United States Patent

Blecherman et al.

[15] **3,668,386**

[45] **June 6, 1972**

[54] APPARATUS FOR MEASUIRNG HEIGHT OF A MOLTEN METAL POOL

[72] Inventors: **Sol S. Blecherman,** Newington; **Nicholas E. Ulion,** Vernon; **Louis L. Packer,** Hazardville, all of Conn.

[73] Assignee: **United Aircraft Corporation,** East Hartford, Conn.

[22] Filed: **Mar. 13, 1969**

[21] Appl. No.: **806,953**

[52] **U.S. Cl.**.....**250/43.5 FL,** 13/31, 250/43.5 D, 250/83.3 D

[51] **Int. Cl.** **G01t 1/17,** G01n 23/10

[58] **Field of Search**.....250/43.5 FL, 43.5 D, 43.5 FC, 250/83.3 D; 13/31

[56] **References Cited**

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Primary Examiner—James W. Lawrence
Assistant Examiner—Morton J. Frome
Attorney—Charles A. Warren

[57] **ABSTRACT**

An apparatus for detecting the liquid level in, or the liquid-solid interface at the bottom of, a pool of molten metal or alloy utilizing a radioactive isotope as a source of radiation and sensing the amount of radiation over or through the pool of metal and in which the melting is accomplished by an electron beam impinging on the pool surface.

3 Claims, 3 Drawing Figures

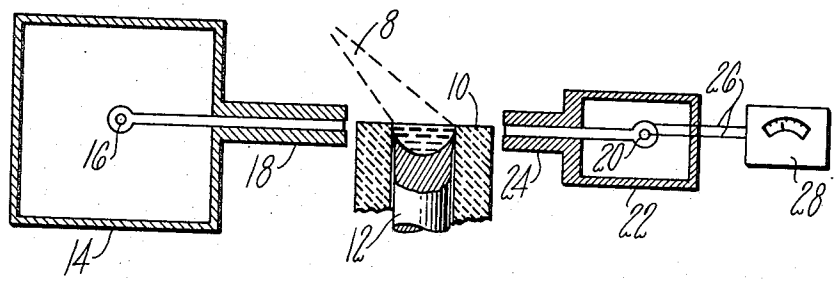


FIG. 1

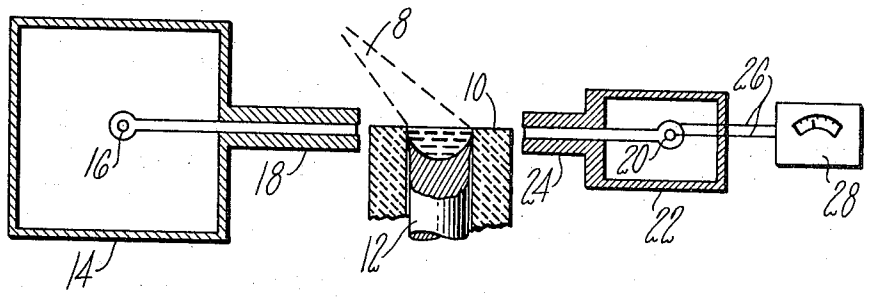


FIG. 2 SIGNAL INTENSITY VS. INTERFACE POSITION

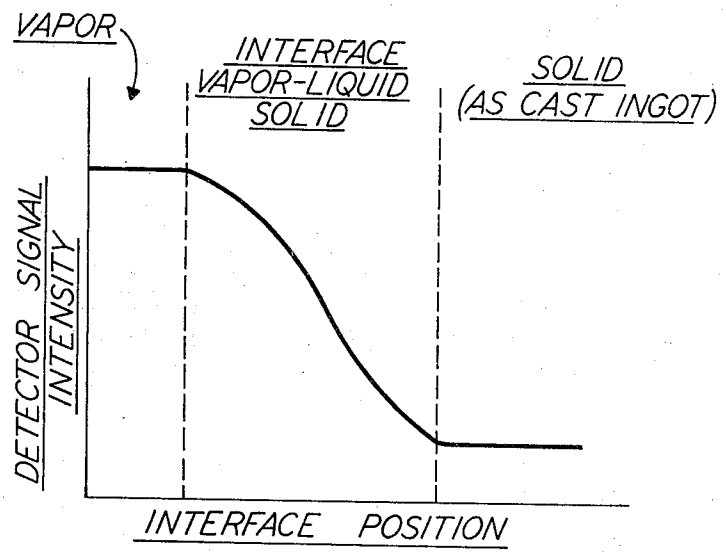
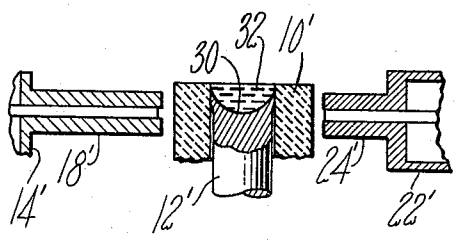


FIG. 3



INVENTORS
SOL S. BLECHERMAN
NICHOLAS E. ULION
LOUIS L. PACKER

BY Charles A Warren
ATTORNEY

APPARATUS FOR MEASUIRNG HEIGHT OF A MOLTEN METAL POOL

SUMMARY OF INVENTION

One feature of the invention is the measurement of the level of a pool of boiling liquid metal using a radioactive isotope. Another feature is the use of this device in measuring the level of a pool of boiling metal or alloy in a crucible in which the melting is done by an electron beam impinging on the surface. One feature is the measurement of a liquid-solid interface of a metal or alloy in a melting or solidifying process as, for example, in a crucible or mold. A particular feature is the determining of the pool level, or the solid-liquid interface level, of an alloy being melted and evaporated in a crucible for the purpose of depositing an alloy on a substrate by electron beam evaporation of the alloy in the crucible.

BRIEF DESCRIPTION OF THE DRAWING

FIG. **1** is a vertical, sectional view, diagrammatic, through a crucible and the sensing device associated therewith.

FIG. **2** is a diagram showing the signal intensity at the liquid-solid and liquid-vapor interfaces.

FIG. **3** is a vertical, sectional view through a crucible showing the relative configurations and location of the interfaces.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The invention is shown in the determination of the level of the liquid-solid or liquid-vapor interface in a crucible from which the alloy is vaporized for the purpose of coating an article. The apparatus for vaporizing the alloy in the coating process is well known. For the present purposes, it will be understood that an electron beam **8** is directed onto the surface of the alloy in the crucible and melts and vaporizes this alloy. The melting is done in a vacuum chamber and the article or substrate to be coated is located above the pool for the deposition of vapor thereon.

The crucible **10** is shown as a bottom-feed crucible in which an ingot **12** is fed vertically into the ring-shaped crucible such that the end of the ingot is close to the open upper end of the crucible. For the purpose of measuring the pool level, a chamber **14** is located at one side of the crucible and is preferably made of a material suitable as a shield for the radioisotope use. A small piece of radioactive material **16**, for example cesium-**137** in a glass matrix, is located centrally within the chamber and the beam of radiation from the material is collimated and directed through a collimator **18** directed horizontally toward the crucible. This beam passes through the crucible and the alloy at the level selected (the top surface of the pool as shown) and is picked up by a detector **20** in a shielded chamber **22**, the beam being guided by a tube **24** aligned with the tube **18**. The detector is connected by suitable leads **26** to a beam transmission intensity indicating device **28**.

The radioactive material may be any of several well-known materials as, for example cesium-**137**, above mentioned. The detector may also be any of several well-known devices; one that has been successfully used is an ionization chamber of well-known construction.

With the device set up in alignment with the top of the molten pool, it will measure the amount of radiation transmitted at the vapor-liquid interface as at the left-hand part of the chart of FIG. **2**. The device **28** may obviously be calibrated to read directly the height of the pool surface in thousandths of an inch, for example, below the top of the crucible. It is obvious that a greater quantity of radiation reaches the detector **20** passing over the pool than passing through it.

By lowering the measuring device relative to the crucible, it may measure the level of the liquid-solid interface as at the right-hand portion of the chart of FIG. **2** and as shown in FIG. **3**. The transmission rate for the radiation beam is so much greater in the vapor than in the liquid that the device is adequately sensitive at the mean pool level. This is true in spite of the turbulent nature of the pool surface resulting from the boiling off of the vapors from the pool.

As shown in FIG. **3**, the sensing means of FIG. **1** has been lowered with respect to the crucible **10'** in order to determine the position of the bottom surface **30** of the molten pool. With a constant energy input from the electron beam this bottom interface **30** will have a direct relationship to the top surface **32** and is a more uniform surface for measurement. Obviously the density of the molten alloy is different from the solid alloy and the detector will sense the change in density as the inteface moves vertically. The sensitivity of the sensing device may be increased by controlling the shape of the radioactive beam as it passes through the ingot. Thus the beam is preferably relatively flat and may be made to the desired shape by the tube **18**.

The bottom surface of the molten alloy, which may be the coating alloy described and claimed in the copending application of Talboom et al., Ser. No. 731,650, filed May 23, 1968, and having the same assignee as this application assumes a noticable convexity, as shown, thus having a centrally located bottom portion the height of which is readily measured.

This device will sense the position of this liquid-solid interface because of the different intensity by reason of the physical state of the alloy, that is to say the different densities of the solid and molten alloy. It has been found that certain coating alloys, made up, for example, of iron, chromium, cobalt, and/or aluminum with other added metals, when melted, will evaporate more of one metal than another, because of the different boiling points, so that the molten pool becomes a different composition than that of the solid ingot. By determining the change in density of the molten pool as evaporation takes place, it is possible to follow the change in density and thereby begin the coating operation when equilibrium is reached in the melting and evaporation process. This occurs when the alloy vapor chemistry becomes the same as the ingot chemistry, so that the same proportions of each element are being evaporated at the same rate that they are being melted from the ingot. At this time the deposited coating will have the same chemistry as the vapor above the pool and also the same chemistry as the solid ingot.

The density is measured by positioning the sensing device so that the beam passes through the molten pool between its top and bottom surface. It is also desirable in this situation to shape the beam into a broad relatively flat beam capable of sensing the density across a substantial area of the molten pool.

The device is particularly important in the measurement of the pool level in an evaporation crucible as above mentioned. The need for such a device is critical where, for example, the crucible has a small diameter such as 2-inch diameter and the evaporation rate is seriously affected by changes in the level of the pool. The chemistry of the vapors from the pool is also affected by the pool height and to insure the application of an alloy coating of the proper chemistry, it is essential to have an accurately controlled pool height.

It may be added that by careful recording of the length of ingot used in each coating operation the thickness of the coating may be determined, based on the amount of alloy evaporated. The signal from the detector may be used to control the feed of the ingot and thereby maintain the level of the ingot or the pool in the crucible. The use of the signal to control the rate of ingot feed in this manner is described and claimed in the copending application of Elam et al., Ser. No. 306,957 (EH–2486), filed Mar. 13, 1970.

We claim:

1. A device for determining the level of a pool of molten alloy in a bottom-feed crucible into which a solid ingot of the alloy is fed, and in which the alloy is melted and vaporized by an electron beam impinging on the surface of the pool, said device including a radioactive source at one side of the crucible, means for directing a beam from said source through said crucible at the liquid-solid level of the pool, means on the side of the crucible remote from the source to detect the radiation through the crucible, and means for sensing the intensity of the detected radiation.

2. In the method of measuring the level of a pool of molten metal alloy within a crucible on the top of a solid of the same alloy being melted and evaporated by an electron beam impinging on the pool surface the steps of projecting a radioactive beam horizontally through the crucible and pool at the liquid-solid interface, and measuring the intensity of the beam at the side of the crucible remote from the source of the projected beam.

3. The method of measuring the level of a pool of molten metallic alloy in a bottom-feed crucible in which an ingot extends upwardly into the crucible and the top end of the ingot is melted and evaporated by an electron beam impinging thereon, including the steps of passing a radioactive beam horizontally through the crucible and alloy at the liquid-solid interface, measuring the intensity of the beam passing through the crucible and alloy and determining from the measured intensity the position of the liquid-solid interface of the pool within the crucible, the intensity varying by reason of the physical state of the alloy.

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