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Technical Report No. 154

# A CYLINDRICAL PARABOLIC REFLECTOR FOR USE WITH PIEZOELECTRIC CYLINDRICAL TRANSDUCERS, AS APPLIED TO LATERAL ECHO UNDERWATER SURVEY

by

F. W. Cole



January 1968



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ABSTRACT

A parabolic lead reflector designed for creating a narrow sound beam at an underwater frequency of 30.5 kHz from an array of cylindrical ceramic piezoelectric crystals is described.

The reflector consists of sheet lead 1/4-in. thick, backed by an aluminum stiffener sheet, 1/8-in. thick.

Brackets for supporting the cylindrical crystal assembly are positioned at three points along the focal axis of the reflector.

Clamping brackets for holding the cylindrical transducer are used to secure the transducer to the mounting brackets along the reflector axis. Spacers of predetermined lengths are used to position the clamping brackets closer to or further away from the mounting brackets in the reflector. In this way, the vertical beam width can be varied to a considerable degree by shifting the transducer inside, at, or forward of the reflector focal axis.

The cylindrical transducer assembly consists of 18 ceramic, lead zirconate cylinders, 1-1/2 in. O.D. and 2-1/2 in. long. The cylinders are cemented end to end to form a single, long, cylinder transducer. The transducer is then enclosed in a snug-fitting, tubular rubber sleeve that has an attached rubber oil reservoir. The entire assembly is evacuated and then filled with oil that has been previously evacuated to remove air contamination. The oil reservoir maintains pressure balance in the transducer as the transducer is raised or lowered or varies in depth during submerged towing.

## INTRODUCTION

Various kinds of transducers have been employed in side-looking sonars, or lateral echo sounders. In Hudson Laboratories Model CL-1,[1] the transducer consisted of a cylindrical crystal array in front of a lead plate bent to a corner angle of 90 degrees. The shape of the sound beam was determined by positioning the center line of the transducer one wavelength from the corner and equidistant from both sides. Several experiments with the corner reflector produced results that were not as precise as desired. Accordingly, other means were used to improve the resolution capability of the cylinder transducer-reflector assembly.

Not all of the sound waves returning to a corner-reflected transducer arrive in the same phase at the transducer, but, in a parabolic reflector, they do arrive in proper phase.

The present report describes such a parabolic reflector. Construction details appear in the Appendix. The main body of this report concerns the results of directivity measurements, and presents results from experiments in the Minas Basin, Nova Scotia, and along the north coast of Jamaica, W.I., where the same areas were scanned using both corner and parabolic reflectors.

A related report will appear soon.[2]

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[1] C. S. Clay and W. Liang, Lateral Echo Sounder - Model CL-1 (Hudson Laboratories of Columbia University Tech. Rept. No. 114, March 12, 1964).

[2] F. W. Cole, A Familiarization with Lateral or Side-Scanning Sonars (Hudson Laboratories of Columbia University Tech. Rept. No. 159, July 1968).

## TEST RESULTS

Tests to determine the directivity patterns obtainable with the parabolic reflector transducer assembly were conducted at the U. S. N. Underwater Sound Reference Laboratory, Orlando, Florida.

Directivity patterns USRL 42416-17-18-19-20-21 and 42423 found on the following pages, with comments, indicate just a few of the possible beam patterns that can be created. USRL 42422 shows the horizontal beam pattern, which is thought to remain unchanged, regardless of the shape of the vertical pattern.

In some of the tests, USRL 42417-18-19, and 42421, a lead reflector channel was used in experiments to determine if distortion of the beam resulting from a mixing of direct radiation from the front of the transducer, and that from the reflector could be eliminated. The channel consisted of 3/16-in. thick lead formed over a 1-3/4-in. diameter round mandrel, 41-1/2 in. long. The channel was designed to cover the entire front half of the transducer when closely coupled to it. Brackets were fastened to the lead reflector channel at points agreeing with the transducer mounting clamps in the parabolic reflector (see Fig. 1).

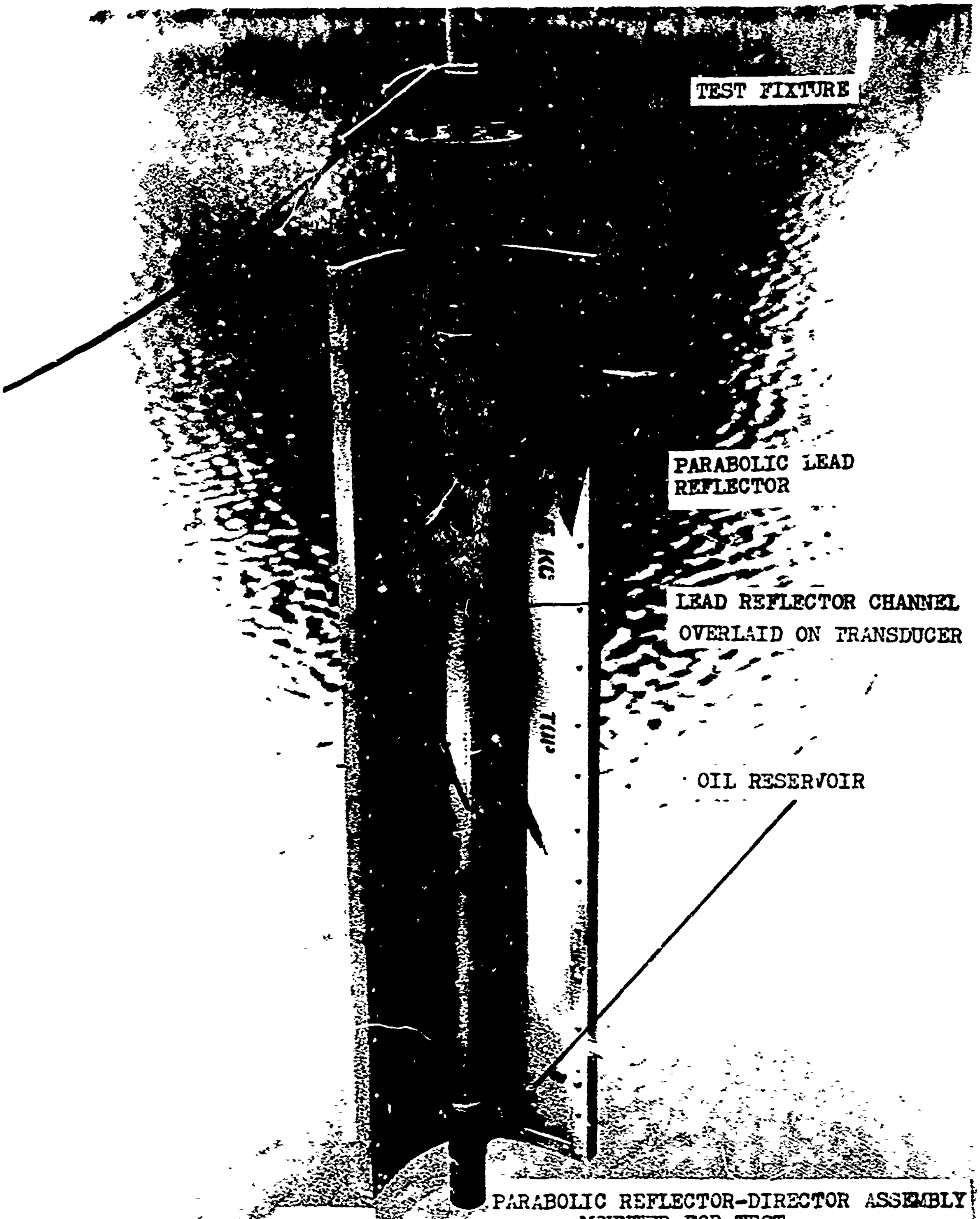
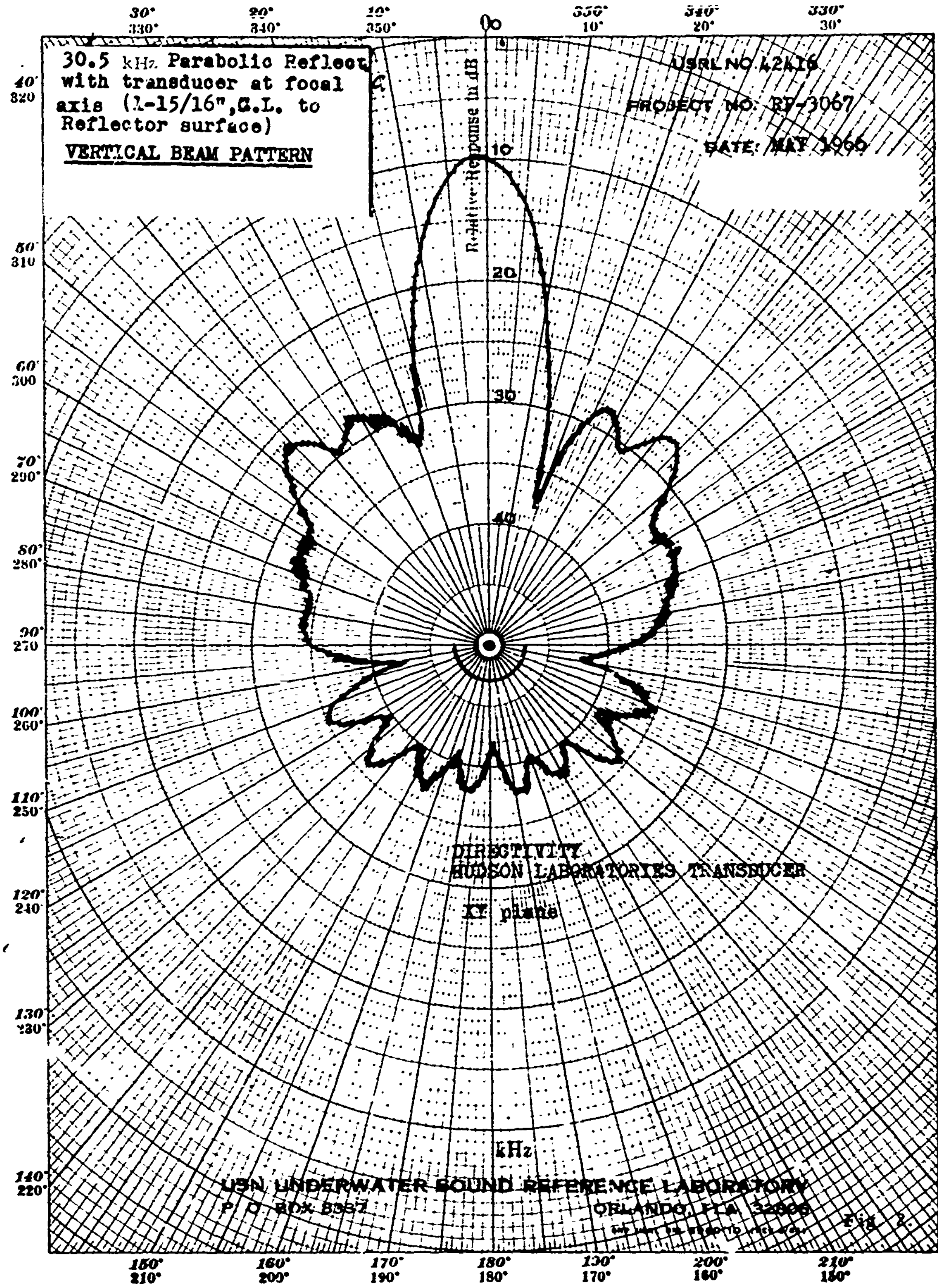



Fig. 1. PARABOLIC REFLECTOR-DIRECTOR ASSEMBLY MOUNTED FOR TEST

USRL 42416 (Fig. 2):

This pattern was obtained with the transducer center line located 1-15/16 in. from the reflector surface, at the design focal axis. The main lobe is approximately 25 degrees wide at the 25-dB reference line, with side lobes 18 dB down from the 10-dB reference.

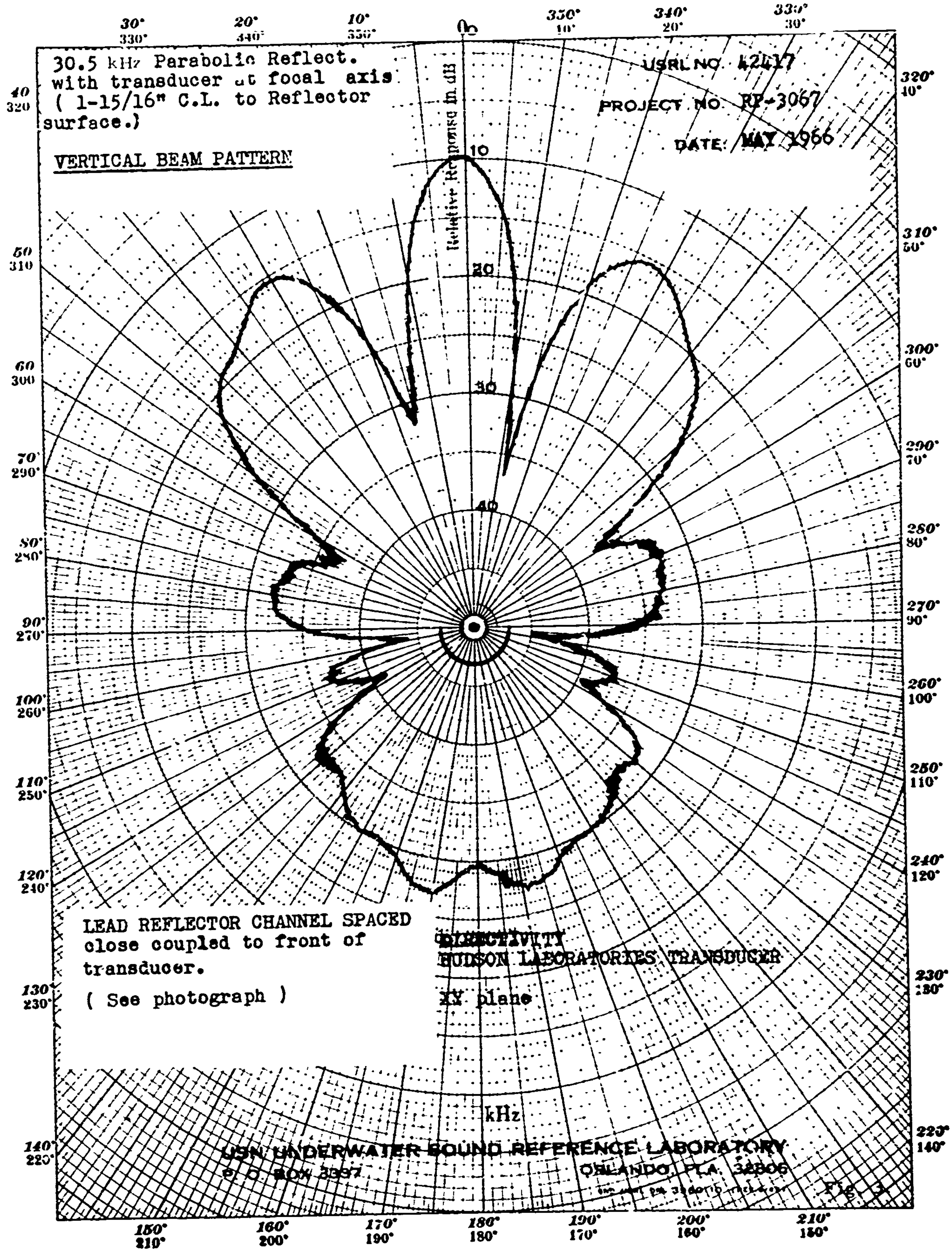
This pattern has been used extensively for lateral echo survey. It results in sharp bottom definition of objects. Over uniform rubble on the bottom, comparatively uniform "shadow" generation allows the sizes of objects to be assessed.


30.5 kHz Parabolic Reflector with transducer at focal axis (1-15/16",C.L. to Reflector surface)
VERTICAL BEAM PATTERN
USRL NO 42A16
PROJECT NO. RF-3067
DATE: MAY 1966
Relative Response in dB
0
10
20
30
40
DIRECTIVITY
HUDSON LABORATORIES TRANSDUCER
XY plane
kHz
USN UNDERWATER SOUND REFERENCE LABORATORY
P. O. BOX 8337
ORLANDO, FLA. 32806
Fig. 2

USRL 42417 (Fig. 3):

The transducer center line in this test was located the same as in USRL 42416, and the lead reflector channel was clamped against the forward transducer surface. The main lobe has been reduced to about 22 legrees at the 25-dB reference line, and the side lobes have increased in strength to only 6 dB below the 10-dB reference line.

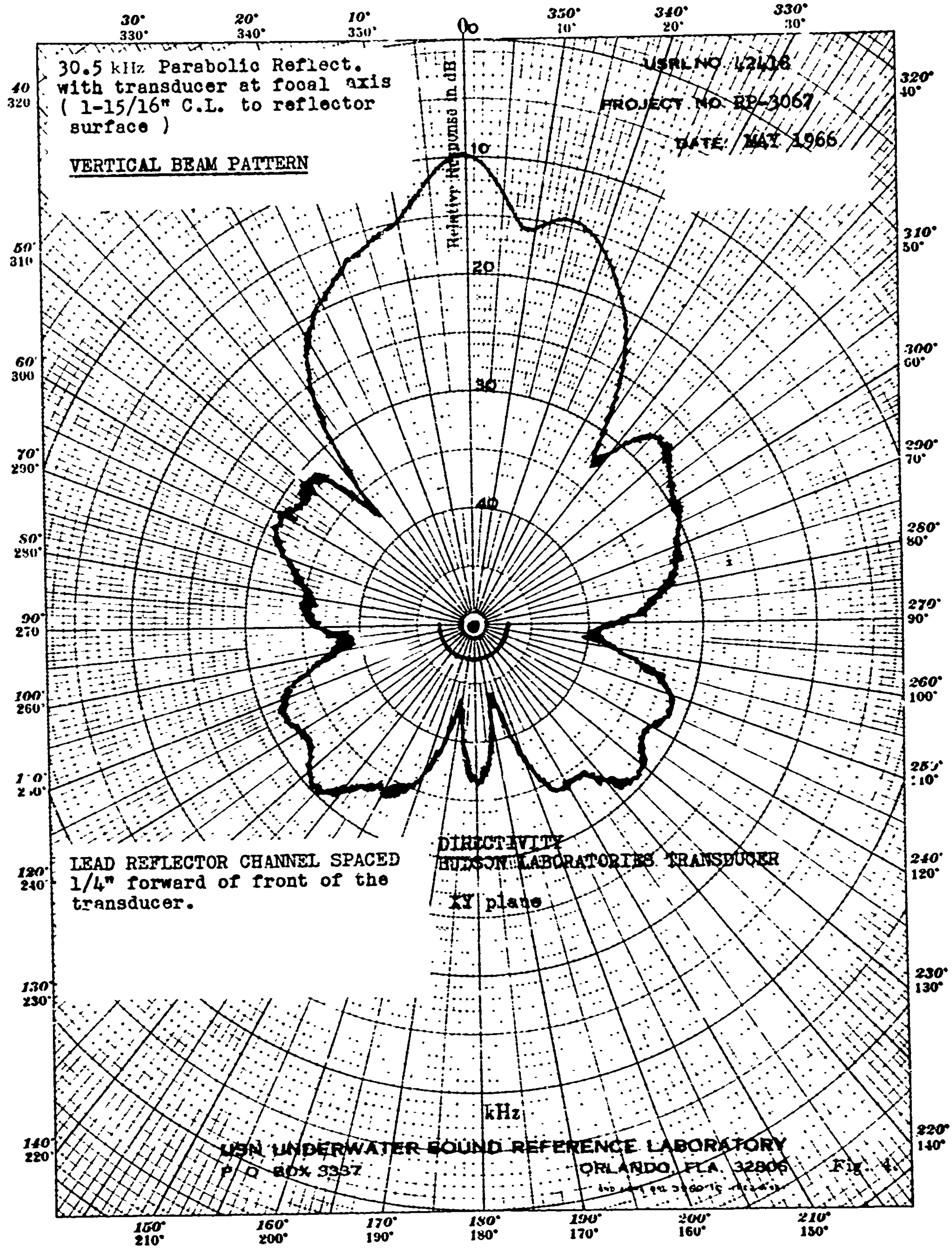
This pattern has been used with much success in determining bottom topography. On the records, the "shifts" in spacing between the returns from each beam lobe outline gulleys, hills, and slopes. Within the area of each individual beam lobe details are clear, but in the areas between lobes, details are more difficult to observe.



30.5 kHz Parabolic Reflect. with transducer at focal axis ( 1-15/16" C.L. to Reflector surface.)
VERTICAL BEAM PATTERN
USRL NO. 42417
PROJECT NO. RP-3067
DATE: MAY 1966
Relative Response in dB
10
20
30
40
LEAD REFLECTOR CHANNEL SPACED close coupled to front of transducer.
( See photograph )
DIRECTIVITY
HUDSON LABORATORIES TRANSDUCER
XY plane
kHz
USN UNDERWATER SOUND REFERENCE LABORATORY
P. O. BOX 3387
ORLANDO, FLA. 32806
Fig. 3

USRL 42418 (Fig. 4):

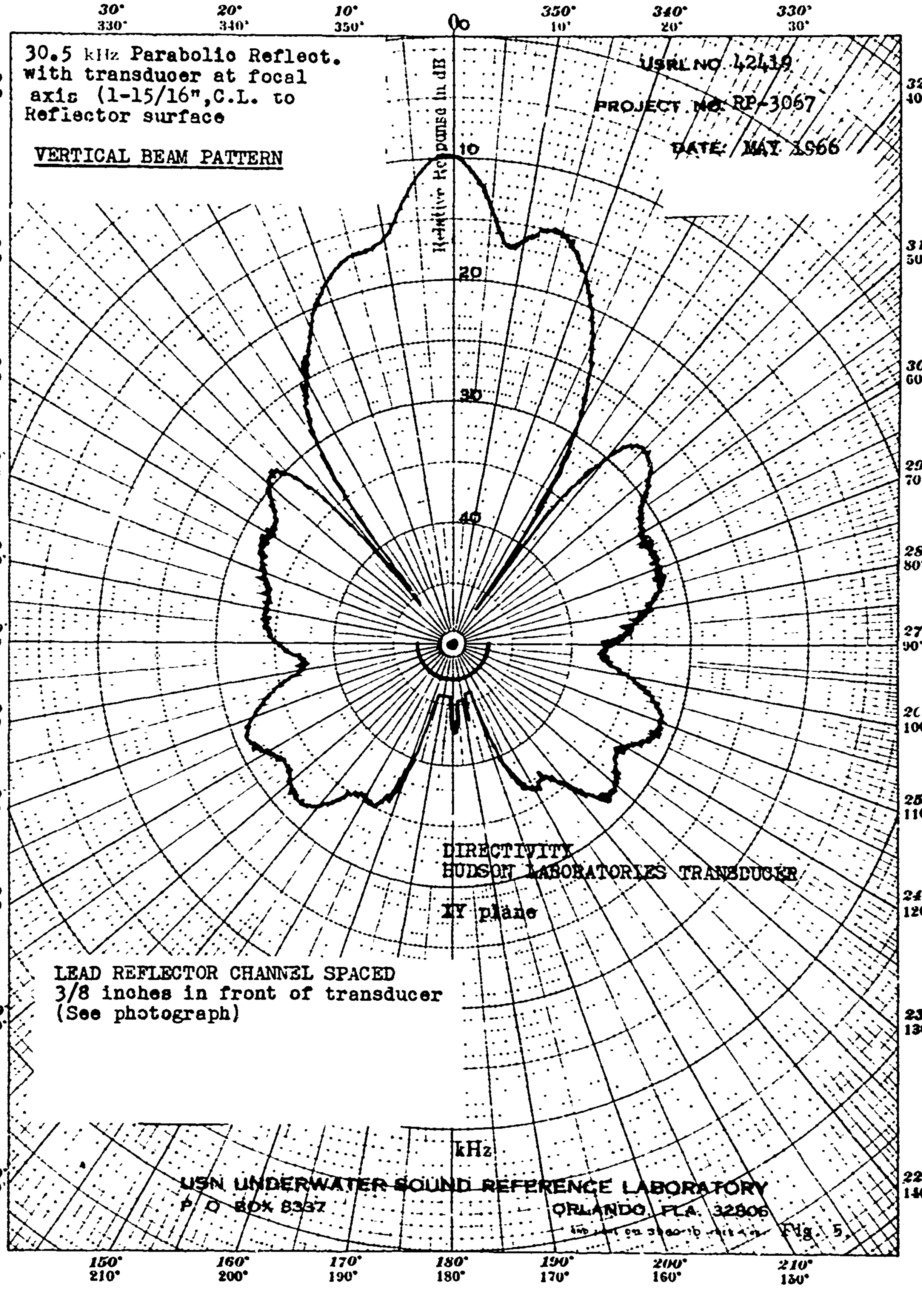
The transducer center line in this test was located the same as in USRL 42416, and the lead reflector channel was spaced 1/4 in. forward of the forward transducer surface. The main beam lobe has widened to about 65 degrees at the 25-dB reference line, and the side lobes have returned to a level about that equal to those shown in USRL 42416. This indicates that the reflector channel can be used successfully to widen the main beam substantially, without increasing the intensities of the side lobes. This beam pattern has been used extensively for bottom search work, for locating wrecks and lost aircraft.



30.5 kHz Parabolic Reflect. with transducer at focal axis ( 1-15/16" C.L. to reflector surface )
VERTICAL BEAM PATTERN
USRL NO. 4218
PROJECT NO. RP-3067
DATE: MAY 1966
Relative Response in dB
10
20
30
40
LEAD REFLECTOR CHANNEL SPACED 1/4" forward of front of the transducer.
DIRECTIVITY
HUDSON LABORATORIES TRANSDUCER
XY plane
kHz
USN UNDERWATER SOUND REFERENCE LABORATORY
P O BOX 3337
ORLANDO FLA 32806
Fig. 4

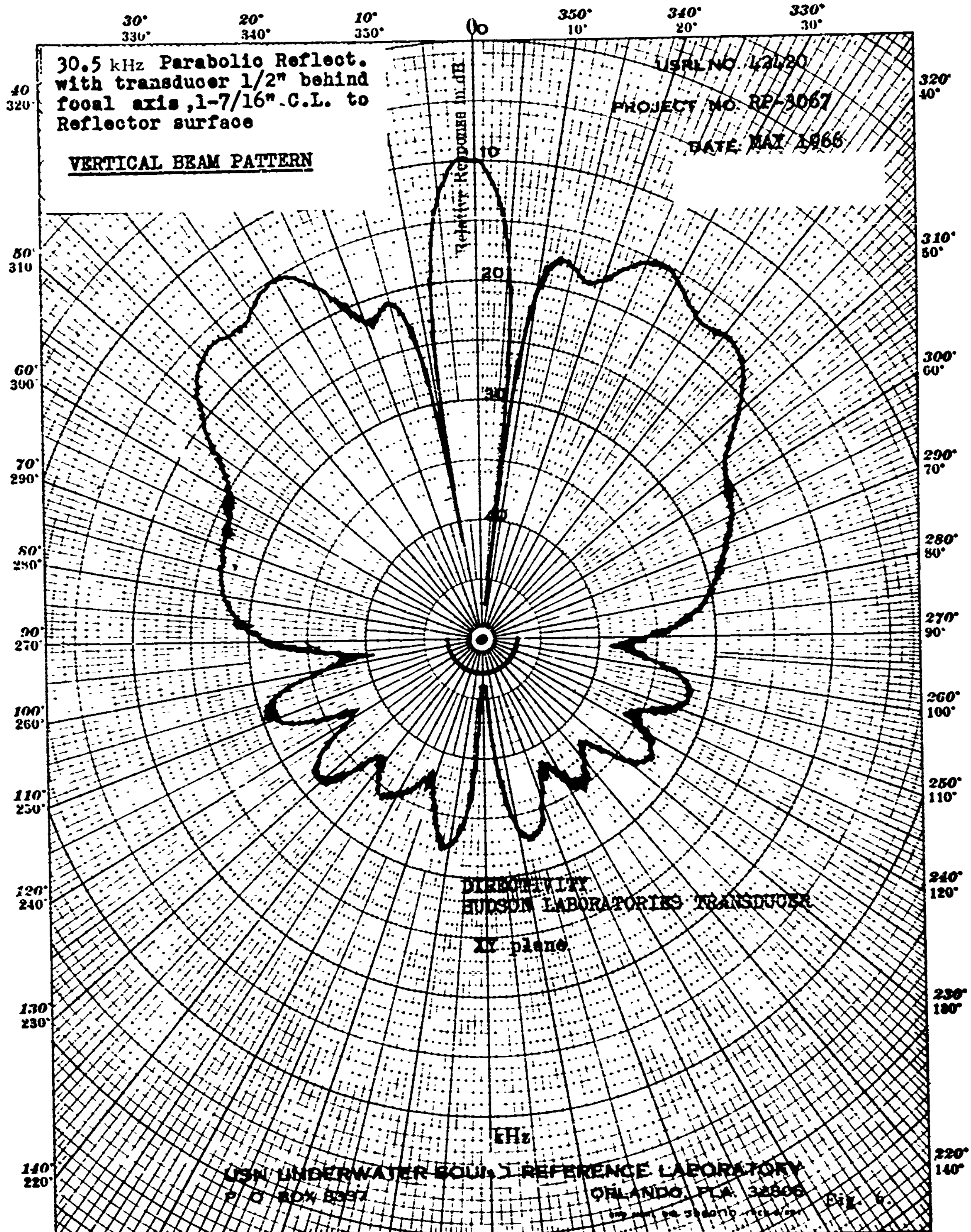
USRL 42419 (Fig. 5):

The transducer center line in this test was located the same as in USRL 42416, and the lead reflector channel was spaced 3/8 in. forward of the forward transducer surface. The main beam lobe has spread to only about 47 degrees wide at the 25-dB reference line, and the side lobes have not greatly increased beyond that seen in USRL 42416. This indicates that the lead reflector channel need only be adjusted forward of the transducer through a comparatively small distance to narrow down the main beam lobe. Field use of this pattern produced the same results as that obtained with USRL 42418 previously shown, with the exception that the bottom area covered with this pattern was smaller in size.


30.5 kHz Parabolic Reflect.
with transducer at focal
axis (1-15/16",C.L. to
Reflector surface
VERTICAL BEAM PATTERN
USRL NO. 42419
PROJECT NO. RP-3067
DATE: MAY 1966
Relative Response in dB
0
10
20
30
40
DIRECTIVITY
HUDSON LABORATORIES TRANSDUCER
XY plane
LEAD REFLECTOR CHANNEL SPACED
3/8 inches in front of transducer
(See photograph)
kHz
USN UNDERWATER SOUND REFERENCE LABORATORY
P. O. BOX 8337
ORLANDO, FLA. 32806
Fig. 5

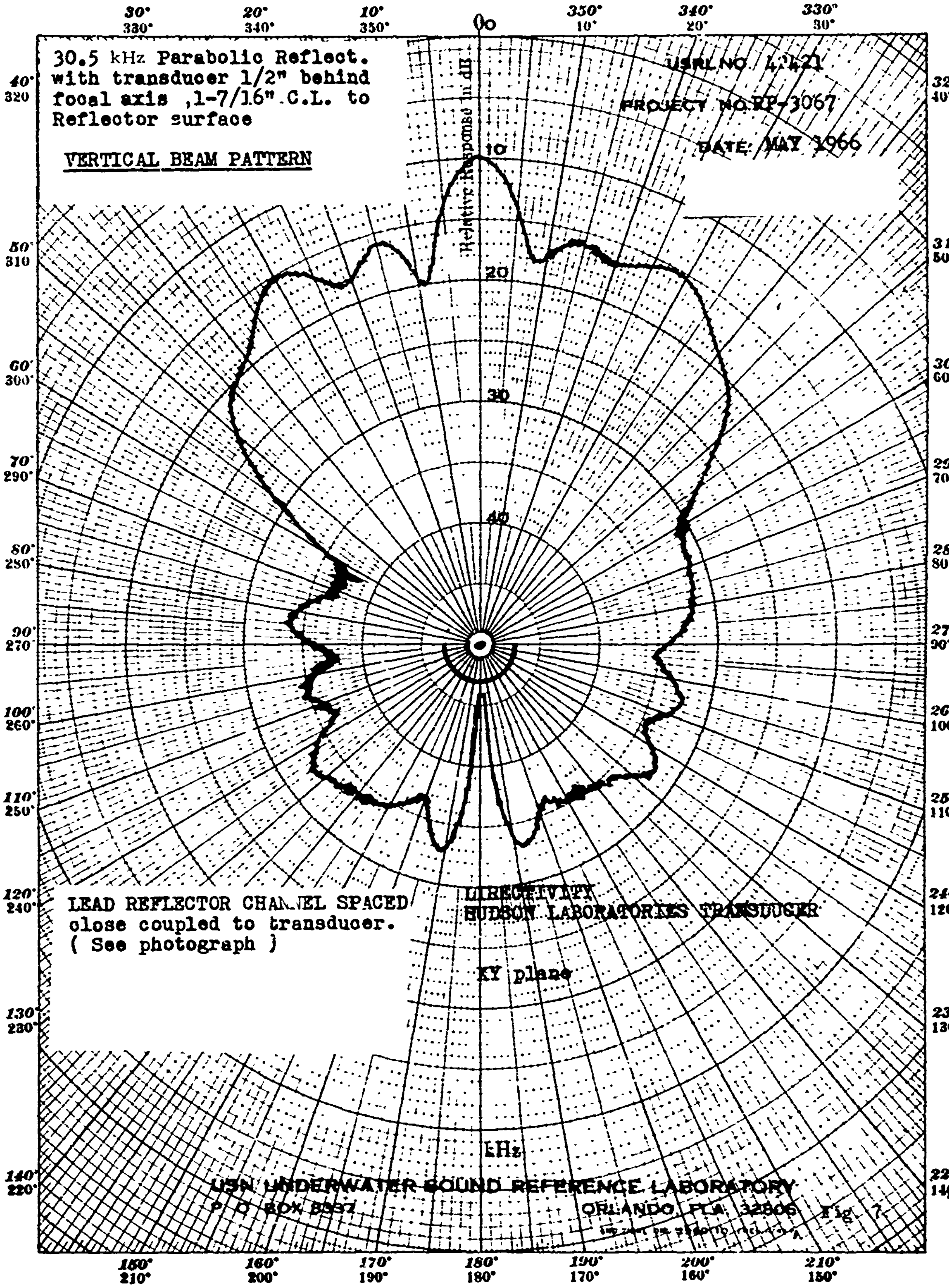
USRL 42420 (Fig. 6):

In this test the transducer center line was located 1/2 in. behind the focal axis of the reflector, or 1-7/16 in. from the reflector surface. The main beam lobe has been reduced to about 9 degrees at the 25-dB reference line, whereas the side lobes have been widened and raised to nearly 6 dB below the 10-dB main lobe reference. This indicates that when the transducer is positioned behind the focal axis of the reflector, the center or main lobe will be reduced, with an attendant large increase in size and strength of the side lobes. This pattern has not been used in the field.


30.5 kHz Parabolic Reflect. with transducer 1/2" behind focal axis ,1-7/16".C.L. to Reflector surface
VERTICAL BEAM PATTERN
USRL NO. 42420
PROJECT NO. RP-3067
DATE MAY 1966
Relative Response in dB
10
20
30
40
DIRECTIVITY
HUDSON LABORATORIES TRANSDUCER
XY plane
kHz
USN UNDERWATER SOUND REFERENCE LABORATORY
P. O. BOX 8337
ORLANDO, FLA. 32806
Fig. 6

USRL 42421 (Fig. 7):

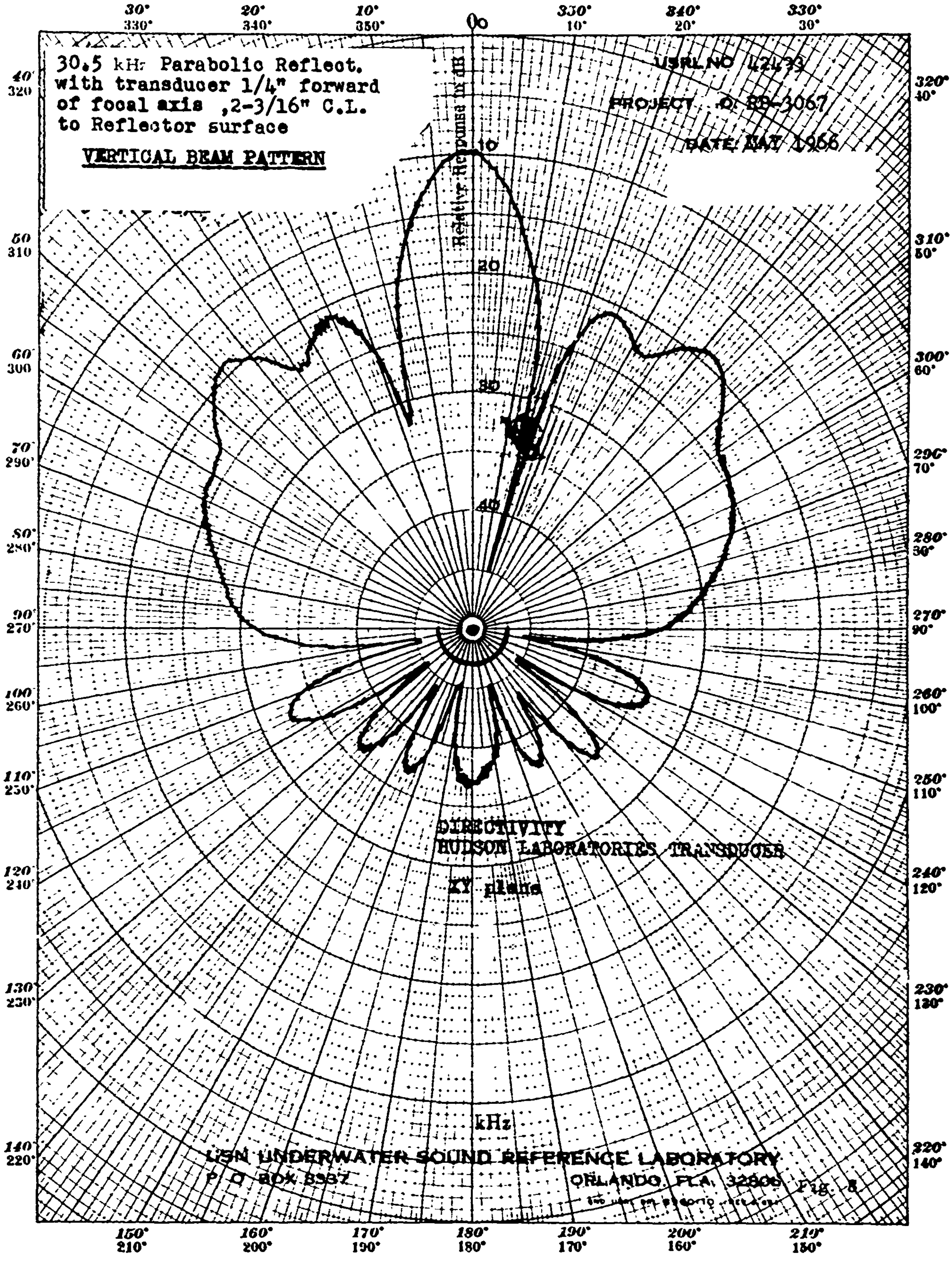
The center line of the transducer was located the same as in USRL 42420, and the lead reflector channel was clamped against the forward transducer surface. Note that the beam has been consolidated by the addition of the lead reflector channel (as compared to USRL 42420), and that the beam width is about 100 degrees at the 25-dB reference line. Side lobes of any consequence are not apparent in this pattern. Further data on this pattern are unavailable, as it has not had sufficient field use for evaluation.



30.5 kHz Parabolic Reflect.
with transducer 1/2" behind
focal axis ,1-7/16" C.L. to
Reflector surface
VERTICAL BEAM PATTERN
USRL NO. L-421
PROJECT NO. RP-3067
DATE: MAY 1966
LEAD REFLECTOR CHANNEL SPACED
close coupled to transducer.
( See photograph )
DIRECTIVITY
HUDSON LABORATORIES TRANSDUCER
XY plane
kHz
USN UNDERWATER SOUND REFERENCE LABORATORY
P. O. BOX 8337
ORLANDO, FLA. 32806
Fig. 7
Relative Response in dB

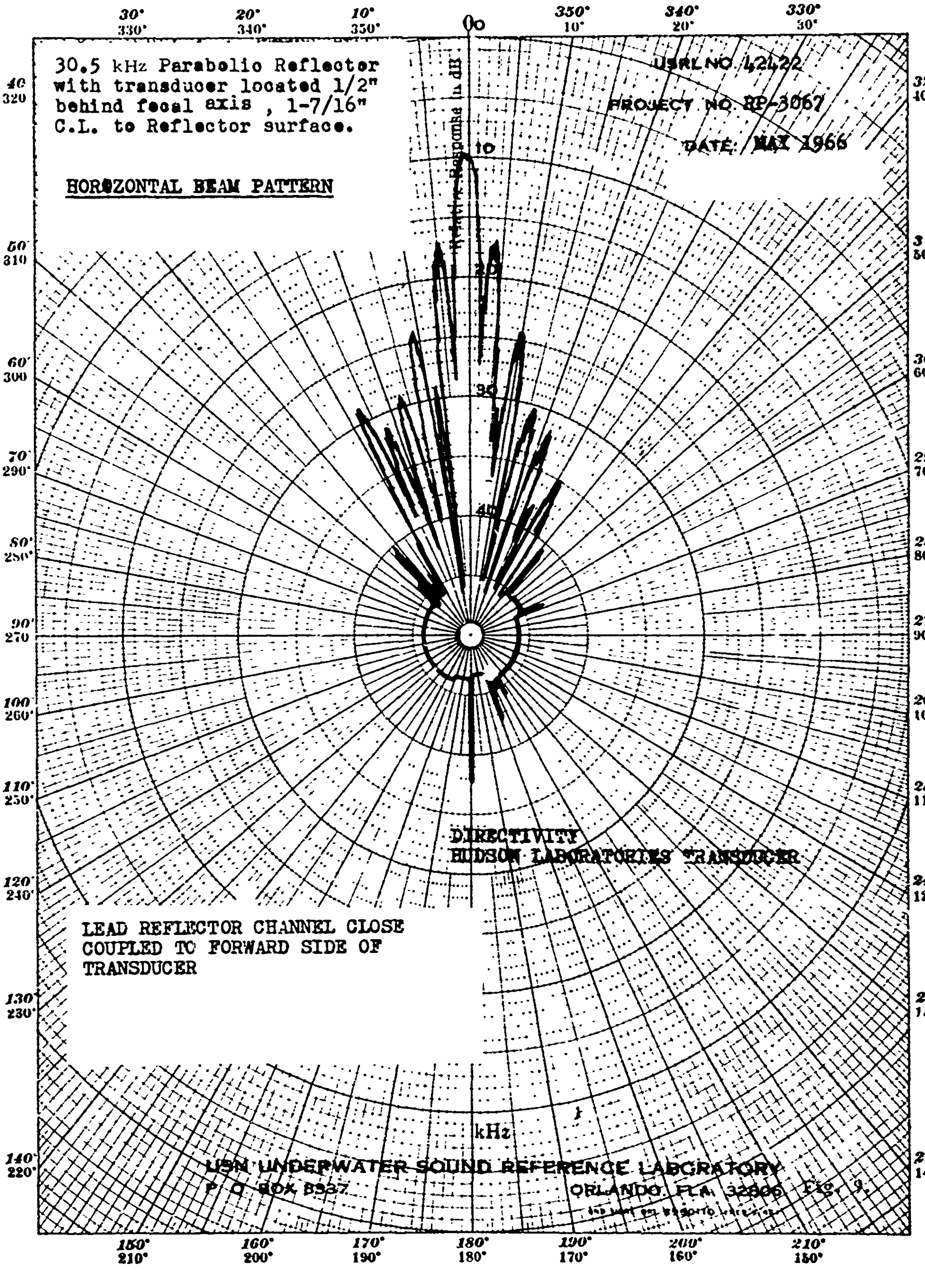
USRL 42423 (Fig. 8):

The transducer center line was located 1/4 in. forward of the reflector focal axis, or 2-3/16 in. from the reflector surface. The main beam lobe has expanded to about 27 degrees wide at the 25-dB reference line, but the side lobes have increased in width and increased in strength to 10 dB below the 10-dB main lobe reference line. Unfortunately, data are not available as to the effect that the lead reflector channel might have on this pattern, as test time limitations prevented further experiment. No field use of this pattern has been made.


30.5 kHz Parabolic Reflect. with transducer 1/4" forward of focal axis ,2-3/16" C.L. to Reflector surface
VERTICAL BEAM PATTERN
USRL NO 4243
PROJECT
DATE MAY 1966
Relative Response in dB
10
20
30
40
DIRECTIVITY
HUDSON LABORATORIES TRANSDUCER
XY plane
kHz
USN UNDERWATER SOUND REFERENCE LABORATORY
P. O. BOX 8337
ORLANDO, FLA. 32806
Fig. 8

USRL 42422 (Fig. 9):

The transducer center line was located 1/2 in. behind the focal axis of the reflector, or 1-7/16 in. from the reflector surface. The lead reflector channel was clamped against the forward transducer surface. This pattern shows the horizontal beam pattern under these conditions. The beam width of the center lobe is about 5 degrees at the 25-dB reference line, with two adjacent major lobes. Removal of the lead reflector channel eliminates the two side lobes, but does not change the width of the main beam. This test was conducted only for the purpose of determining the effect on horizontal beam width when the lead reflector was in place. The horizontal beam width with the transducer center line on the focal axis of the reflector is 5 degrees at the 25-dB reference line with minor side lobes either side not less than 15 dB below the 10-dB main lobe reference.


30.5 kHz Parabolic Reflector
with transducer located 1/2"
behind focal axis , 1-7/16"
C.L. to Reflector surface.
HORIZONTAL BEAM PATTERN
USRL NO. 42422
PROJECT NO. RP-3067
DATE: MAY 1966
Relative Response in dB
DIRECTIVITY
HUDSON LABORATORIES TRANSDUCER
LEAD REFLECTOR CHANNEL CLOSE
COUPLED TO FORWARD SIDE OF
TRANSDUCER
kHz
USN UNDERWATER SOUND REFERENCE LABORATORY
P. O. BOX 8337
ORLANDO, FLA. 32806
Fig. 9.

## COMPARISON OF DATA TAKEN WITH CORNER AND CYLINDRICAL PARABOLIC ANTENNAS

The two photographs (Figs. 10 and 11) that follow, display records of side-scan traverses in the same area obtained on two separate occasions. In the first photograph a corner-type reflector was used in back of the transducer; in the second photograph the cylindrical parabolic reflector was used instead of the corner reflector. In Fig. 10, the event marks are at 1-min intervals; in Fig. 11 event marks indicate 5-min intervals. In both traverses peak pulse power was 100 watts and pulse length was 1 msec. Comparison of the two photographs shows that the cylindrical parabolic reflector markedly improves the detail description of the bottom as compared with the results obtained with the corner-type reflector. In the record from the parabolic reflector, shadows are more clearly shown, soft and hard areas more sharply contrasted, and boulders more clearly outlined, than in the record from the corner reflector.

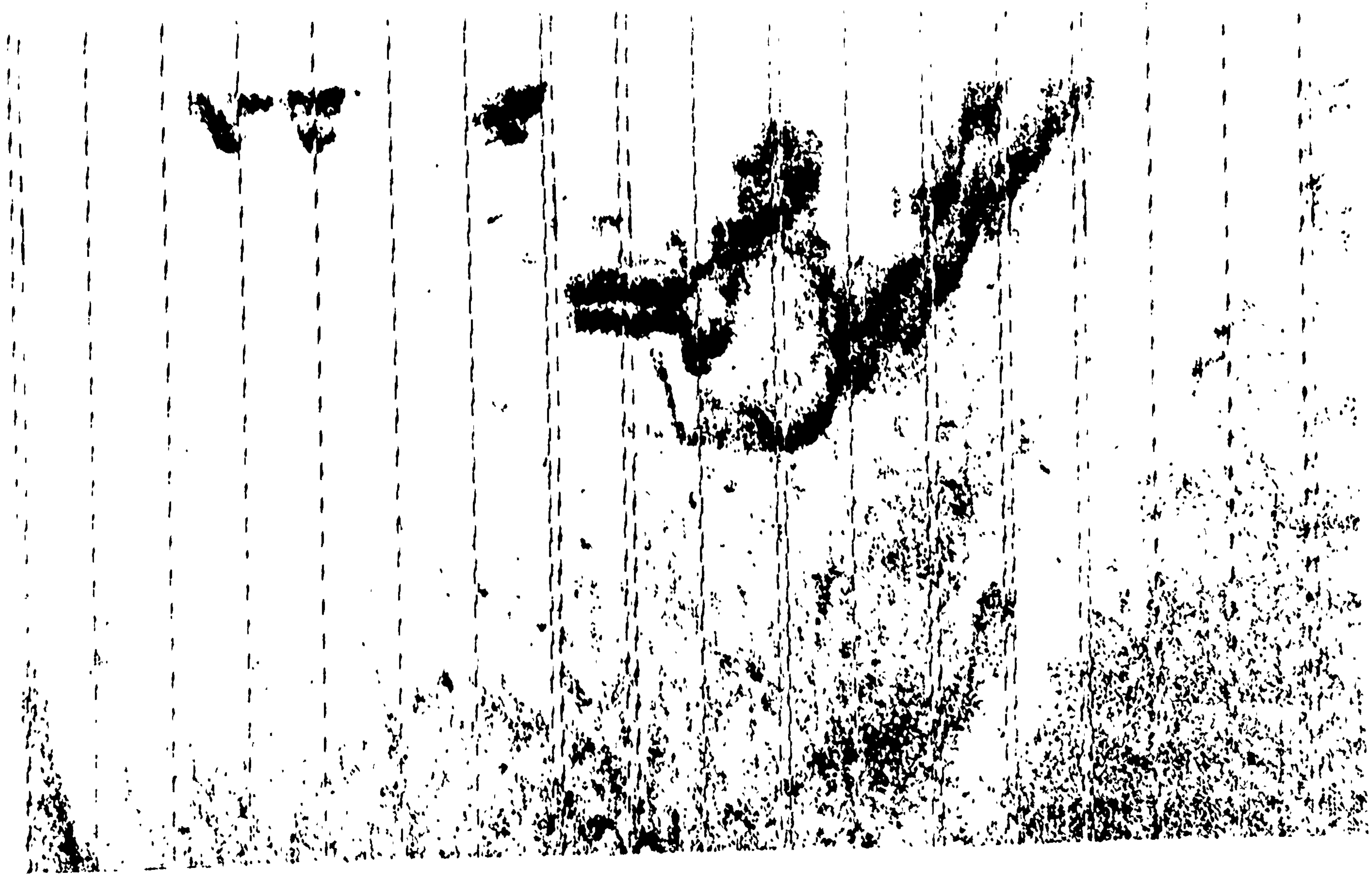


Fig. 10. PHOTOGRAPHIC RECORD;DATA TAKEN WITH CORNER-REFLECTED TRANSDUCER

Fig. 11. PHOTOGRAPHIC RECORD;DATA TAKEN WITH CYLINDRICAL PARABOLIC-REFLECTED TRANSDUCER

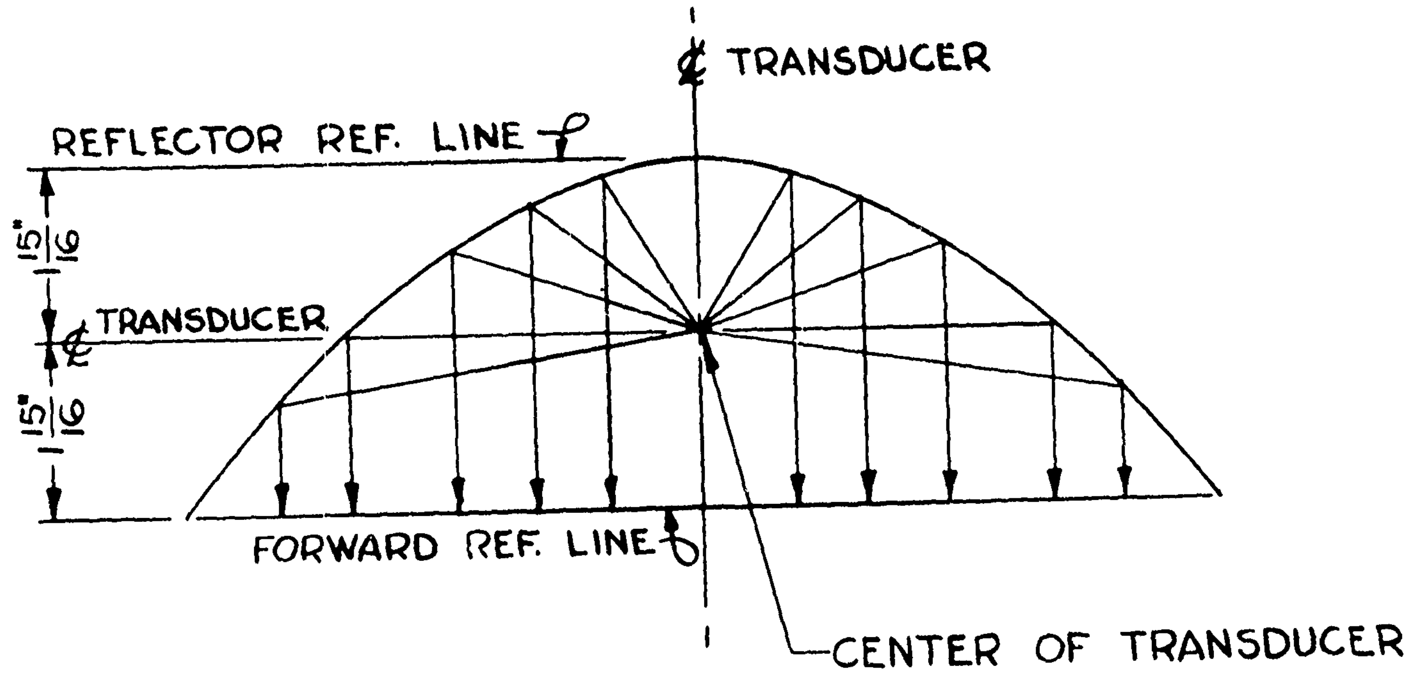
## APPENDIX

Reflector Design:

Using a sound velocity of 4900 ft/sec, and frequency of 30.5 kHz, the focal axis was determined to be 1.92 in., or 1-59/64 in. (one wavelength). The actual dimension used was 1-15/16 in. because of the greater ease of working with this dimension. Two center lines were established at right angles to each other, both called transducer center lines. A reflector reference line, representing the closest point of the reflector to the transducer center was then drawn 1-15/16 in. from the intersect of the transducer center lines. A second reference line, the forward reference, was then drawn located 1-15/16 in. forward of the transducer center line intersect. This located the forward edges of the reflector. Standard parabola development was then used to derive the reflector curvature within the confines of the two reference lines (see Fig. 12).

Reflector Construction:

Because a parabola reflector does not lend itself to standard metal rolling techniques, the following method was used in its construction. The parabola curvature was traced onto a thin aluminum sheet and cut out to be used as a template. A mold was made by laminating pine boards to the ncessary thickness. The mold was planed to shape using the template to check its contour, sanded smooth, and given two coats of epoxy resin to harden its outer surface. The aluminum backing plate was then rolled and pressed to near conformity with the mold. Next, the lead reflector was formed over the mold using a pine block and mallet. When the lead was




(END VIEW)

Fig. 12. PARABOLIC REFLECTOR DEVELOPMENT FOR 30.5 kHz FOCAL AXIS AT 1 15/16" (ONE WAVELENGTH) FROM REFLECTOR

fully formed to the mold, the aluminum backing plate was cemented to it with epoxy cement. An aluminum angle was fastened to the long edges with 10-32 stainless hardware. A 3/4 × 1/16 in. strip of stainless steel was fastened along the curved edges with 10-32 stainless hardware. The aluminum angle acts as a stiffener, while the stainless strip provides edge protection. The focusing bracket assemblies were then located along the central reflector axis, drilled, and bolted into place. The brackets for mounting the reflector to the towing vehicle were fastened to the back of the reflector, and the entire assembly was sanded and given two coats of epoxy paint, thus completing the assembly. Figures 13 and 14 show the mold construction and details of the focusing bracket assembly. The photograph ([illegible] 15) shows the transducer reflector assembly.

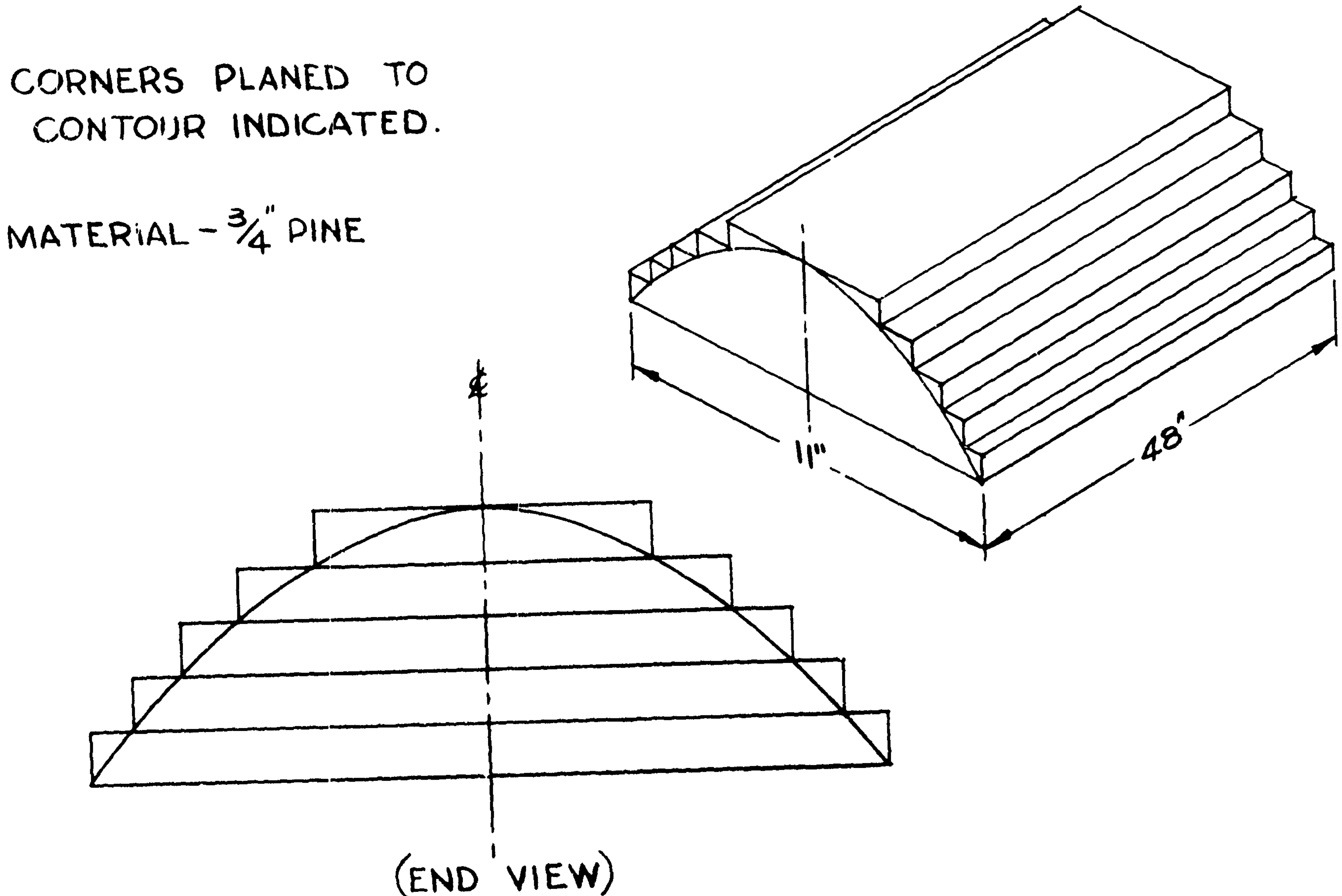



Fig. 13. MOLD FOR 30.5kHz PARABOLIC REFLECTOR

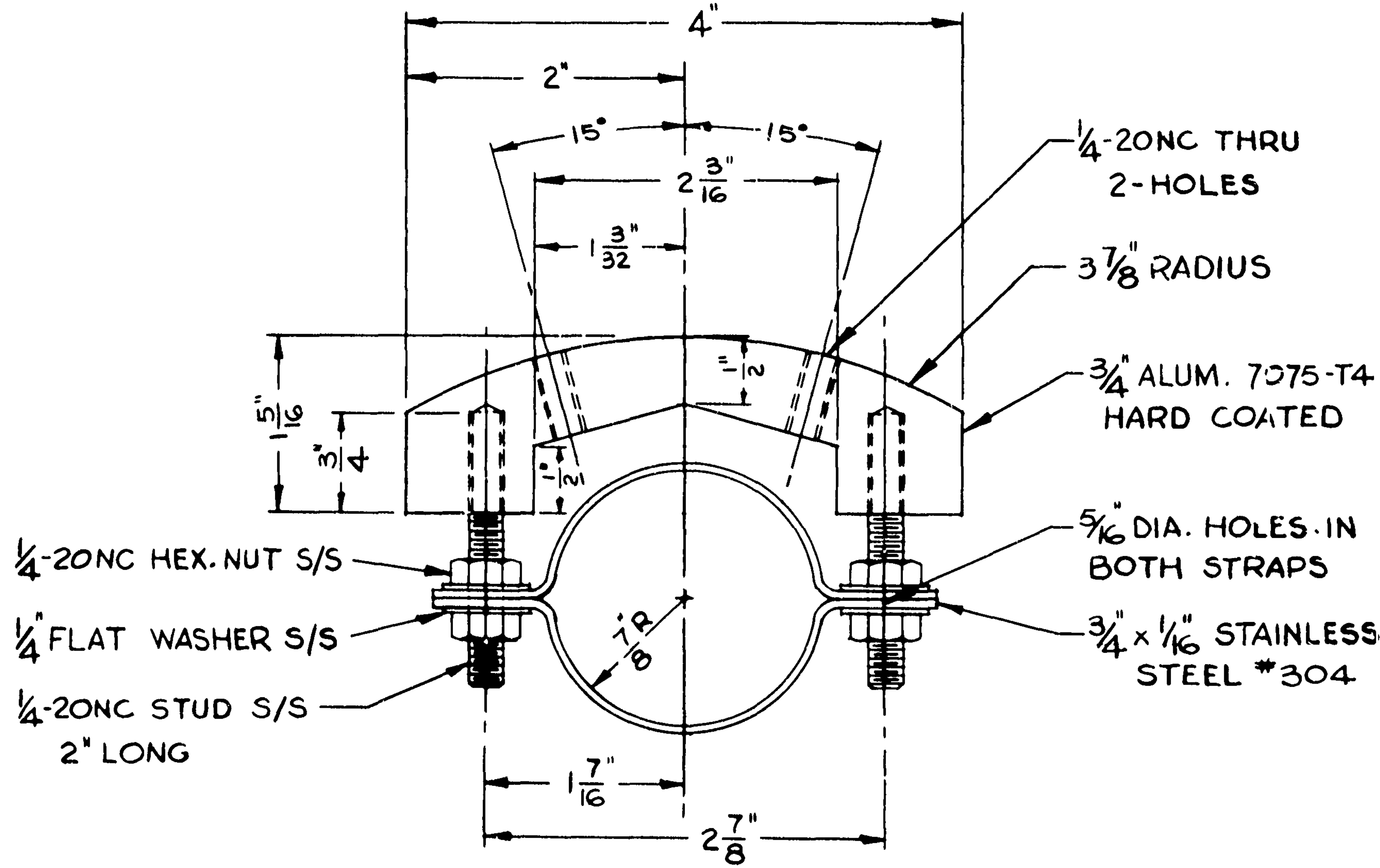



Fig. 14. FOCUSING BRACKET ASSEMBLY
FOR USE IN 30.5 kHz PARABOLIC REFLECTOR

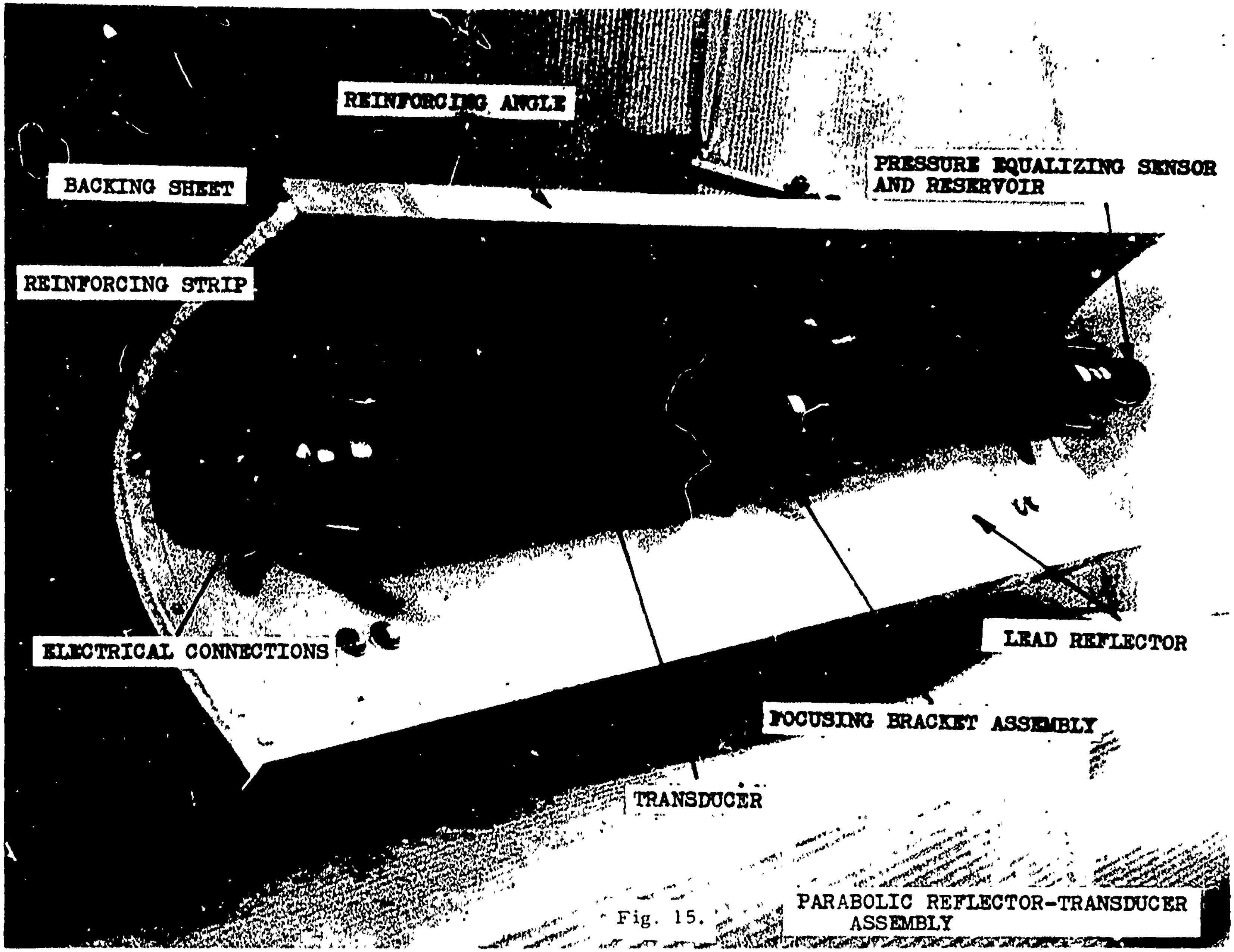



Fig. 15. PARABOLIC REFLECTOR-TRANSDUCER ASSEMBLY

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Mr. Peter E. Weber, Chief Mechanical Engineer, Hudson Laboratories, Columbia University, Dobbs Ferry, N.Y., for assistance in parabola design, and for many constructive consultations during construction phases.

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Monterey, California 93940
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13 ABSTRACT

A parabolic lead reflector designed for creating a narrow sound beam at an underwater frequency of 30.5 kHz from an array of cylindrical ceramic piezoelectric crystals is described.

The reflector consists of sheet lead 1/4-in. thick, backed by an aluminum stiffener sheet, 1/8-in. thick.

Brackets for supporting the cylindrical crystal assembly are positioned at three points along the focal axis of the reflector.

Clamping brackets for holding the cylindrical transducer are used to secure the transducer to the mounting brackets along the reflector axis. Spacers of predetermined lengths are used to position the clamping brackets closer to or further away from the mounting brackets in the reflector. In this way, the vertical beam width can be varied to a considerable degree by shifting the transducer inside, at, or forward of the reflector focal axis.

The cylindrical transducer assembly consists of 18 ceramic, lead zirconate cylinders, 1-1/2 in. O. D. and 2-1/2 in. long. The cylinders are cemented end to end to form a single, long, cylinder transducer. The transducer is then enclosed in a snug-fitting, tubular rubber sleeve that has an attached rubber oil reservoir. The entire assembly is evacuated and then filled with oil that has been previously evacuated to remove air contamination. The oil reservoir maintains pressure balance in the transducer as the transducer is raised or lowered or varies in depth during submerged towing.

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