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(54) Title: **ACTIVELY CONTROLLED NOISE CANCELLATION SYSTEM FOR AN ELEVATOR CAB**

(57) Abstract: A system for attenuating noise in an elevator cab includes an elevator cab, a sound detection system, a signal processor and a sound generating system. The elevator cab comprises a structural enclosure for receiving passengers. The sound detection system detects ambient noise within the enclosure and produces an ambient noise signal. The signal processor processes the ambient noise signal produced by the sound detection system and produces a noise cancellation signal. The sound generating system produces cancellation noise within the enclosure characterized by the noise cancellation signal. The cancellation noise attenuates ambient noise within the elevator cab for the passengers.

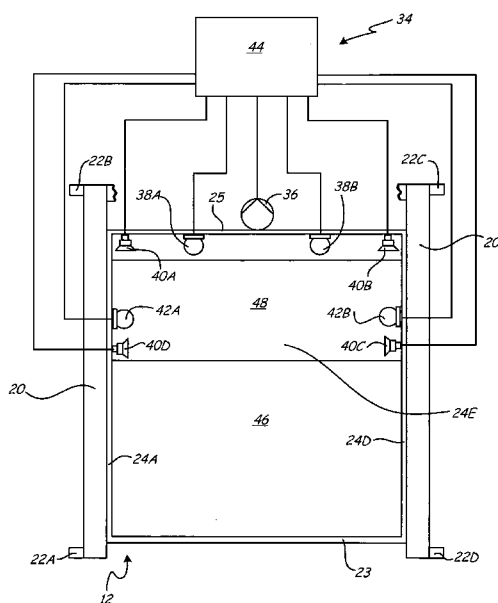


Fig. 2

ACTIVELY CONTROLLED NOISE CANCELLATION SYSTEM FOR AN ELEVATOR CAB

BACKGROUND

The present invention relates to noise management in elevator systems and more
5 particularly to a system for reducing noise within an elevator cab.

Elevator systems are typically used for transporting passengers to different floors
within a building. As the number of floors and people within buildings increase and ride
times and congestion correspondingly increase, there is a need for enhancing passenger
comfort within elevator cabs. Operation of the elevator system contributes to a variety of
10 discomforts within elevator cabs. Specifically, elevator systems include a variety of
mechanical systems that individually generate vibration and sound that propagate into
the cab. For example, typical elevator systems include a machine room that houses a
drive system, such as a geared machine or electric motor, that generates periodic sound
waves and mechanical vibration. Furthermore, motion of the elevator cab produces
15 rolling resistance vibration and air resistance sound waves. Vibration and sound from
these sources and others produce ambient noise that permeates to the elevator cab,
reducing the comfort of the passengers.

Various systems and methods have been developed to reduce vibration and sound
noise within an elevator cab. For example, U.S. Pat. No. 6,494,295 to Grundmann
20 describes counteracting vibrations at an elevator cab by sensing vibration at a source and
at the cab, and then vibrating a compensating mass on the elevator cab in response to the
sensed vibrations. Such a system, however, fails to adequately counteract sound waves
and vibration generated at other sources. U.S. Pat. No. 6,364,064 to Rizzi describes
counteracting total vibration of an elevator cab from all sources by generating a vibration
25 force with a piezoelectric vibration generator to cancel vibration of the elevator cab.
Such a system, however, fails to eliminate sound waves that are transmitted into the
elevator cab from the vibration sources. U.S. Pat. No. 5,135,079 to Shimazaki describes
an apparatus for acoustically canceling sound waves at a source, such as a machine room,
to prevent noise from reaching an elevator cab. Such a system, however, does not reduce
30 noise within the elevator cab generated by other sources or generated by vibration of the
cab. As such, there is a need for attenuating ambient noise within an elevator cab that is
generated by all sources, including mechanical vibrations and acoustic sound waves.

SUMMARY

Exemplary embodiments of a system for attenuating noise in an elevator cab include an elevator cab, a sound detection system, a controller and a sound generating system. The elevator cab comprises a structural enclosure for receiving passengers. The sound detection system detects ambient noise within the enclosure and produces an ambient noise signal. The control system processes the ambient noise signal produced by the sound detection system and produces a noise cancellation signal. The sound generating system produces cancellation noise within the enclosure based upon the noise cancellation signal. The cancellation noise provides active cancellation of ambient noise within the elevator cab for the passengers.

It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only, and are not restrictive of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows a cutaway perspective view of an elevator system in which an embodiment of an actively controlled noise cancellation system of the present invention is used.

FIG. 2 shows a front schematic view of an elevator cab connected to electrical components of an embodiment of an actively controlled noise cancellation system.

These and other features, aspects, and advantages of the present invention will become apparent from the following description, appended claims, and the accompanying exemplary embodiments shown in the drawings, which are hereafter briefly described.

DETAILED DESCRIPTION

Efforts have been made throughout the drawings to use the same or similar reference numerals for the same or like components.

FIG. 1 is a cutaway perspective view of elevator system 10 incorporating an embodiment of the actively controlled noise cancellation system of the present invention. Elevator system 10, which is typically situated in a hoistway within a building, includes passenger cab 12, counterweight 14, traction drive 16, and tension line 18. Passenger cab 12, which is typically positioned between a pair of guide rails (not shown), includes frame 20, roller guides 22A, 22B, 22C and 22D (roller guide 22D being shown in FIG.

2), cab panels 24A, 24B, 24C, 24D and 24E (panels 24D and 24E being shown in FIG. 2), and cab doors 26A and 26B. Traction drive 16, which is typically mounted above the hoistway to beams 28 connected to the guide rails, includes drive machine 30 and drive sheave 32. Cab panels of passenger cab 12, including panels 24A – 24E, are connected
5 together along with ceiling 25 and floor 23 (shown in FIG. 2) to form an enclosure in which passengers of elevator system 10 ride during operation of elevator system 10. Doors 26A and 26B provide access to cab 12 and form part of the enclosure. Cab 12 is mounted within frame 20, which frame provides a rigid structural member linking the enclosure of panels 24A – 24E, ceiling 25, floor 23, and doors 26A and 26B with the
10 guide rails and tension line 18. Roller guides 22A, 22B, 22C and 22D are mounted to frame 20 and roll against the guide rails to direct passenger cab 12 through the hoistway. Likewise, counterweight 14 includes roller guides 33A – 33D that roll against another set of guide rails (not shown) to direct counterweight 14 through the hoistway. Frame 20 and counterweight 14 are suspended from tension line 18, which is slung around drive
15 sheave 32. Drive machine 16, which typically comprises an electric motor or a geared machine, rotates drive sheave 32 to adjust the heights of cab 12 and counterweight 14 within the hoistway such that passengers within the enclosure can be delivered to different floors within the building. Passenger cab 12 is outfitted with the actively controlled noise cancellation system of the present invention to reduce ambient noise
20 perceived within the enclosure of cab 12 thereby increasing passenger comfort.

During operation, various components of elevator system 10, such as counterweight 14, traction drive 16, and roller guides 22A – 22D and 33A – 33D, generate ambient noise that propagates through system 10 and enters the enclosure formed by panels 24A – 24E, ceiling 25, floor 23, and doors 26A – 26B. Although the
25 embodiment of the invention disclosed herein is described with respect to traction drive elevator systems, other embodiments of the invention are directed toward hydraulic drive elevator systems that produce noise within elevator cabs using hydraulic lift systems. Noise is transmitted to cab 12 in primarily two modes: through acoustic sound waves and through mechanical vibration. Acoustic sound waves are transmitted through air and
30 comprise longitudinal waves that cause local regions of pressure deviations. Mechanical vibrations are transmitted through solid mediums and comprise longitudinal waves as well as transverse waves that cause local regions of alternating shear stress. Each of these waves produces sound within cab 12 that is perceived as noise. In particular, these sound waves produce pressure pulses that physically stimulate an eardrum of a human

ear. The components of elevator system 10 contribute to the overall noise within the enclosure of cab 12 by generating mechanical vibration and acoustic sound waves that enter the enclosure within cab 12. For example, drive motor 30 generates longitudinal sound waves that travel through air within the hoistway to penetrate the enclosure, and
5 transverse sound waves that travel through beams 28, the guide rails and frame 20 to penetrate cab 12. Additionally, roller guides 22A – 22D roll against the guide rails to produce longitudinal and transverse sound waves that travel through air and frame 20, respectively, to penetrate cab 12. Additionally, air resistance noise from movement of cab 12 through the hoistway and from counterweight 14 passing by cab 12 produces
10 longitudinal sound waves that enter the enclosure of cab 12. Furthermore, longitudinal sound waves penetrating cab 12 also cause vibration of cab 12 that result in additional transverse sound waves and vibration of cab 12. Noise from these and other sources produce various periodic sound waves that are regular and predictable. The actively controlled noise cancellation system of the present invention is mounted to cab 12 to
15 attenuate composite noise generated from all sources within the enclosure of cab 12 and, in particular, to cancel periodic noise.

FIG. 2 shows a front schematic view of elevator cab 12 with panels 24B and 24C and cab doors 26A and 26B removed to show placement of various electrical components of an embodiment of an actively controlled noise cancellation system 34.
20 Noise cancellation system 34 includes electrical components, such as input transducer 36 and input microphones 38A and 38B mounted, e.g. on ceiling 25. Noise cancellation system 34 also includes sound generators 40A – 40D and error microphones 42A and 42B mounted, e.g., on cab panels 24A – 24E. The input transducer 36, input microphones 38A and 38B, sound generators 40A – 40D, and error microphones 42A
25 and 42B are all connected to electric controller 44. Elevator cab 12 includes structural components, such as panels 24A – 24E and doors 26A and 26B (FIG. 1), that together with ceiling 25 and floor 23 form enclosure 46 in which passengers of elevator system 10 travel. Panels 24A and 24D are connected to frame 20 and connect to guide rails through rollers 22A – 22D, respectively. Panels 24A – 24E, ceiling 25, floor 23, and doors 26A
30 and 26B are comprised of solid materials that restrain passengers within cab 12 as traction drive 16 (FIG. 1) moves frame 20 against the guide rails on rollers 22A – 22D. In various embodiments, panels 24A – 24E, ceiling 25, floor 23 and doors 26A and 26B are comprised of aesthetically pleasing materials, such as wood, glass or stainless steel, to enhance the comfort and experience of passengers within enclosure 46. The electrical

components of noise cancellation system 34 are mounted to the structural components of cab 12 to interact with enclosure 46. Controller 44 operates the electrical components of noise cancellation system 34 to produce sound waves that acoustically cancel the effect of sound waves from noise within enclosure 46, such as from operation of rollers 22A –
5 22D in a traction drive elevator system, or from hydraulic drive components in a hydraulic elevator system such as a hydraulic piston, a hydraulic cylinder, a hydraulic pump and a motor.

The electrical components of system 34 are positioned with respect to passenger region 48 within enclosure 46. Region 48 comprises a three-dimensional sector of
10 enclosure 46 where passengers are most likely to perceive ambient noise within cab 12. The width and depth of region 48 are defined by the width and depth of cab 12. With respect to the height of region 48, region 48 comprises a segment of the height of enclosure 46 positioned with respect to the ears of passengers within cab 12. In one embodiment, the height of region 48 comprises a segment of enclosure 46 extending
15 from approximately 4 feet (~1.22 m) to approximately 7 feet (~2.13 m) above floor 23 of cab 12. In another embodiment, the height of region 48 comprises a segment extending from approximately 5 feet (~1.52 m) to approximately 6.5 feet (~1.98 m) above floor 23 of cab 12. Region 48 is thereby positioned to mitigate noise at levels within enclosure 46 where the ears of most adult passengers are most likely to be located. Noise cancellation
20 system 34 produces canceling sound waves having the opposite phase but equal frequency and amplitude of noise sound waves within cab 12 to reduce the noise level within enclosure 46 and more particularly within region 48. Although the invention is described with respect to one embodiment comprising one input transducer, two input microphones, two error microphones and four sound generators, other embodiments may
25 use different numbers and combinations of electrical components.

Input transducer 36 and input microphones 38A and 38B receive noise sound waves, such as noise sound waves generated by the components of elevator system 10, and generate electrical input signals for controller 44. Input transducer 36 detects mechanical vibration of cab 12 and provides controller 44 with a means for sensing
30 longitudinal and transverse noise sound waves transmitted to cab 12 through frame 20, ceiling 25, floor 23 and panels 24A – 24E. In one embodiment, transducer 36 comprises an accelerometer or a vibration transducer that converts motion into an electrical signal. Particularly, transducer 36 determines the frequency and amplitude of deflections of a panel of cab 12 caused by vibrations. Thus, transducer 36 also determines the frequency

and amplitude of sound waves causing resultant vibrations emanating from cab 12, and produces a corresponding ambient noise signal. In the embodiment shown, input transducer 36 is mounted to ceiling 25 outside of enclosure 46 such that transducer 36 is not visible from within enclosure 46. Transducer 36 is rigidly mounted to cab 12 such
5 that vibration from ceiling 25 is transmitted to controller 44.

Input microphones 38A and 38B detect sound pressure pulses within cab 12 and provide controller 44 with a means for sensing longitudinal noise sound waves transmitted through air within enclosure 46. Input microphones 38A and 38B comprise any conventional transducer that converts pressure from sound waves into an electrical
10 signal, such as a condenser, capacitor or electrostatic microphone. Particularly, microphones 38A and 38B determine the frequency and amplitude of sound pressure pulses within enclosure 46 caused by ambient noise. Thus, microphones 38A and 38B also determine the frequency and amplitude of sound waves traveling through enclosure 46, and produce corresponding ambient noise signals. Input microphones 38A and 38B
15 are mounted to cab 12 near region 48 to detect acoustic sound waves within cab 12. In the embodiment shown, input microphones 38A and 38B are mounted to ceiling 25 inside enclosure 46 so that composite noise from all sound waves within enclosure 46 is detected. Microphones 38A and 38B are positioned at ear level so that they provide input to controller 44 that reflects what is commonly perceived by passengers within
20 enclosure 46.

After conditioning from controller 44, which is discussed in greater detail below, the ambient noise signals from input transducer 36 and input microphones 38A and 38B are directed to sound generators 40A – 40D to produce noise canceling sound waves. Specifically, sound generators 40A – 40D produce longitudinal sound waves that have
25 the opposite phase but same frequency and amplitude of periodic ambient noise sound waves within enclosure 46. The sound waves produced by sound generators 40A – 40D change the pressure of the air within enclosure 46 so as to cancel the change in pressure generated by the ambient noise, yielding a flat or nearly flat total sound wave. Thus, the noise canceling sound waves eliminate physical stimulation of the eardrum. In the
30 embodiment shown, sound generators 40A – 40D are mounted inside of enclosure 46 to panels 24A and 24D and ceiling 25 such that they are able to produce sound within cab 12. Sound generators 40A – 40D are positioned in any orientation such that they provide full coverage of enclosure 46 and particularly region 48. The sound waves produced by sound generators 40A – 40D propagate throughout enclosure 46 such that the specific

orientation or height of sound generators 40A – 40D within enclosure 46 need not be positioned within region 48. Sound generators 40A – 40D comprise any conventional loudspeaker as is known in the art.

In another embodiment of the invention, sound generators 40A – 40D comprise
5 vibration generators that vibrate the structural panels of cab 12 to produce sound waves. The vibration generated by one of the vibration generators is transferred to one of panels 24A – 24E, doors 26A and 26B, floor 23 and ceiling 25 such that the structural member becomes the driver for producing the noise canceling sound wave. In one embodiment, the vibration generators comprise voice coils, as are conventionally used to drive
10 loudspeakers, that are rigidly connected to panels 24A – 24E, doors 26A and 26B, floor 23, and/or ceiling 25. The large size of panels 24A – 24E, doors 26A and 26B, floor 23, and ceiling 25 produces pressure pulses that provide complete coverage of enclosure 46 with the noise canceling sound wave. Additionally, because of the large mass and stiffness of panels 24A – 24E, doors 26A and 26B, floor 23, and ceiling 25 as compared
15 to conventional speaker cones, panels 24A – 24E, doors 26A and 26B, floor 23, and ceiling 25 are especially well suited for producing low frequency sound waves. However, the mass and stiffness of large panels are also more difficult for a conventional voice coil to vibrate. Thus, in another embodiment, sound generators 40A – 40D comprise more powerful vibration generators such as magnetostrictive SolidDrive®
20 sound transducers that are commercially available from Induction Dynamics. Other such sound transducers are described in U.S. Pat. No. 7,386,137 to Combust, which is assigned to Multi Service Corporation, Overland Park, KS.

For any configuration of sound generators 40A – 40D, a sound wave is produced that produces pressure pulses for canceling the sound waves of noise generated within
25 enclosure 46. Controller 44 generates a noise cancellation signal based on the noise signals generated by transducer 36 and input microphones 38A and 38B. Specifically, controller 44 produces a noise cancellation signal for driving sound generators 40A – 40D to produce sound waves having frequencies and amplitudes mimicking that of ambient noise within enclosure 46, but having phases that are shifted (e.g. one-hundred-
30 eighty degrees) with respect to ambient noise to produce active noise cancellation within enclosure 46. Noise cancellation system 34 also includes means for providing an error feedback loop to controller 44 so that the phase shift and amplitude of the noise canceling sound waves can be actively controlled to match that of ambient noise within enclosure 46. Error microphones 42A and 42B are mounted inside cab 12 within

enclosure 46 to detect the composite of noise sound waves generated by elevator system 10 and the cancellation sound waves generated by sound generators 40A – 40B. Error microphones 42A and 42B are positioned within region 48 at ear level such that error microphones 42A and 42B provide input to controller 44 reflecting the net noise perceived by passengers within cab 12. Error microphones 42A and 42B comprise any conventional transducers that convert sound waves into electrical signals. Particularly, error microphones 42A and 42B determine the frequency and amplitude of cumulative pressure pulses within enclosure 46, and produce corresponding error signals that are transmitted to controller 44.

Electric controller 44 includes various signal processing components, such as an analog-to-digital converter, a digital signal processor, a delay circuit, a digital-to-analog converter and an amplifier, for conditioning the input signals generated by input transducer 36 and input microphones 38A and 38B, and the error signals generated by error microphones 42A and 42B. The analog-to-digital converter of controller 44 receives the input signals and error signals and converts the signals to digital signals that are analyzed and processed by the digital signal processor to determine any periodic nature of the signals, and if so, to produce a noise cancellation signal. The delay circuit, which may be a part of the digital signal processor or may be a separate digital or analog device, phase-shifts the noise cancellation signal to be out of phase with the composite noise sound wave. In one embodiment, the delay circuit includes an adaptive filter which adjusts the converted signal for the difference in time it takes for sound waves from sound generators 40A – 40D and from the ambient noise to reach microphones 38A and 38B and 42A and 42B. The delay circuit generates an output noise cancellation signal that is converted by the digital-to-analog converter, amplified by the amplifier, and provided to sound generators 40A – 40D, which then produce noise cancellation sound waves that are phase shifted approximately one-hundred-eighty degrees from the composite noise sound waves. Controller 44 also utilizes the error signal generated by microphones 42A and 42B to maintain the cancellation sound waves in the appropriate phase, frequency, and amplitude to cancel the noise sound waves.

The acoustic noise canceling wave is particularly well-suited for canceling periodic noise that produces an easily repeatable and predictable signature. The motion of rollers 22A – 22D on frame 20 and rollers 33A – 33D for counterweight 14 (FIG. 1) rolling against guide rails, the rotation of a drive shaft within drive machine 30 (FIG. 1) and the motion of tension line 18 against drive sheave 32 (FIG. 1) each produce periodic,

low frequency sounds. Also, hydraulic pumps, hydraulic cylinders and other components also produce periodic sounds in hydraulic drive elevator systems. The composite noise sound wave for all of these sources takes on a sinusoidal wave pattern that repeats itself with a frequency relating to, among other things, the speed of cab 12 within the hoistway. Thus, input microphones 38A and 38B and transducer 36 receive a sinusoidal input that has the frequency and amplitude of the ambient noise within enclosure 46. Controller 44 operates sound generators 40A – 40D to produce a noise canceling sound wave that matches the frequency and amplitude of the ambient sound, but is phase-shifted one-hundred-eighty degrees. As the frequency of the ambient noise sound wave changes, such as when the speed of cab 12 changes, error microphones 42A and 42B provide an error signal to controller 44 such that the frequency of the noise canceling sound wave can be adjusted to be opposite of that of the composite ambient noise sound wave. Thus, controller 44 produces an actively controlled acoustic noise canceling sound wave that attenuates ambient noise and cancels periodic noise within enclosure 46.

Non-periodic sound does not yield a regular sound wave that is easily anticipated by controller 44. For example, human voices produce sound in the range of approximately 80 Hz to approximately 1100 Hz, but that is generally non-periodic. As a passenger speaks or another non-periodic sound is produced within enclosure 46, input microphones 38A and 38B provide input to controller 44. Controller 44 analyzes the input from input microphones 38A and 38B and determines that the input is non-periodic in nature. Thus, controller 44 does not provide sound canceling input to sound generators 40A – 40D and, therefore, sound generators 40A – 40D do not produce a noise canceling sound wave having a frequency that otherwise would be phase-shifted from noise that is no longer being produced. In other words, controller 44 cannot anticipate the proper-phase shift for non-periodic sound that has not yet been produced or cannot be predicted, particularly as microphones 38A and 38B and 42A and 42B are positioned further away from the noise source. Noise cancellation system 34 of the present invention thus has the additional benefit of not interfering with voices of human passengers traveling within cab 12 and/or with intentional background sound such as music that is provided in cab 12 to improve the experience of a passenger traveling in the cab 12.

The sound canceling wave generated by speakers 40A – 40D is configured to optimally cancel noise within region 48, with passengers at different positions within

region 48 experiencing different levels of noise cancellation. Error microphones 42A and 42B are fixedly attached to panels 24A and 24D within enclosure 46, and transducer 36 and input microphones 38A and 38B are fixedly attached to ceiling 25 such that each detects only the sound perceived at a specific position. Thus, controller 44 produces a cancellation signal that comprises an amalgamation of the sound perceived at each of the positions of input transducer 36, input microphones 38A and 38B and feedback microphones 42A and 42B. Each passenger within enclosure 46 hears ambient noise that is slightly different than the noise perceived at each of input transducer 36, input microphones 38A and 38B, error microphones 42A and 42B and the amalgamation of all of these components. The out-of-phase noise canceling effects of system 34 mitigates to some extent the noise for all passengers with the noise for at least one passenger being potentially totally cancelled. For example, a passenger standing within region 48 approximately equidistant between error microphones 42A and 42B and having ears at approximately equal heights within enclosure 46 as microphones 42A and 42 will experience optimal noise cancellation within cab 12.

Furthermore, human hearing is limited to frequencies between about 20 Hz and 20,000 Hz (20 kHz), which are generally low frequencies when compared to the overall sound spectrum. All sound is perceived by humans as a physical pressure pulse on the eardrum. In particular, comparatively very low frequency sound such as 1 kHz and below, is typically perceived by humans as a pressure pulse that can be physically felt by the body. Due to this very low frequency pressure pulse phenomenon, it is commonly understood that it is difficult or impossible for humans to perceive the source of very low frequency sound. The major component of noise generated within cab 12 is very low frequency sound, the origin of which is difficult for passengers within enclosure 46 to determine. Thus, the noise canceling effects of system 34 reduce noise perceived by all passengers within enclosure 46 to some extent as very low frequency sound waves are attenuated, even without full cancellation. Furthermore, due to the small enclosed nature of cab 12, far field effects of noise within cab 12 are not of concern thus making near field attenuation and cancellation more effective for all passengers.

In other embodiments of the invention, active noise cancellation system 34 is combined with means directed toward attenuating higher frequency noise that is still within the low frequency range of the overall sound spectrum. The origin of this higher frequency noise (e.g. noise having a frequency between about 1 kHz and about 20 kHz) is more perceptible to humans and is therefore more difficult to acoustically cancel at all

positions within enclosure 46. This higher frequency noise is more readily cancelled by passive means that physically block the higher frequency sound waves. Thus, in one embodiment of the invention, cab 12 is lined with a noise attenuating barrier such as foam. In yet another embodiment of the invention, the noise canceling sound wave is
5 used to produce white or pink noise that interferes with the ability of passengers to perceive noise, including this higher frequency noise. The sound is not cancelled and the ear remains physically stimulated. However, the threshold at which the passenger notices ambient noise is raised, which provides an overall increase in passenger comfort.

Actively controlled noise cancellation systems of the present invention are well
10 suited for use in all elevator systems, including traction drive and hydraulic drive elevator systems. Elevator systems comprise different configurations of hoistways, guide rails, cabs, rollers, drive machines and other components. Each individual component contributes differently to the composite ambient noise. The ambient noise sound wave within enclosure 46 thus varies widely during operation of elevator system
15 10 and over the lifetime of elevator system 10. Noise cancellation system 34 addresses the problem of noise generated by any elevator system by mitigating the noise at the point where sound produced by the elevator system becomes noise: within cab 12. The individual noise of each sound producing component of an elevator system need not be individually accounted for. Rather, the composite noise is accounted for, regardless of
20 the individual contribution of each component. Thus, as the ambient noise of each component changes over time due to, for example, wear or replacement of components, adjustment of system 34 need not be performed. System 34 continuously adapts to varying sounds by actively monitoring sound with transducer 36, input microphones 38A and 38B and error microphones 42A and 42B. Furthermore, system 34 can be used in
25 addition to noise mitigation systems directed to individual components to provide a combined solution to noise within cab 12.

The aforementioned discussion is intended to be merely illustrative of the present invention and should not be construed as limiting the appended claims to any particular embodiment or group of embodiments. Thus, while the present invention has
30 been described in particular detail with reference to specific exemplary embodiments thereof, it should also be appreciated that numerous modifications and changes may be made thereto without departing from the broader and intended scope of the invention as set forth in the claims that follow.

The specification and drawings are accordingly to be regarded in an illustrative manner and are not intended to limit the scope of the appended claims. In light of the foregoing disclosure of the present invention, one versed in the art would appreciate that there may be other embodiments and modifications within the scope of the present invention. Accordingly, all modifications attainable by one versed in the art from the present disclosure within the scope of the present invention are to be included as further embodiments of the present invention. The scope of the present invention is to be defined as set forth in the following claims.

CLAIMS:

1. A system for attenuating noise in an elevator cab comprising a structural enclosure for receiving passengers, the system comprising:
 - a sound detection system for detecting ambient noise within the enclosure and producing an ambient noise signal;
 - a controller for processing the ambient noise signal produced by the sound detection system and producing a noise cancellation signal;
 - a sound generating system for producing cancellation noise within the enclosure based upon the noise cancellation signal.
2. The system for attenuating noise in an elevator cab of claim 1, wherein at least one of the sound detection system and the sound generating system is mounted to the elevator cab.
3. The system for attenuating noise in an elevator cab of claim 1, wherein both the sound detection system and the sound generating system are mounted to the elevator cab.
4. The system for attenuating noise in an elevator cab of claim 1 wherein the ambient noise comprises a composite of sound waves generated by vibration of the cab and sound waves penetrating the cab from outside the cab.
5. The system for attenuating noise in an elevator cab of claim 4 wherein the sound detection system comprises:
 - an input transducer for detecting vibration of the elevator cab; and
 - an input microphone for detecting sound waves from ambient noise within the enclosure.
6. The system for attenuating noise in an elevator cab of claim 5 wherein the sound generating system comprises at least one loudspeaker and the input transducer comprises an accelerometer.
7. The system for attenuating noise in an elevator cab of claim 5 wherein the sound generating system comprises a vibration generator positioned on a surface of the structural enclosure, wherein the vibration generator vibrates the surface to generate the cancellation noise.
8. The system for attenuating noise in an elevator cab of claim 7 wherein the surface of the structural enclosure comprises a wood, glass or steel panel that forms a part of the enclosure.

9. The system for attenuating noise in an elevator cab of claim 5 wherein the ambient noise comprises a periodic noise and the cancellation noise is phase shifted with respect to the ambient noise.
10. The system for attenuating noise in an elevator cab of claim 9 and further comprising at least one error microphone for detecting cancellation noise and ambient noise within the enclosure and providing an error signal to the controller to adjust the phase shift.
11. The system for attenuating noise in an elevator cab of claim 10 wherein cancellation noise within the enclosure cancels approximately all ambient noise for at least one of the passengers within the structural enclosure.
12. The system for attenuating noise in an elevator cab of claim 10 wherein the error microphone is positioned within the structural enclosure at a position where noise is perceived by passengers within the elevator cab.
13. The system for attenuating noise in an elevator cab of claim 12 wherein the error microphone is positioned above a floor of the elevator cab in a range from approximately 4 feet (~1.22 m) to approximately 7 feet (~2.13 m).
14. The system for attenuating noise in an elevator cab of claim 1 wherein the sound generating system is configured to produce sound at frequencies of approximately 1 kHz or less.
15. The system for attenuating noise in an elevator cab of claim 14 and further comprising passive noise cancellation means for attenuating sound at frequencies of approximately 1 kHz or higher.
16. The system for attenuating noise in an elevator cab of claim 14 wherein the sound generating system further produces white noise.
17. A method for actively canceling noise in an elevator cab, the method comprising:
 - detecting ambient noise within an enclosure of the elevator cab using a sound detection system;
 - processing ambient noise detected by the sound detection system to produce a noise cancellation signal; and
 - producing cancellation noise based upon the noise cancellation signal within the enclosure using a sound generating system to cancel at least a portion of the ambient noise.
18. The method for actively canceling noise in an elevator cab of claim 17 wherein the step of detecting ambient noise within the enclosure comprises:

detecting vibration of the cab with an input transducer; and
detecting sound waves from ambient noise within the enclosure with a microphone.

19. The method of actively canceling noise in an elevator cab of claim 18 wherein producing a noise cancellation signal includes phase shifting the cancellation noise with respect to the ambient noise.

20. The method of actively canceling noise in an elevator cab of claim 19 and further comprising:

detecting cancellation noise and ambient noise within the enclosure with an error microphone;

producing an error signal based upon the detected cancellation noise and ambient noise; and

adjusting the cancellation noise signal based upon the error signal.

21. An elevator system with active noise cancellation, the elevator system comprising:

an elevator cab comprising a structural enclosure for passengers;

a hoisting system for traversing the elevator cab through an elevator hoistway;
and

an active noise cancellation system comprising:

a sound detection system for detecting ambient noise within the structural enclosure generated by the hoisting system and producing an ambient noise signal;

a signal processor for processing the ambient noise signal produced by the sound detection system and producing a cancellation noise signal that is phase shifted with respect to the ambient noise; and

a sound generating system for producing cancellation noise within the structural enclosure based upon the cancellation noise signal to cancel at least a portion of the ambient noise.

22. The elevator system of claim 21 wherein the hoisting system comprises:

a tension line having a first end and a second end, the first end being connected to the elevator cab;

a counterweight connected to the second end of the tension line;

roller guides for directing the elevator cab and the counterweight along a plurality of guide rails; and

a drive machine connected to the tension line to move the elevator cab and the counterweight along the guide rails.

23. The elevator system of claim 22, wherein the ambient noise comprises a composite of noise generated by one or more of: (a) vibration of the cab; (b) air resistance of the cab; (c) air resistance of the counterweight; (d) rolling resistance of the roller guides along the guide rails; and (e) vibration of the drive machine.

24. The elevator system of claim 21 wherein the hoisting system comprises a hydraulic lift system comprising:

a hydraulic cylinder having a piston for lifting the elevator cab through the hoistway;

a pump for providing pressurized fluid to the hydraulic cylinder; and

a motor for driving the pump;

wherein the ambient noise comprises a composite of noise generated by one or more of: (a) the hydraulic cylinder; (b) the piston; (c) the pump; and (d) the motor.

25. The elevator system of claim 21 and further comprising:

an error microphone for detecting cancellation noise and ambient noise within the enclosure and providing an error signal to the signal processor to adjust the cancellation noise signal.

26. The elevator system of claim 21, wherein the ambient noise is substantially periodic.

27. The elevator system of claim 21, wherein at least one of the sound detection system and the sound generating system is mounted to the elevator cab.

28. The elevator system of claim 21, wherein both the sound detection system and the sound generating system are mounted to the elevator cab.

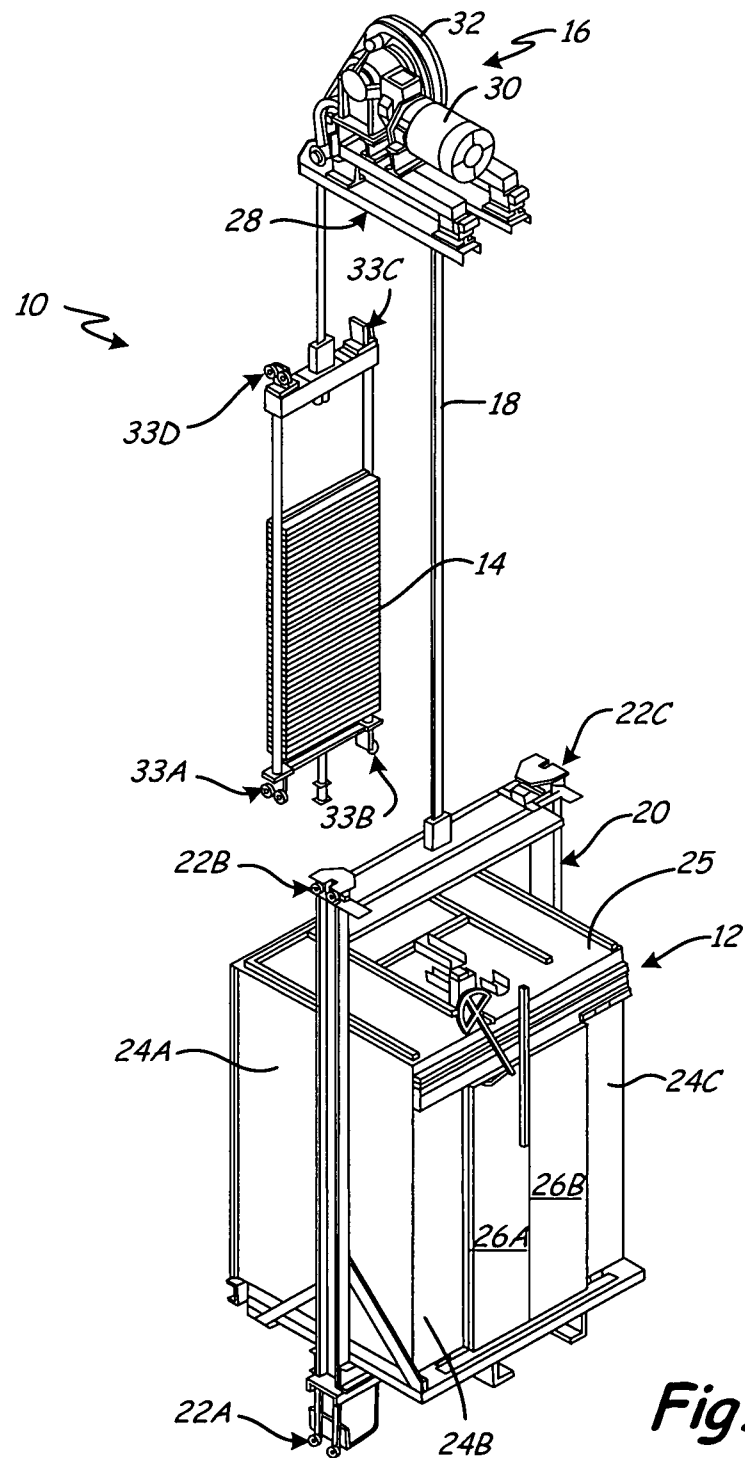
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Fig. 1

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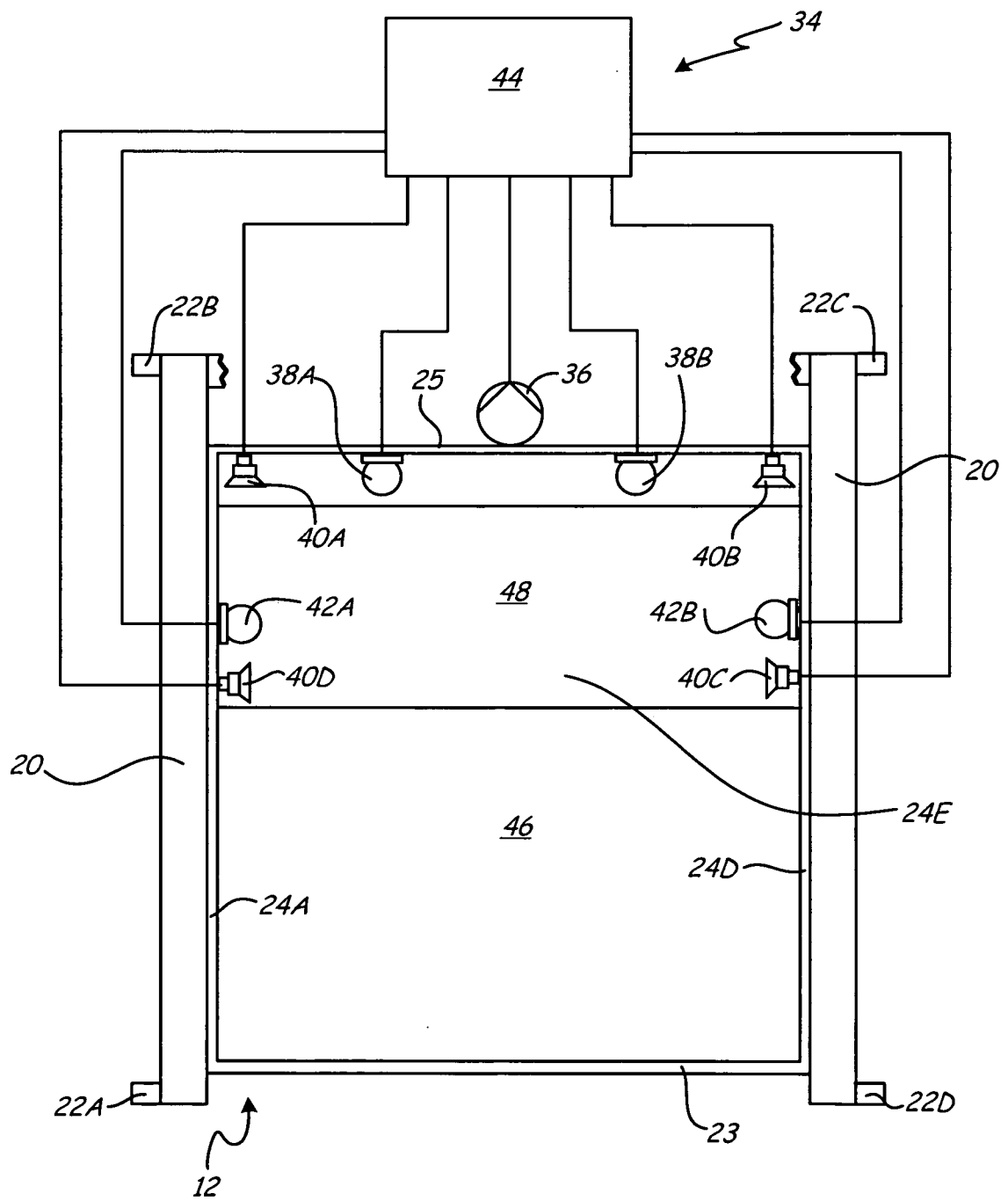


Fig. 2

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2008/010907

A. CLASSIFICATION OF SUBJECT MATTER

INV. B66B11/02 G10K11/178

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B66B G10K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 05 078065 A (HITACHI LTD) 30 March 1993 (1993-03-30)	1-9, 17-19, 21-23, 26-28
Y	abstract; figures 1-7	10-16, 20,25
Y	JP 05 310389 A (HITACHI LTD) 22 November 1993 (1993-11-22) abstract; figures 1-8	10-13, 20,25
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☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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O document referring to an oral disclosure, use, exhibition or other means

P document published prior to the international filing date but later than the priority date claimed

T later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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Z document member of the same patent family

Date of the actual completion of the international search

2 June 2009

Date of mailing of the international search report

12/06/2009

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INTERNATIONAL SEARCH REPORT

International application No

PCT/US2008/010907

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/US2008/010907

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