March 25, 1947. A. C. KELLER 2,417,830

COMPRESSIONAL WAVE SIGNALING DEVICE

Filed July 2, 1943 3 Sheets-Sheet 1

FIG. 1

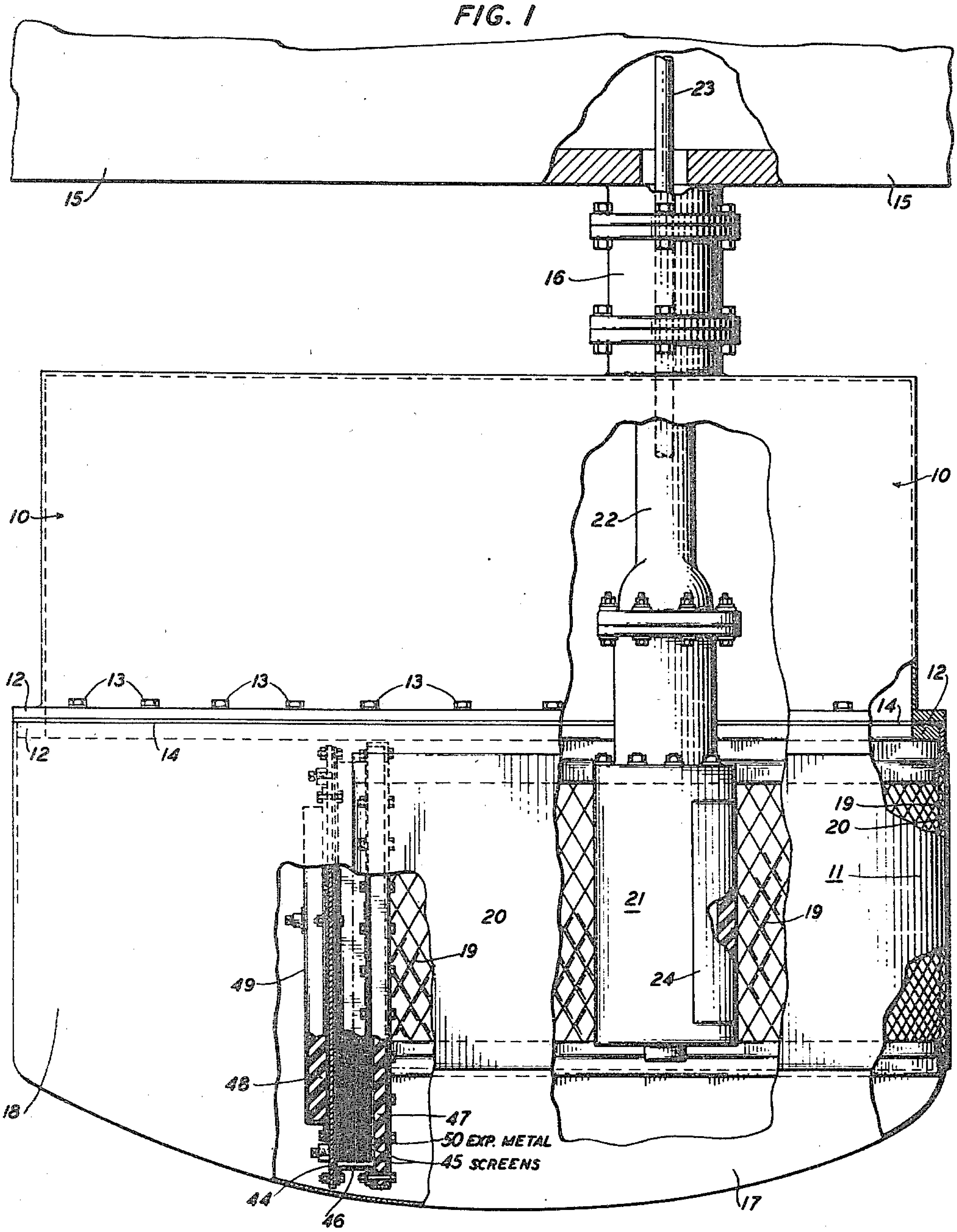

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FIG. 2

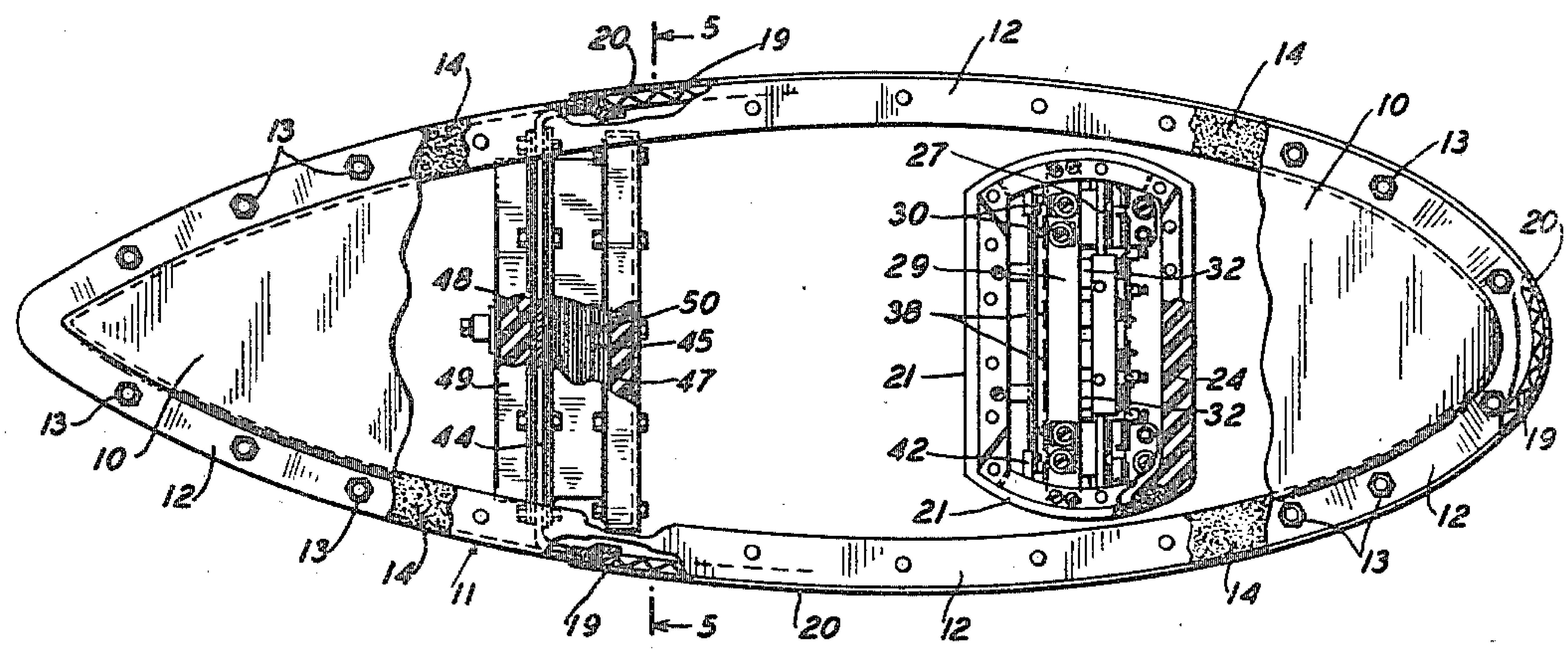


FIG. 5

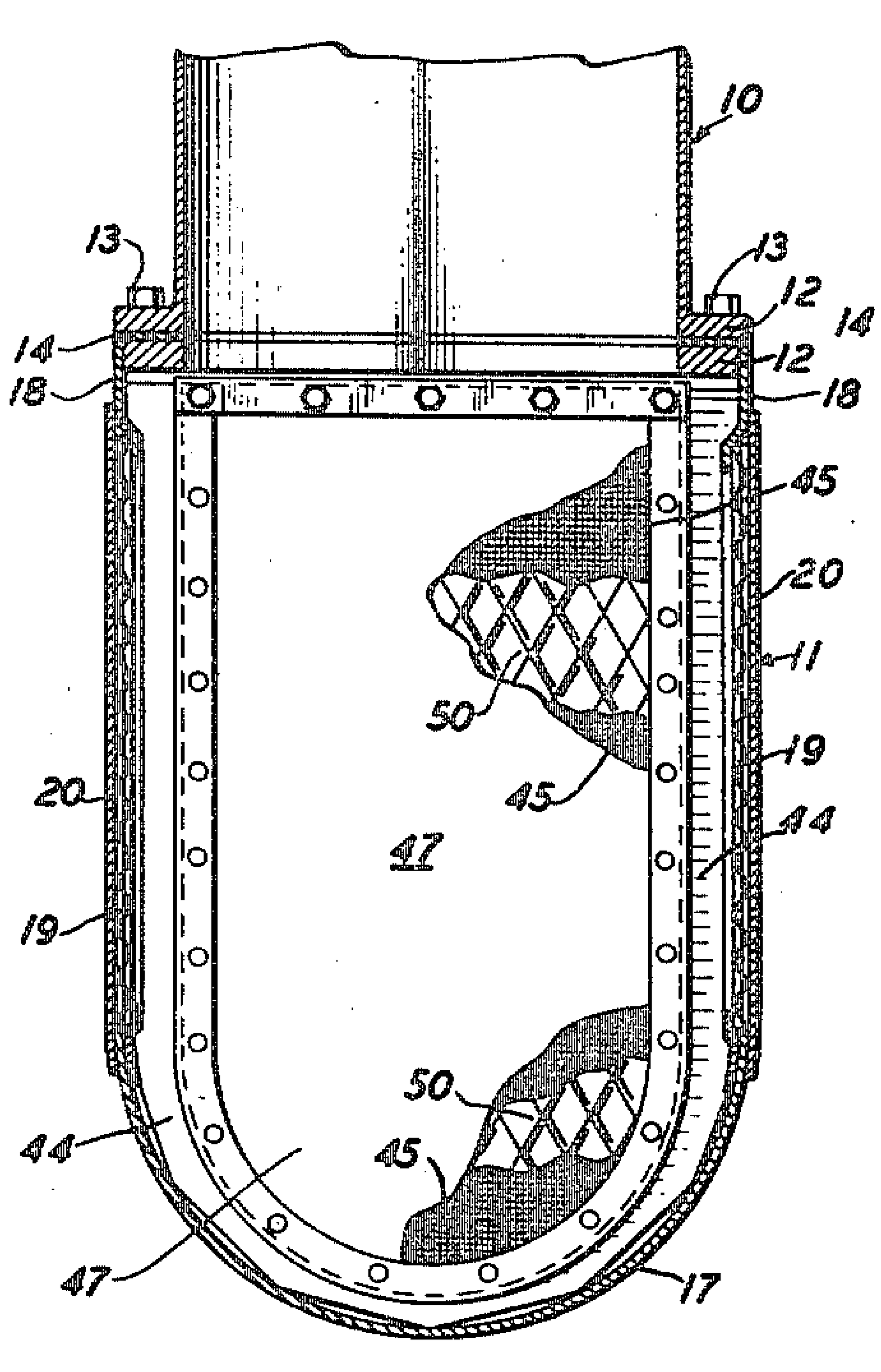


FIG. 6

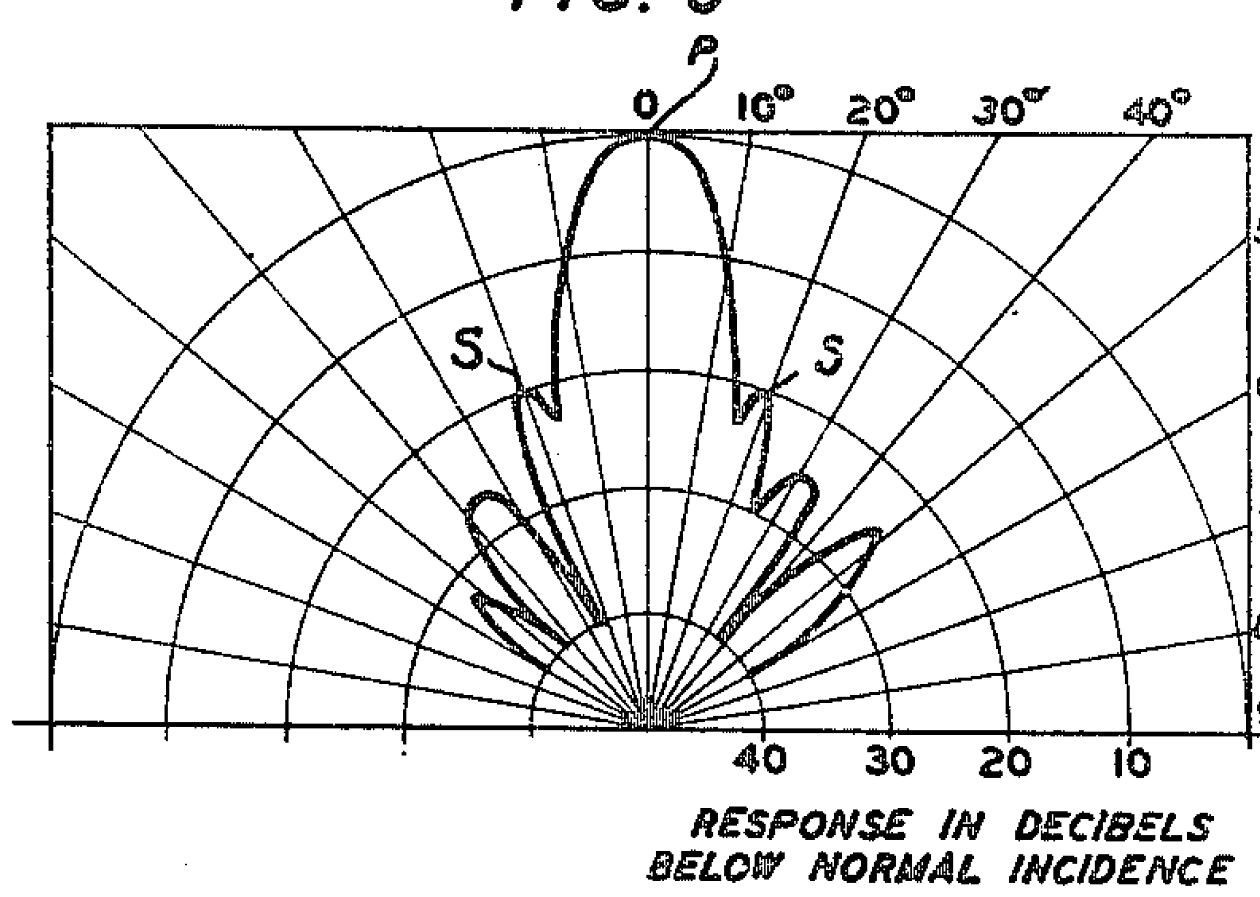
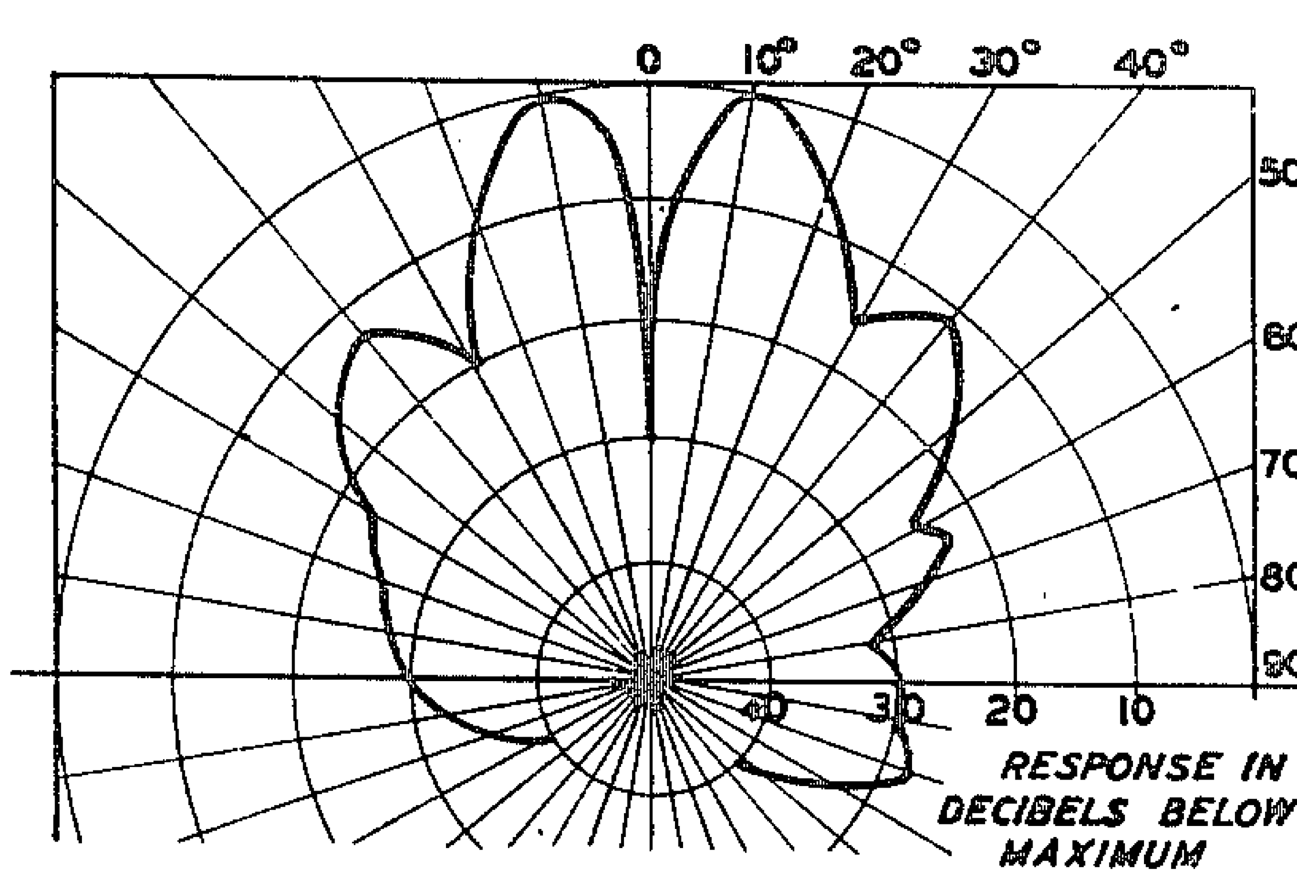


FIG. 7



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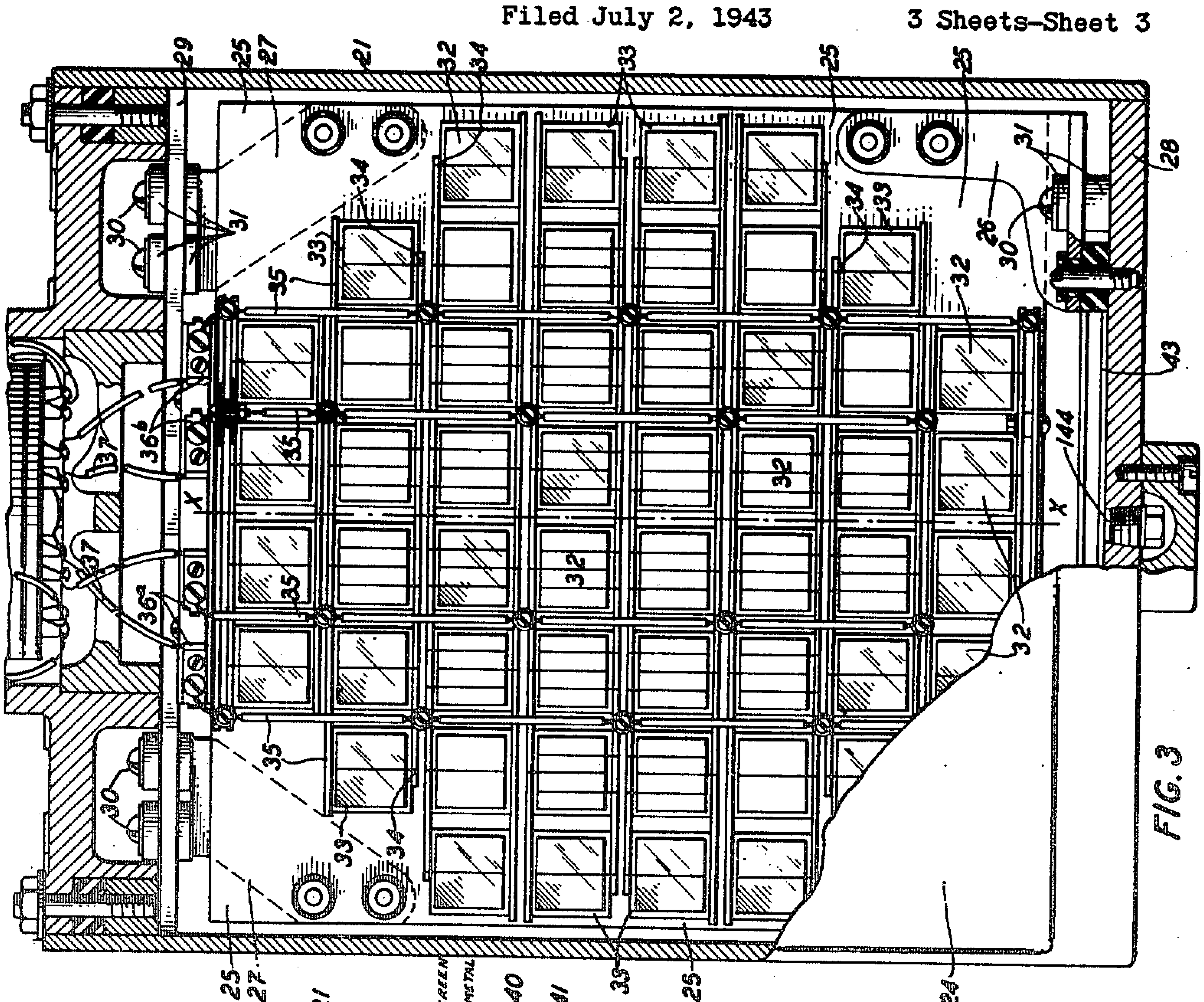

FIG. 3

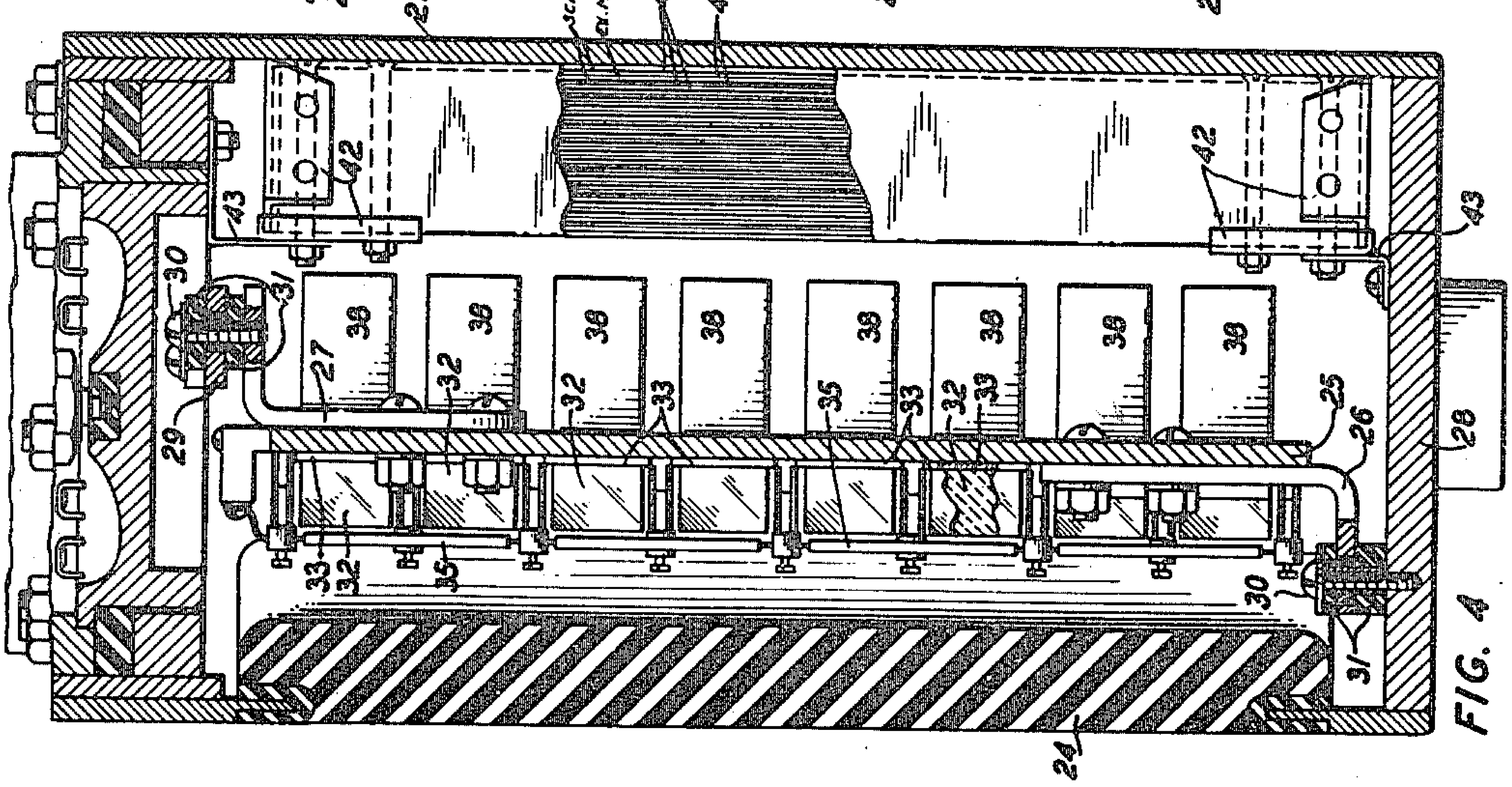

FIG. 4

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UNITED STATES PATENT OFFICE

2,417,830

COMPRESSIONAL WAVE SIGNALING DEVICE

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Application July 2, 1943, Serial No. 493,177

5 Claims. (Cl. 177—386)

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This invention relates to compressional wave signaling devices and more particularly to high frequency or supersonic submarine signal projectors and detectors especially adapted for mounting on or from the hull of a ship.

One object of this invention is to obtain a highly directional propagation or response pattern for a submarine signaling device. More specifically, one object of this invention is to obtain such a pattern wherein all secondary lobes are suppressed to a level greatly below that of the primary lobe.

Another object of this invention is to achieve substantially distortionless translation of supersonic signals in submarine signal projectors and detectors.

A further object of this invention is to realize substantially uniform translation of signals and sharp directionality throughout a wide frequency band in submarine signaling devices.

Still another object of the invention is to improve the efficiency of compressional wave signaling devices.

In one illustrative embodiment of this invention, a submarine signaling device operable as either a projector or detector of supersonic submarine signals comprises a streamlined housing adapted to be mounted from or on the hull of a ship and a signal translating device rotatably mounted within the housing. In one form, the translating device includes a group of piezo-electric crystals arranged and graded as to power capacity to produce a maximum response along the axis normal to the face of the translating device and constructed and mounted to have a maximum sensitivity at a prescribed frequency, the frequency at which the device is to be utilized, if single frequency operation is intended, or the highest frequency in the band to be translated, if band frequency operation is intended or desired.

In accordance with one feature of this invention, the crystals are arranged in coordinately symmetrical rows with their radiating or receiving faces coplanar and the crystal dimensions and spacings are correlated in relation to a preassigned frequency whereby a highly directional propagation or reception pattern is realized and a great and substantially optimum suppression of secondary lobes in this pattern is obtained.

In accordance with another feature of this invention, the housing is provided with a large area portion or window opposite the signal translating device, of an extent sufficient to allow scanning throughout a large angle by rotation of the

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translating device, and this portion is constructed so as to withstand great hydrostatic pressures and forces without yielding or vibration and to be capable of allowing transmission therethrough of high frequency and supersonic compressional wave signals, that is signals having a frequency of the order of 10 kilocycles and higher, without substantial attenuation and with uniformity independent of the angle of incidence of the signal waves thereon. Means are provided within the housing for preventing undue reflection of signal waves which pass through the window and are not received by the device and other means are provided for shielding the translating device from extraneous signals emanating from sources outside of the angular range through which the device is adapted to scan, whereby distortion of the signals by reflection effects or extraneous signals or noises is prevented. In one construction the means noted are fabricated as a unitary assembly with a transverse bulkhead positioned adjacent the ends of the sonically transparent window, the reflection preventing means comprises an attenuator pad capable of absorbing the energy of compressional waves incident thereon and this may be associated with a shielding means comprising a cellular member capable of reflecting compressional waves which impinge upon it.

The invention and the above-noted and other features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is a side elevational view of a supersonic submarine signaling device illustrative of one embodiment of this invention, portions of the housing being broken away and a part of the bulkhead assembly being illustrated in section to show details of construction;

Fig. 2 is a top view of the signaling device illustrated in Fig. 1, portions of the housing being broken away and the bulkhead assembly and the translating device being shown partly in section;

Fig. 3 is a front view of the translating device included in the signaling device shown in Figs. 1 and 2, the major portion of the front wall of the translating device being broken away;

Fig. 4 is a side view, mainly in section of the translating device illustrated in Fig. 3;

Fig. 5 is a sectional view along plane 5—5 of Fig. 2 with a portion of the bulkhead assembly broken away to show details of the assembly; and

Figs. 6 and 7 are diagrams showing typical directional patterns for a submarine signaling device of the construction illustrated in Figs. 1 and 2.

Referring now to the drawing, the submarine signaling device illustrated in Figs. 1 and 2 comprises a rigid housing of streamlined configuration, as shown clearly in Fig. 2, the outer surfaces or walls of which are of a material, such as stainless steel, resistive to the corrosive action of sea water. The housing may be fabricated as a single element or may be defined by an upper dome portion 10 and a lower inverted dome-shaped portion, designated as 11 as a whole, the two portions having juxtaposed flanges 12 joined to one another, together with an interposed washer 14, by bolts 13. The signaling device is adapted to be supported from a wall 15 of the hull of a ship as by a hollow coupler assembly 16.

The lower dome portion 11 comprises a base wall 17 and a body 18, both of relatively thick material, e. g. ⅛ inch steel, secured to one another as by welding, the body 18 having a large area cut away to receive a window structure highly transparent to compressional wave energy. The window structure includes a framework 19 of expanded metal, for example stainless steel, the openings in which constitute of the order of 70 to 80 per cent or more of the total area of the framework, and a thin steel sheet 20, for example about 20 mil stainless steel, secured to the framework 19. Advantageously, the expanded metal framework is relatively thin, and the sheet 20 is secured, as by welding, to each intersection of the element of the framework. Such construction provides a window through which compressional wave energy will pass with substantially negligible attenuation and minimizes reflections from the dome window and provides also a rigid window of great strength which not only will withstand great hydrostatic pressures but also will not introduce extraneous vibrations due to forces acting thereon even when the ship on which the device is supported is traveling at relatively high speeds, e. g. of the order of 20 or more knots. The small thickness of the expanded metal framework and the large ratio of the openings therein to the total window area assure only very small reflection of compressional waves incident upon the window. Further, the impedance of the window to sound waves is substantially independent of the angle of incidence of the compressional waves thereon.

Mounted within the lower dome portion 11 well toward the forward end thereof and aligned with the window 19, 20 is a signal translating device including a water-tight housing 21 which is mounted on a rotatable support 22 the driving shaft 23 for which projects into the interior of the ship. The housing 21 includes a sound transparent wall or window 24 of suitable material, such as commercially available forms of rubber, thin steel or suitable plastics having substantially the same density and impedance to the transmission of supersonic compressional wave energy as sea water. The unit of the signal translating device, as shown clearly in Figs. 3 and 4, comprises a foundation plate 25, for example of metal, which is supported in the housing 21 by four brackets 26 and 27 bolted to the plate 25 and secured to the base wall 28 of the housing 21 and a mounting bar 29 by suitable machine screws 30. Advantageously, resilient, e. g. rubber, spacers 31 are provided between each bracket and the wall or bar to which it is secured to permit limited expansion and contraction of the plate and

to insulate the crystal structure from ship vibrations and noises.

Secured to the face of the plate 25 toward the wall 24 is a group of square piezoelectric crystals 32, each of which may be constituted of two or more 45-degree Y-cut Rochelle salt slabs joined together and connected electrically in parallel and which is secured to the plate 25 by an insulator detail shown at 33 in Fig. 3, cemented or fastened to the crystal and plate.

As shown clearly in Fig. 3, the several crystals are arranged in lateral and longitudinal rows; the two or four end crystals in each row are composed of two slabs and the intermediate crystals are composed of four slabs. Each row is symmetrical with respect to the lateral or longitudinal axis of the entire crystal group and, as will be apparent, the group approximates a circular array or blanket of crystals. One half the crystals, for example all those to the left of the longitudinal axis $x—x$ in Fig. 3, are connected electrically in parallel by conductors 34 and bus wires 35 leading to terminals 36A and the other crystals, that is, those to the right of the axis $x—x$ in Fig. 3, are connected electrically in parallel by similar leads 34 and bus wires 35 leading to terminals 36*b*. Leading-in conductors 37, connected to the terminals 36*a* and 36*b*, enable operation of each half of the crystals separate from the other half or operation of all the crystals in parallel.

Because of the two slab construction of the outer or end crystals in each row, these crystals have twice the impedance and are capable of radiating one-quarter the power of the intermediate crystals. When all the crystals are energized in parallel, the propagation pattern of the translating device is highly directional, approximately a cone, for example of an included angle of the order of 23 degrees at 24 kilocycles about an axis normal to the faces of the plate 25 and passing through the center of the crystal group.

Secured to the other or rear face of the plate 25 or integral therewith are a plurality of backing blocks or resonator members 38, one for each of the crystals 32 and in alignment therewith. In another construction a solid resonator of suitable length for each half of the crystals may be used. The backing blocks 38 advantageously are of a length substantially equal to one quarter the wavelength of the frequency to be translated, or of the mid-band frequency to be translated if the device is intended for band frequency operation, and the height of the crystals 32, that is the dimension thereof normal to the plate 25, likewise is made substantially equal to one quarter wavelength of this frequency whereby vibrational nodes are established substantially at the plate 25 and a high efficiency is obtained. Slight differences in the crystal length and resonator length may be used to further broaden the frequency band.

It has been found that orientation of the faces of the crystal slabs, the dimensions of the crystals and the spacing thereof are highly important factors determining the amplitude of the secondary lobes appearing in the directive pattern of the translating device. Particularly, it has been found that if the major faces of the crystal slabs are parallel to the axis about which the translating device is rotatable, that is parallel to the $x—x$ axis as in Fig. 3, a substantial reduction, of the order of 10 decibels, in the first secondary lobe is obtained as compared with a construction wherein the slab faces are normal to this axis.

Further, a marked and optimum suppression of this secondary lobe is realized when the width of each crystal 32 is equal to of the order of 0.4 the wavelength corresponding to the mid-frequency in the band of frequencies the device is intended to translate and adjacent crystals are spaced center to center of the order of 0.6 this wavelength. For these dimensions, in a particular device for which the mid-band frequency was 24.5 kilocycles, the maximum secondary lobe was down approximately 20 decibels from the primary lobe and 23 decibels at 20 kilocycles.

Further, the dimensional ratios noted have been found to enable realization of excellent cancellation when lobe comparison or beating deviation indication operation is utilized with the device. In this case, as is understood, the two halves of the group of crystals, that is those to the left and right of the x—x axis in Fig. 3, are operated 180 degrees out of phase after the sound source has been located with all the crystals operated in phase, to locate the sound source with respect to one side or the other of the zero axis, that is, the axis normal to the faces of the plate 25. The efficacy of the translating device in side lobe comparison operation is measured by the cancellation obtained along the zero axis. Operation with phase differences between the halves of values other than 180 degrees are also possible.

The features noted in the two preceding paragraphs will be appreciated from the typical directional patterns shown in Figs. 6 and 7. Fig. 6 shows the pattern when all the crystals are operated in phase and, it will be apparent, the greatest secondary lobes S are substantially 20 decibels down from the primary lobe P. The pattern is essentially the same for both projecting and detecting. Fig. 7 shows the directional pattern when the two halves of the crystal group are operated 180 degrees out of phase, the two halves of the pattern on opposite sides of the zero axis being the main portions of the pattern for the respective halves of the crystal group. As is apparent from Fig. 7, the cancellation obtained on the zero axis is substantially 30 decibels or more so that the sound source can be located accurately as on one side of the other of this axis.

Mounted rearwardly of the backing blocks or resonators 38 is an attenuator or absorber which comprises a plurality of fine mesh metallic screens 40, adjacent screens being separated in fixed space relation by spacers 41. The screens may be of 100 mesh steel screens of 4 mil wire and the spacers 41 may be sheets of steel expanded metal of the order of 100 mils thick and the openings in which constitute of the order of 70 to 80 per cent or greater of the total area. The screens and spacers are mounted in pile-up fashion upon a frame 42 which is secured to inner walls of the housing 21 by brackets 43. The housing 21 is filled, as by way of a port 144, with a gas-free viscous fluid, such as castor oil, having substantially the same characteristics for the transmission of supersonic compressional wave energy as sea water. It is possible to change the frequency band by using a liquid which results in some impedance mismatch. The attenuator or absorber immersed in the fluid serves to absorb much of the energy of waves projected rearwardly from the crystal and resonator assembly and thus prevents reflection of such waves to the crystal and resonator assembly and, hence, distortion of the signals translated by the assembly. Similarly this screen assembly reduces the rear response when the instrument is operated as a detector.

A bulkhead 44, for example a steel plate welded at its sides to the body 18, is mounted in the lower dome portion 11 at a region adjacent the ends of the window 19 and 20 and supports a reflecting pad and an attenuator or absorbing pad. The attenuator or absorbing pad, as shown most clearly in Fig. 5, comprises a pile-up of fine mesh screens 45 and expanded metal spacers 50, similar to the attenuator 40, 41, which is mounted within a housing 46, the front wall 47 of which is of a sound transparent material, such as commercially available forms of rubber, capable of transmitting supersonic compressional wave energy therethrough without substantial attenuation. The housing 46 is filled with a gas-free fluid, such as castor oil, so that much of the energy of waves incident upon the wall 47 is absorbed by the attenuator and reflection of such waves is prevented.

The reflecting pad comprises a body 48 of cellular material, such as sponge or multicellular rubber, which is enclosed in a water-tight housing constituted by the bulkhead 44 and a metallic cover 49 bolted thereto. Alternatively, the pad may be enclosed in a sealed housing secured to the bulkhead. It is effective to reflect substantially all supersonic waves incident thereon and thus effectively screens the translating device from signals emanating from sources rearwardly of the window 19, 20.

When the submarine signaling device is in use, the housing 10, 11 is filled with sea water as by way of the top of the upper dome. When the device is operated as a detector compressional waves incident upon the window 19, 20 are transmitted to the crystals 32 without substantial attenuation due to the high transparency of the windows 19, 20 and 24 to such waves and the transmission characteristics of the sea water filling of the housing 10, 11 and the fluid filling of the housing 21. Because of the sharply directive property of the signal translating device, the direction of the source of the signals detected may be located to a high degree of accuracy by rotating the translating device until a maximum response is obtained therefrom. Inasmuch as the window 19, 20 is of large extent, for example about 135 degrees on either side of the longitudinal axis of the housing 10, 11, the device can scan over a large angle, e. g. about 270 degrees.

It is to be noted especially that signals are detected with substantially negligible distortion. The location of the signal translating device well forward in the housing portion 11 places the device at a positive pressure area inasmuch as at the region forward of and adjacent the device the width of this housing portion is increasing. At this region, water turbulence and cavitation are small. Hence, noises due to turbulence and cavitation are small and a high signal to noise ratio is obtained. The window 19, 20 is of great strength and rigidity and will not vibrate even when the ship on which the signaling device is mounted is traveling at high speeds and, as previously noted, is highly transparent to supersonic signals so that signals are passed therethrough without distortion. Compressional waves incident upon the window 19, 20 at such angle as not to pass directly to the window 24 either pass directly through the window 19, 20 and into the sea or are substantially completely absorbed by the attenuator pad 45, 47. Reflection effects in the translating device itself are prevented by the attenuator 40, 41 as pointed out heretofore. Extraneous signals originating to the rear of the housing 10, 11, for example at the propeller of the ship upon which the signaling device is mounted, are substantially completely reflected by the reflector pad 48, 49.

In some cases, particularly where moderate vibrations of the resonators 38 occur, the directional response pattern of the device may include a 180 degree lobe of appreciable magnitude. Such a lobe may be substantially suppressed by providing a reflecting member, for example a thin sheet of cellular material such as cork or a combination of cork and rubber, between the attenuator 40 and the rear of the housing 21.

It may be noted further that devices of the construction shown and described are characterized by a high efficiency, and a wide band width, of the order of 5 to 6 kilocycles, when operated as echo ranging devices. That is, throughout this band, substantially equal over-all response for the system is realized throughout a range of frequencies. A wider band, e. g. of the order of 20 kilocycles may be obtained at some sacrifice in efficiency. The beam width, which may be measured as the included angle between points on the main lobe of the directional pattern 10 decibels down from the maximum, varies with the frequency for which the signal translating device is especially designed and, in general, the higher the frequency the narrower the beam width. In particular constructions, beam width of 24 degrees for a mid-band frequency of 24 kilocycles, 20 degrees for a mid-band frequency of 30 kilocycles, and 28 to 30 degrees for a mid-band frequency of 20 kilocycles have been obtained. Thus, a wide frequency range of uniform response with sharp directionality is realized in devices constructed in accordance with features of this invention. Similar uniformity of power propagation and directionality are obtained also if the signaling device is utilized as a supersonic signal projector.

Reference is made to the application Serial No. 470,807, filed December 31, 1942, of Arthur C. Keller and the application Serial No. 470,837, filed December 31, 1942, of Warren P. Mason wherein certain features of the sonically transparent window of the housing, and the attenuator pads respectively are claimed.

Although a specific embodiment of this invention has been shown and described, it will be understood that it is but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention as defined in the appended claims.

What is claimed is:

1. A compressional wave signaling device comprising a housing including an elongated body portion, said portion having a window transparent to compressional waves and extending over the front end thereof and rearwardly from said end, a signal translating device mounted within said portion adjacent said front end thereof, a compressional wave energy absorbing element mounted within said portion adjacent the rear extremities of said window, and compressional wave reflecting means mounted within said portion rearward of said absorbing element.

2. A submarine signaling device comprising a stream-lined housing, a transverse bulkhead mounted within said housing to the rear of the center thereof, said housing having a portion transparent to compressional waves and extending over the front end of said housing and rearwardly to adjacent said bulkhead, a signal translating device rotatably mounted within said housing adjacent the front end thereof and opposite said portion, a compressional wave attenuator pad mounted on the face of said bulkhead toward said translating device, and a compressional wave reflecting element mounted on the opposite face of said bulkhead.

3. A submarine signaling device in accordance with claim 2 wherein said signal translating device comprises a housing having a wall portion transparent to supersonic compressional waves, a supersonic compressional wave translating unit within said second housing and opposite said wall portion, and compressional wave energy absorbing means within said second housing and to the side of said unit remote from said wall portion.

4. A submarine signaling device in accordance with claim 2 wherein said signal translating device comprises a housing having a wall portion transparent to supersonic compressional waves, a plate opposite said wall portion, a plurality of piezoelectric crystals mounted on the face of said plate toward said wall portion, a compressional wave attenuating pad opposite the other face of said plate, and a fluid filling for said second housing having substantially the same transmission characteristics as sea water for supersonic signals.

5. A submarine signaling device comprising a streamlined housing including a body portion having a window transparent to compressional waves and extending over the front end of said portion and rearwardly beyond the center thereof, said window comprising a thin, rigid framework of expanded metal and a thin steel sheet covering said framework and intimately joined thereto, a second housing rotatably mounted within said first housing adjacent said front end and opposite said window, said second housing having a wall portion opposite said window and transparent to compressional waves, a signal translating unit within said second housing and opposite said wall portion, compressional wave energy absorbing means within said second housing opposite the side of said unit remote from said wall portion, a compressional wave energy attenuator pad extending transversely of said first housing and mounted therein adjacent the ends of said window, and a compressional wave reflector mounted within said first housing rearwardly of said attenuator.

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