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# SOUND ANALYSIS ON ELECTRIC KETTLE

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**Abstract**: Nowadays, in almost every household, an electric kettle has replaced a whistling tea-pot and pots for boiling of water. Kettle is an appliance which, in very short time and relatively inexpensively, brings water to a boil. Except for short click of starting (switch on) button at beginning and at the end of boiling, the most characteristic sign of a working kettle is its typical sound exposition. It changes from almost inaudible cracking through loud wheeze to the smooth and deep bubbling shortly before reaching the boiling point. Where does this sounds come from and why the sound of kettle does not increase linearly in same manner as e.g. temperature of boiled water? Acoustical camera and the analysis of kettle's sound time data can shed light on this acoustic phenomenon.
**Keywords**: sound pressure, sound power, acoustical camera

## 1. INTRODUCTION

Modern day kettle consists of two main parts: plastic, metal or glass tank, which has a submersible heating coil or heating plate on its bottom part. From upper side there is a cover through which one can fill the tank and it also prohibits from scorching with boiled water by manipulation with it. Second part is the base seat, which enables easy connection and disconnection of the kettle from power supply.

Kettles with submersible heating coil enable more compact construction of tank and they also exhibit lower sound power radiation. Disadvantage of these are that whole coil must be covered with water, which disallows boiling of small amount of water.

A kettle with heating plate offers smoother appearance of the inner side of the tank. In comparison with kettles with submersible heating coil, kettles with heating plate produce the typical sound throughout the whole boiling cycle. In this article, the kettle with heating plate will be investigated.

## 2. MEASUREMENT

Electric kettle was measured in semi-anechoic chamber with 10 microphones according DIN EN 60704-1 – pic.1. Sound power level Lw was calculated by averaging of sound pressure level from 10 microphones, according to ISO3744 – figure 1:

$$Lw = \overline{Lp} = 10\lg(\frac{S}{S_0})dB$$

where $\overline{Lp}$ is sound pressure level averaged through whole measurement surface (without correction factors K1 and K2)

$$\overline{Lp} = 10\lg[\frac{1}{N}\sum 10^{0.1Li}]dB$$

and L'i is sound pressure level measured at i-th microphone position in dB, S is area of measurement surface and S0 is reference surface with area of 1 m².

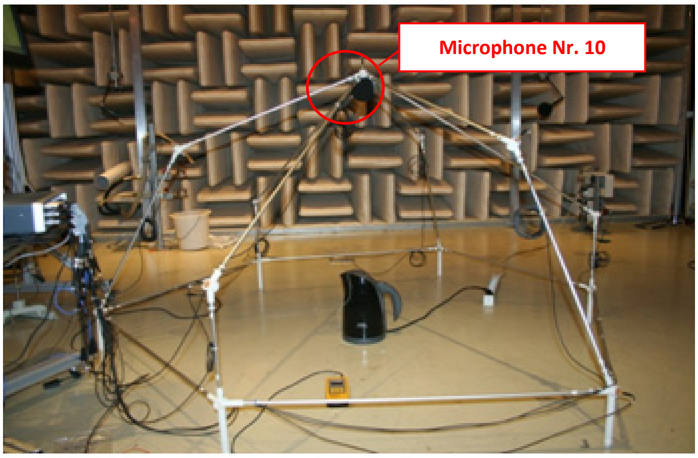
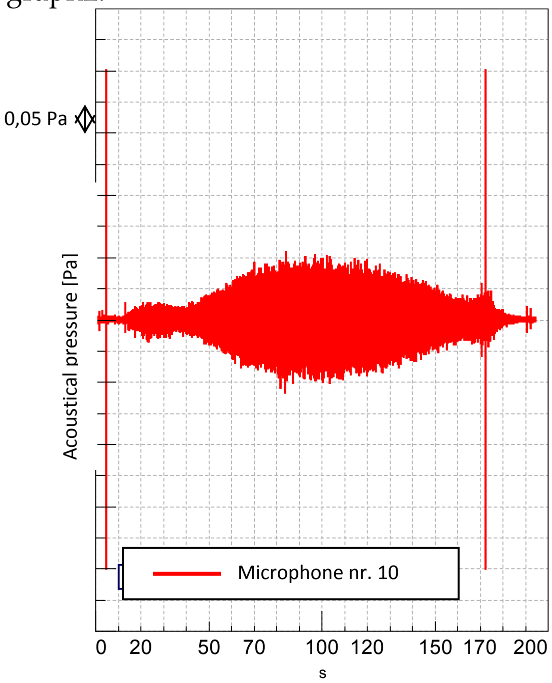
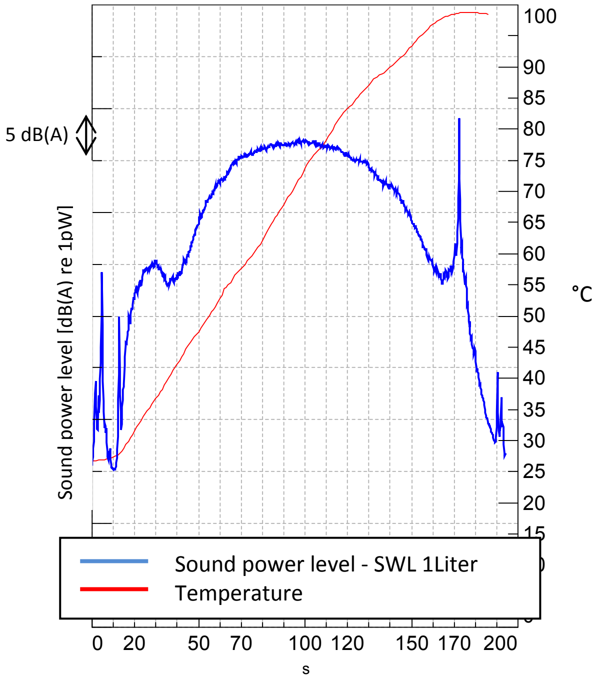



Figure 1: Position of tested object and 10 microphones in semi-anechoic chamber.
Estimating of sound power level according to DIN EN 60704-1

From sound pressure time data – graph 1, an instantaneous sound power overall level in frequency domain was calculated and plotted in the graph with time increment of 1 second – graph2.




Graph 1: Sound pressure time data from microphone nr. 10




Graph 2: Instantaneous sound power level during working cycle

Kettle's overall sound power level was estimated by averaging an instant sound power values over whole working cycle.

## 3. THEORY

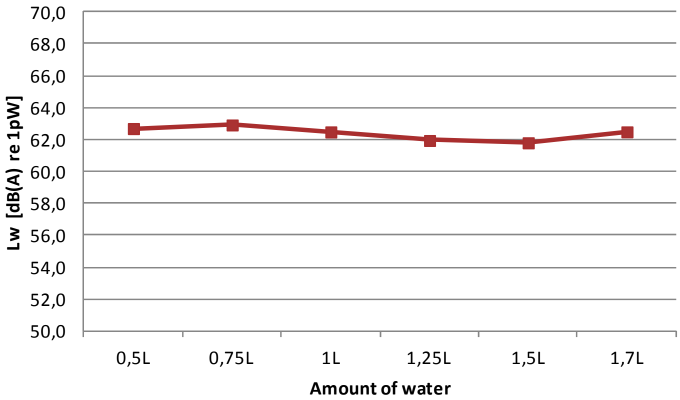
Water boiling sound consists from several phases. Shortly after activation, a silent and sporadic cracking appears. It is generated by miniature bubbles of gaseous water (steam). They form itself on heated bottom plate. On a very small area water suddenly changes its state to gas. This is the first sound source. At the beginning this microscopic bubbles stays at heating plate, but after reaching certain size they are able to unstuck from bottom plate and due to their lower density they move to upper water layers. After short time they reach the water layers which are much cooler then water directly above heating plate. On the upper surface of bubbles, steam which they consisting of starts condensate, inside pressure of bubbles suddenly drops and they implode. This creates the pressure wave and with it the noise. The water inside kettle heats more and more, incipient bubbles are even bigger so they can move up to the top of the water without imploding.

When water temperature is close to the boiling point almost all bubbles move up to the water surface. In this state the loud wheeze changes to the silent bubbling suggesting boiling of water in pot, characteristic by deep tones [6].

**4. RESULTS**

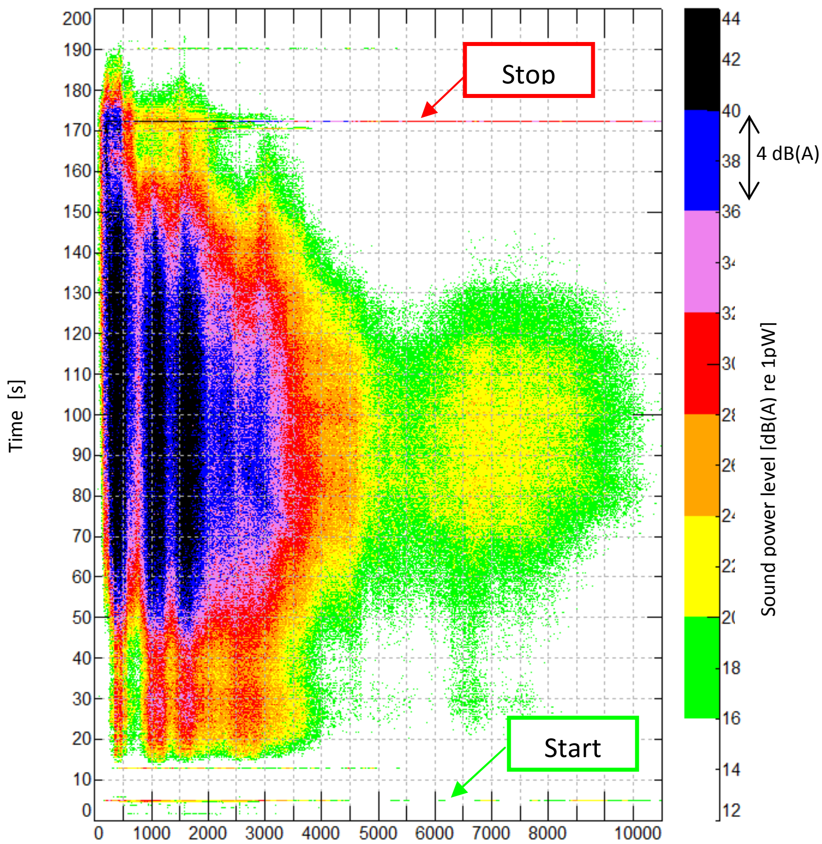
The above-mentioned theory was established by noise measurements. Kettle's sound during whole working cycle significantly changes its spectral composition (color) as well as achieved sound power levels. Difference between maximum sound power level, within the temperatures of 60-70°C and sound power level shortly before switching-off the kettle at approx. 95°C is more than 10dB(A) – graph 2.

In order to investigate noise reduction potentials, measurements with different amount of boiled water were done, in steps of 0.25 liter from 0.5 to 1.7 liter. It can be said that overall sound power does not change with amount of boiled water – graph 3.

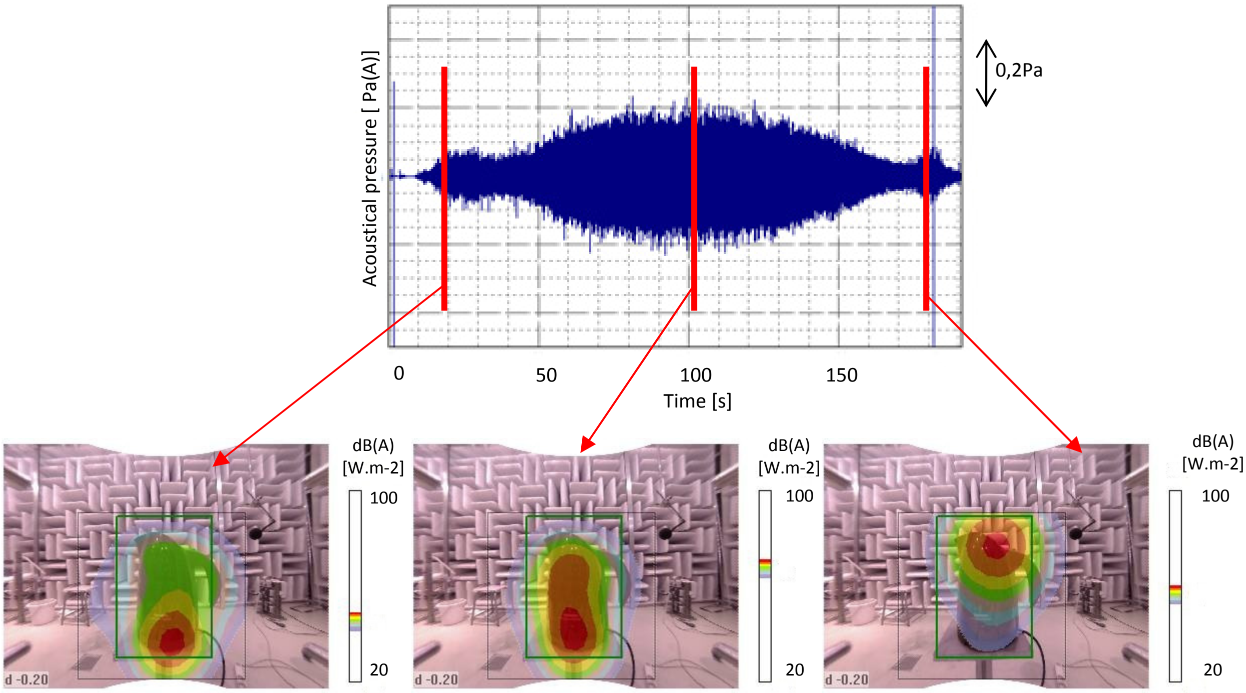



Graph 3: overall sound power level in dependence on amount of boiled water

In Campbell diagram – graph 4, an increase as well as decrease of individual frequency components during whole working cycle can be seen. The most important frequency components were visualized with acoustical camera. At beginning and in middle – the loudest phase of working cycle, middle and higher tones are contributing most to overall noise demonstration. They radiate from the tank shell. Lower tones shortly before reaching the boiling point radiate from the fill cover of tank – graph 5.




Graph 4: 3D Color map (Campbell diagram), time behavior of sound power frequency spectra during boiling of 1 Liter of water




Graph 5: Sound pressure time data, upper, and sound intensity localization maps with 8db dynamic resolution at specific periods of working cycle

## 5. CONCLUSION

From present investigation and theoretical background follows that the sound of kettle is broad banded and very complicated sound source.

With standard noise measures, it is practically impossible to influence the primary sound source – rising and collapsing gaseous water bubbles, considering the primary kettle's function.

Available noise reduction is therefore concealed in suitable damping of primary noise.

It has to be considered how necessary is to reduce kettle's overall sound power level. With modification of psychoacoustical parameters of kettle's sound, especially sharpness, we should be theoretically able to reach its comfortable and more acceptable noise exposition.

**ACKNOWLEDGEMENT**

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