

July 20, 1965

H. V. HILLERY ET AL
TRIPLANE REFLECTOR WITH CONTROLLED
FREQUENCY-DEPENDENT
TARGET STRENGTH

3,195,677

Filed Feb. 28, 1962

4 Sheets-Sheet 1

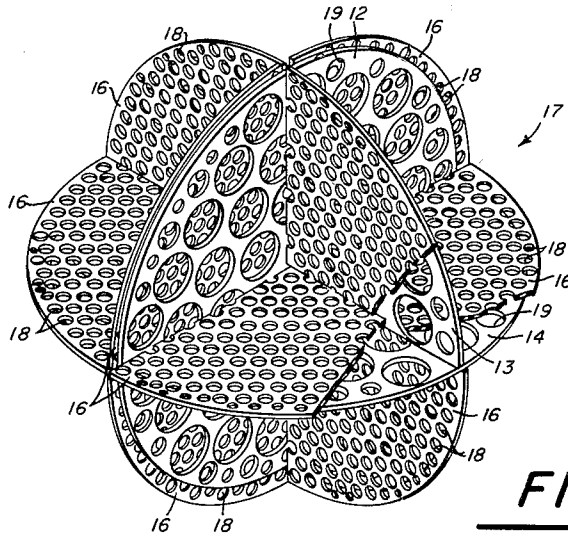


FIG. 1

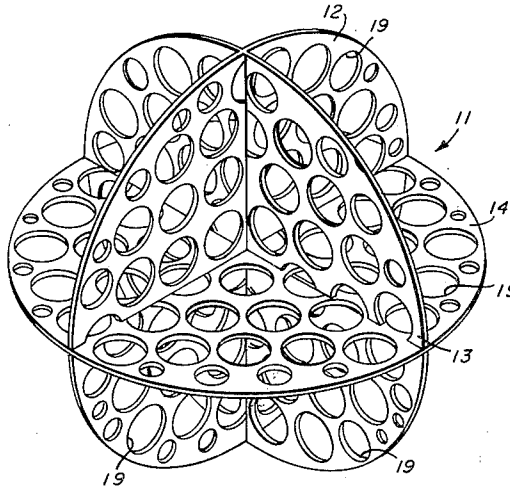


FIG. 2

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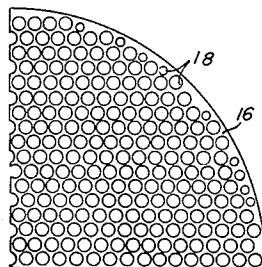


FIG. 3

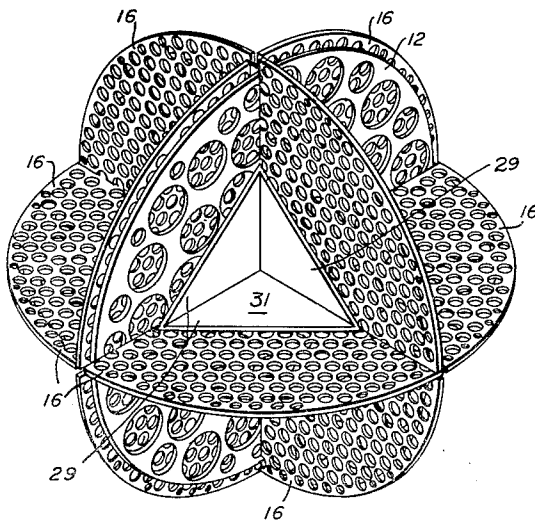


FIG. 4

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FIG. 5

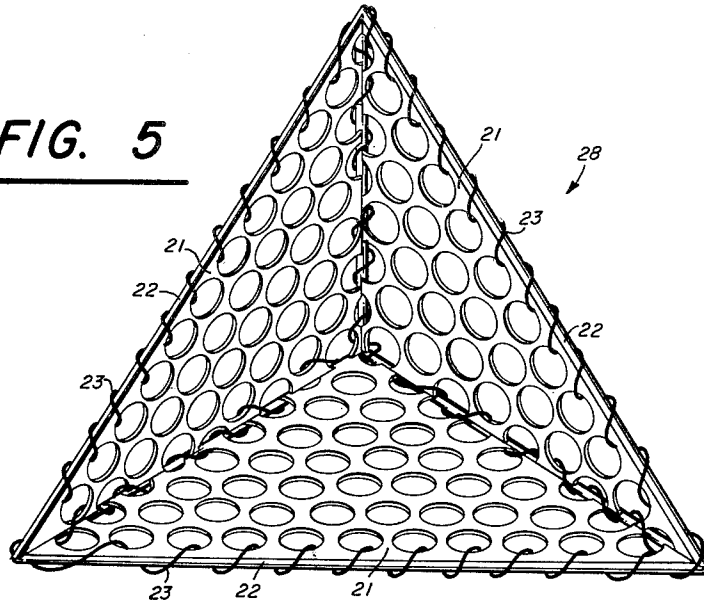
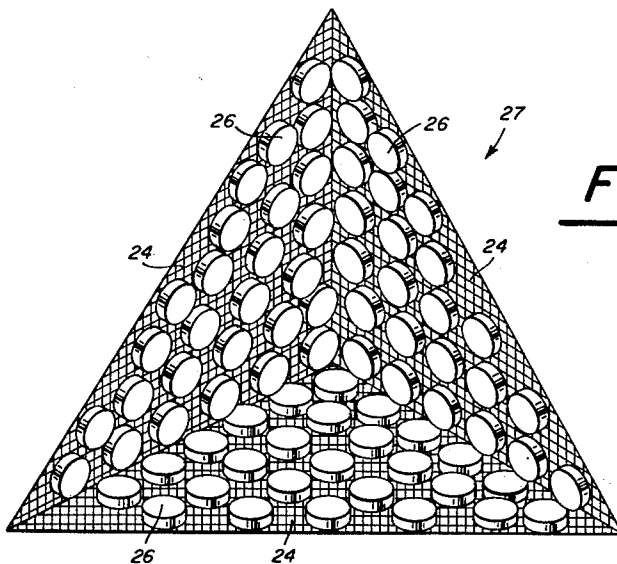


FIG. 6



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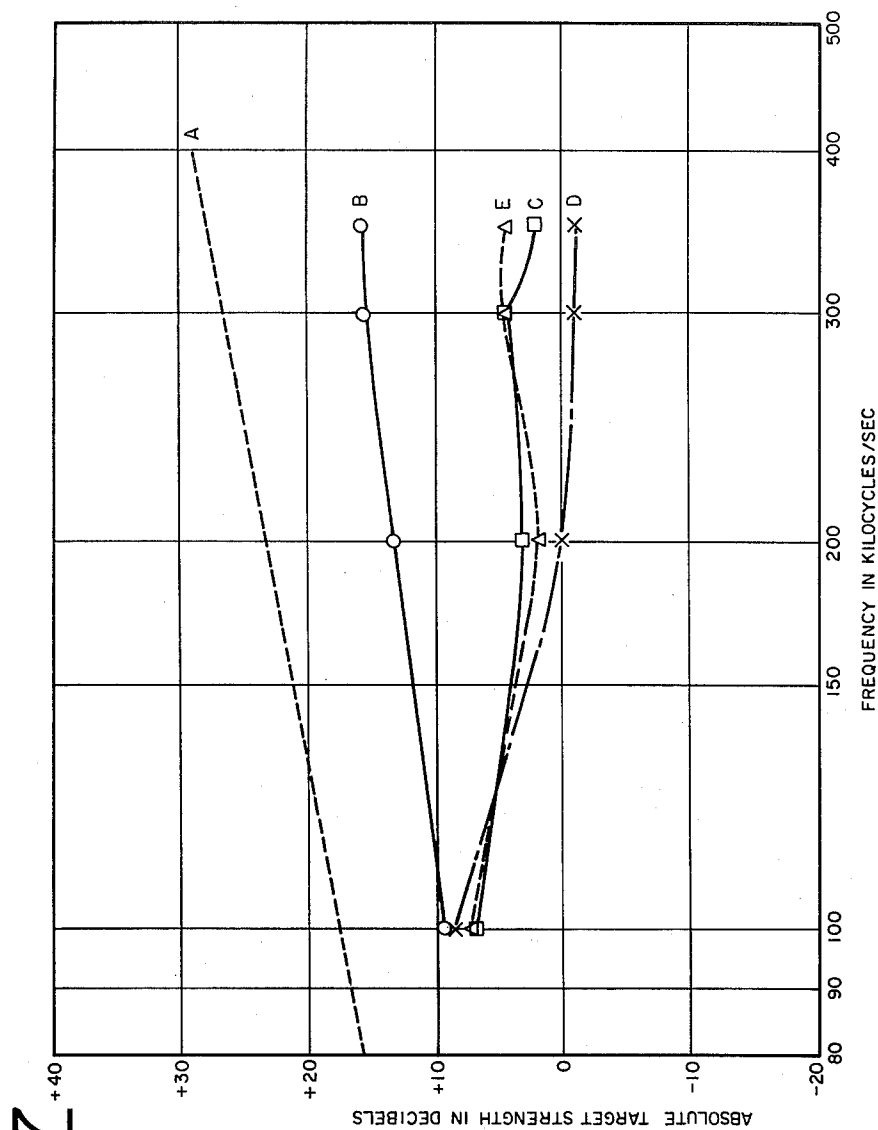
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3,195,677

TRIPLANE REFLECTOR WITH CONTROLLED FREQUENCY-DEPENDENT TARGET STRENGTH

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Filed Feb. 28, 1962, Ser. No. 176,881
2 Claims. (Cl. 181--5)

The present invention relates to triplane or corner sound reflectors and more particularly to triplane or corner sound reflectors capable of having a wide variety of possible functional relationships between coefficients of reflection and frequency of the incident sound.

Standard triplane and corner underwater sound reflectors are known in the art and have been employed for a variety of purposes. They have been employed as sonar targets to serve as subaquatic aids to navigation, as subaquatic position markers, as carried subaquatic targets allowing the position and movements of small boats to be observed by sonar, or as targets for other purposes.

Triplane and corner reflector underwater sound reflectors are of value primarily because they have a large target strength in proportion to their dimensions. That is, triplane and corner reflectors are capable of returning toward the source an unusually large portion of the sound which is incident upon them. Unfortunately, however, ordinary triplane and corner reflectors, such as have been commonly used as sonar targets, have a target strength which increases at about six decibels per octave with increase in the frequency of the incident sound. For some applications where the high target strength of the triplane or corner reflector is desirable, this increase in target strength at the rate of six decibels per octave is undesirable. For these applications, a triplane or corner reflector whose target strength increases at less than six decibels per octave (with increase in sound frequency) or decreases with increasing frequency or whose strength remains constant with increasing frequency is more desirable. This invention produces a triplane or corner reflector whose reflectivity characteristics can be varied so that target strength either increases with frequency at a slower rate than the six decibels per octave which characterizes the standard triplane or corner reflector, or remains constant with frequency change, or even decreases with increasing frequency. An illustrative example of a specific application of this invention is the use of a triplane or corner reflector to simulate a target vessel. Unlike the standard triplane or corner reflector whose target strength has been noted as increasing at about six decibels per octave with increase in frequency of the incident sound, an actual vessel will have a target strength which is roughly constant with increase in frequency of the incident sound over the operating bandwidth. Thus it can be seen that the actual reflectivity characteristics of the vessel over a sound frequency bandwidth are superiorly simulated by a triplane or corner reflector attainable with this invention than with the standard triplane or corner reflector.

One of the objects of the present invention is to produce triplane or corner reflectors susceptible of a wide variety of functional relationships between coefficients of reflection and frequency of the sound incident upon them.

Another object is to provide triplane or corner reflectors whose target strength increases with increase in frequency of the incident sound at a rate less than six decibels per octave.

A further object is to produce triplane or corner reflectors whose target strength remains relatively constant, being relatively unaffected by increase in frequency of the incident sound.

Still another object is to produce triplane or corner reflectors whose target strength decreases with increase in frequency of the incident sound.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in conjunction with the accompanying drawing wherein:

FIG. 1 shows an assembled aluminum-cork-neoprene frequency selective triplane reflector of this invention;

FIG. 2 shows the aluminum framework utilized in the FIG. 1 embodiment;

FIG. 3 shows a section of the cork-neoprene utilized in the FIG. 1 embodiment;

FIG. 4 shows a modification of the FIG. 1 embodiment;

FIG. 5 shows a corner reflector embodiment of the subject invention;

FIG. 6 shows another corner reflector embodiment of the subject invention; and

FIG. 7 is a graph showing a variety of functional relationships between reflector target strength and incident sound frequency for the standard triplane reflector and for illustrative embodiments of the present invention.

The triplane or corner reflectors of this invention are constructed from sheets of material through which many holes have been punched. The defining characteristic of the material is that it have a specific acoustic impedance which is considerably lower than the specific acoustic impedance of water or the fluid medium in which it is to be utilized (the fluid medium herein will be discussed in terms of water). The size, spacing and distribution of the holes and the acoustic impedance of the material in which the holes are punched determine the particular functional relationship which exists between the triplane or corner reflector's target strength and the frequency of the incident sound.

The sheets of material may be rigid, allowing the triplane or corner reflectors to be constructed of the sheets alone or they may be flexible. In the latter case, in order to provide the rigidity of form necessary to the triplane or corner reflector, the flexible sheets of material are fastened to a rigid frame work whose construction is such that it does not acoustically interfere with the operation of the punched sheet material which is the acoustically operative portion of the total structure of the reflector.

FIG. 1 shows a triplane reflector embodiment which illustrates the use of sheet material supported by a rigid framework. Here the sheet material is cork-neoprene and the rigid supporting frame is aluminum. The perforated framework 11, which is seen alone in FIG. 2, is comprised of three perforated intersecting planar members 12, 13, and 14 which are mounted together by welding or in any other suitable fashion to form respective right angles with one another, as seen in the figure. Cemented by a suitable waterproof cement to this perforated framework 11 in quadrant sections 16 is the cork-neoprene sheet material which is the acoustically operative portion of the total structure. The cemented cork-neoprene sections 16 which are in mating registry with corresponding quadrant portions of each of the respective framework planar members 12, 13 and 14, now, in effect, form three intersecting cork-neoprene planar members which intersect one another at right angles, this resulting configuration of the cork-neoprene sheets thus producing a triplane reflector 17 which has buttressing metal support for the acoustically-operative cork-neoprene sheets.

It will be noted that the cork-neoprene quadrant sections 16 are formed with a plurality of holes 18 therein which pass through the cork-neoprene material. The

rigid framework 11 also is formed with a plurality of holes 19; the specific diameters of the holes formed in the framework 11 are not critical, but it is desirable to have their diameters considerably in excess of the thickness of the framework planar members (12, 13, 14).

Description of suitable diameters for the holes in the cork-neoprene sheet material involves a statement of a basic principle upon which the peculiar structure of this invention depends. Underwater sound waves are unable to pass through an infinitely-long water-filled tube if the walls of the tube have an acoustic impedance which is lower than the acoustic impedance of water, unless the wavelength of the sound waves is less than a certain cutoff wavelength determined by the diameter of the tube. An array of holes punched through a sheet of suitable material, such as cork-neoprene or cellular rubber, can constitute an array of short length tubes with walls having an acoustic impedance less than the acoustic impedance of water. Such an array of holes has been found by the present inventors to act upon sound waves in a manner similar to the action of an infinitely-long tube. That is, the array is capable of freely transmitting sound waves of a wavelength shorter than a cutoff wavelength determined by the diameters of the holes and to be relatively incapable of transmitting sounds of greater wavelengths. When underwater sound waves of wavelength greater than the cutoff wavelength impinges upon the punched out sheet material such as quadrant sections 16 of reflector 17, for example, they are largely reflected. Underwater sound waves of shorter wavelength are transmitted through the holes (such as hole 18, for example) and are not reflected. In one particular form of the triplane or corner reflectors of this invention consisting of sheets of flexible cork-neoprene the diameter d of circular cross-section holes to be passed through the cork-neoprene is determinable by the formula $d=113/f_{co}$ wherein f_{co} is the cutoff frequency, and d is the diameter in centimeters.

Thus a triplane reflector such as 17 (or, in like manner, a corner reflector) made of perforated sheets of material, such as cork-neoprene, or the like, which has an acoustic impedance less than the acoustic impedance of water, will selectively reflect sounds of longer wavelengths better than sounds of shorter wavelengths. By suitably choosing the thickness of the material (of the sheets) and its acoustic impedance and by suitably adjusting the diameters, spacings, shapes and distribution of the holes formed in said material a wide variety of functional relationships between the target strength of the triplane or corner reflector and the frequency of the incident sound can be produced. The holes through the acoustically-operative sheet material whose acoustic impedance is less than that of water do not have to be round in shape. The important factor is merely having passages through the acoustically-operative sheet material from one of its faces to the other with the walls of these passages being made of a material whose acoustic impedance is less than the acoustic impedance of water.

FIG. 5 shows a corner reflector involving the type structure of this invention. A plurality of pierced triangular-shaped sheets 21 of the same type of material described above for the triplane reflector 17 of FIG. 1 (i.e., sheet material having an acoustic impedance less than the acoustic impedance of water) are supported in a standard corner reflector configuration by a plurality of interconnected skeletal rods 22 to which the respective triangular sheets 21 are secured by looped wire 23, or the like. Here again is coupled the advantages of the high target strength characteristic of the reflector shape and the selective capability for establishing a desired functional relationship between target strength and frequency of the incident sound.

FIG. 6 shows another corner reflector embodiment of the subject invention which, at first glance, may seem to differ radically from the FIG. 5 embodiment, but which operates in similar fashion thereto. This embodiment of

FIG. 6 shows that the form of the acoustically-operative structure can be something other than sheet material (having acoustic impedance less than that of water) pierced with holes. As seen in FIG. 6 each side of the corner reflector consists of a mesh 24 to which are affixed, in any suitable manner, a plurality of spaced cylindrically-shaped disks 26. With the balance of structure (other than the disks 26) being open to free flow of water there-through, this reflector 27 operates similarly to the reflector 28 of FIG. 5, for the outer, longitudinally-extending boundaries of disks 24 define the same short-length tubes having walls with an acoustic impedance less than the acoustic impedance of water as do the holes in the reflector 28 sheet material.

As previously noted, the framework used to support acoustically-operative sheet material which is too flexible to support itself must have a target strength which is low so that the framework will not interfere substantially with the acoustic action of the perforated sheets. Rigid frameworks of metal or other materials may be made to have a low target strength by perforating them with holes, for underwater sounds of any wavelength can pass through holes in materials having acoustic impedances which are greater than the acoustic impedance of water, regardless of the diameter of the holes. To assure that the sound waves will pass fully through the holes in the framework with a minimum of reflection, the hole diameters can be made considerably greater than the thickness of the framework material. Rigid frameworks can also be made to have a low target strength by constructing them of a material having an acoustic impedance which closely matches the acoustic impedance of water, for such materials are poor reflectors of underwater sound waves.

FIG. 7 is a graph illustrating, on the basis of actually tested values, absolute target strength versus incident sound frequency for a standard type triplane reflector and for illustrative similarly-sized reflectors of this invention which portray some of the wide variety of target strength-frequency relationships available therefrom. Curve A is a theoretical target strength versus incident sound frequency response for the standard type triplane reflector. Curve B shows the actual target strength of the ordinary triplane reflector of curve A made of 0.250 inch thick aluminum plates. Curve C shows the target strength of a triplane of this invention of similar size (to the standard triplane reflected in curve B) constructed of perforated cork-neoprene cemented to a Plexiglas frame 0.125 inch thick. Curve D shows the target strength of a similar-sized triplane of this invention constructed of perforated cork-neoprene cemented to a framework of perforated aluminum 0.157 inch thick. (This is the type triplane illustrated in FIGS. 1-3.) Curve E shows the target strength of the triplane of curve D after the triplane was modified (see FIG. 4 for illustration of this modification) by cementing right triangular solid pieces 29 of unperforated cork-neoprene in the eight right triangles formed by the intersecting planar members 12, 13, 14 with their attached quadrant sections 16. In the actual embodiment used, the unmodified triplane reflector 17 had a 12 inch diameter and the solid right triangular pieces 29 of unperforated cork-neoprene inserted therein and attached thereto (by suitable cement or the like) were 4.25 inches long. This modified construction of the triplane reflector results in a small triplane 31, having unperforated acoustically-operative structure, being mounted at the center of the large perforated triplane. From curve E it will be noticed that the target strength for such modified triplane structure drops between 100 and 200 kc. in a manner characteristic of the large perforated triplane (FIGS. 1-3) and then rises between 200 and 350 kc. in a manner characteristic of the small triplane 31. It is apparent that this and similar modifications in constructing triplane and corner reflectors of this invention can be used to secure

a wide variety of functional relations between target strength of the reflector and frequency of the sound incident thereupon.

The materials listed above for the operative acoustic material and for supporting frameworks (where needed) are exemplary only and should not be construed as limitative. The triplane or corner reflectors of this invention can be made of arrays of holes of any suitable shape, size, spacing and distribution in sheets or plates of any materials whose acoustic impedance is lower than the acoustic impedance of water. These sheets or plates may be supported upon any sort of framework which will not substantially interfere with the acoustic action of the arrays of holes. The sheets or plates can be assembled from pieces of a material having acoustic impedance less than the acoustic impedance of water and the "holes" can be passages between the pieces. The sheets or plates may be made of substances having acoustic impedances greater than the acoustic impedance of water provided that the acoustic impedance of part of the walls of the holes is less than the acoustic impedance of water.

The triplane or corner reflectors of this invention can be used in gases or liquids other than water provided that the acoustic impedance of the walls of the holes is less than the acoustic impedance of these gases or liquids in which they are to be employed.

The triplane or corner reflectors can have any convenient or desirable shape provided that their planes intersect at right angles. They can be made buoyant or nonbuoyant by a suitable selection of the materials of construction.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is intended to cover all such modifications and variations which do not depart from the spirit and scope of this invention.

What is claimed is:

1. A triplane reflector having a predetermined cut-off frequency enabling the reflector to transmit sound waves of a wavelength shorter than cut-off and to reflect sound waves of a wavelength greater than cut-off, said reflector being adapted to serve as an acoustic target in a fluid medium, comprising a plurality of substantially acoustically-inoperative intersecting perforated planar framework members mounted together at respective right angles to one another, the diameters of the perforations in each of said perforated planar framework members being considerably in excess of the thickness of its respective planar framework member; a plurality of flexible acoustically-operative perforated planar members each of which is superimposed in mating registry with one of said planar framework members and connected thereto, said flexible acoustically-operative planar members having perforations determined in accordance with said predetermined cut-off frequency and said flexible acoustically-operative perforated planar members each being composed of a material having a specific acoustic impedance lower than

the specific acoustic impedance of the fluid medium in which said triplane reflector is to serve as a target; the combination of said acoustically-inoperative perforated planar framework members and said superimposed flexible acoustically-operative perforated planar members forming a plurality of solid angle apices; and a triplane structure mounted in each of said solid triangle apices, said triplane structure being composed of unperforated material having a specific acoustic impedance which is less than the specific acoustic impedance of the given fluid medium.

2. A triplane reflector having a predetermined cut-off frequency enabling the reflector to transmit sound waves of a wavelength shorter than cut-off and to reflect sound waves of a wavelength greater than cut-off, said reflector being adapted to serve as an acoustic target in a fluid medium, comprising a plurality of substantially acoustically-inoperative intersecting perforated planar framework members mounted together at respective right angles to one another to define a triplane framework structure, a plurality of flexible acoustically-operative perforated planar members each of which is superimposed in mating registry with one of said framework members and connected thereto, said acoustically-operative planar members being composed of a material having a specific acoustic impedance lower than the specific acoustic impedance of the fluid medium in which said triplane reflector is to serve as a target, the diameters of the perforations in each of said perforated planar framework members being considerably in excess of the thickness of each respective planar framework member and the diameters of the perforations in said flexible acoustically-operative planar members being determined in accordance with said predetermined cut-off frequency, the material of said perforated acoustically-inoperative planar framework members being aluminum, the material of said flexible acoustically-operative perforated planar members being cork-neoprene, and the diameter d of said perforations being determined by the formula $d=113/f_{co}$ wherein f_{co} is the cut-off frequency and d is the diameter in centimeters.

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