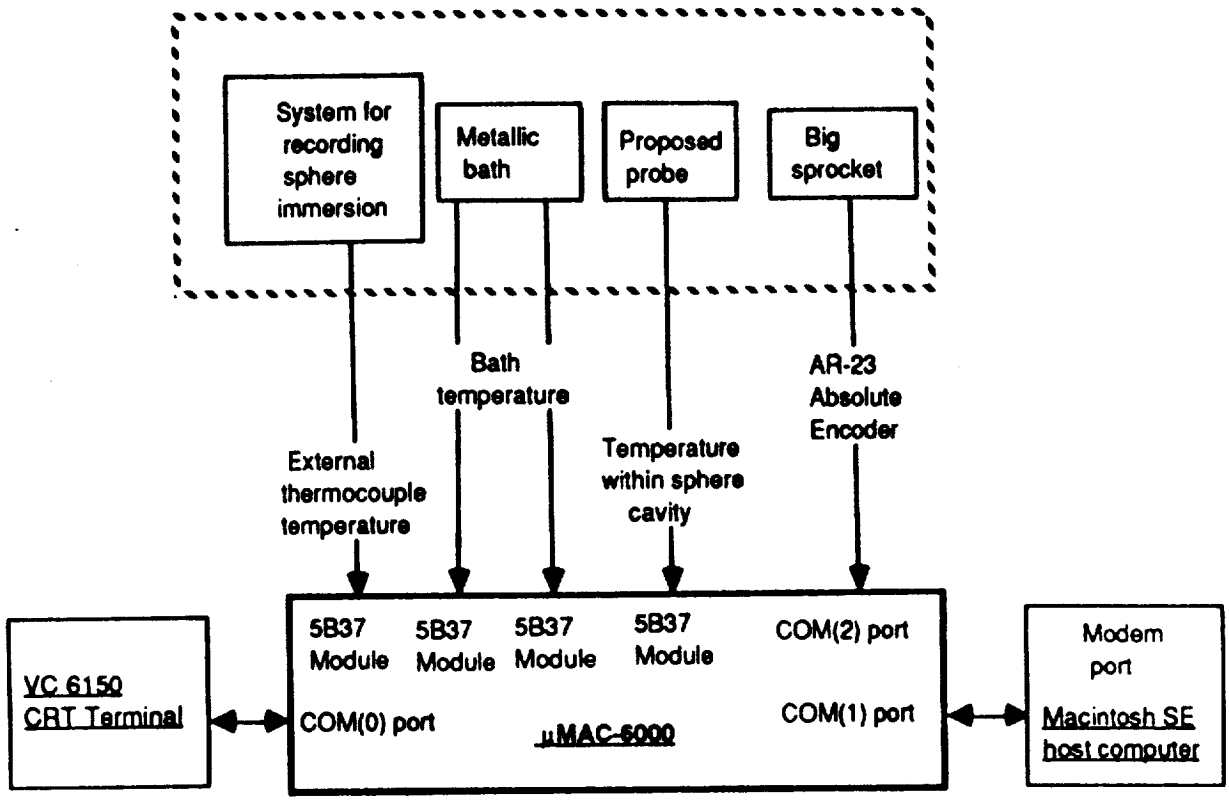


Figure 3 Schematic diagram of the data acquisition system.

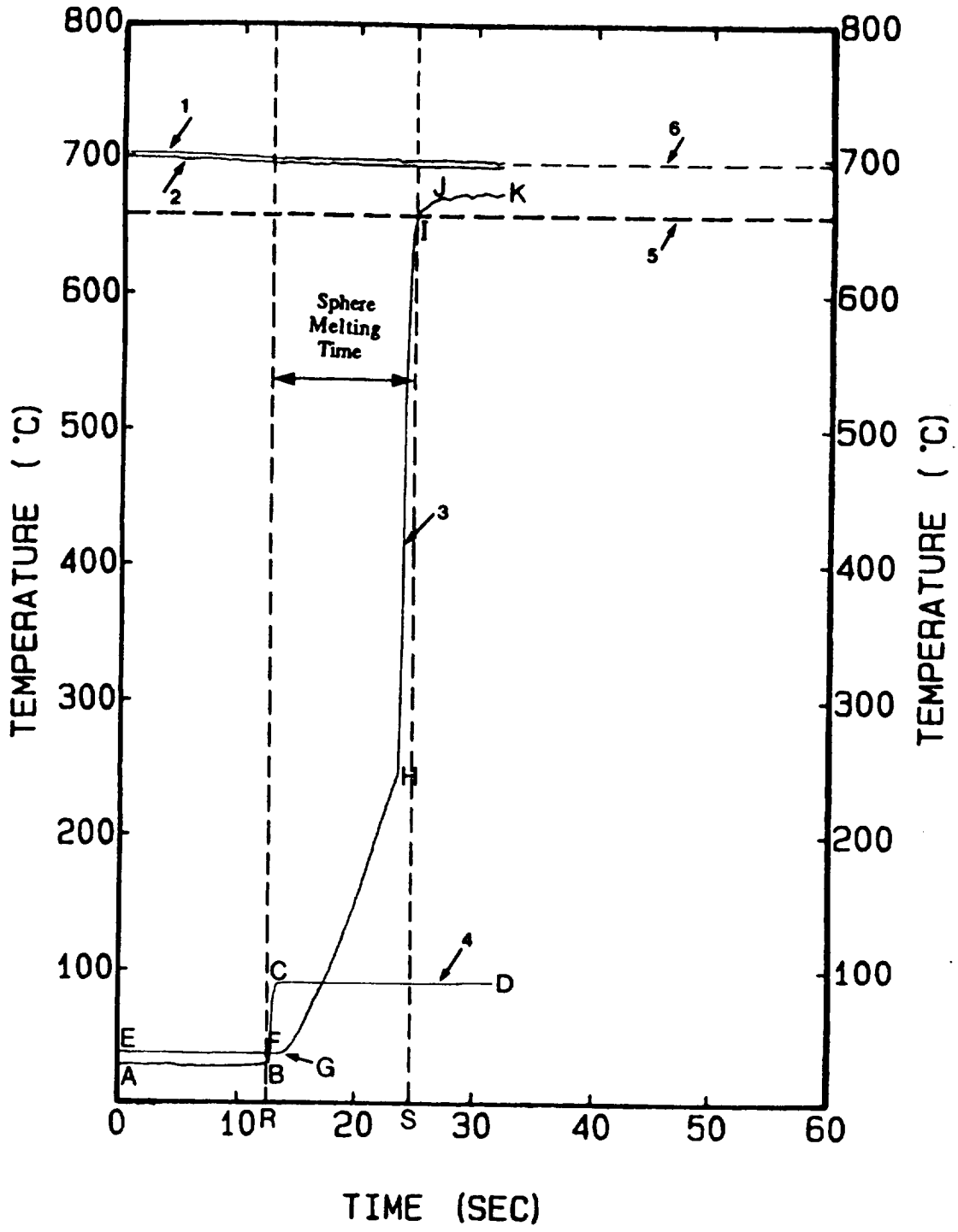


Figure 4 Typical experimental results using the probe with one external thermocouple. Curves 1 &2: Representative bath temperature readings. Curve 3: Temperature profile of probe thermocouple. Curve 4: Temperature profile of external thermocouple that records immersion time. Curve 5: Aluminum melting point. Curve 6: Temperature reading of independent thermocouple at the sphere immersion point at the end of the experiment.

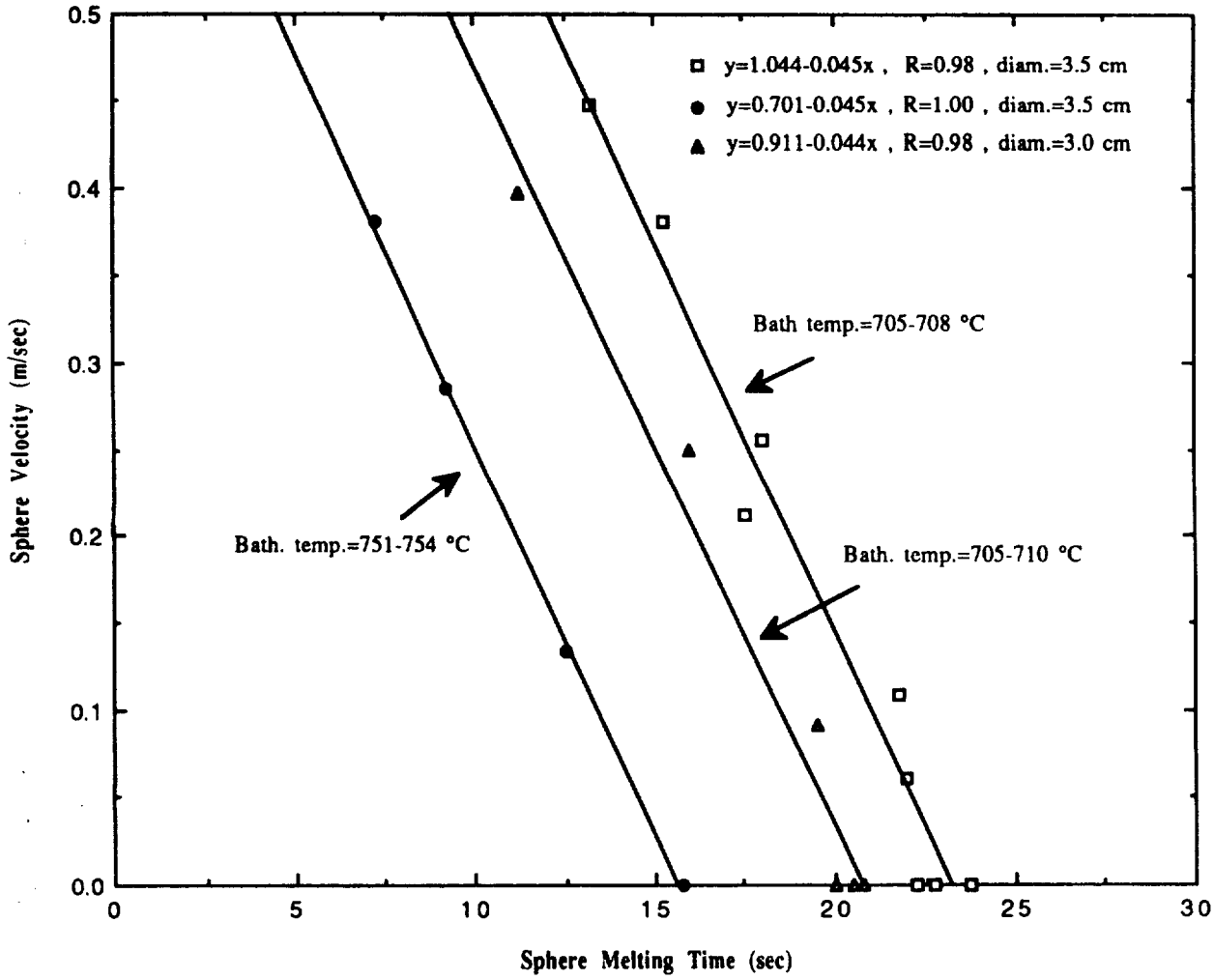


Figure 5 Sphere velocity versus melting time for 3.5 cm diameter spheres and bath temperature ranges 705-708 °C and 751-754 °C, and 3.0 cm diameter spheres and bath temperature range 705-710 °C.

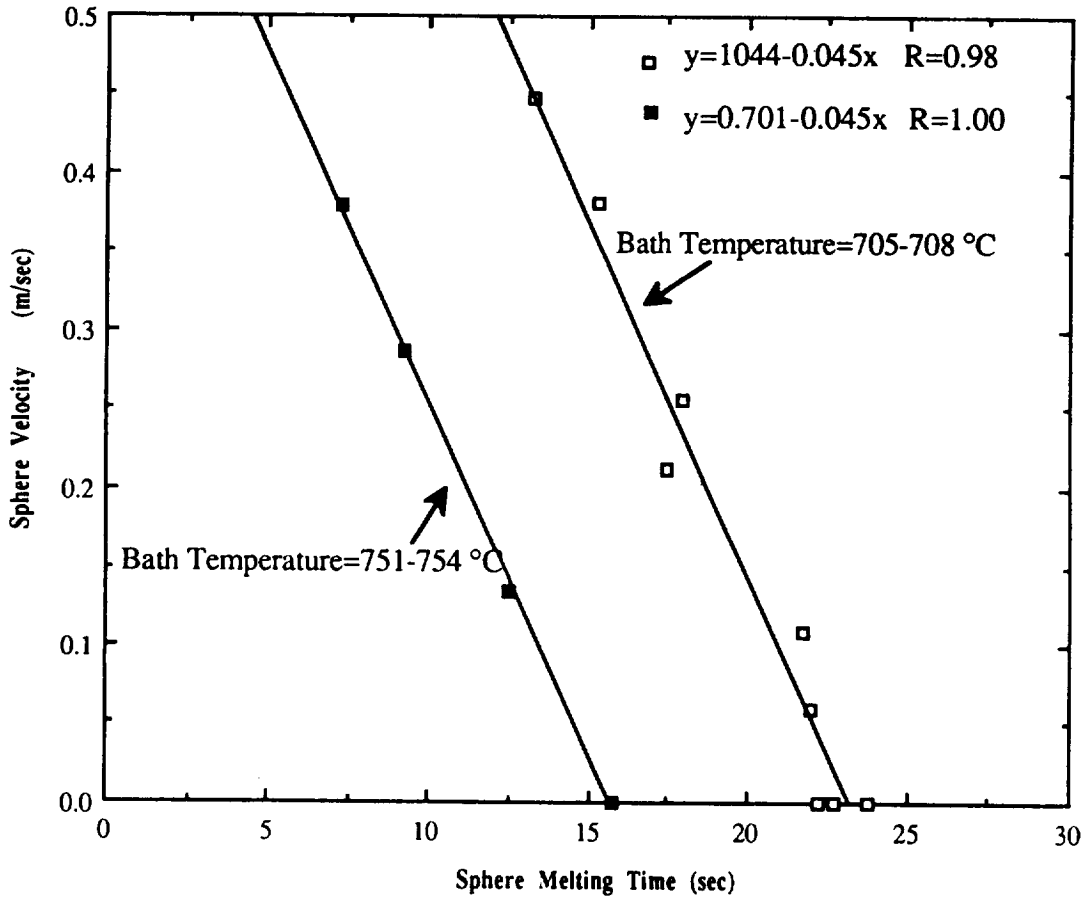


Figure 6 Sphere velocity versus melting time for 3.5 cm diameter spheres and for bath temperature ranges 705-708 °C and 751-754 °C.

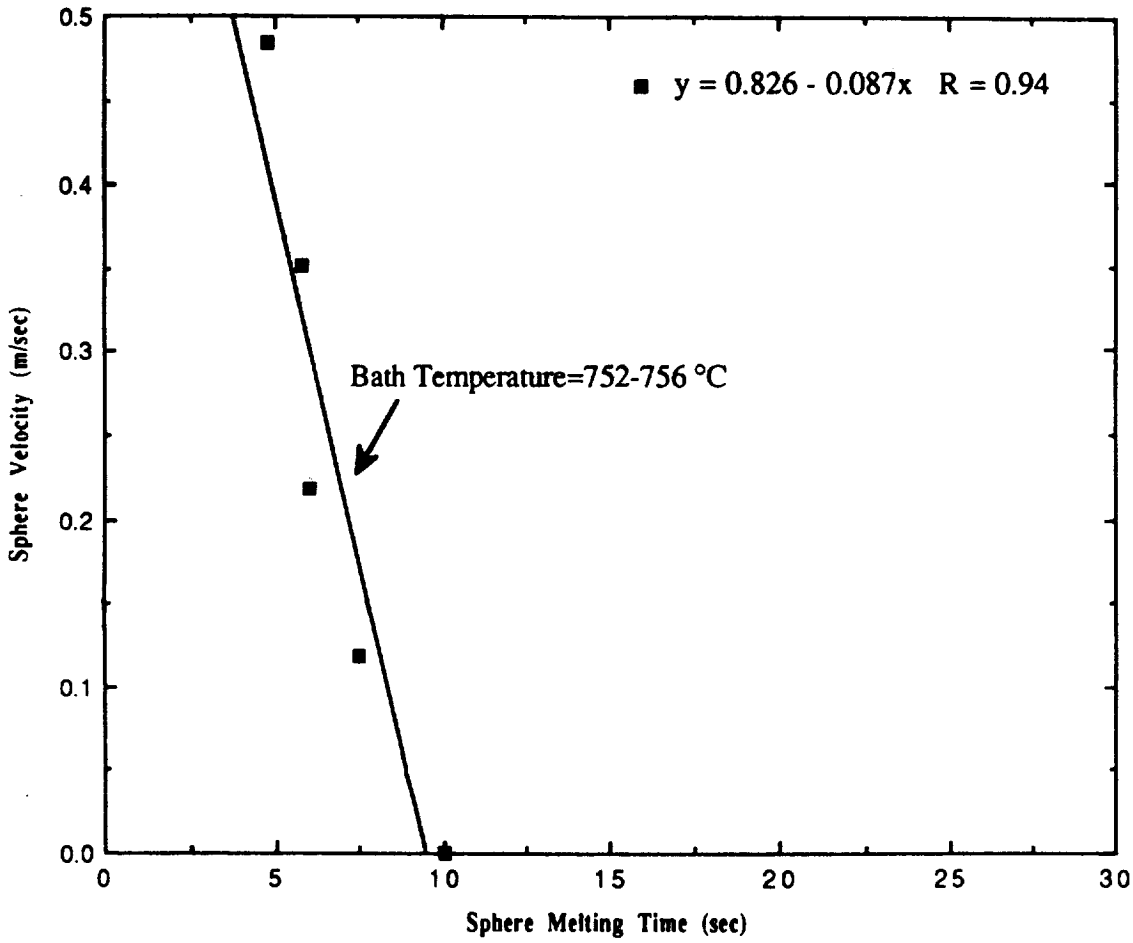


Figure 7 Sphere velocity versus melting time for 2.5 cm diameter spheres and for bath temperature range 752-756 °C.

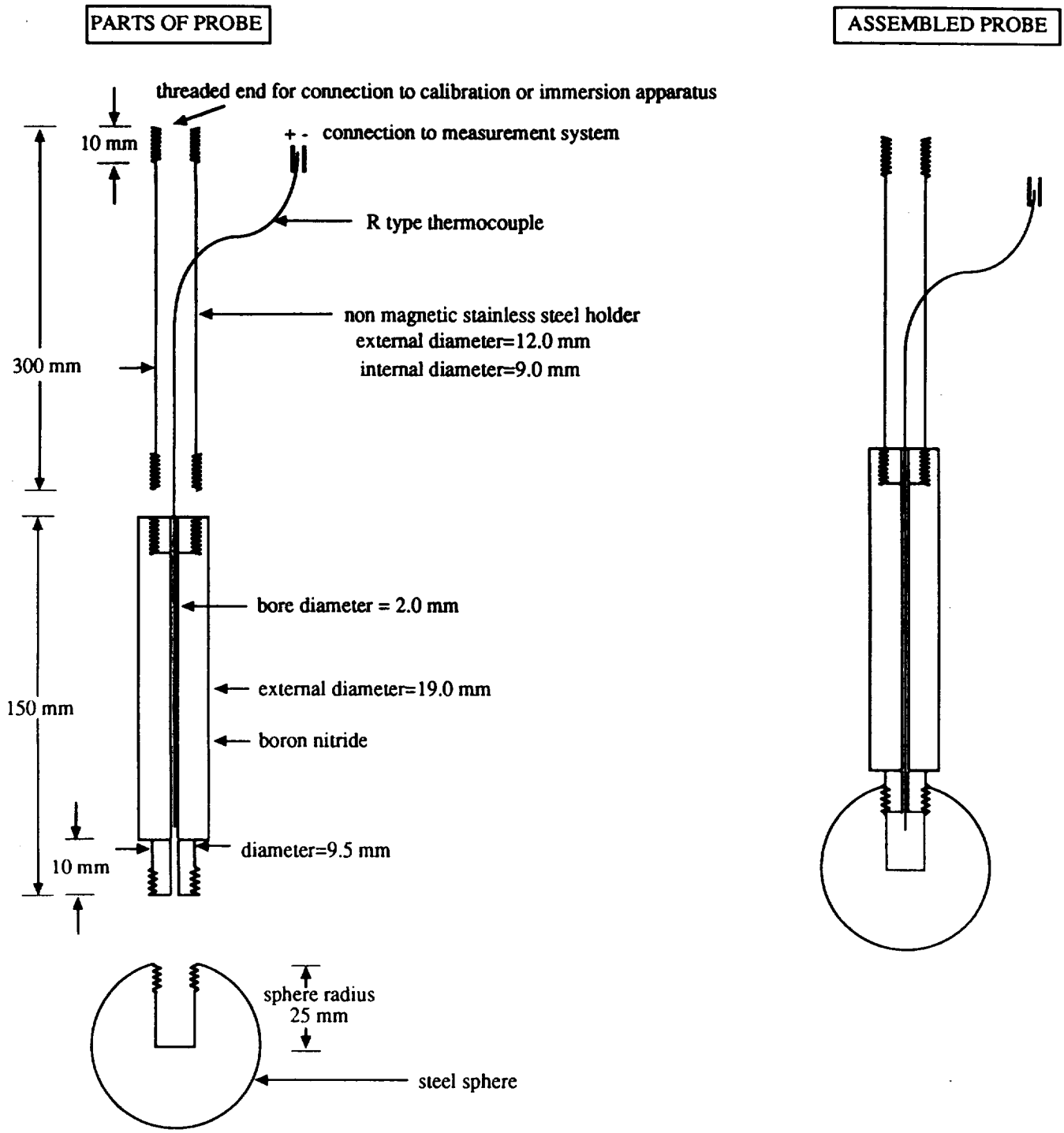


Figure 8 Schematic diagram of the probe used in the liquid steel studies.

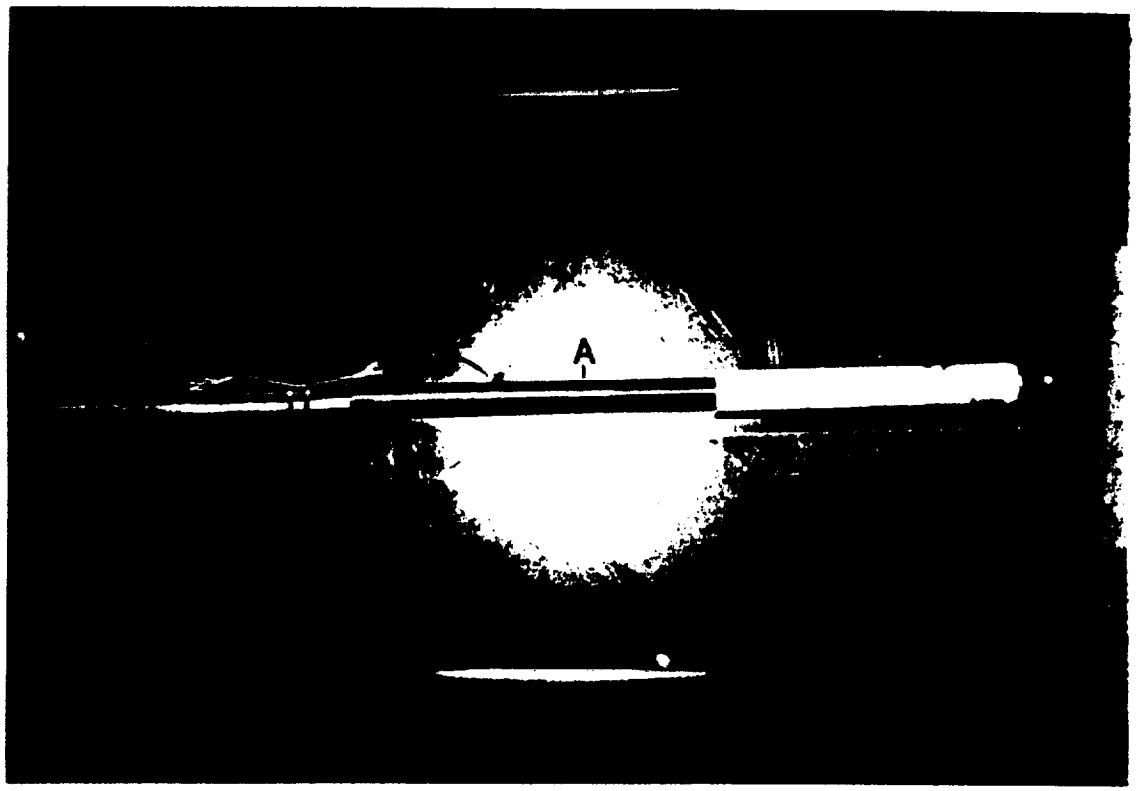


Figure 9 The probe used in the liquid steel studies (A) steel holder (B) boron notride (C) steel sphere.

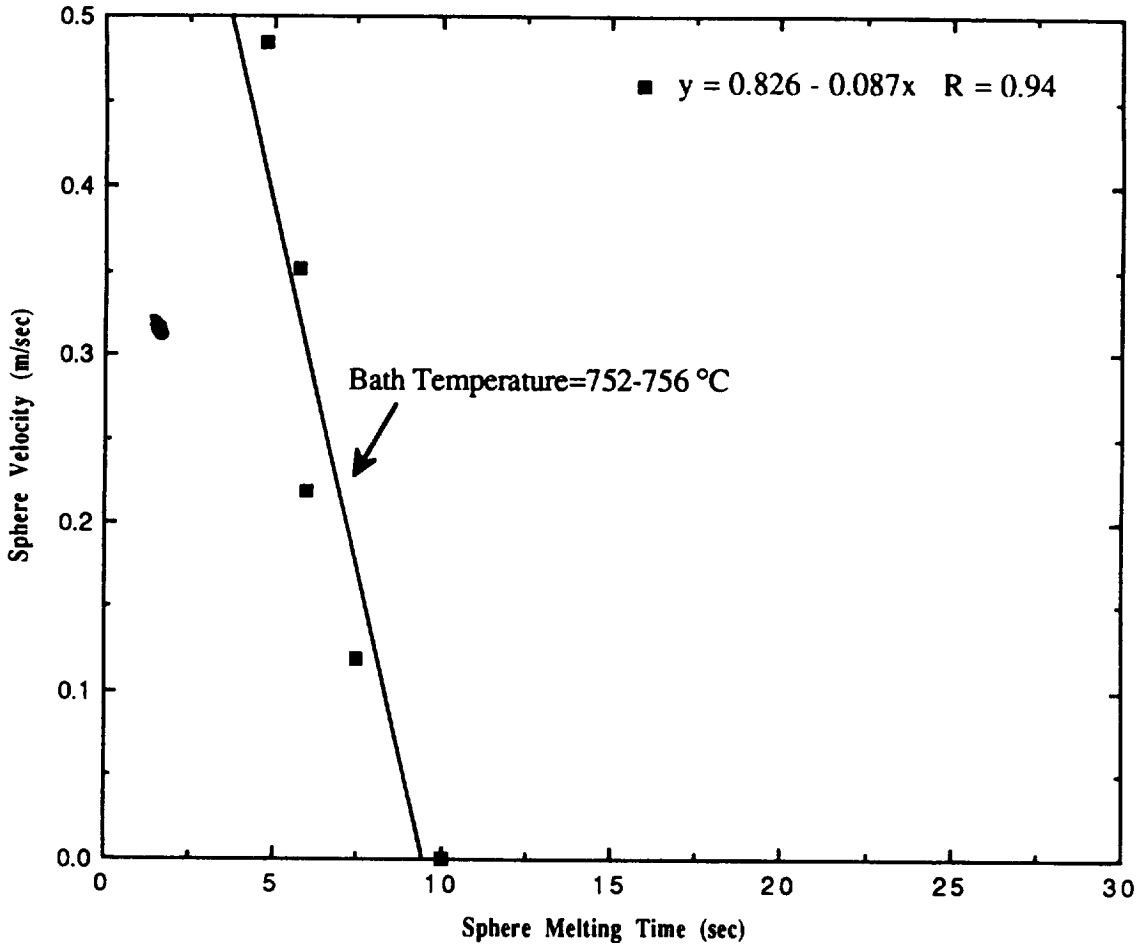


Figure 9 Sphere velocity versus melting time for 2.5 cm diameter spheres and for bath temperature range 752-756 °C.

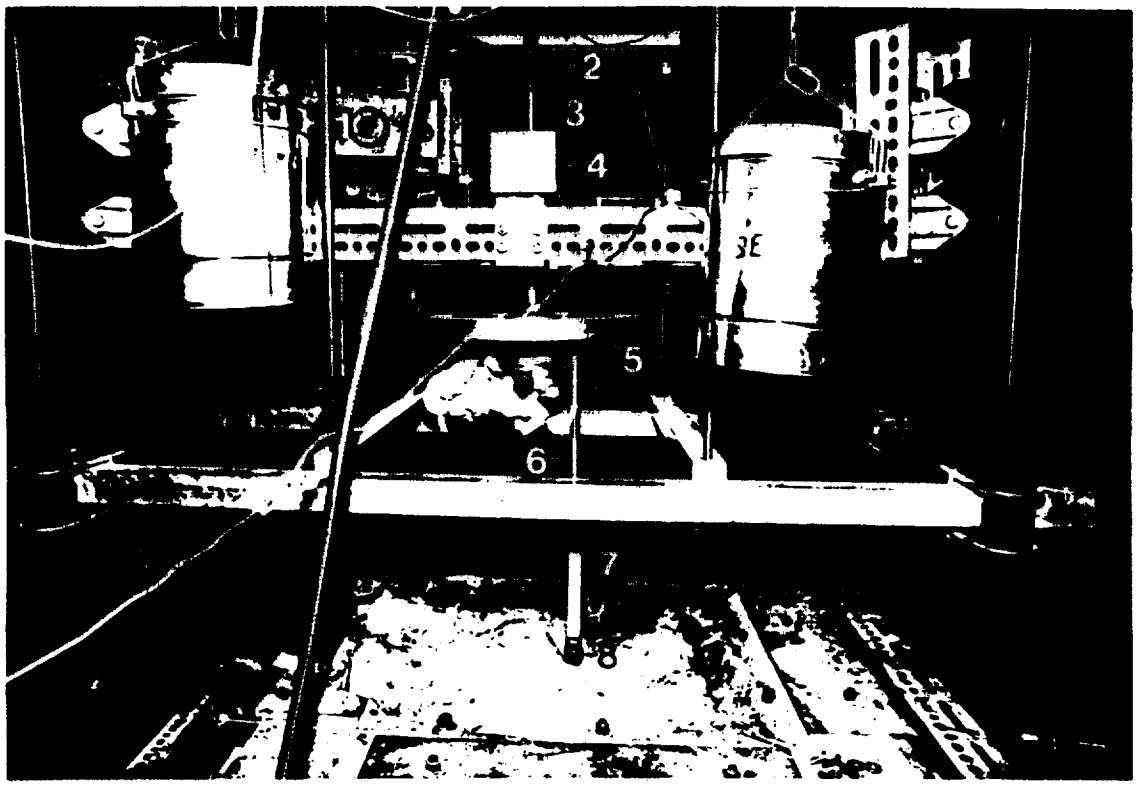


Figure 10 The holder-sphere assembly connected to the apparatus for stirring spheres in liquid steel. (1) motor (2) gears (3) hollow shaft (4) aluminum block (5) disc (6) steel holder (7) boron nitride (8) steel sphere.

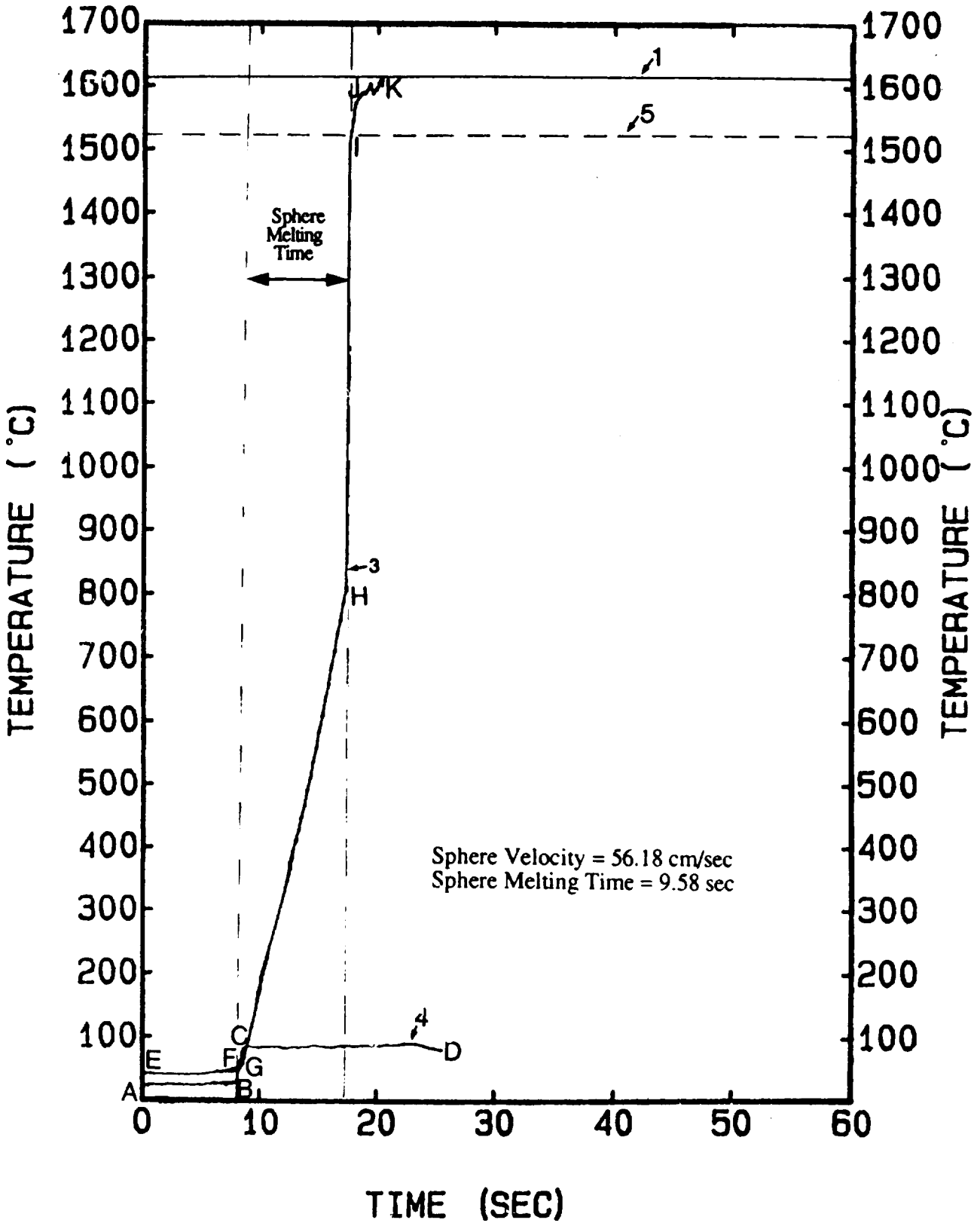


Figure 11 A typical calibration experimental result in liquid steel.