Induction Cooktop Performance:
How Pan Sizes Impact Energy Input

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Executive Summary

Induction technology cooktops have come a long way from when they first appeared on the markets in the 1940's. Today's induction technology has evolved into a viable option for operators with enhanced cooking features, safety functions and wider availability. However there has always been one draw back to this technology, which is the long held belief that induction technology needs to have high quality, expensive pans to function properly.

With this assumption, the Food Service Technology Center (FSTC) decided to "test" this belief and see if there were actually differences between induction technologies and how individual induction units reacted (power draw) to the pan size and type.

To test the notion, the FSTC engineers tested induction cooktops from 3 different manufacturers with 14 very different pans. Induction cooktop performance was characterized by determining how much of the rated energy input was utilized (drawn) with a given pan. During the testing each unit was set to its maximum setting.

The induction cooktop performance test was conducted by placing each pan on the induction unit and measuring the appliance power draw. Each induction cooktop was tested a minimum of three times with each pan to ensure precise results.

Executive Summary

A summary of the test results follow in Table ES-1. Included in the table is the pan diameter in millimeters, power draw in kW and the percentage of the rated input.

Table ES-1. Summary of Induction Cooktops Performance.

Pan & Diameter (Millimeter)	**Unit 1 - 2.5 kW** kW / Percentage	**Unit 2 - 1.5 kW** kW / Percentage	**Unit 3 - 1.5 kW** kW / Percentage
A - 137	1.62 / 65%	1.32 / 89%	0.71 / 48%
B - 159	1.92 / 77%	1.40 / 93%	0.96 / 64%
C - 190	2.22 / 89%	1.36 / 93%	1.36 / 91%
D - 192	2.26 / 91%	1.40 / 94%	1.19 / 79%
E - 225	2.49 / 99%	1.41 / 94%	1.32 / 88%
F - 190	2.25 / 90%	1.40 / 94%	1.16 / 78%
G - 140	2.14 / 86%	1.40 / 94%	1.18 / 79%
H - 110	1.69 / 68%	1.28 / 85%	0.68 / 46%
I - 150	2.20 / 88%	1.41 / 94%	0.93 / 62%
J - 148	1.77 / 71%	1.41 / 94%	0.82 / 55%
K - 230	2.52 / 99%	1.41 / 94%	1.24 / 83%
L - 142	2.19 / 88%	1.42 / 95%	0.97 / 65%
M - 235	2.28 / 91%	1.41 / 95%	1.13 / 76%
N - 165 x 228	1.72 / 69%	1.41 / 94%	1.15 / 77%

As the results in the table ES-1 indicate, Unit #2 proved to be consistent regardless of the pan size tested, and consistently utilized at least 85% of its rated input even with the smallest pans.

Units # 1 & # 3 tested favorably with the high quality pans (K & E), which were designed for use with induction cooktops, however their power draw fell off sharply with both the smaller and lower quality pans.

Executive Summary

Induction Unit #2 operated remarkably well regardless of the pan size or material, proving that high quality, expensive pans are not necessarily required for well-designed induction cook tops. However, small pans will draw full-power on Unit # 2, which could pose an issue on higher powered units. Overall, the performance of Unit # 2 demonstrated the engineering efforts of its design.

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1 Introduction

Background

The Range top is one of the most widely used pieces of equipment in a commercial kitchen and continues to evolve as end users demand more powerful and energy efficient equipment. An interesting development is the application of induction technology to electric range tops and table-side cooking units. One of the potential benefits of induction cooking is that the heat can be evenly distributed into a large cooking surface, similar to a gas burner, without sacrificing the efficiency of electric resistance cooking. Induction range top technology has been available to residential users for several years, but has only recently started to make its way into the commercial sector.

Operators interested in induction cooktops consider energy efficiency, ease of use and compatible pan performance when making their purchasing decisions. To assist the consumers in their selection process, this report examines induction cooktop technology and whether there is a difference between how the cooktops perform with varying sizes and quality of pans.

With support from the Electric Power Research Institute (EPRI), the Gas Research Institute (GRI), and the National Restaurant Association, PG&E's Food Service Technology Center (FSTC) has developed numerous standard test methods (STMs) for commercial cooking equipment. These STMs have been carefully reviewed and subsequently ratified by the American Society for Testing and Materials (ASTM) committee F 26 on commercial food service equipment.

In 1994, the FSTC completed a draft STM for range tops which was later ratified by ASTM (designation F 1521-96).[1,2] This method served as a frame work for conducting pan sensitivity tests on three different induction cooktops.

The glossary in Appendix A is provided so that the reader has a quick reference to the terms used in this report.

Objectives

The objective of this report is to examine the performance of three different induction cooktops using fourteen different pans of diverse size and constructions. The results are a measure of how much of the cooktops rated input (kW) was drawn with each pan and what percentage of the induction unit's rated input was utilized.

Appliance Descriptions

The three cooktops utilized a single induction hob that caused heat to be generated directly into the magnetic material comprising the cooking container (pan) by means of an induced electromagnetic field. The amount of heat generated in the cooking container was controlled by varying the strength of the magnetic field. Each unit had a smooth and continuous ceramic glass plate. Because the surface was not directly heated during operation, it remained relatively cool, gaining only residual heat from the cooking container.

The three induction units are referred to as units # 1, # 2 and # 3. The pans are lettered A through N. Appliance specifications are listed in Table 1-1 through 1-3.

Table 1-1. Unit #1 Specifications.

Generic Appliance Type	Electric induction cooktop
Rated Input	2.50 kW
Dimensions	15" x 20¾" x 5½"
Construction	Ceramic cooktop with Stainless Steel sides panels
Controls	Touch pad cooking controls adjustable for "Fry" and "Warm" modes using a scale of 1 to 5 for each style with an sensor alarm
Notes	Overall this unit seemed to be very well constructed, complimented with its user friendly control touch pad

Table 1-2. Unit # 2 Specifications.

Generic Appliance Type	Electric induction cooktop
Rated Input	1.50 kW
Dimensions	15” x 17½ x 4¼”
Construction	Ceramic cooktop with Stainless Steel side panels
Controls	Touch pad cooking controls adjustable for “Heat” mode using “High, Medium and Low” settings and “Temp” mode with 5 temperature settings ranging from 180°F to 390°F and a cooking timer
Notes	Of the three units tested, this unit had the best control features, design, and overall quality construction

Table 1-3. Unit # 3 Specifications.

Generic Appliance Type	Electric induction cooktop
Rated Input	1.50 kW
Dimensions	13½” x 12½” x 3½”
Construction	Ceramic cooktop with Stainless Steel side panels
Controls	Two cooking control adjust between “Cook” and “Temp” modes using a single dial for both power (360w to 1450w) or temperature (120°F to 410°F) settings
Notes	Construction / controls attributes reflect manufacture emphasis in low first cost induction cooktop.

Pan / Descriptions

The testing of the induction units involved the use of fourteen pans, all varying to some degree. Of these fourteen pans tested, the majority of the pans were either sauté or sauce pans, reflecting typical, real-world usage of range tops. However, to obtain a variation in pan types, also tested was a stock pot, a wok, and a ½ size chaffing dish.

For the purpose of the testing, pan diameter was determined by the bottom contact surface. This was assumed to have the greatest impact on cooktop performance. While some pans were of the same (or similar) diameter, each pan's attributes contrasted.

Pan diameters ranged from 110 millimeters to 235 millimeters. Some pans were from well known manufacturers, while others had no markings. The pans were constructed from materials such as cast iron, stainless steel or laminated alloys. A majority of the bottoms of the pans were level (uniform) and some pans had a machined plate attached to the bottom. Two of the pans were noticeably warped and the two cast iron pans had a raised outer ring on the bottom.

The machined raised flat bottom (MRFB) pans are described as pans that have a flat, machined disk shaped plate attached to the bottom of the pan which allows for even, continuous contact with the induction surface and prevents warping.

A raised ring flat bottom (RRFB) pan is described as a pan that has a thin, narrow ring on the bottom that circles the outer edge of the pan. This design prevents a majority of the pan from coming in direct contact with an induction surface.

Though often difficult and expensive to have the bottom of the pan perfectly level without machining the bottom. Only two of the pans showed noticeable signs of warping. Of these two pans, one was concave (CC) and the other convex (CV) in shape.

Since many of the pans did not have any markings or did not indicate material properties, the researchers wanted to add a "consumer subjectivity" to the pan in the description table/list. This listing in Table 1-4 is only subjective to the point that it gives the reader another perception about the pans. The quality of the pans were broken down into low, average and high. These ratings were based on what a consumer might perceive a pan to be. A "low" quality pan would be thin, very light weight and easily dented or warped. An "average" rating for pans that were well constructed, relatively thick and could with-stand everyday use. A "high" quality pan was very heavy, thick, and had the appearance of lasting a lifetime. See Table 1-4.

Table 1-4. Pan Specification.

Pans	Diameter (mm)	Pan Type	Shape	Bottom Contours	Perceived Quality
H	110	Sauce Pan	Round	Flat Bottom	Average
A	137	Sauté Pan	Round	MRFB	Low-Avg.
G	140	Wok Style	Round	Flat Bottom	Average
L	142	Cast Iron	Round	RRFB	Avg.- High
J	148	Sauce Pan	Round	MRFB	Avg.-High
I	150	Sauce Pan	Round	Flat Bottom (CV)	Low
B	159	Sauté Pan	Round	MRFB	Avg.-High
C	190	Sauté Pan	Round	Flat Bottom	Average
F	190	Braising Pan	Round	MRFB	High
D	192	Sauté Pan	Round	MRFB	Avg.-High
E	225	Sauté Pan	Round	MRFB	High
K	230	Stock Pot	Round	Flat Bottom	High
M	235	Cast Iron	Round	RRFB	Avg.- High
N	165 x 228	½ Chaffing Dish	Rectangle	Flat Bottom (CC)	Average

Eleven companies manufactured the 14 pans used in this study. Three of these 11 companies manufactured the following pairs of pans: B & D, E & F and C & G. On the following pages, Figure 1-1 and 1-2 display the pans used in the testing. This figure is provided to demonstrate the diversity of pans styles that were utilized.

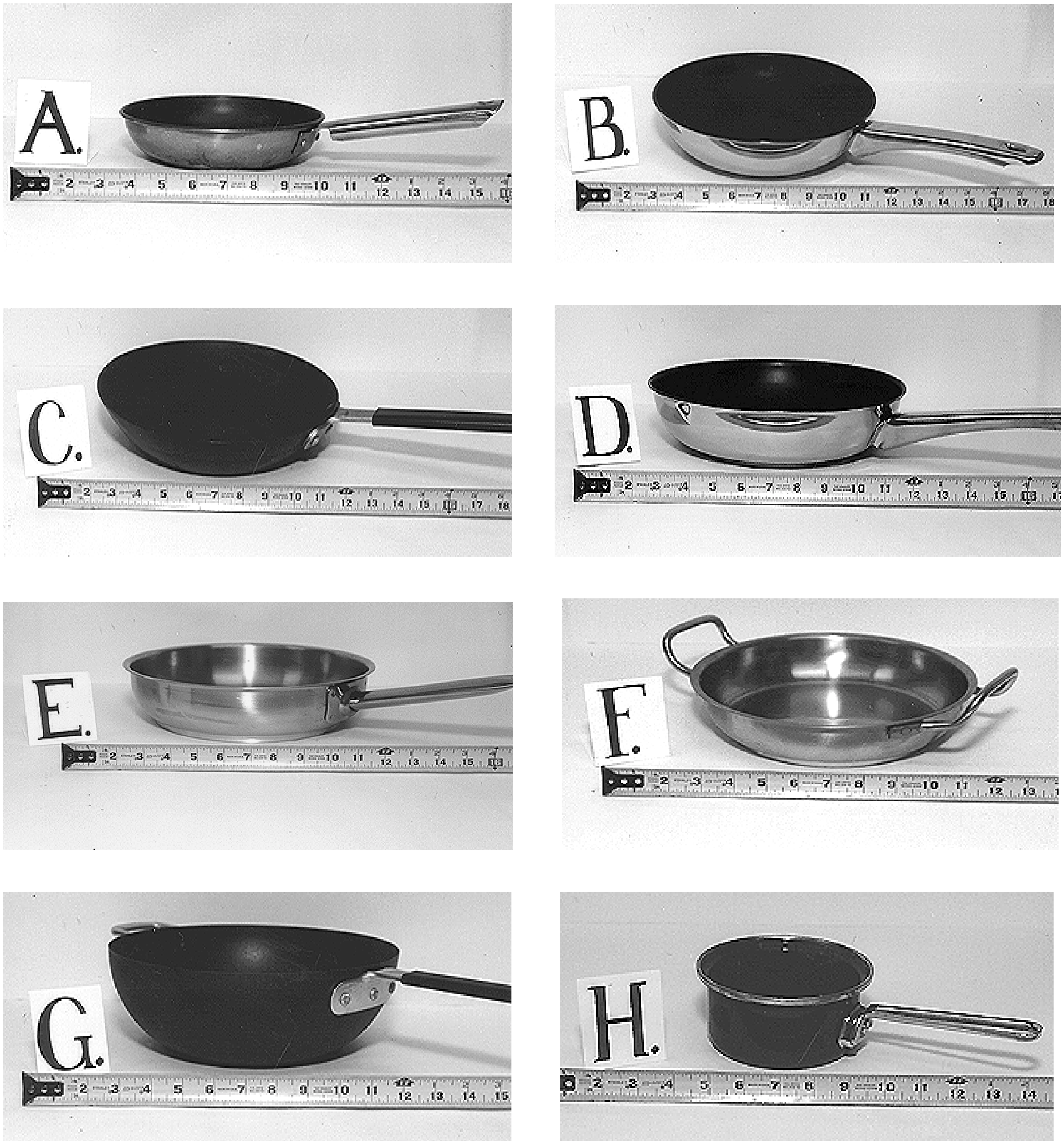

Figure 1-1.
Pans tested - A through H.

Figure 1-2.
Pans tested - I through N.

2 Methods

Setup and Instrumentation

FSTC researchers placed the induction cooktops on a table under a 4-foot-deep canopy hood that was 6 feet, 6 inches above the floor. The hood operated at a nominal exhaust rate of 300 cfm per linear foot of hood. There was at least 6 inches of clearance between the vertical plane of the induction cooktop and the edge of the hood.

Power and energy were measured with a watt/watt-hour transducer that generated an analog signal for instantaneous power and a pulse for every 10 Wh. The transducer was connected to an automated data acquisition unit that recorded data every 5 seconds. A voltage regulator was connected to the induction cooktops to maintain a constant voltage for all tests.

Sensitivity

Prior to the pan performance tests, each induction unit was preheated for 45 minutes using pan (K) filled with 20 pounds of water. Filling the pan with water assured that each unit would draw its full power consumption during the preheat and prevent the pan from heating up to quickly, thereby activating the high-temperature safety cut-off. This preheating stabilized the induction units, allowing for a consistent power draw during the remainder of the testing. This stabilization period accounted for a somewhat higher input (4%) on the Units # 2 & # 3 during the first 30 minutes. Unit # 1 had only a 1% input decrease during this same 30 minutes preheat after the electronics heated up inside the unit.

The cooktop in Figure 2-1 exhibited a decline in power from the moment it was turned on, whereas the unit in Figure 2-2 remained steady for the first seven minutes then began to decrease its power draw. See Figures 2-1 through 2-3.

After the initial decrease in power draw the induction unit in Figure 2-1 remained very stable, whereas the unit in Figure 2-2 has a sudden second dropping of power draw (at 55 min.) which was unique to this unit. In Figure 2-3, Unit # 1 showed little input variation through out this preheat period.

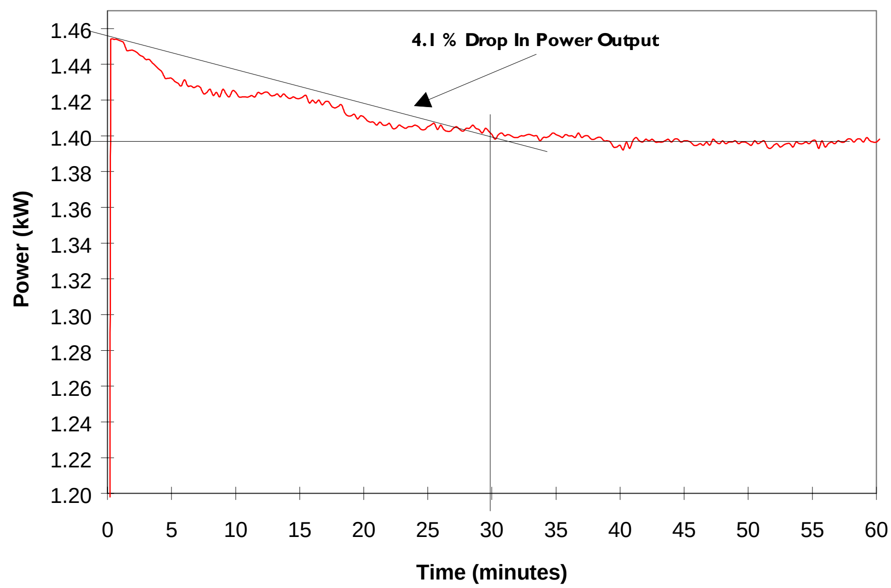

Figure 2-1.
Preheat Test - Unit # 2.

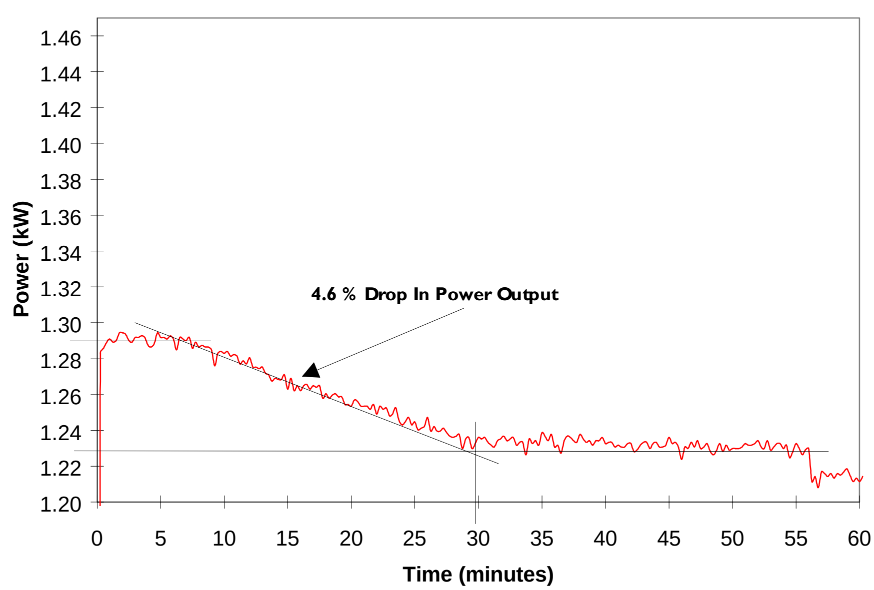

Figure 2-2.
Preheat Test - Unit # 3.

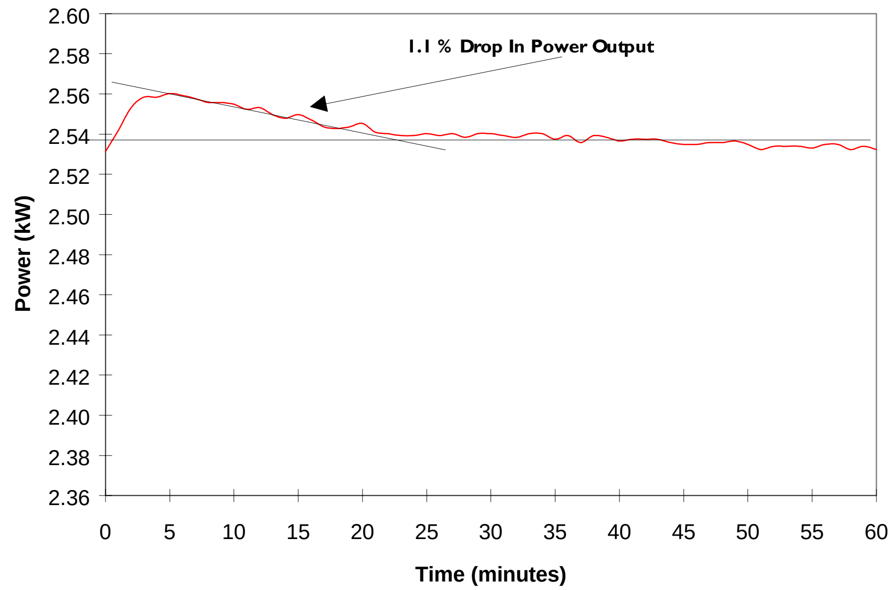

Figure 2-3.
Preheat Test - Unit # 1.

Though these decreases in power draw are minimal in the overall power of the induction units, it was necessary to stabilize the units before conducting the pan sensitivity tests to ensure that such an energy decrease would not occur during testing.

Pan Testing

For the testing of each individual pan, FSTC researchers filled the pans half-full with 70°F water (ensuring full power draw and no safety shutoffs during testing). Each pan was then placed on the test unit, power was recorded, followed by the next pan, until each pan had been tested. Each unit was tested a minimum of three times for accuracy and repeatability.

All the energy input tests results had an uncertainty of less than ± 4%. The results from each test run were averaged, and the absolute uncertainty was calculated based on the standard deviation of the results.

3 Results

Introduction

Prior to testing, there was a wide-held belief that premium pans were best used with induction technology and that using a small, or inexpensive pan would result in poor performance of the induction unit. The price of these premium pans alone made an induction cooktop too expensive for many commercial kitchens. However, as the following results reveal, expensive pans are not necessary when used in combination with a quality induction cooktop.

Results

The three induction units were tested a minimum of three times with fourteen pans under identical testing conditions. Each pan was filled half-full with 70°F water at the beginning of the tests to ensure that each unit would draw the maximum amount of power. This also prevented the pans from heating up to quickly and reaching the high temperature safety cut-off limit of these induction units. The tests were performed with the units set to their maximum setting input rates after a 30-minute stabilization period. The results for each of the induction units were very consistent through out the three tests. In the following graphs, the pans were arranged with the smallest pans on the left-hand side, increasing in size to the right.

Unit # 1 in Figure 3-1 had a nameplate rating of 2.5 kW. The energy that was drawn by the pans was neither consistent with size nor characteristics.

Results

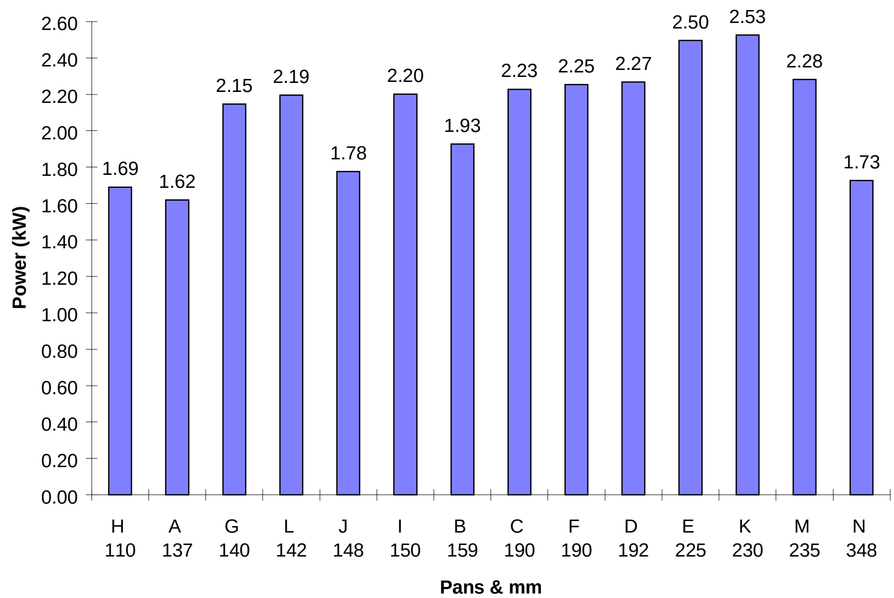

Figure 3-1.
Cooktop #1 Results.

In Figure 3-1 there can been seen a slight trend of increasing performance as the size of the pans increase. However this does not hold true for the cast iron pans (L & M), particularly (M) even though it is one of the largest pans tested. Furthermore, pans (L & M) have a raised ring on the outside portion of the pans, preventing a majority of the pan's surface from direct contact with the induction surface.

The warped pans (I & N) did not exhibit any expected pattern either. The ½ size chaffing dish (N - concave bottom) performed poorly, but was of good sturdy quality. Where as the convex shaped pan (I) performed remarkably well considering it was one of the lowest quality pans. Also interesting about pan (I) is that the two pans closest in size to it, (J & B) had machined raised flat bottoms (MRFB) which exhibited almost perfect contact with the induction surface but performed poorly when compared to pan (I).

Pans (C, F and D) all of the same size (three different manufacturers) had almost identical performances. Pans (H & A) the two smallest pans performed unexpectedly. Pan (A) being larger and having a machined raised flat bottom performed poorly compared to the smallest test pan which was of the "outdoor camping" style and quality, in addition to being slightly warped. Overall, Unit #1 reacted differently to both pan size and construction, forcing the consumer use a pan specially suited for this induction unit.

Unit # 2 in Figure 3-2 had a nameplate rating of 1.5 kW. This induction range top was consistent in performance for both pan size and quality.

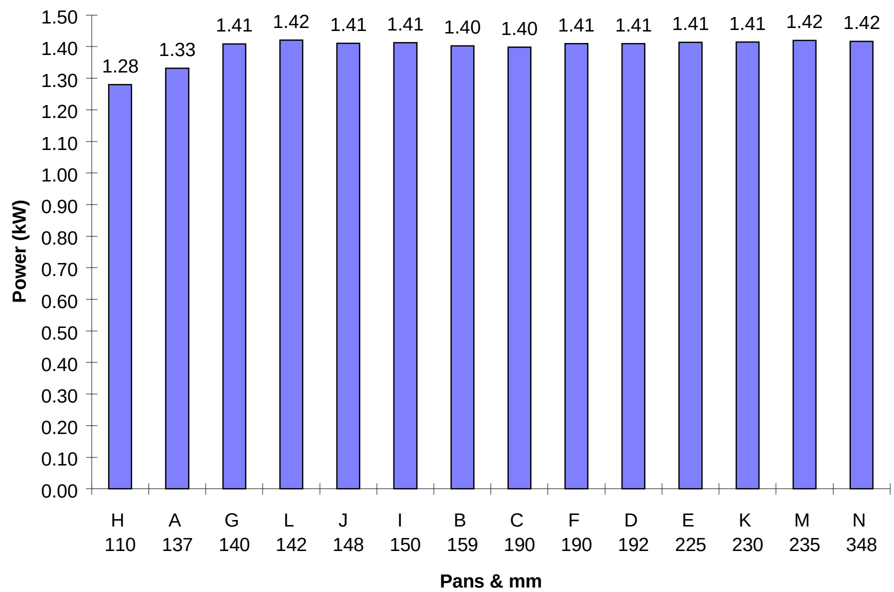

Figure 3-2.
Cooktop # 2 Results.

Unit # 2 consistently delivered at least 85% of its rated input with any pan tested, including the stainless-steel chaffing dish (N). Where as the other two induction units tested would often falter under less than ideal conditions, Unit # 2 excelled. For example, the two cast iron pans (L & M) with their raised ring flat bottom (RRFB) performed very well with Unit #2 however, faired less that perfect with the other two Units (# 1 & # 3).

Another example of Unit # 2's versatility and effectiveness is with pan (I). This pan was warped and of lower quality compared to the other pans tested, performed equally to its counter parts with induction Unit # 2, but fell short with Units # 1 & # 3.

Because of the ability of Unit # 2 to deliver full-input power to the pans regardless of size, shape defects or pan materials (provided its was a ferrous material) it out performs its gas and electric (coil and plate) range top counter parts. As for warped pans, a gas unit will be able to compensate for this imperfection, but will still have a low energy efficiency. In addition the electric coil will also drop in energy efficiency because of the less than perfect contact with the coils. All in all, Unit # 2 is an exceptional unit demonstrating its adaptability with all sizes and types of pans.

The third unit tested (Unit # 3) had a nameplate rating of 1.5 kW. The amount of energy that this induction unit was able to draw for each pan varied considerably, both with pan size and characteristics.

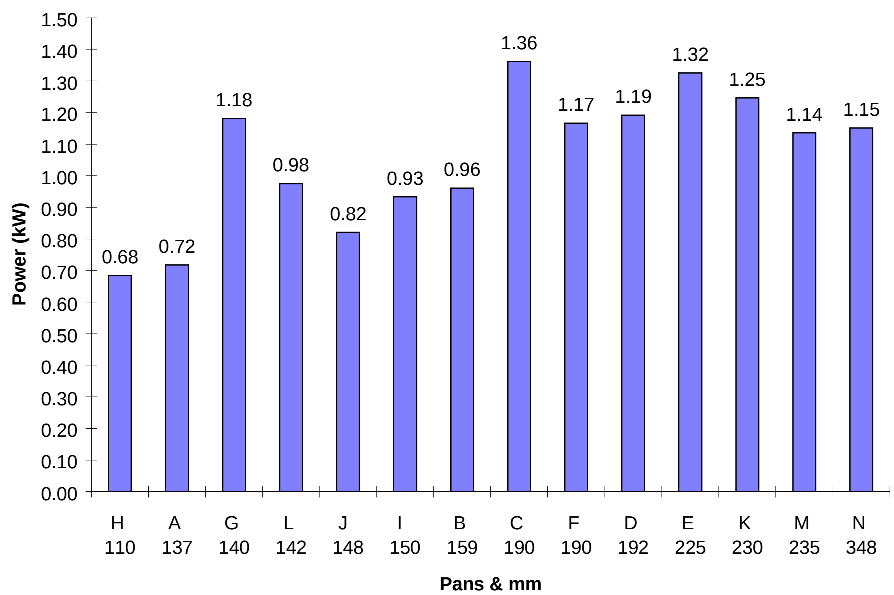

Figure 3-3.
Cooktop # 3 Results.

Unit # 3 performed similarly to Unit # 1 in that, as the size of the pans increased, so did its ability to deliver energy to the pans. Like Unit # 1, the performance of Unit # 3 was not as effective with the cast iron pans (L & M) with their raised ring flat bottom (RRFB). With Unit # 3, pan (C) was the best performer, whereas pan (K) was the best performer on Unit # 1 and Unit # 2 performed well with all its pans.

In addition, Unit # 3 was also unique in that it did not recognize (that is, draw power) pan (H) until the induction unit had been preheated, which was not observed on either of the other induction units (# 1 & # 2). Even when tested with similar sized pans (C, F & D), the effectiveness of Unit # 3 varied noticeably. However, Unit # 3 did perform acceptably with higher quality pans. With lower quality pans, or pans not specifically designed for use with induction cooktops, one could expect up to a 40% drop in rated performance.

All three induction cooktops are represented in Figure 3-4. This Figure compares the percent of rated power (kW) that the cooktops drew for each pan, plotted along the vertical axis, with pan size plotted along the horizontal. It should be noted that Unit # 1 had a slightly higher energy input than its nameplate rating.

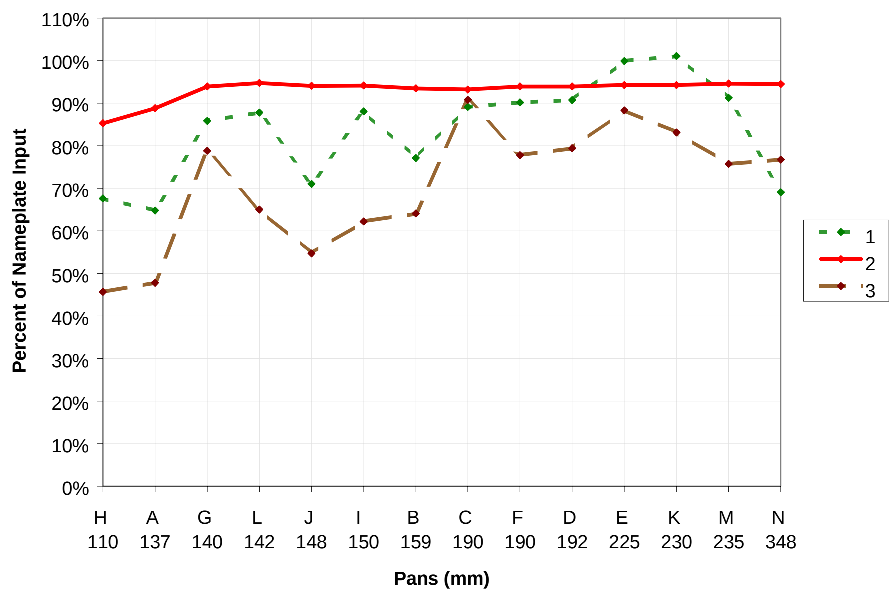

Figure 3-4.
Percent of Rated Input.

Results

The differences between these induction units were many. For example Unit # 1 and Unit # 2 showed little change in the amount of power drawn by the three pans near 190 mm, whereas Unit # 3 showed a drop of 11 % in its power draw between the pans. Another example is the ½ size chaffing dish pan (N) which showed no changes in Unit # 2 and Unit # 3 where as Unit # 1 responded poorly.

Though all three cooktops performed effectively at times, it was clear that it is not the pans that make the induction unit but the induction technology itself that sets manufactures apart.

4 Conclusions

The designers of Unit # 2 have engineered an induction cooktop that is able to deliver full power to the pan, regardless of the pan's size, shape or quality.

The results of the testing clearly demonstrated that there is a difference between induction cooktop technologies. The belief that an expensive high quality pan is needed to utilize the full rated input of an induction range top is no longer indisputable.

Though each of these induction cooktops performed effectively at times, it was Unit # 2 that stood apart from the others with its consistent full power delivery to all fourteen pans which is very desirable in smaller (kW) table top induction cooktops.

Though Unit #2 had this unique ability to deliver its full rated input to the smaller diameter pans, it must be recognized that with larger (kW) units, delivering 3 kW to a small pan could present safety issues. On the other side of the coin, a 3 kW cooktop can afford to be less effective with different pans types, whereas a small unit exhibiting a decrease of 15% in its input could be considered a poor performing induction cooktop.

The designers of Unit # 2 have engineered an induction cooktop that is able to deliver full power to the pan, regardless of the pan's size, shape or quality.

Future testing of induction cooktops should include a wide range of pan sizes and materials in the evaluation of the technology. This will provide a more complete picture of induction cooktop performance for discerning consumers.

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Appendixes

A Glossary

Energy Consumption (kWh or kBtu)

The total energy consumed by an appliance as it is used to heat a container/pan.

Energy Consumption Rate (kW or kBtu/h)

The rate of energy consumption during the testing period.

Cooking Energy Efficiency (%)

The quantity of energy input to the cooking container and water; expressed as a percentage of the quantity of energy input to the appliance during the full energy outputs.

Energy Input Rate (kW or kBtu/h)
Energy Consumption Rate
Energy Rate

The peak rate at which an appliance will consume energy.

Measured Input Rate (kW or Btu/h)
Measured Energy Input Rate
Measured Peak Energy Input Rate

The maximum or peak rate at which an appliance consumes energy, typically reflected during appliance full input rate.

Power Draw

An instantaneous total amount of energy an appliance consumes during a test.

Range Top

A devise for cooking food direct or indirect heat transfer from one or more cooking units to one or more containers

Glossary

Rated Energy Input Rate (kW, W or Btu/h, Btu/h)
Input Rating (ANSI definition)
Nameplate Energy Input Rate
Rated Input

The maximum or peak rate at which an appliance consumes energy as rated by the manufacturer and specified on the nameplate.

Test Method

A definitive procedure for the identification, measurement, and evaluation of one or more qualities, characteristics, or properties of a material, product, system, or service that produces a test result.

B Pan Sensitivity Testing Data

Table B-1. Induction Range Top # 1 Test Data.

Pans Tested	Size	Repetition #1	Repetition #2	Repetition #3
A - Sauté Pan	137 mm	1.629 kW	1.622 kW	1.607 kW
B - Sauté Pan	159 mm	1.941 kW	1.926 kW	1.916 kW
C - Sauté Pan	190 mm	2.225 kW	2.226 kW	2.232 kW
D - Sauté Pan	192 mm	2.274 kW	2.264 kW	2.265 kW
E - Sauté Pan	225 mm	2.506 kW	2.495 kW	2.489 kW
F - Braising Pan	190 mm	2.257 kW	2.252 kW	2.252 kW
G - Wok Style	140 mm	2.149 kW	2.145 kW	2.144 kW
H - Sauce Pan	110 mm	1.689 kW	1.698 kW	1.683 kW
I - Sauce Pan	150 mm	2.201 kW	2.196 kW	2.196 kW
J - Sauce Pan	148 mm	1.770 kW	1.778 kW	1.780 kW
K - Stock Pot	230 mm	2.530 kW	2.524 kW	2.524 kW
L - Cast Iron	142 mm	2.197 kW	2.197 kW	2.190 kW
M - Cast Iron	235 mm	2.282 kW	2.281 kW	2.281 kW
N -1/2 Chaffing Dish	165 x 228 mm	1.729 kW	1.729 kW	1.729 kW

Pan Sensitivity Testing Data

Table B-2. Induction Range Top # 2 Test Data.

Pans Tested	Size	Repetition #1	Repetition #2	Repetition #3
A - Sauté Pan	137 mm	1.334 kW	1.331 kW	1.330 kW
B - Sauté Pan	159 mm	1.399 kW	1.396 kW	1.409 kW
C - Sauté Pan	190 mm	1.397 kW	1.392 kW	1.406 kW
D - Sauté Pan	192 mm	1.406 kW	1.405 kW	1.416 kW
E - Sauté Pan	225 mm	1.411 kW	1.406 kW	1.422 kW
F - Braising Pan	190 mm	1.407 kW	1.403 kW	1.416 kW
G - Wok Style	140 mm	1.406 kW	1.402 kW	1.417 kW
H - Sauce Pan	110 mm	1.271 kW	1.290 kW	1.276 kW
I - Sauce Pan	150 mm	1.412 kW	1.403 kW	1.421 kW
J - Sauce Pan	148 mm	1.412 kW	1.402 kW	1.418 kW
K - Stock Pot	230 mm	1.412 kW	1.405 kW	1.426 kW
L - Cast Iron	142 mm	1.421 kW	1.412 kW	1.428 kW
M - Cast Iron	235 mm	1.419 kW	1.410 kW	1.427 kW
N -1/2 Chaffing Dish	165 x 228 mm	1.421 kW	1.419 kW	1.420 kW

Pan Sensitivity Testing Data

Table B-3. Induction Range Top # 3 Test Data.

Pans Tested	Size	Repetition #1	Repetition #2	Repetition #3
A - Sauté Pan	137 mm	0.717 kW	0.715 kW	0.719 kW
B - Sauté Pan	159 mm	0.961 kW	0.959 kW	0.962 kW
C - Sauté Pan	190 mm	1.365 kW	1.357 kW	1.361 kW
D - Sauté Pan	192 mm	1.195 kW	1.189 kW	1.188 kW
E - Sauté Pan	225 mm	1.324 kW	1.321 kW	1.329 kW
F - Braising Pan	190 mm	1.168 kW	1.163 kW	1.168 kW
G - Wok Style	140 mm	1.189 kW	1.171 kW	1.183 kW
H - Sauce Pan	110 mm	0.688 kW	0.679 kW	0.685 kW
I - Sauce Pan	150 mm	0.939 kW	0.930 kW	0.929 kW
J - Sauce Pan	148 mm	0.821 kW	0.817 kW	0.823 kW
K - Stock Pot	230 mm	1.244 kW	1.242 kW	1.253 kW
L - Cast Iron	142 mm	0.974 kW	0.971 kW	0.979 kW
M - Cast Iron	235 mm	1.135 kW	1.134 kW	1.137 kW
N -1/2 Chaffing Dish	165 x 228 mm	1.151 kW	1.149 kW	1.152 kW