Increase Performance and Productivity with METCAL™ GT Series Inductive Heating Soldering Systems

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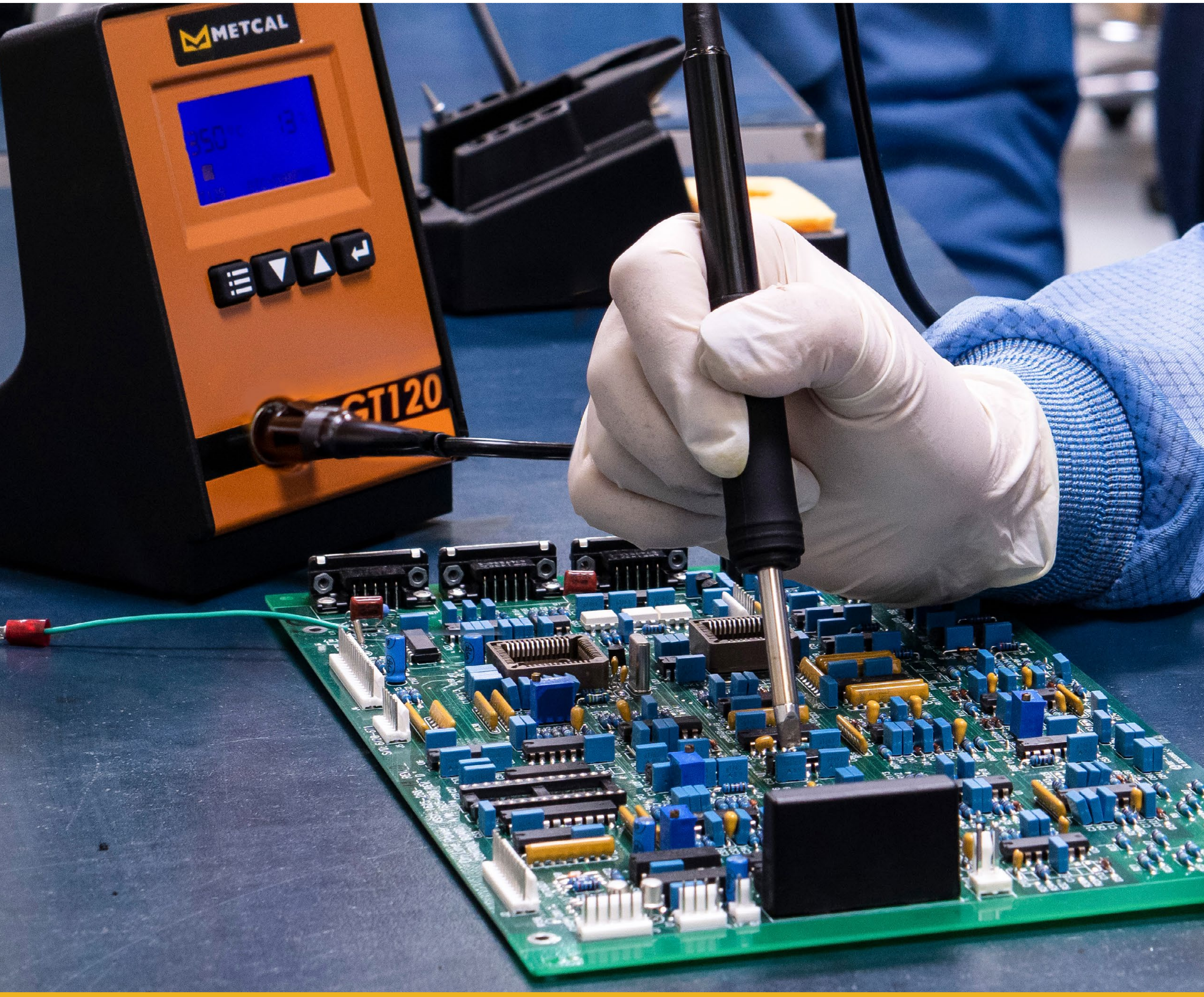
METCAL™



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Key Performance and Productivity Findings for Hand Soldering

This paper examines the effects of heating technology on hand soldering system performance and productivity. A seven-load soldering test was performed on comparable inductive and resistive heating soldering systems. Test results revealed that METCAL™ GT Series inductive heating soldering systems consistently outperform comparable resistive soldering systems in the following ways:

- Faster heating
- Shorter dwell times
- Quicker recovery times
- Reduced total solder times
- Better temperature accuracy and stability throughout the soldering cycle, and
- Better productivity by as much as 260%.

Top 4 Parameters Influencing Hand Soldering Performance and Productivity

In hand soldering systems, performance depends on design parameters that affect the delivery of heat from the power supply to the soldering tip. The top four parameters that influence hand soldering performance are:

- **Power Rating of Soldering Systems** - Optimum power rating depends on the soldering task. Higher wattage systems have more power on reserve, enabling them to maintain heat for longer periods, and making them better suited for heavy-duty soldering projects with high thermal demands. Lower wattage systems are sufficient for many soldering applications, as long as they can regulate a sufficient amount of heat into the tip to create a good solder joint.
- **Distance Between the Soldering System's Heating Element and Soldering Tip** - Heater location relative to the soldering tip is very important to system performance. The closer they are to each other; the faster heat is transferred. This explains why soldering systems that use cartridges achieve better thermal performance than those that use standard tips. Cartridges are designed to integrate the heating element with the soldering tip, in one unit. Whereas, standard soldering tips, are separate pieces added onto the system, thus moving the tip further away from the system's heater.
- **Size & Shape of Soldering Tip** – Size and shape of the soldering tip is important since heat is transferred through the small contact area between the tip and solder pad. The soldering tip should be small enough in size and shape to reach into tight spaces, but blunt enough to ensure that heat is transmitted well to the point of work. A chisel shaped soldering tip is good for most soldering jobs.
- **Heating Technology of Soldering System** - Today's hand soldering systems utilize two different heating technologies.
    - **Inductive Heating Technology**: Heat generated by induction is created by passing an alternating current through a coil to generate an alternating magnetic field around a ferromagnetic heating element. When a ferromagnetic object is magnetized by an alternating magnetic field, the north and south poles of its atoms align with the magnetic field, and rapidly change direction with the frequency of the applied alternating current. The higher the alternating frequency,

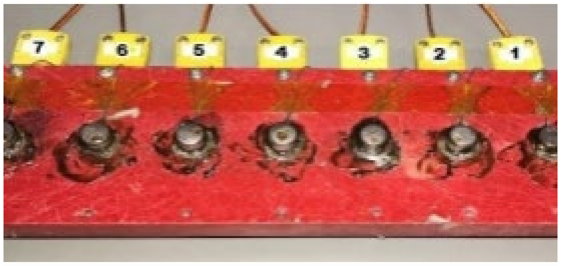
the faster heat is generated. For more information on how inductive heating technology works see the "How it Works" whitepaper on the METCAL™ website at metcal.com

- **Resistive Heating Technology:** As the name suggests, resistive heating is achieved by passing an electric current through a metallic heater coil that is resistant to the flow of electrons. The amount of heat produced is dependent upon the amount of electric current applied and the resistance of the material. Materials that are resistant to the flow of electrons also tend to have higher thermal resistance. Therefore, resistive heating soldering systems typically offer lower thermal performance than inductive heating soldering systems.

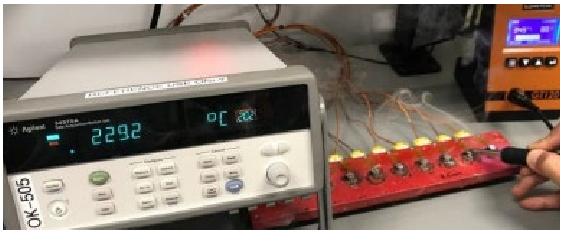
Resistive vs. Inductive Hand Soldering System Performance and Productivity Testing

Test Fixture Setup

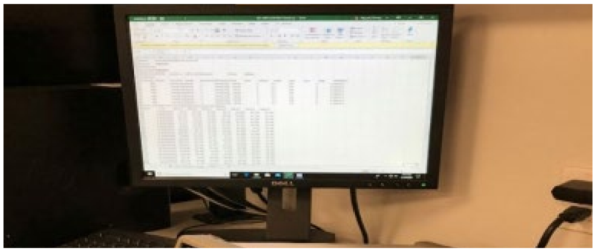
Seven identical thermal loads were machined from copper (8.5 mm diameter, 6.8 mm height) to simulate seven heavy-duty soldering tasks. This test load construction creates a trade-off condition between temperature and throughput, making the setup ideal for measuring temperatures and soldering times.



The test loads were placed on a test fixture as shown. The base material is phenolic resin to prevent heat conduction between the loads. Type-K thermocouples were connected to each test load to measure load temperatures. The thermocouples were connected to a computer port for acquisition and storage of load temperature data.



Type-K thermocouples were spot welded to the soldering tip of each soldering system under test. To minimize tip temperature measurement error and ensure uniform thermal contact, the test fixture was designed so that each soldering iron contacted the thermal load at a 15-degree angle relative to the horizontal as shown above.



The thermocouples were connected to a computer port for acquisition and storage of load temperature and tip temperature data. Temperatures were collected every 0.5 seconds throughout each soldering system test.

Maintenance of Soldering System and Test Fixture Between Runs:

- Test loads were cleared of residual solder and flux and a small but consistent bead of solder paste was applied. The purpose of the paste was to maximize the heat transfer between the soldering tip and the load.

- Loads were cooled to room temperature, approximately 24°C.
- The soldering system under test was set to an idle setpoint tip temperature of 350°C and the temperature was measured and verified at least twice to ensure repeatability.

Test Procedure

Once the 350°C setpoint temperature stabilized, the soldering iron was placed on the first thermal load.

When the temperature of the first load reached approximately 250°C (lead-free solder melts at about 217°C), the soldering iron was moved immediately to the next load. This was repeated until all seven loads were completed.

Resistive and Inductive Hand Soldering Systems Tested

Systems tested were separated into two performance groups based on their power ratings (wattage). Each system was tested with either tips or cartridges as offered by their manufacturer.

Group 1: Included 75W and 90W resistive heating and 90W inductive heating soldering systems. The size and geometry of the soldering tips used were 2.4 mm and 2.5 mm chisels as offered by their manufacturers.

Manufacturer	Heating Technology	Power Rating	Tip or Cartridge	Tip Size and Geometry
METCAL™ GT90	Inductive	90 Watts	Tip	Chisel 2.5 mm
Comparable A	Resistive	90 Watts	Tip	Chisel 2.4 mm
Comparable B	Resistive	75 Watts	Cartridge	Chisel 2.4 mm

Group 2: Included 140W and 150W resistive heating and 120W inductive heating soldering systems. The size and geometry of the soldering tips used were between 5 mm and 6 mm chisels as offered by their manufacturers.

Manufacturer	Heating Technology	Power Rating	Tip or Cartridge	Tip Size and Geometry
METCAL™ GT120	Inductive	120 Watts	Tip	Chisel 5.0 mm
Comparable C	Resistive	150 Watts	Tip	Chisel 5.9 mm
Comparable D	Resistive	140 Watts	Cartridge	Chisel 5.2 mm

Data Collected for Soldering System Performance and Productivity Analysis

When evaluating performance and productivity of hand soldering systems, engineers focus on six key metrics:

1. **Time to Temperature –** The time it takes a soldering iron to heat the tip to the initial ready-to-solder temperature (set point). Time to temperature is crucial since it can be considered lost minutes of manufacturing. Many soldering systems in the market can take longer for initial heating, leading to lower productivity. Over multiple shifts, the time spent waiting for a soldering iron to heat up can be significant.

2. **Dwell Time –** The time it takes a soldering iron to solder a specific joint. When the hot tip contacts the cool solder pad, heat is lost due to heat transfer. Heat loss during any soldering process can be significant and many soldering systems can have difficulty maintaining a stable setpoint soldering temperature. This is especially true in high thermal demand applications. Dwell time can vary significantly from system to system and can have the effect of lost productivity during the manufacturing process.

3. **Recovery Time –** The time it takes the soldering tip to return to the set point temperature after completing a solder joint. Like time-to-temperature, many soldering systems in the market can take longer to recover, leading to lower productivity in the manufacturing process.

4. **Total Solder Cycle Time –** The time it takes to solder a joint. Includes dwell time and recovery time.

5. **Tip Temperature Accuracy and Stability –** Optimum temperature of the soldering iron at the tip is set by the operator and managed by the system's microprocessor with a feedback loop between a temperature sensor and the heater's controller. As thermal energy is delivered to the solder pad during the soldering process, the tip temperature fluctuates due to delays in the system's response time. IPC standard J-STD-001 Revision F states that hand soldering equipment should be able to maintain temperature control within +/-10°C during multiple point-to-point or thermal mass on demand soldering operations. Temperature fluctuations beyond +/-10°C increase the risks of poor-quality solder joints and damage to heat sensitive components.

6. **Component Temperature –** Extrapolated from the temperature of the solder joint, which includes the solder pad, component metallization and solder wire. Component temperature is important to monitor for optimum soldering results. In this experiment the load temperature simulates the component temperature and was used to determine when the solder joint was complete.

Key performance metrics were extrapolated from temperature measurements taken every 0.5 seconds. Maximum, minimum, and average values were used in calculations as needed and data points were potted graphically. Time versus temperature graphs of each test performed are shown in Appendix A. Tip temperature fluctuations can be seen graphically as ups and downs on the tip temperature curves.

Test Results

Group 1: Included 75W and 90W resistive heating and 90W inductive heating soldering systems. The size and geometry of the soldering tips used were 2.4 mm and 2.5 mm chisels as offered by their manufacturers. System setpoint temperature was 350°C.

Manufacturer	Heating Technology	Time to Temp	Average Dwell Time	Average Recovery Time	Average Total Solder Cycle	Average Over-shoot/ Under-shoot (Accuracy)	Maximum Tip Temp Fluctuation (Stability)
METCAL™ GT90	Inductive	20 sec.	14 sec.	2 sec.	16 sec.	+ 4°C	106°C
Comparable A	Resistive	23 sec.	33 sec.	4 sec.	37 sec.	- 18°C	128°C
Comparable B	Resistive	22.5 sec.	26 sec.	4 sec.	30 sec.	+ 8°C	109°C

Group 2: Included 140W and 150W resistive heating and 120W inductive heating soldering systems. The size and geometry of the soldering tips used were between 5 mm and 6 mm chisels as offered by their manufacturers. System setpoint temperature was 350°C.

Manufacturer	Heating Technology	Time to Temp	Average Dwell Time	Average Recovery Time	Average Total Solder Cycle	Average Over-shoot/ Under-shoot (Accuracy)	Maximum Tip Temp Fluctuation (Stability)
METCAL™ GT120	Inductive	15 sec.	11 sec.	2 sec.	13 sec.	+6°C	99°C
Comparable C	Resistive	15.5 sec.	12 sec.	2 sec.	14 sec.	+11°C	133°C
Comparable D	Resistive	18 sec.	28 sec.	4 sec.	32 sec.	+7°C	105°C

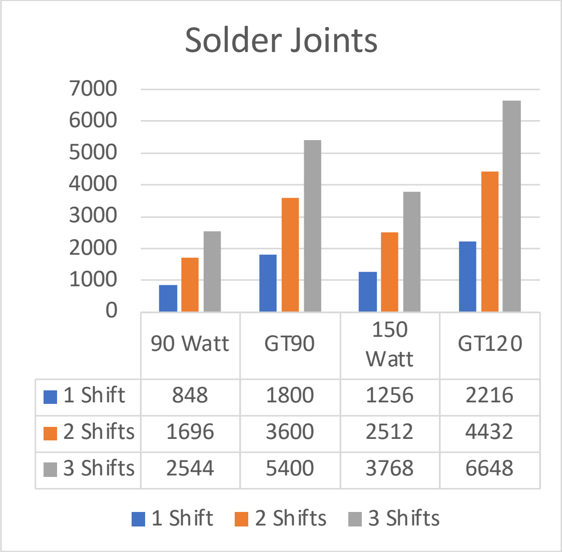
Superior Performance of METCAL Inductive Soldering Systems Revealed

In hand soldering, the heating technology employed significantly affects soldering performance and productivity.

Seven-load test results revealed that METCAL™ GT90 and GT120 inductive heating soldering systems consistently outperform comparable resistive soldering systems in all key performance metrics:

- Faster heating
- Shorter dwell times
- Quicker recovery
- Reduced total solder cycle time
- Superior temperature accuracy and stability throughout the soldering cycle
- Improved productivity by as much as 260%.

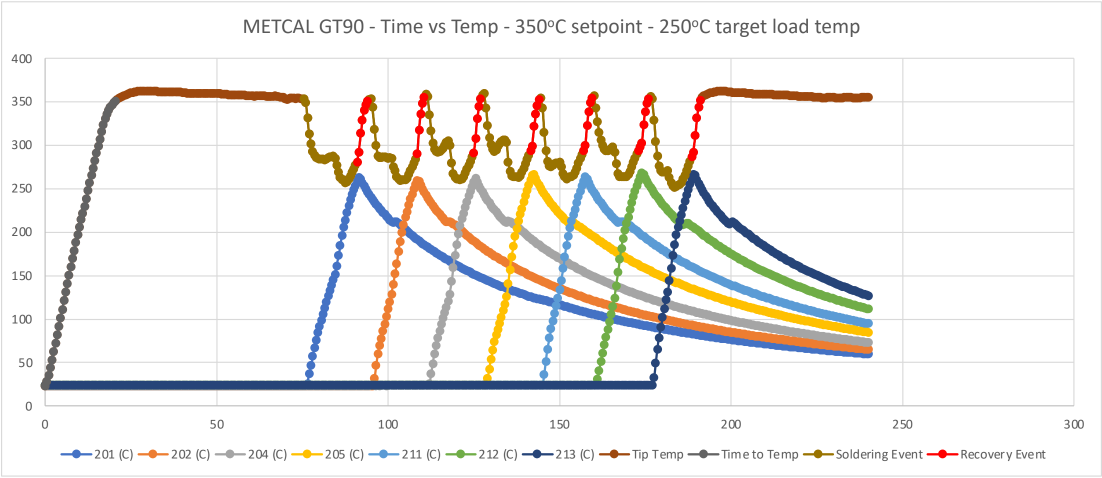
METCAL™ GT90 and GT120 inductive heating technology can increase your productivity by up to 260% compared to competitive resistive products (estimated using the average number of solder joints that can be completed per hour, and assuming standard eight-hour shifts).



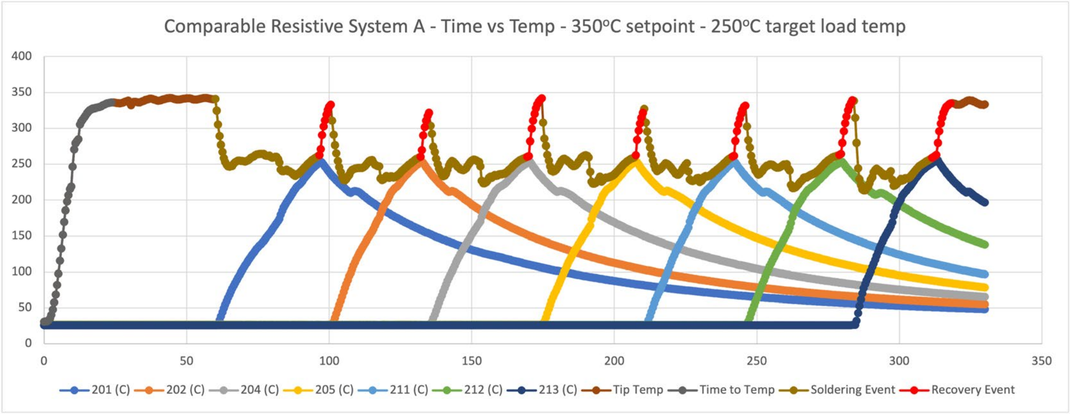
Appendix A: Time versus Temperature Plots for each hand soldering system tested

In each graph:

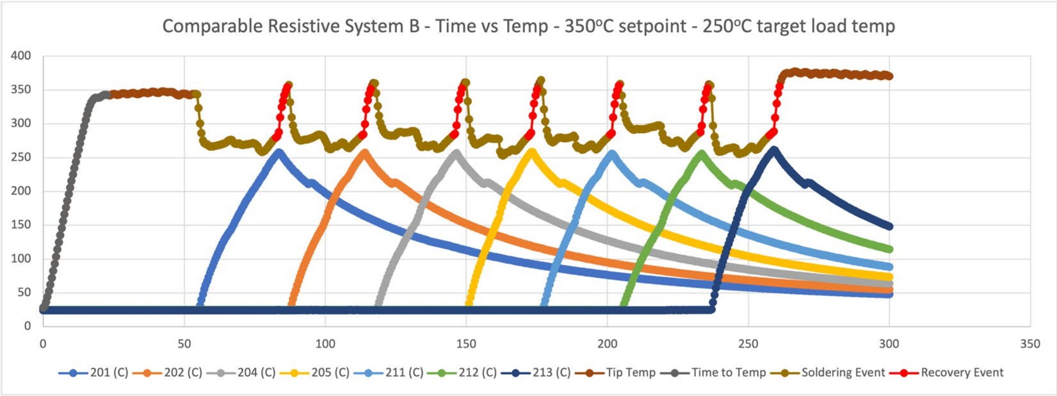
- **Top curve is Tip Temperature**
- **Bottom curves are Load Temperatures**



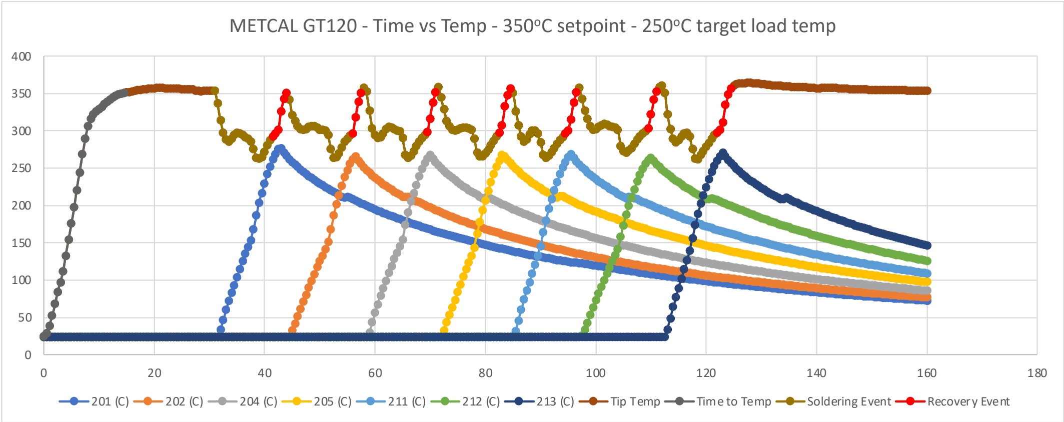
METCAL™ GT90 – 90 Watts



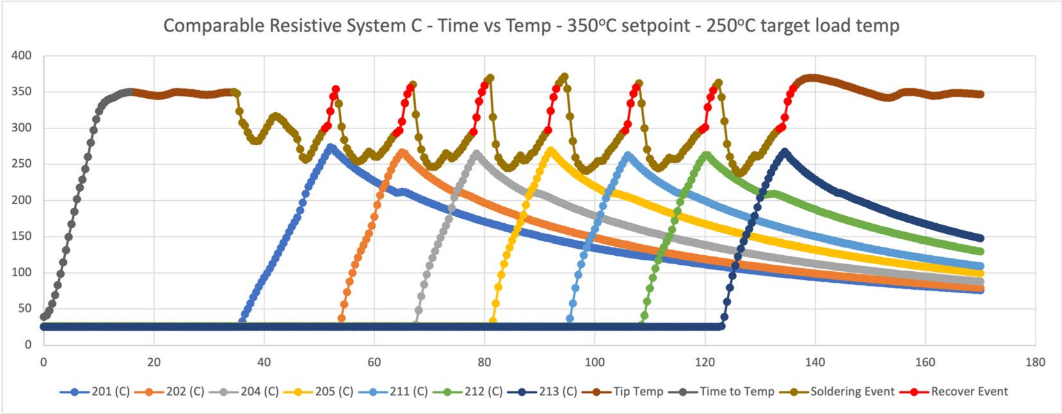
Comparable A – 90 Watts



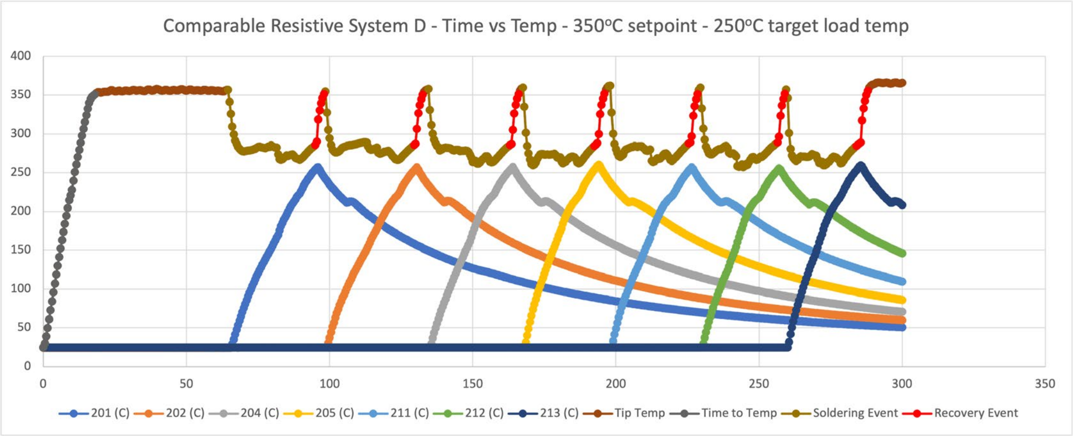
Comparable B – 75 Watts



METCAL™ GT120 – 120 Watts



Comparable C – 150 Watts



Comparing D – 140 Watts

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