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Remarks:

Amended claims in accordance with Rule 137(2) EPC.

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(54) **ACOUSTIC CLEANER**

(57) A method and an apparatus for providing sound waves for cleaning of surfaces, the apparatus comprising an air-tight casing, at least one electric loudspeaker (1A,1B) arranged inside said air-tight casing to produce high pressure sound into said air tight casing, a signal generator (10) for producing signals to drive the at least one loudspeaker (1A,1B), a sound outlet portion (6,7,8)

arranged to emit sound produced by the at least one loudspeaker (1A,1B) to an object (9) to be cleaned. The apparatus is arranged to provide an audio signal with a waveform where the amplitude alternates between a low and high value, the transition between the low and high amplitude value being substantially instantaneous so as to form a substantially square shaped waveform.

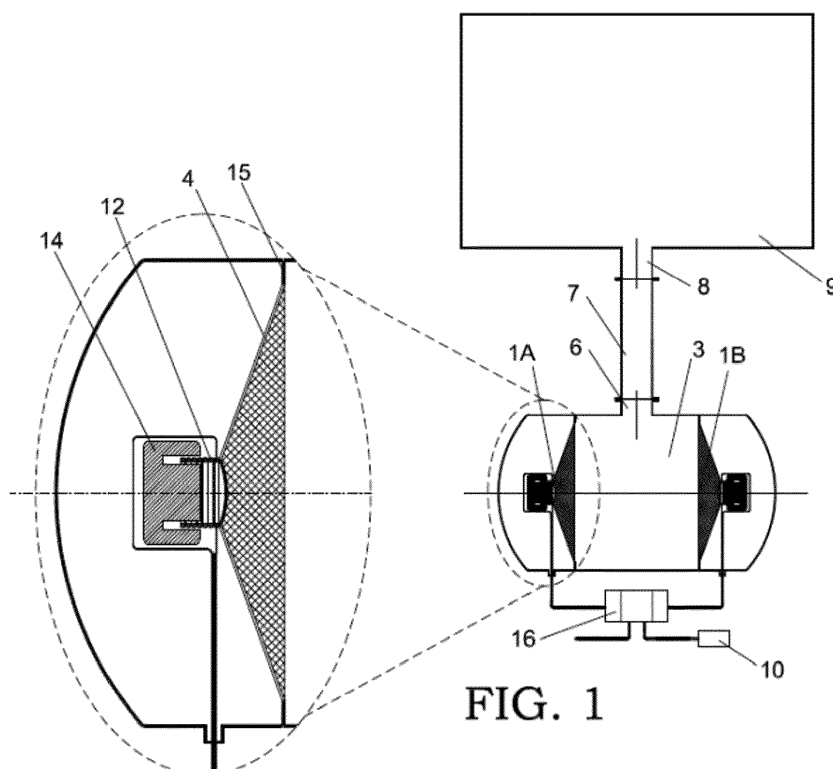


FIG. 1

Description

BACKGROUND

[0001] The invention is in the field of acoustic cleaners, for example cleaning of heat exchanger surfaces in industrial boiler installations and represents an improvement on existing technology. Ash and dust particles from combustion of various fuels deposit onto the heat exchanger surfaces and have deleterious effects on the heat transfer efficiency of the process. Various attempts have been made at removing such dust deposits by generation of acoustic waves inside the heat exchanger. The most common technology is the use of so-called "sonic horns" where low frequency sound waves (approximately 75 - 150 Hz frequency) are generated by compressed air energization of a diaphragm-horn arrangement. Another approach is to use explosive discharge to generate pressure waves inside the heat exchanger.

[0002] Acoustic cleaners may be used in e.g. the following applications:

- Boilers - Cleaning of the heat transfer surfaces.
- Superheaters, economizers and air heaters.
- Duct work.
- Filters - Acoustic cleaners are used on reverse air, pulse jet and shaker units. They are effective in reducing pressure drop across the collection surface which will increase bag life and prevent hopper pluggage. Generally, they can totally replace the both reverse air fans and shaker units and significantly reduce the compressed air requirement on pulse jet filters.
- ID fan - Acoustic cleaning helps to provide a uniform cleaning pattern even for inaccessible parts of the fan. This maintains the balance of the fan.
- Kiln inlet -Acoustic cleaners help to prevent particulate buildup at the kiln inlet and this will minimize nose ring formation.
- Mechanical pre Collectors - Acoustic cleaners help prevent buildup around the impellers and between the tubes.
- Mills Acoustic cleaners help maintain material flow and also prevent blockages in the pre grind silos. They also help prevent material buildup in the downstream separators and fans.
- Planetary Coolers - Acoustic cleaners help prevent bridging and ensure complete evacuation.
- Electrostatic Precipitator - Acoustic cleaners help clean the turning vanes, distribution plates, collecting plates and electrode wires. They can either assist or replace the mechanical rapping systems. They also prevent particulate buildup in the under hoppers which would otherwise result in opacity spiking.
- Pre heaters - Used in towers, gas risers, cyclones and fans.
- Ship cargo holds - used both to clean and de aerate current loads.
- Silos and hoppers - To prevent bridging and rat holing.
- Static cyclones - Acoustic cleaners will work both within the cyclone and with the associated duct work
- Catalysts - Acoustic cleaners to prevent dust layers and other buildup around the catalytic substances.

[0003] An acoustic cleaner consists of a sound source similar to an air horn found on trucks and trains, attached to the material-handling or boiler equipment, which directs a loud sound into the interior of the equipment. The acoustic waves that comprise the loud sound then interact with dust particles on the equipment surfaces and dislodge the particles, thus cleaning the surfaces. The air horn is typically powered by compressed air rather than electricity and consists of two parts:

- The acoustic driver - In the driver, compressed air escaping past a diaphragm causes it to vibrate, generating the

sound. It is usually made from solid machined stainless steel. The diaphragm, the only moving part, is usually manufactured from special aerospace grade titanium to ensure performance and longevity.

- The bell, a flaring horn, usually made from spun 316 grade stainless steel. The bell serves as a sound resonator, and its flaring shape couples the sound efficiently to the air, increasing the volume of sound radiated.

[0004] The sound waves generated by the air horn are primarily determined by the physical shape and length of the bell. It has been generally determined that low frequency sound waves (75 Hz to 150 Hz) are better suited for cleaning purposes, compared to high frequency because:

- They propagate for longer distances inside the equipment with less dissipation due to their longer wave length.
- After leaving the horn they propagate Omni-directionally inside the equipment, thus have a wider angle of cleaning effectiveness.
- Then can be generated with higher sound pressure levels, typically 150 dB.

[0005] The frequency of the sound generation is determined by the physical size of the bell, with longer bells generating lower frequencies. The horn length being $\frac{1}{4}$ wavelength of the sound generated. Technical constraints of the acoustic driver and horn size have limited the frequency to be no less than about 75 Hz. The devices operate with air pressure in the range of 4.8 to 6.2 bars (70 to 90 psi). The resultant sound pressure level will be around 150 dB. In general, better cleaning is achieved with higher sound pressures and lower frequencies.

[0006] Because the sound is generated by the acoustics of the bell, the sound pressure wave is necessarily of a sinusoidal waveform.

[0007] Electrically driven acoustic drivers have normally not been utilized because air drivers can achieve much higher sound pressure levels and thus better cleaning efficacy.

SUMMARY OF THE INVENTION

[0008] It is the object of the invention to provide an improved acoustic cleaner method and apparatus for cleaning of boiler heat exchanger surfaces.

[0009] The invention utilizes conventional electrically driven dynamic drivers, i.e. loudspeakers, to generate acoustic waves to clean surfaces, e.g. inside a boiler heat exchanger. They are mounted in a unique configuration and operated with a unique driving electrical signal to produce acoustic waves of special waveform characteristics inside the boiler heat exchanger. With this unique arrangement, unexpectedly good heat exchanger cleaning results have been achieved.

[0010] Specifically, the invention relates to a method of cleaning surfaces, such as surfaces of a heat exchanger, by means of high pressure sound, the method comprising the steps of:

- providing a low frequency sound wave, between 1 and 100 Hz by means of an electric loudspeaker to the surfaces to be cleaned,
- alternating the amplitude of the low frequency sound between low and high values, the transition between low and high being substantially instantaneous so as to form a substantially square shaped waveform.

[0011] In a specific embodiment the high amplitude value is 90 dB or more, and wherein the low value is below 90 dB. The high amplitude value is preferably above 100 dB, more preferably over 120 dB.

[0012] In another specific embodiment a transition from the low amplitude to the high amplitude is performed in 2 milliseconds or less, preferably in 500 μ s or less.

[0013] In yet another specific embodiment the transition from the high amplitude to the low amplitude is performed in 500 μ s or less, preferably 300 μ s or less.

[0014] Further, the frequency may be varied from a value of between 1 and 20 Hz to a value between 20 and 100 Hz.

[0015] Preferably the alternating of the amplitude of the low frequency sound between low and high values is performed at different frequencies, both at a frequency between 1 and 20 Hz and at a frequency between 20 and 100 Hz.

[0016] The invention also relates to a computer program comprising program code, which when executed in a computer enables said computer to perform the method as described above. It also relates to a computer program product comprising a computer-readable medium containing said computer program.

[0017] According to a second aspect the invention relates to an apparatus for providing sound waves for cleaning of surfaces, the apparatus comprising:

- an air-tight casing,
- at least one electric loudspeaker arranged inside said air-tight casing to produce high pressure sound into said air tight casing,
- a signal generator for producing signals to drive the at least one loudspeaker,
- a sound outlet portion arranged to emit sound produced by the at least one loudspeaker to an object to be cleaned.

[0018] In a specific embodiment two loudspeakers are arranged inside said air-tight casing, opposed to each other, both loudspeakers facing the sound outlet portion at an equal distance from the sound outlet portion and whereby the signal generator is arranged to provide audio signals for each loudspeakers of the same waveform and in phase with each other so that the loudspeakers operate in synchronized unison.

[0019] In another specific embodiment the sound outlet portion comprises a connector for connection to an electric appliance to be cleaned, the connector comprising an output end arranged at the air-tight casing and an input end for connection to an electric appliance to be cleaned.

[0020] Typically, the apparatus comprises a control unit arranged to control the signal generator to provide an audio signal with a waveform where the amplitude alternates between a low and high value, the transition between the low and high amplitude value being substantially instantaneous so as to form a substantially square shaped waveform.

[0021] The control unit may be arranged to control the signal generator so as to perform the steps of the inventive method above.

[0022] Further aspects of the invention will be apparent from the following detailed description.

DETAILED DESCRIPTION OF THE SHOWN EMBODIMENT

[0023] The preferred embodiment of the invention is depicted in FIG. 1, which is a cross-sectional view of the apparatus. Two dynamic drivers 1A and 1B are positioned at either end of the sounding chamber 3 and facing each other. The dynamic drivers may be any kind of electric loudspeakers, preferably woofer loudspeakers arranged to provide a low frequency sound wave, between 1 and 100 Hz. A first dynamic driver 1A of the specific shown embodiment comprises a suspended lightweight cone 4 attached to an electromagnet 12 (a coil of copper wire). The electromagnet 12 is placed in front of permanent magnet 14. The outer edge of the cone is connected to the sounding chamber by flexible support 15. The flexible support acts like a spring to allow the cone to move and then be returned to its starting position if the electrical signal is removed from the electromagnet.

[0024] As depicted in FIG. 2A, the electromagnet- cone is in its nominal, un-energized position. When the amplifier 16 applies electricity to the electromagnet 12, it creates a magnetic field that creates a force and moves 17 the electromagnet relative to the permanent magnet 14 which in turn (FIG. 2B) moves 17 the cone forward. If the electricity reverses its polarity (FIG. 2C) the force also reverses and the electromagnet moves 18 in the opposite direction. These directional changes in the field cause the electromagnet to be attracted and repelled by the permanent magnet behind it. The resulting pull-and-push forces make the electromagnet and attached cone move. Such cone movements create sound pressure waves inside the sound chamber 3.

[0025] Sealed enclosures are provided on the back side of the dynamic drivers. They are of a relatively small enclosed volume so that the acoustic resonant frequency of the enclosure is well above the electrical signal fundamental frequency. If the enclosure had a resonant frequency near the fundamental operating frequency of the device, distortions would be induced to the acoustic waves generated inside the sounding chamber 3.

[0026] The apparatus further comprises a sound outlet portion 6,7,8 arranged to emit sound by the loudspeaker(s) to an object to be cleaned, as exemplified by a boiler equipment 9. An outlet nozzle 6 is connected to the sounding chamber and provides a port for the sound pressure wave generated in the sounding chamber to exit. A connecting pipe 7 carries the sound pressure wave to the boiler equipment 9, which is similarly fitted with an inlet nozzle 8. The sound pressure wave is generated in the sounding chamber 3, then transmitted to the inside of the boiler equipment 9 via the connecting pipe 7. Such a connecting pipe provides for efficient acoustic wave transmission with very little energy loss. The length of the pipe is determined by the logistics of the location of the sounding chamber relative to the boiler equipment. In one embodiment the connecting pipe 7 may be dispensed with such the inlet nozzle 8 and outlet nozzle 6 are closely connected, or the same. Such an embodiment is arranged to be located inside or in direct connection to the object to be cleaned, such as a boiler equipment.

[0027] The electromagnets of the dynamic drivers 1A and 1B are each supplied with electricity from the dual channel amplifier 16. Both channels of the amplifier are provided with the same electrical signal from signal generator 10. The amplifier 16 has sufficient power to move the electromagnet 12 and cone 4 to the required displacements for maximum acoustic wave generation. The signal generator 10 provides a special electrical signal waveform which is in turn delivered to the dynamic drivers 1A and 1B by the dual channel amplifier 16.

[0028] The signal waveform supplied by the signal generator is depicted in FIG. 3A and 3B and is characterized by the following unique features:

EP 3 210 678 A1

- Modified Square Wave - The signal voltage alternates between a positive V_+ and negative value V_- , the magnitude of the positive and negative voltages being essentially the same so as to produce a modified square wave with a fundamental frequency f . For example, +5 volts and - 5 volts.

- Frequency sweep / duration - The fundamental frequency f of the square wave starts at a certain value f_i and then gradually increases to a certain value f_f over a period of time T_s , called the sweep period. Specifically, it is said that the fundamental frequency f of the modified square wave is swept from f_i to f_f over duration T_s . For our preferred embodiment, the starting frequency is 28 Hz, the final frequency is 40 Hz, the sweep period is 60 seconds.

- Duty Cycle -The acoustic cleaner does not need operate continuously. Typically, the rate of dust build-up on the heat exchanger surfaces is very slow. However, it has been discovered that the cohesion of the dust layer will increase over time, i.e. it is far easier to clean a newly formed dust layer than a dust layer that has resided on the surface for a long time.

[0029] This is because chemical reactions will occur between the particles and the gas that can form adhesive products at the dust contact points. As such, it is advantageous to operate the acoustic cleaner at regular and frequent intervals in order to keep the heat exchanger surfaces clean. Generally, the acoustic cleaner is activated for the sweep period, and then de-activated for a waiting period.

- Rise time - The rate of rise, that is the time τ the signal requires to change from its negative voltage to its positive voltage is typically 400 μsec . Similarly, the rate of fall, that is the time the signal requires to change from its positive value to its negative value is typically 400 μsec .

- Momentum nullification - Immediately after each transition from negative voltage to positive voltage, the signal voltage instantly returns to the negative voltage for a period of 200 μsec and then instantly returns to the positive value. Immediately after each transition from positive voltage to negative voltage, the signal voltage instantly returns to the positive voltage for a period of 200 μsec and then instantly returns to the negative value.

- The same signal is delivered to each of the two dynamic driver electromagnets 12 and are said to be "in-phase" with each other. As a result, they move in synchronism toward each other and away from each other in accordance with the applied signal modified square wave. Also, the dynamic drivers are located at an equal distance from the outlet nozzle 6 of the apparatus.

[0030] It should be noted that the precise values for the signal waveform features specified above are the optimum, but a range of each would still function adequately. Table 1 below shows the acceptable ranges of the variables.

Table 1.

	Minimum value	Optimum Value	Maximum Value
Initial frequency, f_i	10 Hz	28 Hz	60 Hz
Final frequency, f_f	15 Hz	40 Hz	100 Hz
Sweep period, T_s	10s	60 s	600 s
Duty cycle,	60 s	300 s	3600 s
Rise time, τ_r	40 μs	400 μs	2000 μs
Momentum nullification period. τ_n	20 μs	200 μs	800 μs

[0031] The purpose of the signal waveform of FIG. 3A and 3B is to move the electromagnet-cone which in turn produce pressure peaks with very high pressure gradients. The increasing electrical signal from negative polarity to positive with short rise time causes the electromagnet and cone to move outward very rapidly. The total amount of electrical power delivered by the amplifier to the electromagnet-cone is termed the starting power and will determine the final velocity of the electromagnet-cone at the end of the signal ramp increase. The cone movement creates the front side positive pressure pulse 19 of the pressure wave as shown in FIG. 4B. The rise time of the waveform of FIG. 3B (also FIG. 4A) is chosen to provide the maximum acceleration of the electromagnet and cone, specifically to match the mechanical impedance of the system. Mechanical impedance is determined by the mass of the electromagnet-cone and the "spring constant" of the flexible connection of the cone to the support. If the rise time were too short, the electromagnet- cone

would not be able to accelerate fast enough to respond at that speed. If the rise time is too long, the electromagnet-cone would move too slowly.

[0032] After the short rise time, the electromagnet and cone are still moving at a high speed due to their momentum. The signal then includes the momentum nullification feature. This feature provides a sharp negative force to the electromagnet and cone in order to stop them quickly. If the momentum nullification is applied instantaneously and with period $\frac{1}{2}$ of the rise time, the amplifier will deliver electrical stopping power equal to the electrical driving power and the electromagnet-cone will be stopped. This quick stoppage of the cone creates the back side pressure pulse 21 of the pressure wave as shown in FIG. 4B. The positive sustained voltage after the momentum nullification serves to maintain the electromagnet and cone in the full extended position.

[0033] This whole process reverses during the decreasing electrical signal portion of the wave form. During this part of the cycle, a negative pressure pulse 20 is produced by the cone movement. In such a way, a series of positive and negative pressure pulses are generated by the dynamic driver which propagate away from the cone.

[0034] The two dynamic drivers 1A and 1 B are operated with the same electrical signal. As a result, the pressure pulses generated by each are synchronized and propagate towards each other in the sounding chamber as depicted in FIG. 5A, 5B, and 5C. FIG. 5A, 5B and 5C show pressure pulses generated by the invention as successive times beginning at production of the pulses at the driver cones 4 and ending at the collision of the two pulses in the center of the sounding chamber 3. Because the two dynamic drivers are positioned directly opposite each other, the pressure pulses collide in the center of the sounding chamber and the resulting pressure peak 22 is double the magnitude of each of the individual pulses. The outlet nozzle 6 is positioned at the center point of the sounding chamber, so this very high pressure pulse wave enters the nozzle and propagates through the connecting pipe and ultimately enters the boiler equipment. The pressure pulse wave exhibits very little dissipation as it transits the pipe, since the pressure wave is collimated in the pipe and not subject to spatial dispersion.

[0035] Because the electrical signal drive is a modified square wave and because of the arrangement of the dynamic drivers, the sound pressure wave generated in the connecting pipe a very steep pressure gradient. The inventors have discovered that the pressure gradient of the sound wave is the important parameter for cleaning effectiveness. For comparison, conventional sound waves have a low sound pressure gradient, even if they have high peak pressure, because they are sinusoidal waves. FIG. 6A and 6B shows the comparison between pressure gradient between a series of pulses 24 as generated with the invention and a sinusoidal wave 23 of frequency 40 Hz with the same peak pressure. As can be seen in FIG. 6B the pressure gradient 25 (i.e. the slope of the pressure wave) for the pulse is some 90 times greater than the pressure gradient 26 for the sinusoidal wave.

[0036] Acoustic waves will propagate through the chamber in complex fashion, and there will exist null areas where the waves don't reach and resonances where the waves will amplify or create standing waves. The position and magnitude of the nulls and resonances depends on the frequency of the acoustic wave, the specific geometry of the chamber and the properties of the gas (i.e. temperature, density and pressure). Because the boiler heat exchanger chambers are rather large compared to normal acoustic wavelengths, the resonances will typically be in the very low frequency range, 10 Hz to 50 Hz.

[0037] Attempts have been made in the past to provide acoustic cleaners (see Infracone) with carefully tuned frequency so as to operate at the exact resonant frequency of the boiler heat exchanger chamber. But two problems have plagued their operation:

- Operation at resonant frequency will result in some regions of the heat exchanger being in a "null" of the resonance, that is there will be very little acoustic intensity at these locations.
- It is very difficult to calculate the resonant frequency in advance (needed for the design of the acoustic driver) because parameters such as gas temperature, pressure, velocity and density are unknown. Indeed, these parameters are often variable during the boiler operation, making it ineffective to operate and the precalculated resonant frequency.

[0038] The invention remedies this by providing acoustic cleaner operation in a range of fundamental frequencies that span the possible resonances of the heat exchanger chamber. Thus during every cleaning cycle, the acoustic cleaner will operate at all the different resonant frequencies of the chamber and also eliminate any "null" regions.

[0039] The foregoing description of the invention illustrates and describes the present invention. Additionally, the disclosure shows and describes only the preferred embodiments of the invention, but as mentioned above, it is to be understood that the invention is capable of use in various other combinations, modifications, and environments and is capable of changes or modifications within the scope of the inventive concept as expressed herein, commensurate with the above teachings and/or the skill or knowledge of the relevant art. The embodiment described hereinabove are further intended to explain best modes known of practicing the invention and to enable others skilled in the art to utilize the invention in such, or other, embodiments and with the various modifications required by the particular applications or

uses of the invention. Accordingly, the description is not intended to limit the invention to the form disclosed herein. Also, it is intended that the appended claims be construed to include alternative embodiments.

[0040] For example, in an alternative embodiment a single dynamic driver is utilized instead of two. While the magnitude of the acoustic pressure pulses would be about half that achievable with the preferred embodiment, there could be many applications where this is sufficient to achieve the intended cleaning results. Further, several synchronized dynamic drivers may be utilized in order to achieve larger effect, the effect of course being proportional to the number of dynamic drivers.

Claims

1. A method of cleaning surfaces, such as surfaces of a heat exchanger, by means of high pressure sound, the method comprising the steps of:

- providing a low frequency sound wave, between 1 and 100 Hz by means of an electric loudspeaker to the surfaces to be cleaned,
- alternating the amplitude of the low frequency sound between low and high values, the transition between low and high being substantially instantaneous so as to form a substantially square shaped waveform.

2. The method according to claim 1, wherein the high amplitude value is 90 dB or more, and wherein the low value is below 90 dB.

3. The method according to claim 1 or 2, wherein the high amplitude value is above 100 dB, preferably over 120 dB.

4. The method according to anyone of the preceding claims, wherein a transition from the low amplitude to the high amplitude is performed in 2 milliseconds or less, preferably in 500 μ s or less.

5. The method according to anyone of the preceding claims, wherein the transition from the high amplitude to the low amplitude is performed in 500 μ s or less, preferably 300 μ s or less.

6. The method according to anyone of the preceding claims, wherein the frequency is varied from a value of between 1 and 20 Hz to a value between 20 and 100 Hz.

7. The method according to claim 6, wherein the alternating of the amplitude of the low frequency sound between low and high values is performed at different frequencies, both at a frequency between 1 and 20 Hz and at a frequency between 20 and 100 Hz.

8. A computer program comprising program code, which when executed in a computer enables said computer to perform the method according to anyone of the preceding claims.

9. A computer program product comprising a computer-readable medium and a computer program according to claim 8, wherein said computer program is contained in said computer-readable medium.

10. Apparatus for providing sound waves for cleaning of surfaces, the apparatus comprising:

- an air-tight casing,
- at least one electric loudspeaker (1A, 1B) arranged inside said air-tight casing to produce high pressure sound into said air tight casing,
- a signal generator (10) for producing signals to drive the at least one loudspeaker (1A,1B),
- a sound outlet portion (6,7,8) arranged to emit sound produced by the at least one loudspeaker (1A, 1B) to an object (9) to be cleaned.

11. The apparatus of claim 10, wherein two loudspeakers (1A, 1B) are arranged inside said air-tight casing, opposed to each other, both loudspeakers (1A, 1B) facing the sound outlet portion (6,7,8) at an equal distance from an outlet nozzle (6) thereof and whereby the signal generator (10) is arranged to provide audio signals for each loudspeakers (1A, 1B) of the same waveform and in phase with each other so that the loudspeakers (1A, 1B) operate in synchronized unison with each other.

12. The apparatus of claim 10 or 11, wherein the sound outlet portion (6,7,8) comprises a connector pipe (7) for connection to an electric appliance to be cleaned, the connector comprising an output nozzle (6) arranged at the air-tight casing and an input nozzle (8) for connection to an electric appliance to be cleaned.

13. The apparatus of anyone of the claims 10-12, wherein a control unit is arranged to control the signal generator (10) to provide an audio signal with a waveform where the amplitude alternates between a low and high value, the transition between the low and high amplitude value being substantially instantaneous so as to form a substantially square shaped waveform.

14. The apparatus of claim 13, wherein the control unit is arranged to control the signal generator (10) so as to perform the method of anyone of the claims 1-7.

Amended claims in accordance with Rule 137(2) EPC.

1. A method of cleaning surfaces, such as surfaces of a heat exchanger, by means of high pressure sound, the method comprising the steps of:

- providing a low frequency sound wave, between 1 and 100 Hz by means of an electric loudspeaker to the surfaces to cleaned,
- alternating the amplitude of the low frequency sound between low and high values, **characterized in that** the transition between low and high being substantially instantaneous so as to form a substantially square shaped waveform, wherein the transition from the low amplitude to the high amplitude is performed in 2 milliseconds or less.

2. The method according to claim 1, wherein the high amplitude value is 90 dB or more, and wherein the low value is below 90 dB.

3. The method according to claim 1 or 2, wherein the high amplitude value is above 100 dB.

4. The method according to anyone of the preceding claims, wherein the transition from the low amplitude to the high amplitude is performed in 500 μ s or less.

5. The method according to anyone of the preceding claims, wherein the transition from the high amplitude to the low amplitude is performed in 300 μ s or less.

6. The method according to anyone of the preceding claims, wherein the frequency is varied from a value of between 1 and 20 Hz to a value between 20 and 100 Hz.

7. The method according to claim 6, wherein the alternating of the amplitude of the low frequency sound between low and high values is performed at different frequencies, both at a frequency between 1 and 20 Hz and at a frequency between 20 and 100 Hz.

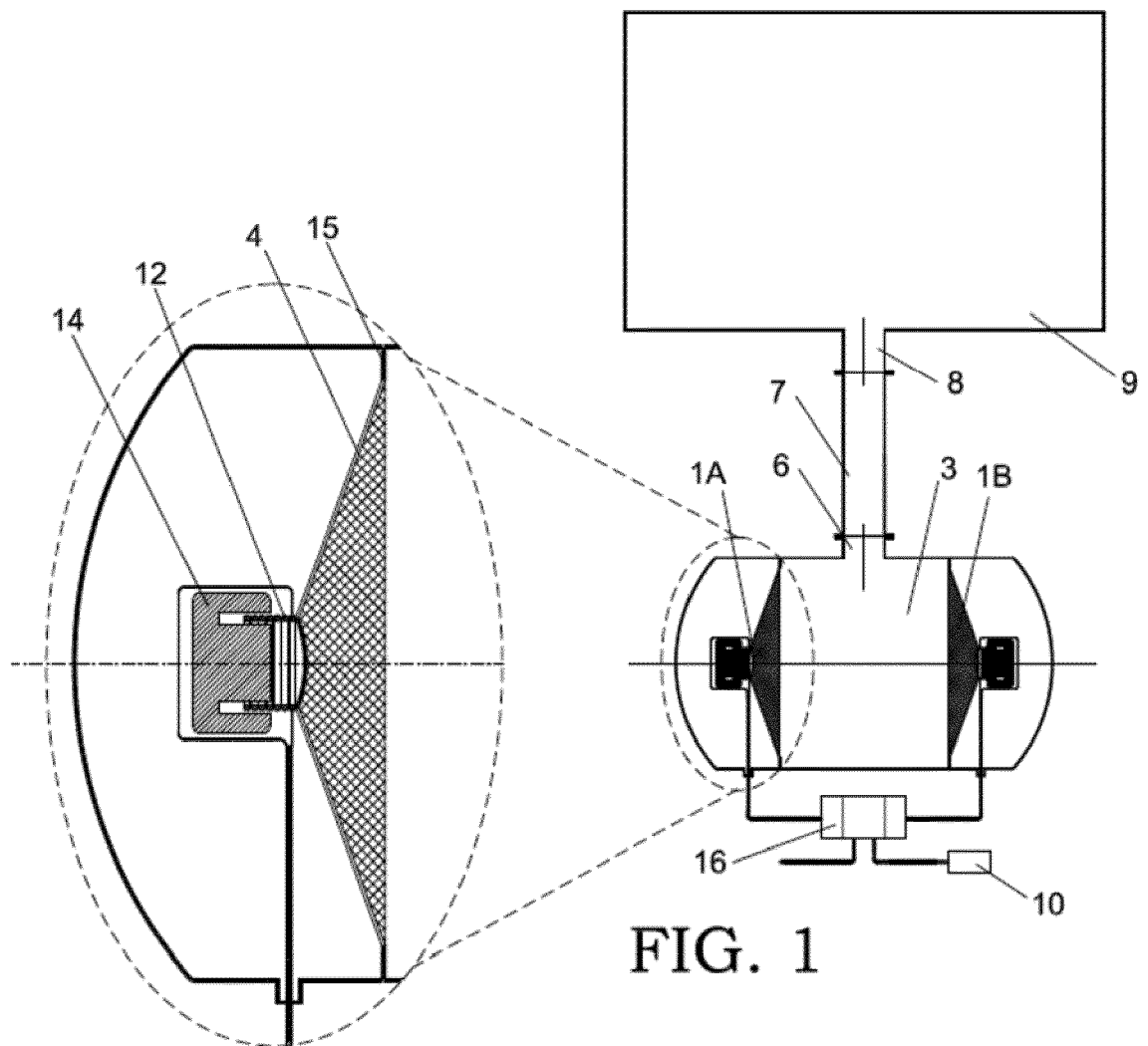
8. A computer program comprising program code, which when executed in a computer enables said computer to perform the method according to anyone of the preceding claims.

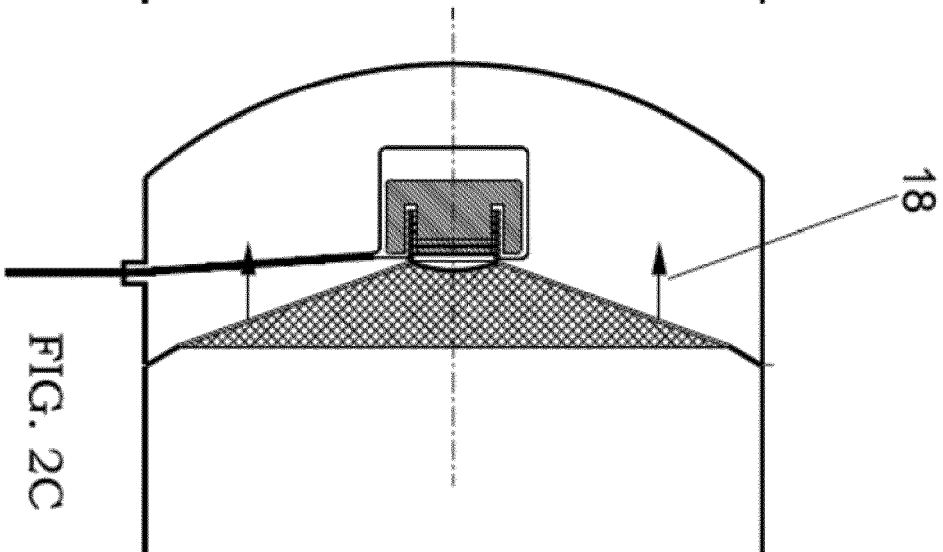
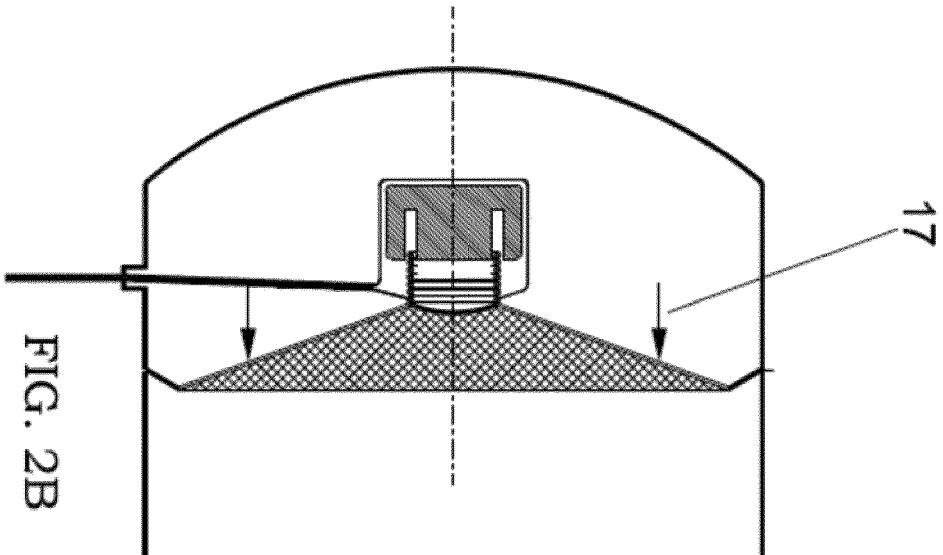
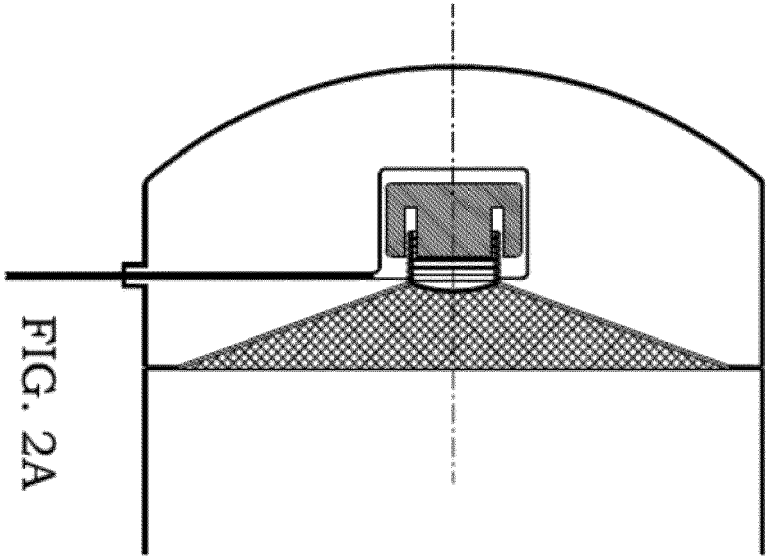
9. A computer program product comprising a computer-readable medium and a computer program according to claim 8, wherein said computer program is contained in said computer-readable medium.

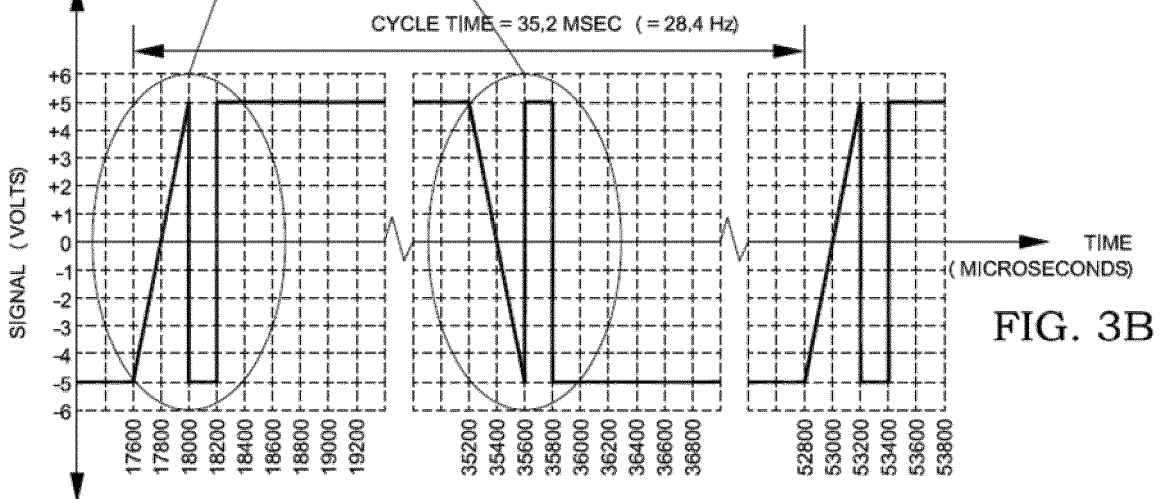
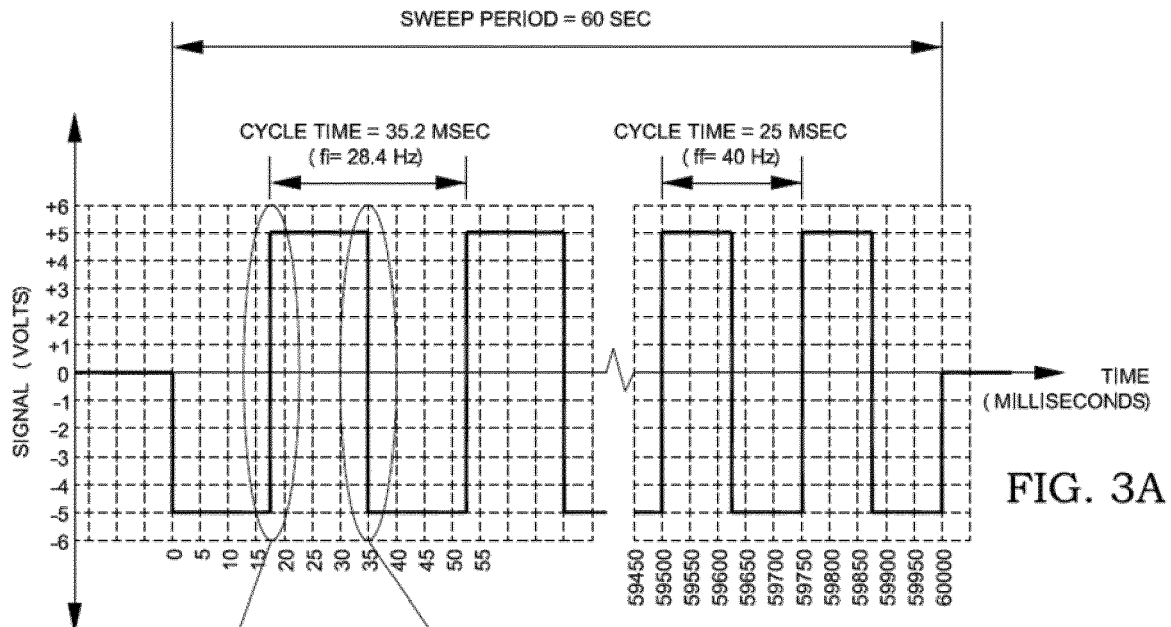
10. Apparatus for providing sound waves for cleaning surfaces of an object to be cleaned, the apparatus comprising:

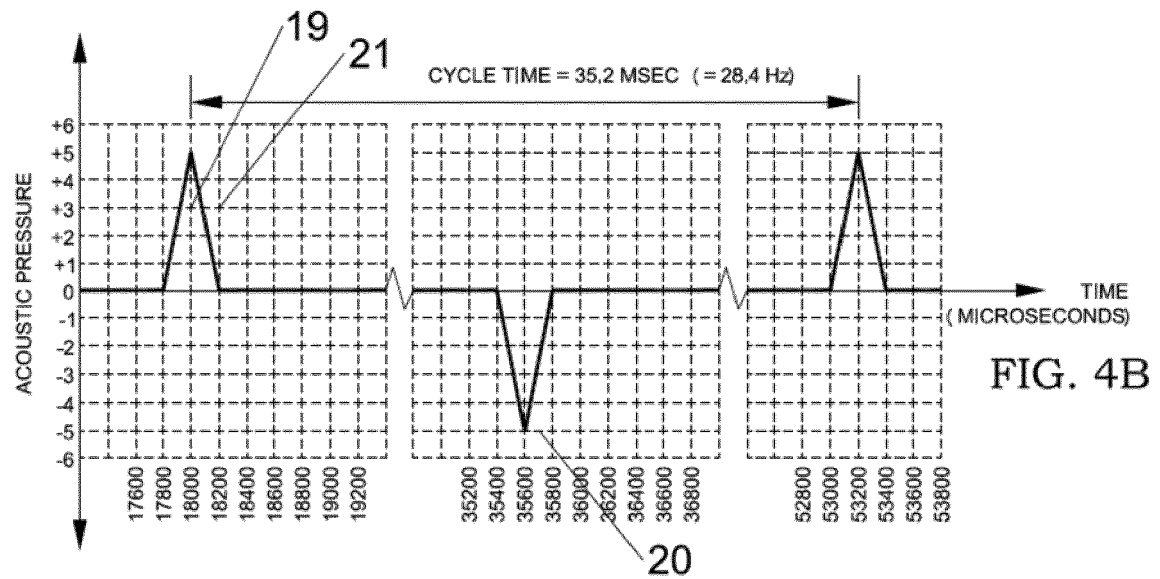
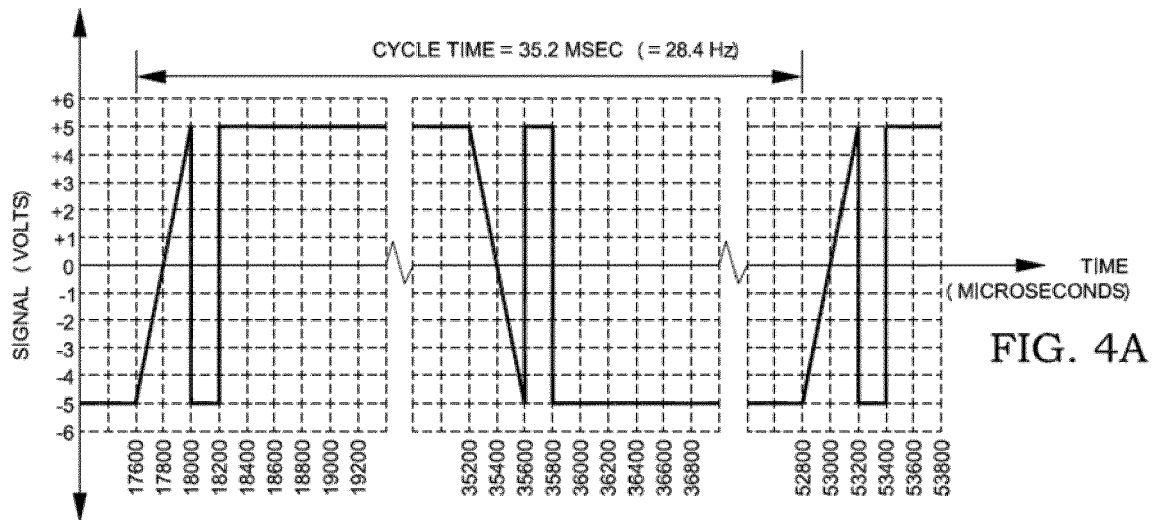
- an air-tight casing,
- at least two electric loudspeakers (1A,1B) arranged inside said air-tight casing to produce high pressure sound into said air tight casing,
- a signal generator (10) for producing signals to drive the at least two loudspeakers (1A,1B),
- a sound outlet portion (6,7,8) arranged to emit sound produced by the at least two loudspeakers (1A,1B) to the object (9) to be cleaned.

- 5 **11.** The apparatus of claim 10, wherein the two loudspeakers (1A,1B) are arranged inside said air-tight casing, opposed to each other, both loudspeakers (1A,1B) facing the sound outlet portion (6,7,8) at an equal distance from an outlet nozzle (6) thereof and whereby the signal generator (10) is arranged to provide audio signals for each loudspeakers (1A,1B) of the same waveform and in phase with each other so that the loudspeakers (1A,1B) operate in synchronized unison with each other.
- 10 **12.** The apparatus of claim 10 or 11, wherein the sound outlet portion (6,7,8) comprises a connector pipe (7) for connection to an electric appliance to be cleaned, the connector comprising an output nozzle (6) arranged at the air-tight casing and an input nozzle (8) for connection to an electric appliance to be cleaned.
- 15 **13.** The apparatus of anyone of the claims 10-12, wherein a control unit is arranged to control the signal generator (10) to provide an audio signal with a waveform where the amplitude alternates between a low and high value, the transition between the low and high amplitude value being substantially instantaneous so as to form a substantially square shaped waveform.
- 20 **14.** The apparatus of claim 13, wherein the control unit is arranged to control the signal generator (10) so as to perform the method of anyone of the claims 1-7.









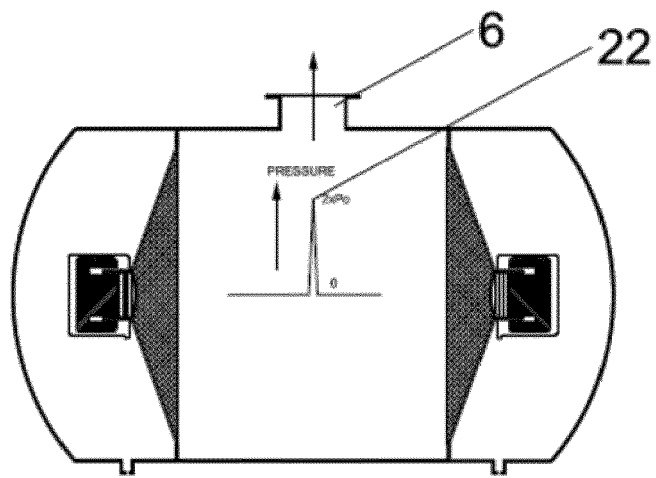


FIG. 5C

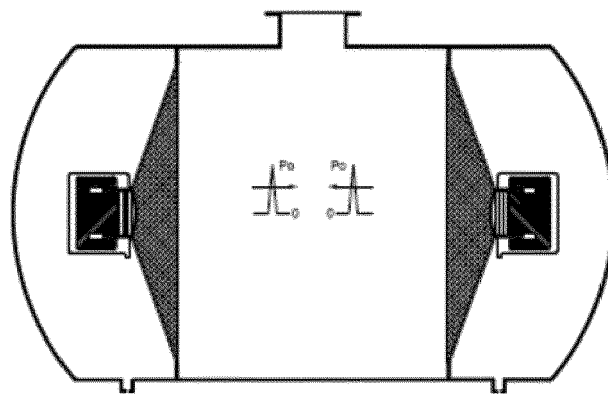


FIG. 5B

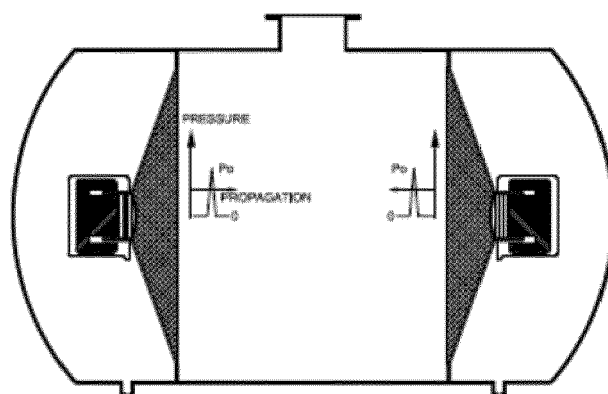
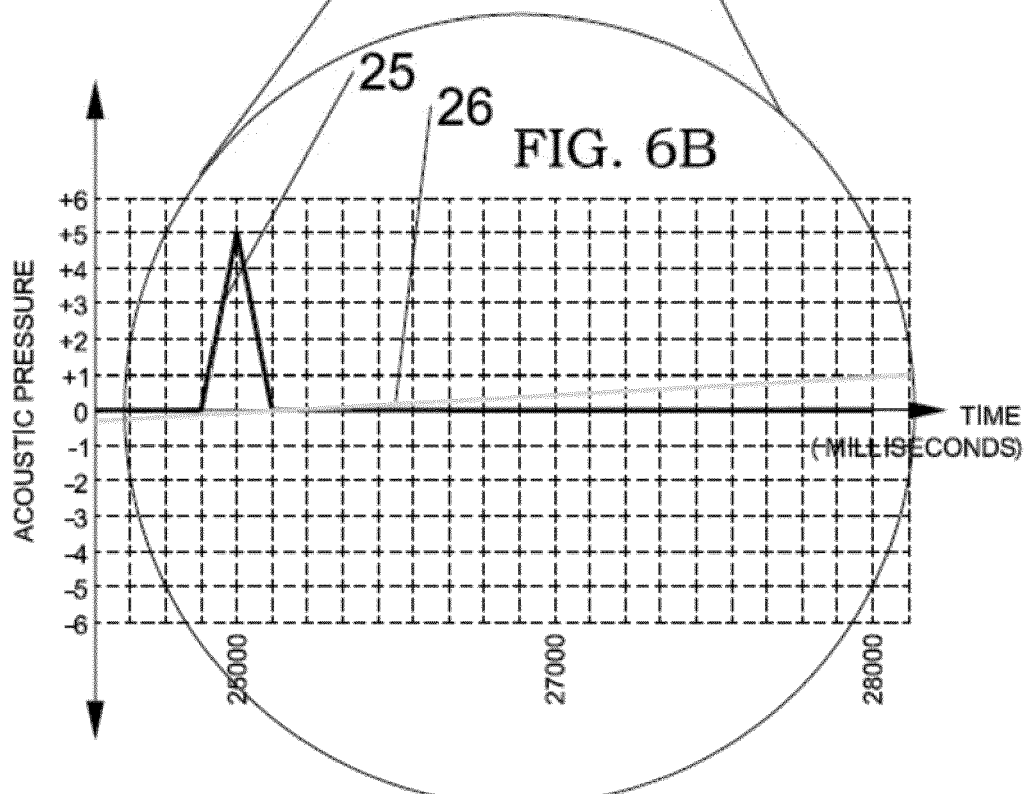
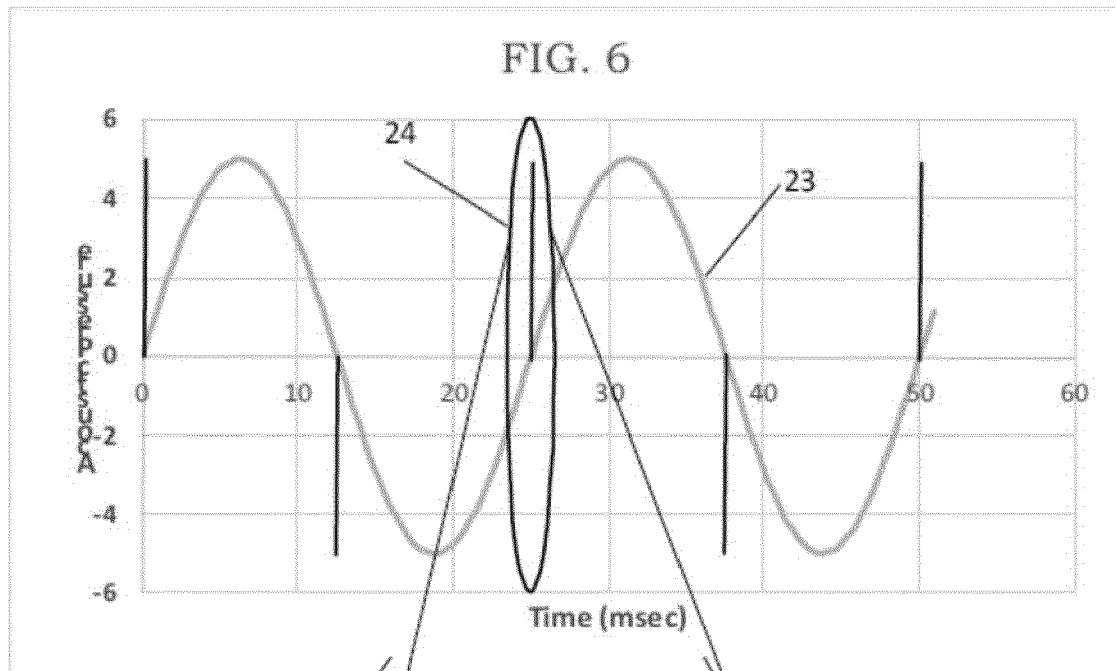


FIG. 5A





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Application Number
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Y	* paragraph [0002] - paragraph [0005] *	2,3	
A	* paragraph [0014] - paragraph [0023] *	4-7	
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	* paragraph [0040] *		
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A	* page 2, line 8 - line 10 *	11-14	
	* page 3, line 18 - line 25 *		
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	* page 7, line 7 - line 16 *		
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**ANNEX TO THE EUROPEAN SEARCH REPORT
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