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NATURAL FREQUENCY AND
RADIATED NOISE MEASUREMENTS ON A
RING-STIFFENED CYLINDER
- EXPERIMENTAL DATA ANNEX -

Layton E. Gilroy

Defence
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**NATURAL FREQUENCY AND
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RING-STIFFENED CYLINDER
- EXPERIMENTAL DATA ANNEX -**

Layton E. Gilroy

December 1993

Approved by W.C.E. Nethercote
Head / Hydronautics Section

Distribution Approved by


Director / Technology Division

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**Defence
Research
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**Centre de
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Canada

Abstract

Defence Research Establishment Atlantic (DREA) has conducted an experiment involving the measurement of radiated noise from a ring-stiffened cylinder subjected to a harmonic load. This experiment was performed to provide validation data for structural acoustics computer codes being developed in-house and under contract. The experiment was in two parts. The first involved determining the natural frequencies of the cylinder in air, while the second stage of testing involved determining the natural frequencies of the cylinder while it was submerged and measuring directivity patterns of radiated noise when the submerged cylinder was excited at some of its natural frequencies. This report contains all the directivity patterns produced in the trials, as well as listings of the measured natural frequencies, both in-air and submerged and, as such serves as an annex to an earlier report describing the experiment.

Résumé

Le Centre de recherches pour la Défense Atlantique (CRDA) a mené une expérience visant à mesurer le bruit rayonné par un cylindre rendu rigide par des anneaux sous l'effet d'une charge harmonique. Cette expérience a été effectuée dans le but de recueillir des données afin de valider certains programmes informatiques d'acoustique élaborés sur place et par le biais de contrats. L'expérience comportait deux parties. La première consistait à déterminer les fréquences de résonance naturelles du cylindre dans l'air, alors que la seconde visait à déterminer les fréquences de résonance naturelles du cylindre immergé et à établir des diagrammes de rayonnement du bruit émis par celui-ci lorsqu'il entrait en résonance. Ce rapport présente les diagrammes de rayonnement produit durant ces essais, de même que les fréquences de résonance naturelles du cylindre immergé et à l'air libre et constitue un annexe d'un rapport précédent décrivant l'expérience.

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1 Introduction

Defence Research Establishment Atlantic (DREA) recently conducted experiments to measure the radiated noise from a ring-stiffened cylinder subjected to a harmonic load. These experiments were performed to provide validation data for structural acoustics computer codes being developed in-house and under contract.

The experiments were conducted in two parts. The first part involved determining the natural frequencies of the cylinder in air for comparison to finite element analysis predictions. These tests were performed in the Heavy Engine Laboratory at DREA. The second part involved determining the natural frequencies of the cylinder while it was submerged and determining directivity patterns of radiated noise when the cylinder was excited at some of its natural frequencies. These tests were carried out at the DREA Calibration Barge in Bedford Basin, the upper part of Halifax Harbour.

The experiments were described in full in previous DREA publications [1, 2]. This technical communication contains a listing of the measured natural frequencies, both in-air and submerged, and all of the measured directivity patterns from the trial. This report is intended to serve as an annex to [1].

2 Cylinder Data

The ring-stiffened right cylinder was manufactured at the Ship Repair Unit (Atlantic) machine shops with material provided by DREA. The cylinder consisted of a longitudinally welded steel tube, stiffened with ring-stiffeners of square cross-section, and capped with thick steel plate. The endcaps were of two pieces with a central 'hatch', which was bolted to the remainder of the endcap and sealed with an O-ring. Ring bolts were welded to the endcaps at various positions to allow handling of the cylinder and the endcaps. The nominal dimensions of the cylinder are given in Table 1. See also [3, 4, 5, 6, 7, 8] for further details.

Dimension	Value
Length	3.0 m
Diameter	762 mm
Wall Thickness	9.5 mm
Endcap Thickness	76.2 mm
Stiffener Thickness	38.1 mm
Stiffener Spacing	500 mm

Table 1: Nominal Dimensions of Cylinder

3 In-Air Results

The in-air testing of the cylinder was done in the Heavy Engine (HE) Laboratory at DREA and is described in [1]. Table 2 lists the natural frequencies found during the experiment for both the impulse (hammer) method and a shaker, and the probable mode associated with each one (the letter N indicates the order of the circumferential mode and M the longitudinal). Note the torsional and endcap modes could not be excited with the shaker.

No.	Impulse Frequency (Hz)	Shaker Frequency (Hz)	Possible Mode (N,M)
1	186.2	168.7	2,1
2	205.0	205.0	2,1
3	230.0	238.7	1,1
4	291.2	291.2	2,2
5	343.7		Endcap
6	368.7		Torsion
7	466.2	467.5	3,1
8	488.7	488.7	3,2
9	460.0	460.0	2,3
10	473.7	475.0	2,3
11	542.5	544.5	3,3
12	588.7	588.7	3,4
13	630.0	630.0	3,5
14	697.5	697.5	4,1

Table 2: Measured Natural Frequencies (Hz) of Cylinder In-Air

4 Submerged Results

The tests on the submerged cylinder were performed at the DREA Calibration Barge using the methods described in [1].

4.1 Natural Frequencies

Table 3 shows the measured natural frequencies from the underwater trial. Possible mode shapes are not shown in this table as there was some difficulty in determining them. A future report detailing numerical work based on these trials will discuss this more fully.

No.	Measured Freq. (Hz)
1	50.0
2	93.0
3	114.8
4	117.5
5	140.6
6	169.0
7	191.4
8	203.7
9	212.5
10	279.7
11	316.2
12	334.4
13	378.7
14	399.2
15	486.2
16	492.2
17	535.0
18	728.7

Table 3: Measured Natural Frequencies (Hz) of Submerged Cylinder

4.2 Directivity Patterns

Directivity patterns were measured for the cylinder in the vertical position with the shaker providing excitation at selected frequencies. As described in [1], a total of fourteen tests were performed with the cylinder in both the vertical and horizontal positions. For each test, the shaker, installed at the midpoint of the cylinder, was run at several different frequencies and directivity patterns (either full or half patterns) were measured for each frequency. For Test 1, the measuring hydrophone was located a distance of 16.5 m from the cylinder centreline, but, for the remainder of the tests, the hydrophone was relocated to a 16 m distance. Tests 1 through 8 were done with the cylinder in the vertical position and Tests 9 through 14 with the cylinder horizontal. Table 4 shows the cylinder and hydrophone depths (measured to the midpoint of the cylinder axes or hydrophone) for each test.

Test	Cylinder Depth (m)	Hydrophone Depth (m)
1	3.45	3.45
2	6.50	6.32
3	6.50	6.32
4	9.55	9.37
5	9.55	9.37
6	9.55	10.90
7	9.55	7.85
8	15.65	15.47
9	2.92	3.28
10	5.97	6.32
11	9.02	9.37
12	12.07	9.37
13	12.07	12.42
14	12.07	15.47

Table 4: Cylinder Test Depths

The applied loads from the shaker were determined with a force transducer. These loads are listed in Table 5.

The following sections contain the directivity patterns for each test. The polar scales run from 0 dB to 50 dB *re* 1 μ Pa. This was done to improve the clarity of the individual graphs. These are not the raw readings. The actual levels are 90 dB higher than shown, but the scales have been truncated to show the directivity pattern. Unless otherwise indicated, the shaker was acting at the 0° point on the graph. In Reference [1], it was indicated the shaker was acting at the 10° point for the vertical cylinder trials. For simplicity, the data shown here have been rotated by ten degrees to align the shaker with the 0° axis.

Test	Frequency (Hz)					
	117.5	203.7	316.2	378.7	486.2	535.0
1	11.3	11.8	8.3	8.9	11.1	11.7
2	12.3	11.7	8.7	9.7	10.4	12.4
3				8.9		
4	12.3	11.7	8.7	9.7	10.4	12.4
5					10.4	
6	12.3	11.7	8.7	9.7	10.4	12.4
7	12.3	11.7	8.7	9.7	10.4	12.4
8	12.3	11.7	8.7	9.7	10.4	12.4
9	9.9	12.3	9.0	12.7	12.3	12.4
10	12.3	12.0	9.4	10.2	10.8	10.7
11	12.6	11.9	9.5	10.3	11.1	9.8
	117.5	203.7	316.2	250.0	400.0	535.0
12	13.0	11.3	9.8	12.2	11.4	9.7
13	12.9	11.3	9.8	12.0	11.4	9.7
14	13.0	11.3	9.8	12.2	11.4	9.7

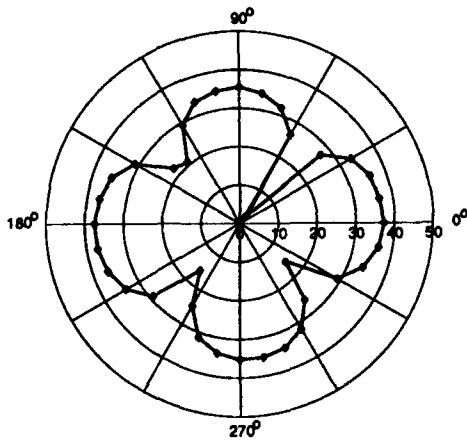
Table 5: Cylinder Applied Forces (N)

4.2.1 Test 1

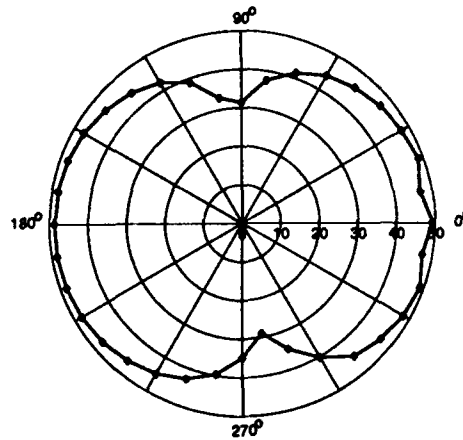
Cylinder Position	Vertical
Cylinder Depth	3.45 m
Hydrophone Height	3.45 m

Notes:

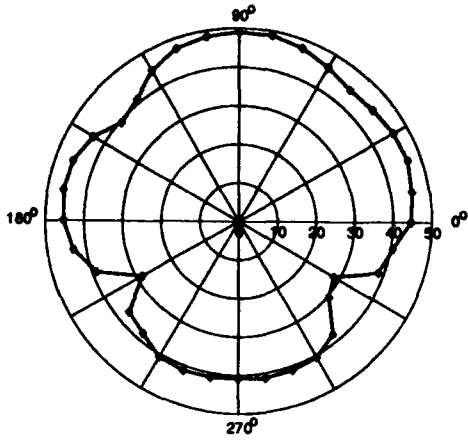
1. The hydrophone was at a distance of 16.5 m, hanging by a cable only.
2. This test was completed over a two day period with a 180° arc covered each day.



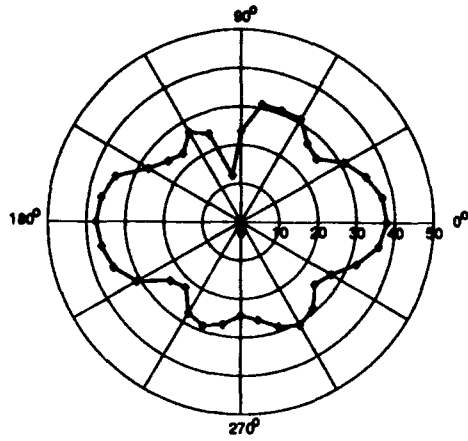
Test 1 - 117.5 Hz



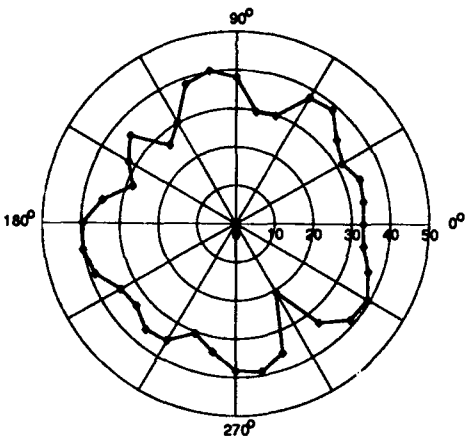
Test 1 - 203.7 Hz



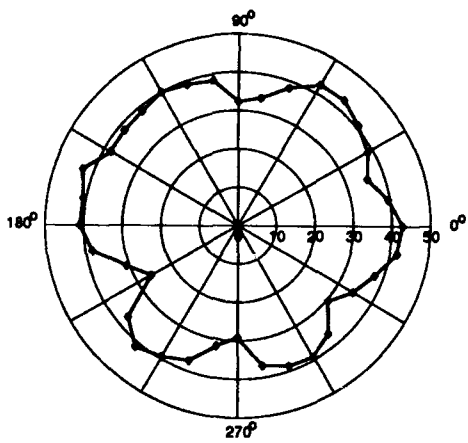
Test 1 - 316.2 Hz



Test 1 - 378.7 Hz



Test 1 - 486.2 Hz



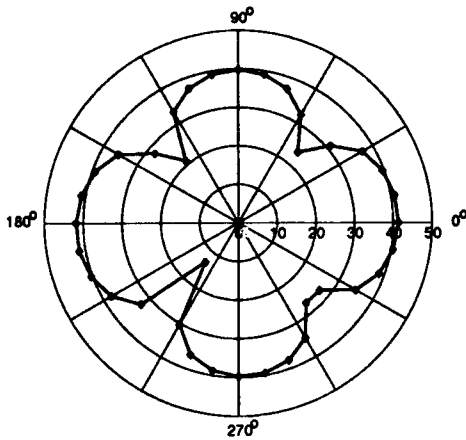
Test 1 - 535.0 Hz

4.2.2 Test 2

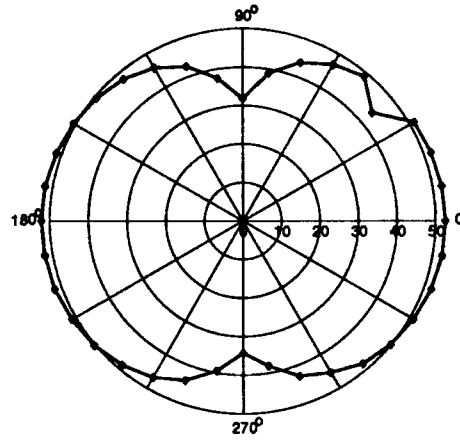
Cylinder Position	Vertical
Cylinder Depth	6.50 m
Hydrophone Height	6.32 m

Notes:

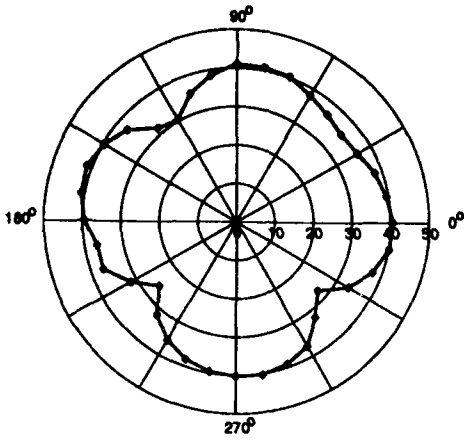
1. The hydrophone was on a rigid station at a distance of 16 m for this and all subsequent tests.



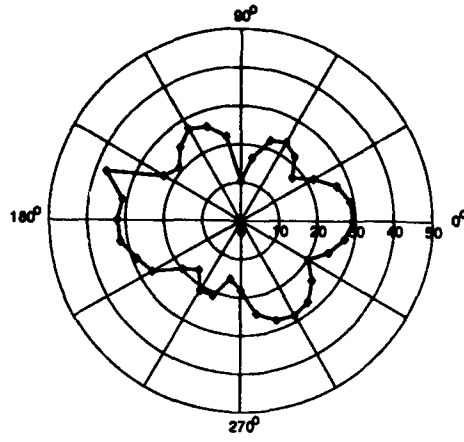
Test 2 - 117.5 Hz



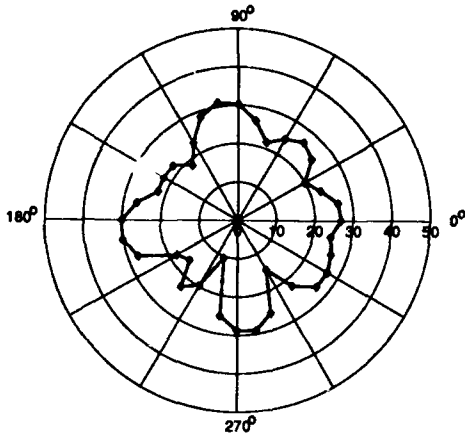
Test 2 - 203.7 Hz



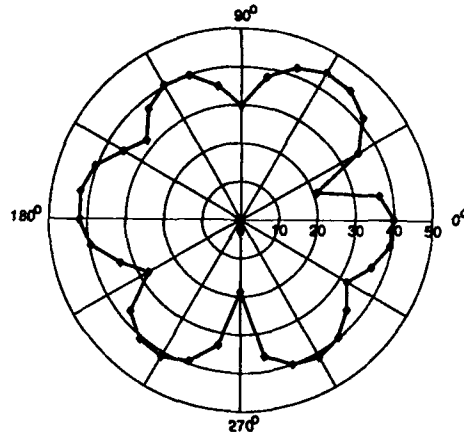
Test 2 - 316.2 Hz



Test 2 - 378.7 Hz



Test 2 - 486.2 Hz



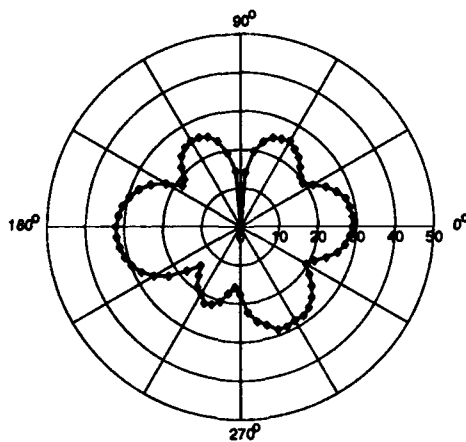
Test 2 - 535.0 Hz

4.2.3 Test 3

Cylinder Position	Vertical
Cylinder Depth	6.50 m
Hydrophone Height	6.32 m

Notes:

1. This was a retest of the 378.7 Hz mode with the directivity pattern grid refined to 5° increments to improve the resolution.
2. This test was spread over two days with the 0° to 60° arc being done on the second day.

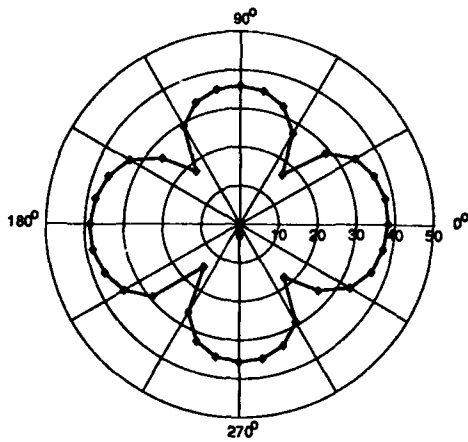


Test 3 - 378.7 Hz

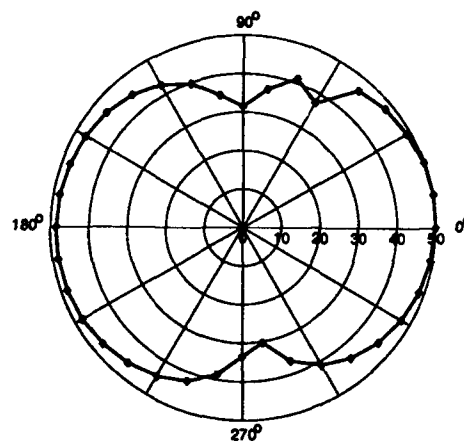
4.2.4 Test 4

Cylinder Position	Vertical
Cylinder Depth	9.55 m
Hydrophone Height	9.37 m

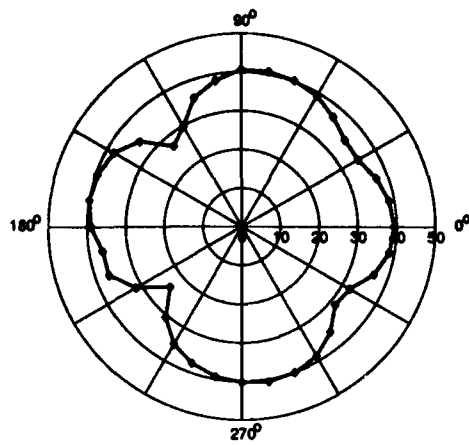
Notes:



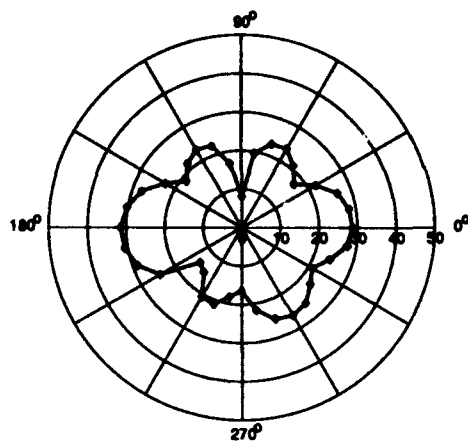
Test 4 - 117.5 Hz



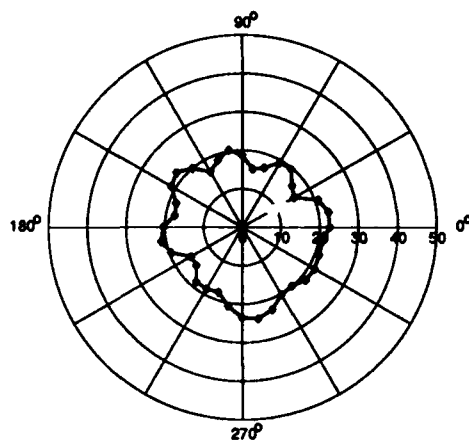
Test 4 - 203.7 Hz



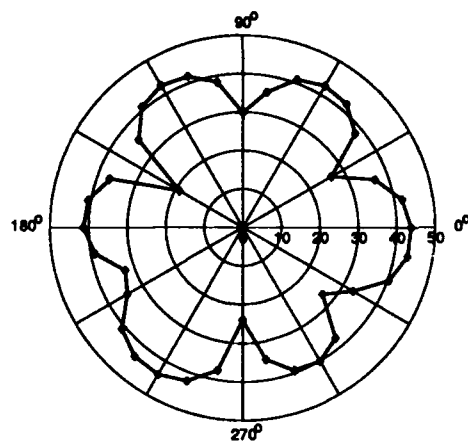
Test 4 - 316.2 Hz



Test 4 - 378.7 Hz



Test 4 - 486.2 Hz



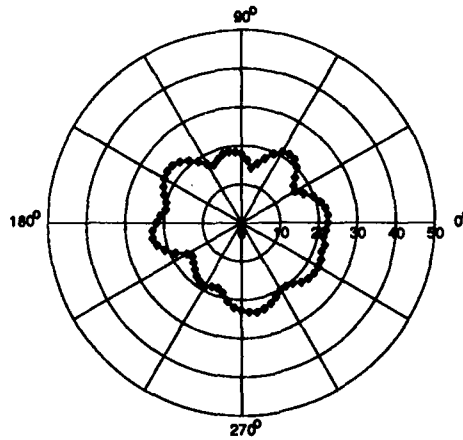
Test 4 - 535.0 Hz

4.2.5 Test 5

Cylinder Position	Vertical
Cylinder Depth	9.55 m
Hydrophone Height	9.37 m

Notes:

1. This was a retest of the 486.2 Hz mode with the directivity pattern grid refined to 5° increments to improve the resolution.



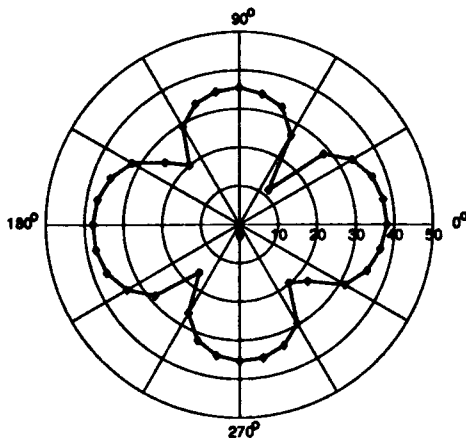
Test 5 - 486.2 Hz

4.2.6 Test 6

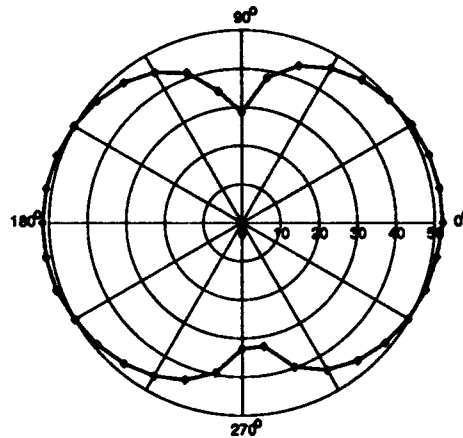
Cylinder Position	Vertical
Cylinder Depth	9.55 m
Hydrophone Height	10.9 m

Notes:

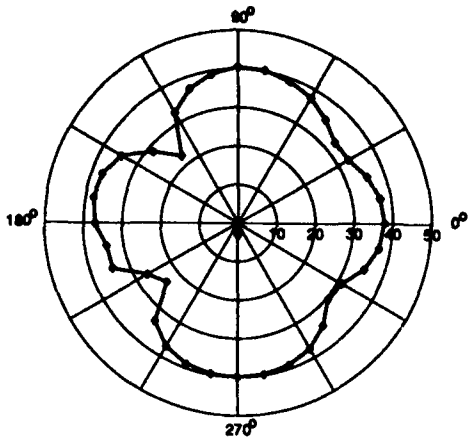
1. It was intended to split this test over two days; however, the data did not match up upon continuation on the second day, so the data from the first day was discarded and the test restarted from scratch.
2. The hydrophone was set one half station below the cylinder centre. A station is one 3.05 m (10 ft) section of rigid support pipe for hanging the cylinder or hydrophone in the water.



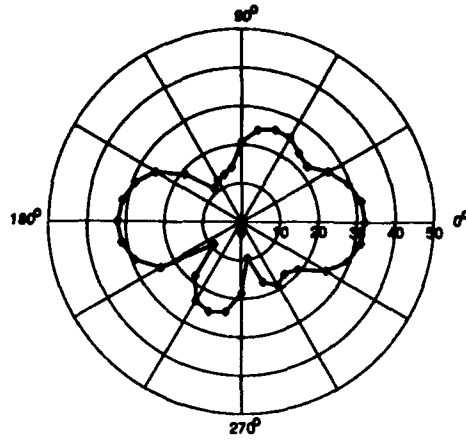
Test 6 - 117.5 Hz



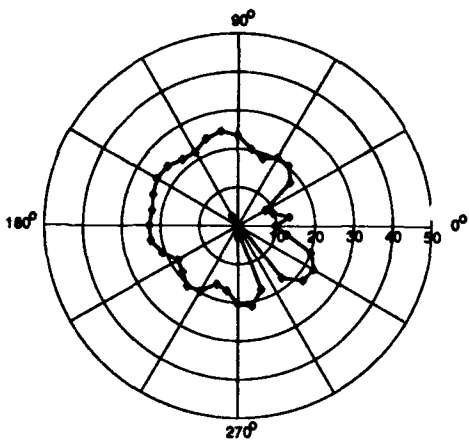
Test 6 - 203.7 Hz



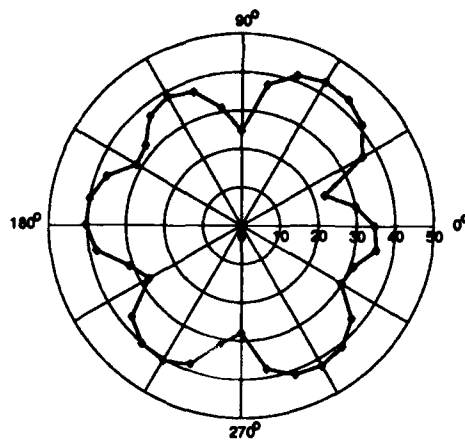
Test 6 - 316.2 Hz



Test 6 - 378.7 Hz



Test 6 - 486.2 Hz



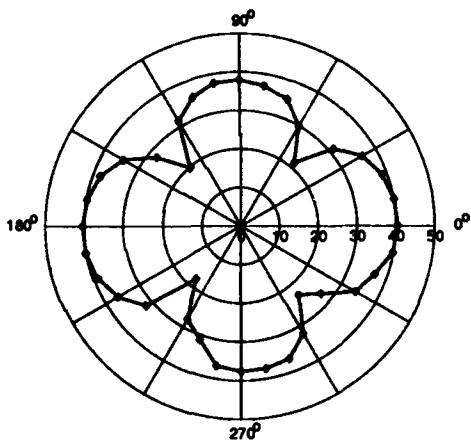
Test 6 - 535.0 Hz

4.2.7 Test 7

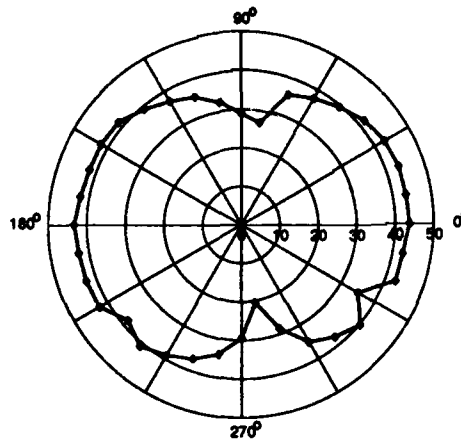
Cylinder Position	Vertical
Cylinder Depth	9.55 m
Hydrophone Height	7.85 m

Notes:

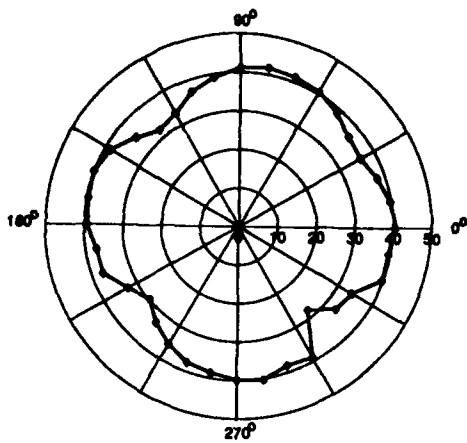
1. The hydrophone was set one half station above the cylinder centre.



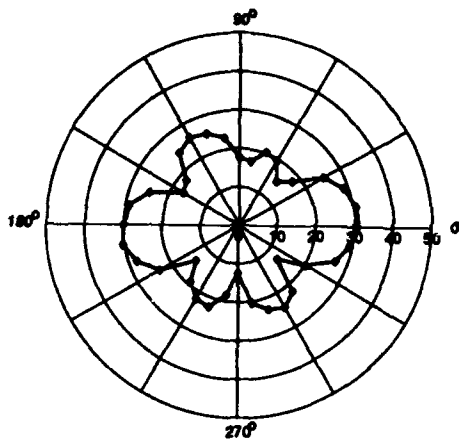
Test 7 - 117.5 Hz



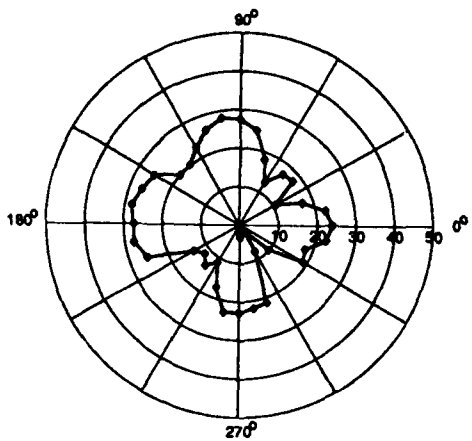
Test 7 - 203.7 Hz



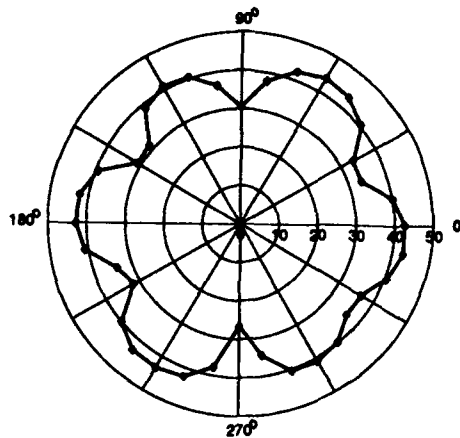
Test 7 - 316.2 Hz



Test 7 - 378.7 Hz



Test 7 - 486.2 Hz

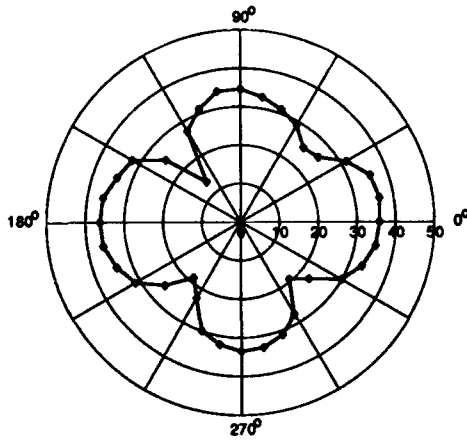


Test 7 - 535.0 Hz

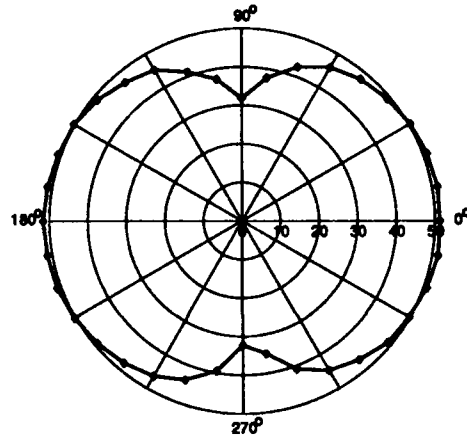
4.2.8 Test 8

Cylinder Position	Vertical
Cylinder Depth	15.65 m
Hydrophone Height	15.47 m

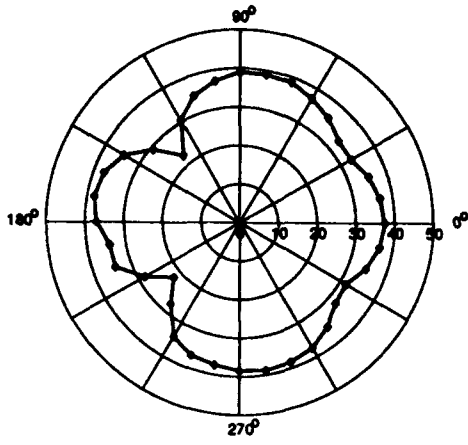
Notes:



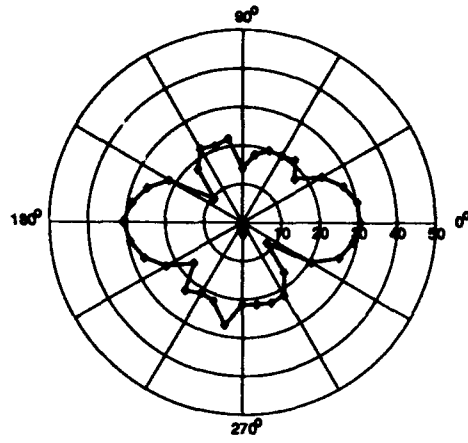
Test 8 - 117.5 Hz



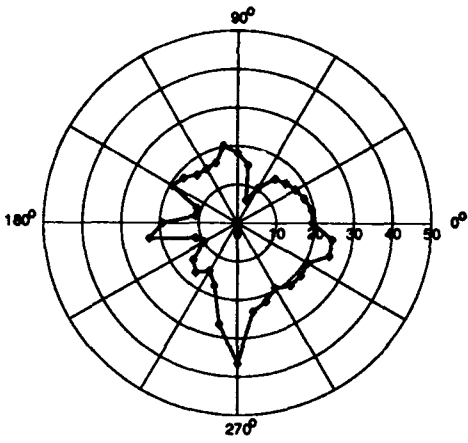
Test 8 - 203.7 Hz



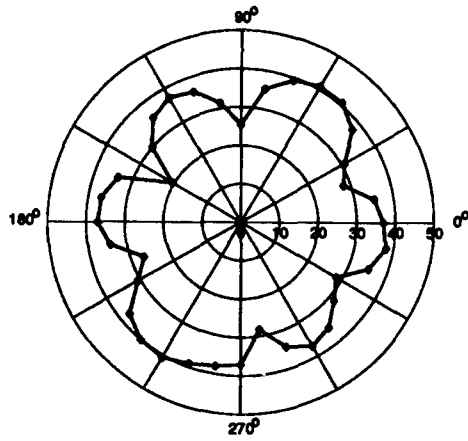
Test 8 - 316.2 Hz



Test 8 - 378.7 Hz



Test 8 - 486.2 Hz



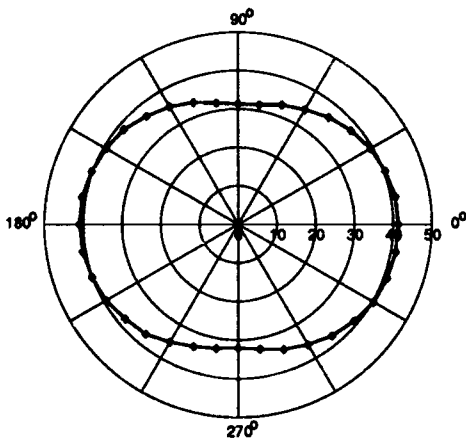
Test 8 - 535.0 Hz

4.2.9 Test 9

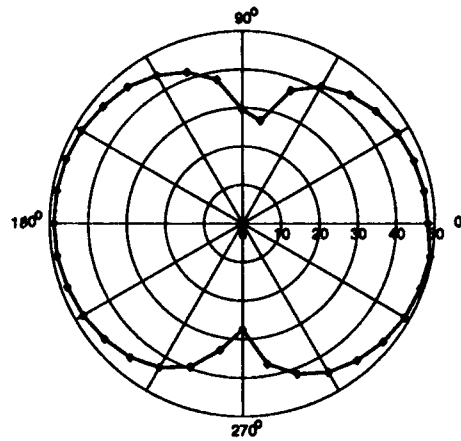
Cylinder Position	Horizontal
Cylinder Depth	2.92 m
Hydrophone Height	3.28 m

Notes:

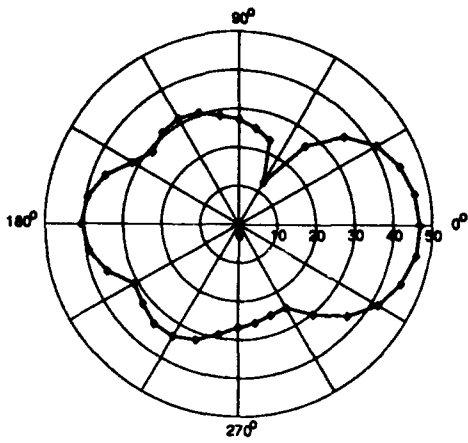
1. The cylinder was now in the horizontal position.



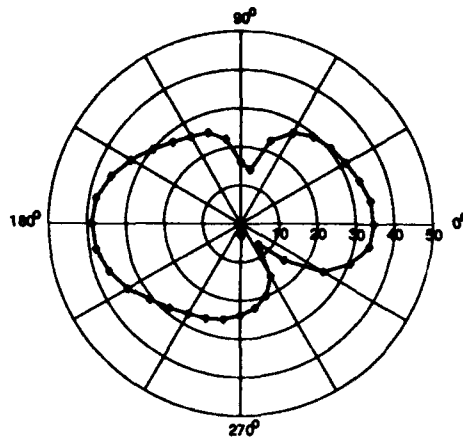
Test 9 - 117.5 Hz



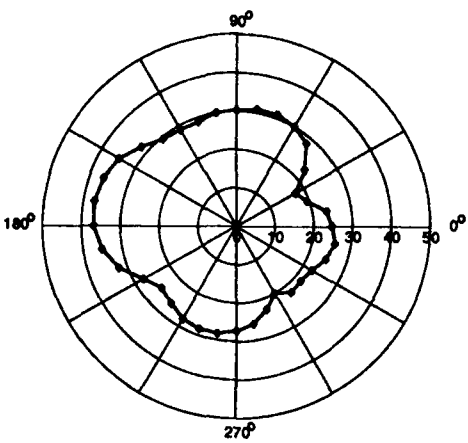
Test 9 - 203.7 Hz



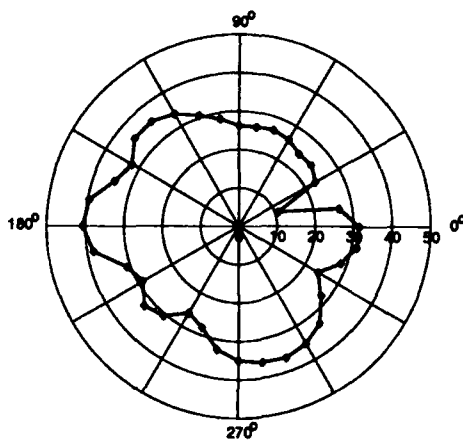
Test 9 - 316.2 Hz



Test 9 - 378.7 Hz



Test 9 - 486.2 Hz



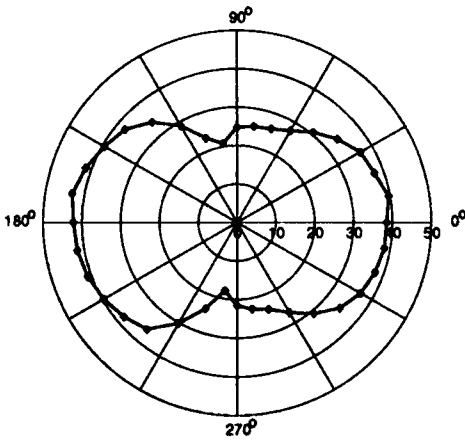
Test 9 - 535.0 Hz

4.2.10 Test 10

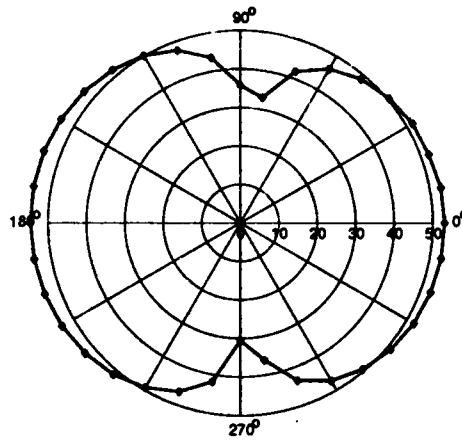
Cylinder Position	Horizontal
Cylinder Depth	5.97 m
Hydrophone Height	6.32 m

Notes:

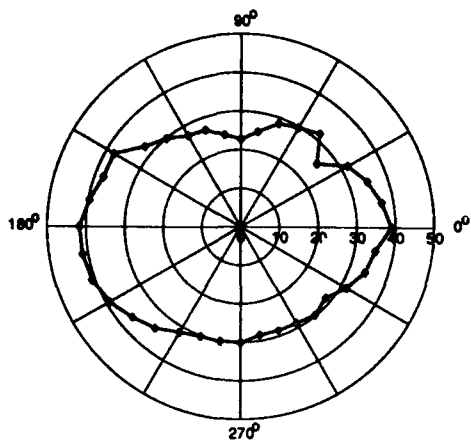
1. The Canadian Coast Guard Vessel *Louis St. Laurent* was sailing around Bedford Basin during Tests 10 to 14, and sometimes interfered with the measurements by raising the ambient noise levels sufficiently to exceed the cylinder signals.



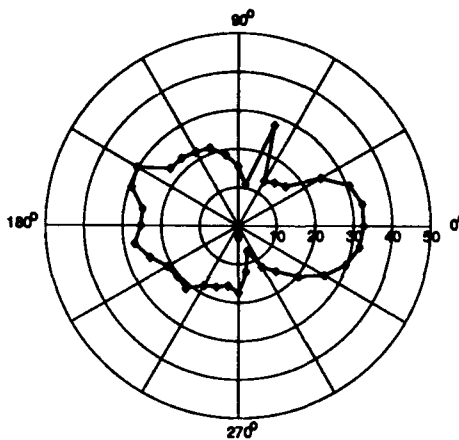
Test 10 - 117.5 Hz



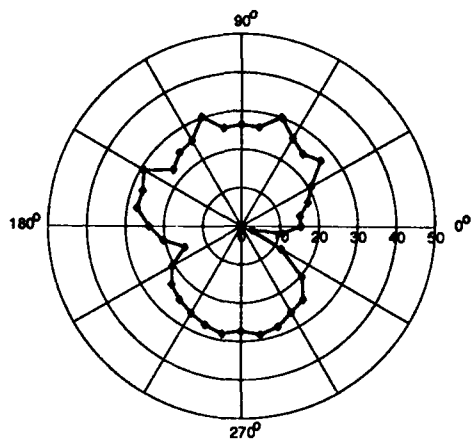
Test 10 - 203.7 Hz



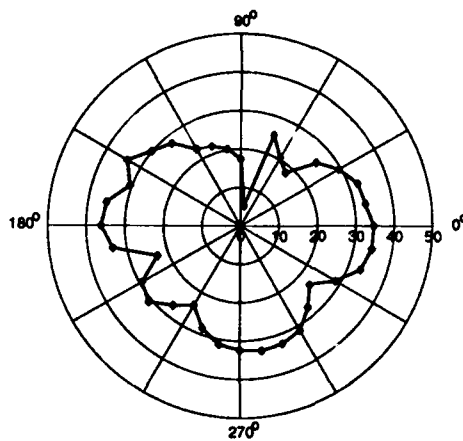
Test 10 - 316.2 Hz



Test 10 - 378.7 Hz



Test 10 - 486.2 Hz

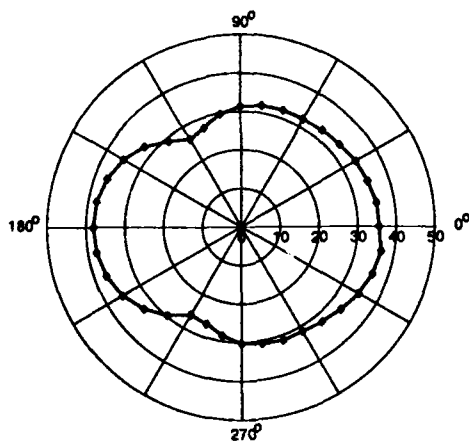


Test 10 - 535.0 Hz

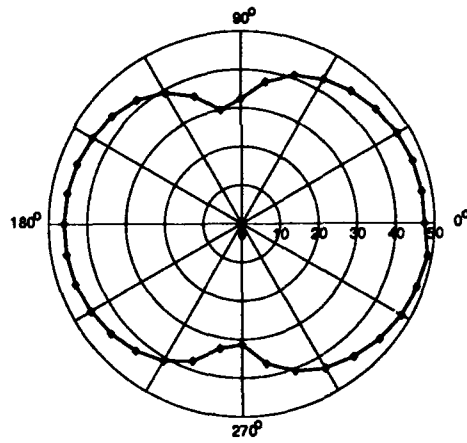
4.2.11 Test 11

Cylinder Position	Horizontal
Cylinder Depth	9.02 m
Hydrophone Height	9.37 m

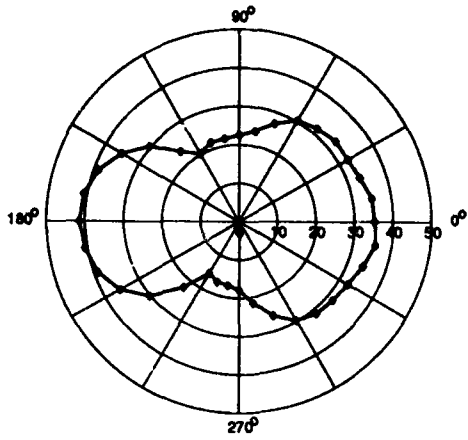
Notes:



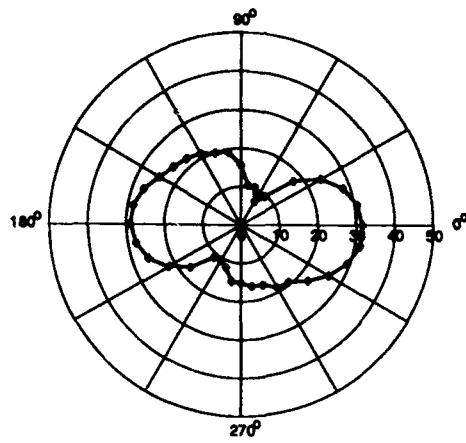
Test 11 - 117.5 Hz



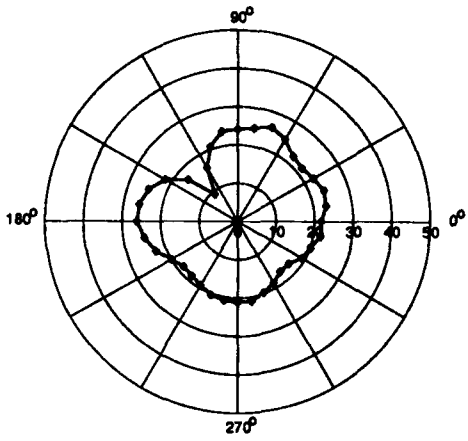
Test 11 - 203.7 Hz



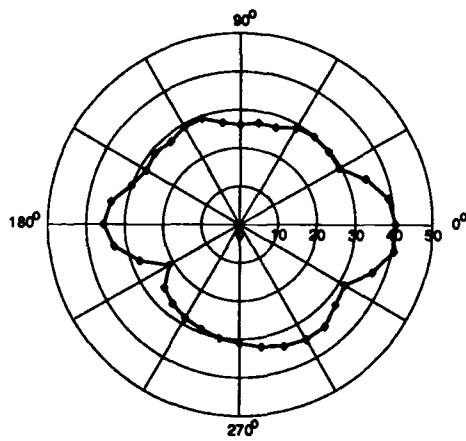
Test 11 - 316.2 Hz



Test 11 - 378.7 Hz



Test 11 - 486.2 Hz



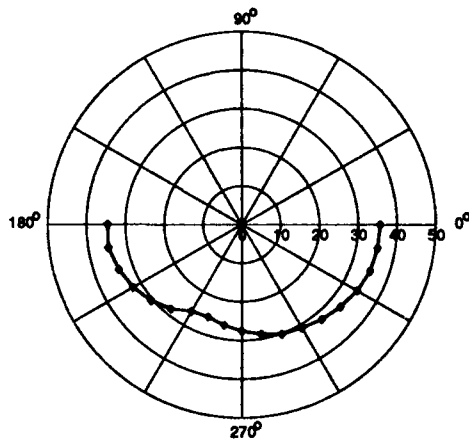
Test 11 - 535.0 Hz

4.2.12 Test 12

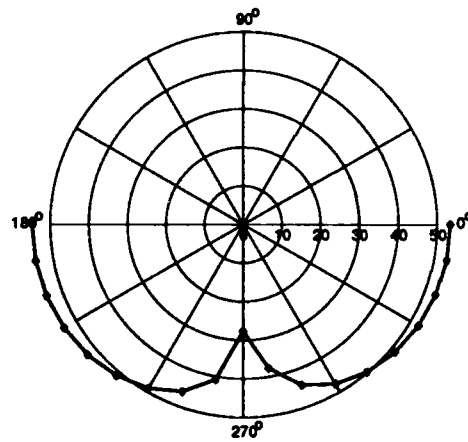
Cylinder Position	Horizontal
Cylinder Depth	12.07 m
Hydrophone Height	9.37 m

Notes:

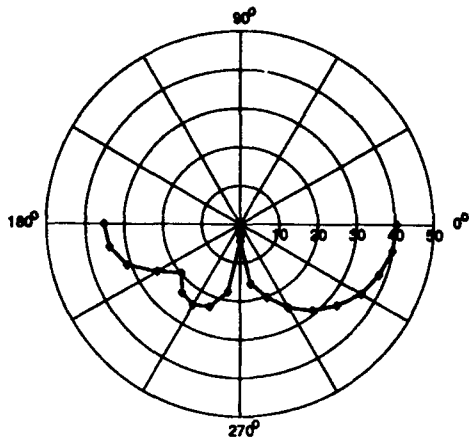
1. As the signals were not strong at 378.7 Hz and 486.2 Hz, for Tests 12, 13, and 14, two nonresonant frequencies, 250 Hz and 400 Hz, were selected.
2. As the remaining time at the calibration barge was limited, only half patterns were done for Tests 12 through 14.
3. The hydrophone was a full station below the cylinder centre.



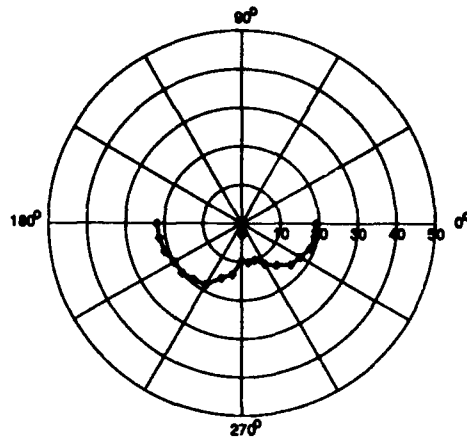
Test 12 - 117.5 Hz



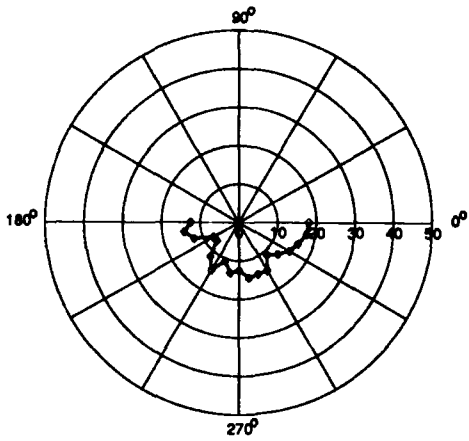
Test 12 - 203.7 Hz



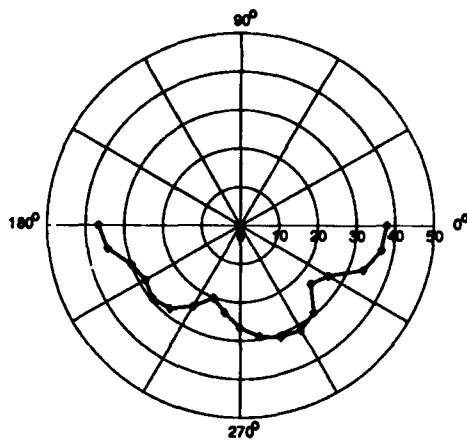
Test 12 - 316.2 Hz



Test 12 - 250.0 Hz



Test 12 - 400.0 Hz

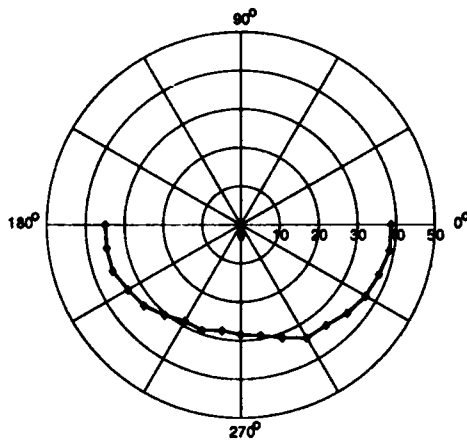


Test 12 - 535.0 Hz

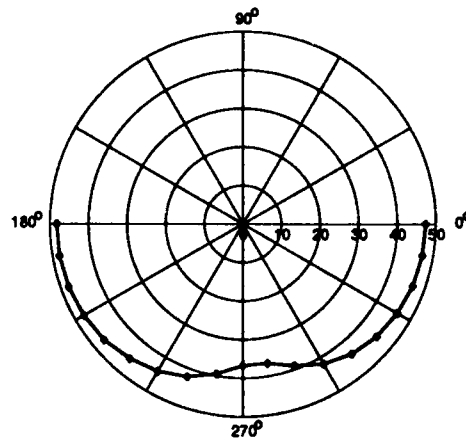
4.2.13 Test 13

Cylinder Position	Horizontal
Cylinder Depth	12.07 m
Hydrophone Height	12.42 m

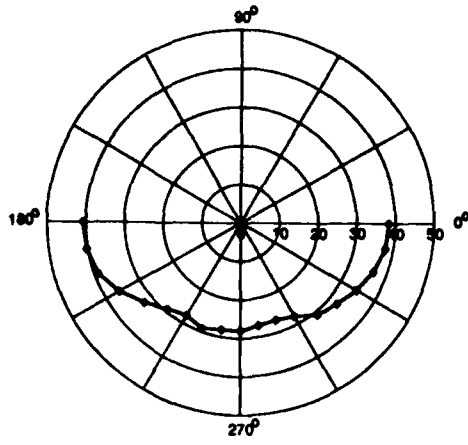
Notes:



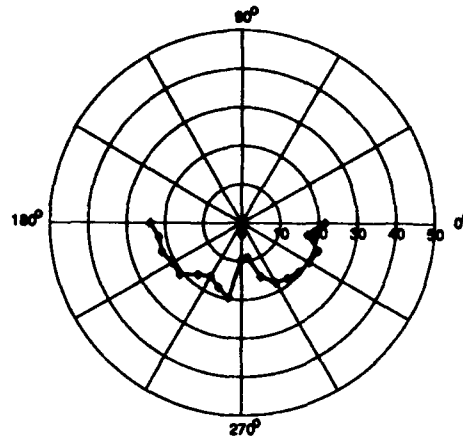
Test 13 - 117.5 Hz



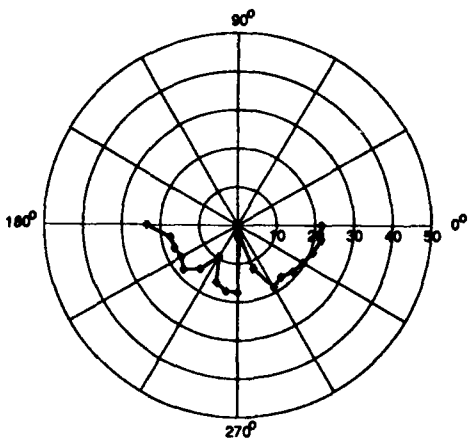
Test 13 - 203.7 Hz



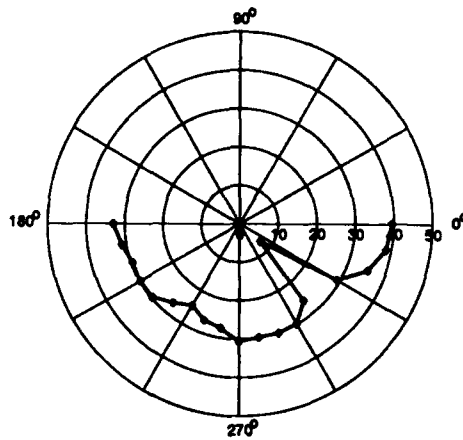
Test 13 - 310.2 Hz



Test 13 - 250.0 Hz



Test 13 - 400.0 Hz



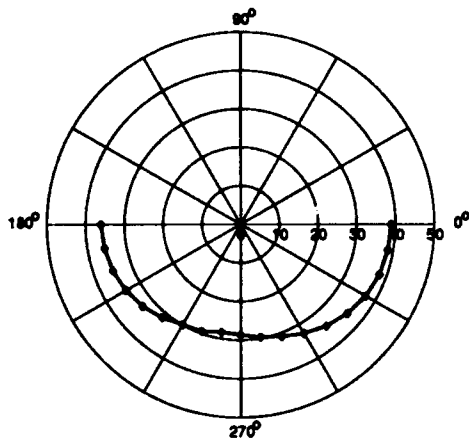
Test 13 - 535.0 Hz

4.2.14 Test 14

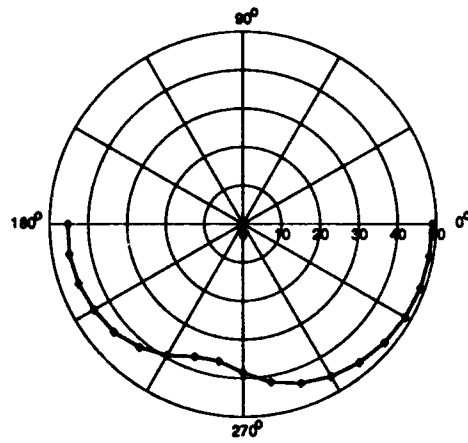
Cylinder Position	Horizontal
Cylinder Depth	12.07 m
Hydrophone Height	15.47 m

Notes:

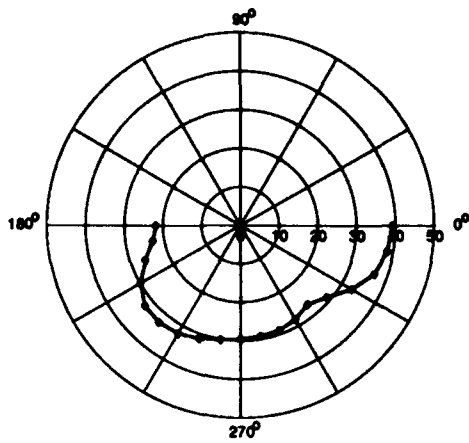
1. The hydrophone was one full station lower than the cylinder centre.



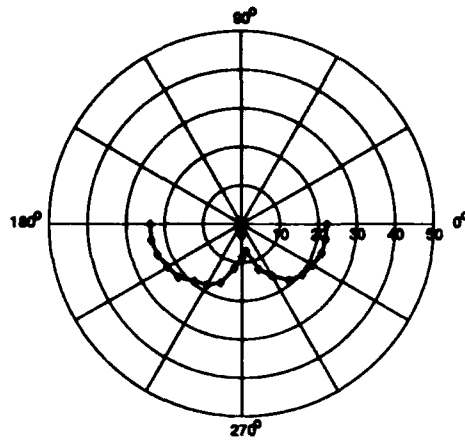
Test 14 - 117.5 Hz



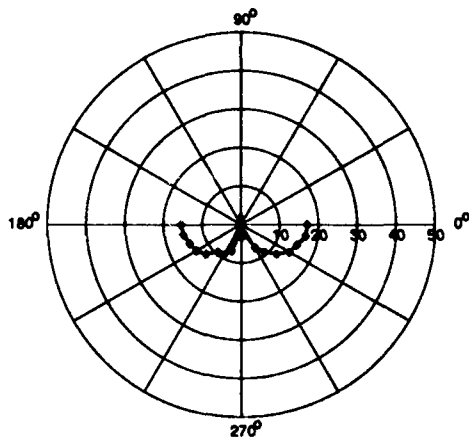
Test 14 - 203.7 Hz



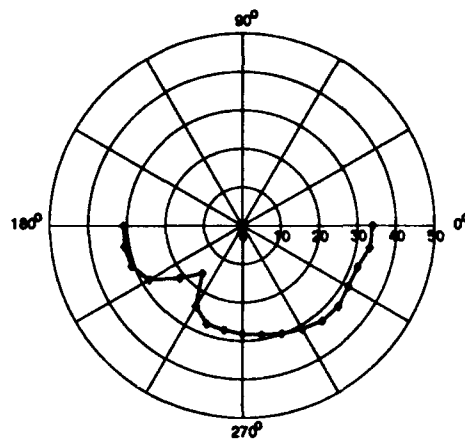
Test 14 - 316.2 Hz



Test 14 - 250.0 Hz



Test 14 - 400.0 Hz



Test 14 - 535.0 Hz

5 Conclusions

Experiments were performed at DREA and at the DREA Acoustics Barge to measure the natural frequencies of a cylinder in air and in water and to measure acoustic radiation directivity patterns for a point-excited submerged cylinder. These experiments were performed to obtain

data with which DREA structural and acoustic computer codes could be evaluated. This report serves as an annex to a previous report describing the experiments in full and contains a complete listing of all frequencies and directivity patterns measured.

References

- [1] Gilroy, L.E., "Natural Frequency and Radiated Noise Measurements on a Ring-Stiffened Cylinder," DREA Technical Memorandum (in review), August, 1993.
- [2] Gilroy, L.E., "Proposal for a Test to Measure Acoustic Radiation from a Submerged Ring-Stiffened Cylinder," DREA Note H/92/1, 1992.
- [3] "Cylinder," DREA Drawing No. M21-0011.
- [4] "Lid Cylinder," DREA Drawing No. M21-0012.
- [5] "Lid Handling Tool Cylinder," DREA Drawing No. M21-0013.
- [6] "Lid Blank Cylinder," DREA Drawing No. M21-0014.
- [7] "End Plate Cylinder," DREA Drawing No. M21-0015.
- [8] "Stiffened Cylinder," DREA Drawing No. M21-0016.

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Defence Research Establishment Atlantic (DREA) has conducted an experiment involving the measurement of radiated noise from a ring-stiffened cylinder subjected to a harmonic load. This experiment was performed to provide validation data for structural acoustics computer codes being developed in-house and under contract. The experiment was in two parts. The first involved determining the natural frequencies of the cylinder in air, while the second stage of testing involved determining the natural frequencies of the cylinder while it was submerged and measuring directivity patterns of radiated noise when the submerged cylinder was excited at some of its natural frequencies. This report contains all the directivity patterns produced in the trials, as well as listings of the measured natural frequencies, both in-air and submerged and, as such, serves as an annex to an earlier report describing the experiment.

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