

Incident Summary #II-1399412-2022 (#28552) (FINAL)

SUPPORTING INFORMATION	Incident Date	June 28, 2022	
	Location	Mission	
	Regulated industry sector	Electrical - High voltage electrical system (greater than 750V)	
	Impact	Qty injuries	1
		Injury description	Electrocution with severe burns to fingers on right hand and burns to right abdomen and left leg.
		Injury rating	Fatal
	Damage	Damage description	Burnt and melted wiring on a domestic microwave oven.
		Damage rating	Minor
	Incident rating	Severe	
	Incident overview	A maintenance worker at a commercial nursery was electrocuted after contacting high voltage electricity while working on exposed and energized internal components of a domestic microwave oven.	
INVESTIGATION CONCLUSIONS	Site, system and components	<p>At the time of the incident, high voltage electricity in BC was defined as voltage greater than 750 volts. The high voltage components in a typical consumer microwave oven can range between 1800-4000 volts. High voltage in this range can easily bypass the insulation characteristics of <i>basic</i> insulated tools, measuring devices and personal protective equipment. Specialty training, tools and equipment are needed to safely test or work around voltages in this range. High voltage components within the protective housing of a microwave oven should not be used outside their intended application.</p> <p>Conventional consumer microwave ovens are designed to heat food using electromagnetic radiation in the “microwave” spectrum. The microwave radiation is produced by a device called a magnetron. For the magnetron to function it requires a high voltage electrical supply typically above 3200 volts to overcome the high resistance in the magnetron and activate it to produce microwaves. To achieve this high voltage, an incoming 120-240 volt power supply is increased to around 2000 volts by a step up transformer. That voltage is essentially doubled in a voltage doubling circuit which includes a high voltage capacitor and rectifier diode. The operating voltage supplied to the magnetron of the microwave involved in the incident was listed at 3700 volts.</p> <p>The high voltage capacitor in a microwave will hold electricity even after power has been disconnected. They have an internal resistor which will slowly bleed off the stored electricity for up to one minute after the power is disconnected. Contact with the capacitor terminals during this time could deliver a potentially lethal electric shock even after the power had been disconnected.</p> <p>Appliance service technicians in the province of BC hold a trade qualification and receive specific training on servicing consumer microwave ovens. The training material and practical exercises include specific safety instructions for the high voltage circuits. Some of these instructions include:</p> <ul style="list-style-type: none"> • Never work on the high voltage circuits with the power on. 	

Incident Summary #II-1399412-2022 (#28552) (FINAL)

	<ul style="list-style-type: none"> • Dangers don't go away even when the microwave is unplugged. • Ensure the capacitor is fully discharged before performing any checks on the high voltage section. • Never operate the microwave when the cabinet is removed. <p>CSA Group is an accredited third-party certification body and testing agency in North America. A CSA approval mark on an appliance indicates its design has been evaluated against an applicable standard. The “CSA C22.2 No.150 – microwave ovens”, is the Canadian standard for design, construction and testing of microwave ovens generating less than 25kW and intended for household and commercial applications. The standard outlines the requirements and testing of an appliance for approval. Some of the requirements include:</p> <ul style="list-style-type: none"> • Markings and warning labels • Material design and insulation factors of the high voltage components • Safe functionality of the appliance under normal operating and some abnormal conditions.
<p>Failure scenario(s)</p>	<p>The nursery provided multiple break rooms for several employees around the property. Most of the break rooms had microwave ovens to allow the workers to heat up food and beverages. One of the microwave ovens had quit working and the maintenance worker for the nursery removed the microwave and brought it back to the maintenance shop.</p> <p>The maintenance worker had been employed at the nursery for approximately 2.5 years and had acquired some technical experience previous to working in the province. They did not hold and a technical certification or qualification as an electrician or appliance service technician in the province.</p> <p>The maintenance worker attempted to repair the non-operational microwave and had two microwaves disassembled in the maintenance shop. During the work, one of the microwaves was plugged in and turned on with the cover removed, energizing the high voltage circuit and two high voltage wires that were disconnected from the microwave magnetron. The worker grabbed the high voltage wires with their hand and was likely unable to let go of the energized wires due to muscle contraction. The design of the high voltage transformer circuit allowed the contact with the high voltage circuit to be sustained while not drawing enough amps to blow the internal fuse or trip the overload breaker for the primary circuit. The worker sustained severe burn injuries to their right hand, and additional burns to their abdomen, and legs. The worker was alone in the maintenance shop at the time and was later discovered lying on the ground beside the microwaves.</p>
<p>Facts and evidence</p>	<p>Witness statements</p> <ul style="list-style-type: none"> - The worker involved in the incident had been employed at the nursery for approximately 2.5 years and was responsible for general upkeep, maintenance, and repair of equipment on the farm. - The worker did not hold any qualifications or certifications as an appliance service technician or electrician. - Another employee had informed the worker that the microwave in one of the break rooms had stopped working. - The worker replaced the microwave with a functioning unit and brought the faulty microwave back to the maintenance shop.

Incident Summary #II-1399412-2022 (#28552) (FINAL)

- Microwave ovens were not typically repaired at the nursery if they quit working.
- No supervisors had directed the worker to repair the microwave.
- The worker had been in the maintenance shop alone and was found unresponsive lying on the floor with significant burns on their right hand.
- A blue extension cord from the area of the microwave was unplugged from the wall by a supervisor after the worker was found.

Site observations

- Two microwaves were observed on a workbench in the maintenance shop both with the covers removed.
- The microwave on top had two wires disconnected from the magnetron with burnt and melted connectors.
- A digital multimeter was observed on the workbench next to the microwaves with the dial set to the Ohms scale that would be typically used to measure resistance in de-energized electrical components like those inside the microwave.
- No burn marks were observed on any of the multimeter test leads or multiple tools in and around the area of the microwaves.
- Warning labels were visible on the microwave transformer with the cover removed ([Photo 8](#))
- The rear of the microwave has a label that states the following:

*CAUTION "THIS DEVICE IS TO BE SERVICED ONLY BY PROPERLY QUALIFIED SERVICE PERSONNEL."

*DANGER "DISCONNECT APPLIANCE BEFORE SERVICING. REMOVAL OF ENCLOSURE WITH PRODUCT ENERGIZED MAY EXPOSE SERVICEMAN TO HAZARDOUS HIGHVOLTAGE POTENTIALS."

The severity of the burns the worker sustained suggests the microwave transformer was energized when they contacted the high voltage wires. For the transformer to be energized the microwave would have had to have been plugged in with the door closed and the microwave timer switch turned on.

Documents

The *owner's* manual for the microwave had a "DANGER Electrical Shock Hazard" warning that states: "Touching some of the internal components can cause serious injury or death. Do not disassemble this appliance."

A typical *service* manual from the manufacturer of the microwave has several safety warnings and precautions regarding working around the high voltage components in microwaves. Some of these precautions include:

- High voltage is present at the high voltage terminals during any cook cycle.
- It is neither necessary nor advisable to attempt measurement of high voltage.
- Before touching any oven components or wiring, always unplug the oven from its power source and discharge the high voltage capacitor.
- Never touch any circuit wiring with your hand nor with an insulated tool during operation.

Incident Summary #II-1399412-2022 (#28552) (FINAL)

- There exists HIGH VOLTAGE ELECTRICITY with high current capabilities in the circuits of the high voltage transformer...It is extremely dangerous to work on or near these circuits with the oven energized.

Testing and measurements

- The electrical outlet in the maintenance shop that the extension cord was plugged into was confirmed to be connected to an energized 120-volt 15 amp circuit breaker.
- The microwave was examined, and components were tested and measured including the fuse, transformer, capacitor, discharge resistor and diode. All the measurements confirmed the components were in good working order with no defects found.
- Electrical continuity was tested from the blade of the male end of the plug to the hot lead to the primary side of the transformer and continuity was only measured when the cook switch timer was activated, and the microwave door was closed. The transformer would only be powered on if it was plugged into an electrical source with the door and switch in this configuration.

Appliance approval

The microwave received a certificate of compliance and bears a CSA approval mark based on adherence with the CSA-C22.2 150-M89 Microwave oven standard.

Engineering report (Appendix A)

An independent engineer report was produced detailing the functionality of various components within a microwave oven and to identify hazards associated with those components and how the hazards might lead to harm through electric shock. The report identifies the following:

- The insulation on basic electrical measuring devices and tools can be overcome by high voltage, leading to electrocution.
- The high voltage transformer is an "isolation transformer" where the secondary side is not physically connected to the primary side but coupled together through the magnetic core of the transformer.
- The output of the high voltage secondary winding can produce lethal current before it draws enough amps to trip the breaker or blow the appliance fuse.
- A person being shocked by the output of the transformer would not trip a ground fault circuit interrupter (GFCI) as it would not recognize a ground fault on the secondary side.
- The high voltage transformer may not create any sound when energized that would identify the presence of high voltage electricity.
- The capacitor and diode are connected in the system in a manner which essentially doubles the voltage from the transformer to the magnetron from approximately 2000 to 4000 volts.
- The energy present in a high voltage capacitor can release a potentially lethal electrical shock for up to approximately 30 seconds after the microwave is de-energized.
- If accidental contact was made with a capacitor during this time, it would completely discharge within 10 milliseconds.

Incident Summary #II-1399412-2022 (#28552) (FINAL)

	<ul style="list-style-type: none">- The amount of energy that would be released from a de-energized capacitor would not produce the burns sustained by the worker.- An electrical shock by the electrical currents present in the microwave high voltage circuit may cause muscles to contract causing the inability to let go of an energized component grabbed with the hand.- Burn damage from an electric shock is much more drastic at high voltages.- An electric shock to an individual with a total body resistance of 10,500 ohms would produce heat dissipation of 1.4 watts at 120 volts but 1,500 watts at 4,000 volts (Hotter than most household space heaters).- High voltage can arc through the air and high voltage arcs can produce an abundance of heat, even if not directly touched.
Causes and contributing factors	<p>The individual servicing internal components of the microwave with the protective cover removed and with an energized high voltage circuit was the cause of the incident.</p> <p>Contributing factors to the incident include:</p> <ul style="list-style-type: none">• The worker not being a qualified service technician may have led to an incomplete understanding of the potential high voltage hazards as well as how to safely de-energize and work on the microwave.• The transformer label not identifying the output voltage may have contributed to the worker not fully understanding the hazards.• The electrical system within the microwave permitted a sustained high voltage electrocution without tripping overloads or safety circuits.



Photo 1 – Workshop area showing two partially disassembled microwaves and tools. **RED** box showing the microwave involved in the incident. The blue extension cord on the ground was unplugged by another employee after the incident.



Photo 2 – Front of the microwave



Photo 3 – Microwave with cover removed exposing internal components. **RED** - shows digital multimeter on table next to microwave.

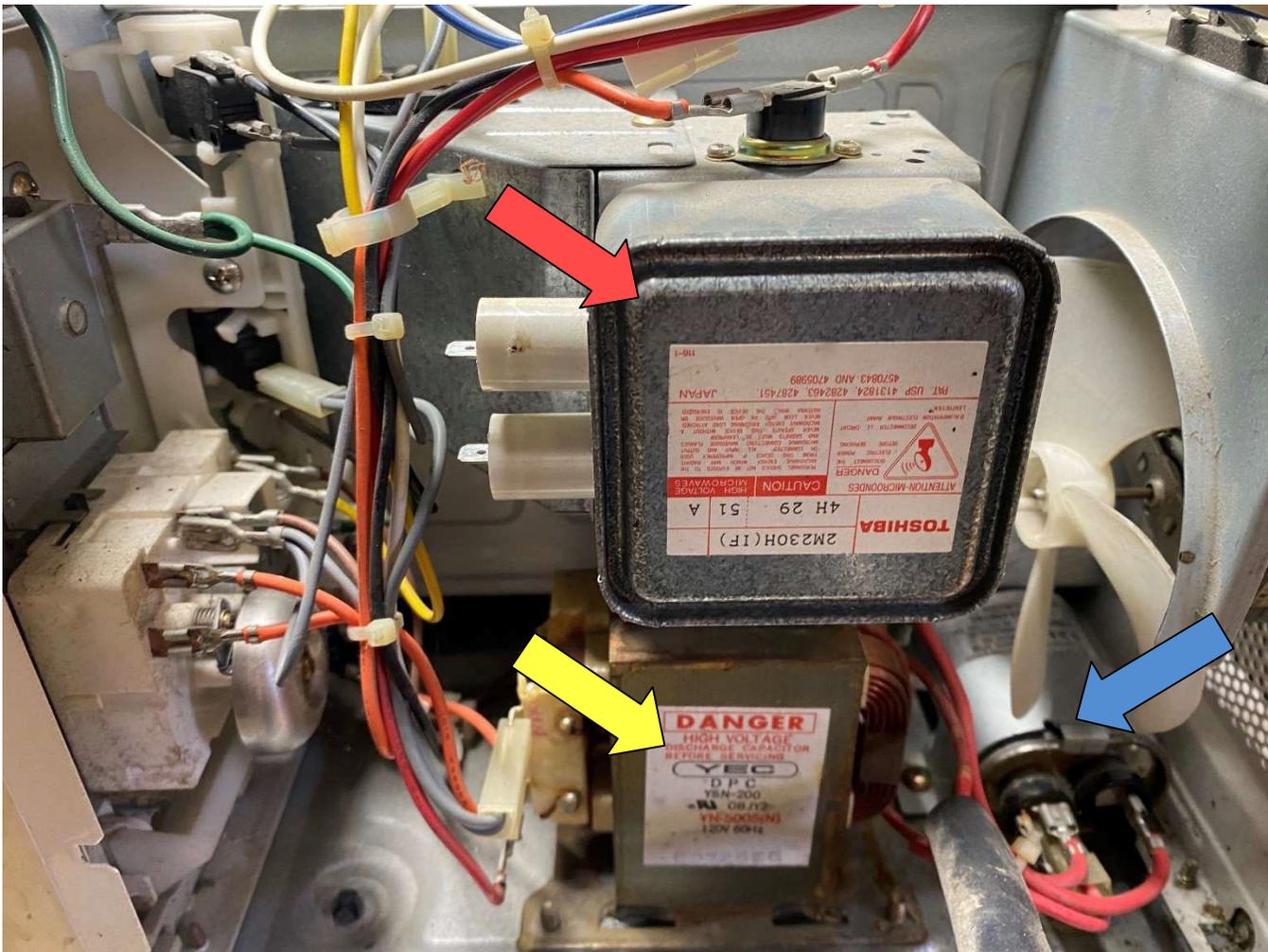


Photo 4 – Microwave internal components: **RED** – magnetron. **YELLOW** - high voltage transformer. **BLUE** - high voltage capacitor.

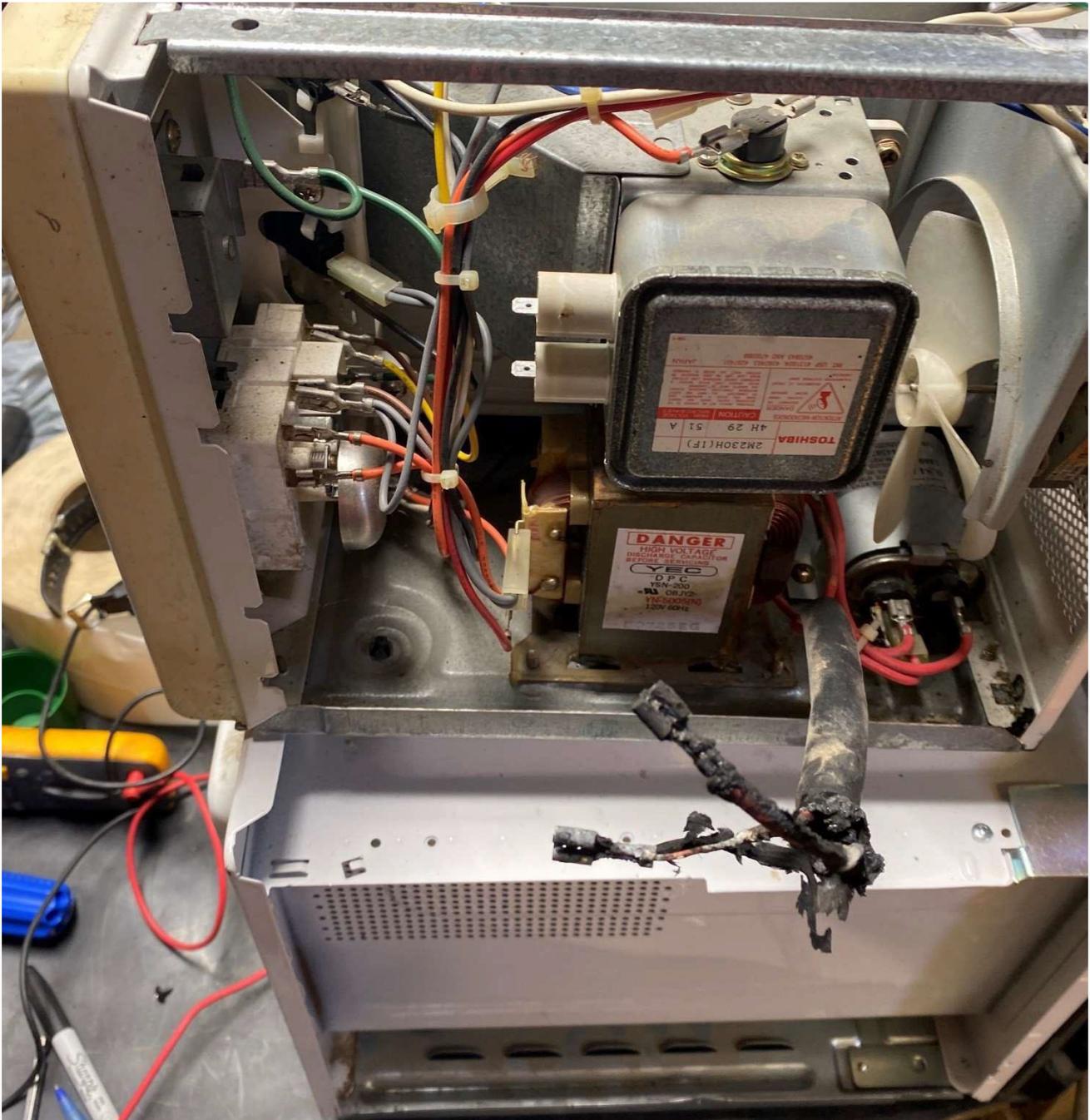


Photo 5 – Showing internal microwave components and burnt and melted magnetron wiring.

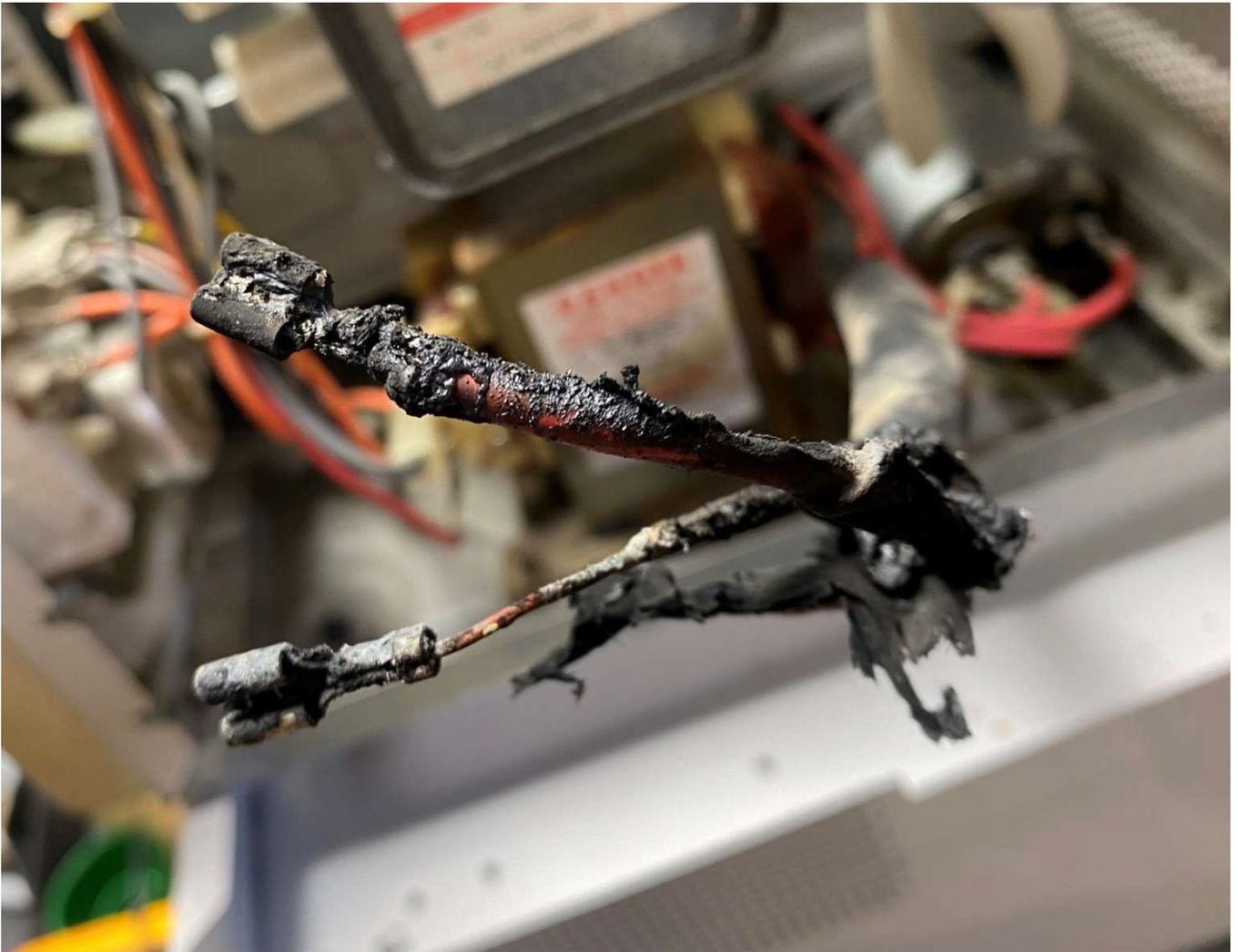


Photo 6 – Closeup of burnt and melted high voltage wiring.



Photo 7 – High voltage capacitor from microwave showing 1800-volt rating and danger warning.



Photo 8 – Microwave high voltage transformer with danger warning label. Voltage rating showing incoming primary voltage. Label does not state secondary high voltage output.

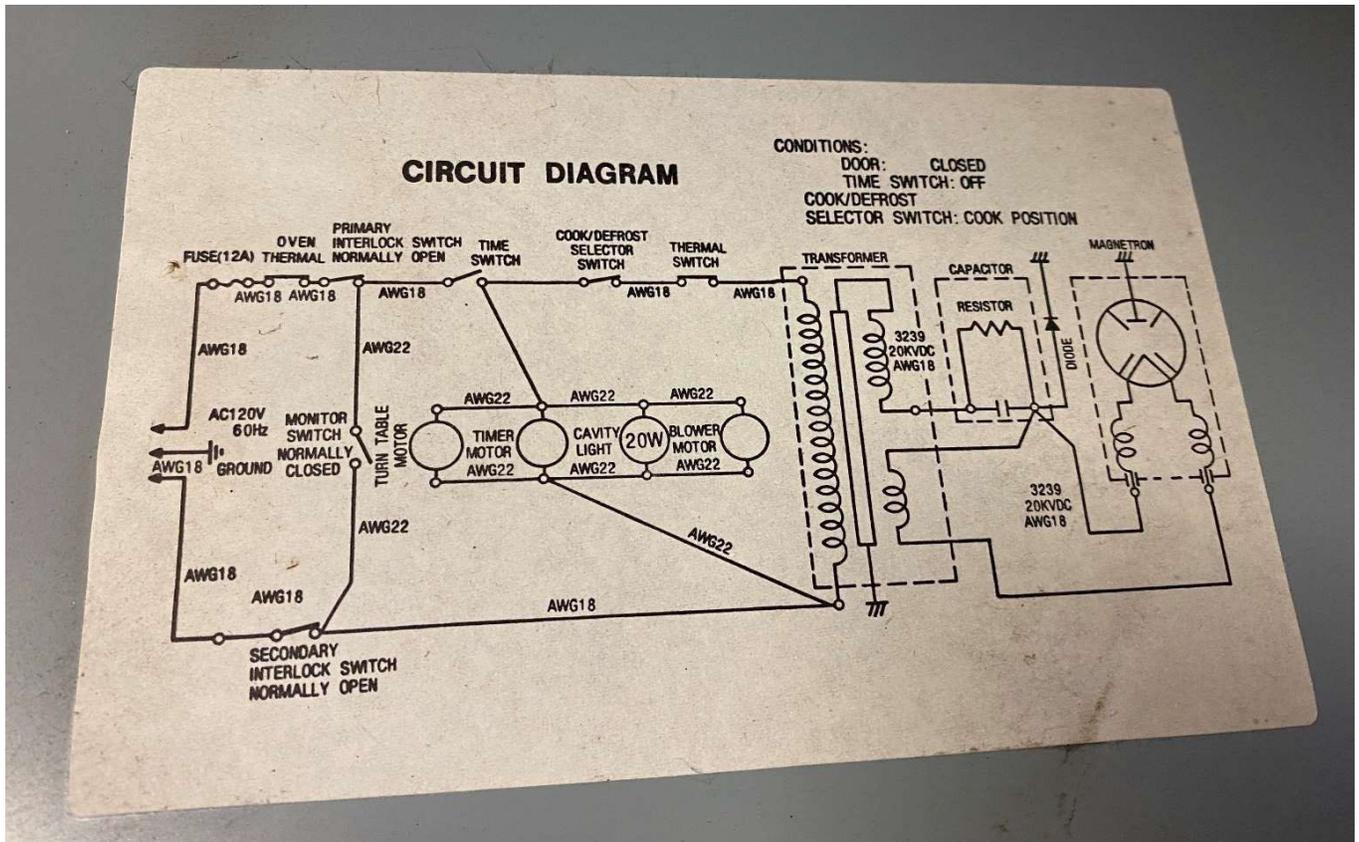


Photo 9 – Microwave electrical circuit diagram on inside of microwave cover showing primary and high voltage circuits.

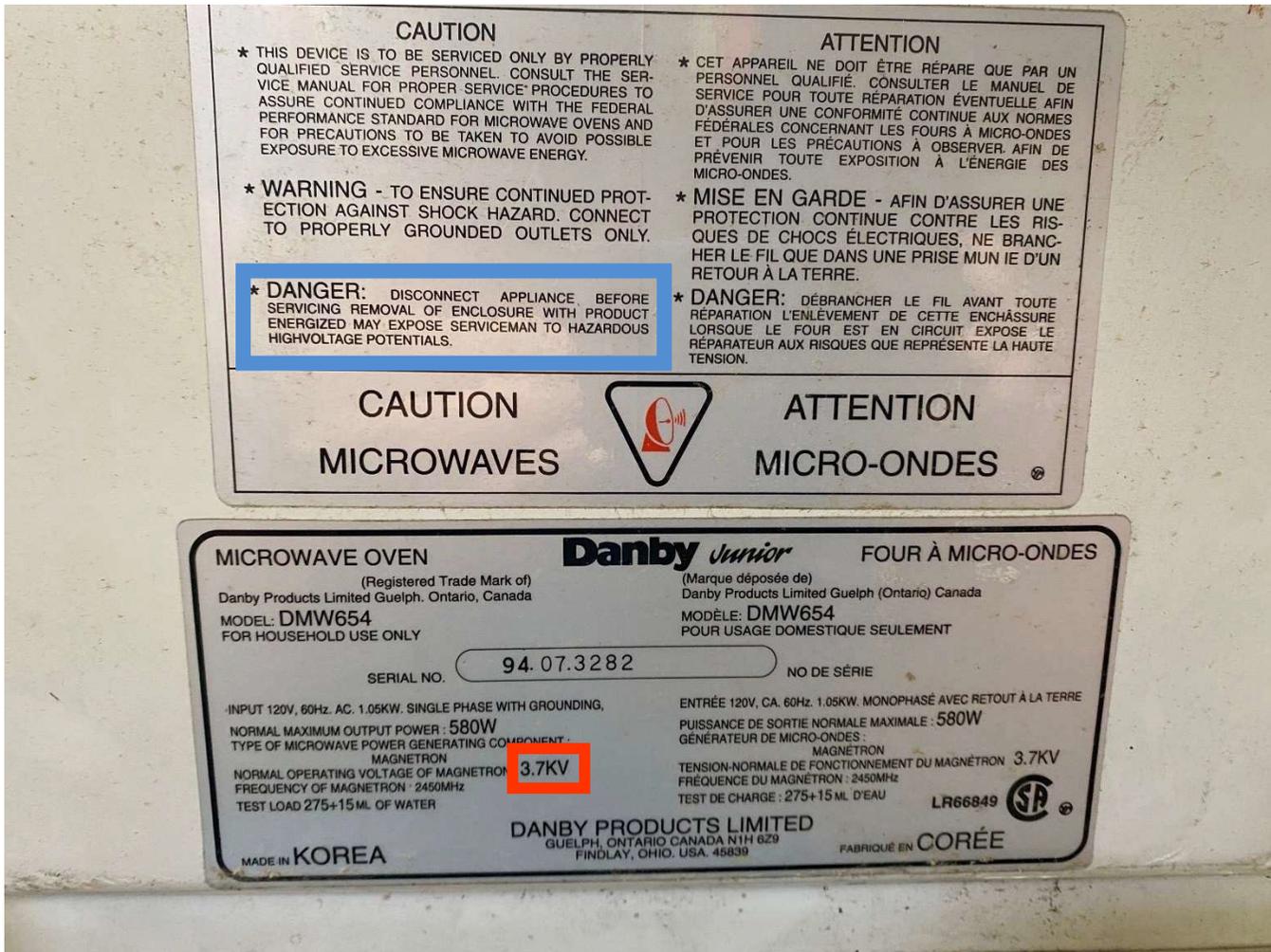


Photo 10 – Microwave data tag with **ORANGE** box showing output voltage to magnetron at 3700 volts. Danger label in **BLUE** box identifying hazardous high voltage potentials and instructing to disconnect the appliance before servicing.