The electric kettle test revisited:

PROPER LOW-LEVEL TEST CLASSES AND TEST CASES

In the Quality Assurance profession, job applicants are sometimes given a mock question how would they test an electric kettle.

Usual applicant's answer to the "testing electric kettle question" probably contains few positive and maybe few destructive and negative test cases. My answer contains over 40 test cases.

That's because "*Only positive tests*" is 2nd level of testing maturity and "*Also destructive tests*" is 3rd level (or 1st and 2nd level respectively, if you consider "just debugging" to be level 0).

However, I firmly believe in "proper QA" featuring:

- Level 4 testing maturity as per Boris Beizer's definition
- Detailed test research and analysis
- QA engagement from the beginning of the design process and removal of ambiguity
- Usage of IEEE829 Test Classes to make sure no important test is missed
- Fail-safe and safety testing where applicable
- FMEA or FTA where reasonable given Integrity levels (consequences of SUT failure)
- Multi-stage testing process (high-level test cases→ low-level test cases→ executable tests)
- Proper documentation (HLTC, LLTC, TARs) facilitating test reviews and zero "lost" bugs

My take at the "kettle testing exercise" aims for that 4th level of testing maturity including all the "proper testing" features highlighted above (with the obvious limitation that since there is no feedback from a real Project team in this hypothetical scenario, assumptions were used instead).

Note about the document format

I am not using Excel-style tables for documenting Test Cases because my Low-Level Test Cases are usually automated and the LLTC description is part of the automated scripts and their outputs.

Since we usually write documentation only for High-level TCs, my experience shows that Word document with multi-level lists (which subsequently translate to Test Case IDs like 2A1 etc. because of the 8-character length file limitation of the z/OS) are far more readable – and especially reviewable – by other team members than Excel tables spanning multiple screen widths. This document is exception to a rule, for it implements manual LLTCs from HLTCs in the doc.

Note about general analysis limitations

Please do bear in mind that there is a serious limitation in this type of mental exercises: an analyst could only do his job properly if he has an intimate knowledge of the domain in question. If he doesn't, all he could do is a quick research.

However, given the lack of experience and depth of knowledge, such shallow research is prone to err somewhere. I know nothing about testing kitchen appliances. Every more complex Test Case in this document was based on combination of divergent thinking, common sense and fragments of high-school physics and DYI, all enabled by quick internet (re)search for the first formula, regulation or term which gave sense. If you happen to be a kitchen appliance testing expert, have a good laugh reading this document.

Electric kettle test case suite

Revision	Author	Date changed	Description
0.1	TULON	2017-07-21	Test classes 1 through 4 created
0.2	TULON	2017-11-06	Test classes 5 through 7 created

Low-level Test Cases sorted by Test Classes

1. Basic positive tests (smoke tests)
   (Note: BPTs purpose is to determine whether it's worth proceeding with further testing)
   A. **Setup:** Fill kettle with water to the top mark. Plug into electric socket. Put it on it's stand.
      Test: Turn kettle on.
      Expected result: kettle starts to warm the water and shuts down when water is around 100°C hot.

2. Negative tests
   (Note: kettle is tested on it's stand and plugged in to electrical socket except where nothed otherwise)
   A. Fire safety
      1) „Safe automatic power-off when without water"
         Setup: do not fill kettle with any water
         Test: turn kettle on.
         Expected result: kettle shall either not turn on or turn off in less than 5 seconds.
      2) „Safe automatic power-off with insufficient water"
         Setup: fill the kettle with water under the minimal mark
         Test: turn kettle on.
         Expected result: kettle shall turn off instantly if water boils out and no damage is observed.

   B. Electrical safety
      1) „Electrical insulation test in max-humidity and temperature conditions"
         Set environment: <maximal allowed air humidity> and <maximal allowed ambient temperature>.
         Fill the kettle to the top mark. Turn kettle on. Measure voltage on all surfaces of kettle exposed to user.
         Expected result: exposed surfaces of the kettle must have 0V voltage at all times.
      2) „Electrical insulation test in max-humidity and min-temperature conditions"
         Set environment: <maximal allowed humidity> and <minimal allowed ambient temperature>.
         Fill the kettle to the top mark. Turn kettle on. Measure voltage on all surfaces of kettle exposed to user.
         Expected result: exposed surfaces of the kettel must have 0V voltage at all times.
      3) „Hot-plug-to-socket electrical insulation test"
         Setup: Plug the kettle out of the socket. Put it on it's stand Press and hold the kettle's switch on. Plug the stand's cord into the electric socket. Measure voltage on all exposed surfaces.

Expected result: exposed surfaces of the kettle must have 0V voltage at all times.

4) „Hot-swap-to-stand electrical insulation test"
Setup: Plug the kettle base into the socket. Raise the kettle out of it's stand.
Test: Press and hold the kettle's switch on. Put the kettle on it's powered stand. Measure voltage on all exposed surfaces.
Expected result: exposed surfaces of the kettle must have 0V voltage at all times.

5) „Power switch lifetime electrical insulation test"
Setup: Fill the kettle with water to the top mark. Put it on it's stand and plug it into electrical socket.
Test: cycle the kettle's power swtich on and off (10 times a day x 365 days x 2 years warranty x 2 safety margin) times. Measure voltage on safety switch and kettle surface.
Expected result: power switch and all exposed surfaces of the kettle must have 0V voltage at all times.

6) „Kettle base flooding test"
Requirement: execute this test in an electrically insulated, waterproof container, not touching the kettle and using only electrically insulated tools and with power sockets being equipped with both current protectors and fuses.
Setup: fill the kettle with water, put it on it's stand, put the stand on a electrically conductive pad, attach sensor cables indicating voltage to kettle, to kettle's stand, to the conductive pad. Plug the kettle stand's power cord to the socket.
Test: power on the kettle. After 30 seconds, flood the insulated container with water so that the water level is at least 3cm above the kettle stand's highest point. Monitor status of current protectors and fuses, monitor voltage meters.
Expected result: Short-circuited kettle stand has triggered fuse or current-protector to disconnect electric power so no voltage was indicated at any of the voltmeters attached to the kettle, stand, or pad.

C. Burns safety

1) „Standard boiling water splash-out test"
Setup: fill the kettle with water to the top mark.
Test: turn kettle on. Keep the lid closed. Observe lid.
Expected result: burning water shall not splash out of the kettle.

2) „Exposed surfaces temperature test"
Setup: fill the kettle with water to the top mark.
Test: turn kettle on. Keep the lid closed. Measure temperature on all exposed surfaces.
Expected result: no control or handling surface accessible to user gets hotter than 50°C.

3) „After-use exposed surfaces temperature test"
Setup: fill the kettle with water to the top mark. Turn kettle on. When the kettle boils the water and shuts down, pour out the water. **Test:** measure temperature on exposed surfaces.
Expected result: no control or handling surface accessible to users sgets hotter than 50°C.

D. Fail-safe

1) „Over-voltage testing“
   Setup: plug the kettle to special electric socket providing 20% bigger input voltage than specified.
   Test: remotely power on the kettle.
   Expected result: kettle‘s circuit breaker breaks. Kettle’s safety is not compromised (re-run test class 2A, 2B, 2C), exposed surfaces have 0V voltage and temperature <= 50°C, kettle doesn‘t start burning.
2) „Temperature shock failure testing“
   Setup: fill the water to the maximal mark. Power on the kettle and let the water warm to 100°C. Let the heated water transmit it’s temperature to the kettle’s material for 10 minutes. Power on the kettle again and let the water reach 100°C.
   Test: pour the hot water out of the kettle and immediately re-fill the kettle with fresh tap water from standard sink battery with
   output d=35mm, output P=600kPa (max. allowed), output t= 5°C.
   Repeat setup and test 10 times.
   Expected result: the kettle must not burst or crack from the temperature shock.
3) „Freeze failure testing“
   Setup: fill the kettle with water to the minimal mark. Expose to temperature <0°C. Let the water in the kettle freeze.
   A) If the kettle is undamaged:
      Test: power on the kettle.
      Expected result: kettle must either power off or melt and boil the frozen water. Kettle must not be mechanically damaged, start burning or warm any exposed surface beyond 50°C.
   B) If the kettle is damaged:
      Test: using increased and appropriate safety measures against electric shock, power on the kettle
      Expected result: that there is no risk of electric shock
4) „Power-off beyond threshold“
   Setup: fill the kettle with water to the maximal mark. Power on the kettle and let the water reach boiling point. Wait and let the kettle enter the auto-power-off state when it switches off the power switch upon reaching 100°C.
   Test: when the kettle auto-powers off, re-energize the power switch and hold it in the energized/on position manually for 15 seconds. Then release the hold and let the kettle be.
   Expected results:
   A) upon releasing the pressure on the power swtitch, the kettle would again power off automatically.
   B) the boiling water would not splash on the power switch or kettle’s handle.
   C) no control or handling surface accessible to users sgets hotter than 50°C.

3. Equivalence class-based tests
   A. Allowed boundary values handling
      (Note: „boiling“ is understood as having 100°C unless noted otherwise)
      1) „Automatic power-off at 100°C, cold start“
         Setup: fill the kettle with water warm <minimal allowed operating temperature>
         Test: power on the kettle
         Expected result: kettle could be powered on and stays powered on until the water is boiling
      2) „Automatic power-off at 100°C, hot start“
         Setup: fill the kettle with water warm <100°C-10%>
         Test: power on the kettle
         Expected result: kettle could be powered on and stays powered on until water is boiling
   B. Thresholds handling
      1) „Automatic power-off test“
         Setup: fill the kettle with water to the top mark.
         Test: power on the kettle and measure temperature at the top and at the bottom while observing the kettle's power switch.
         Expected result: kettle always powers on when water temperature is 100±3°C at the bottom or 100±10°C at the top

4. Output tests
   A. „Minimal water level mark accuracy“
      Setup: dry the kettle.
      Test: fill the kettle with exactly <marked minimal allowed volume of water>
      Expected result: the kettle water level indicator is at the minimal mark
   B. „Maximal water level mark accuracy“
      Setup: dry the kettle.
      Test: fill the kettle with exactly <marked maximal allowed volume of water>
      Expected result: the kettle water level indicator is at the maximal mark
   C. „SI water liter accuracy“
      Setup: dry the kettle
      Test: fill the kettle with exactly 1 liter of water
      Expected result: the kettle water level indicator is at the 1 liter mark

5. Advanced or atypical circumstances and scenarios
   A. Atypical activity handling tests
      1) „Low pressure test“
         Environment: barometric pressure 0.34 bar (as on Mt.Everest summit)
         Setup: fill the kettle with water up to the maximal mark
         Test: power on the kettle
         Expected results: the water will start boiling way before the kettle's thermo-stat powers off the kettle. However:
            A) the lid of the kettle must not open
            B) the boiling water must not splash from the kettle in a way preventing the user from safely accessing the kettle's power on/off switch
            C) the boiling water must not splash from the kettle farther than 10cm
      2) „High pressure test”
         Environment: barometric pressure 1.084 bar (highest recorded)

Setup: fill the kettle with water up to the maximal mark
Test: power on the kettle
Expected results:

A) the kettle must not rupture or exhibit cracks under the pressure
B) regardless of the time required to heat the water, no control or handling surface accessible to user shall get hotter than 50°C
C) the kettle must power off when the water's temperature reaches 100°C or after less than 5 minutes of continuous boiling

3) „Opened-lid minimal-mark boiling-water splash-out test"
Setup: fill the kettle with water to the minimal mark.
Test: turn kettle on. Keep the lid closed. Observe lid.
Expected result: burning water shall not splash out of the kettle.

B. Atypical content handling tests

1) „Ice cubes"
Setup: fill the kettle with ice cubes of 1x1x1cm dimensions.
Test: power on the kettle.
Expected result: kettle must either power off or melt and boil the ice cubes/water. Kettle must not be mechanically damaged, start burning or warm any exposed surface beyond 50°C.

2) „Hard water"
Setup: fill the kettle to the maximal mark with „hard water": 181 mg CaO per liter
Test: power on the kettle, let the water heat to 100°C, wait 10 minutes, pour out the water, repeat the cycle 100-times
Expected result: mineral residue on the kettle's heating surface is <u>not</u> causing:

A) the kettle's exposed surfaces to heat to more than 50°C
B) the kettle's heating surfaces to overheat as indicated by dark burn-marks

3) "Sea water"
Setup: fill the kettle to the maximal mark with salt seawater
Test: power on the kettle, let the seawater heat to 100°C, wait 10 minutes, pour out the seawater, repeat the cycle 100-times
Expected result: salt residue on the kettle's bottom and/or heating surface is <u>not</u> causing:

A) the kettle's exposed surfaces to heat to more than 50°C
B) the kettle's heating surfaces to overheat as indicated by dark burn-marks

4) "Vinegar kettle cleaning test"
Setup: fill the kettle to the minimal mark with only kitchen vinegar
Test: power on the kettle, let the water heat to 100°C, wait 10 minutes, pour out the vinegar, repeat the cycle 10-times
Note: verifying some results requires disassembly and check of kettle's base and power switch
Expected result: exposure to vinegar is <u>not</u> causing:

A) the kettle's exposed surfaces to heat to more than 50°C
B) the kettle's plastic or metal parts to deteriorate
C) the vinegar to leak from the kettle's container

D) the power switch to accumulate condensated vinegar

C. Atypical system states handling tests

1) „Power outage simulation test”
Setup: fill the kettle with water, connect kettle stand’s cord to the socket equipped with independent switch
Test: power on the socket switch, power on the kettle, wait 30 seconds, power off the socket switch, wait 30 seconds, power on the socket switch
Expected result: power outage causes the kettle to power-off automatically
Note: correct behavior here is ambiguous: cheaper kettles whose switches are thermostat-only based resume heating upon renewed supply of electric current but specified behavior is safer

2) „Indirect lightning strike electrical surge simulation”
Setup: fill the kettle with water. Place the kettle into an electrically fully insulated container with safely installed and firewalled power supply consisting of normal uninterrupted AC 230V power supply and high-power switch to a capacitator simulating lightning-induced power surge and thus loaded to provide 6kV for 10µs, which is connected to a standard power socket. Plug the kettle stand’s cord into the power socket.
   A) **Test:** power on the kettle. After 30 seconds, switch the circuit to expose the kettle to the simulated lightning-induced surge.
   Expected result: kettle must not explode or catch on fire.
   B) **Test:** leave the kettle powered off. After 30 seconds, switch the circuit to expose the kettle to the simulated lightning-induced surge.
   Expected result: kettle must not explode or catch on fire.

3) „Undervoltage condition testing”
Setup: connect the kettle stand’s power cord to a 3kV regulated power source (further RPS) capable of output voltages within the 50 to 250V range AC. Set the RPS to 240V AC. Attach temperature measuring probes to kettle’s and kettle stand’s exposed surfaces. Measure electrical current flowing to the kettle.
Iterative tests: in each iteration fill the kettle with water and power it on. Wait 30 seconds. Lower the voltage by 10V. Observe the kettle and temperatures: no exposed surface shall get hotter than 50°C. After the water has boiled and the kettle has powered-off automatically, or after 5 minutes, power off the kettle, pour out the water and inspect the kettle for burn marks, burn smells or damage.
Repeat test until voltage has reached zero, kettle has powered off or kettle is unable to power on.
Expected result: the undervoltage condition must not cause the kettle to overheat, start burning, or increase the current consumption by more than 25%.

6. Feature specific tests

A. Government regulations

1) „CE marking conformity”
Test: execute required suite of tests verifying that the kettle conforms to regulation „93/68/EEC”
Expected result: the kettle meets or exceeds all requirements.

2) „Electro-Magnetic Compliance”
Test: execute required suite of tests verifying that the kettle conforms to regulation „2014/30/EU”
Expected result: the kettle meets or exceeds all requirements.

3) „Low-voltage Directive”
Test: execute required suite of tests verifying that the kettle conforms to regulation „2006/95/EC”
Expected result: the kettle meets or exceeds all requirements.

4) „RoHS”
Test: execute required suite of tests verifying that the kettle conforms to regulation „2002/95/EC”
Expected result: the kettle meets or exceeds all requirements.

5) „WEEE”
Test: execute required suite of tests verifying that the kettle conforms to regulation „2002/96/EC”
Expected result: the kettle meets or exceeds all requirements.

6) „Ecodesign”
Test: execute required suite of tests verifying that the kettle conforms to regulation „2009/125/EC”
Expected result: the kettle meets or exceeds all requirements.

7) „EU Food Contact Materials”
Test: execute required suite of tests verifying that the kettle conforms to regulations „2004/1935/EC”, „2006/2023/EC”, „2005/1895/EC” and potentially „2011/284/EU”
Expected result: the kettle meets or exceeds all requirements.

7. Performance testing

A. „Time to heat water”
Setup: fill the kettle with water cold 5°C to the top mark. Plug the kettle stand’s power cord to the socket.
Test: power on the kettle. Measure the time before the kettle powers off having heated the water to 100°C.
Expected result: the time was lesser than 4 minutes.

B. „Power efficiency test”
Setup: fill the kettle with 1l of water cold 5°C. Plug the kettle stand’s power cord to the socket.
Test: power on the kettle. Measure the time before the kettle powers off (t), having heated the water to 100°C. Measure kettle’s maximal input electrical current (I) and voltage (U).
Expected result: (400/t)/(I*U/1000) must be higher than 0,9 (=90% efficiency).
Notes: theoretically, it would take 400kW to heat 1l of water by 95°C in 1sec. The power has been estimated as U*I knowingly disregarding phase and R-C shifts etc.