Jan. 1, 1957 W. B. CONOVER ET AL 2,776,020

NOISE REDUCING SYSTEM FOR TRANSFORMERS

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Fig. 1.

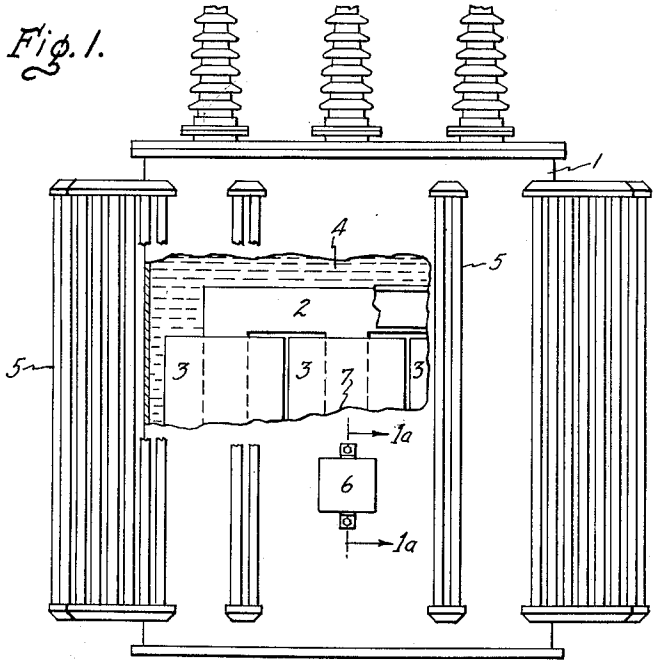
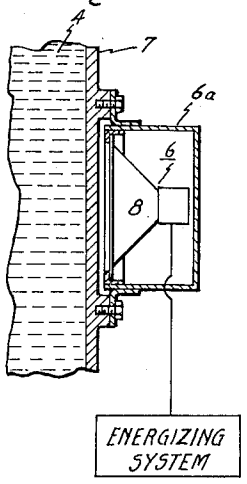



Fig. 1a.



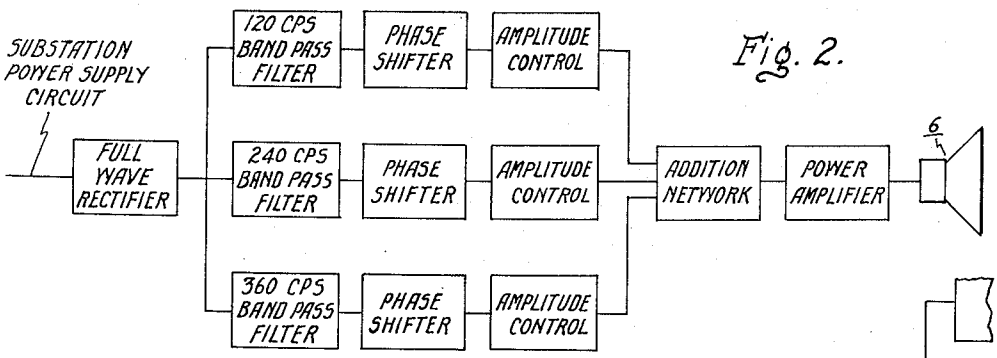




Fig. 2.

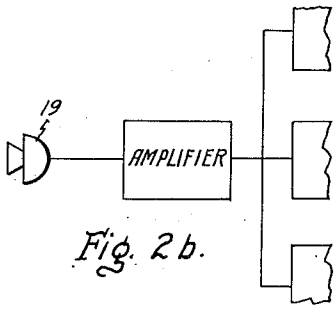



Fig. 2b.

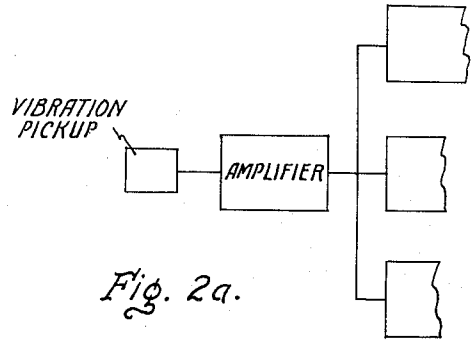



Fig. 2a.

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Fig. 3.

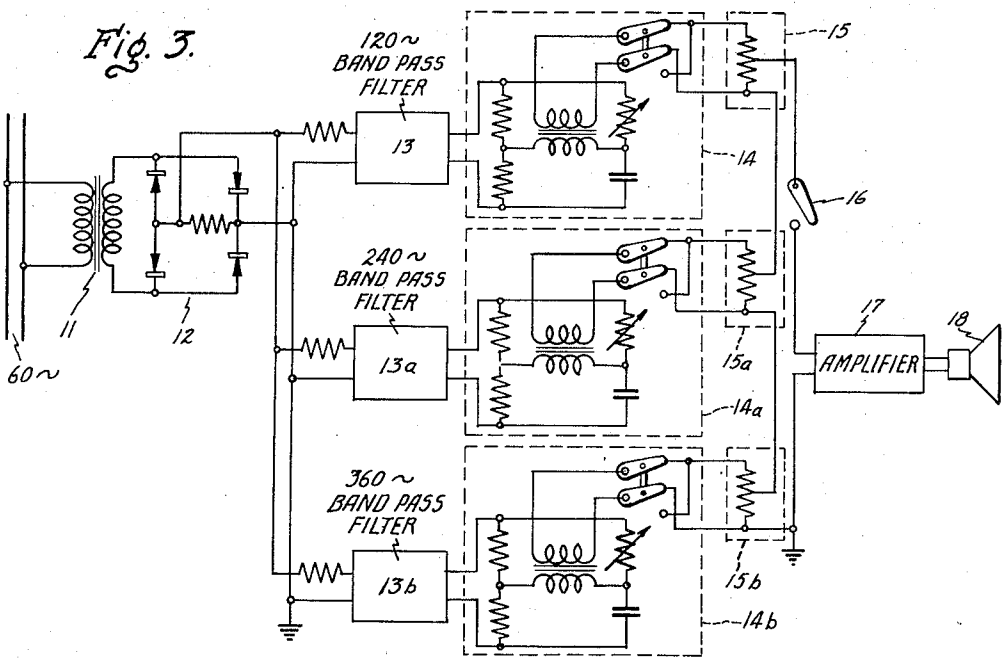
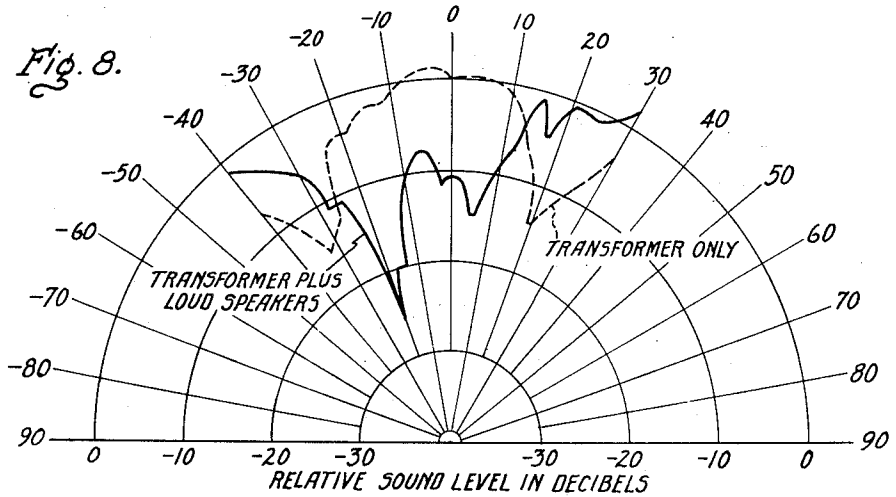



Fig. 8.



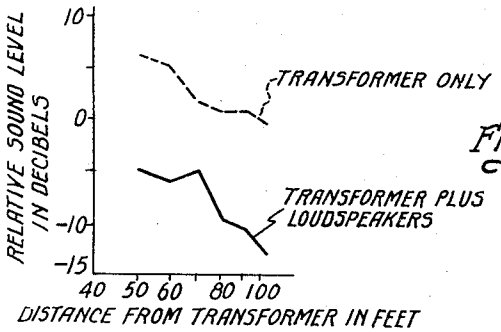




Fig. 9

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Fig. 4.

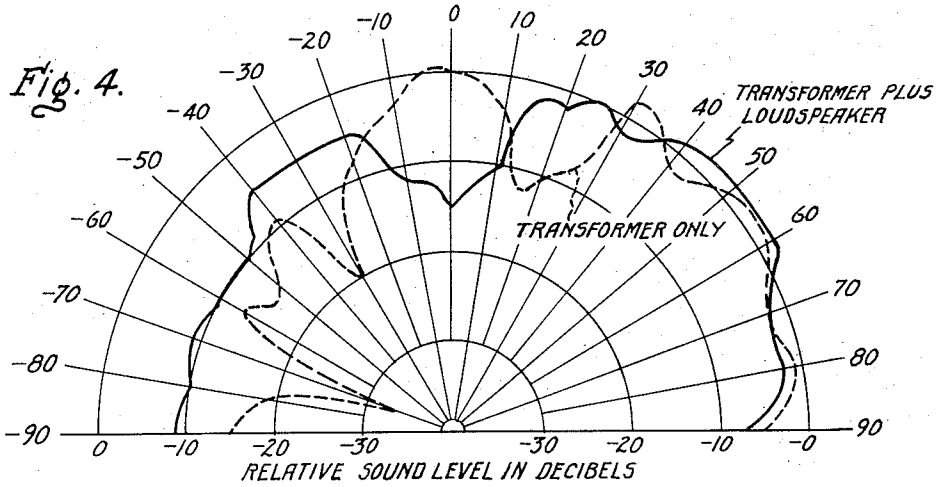



Fig. 6.

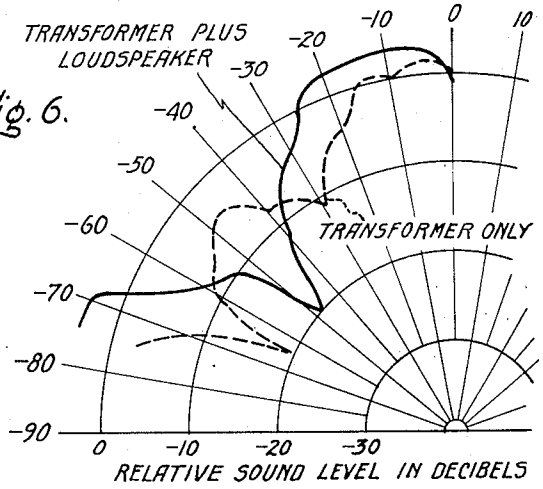



Fig. 5.

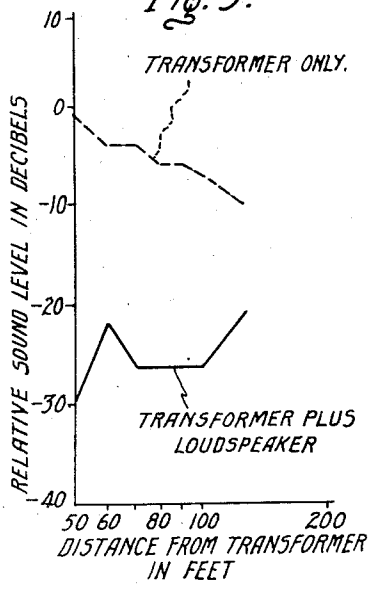
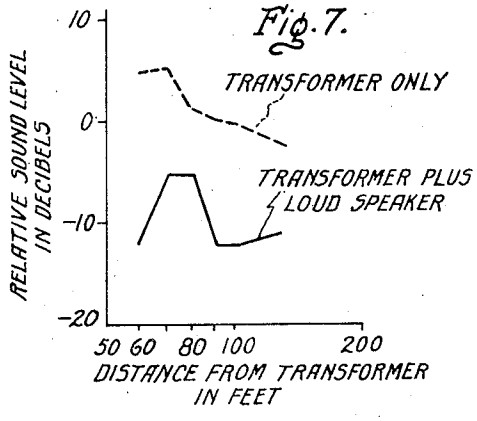



Fig. 7.

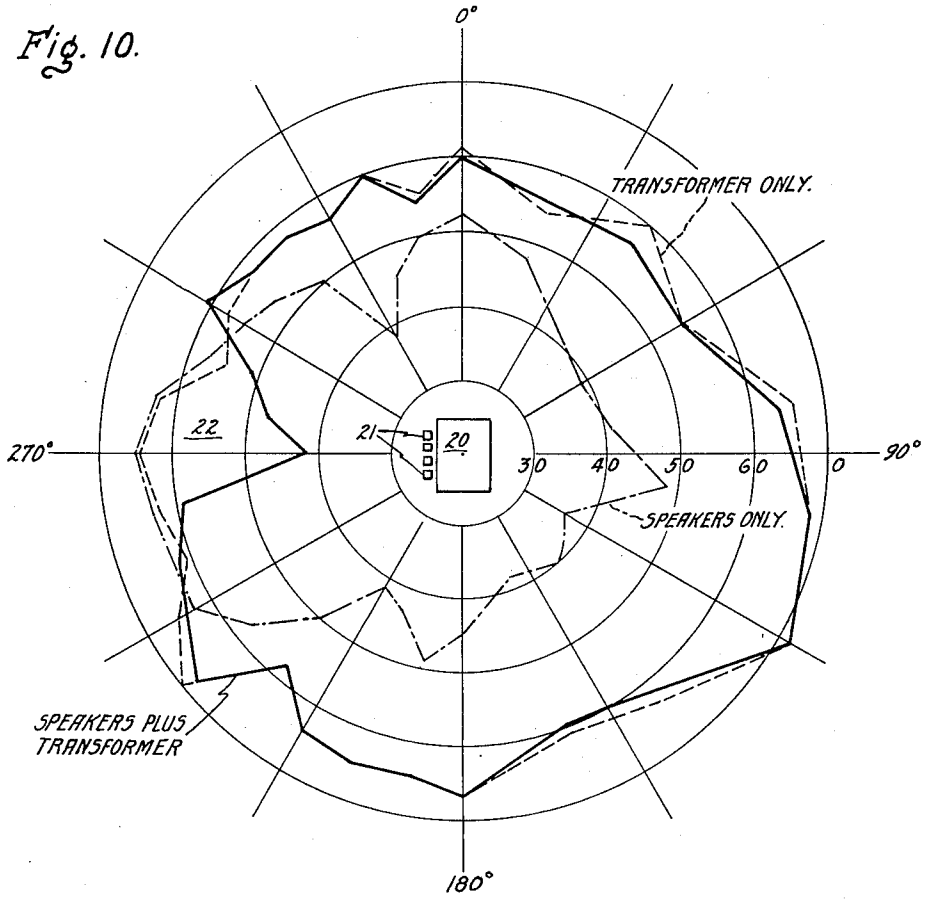



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NOISE REDUCING SYSTEM FOR TRANSFORMERS

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Fig. 10.




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United States Patent Office 2,776,020 Patented Jan. 1, 1957



2,776,020

# NOISE REDUCING SYSTEM FOR TRANSFORMERS

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Application February 9, 1955, Serial No. 487,628

14 Claims. (Cl. 181—31)

The present invention relates to the control of noise, and more particularly concerns a sound cancellation system and method for controlling and reducing the noise emanating from electrical induction apparatus such as transformers and the like.

The audible noise produced by transformers and the complaints arising therefrom have become a major problem as a result of the trend toward locating power substations in or near residental areas. For this reason, the noise level of transformers has become of primary importance in the design, installation and operation of such apparatus, and various attempts have been made in the past to overcome the noise problem. One method suggested has been to design transformers to operate at low flux density, in order to reduce the magnetostrictive effects causing noise at high levels of induction. Another approach involved the provision of double walls on the transformer tank, or, to produce a similar effect, enclosing the transformer in a surrounding masonry wall or housing of suitable construction. A further expedient provided for sound absorbent barriers inside the transformer tank. However, these and other proposed noise reducing measures have generally proved expensive, impractical or inadequate.

It is an object, therefore, of the present invention to provide an effective sound reduction system, especially in combination with electrical induction apparatus such as transformers, for reducing noise emanating therefrom and which overcomes the above-mentioned disadvantages.

It is another object of the invention to provide a sound reducing system and method for substantially eliminating transformer noise at least in a particular area remote from the transformer.

A further object of the invention is the provision of a sound reducing system and method by means of which the direction, size and angular position of the sound cancelled zone relative to the sound producing apparatus may be readily varied.

In its broad aspects, the present invention relates to a system for effectively cancelling in a predetermined zone remote from a primary source of sound the sound produced thereby, the primary source of sound having a comparatively large vibratory surface which propagates a sound wave of given frequency, shape and amplitude, the present system comprising in combination at least one constant velocity variable volume auxiliary source of sound having a comparatively small vibratory surface located closely adjacent the large vibratory surface, and means for driving the small vibratory surface of the auxiliary source of sound so that when considered by itself is produces at least in the predetermined remote zone a sound wave of essentially the same frequency, shape and amplitude as, but substantially in phase opposition to the first-mentioned sound wave in said zone when said auxiliary source is not operating. While the exact mechanism of the effective sound cancellation or sound reduction is not fully understood there is evidence that in addition to interference between sound waves,



the primary and auxiliary sounds also interact on each other through a proximity effect which reduces their total sound energy output.

In preferred embodiments of the invention, the auxiliary source of sound is constituted by a loud speaker which has a diaphragm serving as the small vibratory surface and which is enclosed on one side by a baffle so that only the other side of the diaphragm is in direct contact with the air surrounding the primary source of sound. The loud speaker may be energized by any suitable driving mechanism to produce a sound wave of desired characteristics relative to the sound wave propagated by the large vibratory surface. Such an auxiliary source is an example of a constant velocity variable volume source of sound. In accordance with the invention, the driving means is preferably an energizing system which provides for the control and adjustment of the frequency, phase, and amplitude of the energy driving the loud speaker. By suitable adjustment of the phase and amplitude of the energizing system not only is an effective cancellation of sound in a remote zone achieved but also the angular position of the sound cancelled zone may be varied as desired.

The invention will be better understood from the following description taken in conjunction with the accompanying drawings in which:

Fig. 1 is a perspective view partly in section of a transformer arrangement including a loud speaker mounted on the transformer tank wall in accordance with an embodiment of the present invention;

Fig. 1*a* is an enlarged sectional view of the loud speaker arrangement taken along the line 1*a*—1*a* in Fig. 1;

Fig. 2 is a block diagram of a form of loud speaker energizing system which may be utilized in the present sound cancellation system;

Fig. 2*a* shows a different embodiment of the energizing system shown in Fig. 2;

Fig. 2*b* shows still another form of the Fig. 2 energizing system;

Fig. 3 is a circuit diagram of a specific form of energizing system of the type shown in Fig. 2*a*;

Fig. 4 is a graphical showing of results obtained with adjustment of the sound cancellation system to produce optimum sound cancellation in a zone in a given direction with respect to the transformer;

Fig. 5 graphically illustrates the reduction of sound at varying distances from the transformer in the direction of sound cancellation zone as represented by Fig. 4;

Fig. 6 is a graphical showing similar to Fig. 4 but with the sound cancellation zone shifted in angular position;

Fig. 7 shows the results obtained at varying distances from the transformer with the sound cancellation zone in the angular position shown in Fig. 6;

Fig. 8 shows results obatnied with the use of two loud speakers;

Fig. 9 illustrates the sound reduction at varying distance from the transformer with the arrangement represented by Fig. 8; and

Fig. 10 graphically illustrates the results of another arrangement which clearly shows reduction in total sound energy output.

Referring now to the drawings, and particularly to Fig. 1, there is graphically shown a power transformer of known type comprising tank 1 containing a core 2, coils 3, and insulating and cooling liquid 4. The transformer shown is also equipped with radiator tubes 5 attached to tank 1 and through which the liquid 4 may pass for cooling. The alternating magnetization of the transformer core 2 during normal operation of the transformer gives rise to magnetostriction effects in the core material which cause vibration of the core surfaces. These vibrations are communicated to the surrounding liquid 4 and travel

as sound waves through it to the walls of the transformer tank 1, which in turn are caused to vibrate and send out sound waves in the surrounding air. The core vibrations may also be transmitted to the tank walls by the core mountings. The result is an unpleasant hum which is frequently sufficiently loud to be objectionable in certain locations such as residential communities in or near which the transformer is located.

In accordance with a preferred embodiment of the present noise control system, a loud speaker 6 is mounted by any suitable means preferably on a wall 7 of the transformer tank which faces the area in which it is desired to reduce the transformer noise. As more clearly shown in Fig. 1*a*, the diaphragm 8 of loud speaker 6 is mounted in an enclosed baffle 6*a* (or closed-back cabinet) in such manner that only the front surface of the diaphragm is directly exposed to the air. This construction is necessary to avoid rendering the loud speaker ineffective due to the sound pressure produced at one surface of the diaphragm being drawn into and nullified by the vacuum simultaneously produced at the opposite surface of the diaphragm in the absence of such an enclosure. The loud speaker 6 is energized by the energizing system shown diagrammatically, and more fully described below.

It has been found that by suitably energizing loud speaker 6 at the frequency of the noise produced by the transformer and by properly adjusting the phase and amplitude of the energy supplied to the loud speaker, an astonishing degree of noise reduction can be achieved in a desired area remote from the transformer. It has further been found that more than one such auxiliary source of sound similarly arranged adjacent the transformer and energized will produce even more improved results in noise cancellation, as pointed out below.

Various means may be used for energizing the loud speaker 6 to give the correct phase and amplitude of the diaphragm motion. Fig. 2 shows in block diagram one type of energizing system which may be used, in which a rectifier is incorporated. As shown in the diagram, the rectifier, which may be connected to the transformer substation power supply circuit, provides an electrical signal comprising the same fundamental and harmonic frequencies as the fundamental and harmonic frequencies of the noise produced by the transformer and transmits it to a system of three frequency channels of 120 cycles and harmonics thereof selectively passed by suitable band-pass filters. In this connection, it is to be understood that the expression "non-sinusoidal shape" as recited in the claims is intended to refer to the wave characteristic of a fundamental frequency having superimposed harmonic frequencies. Each frequency channel is provided with a manually adjustable phase shifter and amplitude control. The properly adjusted and controlled component voltages are then recombined in an addition network, suitably amplified and then transmitted for energizing the loud speaker 6 which is located closely adjacent the noise source, i. e., the transformer.

Fig. 3 is a circuit diagram of a specific form of the Fig. 2 energizing system incorporating a rectifier, which may be used in accordance with the invention for driving the loud speaker. As shown in Fig. 3, a source of fundamental frequency and higher harmonics is provided by a bridge rectifier 12, comprising, for example, selenium rectifiers, which is arranged on the output side of a suitable transformer 11, the primary of which is connected to a 115-volt alternating current power source by plugging into a convenient outlet or by other suitable means. The voltage output from the rectifier 12 is applied to the inputs of parallel band pass filters 13, 13*a*, and 13*b* which selectively pass the desired frequencies corresponding to the fundamental and major higher harmonic frequencies of the transformer wave. Phase shifting networks 14, 14*a* and 14*b* of typical construction as shown are connected to the outputs of the band pass filters of the respective frequency channels for manual adjustment of the phase angle of the current passing through each channel, while potentiometers 15, 15*a*, and 15*b* serve for adjustment of the amplitude of the respective voltage outputs of the phase shifting networks. The voltages are then combined in series connection for transmission via amplifier 17 to loud speaker 18 which may be a 12-inch type in a closed back cabinet, a switch 16 being provided for turning the loud speaker energy supply on and off.

Fig. 2*a* shows a different embodiment of the loud speaker energizing arrangement in which a vibration pickup device including an amplifier is employed in place of the rectifier of Figs. 2 and 3, the vibration pickup being fastened, for example, directly to the transformer tank wall, radiator tubes or other part of the transformer to provide a source for energizing the loud speaker.

Fig. 2*b* shows still another form of energizing system which incorporates a microphone 19 which may be attached to the transformer tank to pick up the actual sound of the sound source. The energy from the microphone can be suitably amplified as shown, if necessary. In this embodiment, a feed-back arrangement involving the microphone and loud speaker is to be avoided, in order to obviate the howling effect produced by such an arrangement. It is desirable, therefore, to acoustically isolate the microphone from the loud speaker to prevent such feed-back, and in practice it has been found that to avoid undesirable feed-back effects the microphone should not be located in the vicinity of the loud speaker.

In field tests conducted on an actual transformer installation, a 12 inch loud speaker, direct radiator type, mounted in an enclosure of ¾ inch plywood was mounted on the tank wall of a 15,000 kva. transformer located in an open field. To provide a source of vibration synchronized with the sound output of the transformer, a vibration pickup of known type was taped to one of the cooling radiator tubes of the transformer. The output of the vibration pickup was amplified by means of a vibration meter device of known commercial type and applied to a three-channel filter and phase shifter circuit of the type shown in Fig. 2 which isolated the 120-(fundamental), 240-, and 360-cycle components of the vibration pickup output from each other and permitted adjustments in the magnitude and phase angle of each. It was found that the only significant component of noise in the 15,000 kva. transformer was the fundamental 120-cycle tone, so that the amplitude controls for the 240 and 360-cycle channels of the filter phase shifter circuit were set to zero.

After noise reduction tests were carried out by the vibration meter pickup, the latter was replaced with a selenium rectifier of the type shown in Fig. 3 on the output side of a filament transformer whose primary was plugged into a 110-volt convenience outlet connected to the source of supply for the transformer. This provided a source of 120-cycle frequency and harmonics thereof which worked as satisfactorily as the vibration pickup device and was considerably less expensive and more compact.

In making the initial sound tests the microphone of a sound level meter was located at a distance of 100 feet from the face of the transformer tank adjacent the loud speaker and substantially on a radial axis extending through the loud speaker and perpendicular to the face of the transformer tank. A sound analyzer was also located at this point in the field and it was tuned to the 120 cycle frequency with its gain control set to give a zero decibel reading.

After the sound cancellation equipment was energized, the magnitude and phase angle of its excitation was adjusted to give a minimum reading on the sound analyzer. The audible effect of the noise cancellation thus produced was considerable and surprising, the noise from the transformer being substantially eliminated in the test area. Once the adjustment had been made, the transformer noise could be turned off and on at will, merely by

switching the loud speaker on and off. At the same adjustment, several sound level readings were taken at different microphone positions with the speaker off and on. The results obtained are shown graphically in Figs. 4 and 5.

Fig. 4 shows the sound levels found with the loud speaker system adjusted for maximum cancellations of the 120-C. P. S. component only in an area adjacent the zero degree axis about 100 feet distance from the transformer, the loud speaker being mounted on the tank wall about 6 feet high, ½ inch away, and facing the approximate center of the tank. Fig. 5 shows the sound levels plotted against the distance along the zero degree axis obtained with the same arrangement of the loud speaker but with the adjustment made for optimum cancellation at 50 feet. It will be noted from the graph of Fig. 4 that a beam of sound reduction of at least 6 db was produced which had a width of about 23°. It is clear from Fig. 5 that substantial reduction in transformer noise was obtained with one adjustment along the distance of 50–125 feet tested. In general, it was found that the zone of sound reduction increased in width or diameter along a radial line extending from the transformer.

It was also unexpectedly found that the beam of sound reduction could be aimed merely by suitable adjustment of the phase and amplitude of the loud speaker excitation. The results shown in Fig. 6 were obtained with the adjustment for maximum cancellation in an area at −45° relative to the arbitrary zero axis and at a 100 foot radius, the loud speaker being arranged as previously described in connection with Fig. 4. As indicated in the graph, a substantial reduction of sound was likewise obtained in this manner in the new location. Fig. 7 shows the results obtained with the Fig. 6 arrangement along a distance from 60 to 125 feet in a direction −45° from the zero degree axis.

It was found, further, that improved results in terms of greater width of the sound reduction beam could be obtained by two loud speakers operating in parallel from the same source. In a test arrangement producing marked improvement in this respect, two speakers were mounted about 80 inches apart on the transformer tank wall, facing the wall about ½ inch away and adjusted for maximum cancellation at 100 feet along the zero degree axis. Fig. 8 shows the results obtained by this arrangement, and it is apparent from the figure the beam width produced was about 35°, which constituted a substantial improvement over the results obtained with a single speaker.

Fig. 9 illustrates the results of a two speaker arrangement obtained over a distance of 50–100 feet, the two loud speakers being mounted 52 inches apart 6 feet high on the tank wall and facing the wall ½" away and with the adjustment made for maximum cancellation at 100 feet along the zero degree axis.

While Figs. 5, 7 and 9 show that the present sound cancellation system was effective over a distance of about 50 to 125 feet, further tests made at distances up to 500 feet indicated that the sound reduction along a radial line originating at the transformer was never less than 6 db.

The results obtained in the above described tests were measurements based on the 120-cycle component of noise only, since in the 15,000 kva. transformer used this was substantially greater than the other harmonics. However, it was found in a listening test that when the 360-cycle harmonic was also cancelled, the improvement was even more marked. This was true even though the 360-cycle tone was 15 db below the level of the 120-cycle tone before cancellation was applied.

The principles underlying the reduction of transformer noise by the present invention have not as yet been clearly established. In part, they appear to involve the interference, at least in the area of sound reduction remote from the transformer, between the sound waves produced by the transformer as the primary sound source and by the loud speaker as the auxiliary sound source. The principal source of noise from the transformer is undoubtedly the magnetostriction effect produced in the transformer core, as hereinbefore described, the vibrations being transmitted to the transformer tank wall. If the tank wall could be considered a point source of sound, it would seem in theory that the arrangement of the loud speaker as close as possible to the wall and energizing the loud speaker to produce sound waves of the same frequency, amplitude and shape as, but in phase opposition to, the sound waves produced by the transformer tank wall would substantially eliminate by interference effects all noise emanating from the transformer, and produce quiet even close to the apparatus. As a practical matter, however, the tank wall does not behave as a point source of sound, and due to this as well as other factors, such as the presence of sound reflecting surfaces in the vicinity, wind effects, temperature variations and the like, sound cancellation could not be achieved in all areas surrounding the transformer. In fact, in certain areas outside the sound cancellation zone obtained in field tests by the present system the noise was actually increased (as shown by Figs. 4, 6, and 8), presumably due to reinforcement effects between the sound waves produced by the transformer and loud speaker, and this effect was frequently observed, for example, in the area in the immediate vicinity of the transformer which lay directly between the remote zone of effective sound cancellation and the transformer. For similar reasons, it has not been found possible to determine accurately beforehand the particular arrangement of the loud speaker relative to a given transformer installation, or the particular phase and amplitude adjustment of the energy supply driving the loud speaker, to obtain the optimum reduction of noise in the desired area remote from the transformer. It has been found, however, that for any given set of conditions it is necessary only to energize the loud speaker at the noise-producing frequency and to suitably adjust the phase and amplitude of the loud speaker excitation to produce effective noise cancellation in the desired area. It appears that by such adjustment the sound waves from the respective sound sources, i. e., the loud speaker and the transformer wall, can be made to interfere with each other to a substantial degree in (at least) the remote zone where reduction of sound is desired.

While placing the loud speaker as close as possible to the transformer tank wall did not in practice always produce substantial noise reduction in the immediate vicinity of the transformer under conditions where a remote zone of silence could be obtained at a desired point, it did appear that the closer to the tank the loud speaker was mounted, the larger was the zone of silence produced. This phenomenon may possibly be explained on the basis (1) that the rate of drop in amplitude of the sound waves produced by the two sound sources along their coincident paths would be more nearly alike the closer the two sources were to each other, to thereby produce more effective interference over a longer distance, and (2) the shape of the respective wave fronts would be more nearly alike, i. e., the radii of curvatures of the wave fronts would be nearly uniform over an area beginning nearer the sources if the latter were close together, thus producing an interference (silent) zone of greater angle in azimuth.

In certain cases it has been found that locations of the loud speaker other than on the tank wall would give optimum results. For example, in a test involving a transformer installation surrounded by a masonry wall, it was found that mounting the loud speaker on the top of the wall at a corner thereof nearest the desired zone of sound cancellation gave best results in sound reduction

in the intended area. In this case, apparently the sound produced by the transformer which caused objectionable noise in the particular remote zone concentrated at the top of the masonry wall and served, in effect as a sound source, so that arrangement of the loud speaker at that point was tantamount to mounting the loud speaker on the transformer tank wall under the usual conditions where no surrounding barrier was present.

As indicated, the tests described above were conducted in the field in connection with full-sized transformers. In order to obtain sound reduction data in a more ideal environment and to avoid ambient noise, weather variations and other factors which might affect the results obtained, tests were made on a scale model 125,000 kva. transformer (1/4 normal size) in a large sound-proof anechoic chamber. In these tests an array of four 2 inch loud speakers were located adjacent the transformer, and cancellation tests were made at the fundamental (840 C. P. S.) and second harmonic (1680 C. P. S.) frequencies of the model transformer noise. The results of a typical test made under these conditions are shown in Fig. 10, which shows the relative arrangement of the transformer 20 and loud speaker array 21.

As shown in the Fig. 10 graph, while the sound cancellation was effective throughout a beam width of about 26° as indicated by zone 22 along the 270° axis, it left the noise level practically unchanged in areas outside the cancellation zone. It seems apparent, consequently, that a phenomenon may be involved which is not in all respects the same as the interference phenomenon already discussed, since the total sound energy produced by both sound sources seems to be reduced, in view of the Fig. 10 results. The principle involved in producing the latter effect may perhaps be explained by considering at least a portion of the vibrating transformer wall as the primary noise generating surface which it is desired to neutralize and the loud speaker as an acoustic compensating device for neutralizing the primary sound source. The size of the compensating device and its distance from the primary noise generating surface which it is desired to neutralize must both be small compared with the wave length of the frequency of sound involved, i. e., under 1/6 wave length. The compensating device changes in volume at the frequency of the sound involved. A non-baffled or simple moving diaphragm does not accomplish the desired purpose. When the primary noise generating surface moves outward against the air the compensating device contracts in volume and provides a place for the air displaced by the primary noise generating surface to go, so that the amount of force that must be applied by the primary surface to the air is reduced and the amount of energy transferred from the primary surface to the air is reduced by virtue of the presence of the compensating device. Since less energy is transferred from the primary surface to the air, less energy is transmitted through the air away from the primary surface and the objective of neutralizing, to a degree, the noise radiated by the primary source is accomplished.

Since this arrangement consists in part of what may be called acoustic interference it is important to note that more than acoustic interference is required to produce the desired result. If two systems of plane acoustic waves tend to cause continuously opposing space displacement of the air at a given point, the opposing tendencies cancel each other and the air at the point does not move. This constitutes interference at the given point, and at any other point where the two systems of waves are in the necessary phase relationship. In other locations the phase relationship is such that the effects are additive instead of subtractive. Over a volume of many wave lengths in each dimension the amount of addition approaches equality with the amount of subtraction and the average density of energy flow is not changed.

The compensating mechanism described reduces the total acoustic energy in the sound field by permitting the primary noise generating surface to move without transferring significant amounts of energy to the adjacent air, and in order to accomplish this purpose it is necessary to go beyond a process which might be interpreted as acoustic interference. It is reasonable to consider that the compensating procedure described constitutes a special way of obtaining interference which results in decreased total energy as opposed to the customary concept which comprises decreased energy levels at certain spots and increased energy levels at other spots.

Numerous tests of the type described above have led to the formulation of a sound cancellation procedure in accordance with the invention which has given satisfactory results in most cases. The technique which has been evolved is as follows:

With the loud speaker placed as close to the transformer as possible, the amplitude controls of all frequency channels in the loud speaker energizing equipment should be turned to zero. The sound analyzer is set to 120 C. P. S. and with the phase control of the 120 C. P. S. channel set at an arbitrary point, the amplitude control on the 120 C. P. S. channel is increased. The gain is increased until the 120 C. P. S. noise has either begun to diminish or has increased approximately 3–4 db. The gain control is allowed to remain at this setting and the 120 C. P. S. phase control is is adjusted until a minimum in 120 C. P. S. sound is reached. This alternating adjustment is continued until a reduction of 15–20 db is reached. After the 120 C. P. S. sound is thus reduced, the process is repeated for the 240 C. P. S., 360 C. P. S. and higher frequency sounds. If sound tests show that the silent zone is not sufficiently wide or deep to cover disturbing transformer noise over the entire region desired, one or more additional loud speakers may be provided in an array, as already described, to cover the area desired.

While particular types of transformer, loud speaker and relative arrangements thereof have been described and shown, it is to be understood that sound cancellation constructions and procedures may be used which differ from those described. For example, the transformer may be a gas-filled type, and the loud speaker may be suitably arranged within the transformer whether of the liquid or gas-filled type. Further, the loud speaker or loud speakers may be located at any suitable position or in desired arrangement on or near the tank wall or other portion of the transformer structure depending on optimum sound reduction results obtained. Tests have been carried out both with the loud speaker diaphragm facing toward the tank and away from the tank, and each position has been found to produce improved results under different conditions. Moreover, auxiliary sound sources other than loud speakers may be used, and it is contemplated that any vibrating surface which can be controlled in frequency, phase and amplitude may be employed.

It will be understood, therefore, that numerous modifications may be made by those skilled in the art without actually departing from the scope of the invention. Accordingly, the appended claims are intended to cover all such equivalent variations as come within the true spirit and scope of the foregoing disclosure.

What we claim as new and desire to secure by Letters Patent of the United States is:

1. A system for effectively cancelling in a predetermined zone remote from a primary source of sound the sound produced thereby, said primary source of sound having a comparatively large vibratory surface which propagates a sound wave of given frequency, shape, and amplitude, comprising, in combination, at least one auxiliary source of sound having a comparatively small vibratory surface located closely adjacent said large vibratory surface, and means for driving said small vibratory surface of said auxiliary source of sound so that it produces at least in said predetermined remote zone a sound wave of essentially the same frequency, shape and amplitude as, but substantially in phase opposition to,

said first mentioned wave, so that said waves are substantially in interference with each other in said predetermined remote zone.

2. A system for effectively cancelling in a zone remote and in a given direction from an electrical induction apparatus the sound produced thereby, said apparatus having a comparatively large vibratory surface which propagates a sound wave of given frequency, shape and amplitude, comprising in combination, at least one auxiliary source of sound having a comparatively small vibratory surface located closely adjacent said large vibratory surface of said electrical induction apparatus, and means for driving said small vibratory surface of said auxiliary source of sound so that it propagates in said given direction a sound wave of the same frequency, shape and amplitude as, but substantially in phase opposition to, said first-mentioned wave so that said waves are substantially in interference with each other in said remote zone.

3. A sound cancellation system comprising, in combination, a constant velocity variable volume primary source of sound whose sound is to be minimized in a predetermined zone spaced from said primary source by a distance equal to many times the maximum dimension of said primary source, said primary source propagating in the direction of said zone a sound wave of given frequency, shape and amplitude, an auxiliary constant velocity variable volume source of sound having a maximum dimension many times smaller than the maximum dimension of said primary source and located no more than a small portion of the length of said sound wave from said primary source, and means for driving said auxiliary source of sound so that it produces at least in said predetermined zone a sound wave of essentially the same frequency, shape and amplitude as, but substantially in phase opposition to, said first-mentioned wave so that said waves are substantially in interference with each other in said predetermined zone and said sources interact on each other through a proximate effect which reduces their combined total sound energy output.

4. A system for effectively cancelling in a predetermined zone remote from a primary source of sound the sound produced thereby, said primary source having a comparatively large vibratory surface which propagates a sound wave of given frequency, shape and amplitude, comprising, in combination, a plurality of auxiliary sources of sound each having a comparatively small vibratory surface located closely adjacent said large vibratory surface, and means for driving the small vibratory surface of each auxiliary source of sound so that said auxiliary sound sources produce at least in said remote zone sound waves of the same frequency, shape and amplitude as, but substantially in phase opposition to, said first-mentioned wave so that said first and said second-mentioned waves are substantially in interference with each other in said remote zone.

5. A system for effectively cancelling in a predetermined zone remote from an electrical induction apparatus the sound produced thereby, said apparatus having a comparatively large vibratory surface which propagates a sound wave of given frequency, shape and amplitude, comprising, in combination, at least one auxiliary source of sound having a comparatively small vibratory surface located closely adjacent said large vibratory surface, means for energizing said auxiliary source of sound to drive said small vibratory surface thereof, and means for controlling the frequency, phase and amplitude of the vibration of said small vibratory surface of said auxiliary source of sound so that it produces at least in said remote zone a sound wave of the same frequency, shape and amplitude as, but substantially in phase opposition to, said first-mentioned wave so that said waves are substantially in interference with each other in said remote zone.

6. A system for effectively cancelling in a predetermined zone remote from an electrical induction apparatus the sound produced thereby, said apparatus having a vibratory surface which propagates a sound wave of given frequency, shape and amplitude, comprising, in combination, at least one auxiliary source of sound comprising a loud speaker having a diaphragm enclosed on one surface thereof and located closely adjacent said vibratory surface of said apparatus, means for energizing said loud speaker to drive said diaphragm thereof, and means associated with said energizing means for controlling the frequency, phase and amplitude of the vibration of said diaphragm so that it produces at least in said remote zone a sound wave of the same frequency, shape and amplitude as, but substantially in phase opposition to, said first-mentioned wave so that said waves are substantially in interference with each other in said remote zone.

7. A system as defined in claim 6, wherein said energizing means comprises a vibration pickup device associated with said electrical induction apparatus.

8. A system as defined in claim 6, wherein said energizing means comprises a microphone associated with said electrical induction apparatus and arranged remote from said diaphragm of said loud speaker.

9. A noise-controlled electrical apparatus providing sound cancellation in a predetermined zone remote therefrom, comprising, in combination, a source of alternating electric current; an electrical induction apparatus energized at a given frequency by said alternating current source and having a comparatively large vibratory surface which propagates a sound wave of given frequency, shape and amplitude; at least one auxiliary source of sound comprising a loud speaker having a diaphragm enclosed on one surface thereof and located closely adjacent said large vibratory surface of said induction apparatus; means comprising a full-wave rectifier connected to said alternating current source for energizing said loud speaker to drive said diaphragm thereof; and means associated with said energizing means for controlling the frequency, phase and amplitude of the vibration of said diaphragm so that it produces at least in said predetermined remote zone a sound wave of the same frequency, shape and amplitude as, but substantially in phase opposition to, said first-mentioned wave so that said waves are substantially in intereference with each other in said remote zone.

10. A system for effectively cancelling in a predetermined zone remote from a primary source of sound the sound produced thereby, said primary source of sound having a comparatively large vibratory surface which propagates a sound wave of given frequency, shape and amplitude, comprising, in combination, at least one auxiliary source of sound having a comparatively small vibratory surface located closely adjacent said large vibratory surface, and means for driving said small vibratory surface of said auxiliary source of sound so that it produces at least in said predetermined remote zone a sound wave of the same frequency, shape and amplitude as, but substantially in phase opposition to, said first-mentioned wave so that said waves are substantially in interference with each other in said predetermined remote zone, said driving means being operable for varying the angular position of said predetermined remote zone relative to said primary source of sound.

11. A system for effectively cancelling in a predetermined zone remote from an electrical induction apparatus the sound produced thereby, said apparatus having a comparatively large vibratory surface which propagates a sound wave of given frequency, shape and amplitude, comprising, in combination, at least one auxiliary source of sound having a comparatively small vibratory surface located closely adjacent said large vibratory surface, means for energizing said auxiliary source of sound to drive said small vibratory surface thereof, and means for controlling the frequency, phase and amplitude of the vibration of said small vibratory surface of said auxiliary source of sound so that it produces at least in said remote zone a sound wave of the same frequency, shape and amplitude as, but substantially in phase opposition

to, said first-mentioned wave so that said waves are substantially in interference with each other in said remote zone, said controlling means being operable to vary the angular position of said remote zone of cancelled sound relative to said electrical induction apparatus.

12. A system for effectively cancelling in a predetermined zone remote from a transformer the noise emanating therefrom during its operation, said transformer having a large vibratory surface producing a sound wave of given frequency, phase and amplitude, comprising, in combination, at least one loud speaker means mounted closely adjacent said transformer and having a baffled diaphragm only one side of which is in direct contact with the air surrounding said transformer and being a small fraction of the size of said large vibratory surface, energizing means connected to said loud speaker means for driving the same at the frequency and harmonics thereof at which said vibratory surface of said transformer vibrates, filter means for selectively transmitting to said loud speaker said frequency and harmonics thereof, and control means associated with said filter means and said loud speaker means for controlling the phase and amplitude of the vibration of said diaphragm of said loud speaker means at each of said frequency and harmonics thereof, said control means being operable for producing from said baffled diaphragm at least in said predetermined remote zone a sound wave of the same frequency, shape and amplitude as, but substantially in phase opposition to, said first-mentioned wave so that said waves are substantially in interference with each other in said remote zone.

13. A noise-controlled transformer arrangement providing sound cancellation in a predetermined zone remote therefrom, comprising, in combination, a transformer having a large vibratory surface which propagates in said remote zone a sound wave of given frequency, shape and amplitude, at least one loud speaker mounted adjacent said large vibratory surface of said transformer and having a baffled diaphragm of an area small compared to said large vibratory surface, and means for driving said diaphragm of said loud speaker so that it produces at least in said remote zone a sound wave of the same frequency, shape and amplitude as, but substantially in phase opposition to, said first-mentioned wave so that said waves are substantially in interference with each other in said remote zone.

14. A noise-controlled transformer arrangement providing sound cancellation in a predetermined zone remote therefrom, comprising, in combination, a transformer having a large vibratory surface driven at approximately 120 cycles per second which propagates in said remote zone, a sound wave of given frequency, shape and amplitude, at least one loud speaker mounted adjacent said large vibratory surface of said transformer and having a baffled diaphragm of an area small compared to said large vibratory surface, and means for driving said baffled diaphragm of said loud speaker at 120 cycles per second and for producing at least in said remote zone a sound wave of the same shape and amplitude as, but substantially in phase opposition to, said first-mentioned wave so that said waves are substantially in interference with each other in said remote zone.

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