# 17. SOUND FROM THE WATER

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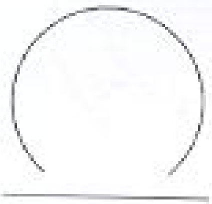
Sound appearance is caused by small vapor bubble, exactly by different processes, occurring with them. Water is involved in all these processes. In cause of it are propagated waves of compression and expansion. That is why we hear sound.

Later some frequencies, generated by definite mechanism come into the resonance with a kettle, there happened some processes, connected with passage throw the vapor medium. But all these influence only on loudness of hearing sound.

To the solution if this problem I approach in such a way: I consider some mechanisms, at the same time I explain them and make theoretical investigation. In all each mechanism I estimate the frequency and the intensity. Then I construct the theoretical spectrum to be in interval of heard sound and getting intensities to be higher then threshold of audibility. After that I make some conclusions and compare theory with the experimental data.

All considered mechanisms describe the behaviors of one bubble. That is why I will present them in such order in which they take place in reality.

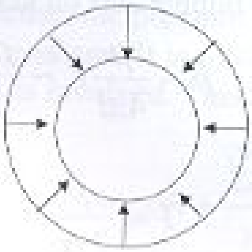
Considered mechanisms:



Breaking off

$\nu \sim 100 Hz$

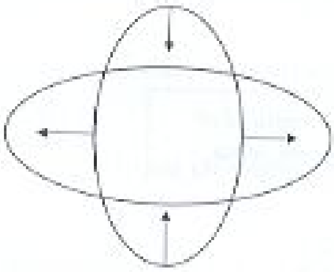
$I \sim 10^{-8} \frac{Wt}{m^2}$



Collapce

$\nu \sim 1800 Hz$

$I \sim 10^{-5} \frac{Wt}{m^2}$



Oscillation in cause of surface tension

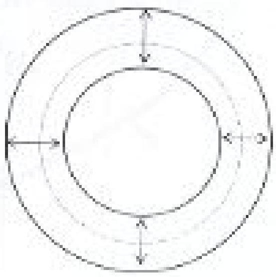
$\nu \sim 350 Hz$

$I \sim 10^{-7} \frac{Wt}{m^2}$

Volum oscilation

$\nu \sim 20000 Hz$

$I \sim 10^{-7} \frac{Wt}{m^2}$



First considered mechanism is <u>growth</u> of vapor bubble on the bottom. Then bubble changes it's volume it occures water. Exists possibility us to hear sound. But making rough estimation we got $\nu \sim 10^6\,Hz$. Such sound does not lies over hearing range. That is why it is not interesting to discuss this mechanism here.

The next mechanism is bubbles breaking off. When bubble reaches such a size that Archimed force balances the surface tention force bubble begans to break off. In this moment the resistance force begins to act on it. Here we wright Newton's II law:

$$M_f a = F_A - M_f g - M_{AD} a - F_\sigma$$

All the forces except Arkhimed and Resistance forces are negligible small. From this we can get the acceleration:

$$a \approx \frac{F_A}{M_{AD}} = 2g$$

During breaking off bubble moves on a distance which is equal to bubble's radius.

$$r = \frac{at^2}{2}$$

The frequency of generated sound is equal to the order of

$$\nu \sim \frac{1}{t} \sim \sqrt{\frac{g}{r}} \sim 100Hz\,,$$

t is character time. ( in this case time of breaking off.)

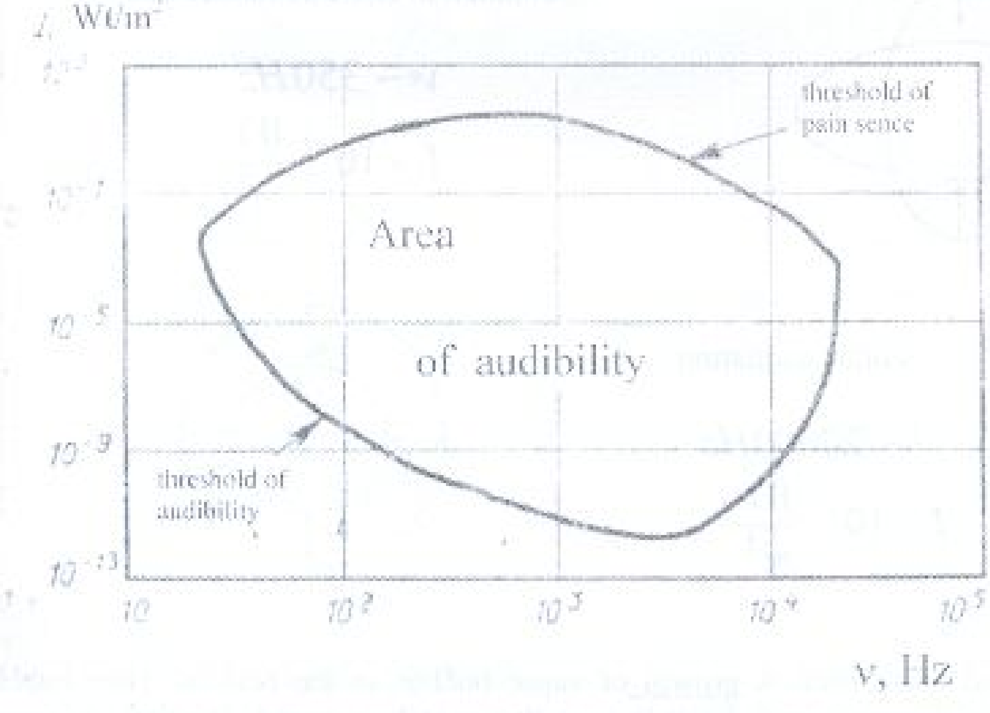
The pressure, with which bubble acts on kettle, is following:

$$p \sim \frac{\rho}{4\pi l}\ddot{V} \sim \frac{\rho r^3}{3l}\nu^2$$

For intensity we will have:

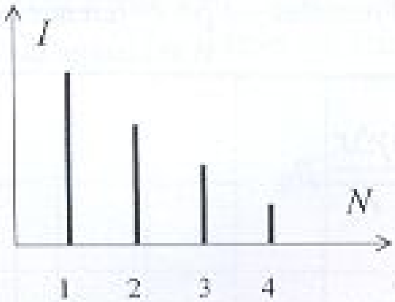
$$I \approx \frac{p}{2\rho c} \sim 10^{-8}\,\frac{Wt}{m^2}$$

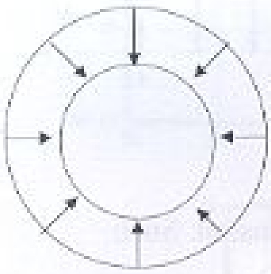
When we compare this with threshold of audibility it is clear that we will not hear the sound



of one bubble. But in the kettle several bubbles are breaking off at the same time. That's why it is possible that we will hear them.

After that we use that character of generating sound is not sinusoidal. We decompose given signal into Furies sum. Besides the main sound with frequency $\nu$ we will hear sound with frequencies which differ in whole number but with low intensities. Using ready result, taking into account that $I \sim A^2$, we have that n-number harmonic differs from initial at $\frac{1}{n^2}$ times.



The next mechanism that I consider is the collapse of the bubble. After the bubble will break off the bottom it will raise up to the colder layers. Vapor inside it will begin to condense, the pressure will decrease and it will not compensate outside pressure. It is obvious that by the collapse the definite waters mass is involved. This pressure acts on vapoour bubble is:

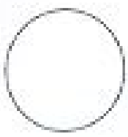
$$p_0 + \rho g h + \frac{2\sigma}{r} \approx p_0$$

We write Newton's II law for small waters mass $\Delta m$ :

$$\Delta m a \sim \Delta F$$

I calculate mass $\Delta m$ and force $\Delta F$ .

$$\Delta m \sim R^3 \rho$$



It's mass of water layer , which moves together with bubble

$$\Delta F = \Delta p R^2$$

In the expression for $\Delta F$ $\Delta p$ is the pressure's difference on which decreases pressure inside the bubble by decreasing temperature on 1° C. After that I estimate frequency.

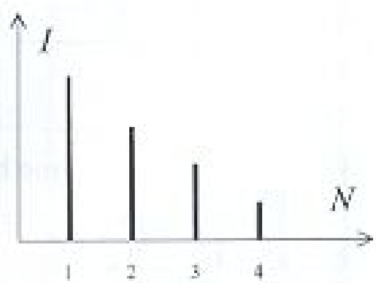
$$\Delta p = p_{100} - p_{99} \approx 10^3\, Pa$$

Then frequency is following:

$$\nu \sim \frac{1}{r}\sqrt{\frac{\Delta p}{\rho}} \sim 1800 Hz$$

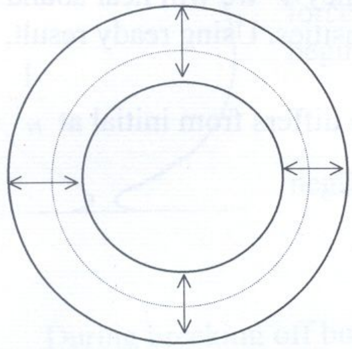
Intensity is:

$$I \sim 10^{-5}\, \frac{Wt}{m^2}$$



Now let us consider mechanism of volume oscillations. Let us assume that our bubble got into the sound wave. In cause of this it changed its volume. During this it creates sound itself too.

$$\Delta ma \sim \Delta F$$



We consider this process adiobatic in cause it occures fastly. That is why we write adiobats equestion.

$$p\left(\frac{4\pi r^3}{3}\right)^{\gamma} = p'\left(\frac{4\pi}{3}(r-\Delta r)^3\right)^{\gamma}$$

From this we get difference between pressures that makes it to change the volume.

$$\Delta p = p' - p \approx \frac{3\gamma\Delta r}{r} p_0$$


The frequency is following:

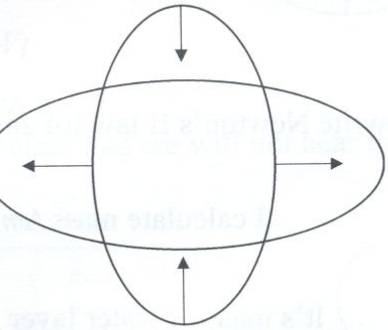
$$\nu \sim \frac{1}{r}\sqrt{\frac{3\gamma p_0}{\rho}} \sim 20000Hz$$

The intensity is:

$$I \sim 10^{-4}\frac{Wt}{m^2}$$

The next mechanism is volumes oscillations in cause of surface tension. Such oscillations cough be caused by breaking off.

$$\Delta ma = \Delta F$$



Here the Laplass pressure plays role of returning pressure.

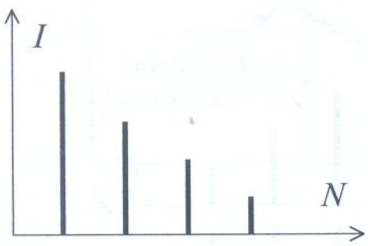
$$\frac{2\sigma}{r} dS \sim a\Delta r R^2 \rho$$

Frequency of this mechanism is:

$$\nu \sim \sqrt{\frac{\sigma}{R^3\rho}} \sim 350Hz$$

The intensity is:

$$I \sim 10^{-7}\frac{Wt}{m^2}$$




The both lust processes occure in reality in the same time but for simplier I devided them.

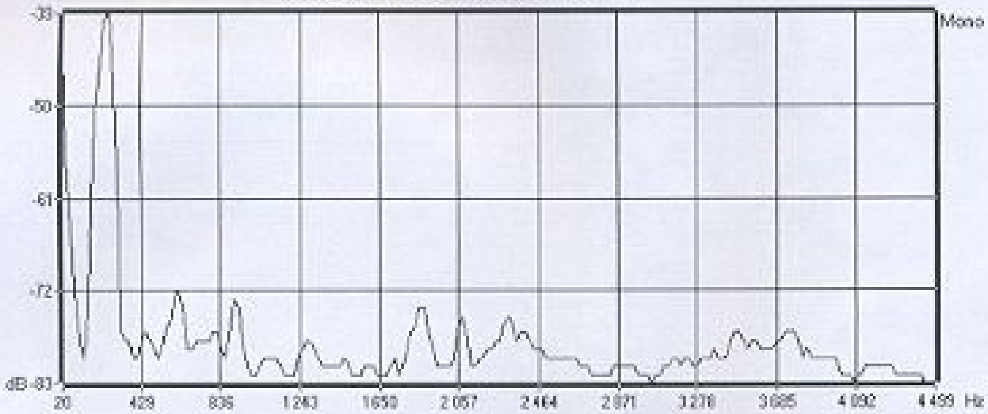
Now let us understand what mechanism plays first role. First mechanism has quit low frequensy and intensity. In two lust mechanisms take place volume oscillations by order equal to radius. That means that our bubble can collapse essidentaly. The main mechanism is collapse. Its frequensy is by order equal to 1000 Hz and how we know our ear is more sensetive to sounds with such frequensies. So it selects this sound too.

Let us speak about experimental part. How we see from it the audibilitable interval is in first quadrant. Other sounds we hear worstly. So how we can see such rough and simply theory can describe difficult processes.

We made some experiments with different water's heights in kettle. We recorded kettles natural frequency and got some peaks with correspondent frequencies.

Sound from the water:


natural frequense of kettle:




Besides it we wrote sound of heated kettle with soda water. We were interested what will change with high gas concentration. How we can see it differs.

sound from soda water: