

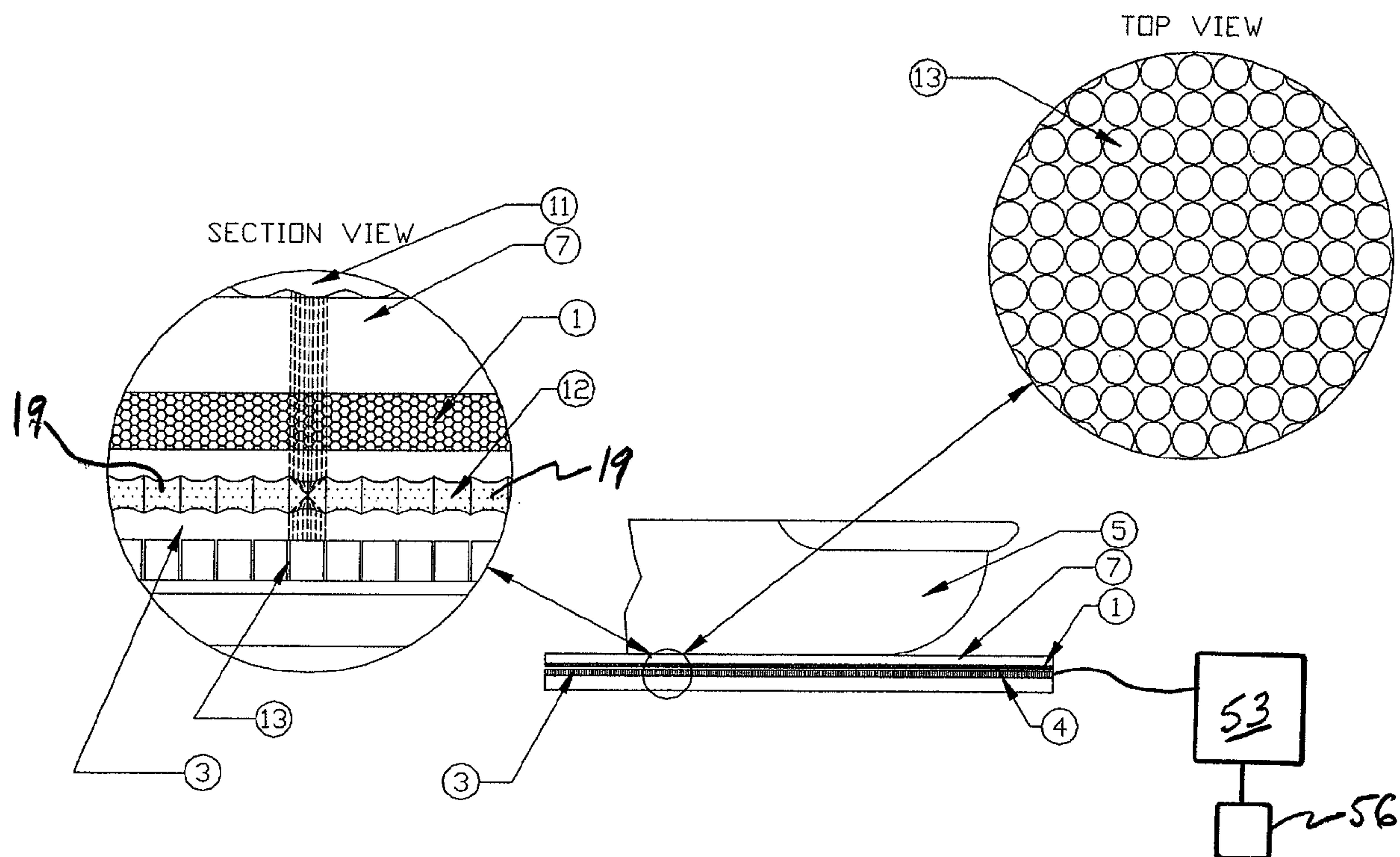


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(71) Demandeur/Applicant:
ULTRA-SCAN CORPORATION, US
(72) Inventeurs/Inventors:
SCHNEIDER, JOHN, K., US;
VENIKOV, FEDIR, CA;
SHMELKIN, IGOR, US;
KITCHENS, JACK, US
(74) Agent: PIASETZKI & NENNIGER LLP

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(54) Title: BIOMETRICAL OBJECT READER HAVING AN ULTRASONIC WAVE MANIPULATION DEVICE



(57) Abrégé/Abstract:

Devices and methods of creating an image of a biological object are disclosed. In one embodiment of the invention there is a plane wave ultrasonic pulse generator, an ultrasonic wave manipulation device, an ultrasonic detector and an image generator. In a method according to the invention, a biological object is imaged by emitting an unfocussed ultrasonic energy wave front, reflecting at least a portion of the ultrasonic energy wave front from the object, altering a direction of the ultrasonic energy, detecting that energy, and using the detected energy to create an image of the object.



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(71) Applicant (for all designated States except US): **ULTRA-SCAN CORPORATION** [US/US]; 4240 Ridge Lea Road, Amherst, NY 14226 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **SCHNEIDER, John, K.** [US/US]; 228 Lamarck Drive, Snyder, NY 14226 (US). **VENIKOV, Fedir** [CA/CA]; 228 Lamarck Drive, St. Catharines, ON (CA). **SHMELKIN, Igor** [US/US]; 186 New Road, East Amherst, NY 14051 (US). **KITCHENS, Jack** [US/US]; 198 Fairfield Avenue, Tonawanda, NY 14223 (US).

(74) Agents: **KENT, Roberts, R.** et al.; HODGSON RUSS LLP, The Guaranty Building, 140 Pearl Street, Suite 100, Buffalo, NY 14202-4040 (US).

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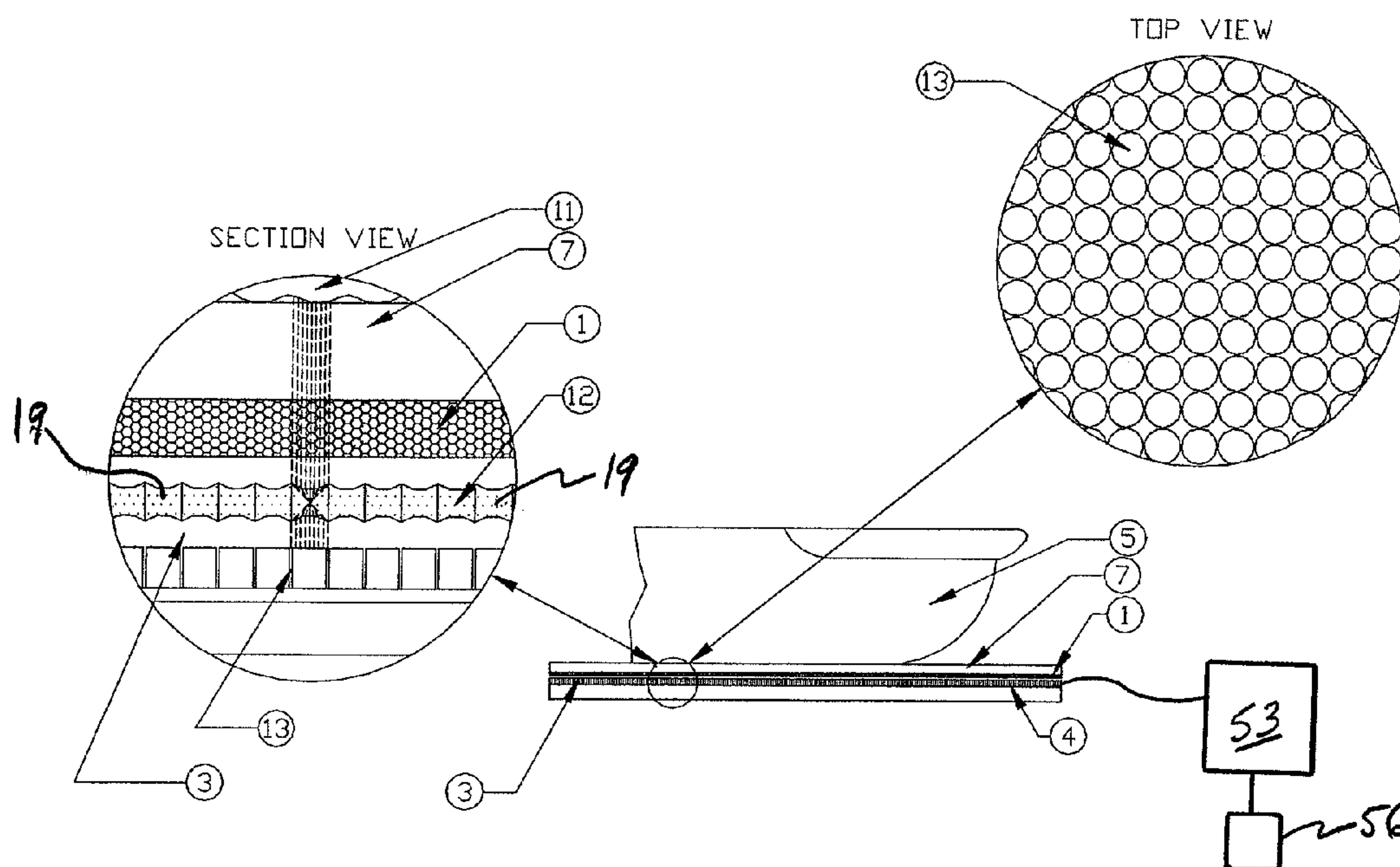
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(57) Abstract: Devices and methods of creating an image of a biological object are disclosed. In one embodiment of the invention there is a plane wave ultrasonic pulse generator, an ultrasonic wave manipulation device, an ultrasonic detector and an image generator. In a method according to the invention, a biological object is imaged by emitting an unfocused ultrasonic energy wave front, reflecting at least a portion of the ultrasonic energy wave front from the object, altering a direction of the ultrasonic energy, detecting that energy, and using the detected energy to create an image of the object.

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BIOMETRICAL OBJECT READER HAVING AN ULTRASONIC WAVE MANIPULATION DEVICE

Cross-Reference To Related Application

5 This application claims the benefit of priority to U.S. provisional patent application serial number 60/803,150, filed on May 25, 2006 and U.S. provisional patent application serial number 60/822,087, filed on August 11, 2006.

Field Of The Invention

The invention relates to an ultrasonic biometric fingerprint reader.

Background Of The Invention

10 Since the 1800's fingerprint information has been collected from human fingers and hands by means of ink and paper. For the purposes of this document, the term fingerprint is used to mean the skin surface friction ridge detail of a single fingerprint, partial fingerprint or any portion of the skin surface friction ridge of up to and including the entire hand. In recent years various electronic fingerprint scanning systems have been developed utilizing optical,
15 capacitance, direct pressure, thermal and ultrasonic methods. Methods based upon ultrasound have proven to be the most accurate, since they are virtually immune to the effects of grease, dirt, paint, ink and other image contaminants.

The ultrasound method employs a piezoelectric transducer that sends a sound wave or pulse through an ultrasonic transmitting media. The pulse is then partially reflected back at
20 each media interface. The reflected pulse is received by the transducer, and the lapsed time between sending and receiving the pulse may be used as a measure of the distance traveled by the pulse going and returning from each reflecting material interface. In order to detect those reflected signals corresponding to the fingerprint, a particular time interval may be monitored. Since the finger is positioned a known distance from the transducer and since the
25 speed of the ultrasound signal is known, the signals reflected from the finger will be expected at the transducer during a particular time interval. This process is called range gating (biasing). The signal received during the particular time interval may be converted to a

digital value representing the signal strength. The lapsed time may be displayed graphically to create a contour map of the fingerprint. Often a gray-scale bitmap image is used to graphically display the information.

Although ultrasound imaging of a fingerprint is superior in detail to a similar image collected by an optical system, it takes more time to collect a raster scanned ultrasonic image because common ultrasonic scanning mechanisms often collect each pixel of image information individually by means of a two axis mechanical scanning apparatus. Optical systems usually collect many pixels of information at a single time.

Summary Of The Invention

The invention may be employed to create an image of a biological object, such as the fingerprint of a human finger. In one embodiment of the invention there is a plane wave ultrasonic pulse generator, an ultrasonic wave manipulation device, an ultrasonic detector and an image generator. The generator may be capable of producing an unfocussed ultrasonic energy wave.

The ultrasonic wave manipulation device may alter the direction of at least some of the ultrasonic energy produced by the generator. For example, the wave manipulation device may alter the direction of ultrasonic energy that has been reflected by the object being imaged. The wave manipulation device may be an ultrasonic lens, an ultrasonic mirror or an ultrasonic energy wave guide.

The detector may be positioned to detect ultrasonic energy reflected from the object being imaged and the image generator may be capable of creating an image of the object using the detected ultrasonic energy.

The invention may be embodied as a method of imaging a biological object, such as a finger having a fingerprint. In one such method, an unfocussed ultrasonic energy wave front is emitted and reflected by the finger. The reflected energy may be manipulated so that a direction of the ultrasonic energy is altered, and then detected by a detector. The direction of the ultrasonic energy may be altered by refraction or by reflection, or a combination of both.

The detected energy may be used to create an image of the fingerprint using the detected ultrasonic energy.

Brief Description Of The Drawings

For a fuller understanding of the nature and objects of the invention, reference should
5 be made to the accompanying drawings and the subsequent description. Briefly, the drawings are:

Figure 1 is a diagram of a fingerprint scanner according to the invention which uses a piezoelectric ultrasonic-plane-wave pulse-generator, an ultrasonic micro-lens array, and an ultrasonic
10 detector array.

Figure 2 is a diagram of a fingerprint scanner according to the invention which uses a piezoelectric ultrasonic-plane-wave pulse-generator, a compound lens assembly, and an ultrasonic detector array.

Figure 3 is a diagram of a fingerprint scanner according to the invention which has a piezoelectric ultrasonic-plane-wave pulse-generator, an ellipsoidal ultrasonic mirror that transfers the reflected pulse from one focal point of the ellipsoid to an array of ultrasonic detectors located at the second focal point of the
15 ellipsoid.
20

Figure 4 is a diagram of a fingerprint scanner according to the invention which has a piezoelectric ultrasonic-plane-wave pulse-generator and an ultrasonic mirror to reflect an ultrasonic pulse to an ultrasonic detector array.

Figure 5 is a diagram of a fingerprint scanner according to the invention which has a piezoelectric ultrasonic-plane-wave pulse-
25

generator, two plano-concave lenses, and an ultrasonic detector array.

Figure 6 is a diagram of a fingerprint scanner according to the invention which has a piezoelectric ultrasonic-plane-wave pulse-generator and a plano-concave lens to transfer a reflected ultrasonic pulse to an ultrasonic detector array.

Figure 7 is a diagram of a fingerprint scanner according to the invention which has a piezoelectric ultrasonic-plane-wave pulse-generator and a plano-concave lens to transfer a reflected ultrasonic pulse to an ultrasonic detector array.

Figure 8 is a diagram of a fingerprint scanner according to the invention which has a piezoelectric ultrasonic-plane-wave pulse-generator and a concave-concave lens to transfer a reflected ultrasonic pulse to an ultrasonic detector array.

Figure 9 is a diagram of a fingerprint scanner according to the invention which has a piezoelectric ultrasonic-plane-wave pulse-generator and a pulse splitter that reflects ultrasonic energy toward the platen and finger where the pulse is reflected back toward the splitter, and some of the reflected pulse passes through the splitter to continue toward and be received by the ultrasonic detector array.

Figure 10 is a diagram of a fingerprint scanner according to the invention which has a piezoelectric ultrasonic-plane-wave pulse-generator and a pulse splitter that reflects the ultrasonic pulse toward the platen and finger where the pulse is reflected back toward the splitter, and some of the reflected pulse passes through the splitter to continue toward and be received by the ultrasonic detector array, which is physically smaller than the area of the

finger, and an ultrasonic lens system focuses the reflected pulse on the ultrasonic detector array.

Figures 11A and 11B are diagrams of a fingerprint scanner according to the invention illustrating how an image of an object may be transferred from the platen surface to the ultrasonic detector array.

Figure 12 is a diagram depicting the “Wave” and “Ray” methods of illustrating optic and ultrasonic systems, and it should be noted that ultrasonic systems obey Snell's Law.

Figure 13 is a diagram of a fingerprint scanner according to the invention which has a piezoelectric ultrasonic-plane-wave pulse-generator and a compound lens assembly to transfer and enlarge the reflected pulse in order to produce an enlarged fingerprint image.

Figure 14 is a diagram of a fingerprint scanner according to the invention which has a piezoelectric ultrasonic-plane-wave pulse-generator and an ultrasonic lens array to transfer a reflected pulse to an ultrasonic detector array. This embodiment is similar to that of Figure 1 but the lens array elements are larger in size than a single pixel, and each lens element of the array transfers an image that is received by a group of detector elements.

Figure 15 is a diagram of a fingerprint scanner according to the invention which has a piezoelectric ultrasonic-plane-wave pulse-generator and a 45-90-45 right angle prism. This configuration makes use of frustrated total internal reflection (“FTIR”) to obtain a reflected ultrasonic pulse. The image platen is the long dimension side of the prism.

Figure 16 is a diagram of a fingerprint scanner similar to that depicted in Figure 15 except that in Figure 16 there is a compound ultrasonic lens assembly, which may be a compound cylindrical lens assembly to substantially restore the reflected image to its original dimensions.

Figure 17 is a diagram of a fingerprint scanner according to the invention which has a piezoelectric ultrasonic-plane-wave pulse-generator and an ultrasonic fiber waveguide array to transfer a fingerprint image to an ultrasonic detector array.

Figure 18 is a diagram of a fingerprint scanner according to the invention which has a piezoelectric ultrasonic-plane-wave pulse-generator and an ultrasonic fiber waveguide array that is integral to the platen in order to facilitate transfer of the ultrasonic pulse to an ultrasonic detector array.

Figure 19 is a diagram of a fingerprint scanner according to the invention which has a piezoelectric ultrasonic-plane-wave pulse-generator and two ultrasonic fiber waveguide array plates that sandwich the generator and facilitate transfer of the ultrasonic pulse to an ultrasonic detector array.

Figure 20 is a flow chart depicting a method according to the invention.

The following list may be useful in understanding the figures.

1. Piezoelectric plane wave generator
2. Plano-curved lens (may be plano-convex or plano-concave depending upon the material and propagation media properties)
3. Ultrasound transmitting media (e.g. oil, gel, plastisol)
4. Solid state ultrasound receiving detector array

- | | | |
|----|-----|--|
| | 5. | Finger |
| | 6. | Image of the finger (illustrated as a phantom finger image) |
| | 7. | Imaging platen |
| | 8. | Reflector (e.g. prism, mirror, or polished flat surface) |
| 5 | 9. | Ellipsoidal reflector |
| | 10. | Compound lens assembly |
| | 11. | Fingerprint ridges |
| | 12. | Molded ultrasonic micro-lens assembly |
| | 13. | Detector array elements |
| 10 | 14. | Curved-lens (may be convex-convex or concave-concave depending upon the material and propagation media properties) |
| | 15. | Ultrasonic plane wave represented as a ray |
| | 16. | Ray representation of a plane wave pulse |
| | 17. | Ray representation of a plane wave echo |
| 15 | 18. | Ultrasonic beam splitter |
| | 19. | Lens array elements |
| | 20. | 45-90-45 prism |
| | 21. | Plano-curved cylindrical ultrasonic lens assembly. |
| | 22. | plate array of ultrasonic waveguide elements |
| 20 | 50. | image generator |
| | 53. | computer |
| | 56. | monitor |

Further Description Of The Invention

Figure 1 is a diagram of a scanner that may be used to create an image of a surface of a biological object. In this example, the scanner is a fingerprint scanner. The fingerprint scanner of Figure 1 has a plane wave generator 1, an ultrasonic detector array 4 suitable for receiving an ultrasonic signal, a wave manipulation device in the form of a micro-lens array assembly 12, and an ultrasonic detector 4. The ultrasonic detector 4 is in communication with an image generator 50, which in this example is a computer 53 having software running

thereon for causing the computer 53 to receive signals from the detector 4, interpret those signals as fingerprint information, and display an image of the fingerprint on the monitor 56.

The plane wave generator 1 may be made from a piezoelectric film. Such a generator 1 is described in more detail in Appendix A, which is attached hereto and made a part of this document.

The ultrasonic detector array 4 may be a hydrophone, or hydrophone array module, examples of which are described in Appendix B.

The embodiment of the invention that is shown in Figure 1 has each element 13 of the ultrasonic detector 4 aligned with an individual ultrasonic lens 19. Each lens 19 may refract the ultrasonic energy so as to focus the ultrasonic energy of the reflected plane wave onto an array element 13 to provide improved signal reception by the detector 4.

Such a fingerprint scanner may perform in the following manner. The plane wave generator 1 creates an ultrasonic wave, which emanates from the plane wave generator 1 both toward and away from the platen 7 surface, where the finger 5 is placed. The wave emanating from the generator 1 and traveling away from the platen 7 may be ignored by the detector 4. The wave emanating from the generator 1 and traveling toward the platen 7 reaches the platen 7 where the finger 5 has been placed, and at least some of the ultrasonic energy is reflected back toward the generator 1 by the platen 7 and some of the ultrasonic energy is reflected back toward the generator 1 by the finger 5. At those locations where fingerprint ridges 11 contact the platen 7, some of the ultrasonic energy travels into the finger 5 and some is reflected back. Where no part of the finger touches the platen 7 - e.g. where fingerprint valleys are located - some of the ultrasonic energy that passed through the platen 7 will be reflected back once it reaches the surface of the finger 5.

When an ultrasonic pulse reaches the finger, at least some of the ultrasonic energy is reflected back toward the detector 4. The amount of energy reflected back will be different depending upon whether the reflection is caused by a ridge or a valley of the fingerprint. At a valley, all or nearly all of the energy is reflected back, because air is in contact with the platen

7. At a ridge, most of the energy is absorbed by the finger and only a small quantity of ultrasonic energy is reflected back. At the ridge-valley transition region, the energy reflected back will be between these two values. The detector 4 then measures the amount of energy received, and then the computer 53 translates that value into the grey scale image that is
5 displayed on monitor 56?]

The waves reflected back, which carry image information about the fingerprint, pass through the plane wave generator 1 where a small portion of the energy may be absorbed, reflected and scattered. Most of the reflected ultrasonic energy continues through the generator 1 toward the ultrasonic detector array 4. Upon reaching the micro-lens assembly
10 12, each lens 19 focuses the reflected ultrasonic energy onto the associated array element 13. The array element 13 detects the reflected ultrasonic energy and converts it into an electric signal that may be measured and used with the signals from all of the other array elements 13 to create a grey-scale image of the fingerprint.

The platen 7 may be constructed to prevent electrostatic discharge with the detector
15 array elements 13. For example, the platen 7 may be a polycarbonate layer approximately 1/32 inch thick. Other suitable materials include acrylic, polystyrene or an insulating plastic material. The platen 7 provides a surface on which a finger may be placed.

A 0.001 inch thick layer of epoxy adhesive may be used to bond the plane wave generator 1 to the platen 7. The plane wave generator 1 may be a 0.001 inch thick layer of
20 piezoelectric material, for example PVDF or PVDF-TrFE copolymer. A 0.001 inch thick layer of epoxy adhesive may be used to bond a 1/32 inch thick second layer of polycarbonate (or acrylic, polystyrene or an insulating plastic material) to the plane wave generator 1.

Figure 2 depicts an embodiment of the invention in which a fingerprint scanner uses a plane wave generator 1, an ultrasonic detector array 4 suitable for receiving an ultrasonic
25 signal, and a wave manipulation device, which in this embodiment is a compound lens assembly 10 that transfers the reflected ultrasonic energy to the ultrasonic detector array 4. In the embodiment depicted in Figure 2, the first lens 2 is plano-concave and the second lens 2

is concave-concave. The lenses of the assembly 10 may be made from a material such as polystyrene, acrylic resin or silicone rubber.

5 In the embodiment depicted in Figure 2, (as in the device of Figure 1) a plane wave pulse may be generated by the plane wave generator 1, and the pulse may travel toward the platen 7 and finger 5. Upon reaching the platen 7 and finger 5, ultrasonic energy may be reflected back. The reflected energy travels back through the plane wave generator 1 and the transmission media 3. The compound lens system 10 shapes the reflected energy and directs it toward the ultrasonic detector array 4 where it is received at each element 13. The image information from each array element 13 may be used to create a two dimensional grey-scale image 6 of the fingerprint. Although the image 6 is depicted in Figure 2 as being on the detector 4, this is done merely to illustrate the orientation of the image 6 in relation to the orientation of the finger 5 - the image 6 will normally be presented on a device that is distant from the detector 4, such as on the monitor 56. Having shown the computer 53 and monitor 56 in two figures, it will be understood that the computer 53 and monitor 56 may be connected to the detector 4 in the other embodiments of the invention, and so the computer 53 and monitor 56 will not be repeatedly illustrated in the other figures, even though it will be understood that these devices may be used in the embodiments illustrated in those other figures.

20 Figure 3 shows an embodiment of the invention in which a fingerprint scanner uses a plane wave generator 1, an ultrasonic detector array 4 suitable for receiving an ultrasonic signal, and a wave manipulation device, which in this embodiment is an ellipsoidal reflector 9 that reflects the ultrasonic energy that was reflected by the finger 5 to the ultrasonic detector array 4. The reflector 9 may be a polished polystyrene surface or a metallized surface. The reflector 9 may also be polished glass, acrylic, aluminum, or steel.

25 In the embodiment depicted in Figure 3, a plane wave pulse is generated by the plane wave generator 1. The pulse travels toward the platen 7 and finger 5, which is located at one of the ellipsoid's focal points. Upon reaching the platen 7, some of the ultrasonic energy may be reflected back while some travels into the finger. Additionally some of the energy may be

scattered. The reflected energy, for example the energy reflected by the valleys of the fingerprint, travels back through the plane wave generator 1 and the transmission media 3. The ellipsoidal reflector 9 reflects the ultrasonic energy that passed through the generator 1 to the ultrasonic detector array 4, which is located at the ellipsoid's second focal point, where
5 the reflected energy is received by the detector array 4. Signals from the detector array 4 correspond to the energy received, and may be used to create a two dimensional grey-scale image 6 of the fingerprint. Although the image 6 is depicted in Figure 3 as being on the detector 4, this is done merely to illustrate the orientation of the image 6 in relation to the orientation of the finger 5 - the image 6 will normally be presented on a device that is distant
10 from the detector 4, such as on the monitor 56.

Figure 4 shows an embodiment of the invention in which a fingerprint scanner uses a plane wave generator 1, an ultrasonic detector array 4 suitable for receiving an ultrasonic signal, and a wave manipulation device, which in this embodiment is a substantially flat surface reflector 8 that may be a surface of a prism. The prism may be made from a material
15 such as polystyrene, acrylic resin or silicone rubber. The reflector 8 transfers the ultrasonic energy that was reflected by the finger 5 to the ultrasonic detector array 4. In this embodiment a plane wave pulse is generated by the plane wave generator 1. The pulse travels toward the platen 7 and finger 5. Upon reaching the finger 5, some of the ultrasonic energy may be reflected back while some travels into the finger. Additionally some of the
20 energy may be scattered. The reflected energy travels back through the plane wave generator 1 and the transmission media 3. The reflector 9 transfers the ultrasonic energy to ultrasonic detector array 4. The signals from each array element 13 of the detector 4 may be used to create a two dimensional grey-scale image 6 of the fingerprint. Although the image 6 is depicted in Figure 4 as being on the detector 4, this is done merely to illustrate the orientation
25 of the image 6 in relation to the orientation of the finger 5 - the image 6 will normally be presented on a device that is distant from the detector 4, such as on the monitor 56.

It should be noted that the embodiment of Figure 4 has the generator 1 oriented substantially at right angles to the detector 4. Other embodiments of the invention are shown

herein (see Figures 9, 10, 15 and 16) with the generator 1 and the detector 4 oriented substantially at right angles to each other.

Figure 5 shows an embodiment of the invention in which a fingerprint scanner uses a plane wave generator 1, an ultrasonic detector array 4 suitable for receiving an ultrasonic
5 signal, and a wave manipulation device, which in this embodiment is a pair of matched ultrasonic lenses 2. The lenses 2 may be made from a material such as polystyrene, acrylic resin or silicone rubber. It will be recognized that the lenses 2 will manipulate the ultrasonic energy reflected by the finger 5 so as to produce an inverted image, once the computer 53 processes the signals received from the detector 4. In this embodiment a plane wave pulse
10 may be generated by the plane wave generator 1. The pulse travels toward the platen 7 and finger 5. Upon reaching the platen imaging surface 7, some of the ultrasonic energy may be reflected back while some travels into the fingerprint ridges and finger. Additionally some of the energy may be scattered. The reflected energy travels back through the plane wave generator 1 and the transmission media 3. A first plano-curved lens 2 shapes the reflected
15 energy pulse and directs it through the media 3 toward a second plano-curved lens 2 where the wave (represented by rays) is re-collimated before going on to the ultrasonic detector 4 where it is received at each element 13. The image information from each array element 13 may be used to create a two dimensional grey-scale image 6 of the fingerprint. Although the image 6 is depicted in Figure 5 as being on the detector 4, this is done merely to illustrate the
20 orientation of the image 6 in relation to the orientation of the finger 5 - the image 6 will normally be presented on a device that is distant from the detector 4, such as on the monitor 56.

Figure 6 shows an embodiment of the invention in which a fingerprint scanner uses a plane wave generator 1, an ultrasonic detector 4 suitable for receiving and detecting
25 ultrasonic energy, and a wave manipulation device, which in this embodiment is a single ultrasonic lens 2 that may be used to focus the ultrasonic energy onto an ultrasonic detector array 4 that is smaller than the finger 5. The lens 2 may be made from a material such as polystyrene, acrylic resin or silicone rubber. In this embodiment of the invention, a plane wave pulse may be generated by the plane wave generator 1. The pulse travels toward the

platen 7 and finger 5. Upon reaching the platen imaging surface 7, some of the ultrasonic energy may be reflected back while some travels into the fingerprint ridges and finger. Additionally some of the energy may be scattered. The reflected energy travels back through the generator 1 and the transmission media 3. A plano-curved lens 2 shapes the pulse and
5 directs it toward the ultrasonic detector array 4 where it is received at each element 13. The signals generated by the elements 13 may be used by the computer 53 to create a two dimensional grey-scale image 6 of the fingerprint. Although the image 6 is depicted in Figure 6 as being on the detector 4, this is done merely to illustrate the orientation of the image 6 in relation to the orientation of the finger 5 - the image 6 will normally be presented
10 on a device that is distant from the detector 4, such as on the monitor 56.

Figure 7 shows an embodiment of the invention which is similar to that shown in Figure 6. However, unlike the embodiment of Figure 6, in the embodiment depicted in Figure 7 the ultrasonic energy received at the detector 4 will produce an inverted image because the detector 4 is located beyond the focal point of the lens 2. In this embodiment a
15 plane wave pulse is generated by the plane wave generator 1. The pulse travels toward the platen 7 and finger 5. Upon reaching the platen imaging surface 7, some of the ultrasonic energy may be reflected back while some travels into the fingerprint ridges and finger 5. Additionally some of the energy may be scattered. The reflected energy travels back through the plane wave generator 1 and the transmission media 3. A plano-curved lens 2 shapes the
20 pulse and directs it toward the ultrasonic detector array 4 where it is received at each element 13. The image information from each array element 13 may be used to create a two dimensional grey-scale image 6 of the fingerprint. Although the image 6 is depicted in Figure 7 as being on the detector 4, this is done merely to illustrate the orientation of the image 6 in relation to the orientation of the finger 5 - the image 6 will normally be presented
25 on a device that is distant from the detector 4, such as on the monitor 56.

Figure 8 shows an embodiment of the invention in which a fingerprint scanner uses a plane wave generator 1, an ultrasonic detector array 4 suitable for receiving ultrasonic energy, and a wave manipulation device, which in this embodiment is a single ultrasonic lens 14 that is not flat on either side. The lens depicted in Figure 8 is a convex-convex lens. The

lens 14 may be made from a material such as polystyrene, acrylic resin or silicone rubber. The lens 14 may be used to focus the reflected ultrasonic energy onto an ultrasonic detector array 4 while inverting the fingerprint image 6. In this embodiment a plane wave pulse is generated by the plane wave generator 1. The pulse travels toward the platen 7 and finger 5. Upon reaching the platen imaging surface 7, some of the ultrasonic energy may be reflected back while some travels into the fingerprint ridges and finger 5. Additionally some of the energy may be scattered. The reflected energy travels back through the plane wave generator 1 and the transmission media 3. A double-curved lens 14 shapes the pulse and directs it toward the ultrasonic detector 4 where it is received at each element 13. The image information from each array element 13 may be used to create a two dimensional grey-scale image 6 of the fingerprint. Although the image 6 is depicted in Figure 8 as being on the detector 4, this is done merely to illustrate the orientation of the image 6 in relation to the orientation of the finger 5 - the image 6 will normally be presented on a device that is distant from the detector 4, such as on the monitor 56.

Figure 9 shows an embodiment of the invention in which a fingerprint scanner uses a plane wave generator 1, an ultrasonic detector array 4 suitable for receiving an ultrasonic signal, and a wave manipulation device, which in this embodiment is a splitter 18 that is partially reflective and partially transmissive, so that some of the ultrasonic energy impacting the splitter 18 may be reflected toward the platen 7 and finger 5, and so that some of the ultrasonic energy reflected from the finger is allowed to pass through the splitter 18 and continue on to the ultrasonic detector array 4. The splitter may be formed from a material such as paper or mylar. In this embodiment a plane wave pulse is generated by the plane wave generator 1. The pulse travels toward the splitter 18. The splitter 18 reflects a portion of the ultrasonic energy from the pulse toward the platen 7 and finger 5. Some of the ultrasonic energy received by the finger 5 may be reflected back while some travels into the fingerprint ridges and finger. Additionally some of the energy may be scattered. The reflected energy travels back and passes through the splitter 18 and the transmission media 3. After passing through the splitter 18, the reflected energy continues toward the ultrasonic detector array 4 where it is received at each element 13. The image information from each array element 13 may be used to create a two dimensional grey-scale image 6 of the

fingerprint. Although the image 6 is depicted in Figure 9 as being on the detector 4, this is done merely to illustrate the orientation of the image 6 in relation to the orientation of the finger 5 - the image 6 will normally be presented on a device that is distant from the detector 4, such as on the monitor 56.

5 Figure 10 shows a modified version of the fingerprint scanner shown in Figure 9. In this embodiment an ultrasonic compound lens assembly 10 may be used to focus the ultrasonic energy onto the ultrasonic detector array 4. The lens assembly 10 may be made from a material such as polystyrene, acrylic resin or silicone rubber. This arrangement may be used if the ultrasonic detector array 4 is smaller than the area of the finger 5 that is
10 required for imaging.

 Figures 11A and 11B are simplified diagrammatic versions of a fingerprint scanner according to the invention, and these figures may be used to illustrate aspects of some of the embodiments described herein. The plane wave pulse generator 1 creates an ultrasonic pulse 16. The ultrasonic pulse 16 travels through the transmission media 3 to the platen 7 where it
15 continues to the platen 7 and finger 5. Fingerprint ridges in contact with the platen 7 allow some of the ultrasonic energy to continue into the finger, some to be scattered, and some to be reflected. The valleys of the fingerprint will also reflect some of the ultrasonic energy. The reflected ultrasonic energy is shown as feature 17 in Figure 11A. The reflected energy travels back and passes through the plane wave generator 1 continuing on to the wave
20 manipulation device (in this case a lens 2) that alters the direction of the ultrasonic energy, for example by reflection or by refraction depending upon the devices used. Finally the reflected energy is received by the ultrasonic detector 4 and may be converted into an image 6 of the finger surface. Although the image 6 is depicted in Figure 11A and 11B as being on the detector 4, this is done merely to illustrate the orientation of the image 6 in relation to the
25 orientation of the finger 5 - the image 6 will normally be presented on a device that is distant from the detector 4, such as on the monitor 56.

 Figure 11B shows two cycles of the operation of the system. In the pulse cycle, the plane wave is generated and travels in both directions away from the plane wave generator 1.

In the echo cycle the wave is shown reflected from the finger 5, passing through the plane wave generator 1, being modified by the lens system 2 and finally arriving at the ultrasonic detector 4 to be processed into a grey-scale image 6.

5 There may be situations in which increased resolution may be required, but where manufacturing considerations limit the size of the detector array element. In those situations, it may be necessary to enlarge the image of the object that is in contact with the platen. In this case, the detector may be manufactured larger than the object being imaged, and a lens system may be used to expand the reflected energy i.e. enlarge the footprint of the energy. Such a system is shown in Figure 13. In Figure 13, the lens assembly 10 has plano-convex
10 lenses.

Figure 14 shows an embodiment of the invention similar to that of Figure 1, but in this embodiment the lens array elements 19 are larger than the elements 13 of the detector 4, and energy emanating from a particular elements 19 may impact multiple detector elements 13. In operation each lens array element 19 transfers reflected ultrasonic energy to a group of
15 detector elements 13, instead of individual detector elements 13. Use of such a lens array allows for shorter image transfer distances.

Figure 15 shows an embodiment of the invention in which the plane wave pulse generator 1 and the piezoelectric detector 4 are mounted to the right angle surfaces of a 45-90-45 prism 20 and the ultrasonic energy may be transferred using frustrated total internal
20 reflection ("FTIR") with the finger platen constituting the long-dimension side of the prism 20. It should be noted that the FTIR image received at the detector 4 will be 70.7% of its original size in one direction (in the plane of the diagram shown) and will be its original size in the other dimension (perpendicular to the diagram shown).

Figure 16 depicts an embodiment of the invention similar to that of Figure 15, but an
25 ultrasonic compound cylindrical lens system 21, mounted with the axis of the cylinder parallel to the parallel vertex lines of the prism 20, is used to restore the image aspect ratio back to a 1:1 ratio.

Figure 17 shows an embodiment of the invention in which a fingerprint scanner uses a plane wave generator 1, an ultrasonic detector array 4 suitable for receiving an ultrasonic signal, and a plate array 22 of ultrasonic waveguide elements. The ultrasonic fiber plate may be similar in construction to a photonic type fiber optics plate. Many fibers may be bundled
5 together and fused, bonded or potted so that they have substantially the same orientation.

Once bundled, the fibers may be sliced perpendicular to the fibers into sheets of the thickness needed to form the plate.

The individual fibers may be constructed by creating a cylinder of the core material selected for its ultrasound transmission qualities. The core then may be clad with another
10 material having a substantially lower speed of sound. The cylinder of core and cladding may be heated to soften the core and cladding, and drawn out until the desired diameter is obtained. This creates an ultrasonic fiber which uses total internal reflection to guide ultrasonic energy from one end of the fiber to another end of the fiber. In one particular embodiment where a resolution of 500 dots per inch is needed, each fiber has a diameter of
15 about 0.002 inches, which is comprised of a 0.0015 inch diameter core of polystyrene and a 0.00025 inch thick cladding of acrylic or glass. Each fiber of the plate array uses internal reflection to prevent the ultrasonic energy from spreading, and in this manner alters the direction of the ultrasonic energy.

In the embodiment depicted in Figure 17, upon reaching the ultrasonic waveguide
20 fiber array 22, each fiber guides the ultrasonic energy onto the corresponding array element 13. Each of the array elements 13 detects the ultrasonic energy and converts it into an electric signal that may be measured and used with the signals from all of the other array elements 13 to create a grey-scale image of the fingerprint.

In the embodiment depicted in Figure 17 there is a platen 7 on which the finger is
25 positioned. The platen 7 may be 1/32 to 3/32 inches thick. In a variation of this embodiment, the platen is a plastic layer approximately 0.005 to 0.010 inches thick. A 0.001 inch thick layer of epoxy adhesive may be used to bond the plane wave generator 1 to the platen 7. A

0.001 inch thick layer of epoxy adhesive may be used to bond an ultrasonic fiber plate 22 to the plane wave generator 1.

Figure 18 is a diagram of a fingerprint scanner according to the invention, which uses a plane wave generator 1, an ultrasonic detector array 4 suitable for receiving an ultrasonic
5 signal, and a plate array 22 of ultrasonic waveguide elements. Each array element 13 of the ultrasonic detector 4 may be aligned with an element of the ultrasonic waveguide array 22, which conducts the ultrasonic energy from the plane wave generator 1 onto an array element 13 to provide maximum signal reception. Such a fingerprint scanner may perform in the following manner. The plane wave generator 1 may create an ultrasonic wave of the
10 ultrasonic frequency necessary for the system. The wave may emanate from the plane wave generator 1 both toward and away from the platen 7 surface where the finger 5 is placed. The wave emanating from the generator 1 and traveling away from the platen 7 may be ignored by the detector 4. The wave emanating from the generator 1 and traveling toward the platen 7 may be guided by the plate array 22 of ultrasonic waveguide fibers, which may be an
15 integral part of the platen 7 on which the finger 5 has been placed. Some of the ultrasonic energy is reflected back by the finger, and this reflected energy passes through the plane wave generator 1 where a small portion of the energy may be absorbed, reflected and scattered. Most of the ultrasonic energy continues on toward the ultrasonic detector 4. Each array element 13 of the detector 4 detects the ultrasonic energy and converts it into an
20 electrical signal that may be measured and may be used with the signals from all of the other array elements to create a grey-scale image of the fingerprint.

Figure 19 is a diagram of a fingerprint scanner according to the invention, which uses a plane wave generator 1, an ultrasonic detector array 4 suitable for receiving an ultrasonic
25 signal, and a plate array of ultrasonic waveguide elements 22. Each array element 13 of the ultrasonic detector array 4 may be aligned with an individual ultrasonic lens that focuses the ultrasonic energy from the plane wave onto the array element 13 to provide maximum signal reception. Such a fingerprint scanner may perform in the following manner. The plane wave generator 1 may create an ultrasonic wave of the ultrasonic frequency necessary for the system. The wave may emanate from the plane wave generator 1 both toward and away from

the platen 7. The wave emanating from the generator 1 and traveling away from the platen 7 may be ignored by the detector 4. The wave emanating from the generator 1 and traveling toward the platen 7 reaches the platen 7 where the finger 5 has been placed. Upon reaching the finger 5, some of the ultrasonic energy may be reflected back and through the plane wave generator 1, and on to a second ultrasonic waveguide plate array toward the ultrasonic detector array 4. The individual ultrasonic waveguide fibers of the ultrasonic waveguide fiber array 22, guide the ultrasonic energy onto the corresponding array element 13. The array element 13 detects the ultrasonic energy and converts it into an electric signal that may be measured and used with the signals from all of the other array elements to create a grey-scale image of the fingerprint.

A plane wave generator 1, an ultrasonic detector array 4 and an ultrasonic manipulation device that transfers the ultrasonic image information of a biological object in contact with the imaging platen 7 surface to the ultrasonic detector array 4 may be used to obtain information about an object that is in contact with the platen, and the information may be used to generate an image of the object. Although the invention has been described in conjunction with a fingerprint scanner or reader, the invention can be used in other applications which seek to create an ultrasonic image of an object.

Having described many devices which embody the invention, it will be recognized that the invention may be embodied as a method of creating an image of a biological object having a surface to be imaged. For example, the biological object may be a finger and the surface may be the friction ridge surface (fingerprint) of the finger. Figure 20 depicts one such method in which an unfocussed ultrasonic energy wave front is emitted 200, and at least some of the energy wave front is reflected 203 by the biological object. For example, the valleys of a fingerprint may reflect the ultrasonic energy. The reflected energy is manipulated 206 so that a direction of the ultrasonic energy is altered, and then that reflected energy is detected 209. The direction of the energy may be altered by refraction (such as by an ultrasonic lens) or reflected (such as by an ultrasonic mirror or waveguide), or a combination of refraction and reflection. An image may then be created 212 using the detected energy. Devices for creating the image from the detected energy are well known,

and will not be described in detail in this document. However, one such device is disclosed in U.S. Patent No. 6,552,841.

Those skilled in the art will recognize that this invention is not limited to the embodiments and applications disclosed. They will also recognize that for any configuration
5 presented that the mechanics of imaging a same size image, an enlarged image or a reduced image may be similar in practice and that they may differ in the optics system selected for the particular embodiment.

Although the present invention has been described with respect to one or more particular embodiments, it will be understood that other embodiments of the present
10 invention may be made without departing from the spirit and scope of the present invention. Hence, the present invention is deemed limited only by the appended claims and the reasonable interpretation thereof.

What is claimed is:

1. A biological object reader, comprising:

a plane wave ultrasonic pulse generator capable of producing an unfocussed ultrasonic energy wave;

5 an ultrasonic wave manipulation device which alters the direction of at least some of the ultrasonic energy produced by the generator after the energy is reflected by an object being imaged;

an ultrasonic detector positioned to detect ultrasonic energy reflected from a biological object being imaged; and

10 an image generator, capable of creating an image of the object using the detected ultrasonic energy.

2. The biological object reader of claim 1, wherein the wave manipulation alters the direction of the ultrasonic energy so as to enlarge a footprint of the reflected ultrasonic energy.

15 3. The biological object reader of claim 1, wherein the wave manipulation device includes an ultrasonic lens.

4. The biological object reader of claim 1, where the wave manipulation device includes an array of lenses.

5. The biological object reader of claim 1, wherein the wave manipulation device
20 includes a first plano-concave lens and a second plano-concave lens.

6. The biological object reader of claim 1, wherein the wave manipulation device includes a first plano-convex lens and a second plano-convex lens.

7. The biological object reader of claim 1, wherein the wave manipulation device includes a concave-concave lens.

8. The biological object reader of claim 1, wherein the wave manipulation device includes a convex-convex lens.
9. The biological object reader of claim 1, wherein the wave manipulation device is an ultrasonic mirror.
- 5 10. The biological object reader of claim 1, wherein the wave manipulation device is partially reflective and partially transmissive.
11. The biological object reader of claim 10, wherein the mirror is substantially flat.
12. The biological object reader of claim 10, wherein the mirror is curved.
13. The biological object reader of claim 12, wherein the mirror is ellipsoidal.
- 10 14. The biological object reader of claim 1, wherein the pulse generator and the detector are oriented substantially at right angles to each other.
15. A method of imaging a biological object, comprising:
emitting an unfocussed ultrasonic energy wave front;
reflecting the ultrasonic energy with a biological object having a surface to be
15 imaged;
manipulating the reflected ultrasonic energy so that a direction of the ultrasonic energy is altered;
detecting the reflected ultrasonic energy;
creating an image of the surface using the detected ultrasonic energy.
- 20 16. The method of claim 15, wherein the direction of the ultrasonic energy is altered by reflecting the ultrasonic energy.
17. The method of claim 15, wherein the direction of the ultrasonic energy is altered by refracting the ultrasonic energy.

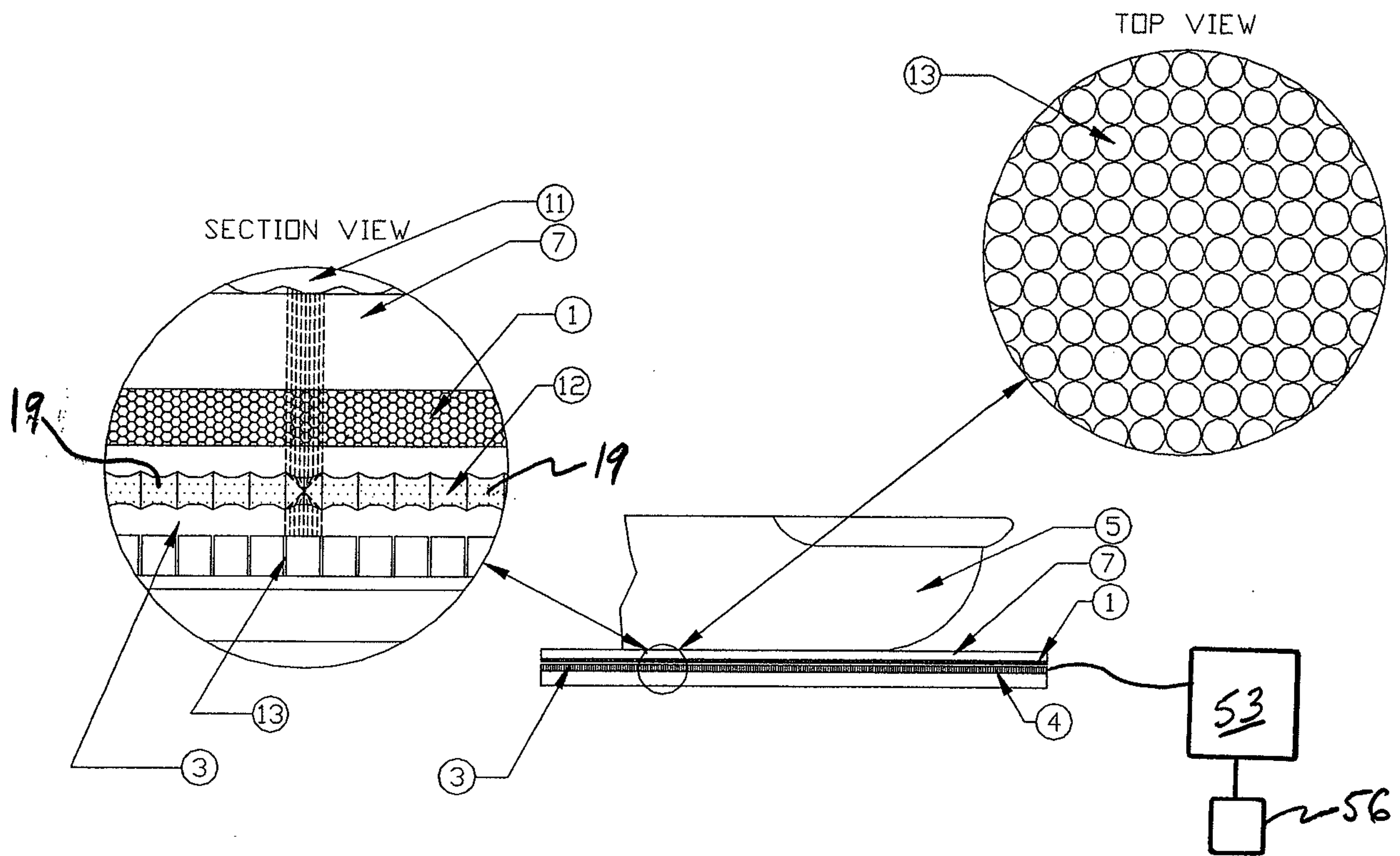


Figure 1

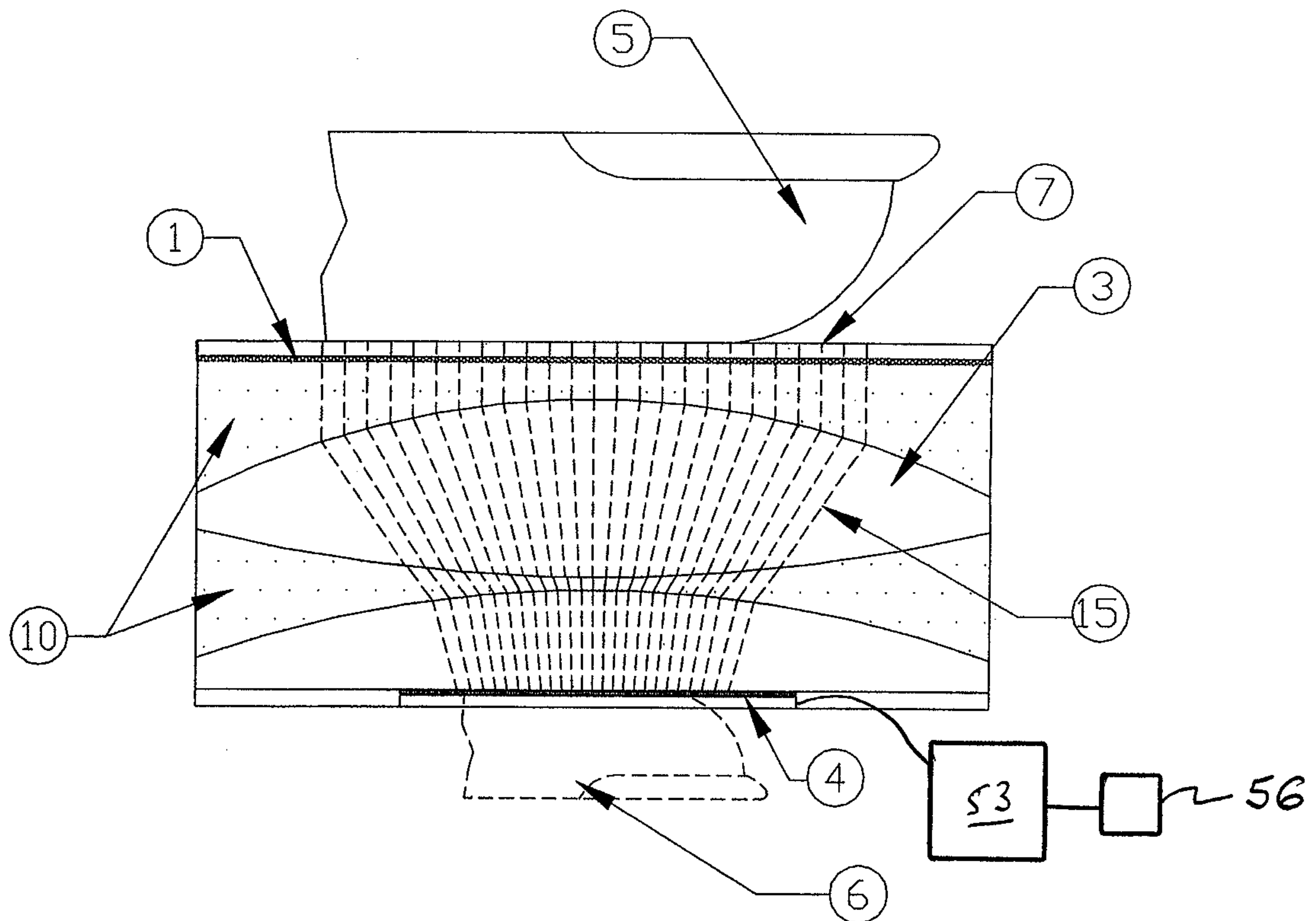


Figure 2

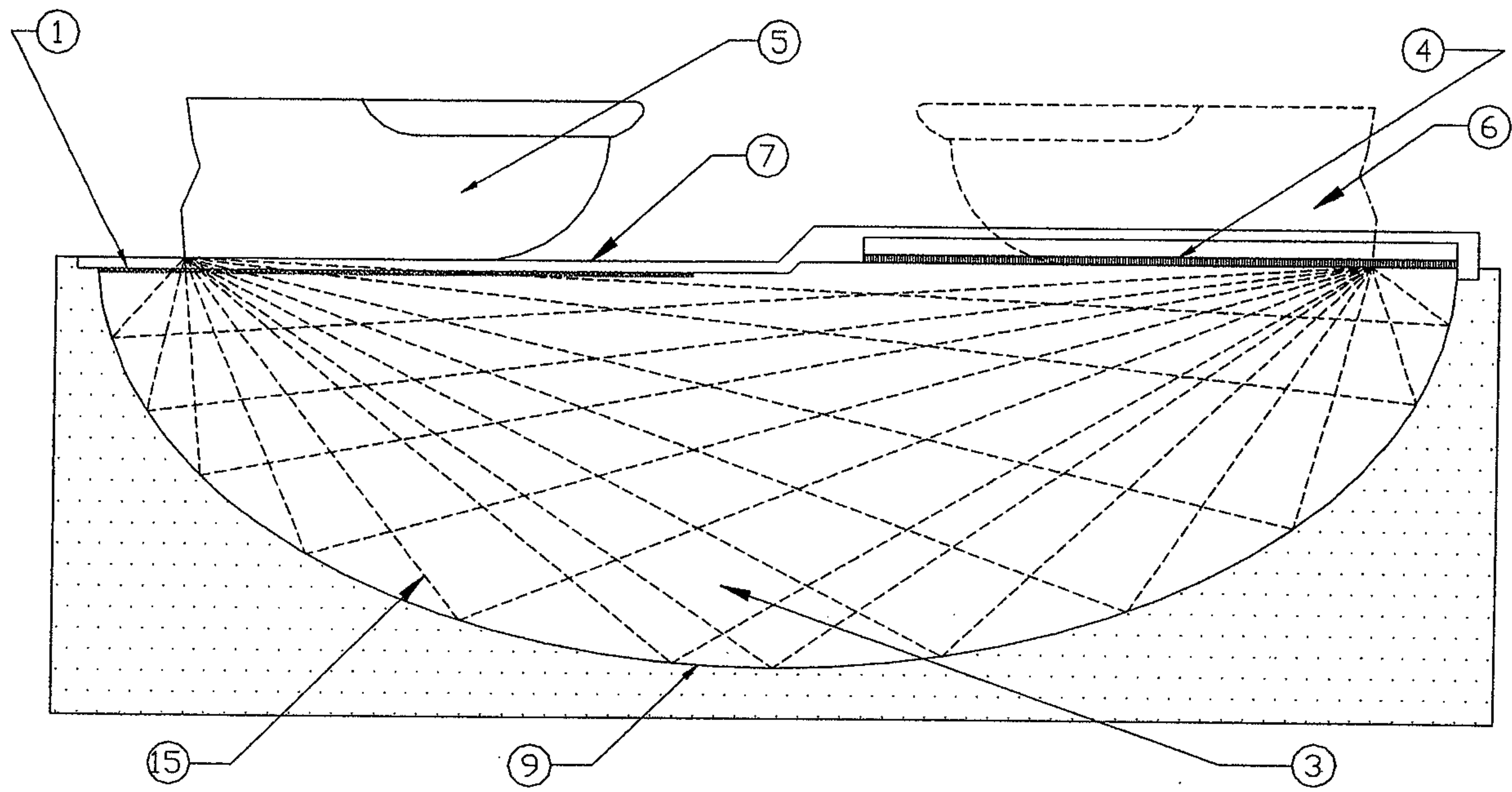


Figure 3

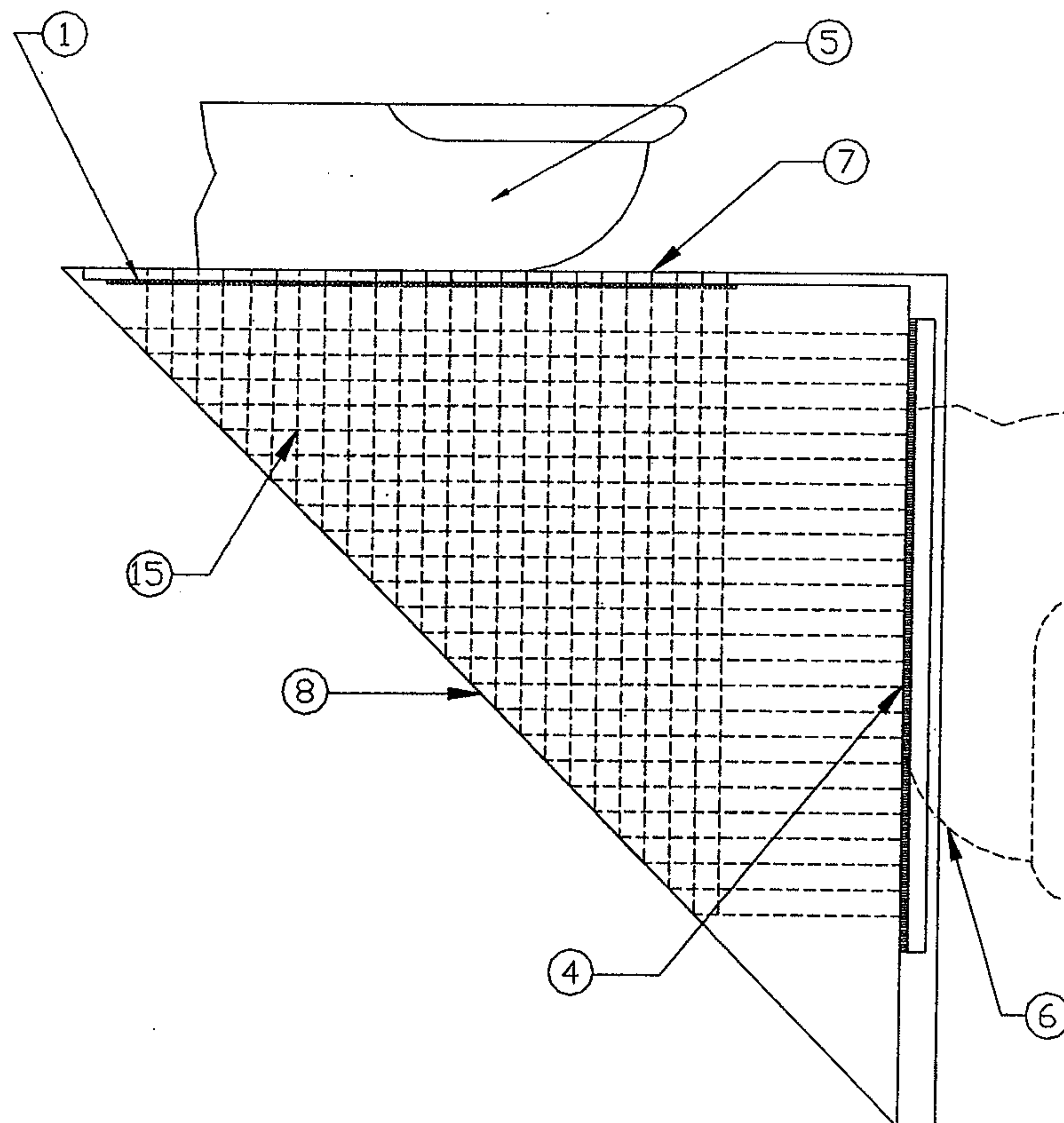
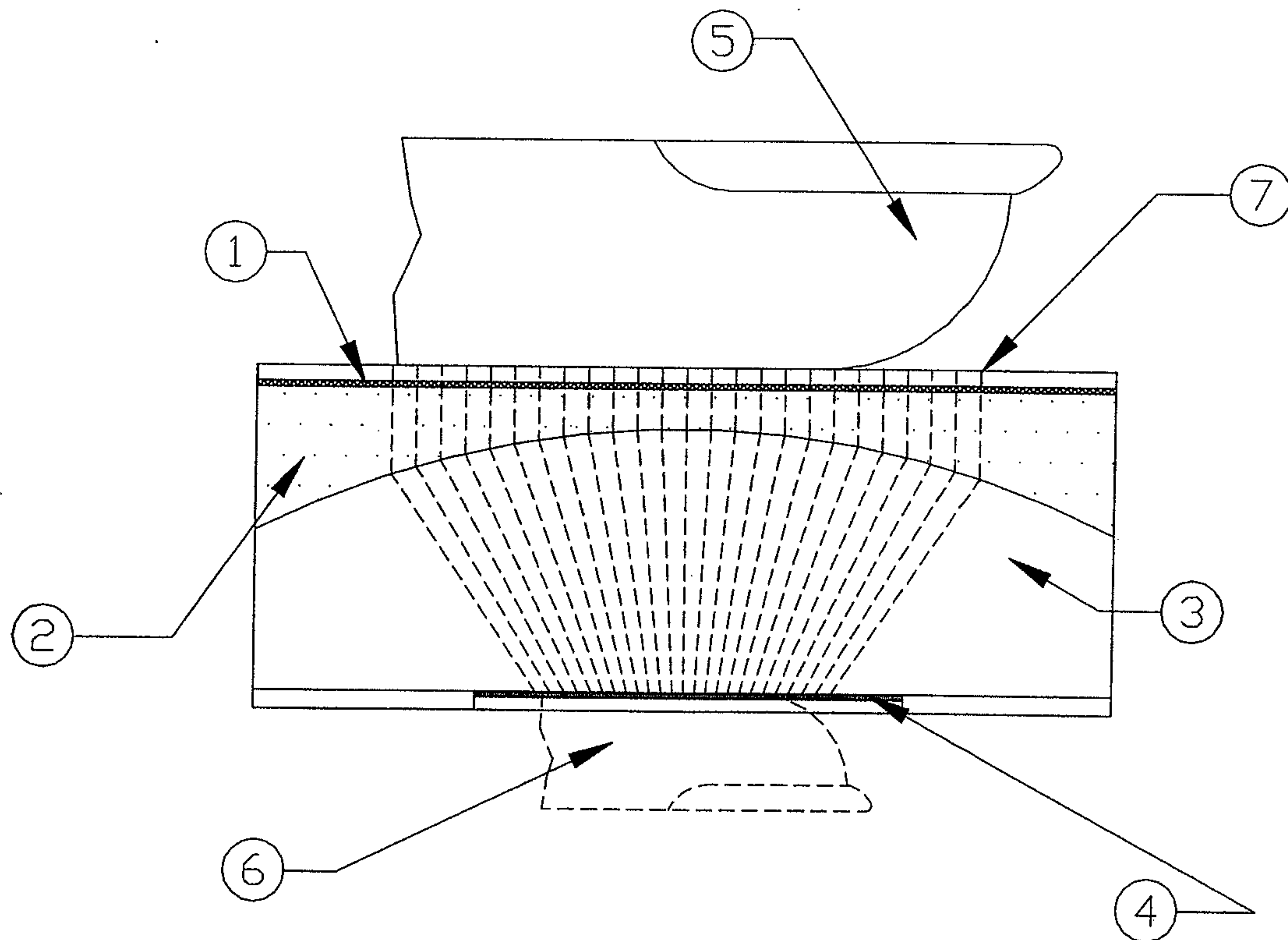
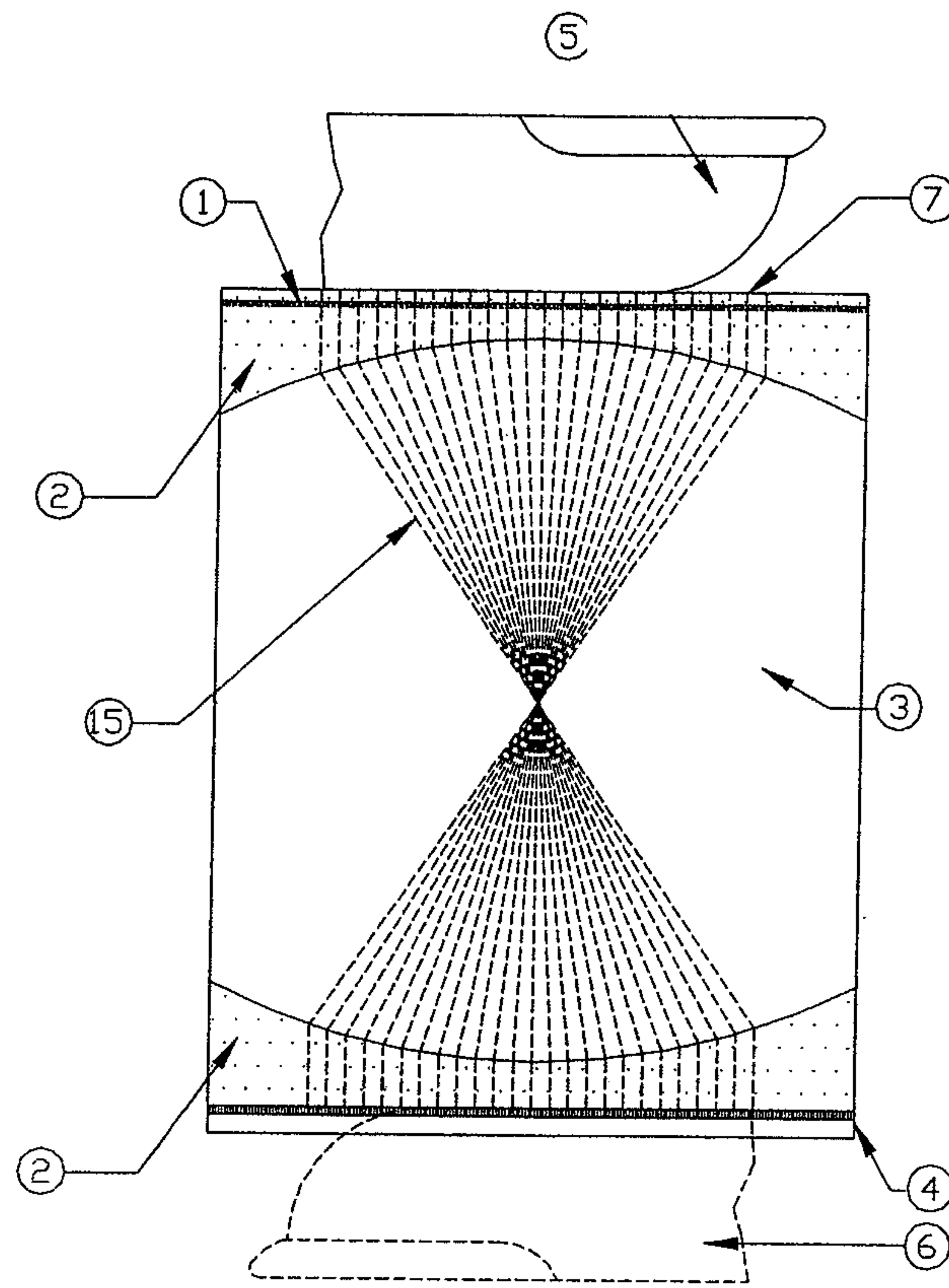


Figure 4



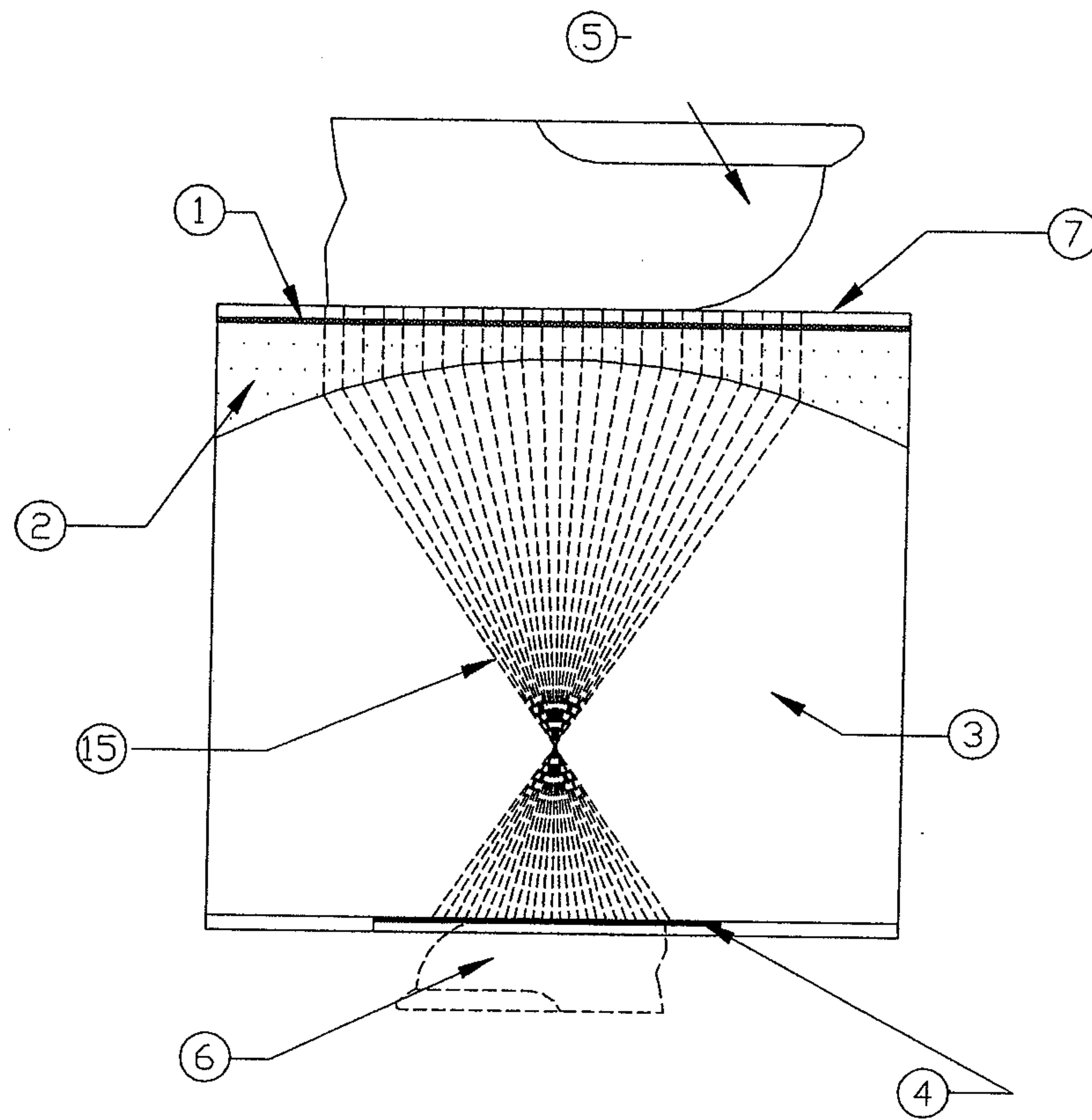


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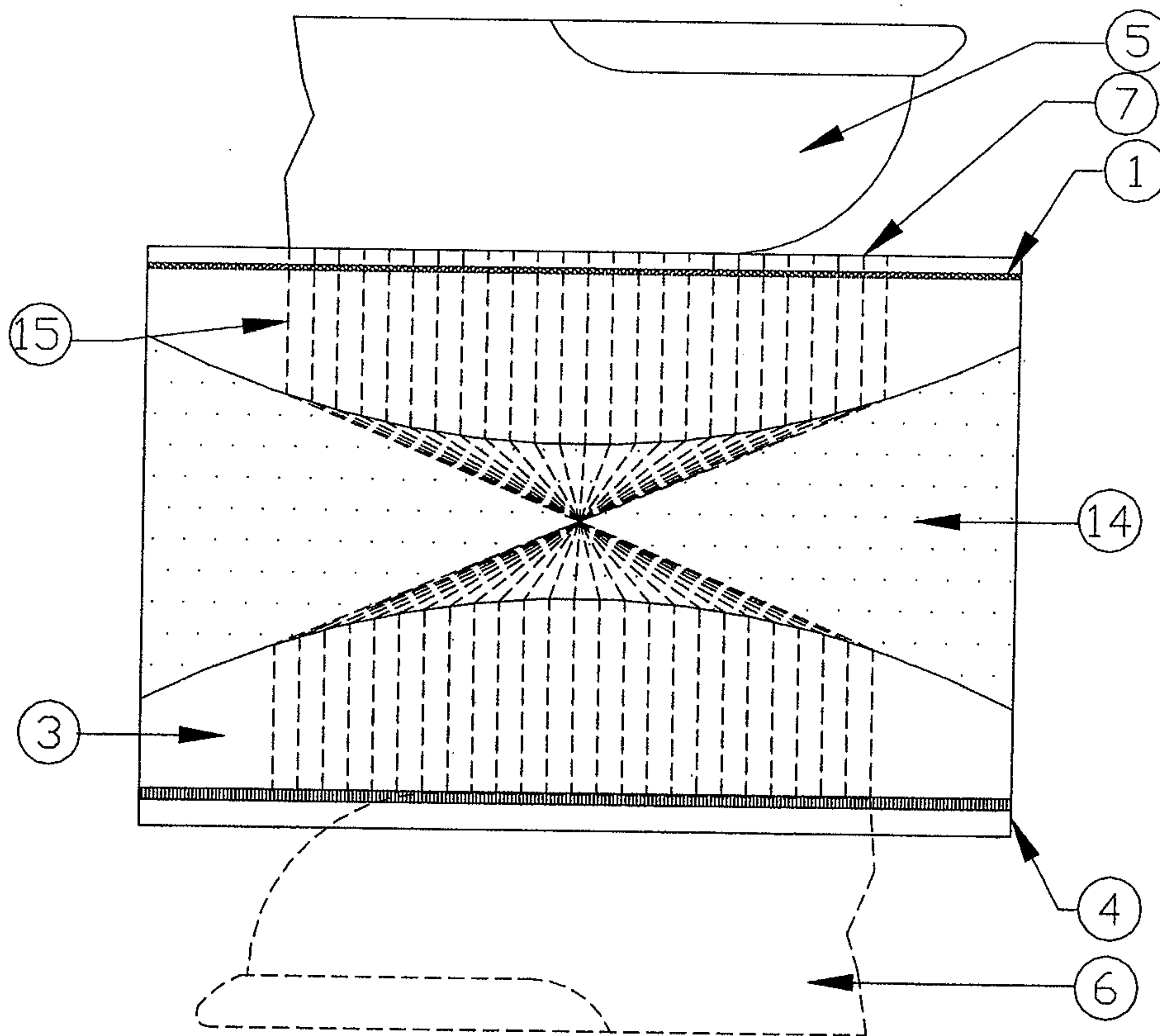


Figure 8

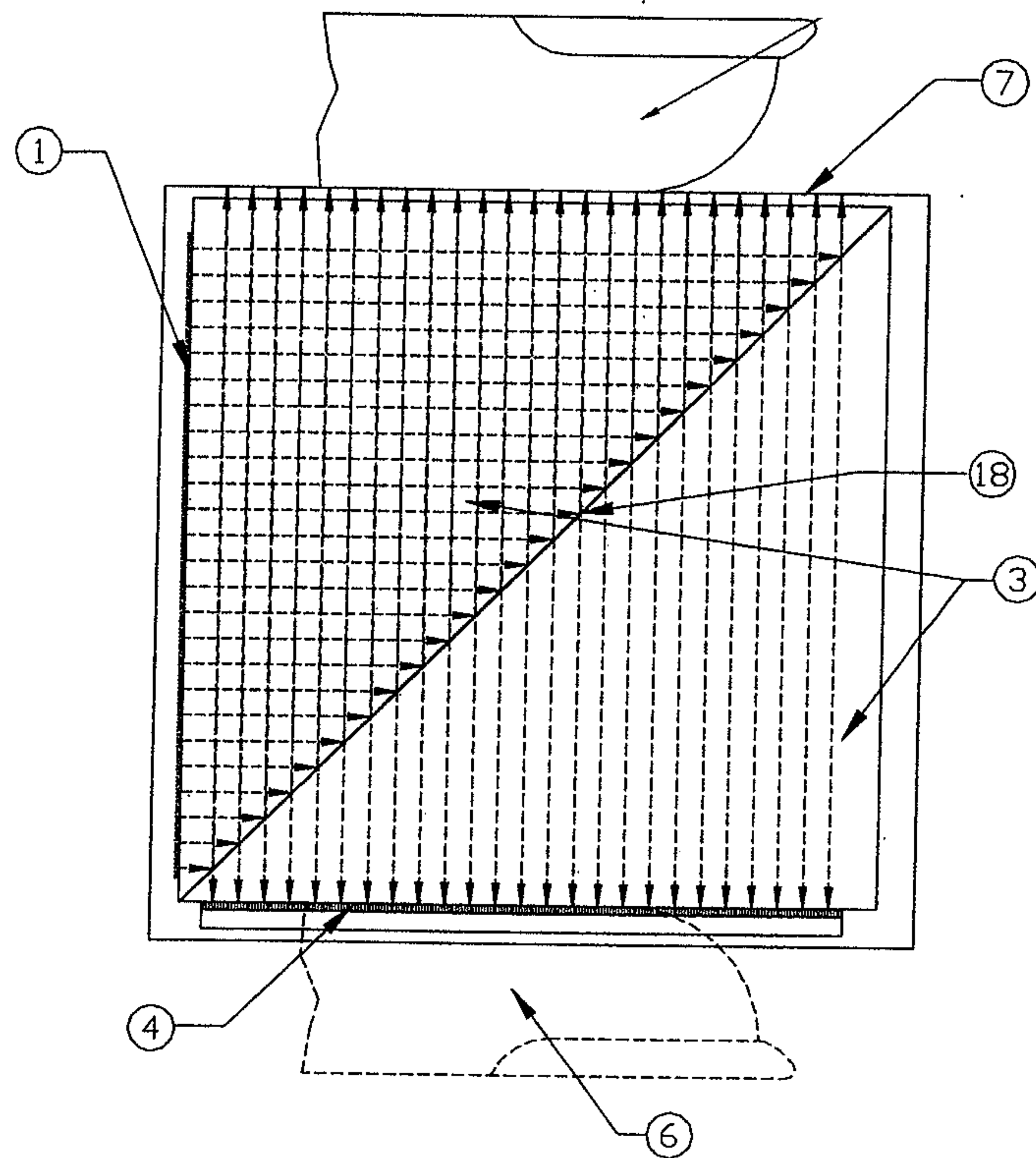


Figure 9

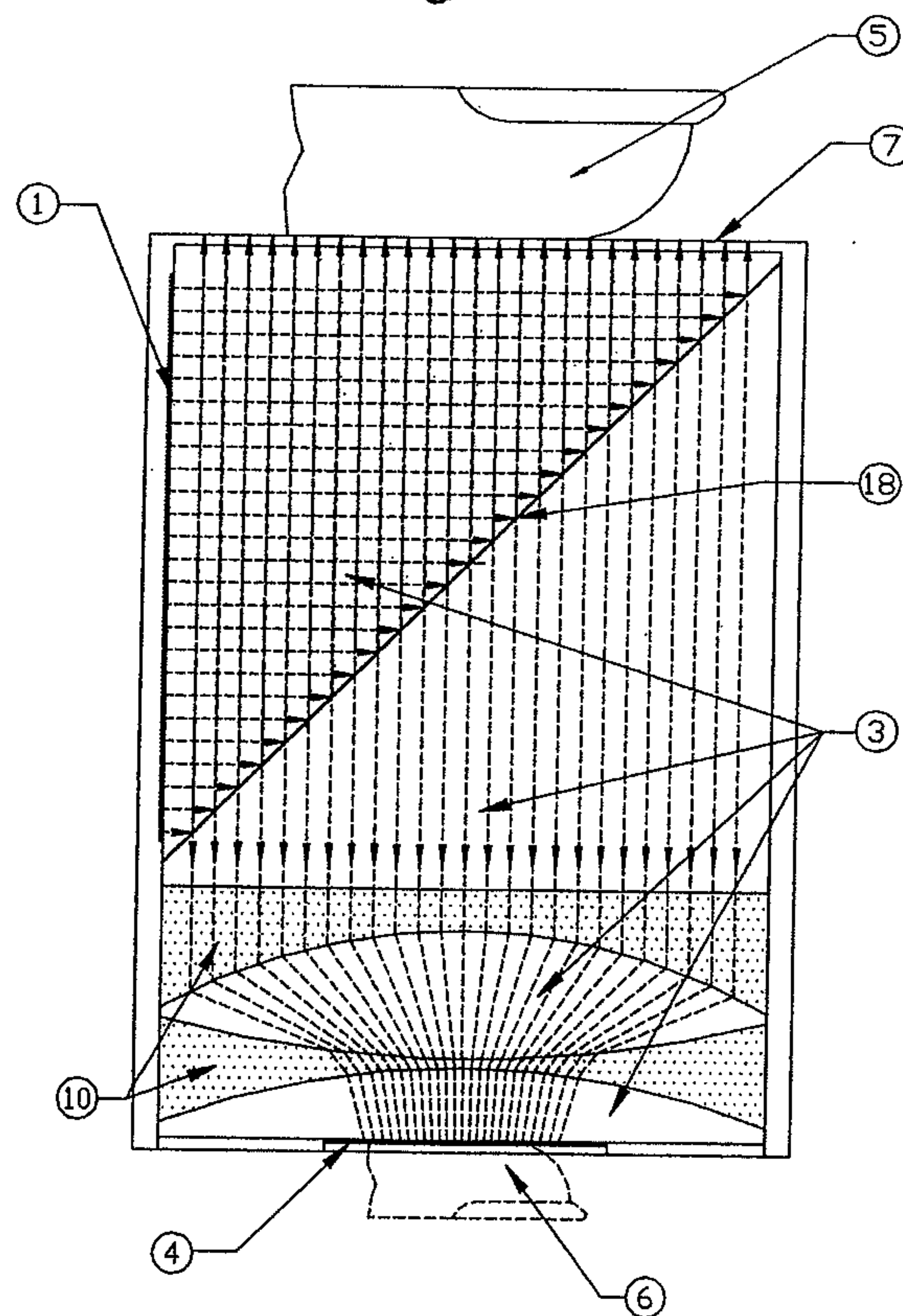


Figure 10

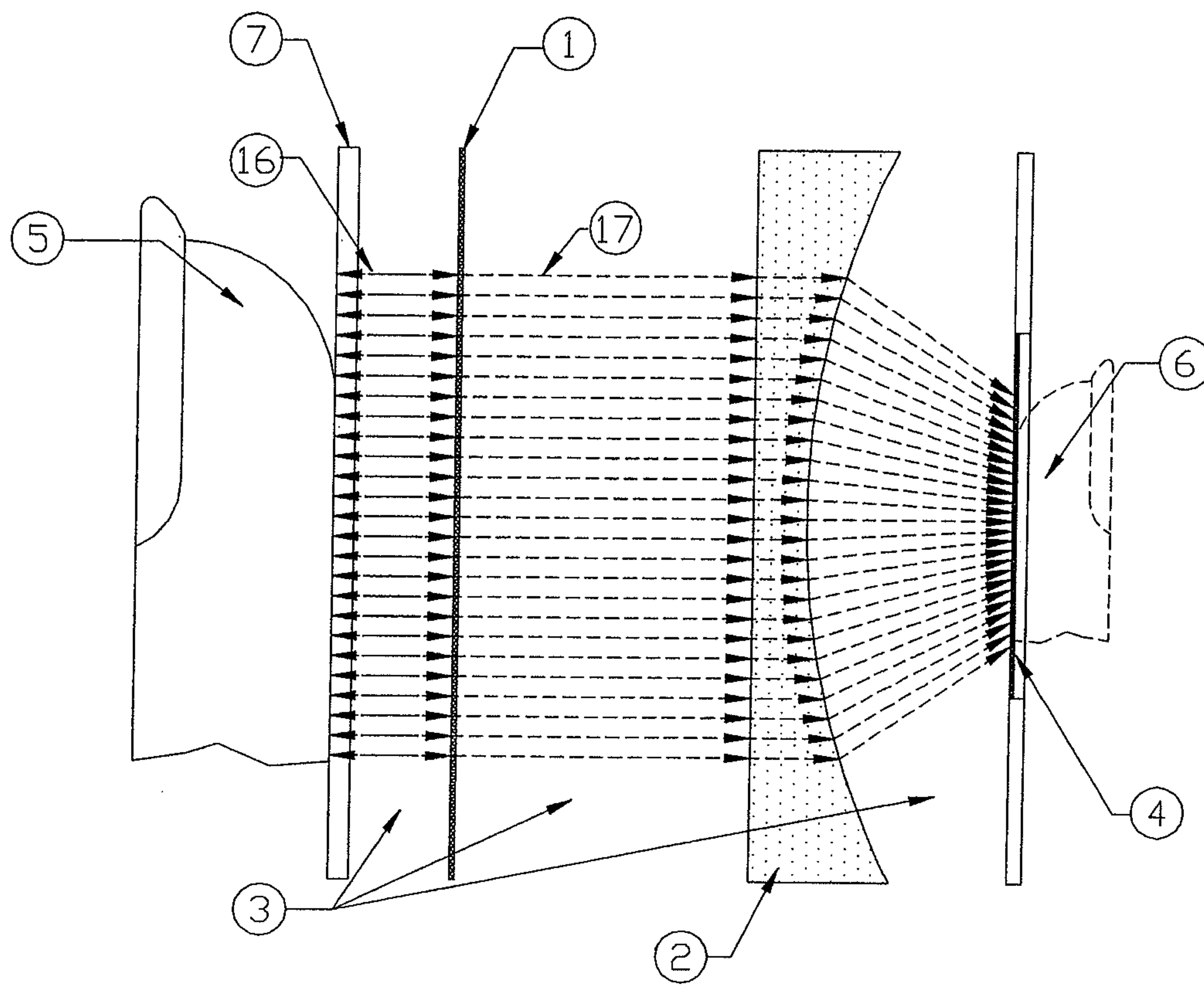


Figure 11A

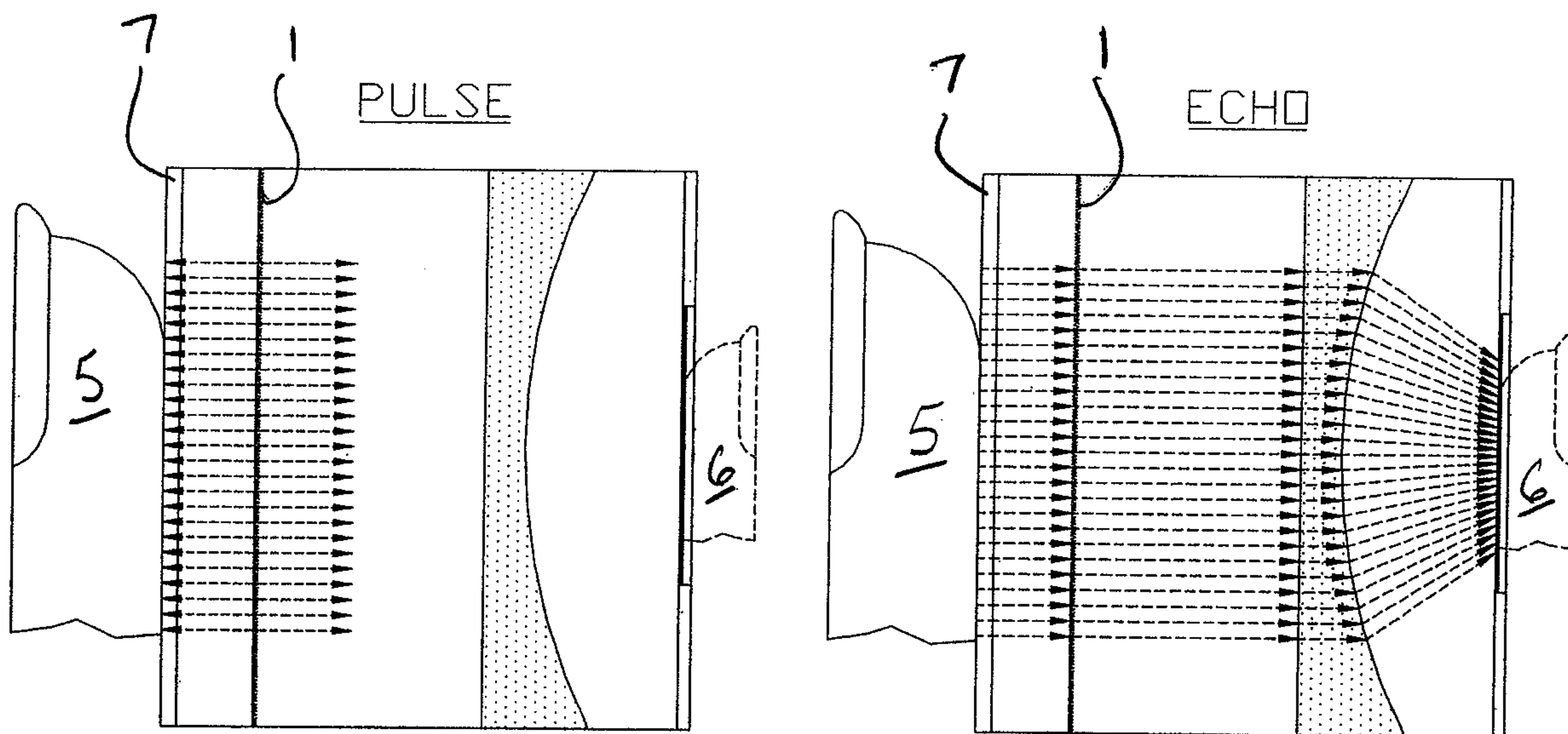


Figure 11B

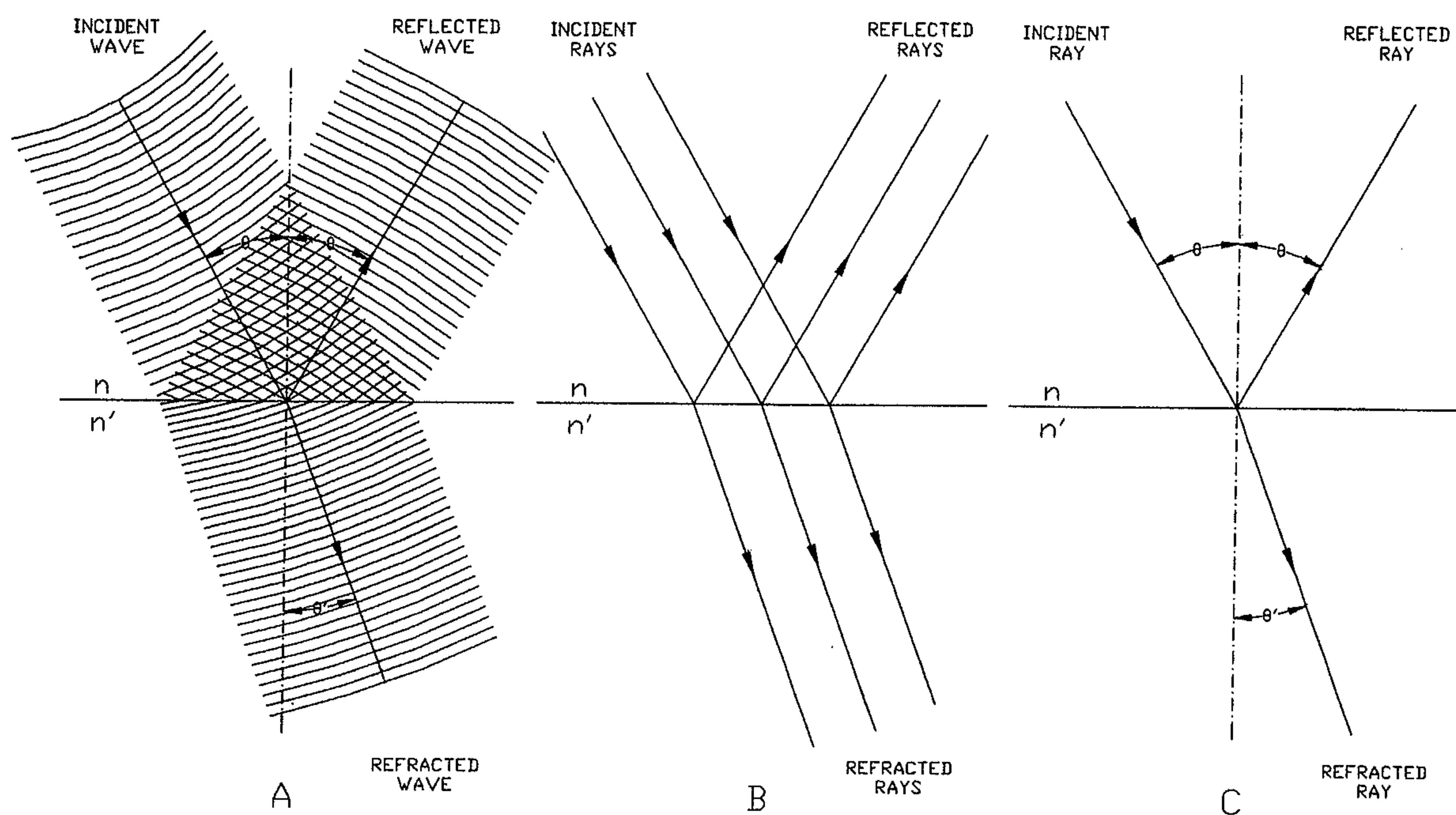


Figure 12

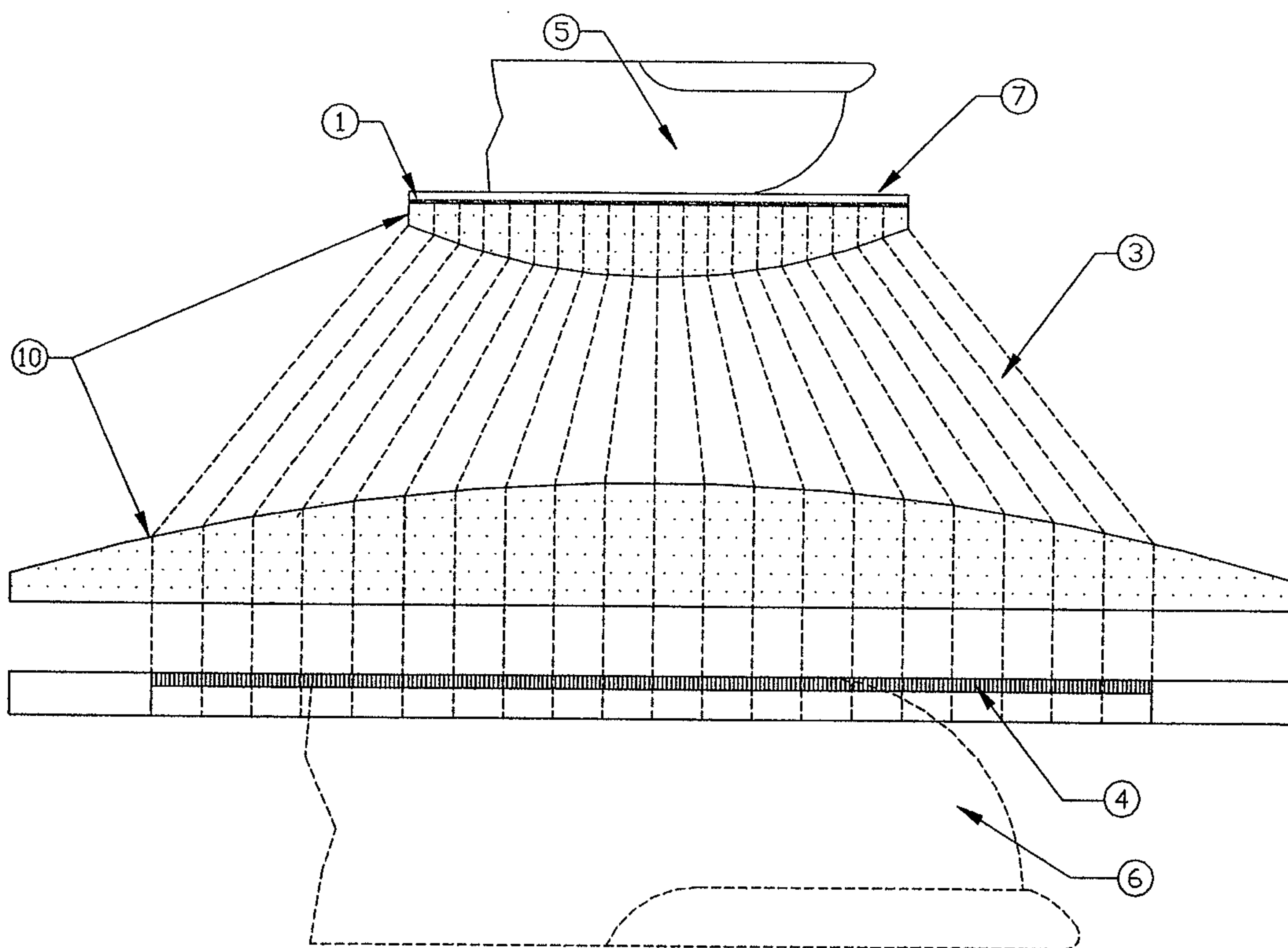


Figure 13

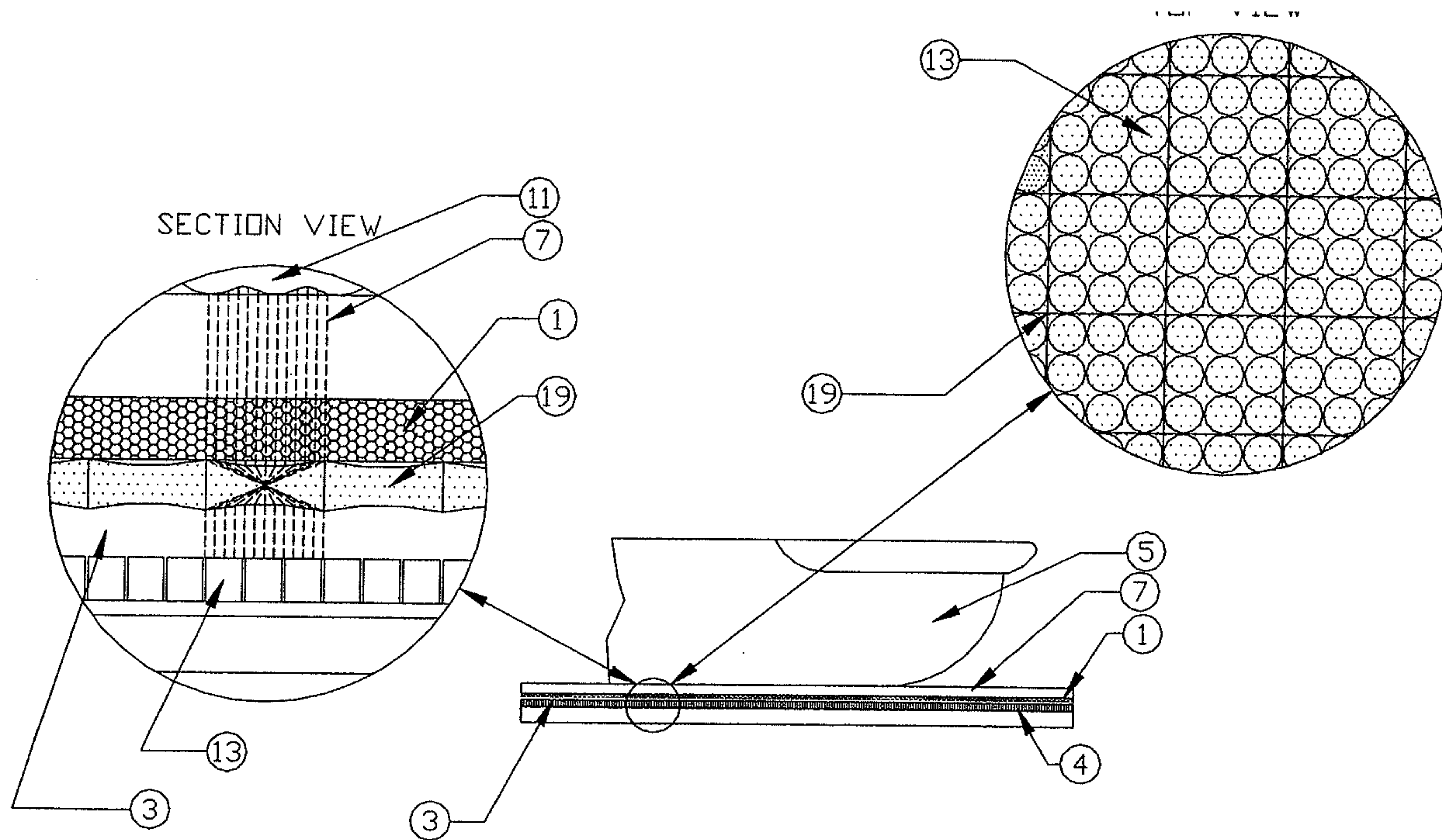


Figure 14

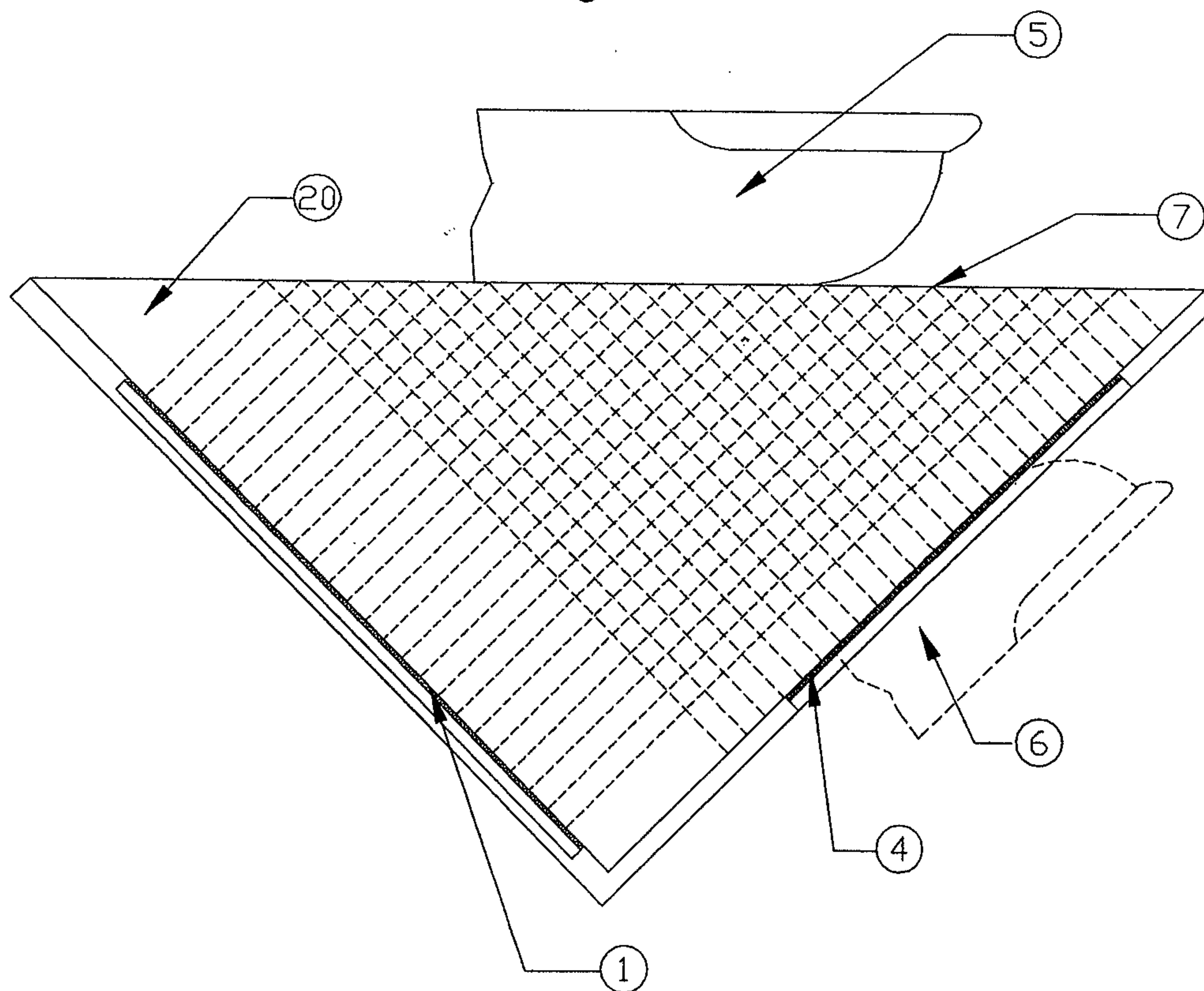


Figure 15

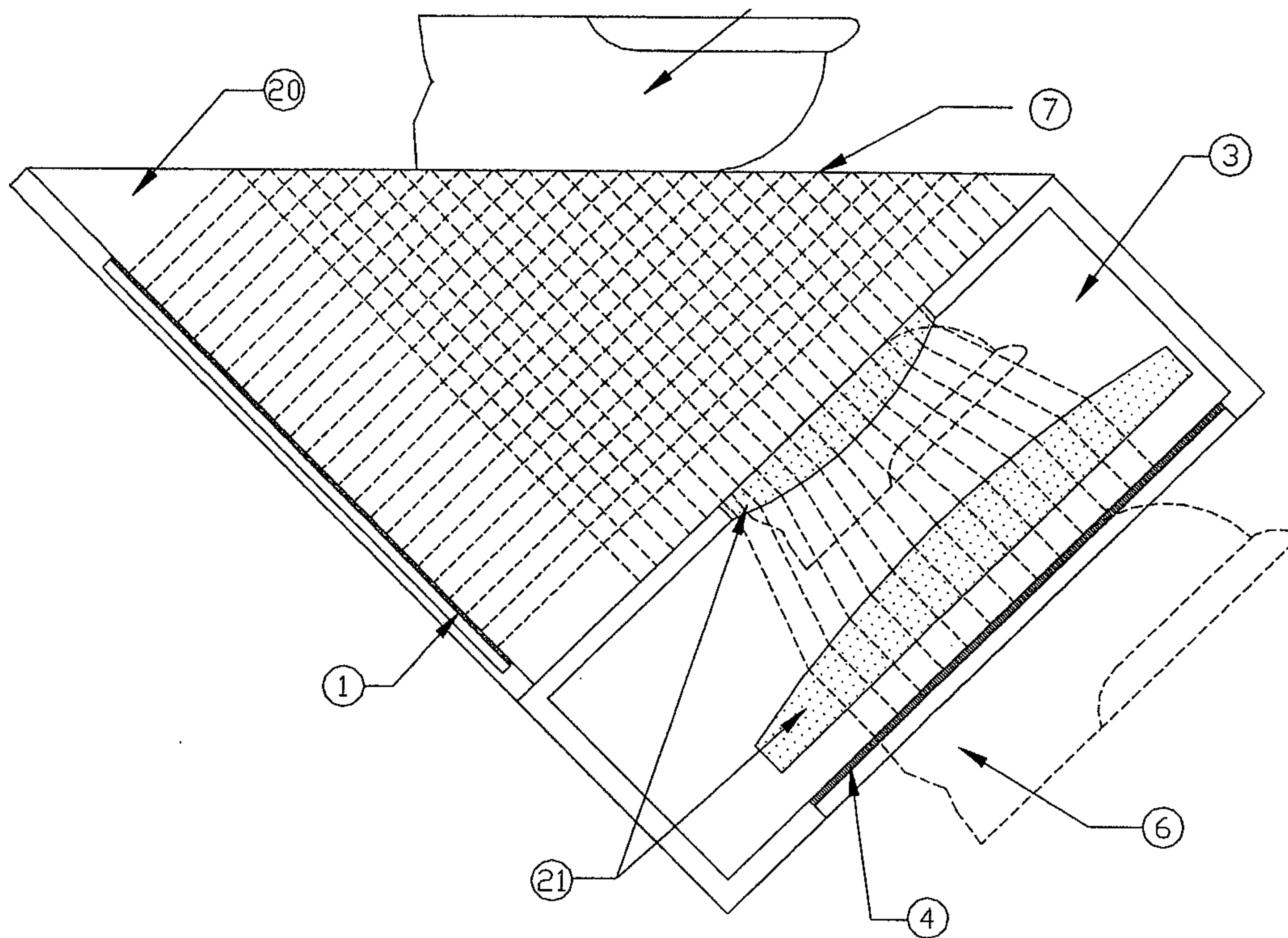


Figure 16

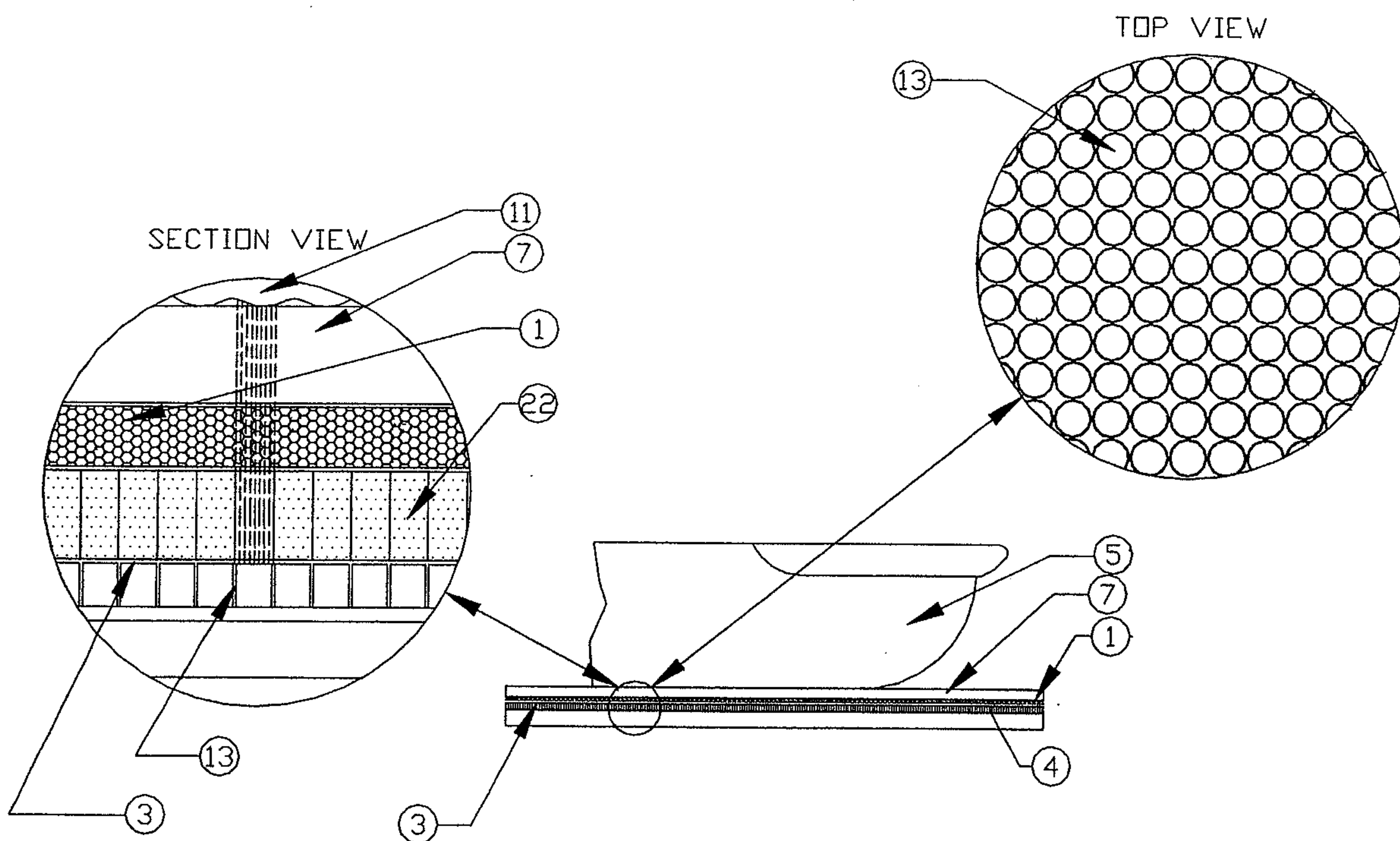


Figure 17

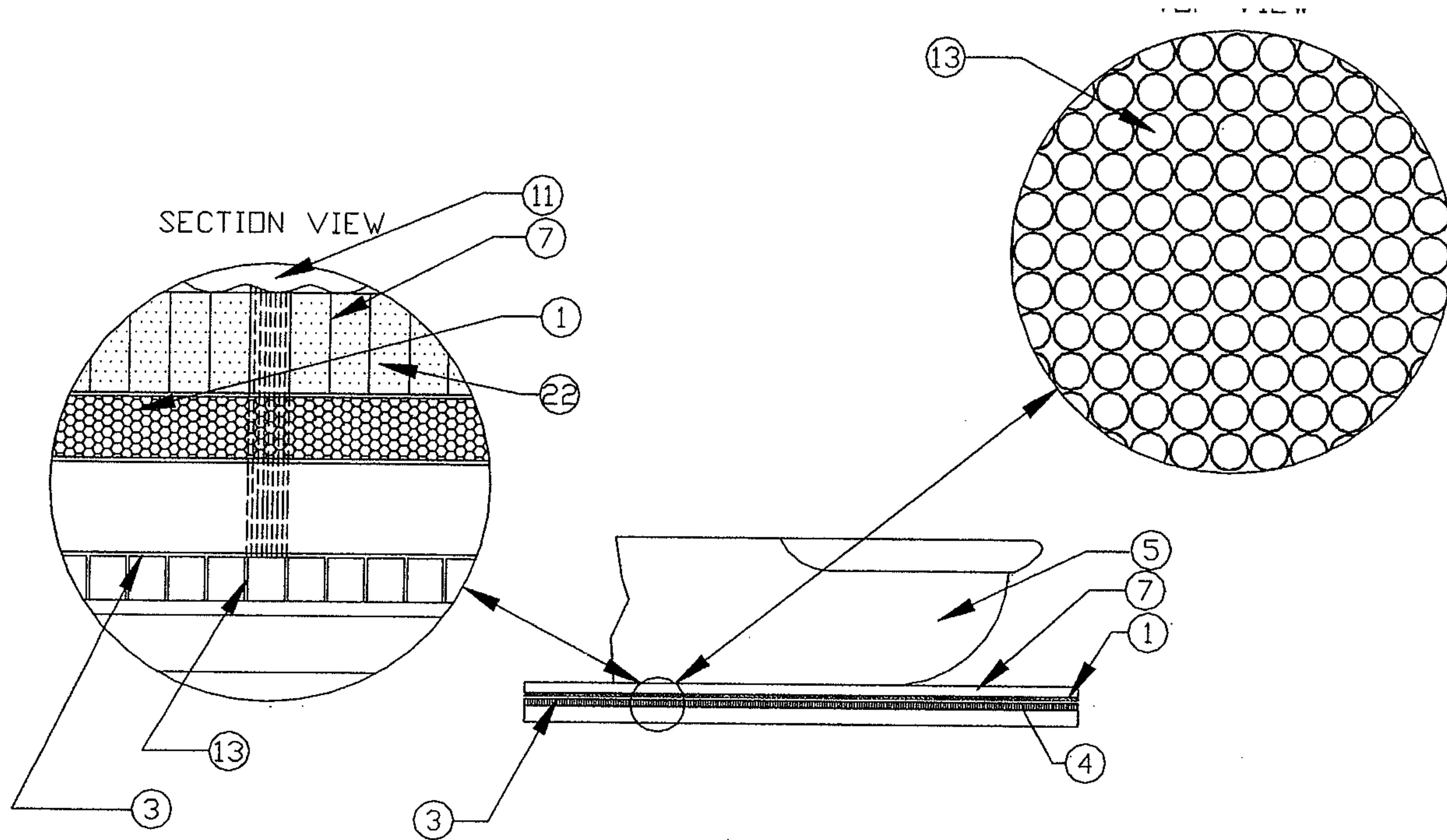


Figure 18

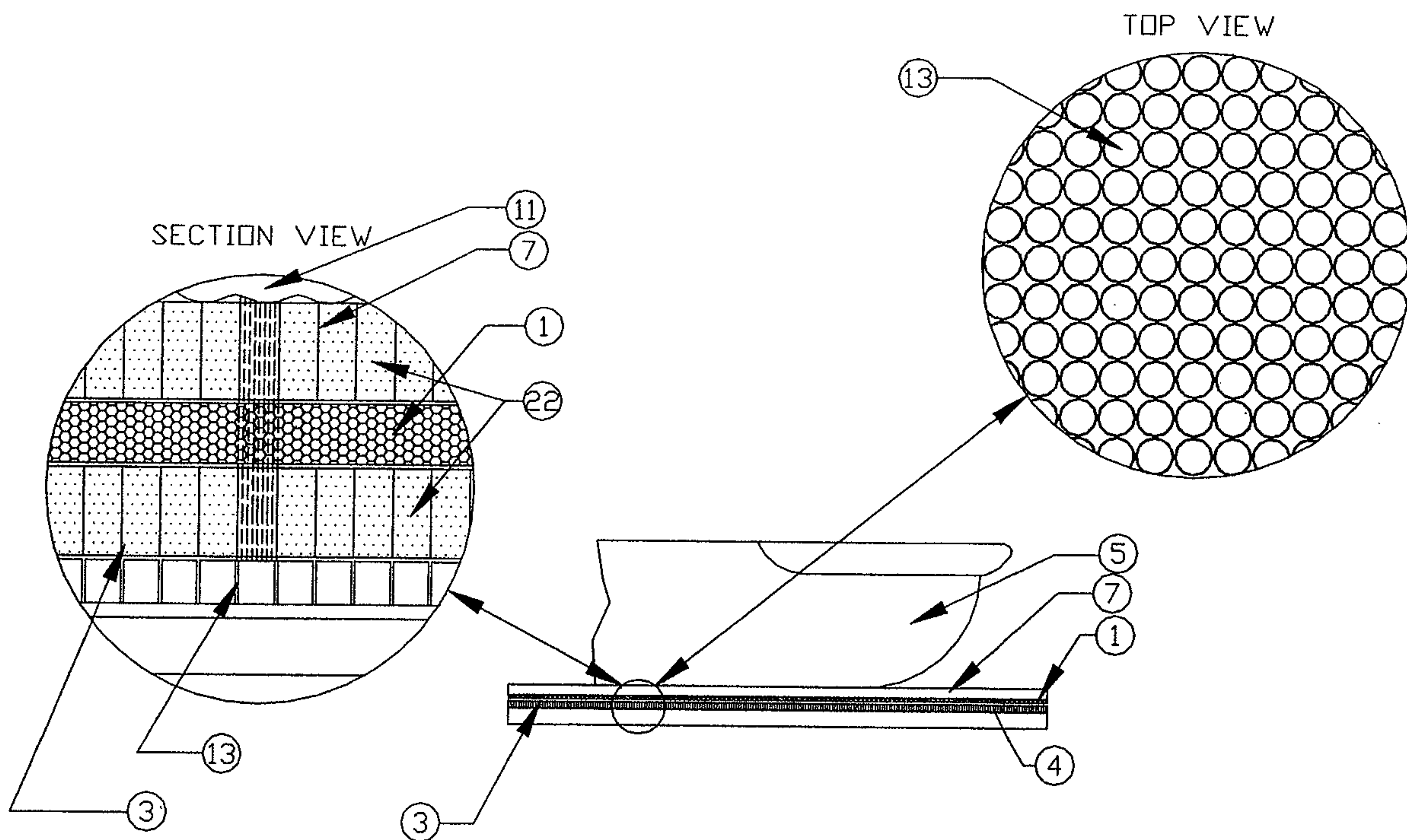


Figure 19

Figure

