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AN ADIABATIC SURFACE THERMOMETER FOR IMPROVED PRODUCTION BRAZE QUALITY

G. R. Dittbenner

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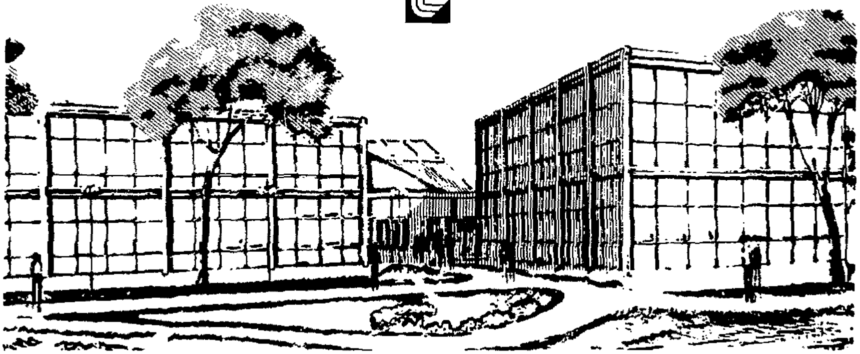

AN ADIABATIC SURFACE THERMOMETER FOR IMPROVED PRODUCTION BRAZE QUALITY*

Gerald R. Dittbenner
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ABSTRACT

An adiabatic surface thermometer was developed to control automatically the critical temperature-time cycle of a production vacuum-brazing process. Investigations revealed that optimum braze-joint strength required precise control of the brazing temperature. Spot-welded thermocouples could not be used because the spot welds cause surface damage. This thermometer touches the surface and uses a differential thermocouple and heater to measure surface temperature without heat flow, thereby eliminating large errors caused by conduction losses common to conventional spring-loaded thermocouples. Temperatures in air or vacuum are measured to 800°C with errors less than 5°C. This thermometer has minimized the rejection of production parts, resulting in a cost saving to the U.S. Energy Research and Development Administration.

INTRODUCTION

Dow Chemical's Rocky Flats Plant had a need to automate one of their vacuum production brazing processes. Investigations revealed that the brazing time-temperature cycle was critical to the braze-joint strength. Attempts were made to manually control the braze temperature while simultaneously observing the onset of melting of the eutectic braze filler (780°C). This contact thermocouple indicated dynamic temperature errors as much as 150°C; hence, it was difficult to produce consistently good joints using this technique. In late 1973 a significantly improved brazing method was incorporated into the production process. This method was made possible by our development of the adiabatic thermocouple probe, suitable for high-vacuum, high-temperature applications. This probe development enabled complete automation of the production brazing process.

MEASUREMENT OF BRAZE-JOINT TEMPERATURE

Unlike conventional temperature probes, this adiabatic probe measures the braze-joint temperature without heat transfer down the probe and therefore without the large errors usually associated with such heat transfer.

Prior to the development of this probe, there was no way to measure accurately the temperature of the brazing process at Dow-Rocky Flats. Preliminary evaluations using radiation thermometry were inaccurate because the beryllium emittance was not accurately known during the time-temperature cycle of the braze. Attaching thermocouples to the beryllium surface was not acceptable

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*This work was performed under the auspices of the U.S. Energy Research & Development Administration.

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because of the spot-weld damage to the part and because of a tendency of the thermocouple to become detached during the braze cycle. Holding a conventional spring-loaded metal or ceramic rod-type thermocouple in contact with the part was also unsuccessful because the heat conduction down the rod cooled the point of contact sufficiently to cause the thermocouple to indicate temperatures up to 150°C less than the true bulk-part temperature.

The brazing temperature is the most critical parameter. The brittle weakness of the joint is a function of the amount of beryllium-copper intermetallic formed at the interface of the beryllium and copper-silver braze alloy. The brittleness and the width of the intermetallic layer both increase with the brazing temperature.

Investigation has shown that to produce maximum joint strength and still pass nondestructive test inspection, the part temperature should be held at 804°C. The MCS-8 microprocessor accurately controls the temperature within ±0.2°C. The braze-alloy melting temperature is 780°C.

The production brazing process involves local induction heating of the braze area in a vacuum chamber. In the improved process, an MCS-8 microprocessor precisely controls the power input to the induction coil. It uses the output signal from the thermocouple probe monitoring the part temperature immediately adjacent to the joint to control automatically the entire time-temperature cycle of the brazing process (see Figs. 1 and 2).

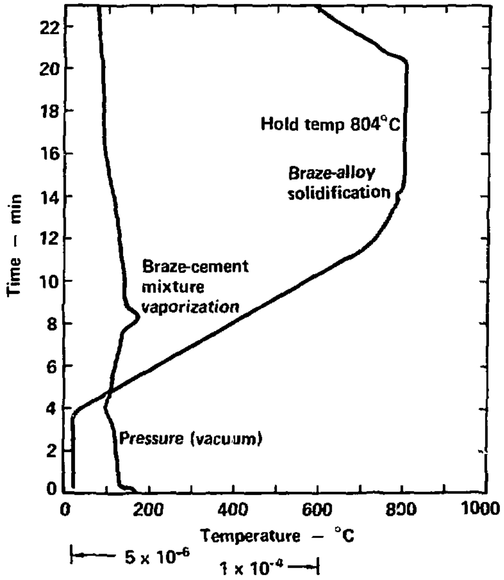

Fig. 1. Time-temperature cycle of brazement subassembly.

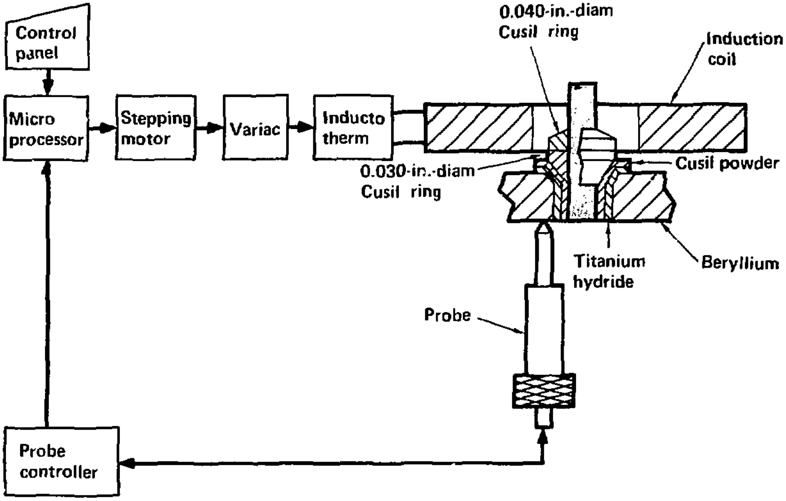

Fig. 2. Brazement subassembly.

For several years Leeds and Northrup[†] have been marketing an adiabatic thermometer that measures temperature from 30 to 530°C. Their probe is designed for intermittent use in air, and was not suitable for continuous temperature measurements in vacuum.

Our probe is a second-generation development of the Leeds and Northrup concept and uses the same L and N controller. The new probe has been completely redesigned with the following improvements (see Fig. 3):

- Maximum temperature has been increased to 1300°C.
- The probe is manufactured from materials suitable for high-temperature, high-vacuum service.
- It is designed for continuous service.
- The spring-loading system is designed for use at high temperature.
- Broken probes can be easily replaced by an integral connector.

When the probe first contacts the beryllium there is a large temperature difference between the two thermocouple junctions, S (surface temperature) and R (reference thermocouple temperature), shown in Fig. 4. The controller unit detects this difference and applies power to the heater (H), so that the temperature of R becomes equal to the temperature of S. At this null-balance condition there will be no heat flow into or out of the beryllium. Hence junction S will be at the beryllium temperature, and the beryllium temperature will be the same as if the thermometer were not touching the part at all. Construction of probe assembly is shown in Fig. 5.

[†] Reference to a company or product name does not imply approval or recommendation of the product by the University of California or the U.S. Energy Research and Development Administration to the exclusion of others that may be suitable.

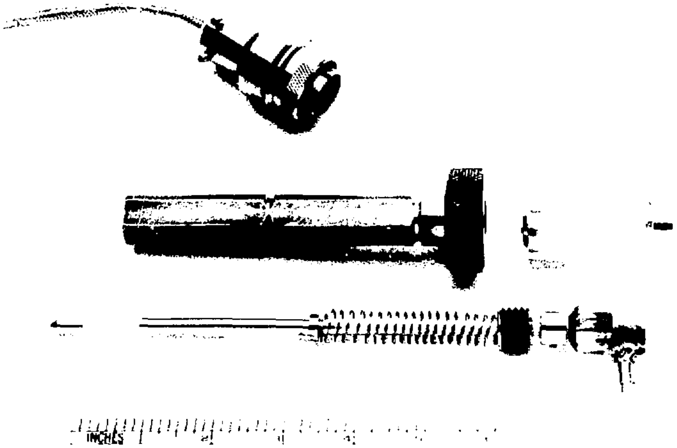

Fig. 3. High-temperature, high-vacuum probe.

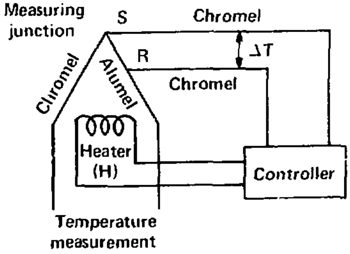

Fig. 4. Operational schematic diagram.

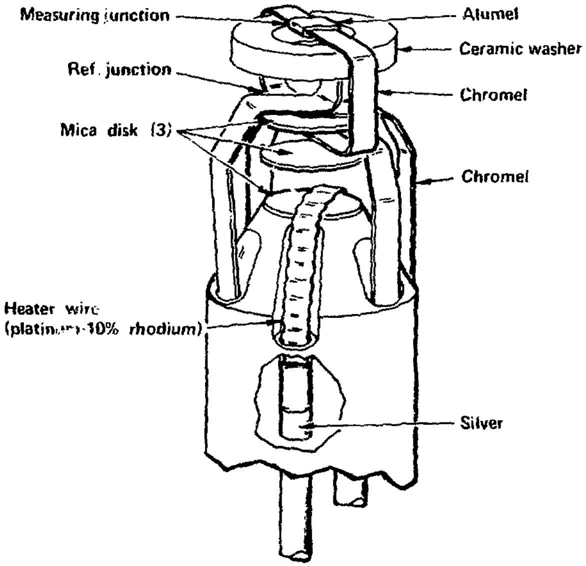

Fig. 5. Adiabatic probe assembly.

The limits of error of the Chromel-Alumel (type K) thermocouple probe are ±0.375% of the measured temperature. This accuracy corresponds to the limits of error of special-grade, type-K thermocouple wire. Investigation has shown that the overall system will consistently measure temperatures repeatedly with an inaccuracy less than 3°C at 804°C. The response time of the probe (99%) is about four seconds. Our adiabatic thermometer represents a significant breakthrough in surface-temperature measurement, as applied to improvements for production brazing and reliability. This thermometer is currently being adapted to other process-control applications requiring adiabatic temperature measurements. The probe, which is fabricated at LLL, is presently being used at LLL, Bendix, and Rocky Flats.

CONCLUSIONS

The Research and Development Joining Group at Rocky Flats is now able to accurately control temperature during a brazing cycle. This temperature measuring system has also minimized the variables and the effects that operators have introduced into the production parts. Rejection of production parts for failure in the braze joints has been minimized, which in turn results in a cost savings for U.S.E.R.D.A. LLL has also gained a great deal of knowledge from the development of a probe that will work in high vacuum and high temperature.

ACKNOWLEDGMENTS

This combined temperature-measuring system for process control would not have been successful without the support of Donald Walmsley, Jim Morrison, and Jim Husk from LLL and Joe Zeren, Charles Cleaver, Dave Henry, Phil Crocker, and John Skufca from the Dow Chemical Rocky Flats Plant.

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