# Calibration and Hot Air Rework Station Temperature

A common question from users of hot air rework equipment such as the Hakko FR-802 SMD Hot Air Rework Station is how to calibrate the station. Knowledge Base article Q10177 identifies various Hakko products that do not require calibration, which includes Hakko SMD Hot Air Rework Stations. The purpose of this article is to clarify why hot air stations are identified as not requiring calibration.

First, the term Calibration must be defined. Calibration is the set of operations that establishes, under specific conditions, the relationship between the values of quantities indicated by a measuring instrument and the corresponding values realized by standards. The result of a calibration permits either the assignment of values of measure to the indications on the instrument or the determination of correction with respect to the indications.

Section 7.6 of the ISO 9001:2000 standard states that “the organization shall determine the monitoring and measurement to be undertaken and the monitoring and measuring devices needed to provide evidence of conformity of product to determined requirements”. The standard also states that “where necessary to ensure valid results, measuring equipment shall be calibrated or verified at specified intervals prior to use against measurement standards”. At this point, the requirement to calibrate hot air rework stations is entirely a user requirement and typically based on the digital display on the station being used as a measuring device that provides evidence of conformity of the product. Most quality systems fail to recognize and adequately deal with the variations inherent with the temperature measurement of the air flow existing the station and herein lies the problem.

It is reasonable to consider that conformity of the product can be impacted by the ability of the hot air rework station to provide repeatability in its operation, and thus some type of periodic verification of the temperature of the air flow exiting the nozzle should be performed. This verification can be performed but the tolerance of such a measurement is well outside most manufacturing tolerances. In these cases, the temperature display should be used for reference to ensure approximate equal setup between hot air rework stations, and calibration should be focused on the device used to measure the temperature of the air flow existing the station.

In order to perform a sound verification of the temperature of the hot air exiting the station there must be an understanding of how the temperature measurement is made by the Hakko stations and the variations that will affect your temperature measurement. This same verification concept can be applied to other hot air devices and not just to devices that have adjustable settings and/or displays.

Figure 1 below is a cross-section image of the heater pipe assembly of a Hakko FR-802 SMD Hot Air Rework Station with a Hakko A1130 Single Jet Nozzle attached. Note the various parts of the assembly that are pointed out particularly the location of the thermocouple that is used by the digital display on the station.

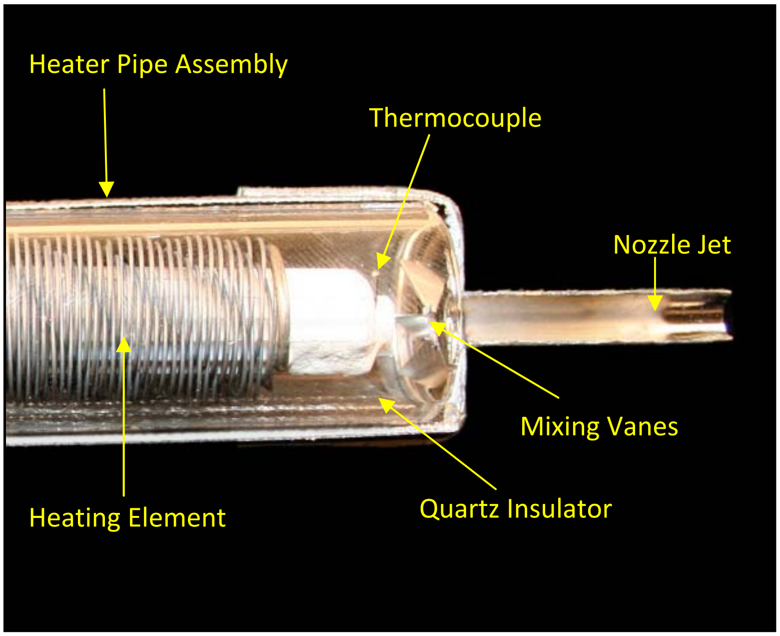


Figure 1

The biggest factors that affect the measured temperature of an air flow are the position of the thermocouple when making the measurement, the flow rate, and ambient conditions that cause error in the measurement.

When multiple Hakko SMD Hot Air Rework Station are set to the same temperature and airflow settings, and the same nozzle is attached, each of the stations flow rate of the air across the heater and past the thermocouple is relative between the different station and within the ±10% accuracy of the ball flow meter. The position of the thermocouple for the measurement is approximately the same since the thermocouple is built into the heating element at a fixed position, and the error that can be caused by ambient conditions is mitigated since the measurement is taken inside the heater pipe.

The major difficulty is establishing the measured temperature to which each of the stations is referenced. Measurement of the air temperature in a free flow jet by a thermocouple is subject to many variables making calibration impractical.

Figure 2 below shows a typical jet velocity field distribution measured using PIV. Instantaneous PIV velocity fields are ensemble-averaged in order to obtain this time-averaged flow field image.

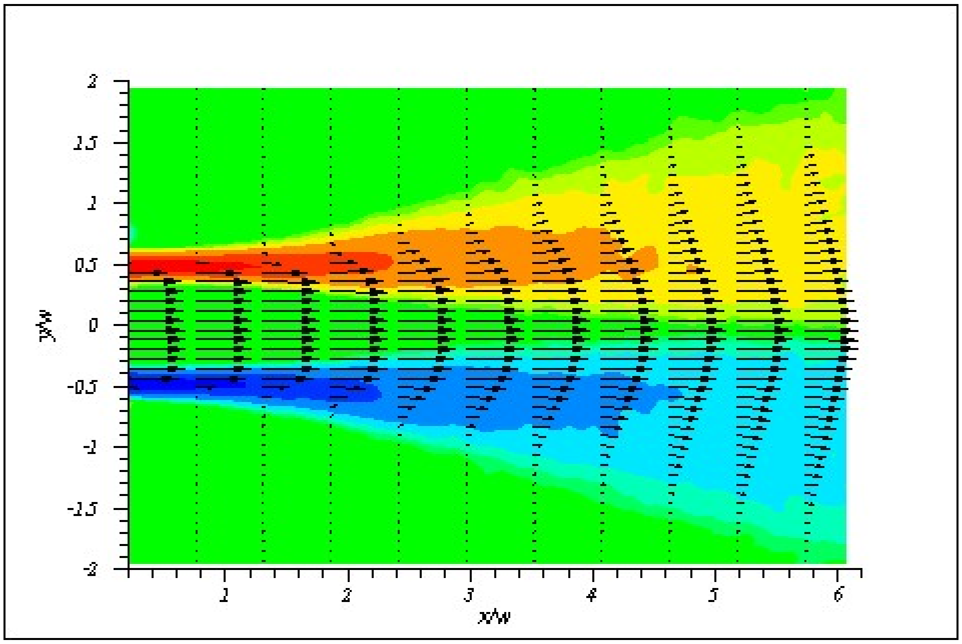


Figure 2

The time-averaged jet velocity at the exit of a free flow jet is a uniform profile. Due to the large velocity different between the jet and ambient air, a thin shear layer is created and it is highly unstable. The shear layer is subject to flow instabilities that eventually lead to the generation of strong turbulent fluctuations and the shear layer continuously grows downstream. The highly turbulent flow entrains ambient air into the jet and enhances flow mixing causing wide variations in temperature as depicted in the image below.

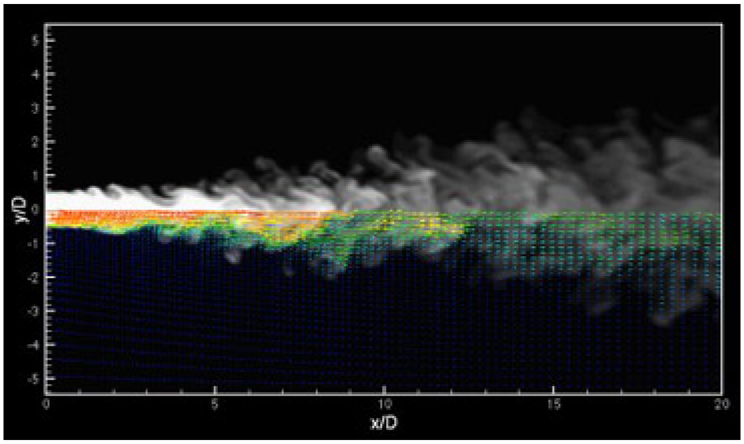


Figure 3

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As shown in Figure 4 below, the central portion of the jet, a region with almost uniform mean velocity, is called the potential core. Because of the spreading shear layer, the potential core eventually disappears downstream at a distance of between 4 to 6 times the diameter of the jet opening.

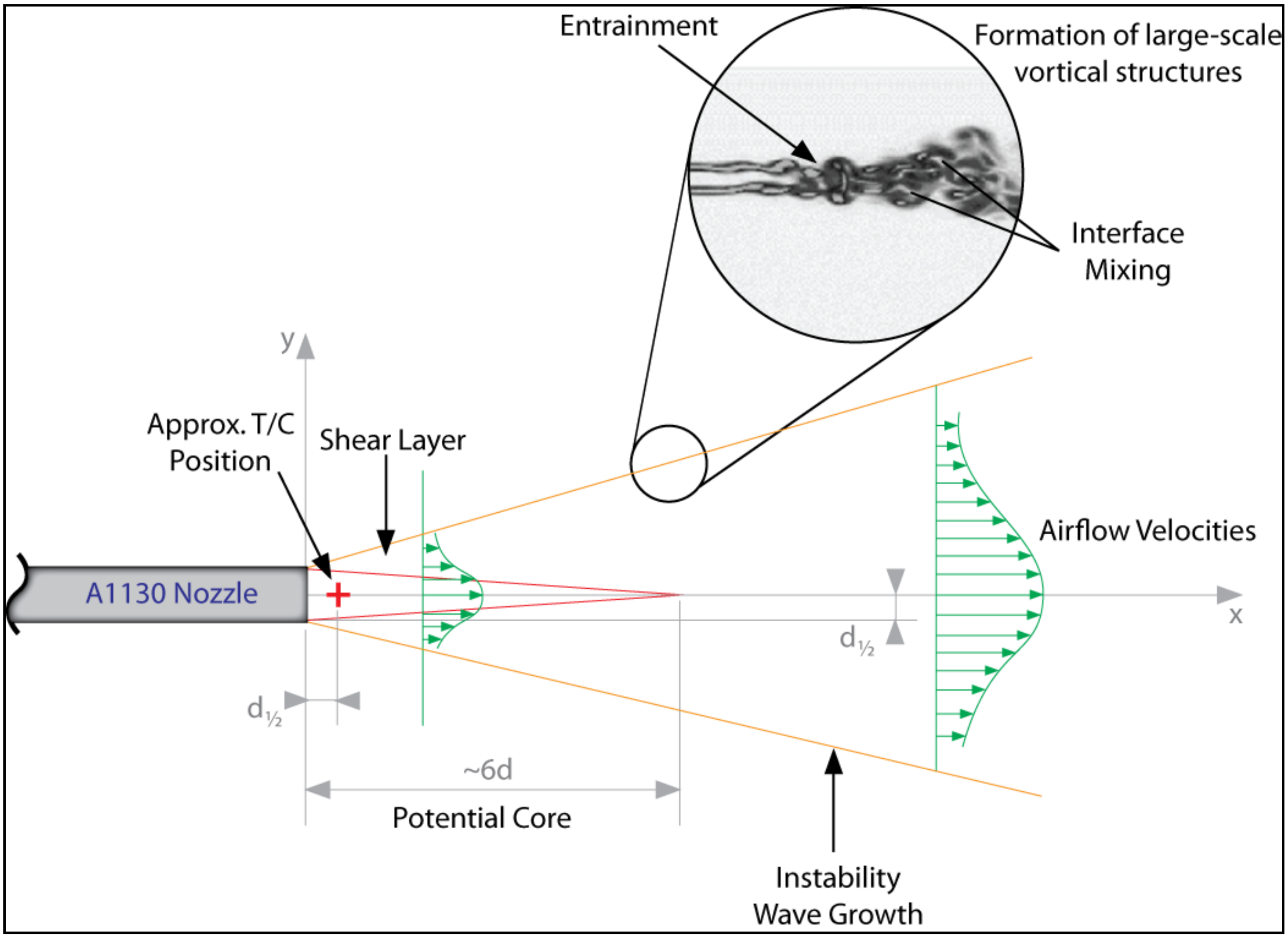


Figure 4

Positioning of a thermocouple for a measurement would need to be made consistently at the same location within the potential core downstream of the opening by approximately half the diameter of the opening. Fixing the hot air station and thermocouple in such a way to make this positioning consistent between measurements is impractical.

Adding to the variations in the measurement of the hot air at this point are the stacked tolerances of the measurement device being used to measure the hot air by way of thermocouple, the tolerance of the ball flow meter, and variations in the relative humidity in the air.

At this point, provided all variables have been kept within reasonable control, one can verify the airflow temperature by setting the airflow on each station to 20 L/min and the temperature to 300°C. The tolerance under these controlled conditions would be -0°C/+50°C for any measurement made, which is well outside most manufacturing tolerances.

It is important when attempting to make this temperature verification that precautions are taken against measurement error that can be introduced unintentionally. To mitigate the common errors:

- Measurements should be made in a location free from any air currents or drafts such as from an air conditioning system
- Measurements should be made by the same person under the same conditions to reduce the affect of errors between variations in conditions and techniques used.

It is important to point out that we have been discussing the measurement of the temperature of the air flow leaving the nozzle at roughly half the diameter of the nozzle downstream. In practical use, the component or assembly would unlikely ever be positioned in this way so the actual temperature seen by the component or assembly is lower.

Figure 5 to the right is a simulation of the large eddy formations created by an impinging jet of hot air against a plane. The black contours indicate variations in air flow temperature in the Z plane while the color flood contours represent the temperature the component or assembly would see.

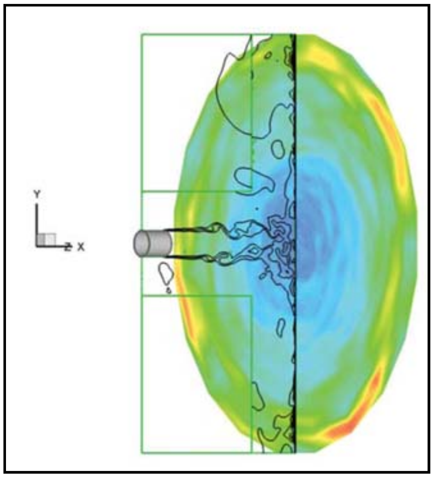

Figure 5

As shown by the black contour lines, the entrainment of ambient air into the air flow after exiting the nozzle causes a cooling of the air flow, so even if the temperature display on the Hakko SMD Hot Air Rework Station was verified, it is still not the actual temperature that the solder joint and component will see during the process.

Recall that the ISO 9001:2000 standard calls for the use of measurement devices that provide evidence of conformity of the product to determined requirements. Since the measurement of hot air by the equipment is not the measurement of the soldering temperature the product sees during the process, and the tolerance of the verification measurement is well outside most manufacturing tolerances, it should only be used as a reference to ensure approximate equal setup and performance repeatability. What should be controlled and calibrated is the device that measures the temperature the solder joint and component will see during the process, much like a thermal profiler that runs through an SMD convection oven.

Figure 2 PIV jet data courtesy of Mr. Bahadir Alkislar and Dr. Luiz Lourenco FAMU-FSU College of Engineering
Figure 3 image courtesy of David Glaze, Purdue University and Tecplot
Figure 5 simulation image from TURBULENT FLOW AND HEAT TRANSFER by von Karman Institute for Fluid Dynamics, Rhode-St-Genèse, Belgium