Inductive vs. Resistive Heating Technology Used in Soldering Systems

A Performance Comparison

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METCAL™

Introduction

In hand soldering, when it comes to delivering heat from the power station to the tip, there are several factors that need to be accounted for regarding the performance of the system. The power of the unit and whether the handpiece uses tips or cartridges are two such factors used today by most people making a decision on a new soldering system. In addition to these, today's soldering systems utilize two different heating technologies; inductive and resistive which can also greatly affect performance. In inductive heating, also called direct heating, an alternating current flowing through a precise coil generates a magnetic field. Placing an object (tip) within the field induces eddy currents which will create heat. Heat is produced where and only where these eddy currents flow. Customizing chemical composition alloy and optimizing the frequency allows the eddy current to flow to the outer surface resulting in less skin depth for instantaneous response.

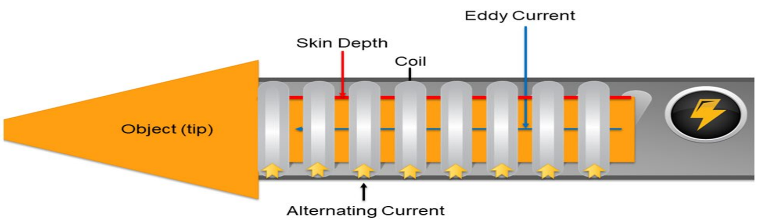


Figure 1a.

With resistive technology, heat is created from the heater coil, then conducted to the tip. Resistive heating has higher thermal resistance and therefore offers lower thermal performance than inductive heating.

This paper outlines a test procedure for measuring performance of hand soldering systems, and then illustrates the results from testing Metcal's new GT series inductive heating soldering stations with multiple solutions on the market today utilizing resistive heating technology.

Experiment Setup and Procedure

Seven identical thermal loads were machined from copper (8.5 mm diameter, 6.8 mm height). This setup was selected to represent a heavy load that would create a trade-off condition between a given soldering temperature and high throughput. An actual production example would be soldering to ground planes.

Figure 1b. 7-load test fixture

These loads were placed on a test fixture as shown in figure 1b. The base material is phenolic resin to prevent heat conduction between the loads. A type K thermocouple was connected between a load and a port of the data acquisition system which recorded temperature output and stored the profile n a computer shown in figure 2&3.

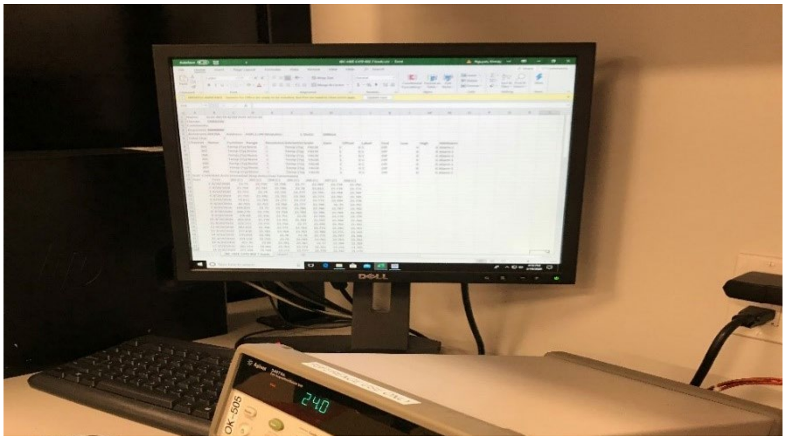


Figure 2: Date acquisition system gathering temperature profiles

Prior to each test run, the 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. The loads were cooled to about 240° C prior to each run. For this experiment, each soldering system under test was set to an idle tip temperature of 400° C and the attached soldering iron was validated by a temperature meter for 400° C measurement. The temperature for each soldering iron was measured at least twice to ensure repeatability. Once the 400° C stabilized, the soldering iron was placed on the first thermal load. To minimize tip measurement error and ensure uniform thermal contact, the test fixture was designed so that each soldering iron contacted the thermal load at a 15° angle relative to the horizontal as shown in figure 3. Once the temperature of the first load was raised from about 24° C to approximately 250° C (lead-free solder melts at about 217° C), the solder iron was moved immediately to the next load until all seven loads were completed. The time to bring all seven loads to 250° C was recorded.

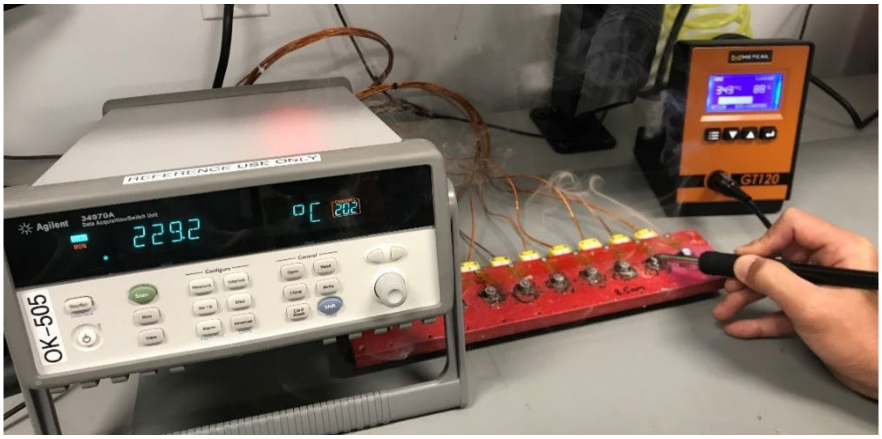


Figure 3: Placing the soldering tip on the thermal load

Hand Soldering Systems Tested

To perform the test, we chose soldering systems from multiple manufacturers. Systems were broken into two performance groups based on wattage of the system. Each system was tested with tips or cartridges as offered by the manufacturer. Solder tips are offered by some manufacturers as a lower cost iron and tend to offer lower performance than cartridges as they are indirectly heated by a heating element.

Group 1 included resistive heating systs from 75W to 130W, and inductive heating systems of 90W. The soldering irons used in this experiment were 2.4 mm and 2.5 mm chisels as offered by the manufacturer.

Manufacturer	System Part#	Heating Technology	Tip/Cartridge Part#	Tip or Cartridge	Geometry
Metcal	GT90	Inductive	GT6-CH0025S	Standard Tip	Chisel 2.5mm
Metcal	GT90	Inductive	GT4-CH0025S	Slim Tip	Chisel 2.5mm
JBC	CD-1BQE	Resistive	T245759	Cartridge	Chisel 2.4mm
Weller	WT1010	Resistive	XNT-B	Tip	Chisel 2.4mm
Hakko	FX-951	Resistive	T15-D24	Cartridge	Chisel 2.4mm

Group 2 included resistive heating systems from 130W to 250W, and inductive heating systems of 120W. The soldering irons used in this experiment were between 5 mm and 6 mm chisels as offered by the manufacturer.

Manufacturer	System Part#	Heating Technology	Tip/Cartridge Part#	Tip or Cartridge	Geometry
Metcal	GT120	Inductive	GTC-CH0050S	Cartridge	Chisel 5.0mm
Metcal	GT120	Inductive	GT6-CH0050S	Tip	Chisel 5.0mm
JBC	HDE	Resistive	C470002	Cartridge	Chisel 6.0mm
JBC	DI-1D	Resistive	C470002	Cartridge	Chisel 6.0mm
Weller	WT1010H	Resistive	XT-E	Tip	Chisel 5.9mm
Hakko	FM-203	Resistive	T15-D52	Cartridge	Chisel 5.2mm

Results – Thermal Performance Comparison

When looking at performance for hand soldering, operations engineers focus on three key metrics: time to **temperature**, **dwell time**, and **thermal recovery**. These three metrics together will identify the best soldering product for the production line and will help maximize throughput and lower scrap in the process.

Time to temperature is measured by how fast the soldering iron heats up on initial start-up. Time to temperature is crucial because it can be considered as lost minutes of manufacturing every day. Many soldering products in the market can take longer time for initial heating of the iron, leading to lower productivity. Over a shift or multiple shifts this wasted time spent waiting to solder can become quite significant.

Dwell time, sometimes referred to as temperature stability, is based on how long it takes to solder a specific joint. As the hot tip comes in contact with the solder joint, the dwell time is directly related to how well the soldering iron can keep temperature stable while losing heat due to thermal transfer during the soldering process. The performing units often will dip significantly during this process and can have trouble getting back to temperature, elongating the process. This is especially true with higher thermal demand applications.

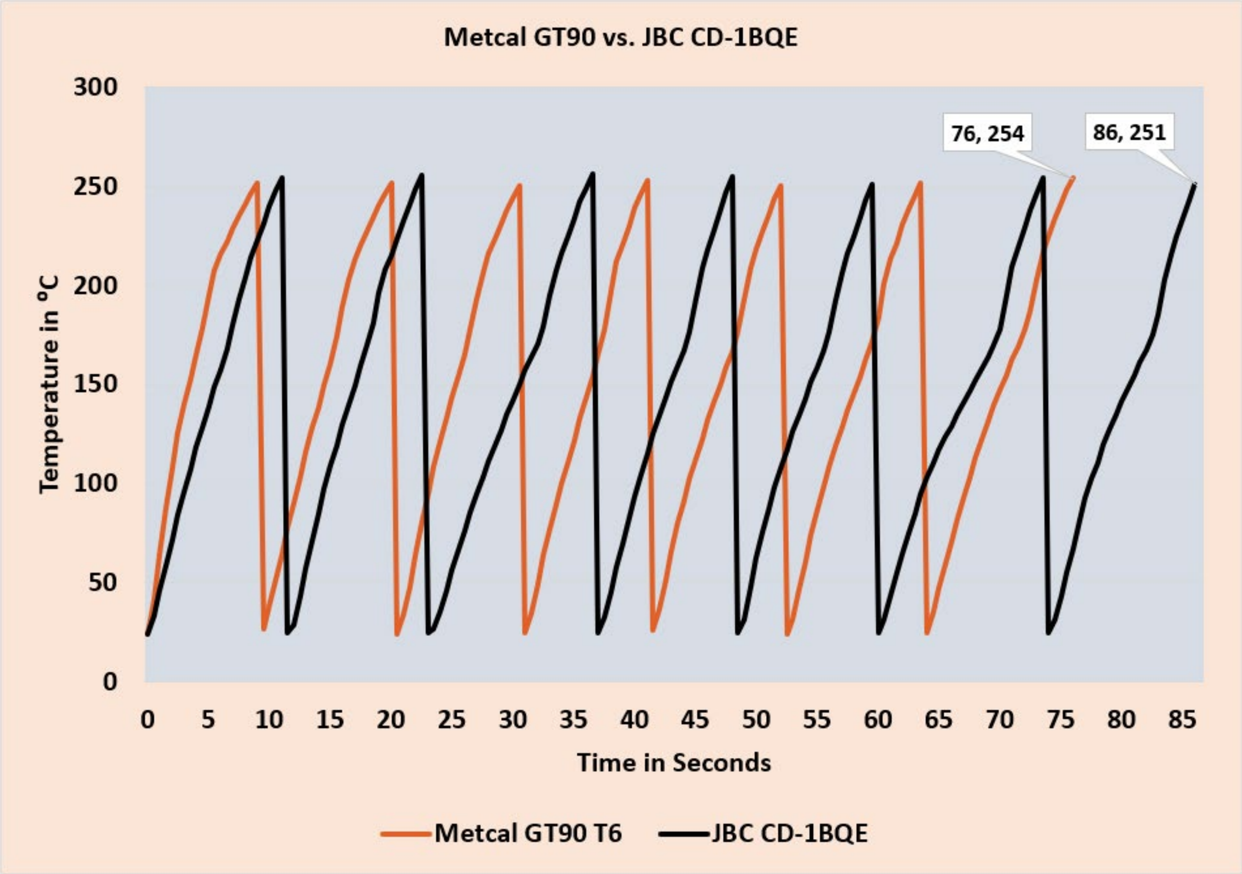
Recovery time is the time it takes for a soldering iron to return to temperature after completing a solder joint and is ready to begin the next joint. Like time to temperature, this time can vary significantly from model to model and can have the effect of losing time during manufacturing.

In this section, we used the test method described in the previous section to compare the thermal performance (the time to bring all seven loads to 250° C) of the soldering systems.

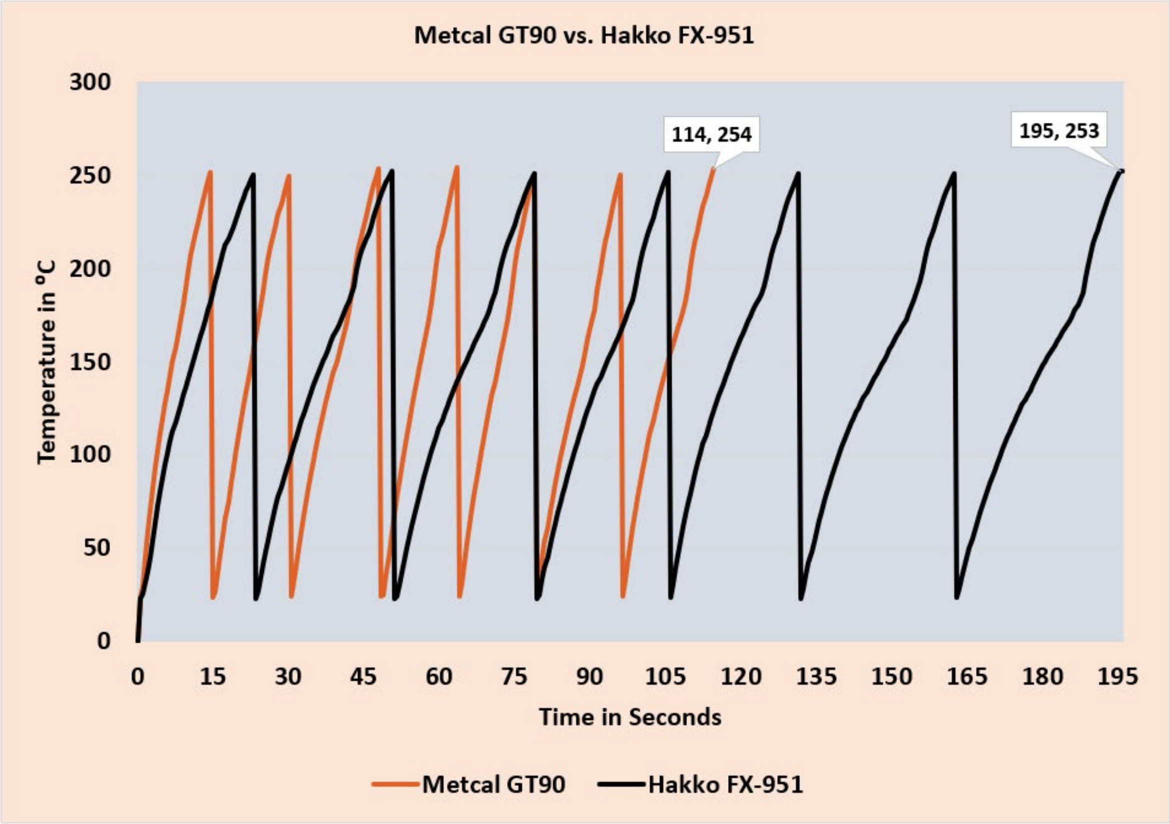
Light to Medium Power Systems, 7-Load Test

The Metcal GT90 inductive soldering system was tested against resistive solutions including: JBC CD-1BQE, Hakko FX-951, and Weller WT-1010.

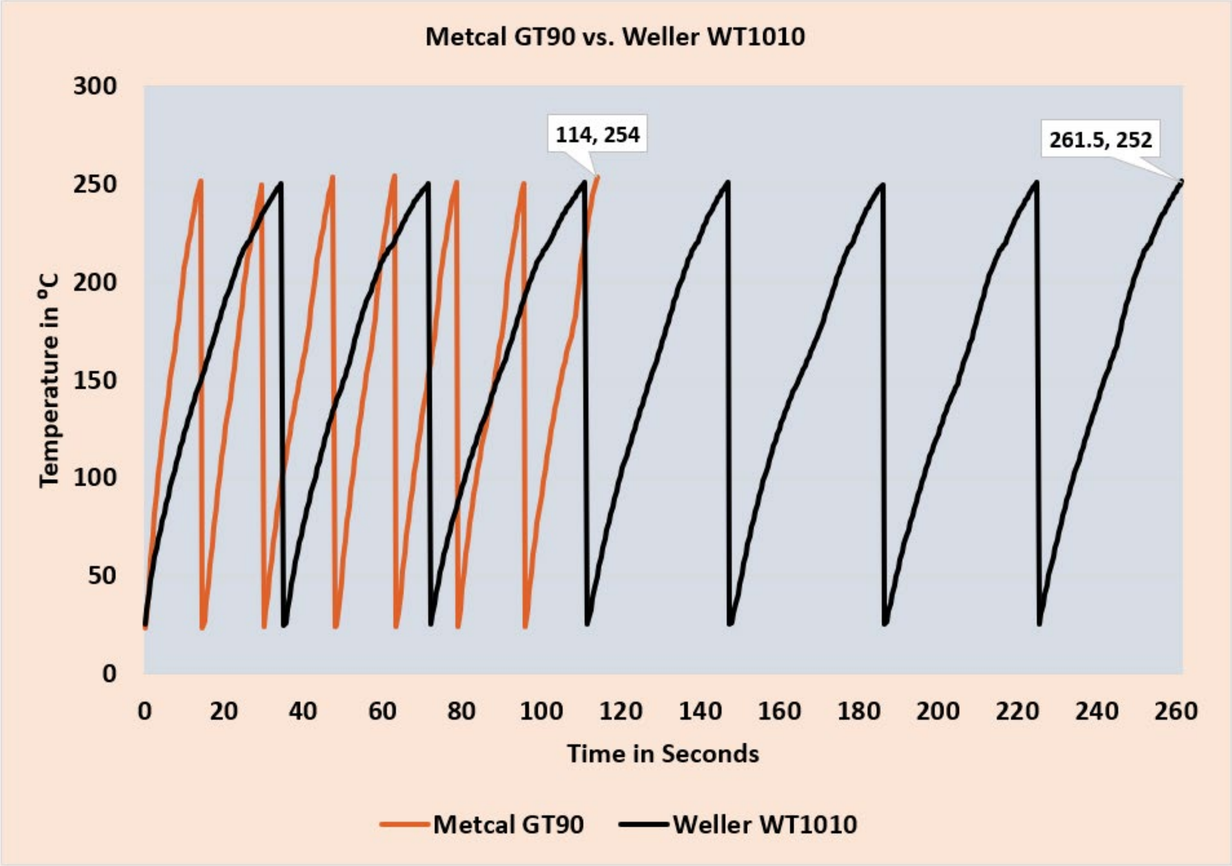
Manufacturer	System Part#	Tip/Cartridge Part#	Tip or Cartridge	Geometry
Metcal	GT90	GT6-CH0025S	Standard Tip	Chisel 2.5mm
JBC	CD-1BQE	T245759	Cartridge	Chisel 2.4mm



Manufacturer	System Part#	Tip/Cartridge Part#	Tip or Cartridge	Geometry
Metcal	GT90	GT4-CH0025S	Slim Tip	Chisel 2.5mm
Hakko	FX-951	T15-D24	Cartridge	Chisel 2.4mm



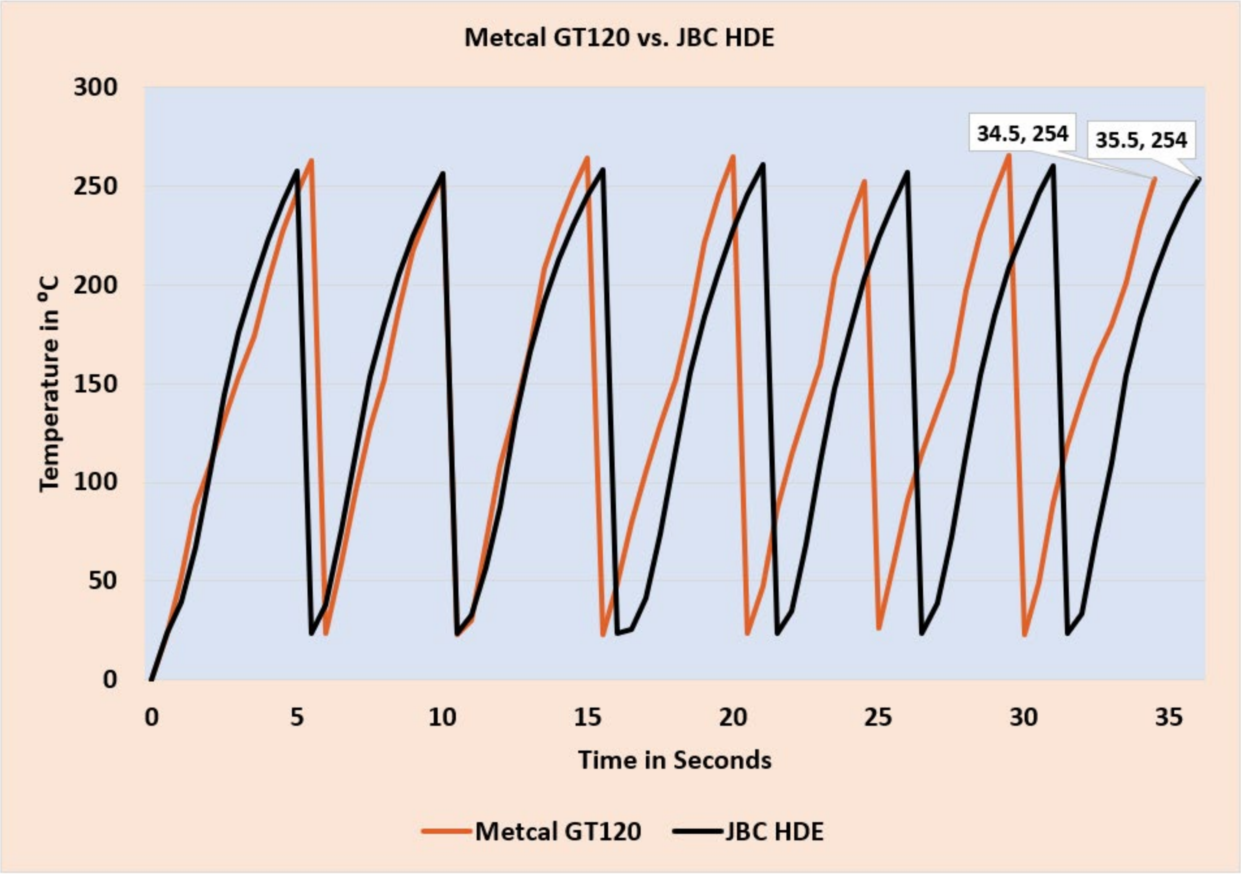
Manufacturer	System Part#	Tip/Cartridge Part#	Tip or Cartridge	Geometry
Metcal	GT90	GT4-CH0025S	Slim Tip	Chisel 2.5mm
Weller	WT1010	XNT-B	Tip	Chisel 2.4mm



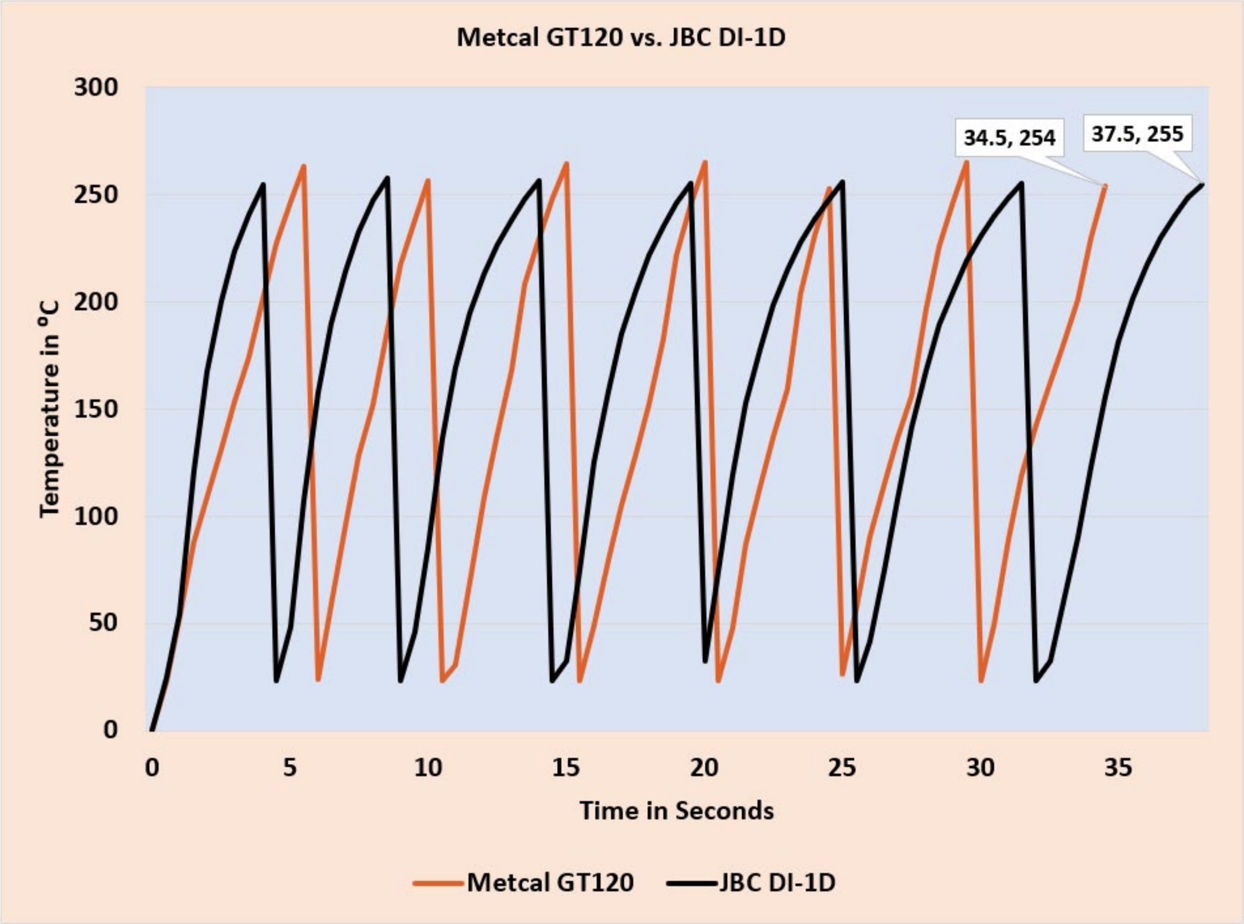
High Power Systems, 7–Load Test

The Metcal GT120 inductive soldering system was tested against resistive solutions including: JBC HDE, JBC DI-1D, Hakko FM-203, and Weller WT-1010H.

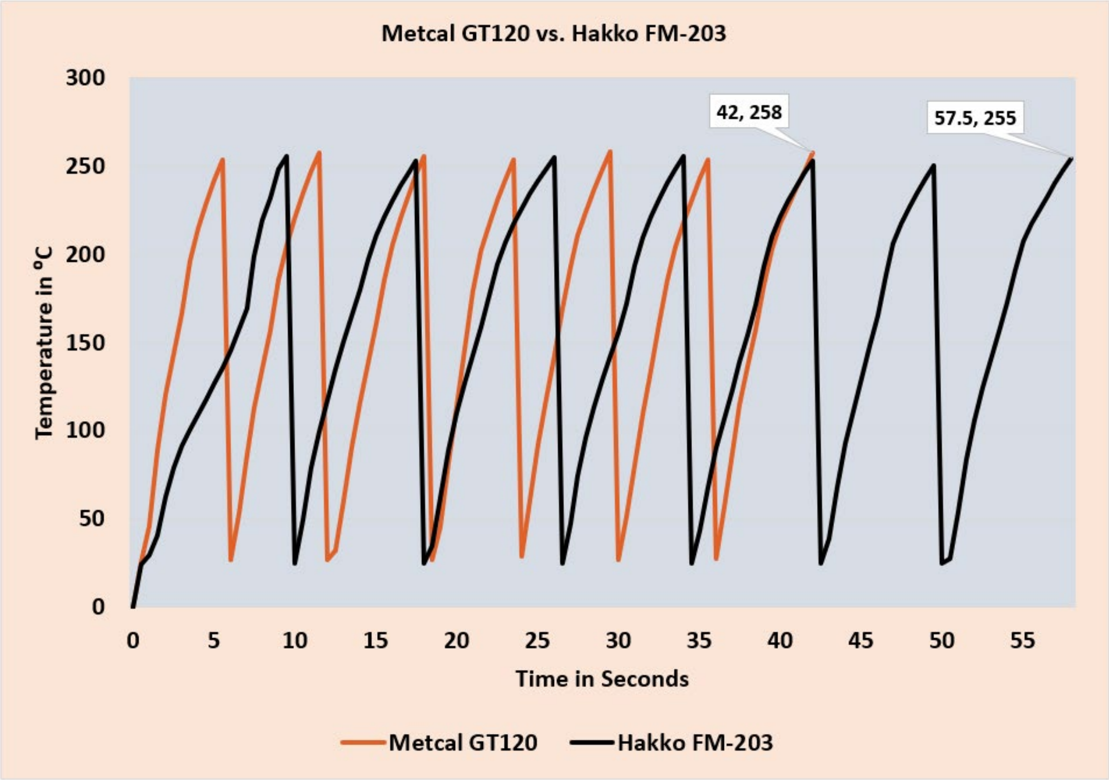
Manufacturer	System Part#	Tip/Cartridge Part#	Tip or Cartridge	Geometry
Metcal	GT120	GTC-CH0050S	Cartridge	Chisel 5.0mm
JBC	HDE	C470002	Cartridge	Chisel 6.0mm



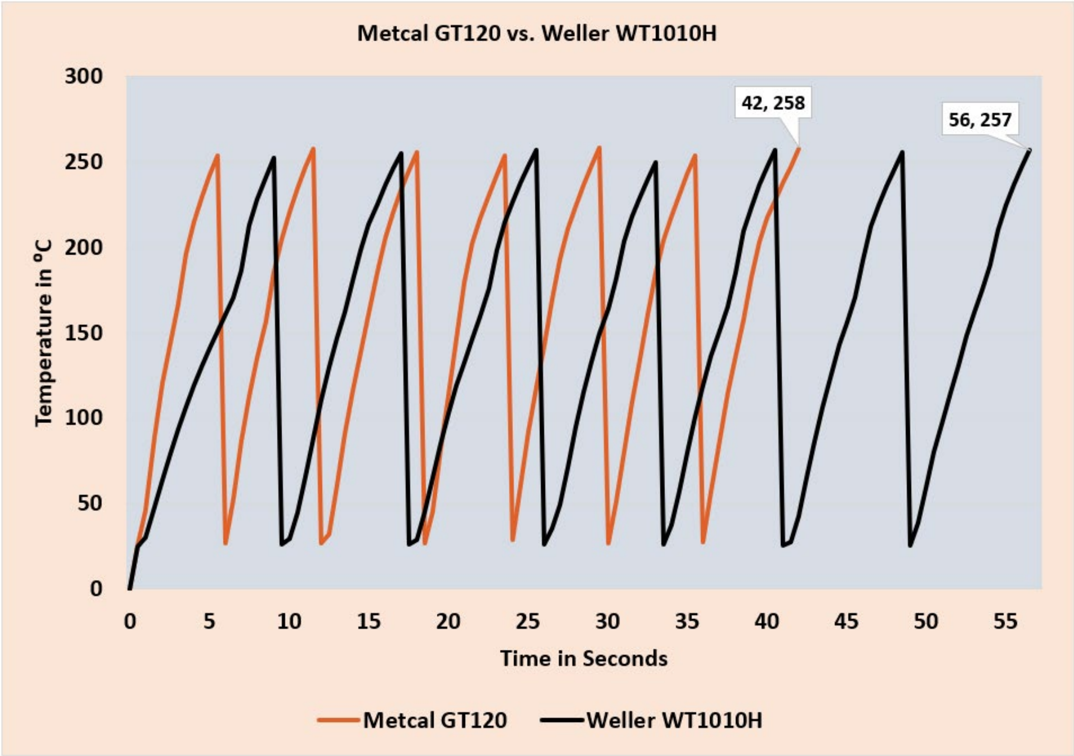
Manufacturer	System Part#	Tip/Cartridge Part#	Tip or Cartridge	Geometry
Metcal	GT120	GTC-CH0050S	Cartridge	Chisel 5.0mm
JBC	DI-1D	C470002	Cartridge	Chisel 6.0mm



Manufacturer	System Part#	Tip/Cartridge Part#	Tip or Cartridge	Geometry
Metcal	GT120	GT6-CH0050S	Tip	Chisel 5.0mm
Hakko	FM-203	T15-D52	Cartridge	Chisel 5.2mm

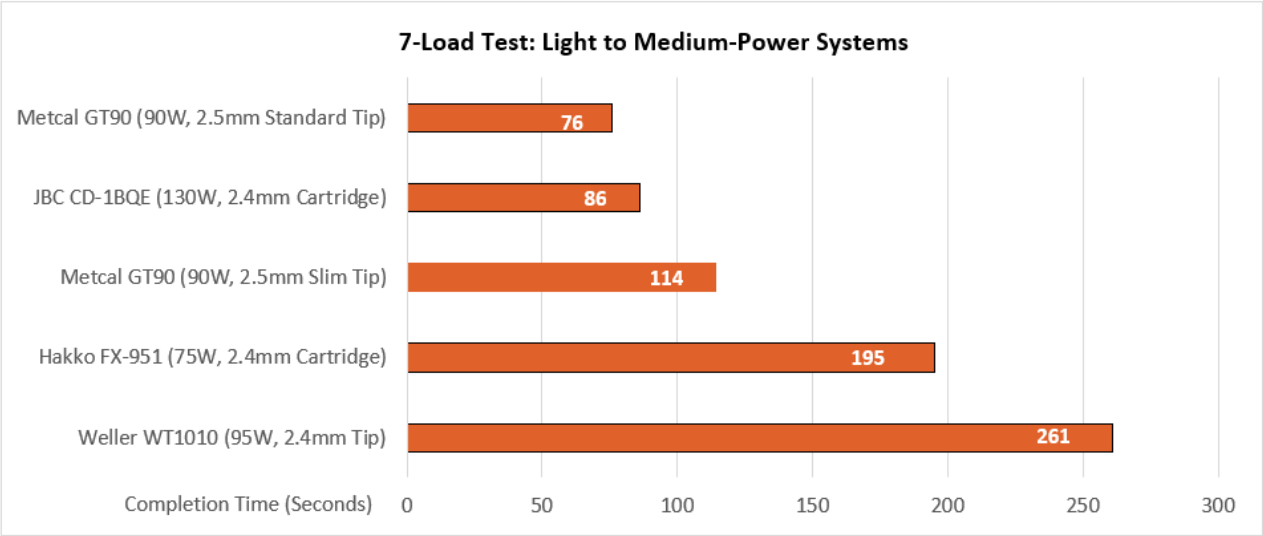


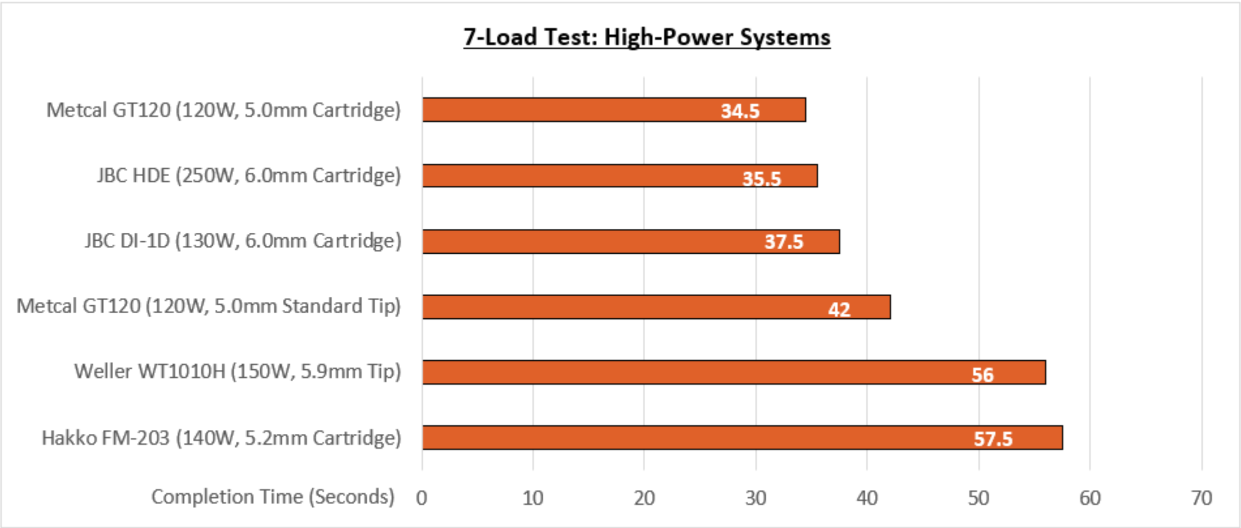
Manufacturer	System Part#	Tip/Cartridge Part#	Tip or Cartridge	Geometry
Metcal	GT120	GT6-CH0050S	Tip	Chisel 5.0mm
Weller	WT1010H	XT-E	Tip	Chisel 5.9mm



Summary

Below are the combined results from the light to medium-power test and the high-power tests:





Results from both tests show correlation between performance and three different factors:

- Heating Technology
- Power of the System
- Tip vs. Cartridge

Though power plays an important role in the performance of like systems, the tests show that heating technology, followed by the choice of a tip or cartridge seem to have a greater effect. This can be seen by the improvement in performance in each of the following cases:

1. The 90W inductive heating system with a standard tip outperformed all resistive heating systems tested whether they used tips or cartridges
2. The 120W inductive system performed equivalently to the 250W resistive system and outperformed the 130W resistive system tested where all used cartridges
3. The 120W inductive system with tips outperformed all resistive systems under 150W using tips and cartridges except for the JBC DI-1D utilizing a cartridge.
4. When comparing like resistive systems in both tests, units tested with cartridges significantly outperformed units tested with tips.

One note is that the resistive JBC systems seems to show improved performance over other competitive resistive systems in the same power range. This is likely due to a technology advantage in the development of the systems or cartridges. Further testing between these units and other resistive systems is needed to further explain this finding.

Conclusion

When evaluating performance, most users only compare the power rating of the soldering systems. If everything else between two systems is equal, this performance evaluation makes sense. In reality, no two systems are alike, and other variables including the type of heating technology used, whether the system is utilized with tips or cartridges, and even engineering differences from one manufacturer to the next can greatly affect performance.

Where the heater is located with reference to the soldering tip is very important to how the system performs. The closer the heater is to the tip, the faster it heats up.

This explains why soldering systems get better performance from cartridges than tips. Solder tips are a lower cost solution but add an additional “piece” to the system and move the tip further away from the heater. This lowers thermal efficiency and ultimately performance.

This principle also explains why inductive heating solutions outperform resistive heating solutions. In inductive soldering systems, the heater is physically a part of the tip, making it a one-piece heater and tip design. Resistive heating systems are two-piece designs because the heat is generated in the heater coil and then conducted to the tip. Inductive heating soldering solutions have much lower thermal resistance due to eliminating the need to transfer this heat and therefore offers faster time to temperature, dwell time, and recovery time.

The GT90 and GT120 adjustable soldering systems by Metcal utilize patented technology to combine inductive heating with adjustable temperature. This technology allows the systems to offer best in class soldering performance. This performance allows users to enjoy higher quality solder joints, improved throughput, and the ability to utilize lower cost tips for standard applications while still getting improved performance over competitive resistive systems.

The GT90 and GT120 adjustable soldering systems by Metcal utilize patented technology to combine inductive heating with adjustable temperature. This technology allows the systems to offer best in class soldering performance. For more information, visit us at metcal.com.