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# ANECHOIC CHAMBER MEASUREMENTS OF RADIATED NOISE FROM A RING-STIFFENED CYLINDER

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Defence Research Establishment Atlantic
Centre de Recherches pour la Défense Atlantique

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## Abstract

Defence Research Establishment Atlantic (DREA), with the assistance of Health Canada, has conducted an experiment involving the measurement of radiated noise from a ring-stiffened cylinder subjected to a harmonic load in an anechoic chamber. This experiment was performed to provide validation data for structural acoustics computer codes being developed in-house and under contract. These codes are used to predict the vibrations of structures submerged in, or filled with, a dense fluid and to also predict the resulting radiated noise.

## Résumé

Le Centre de recherches pour la défense Atlantique (CRDA) a procédé, avec l'assistance de Santé Canada, à une expérience visant à mesurer les émissions de bruit d'un cylindre renforcé d'anneaux soumis à une charge harmonique dans une chambre anéchoïque. L'expérience avait pour but de fournir des données de validation pour les codes machines en acoustique des structures qui sont développés par le Centre et sous contrat. Ces codes sont utilisés pour prédire les vibrations des structures submergées ou des structures remplis d'un fluide dense et aussi pour prédire le bruit emis par ces structures.

DREA TM 95/231

## Anechoic Chamber Measurements of Radiated Noise from a Ring-Stiffened Cylinder

by

L. E. Gilroy

## Executive Summary

Defence Research Establishment Atlantic (DREA) recently conducted experiments to measure the radiated noise from a ring-stiffened steel cylinder subjected to a harmonic load under the controlled conditions at Health Canada's anechoic chamber located at the Brookfield Road lab in Ottawa. These experiments were performed to provide validation data for two suites of structural acoustics computer codes being developed in-house and under contract to predict the vibrations and the resulting radiated noise of ship or submarine structures. The ultimate goal of this work is to develop methods of reducing the acoustic signature of CF vessels.

The first suite of codes is based on the finite element method and is primarily intended for the prediction of the natural frequencies of coupled fluid/structure systems. It models both the structure and the fluid region with finite elements. If necessary, a commercial boundary element code can then be used to predict the radiated noise from the fluid-loaded structure. The second suite of computer codes is based on both the boundary element and finite element methods. A finite element code is still used to generate the structural information; however, boundary elements are used for the fluid model which means that it is only necessary to discretize the wetted surface of the structure to predict the radiated noise from an applied load. The second suite cannot be used to predict natural frequencies.

DREA's ring-stiffened cylinder, used in previous experiments at the DREA Acoustic Calibration Barge, was shipped to Ottawa for testing at the anechoic chamber which is part of the Radiation Protection Bureau of the Health Protection Branch of Health Canada. The DREA cylinder measures 3m long by 0.75m in diameter and weighs in excess of 1 tonne. Health Canada provided the in-air measurement equipment and the laboratory space, as well as the technical expertise for running the chamber. During the test period, the natural frequencies and mode shapes of the cylinder were measured using accelerometers placed throughout the cylinder with excitation provided by an electromagnetic shaker or loudspeakers. A turntable (constructed by DREA for this trial) was then used to rotate the cylinder while the cylinder was excited with the shaker and directivity patterns of the resulting radiated noise were measured using a microphone at a specified position. Directivity patterns were also measured with the cylinder fixed and the microphone position varied using the robotic capability of the anechoic chamber.

The testing was relatively successful, in that over 25 resonant frequencies of the cylinder were identified. Circumferential and longitudinal directivity patterns for a variety of frequencies were measured, but difficulties were encountered in identifying some modes (particularly the higher frequency modes). Comparisons to code predictions will follow in another report.

# Contents

# 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 under the controlled conditions at Health Canada's anechoic chamber located at the Brookfield Road lab in Ottawa. These experiments were performed to provide validation data for structural acoustics computer codes being developed in-house and under contract.

DREA's ring-stiffened cylinder, used in previous experiments at the DREA Acoustic Calibration Barge, was shipped to Ottawa for testing at the anechoic chamber which is part of the Radiation Protection Bureau (RPB) of the Health Protection Branch of Health Canada. DREA also arranged for the construction of a supporting turntable on which the cylinder could be mounted in the anechoic chamber and which could be driven by a stepper motor in a remote fashion from outside the chamber. Health Canada provided the in-air measurement equipment and the laboratory space, as well as the technical expertise for running the chamber. During the test period, the natural frequencies and mode shapes of the cylinder were measured using accelerometers placed throughout the cylinder with excitation provided by an electromagnetic shaker or loudspeakers. The turntable was then used to rotate the cylinder while the cylinder was excited with the shaker and directivity patterns of the resulting radiated noise were measured using a microphone at a specified position. Directivity patterns were also measured with the cylinder fixed and the microphone position varied using the robotic capability of the anechoic chamber.

This technical memorandum discusses the specifics of the cylinder and the instrumentation, as well as the experimental procedure. This report also contains the results of the natural frequency testing and the plots of the measured directivity patterns. A full comparison of the results with numerical analysis will be discussed in another report.

# 2 Experimental Set-Up and Equipment

The anechoic chamber is a part of the Radiation Protection Bureau of the Health Protection Branch of Health Canada and is located at the RPB's laboratory in Ottawa, Canada. The chamber is the largest in Canada and is of double room construction with the inner room floating on coil springs to isolate it from structurally-borne vibrations. The inside dimensions of the chamber are 12m $\times$ 16m $\times$ 11m high. The anechoic lining of the chamber consists of fibreglass wedges roughly 1.5m deep with a low frequency cut-off of 50 Hz. As the floor is covered with these wedges, a working surface is provided by a wire grid floor which may be supplemented by a steel grating floor (.61m $\times$ 1.22m sections) which is installed on posts fitting into bayonet mounts located between the floor wedges on either .61m or 1.22m centres. For this trial, the grating floor was used for the installation and removal of the cylinder, but was not in place for the experiment itself. Winches are provided in the roof; however, RPB staff were not confident the winches could support the weight of the DREA cylinder, so a more robust winch was rented for the duration of the trial. A sketch of the chamber floor plan is given in Figure 1.

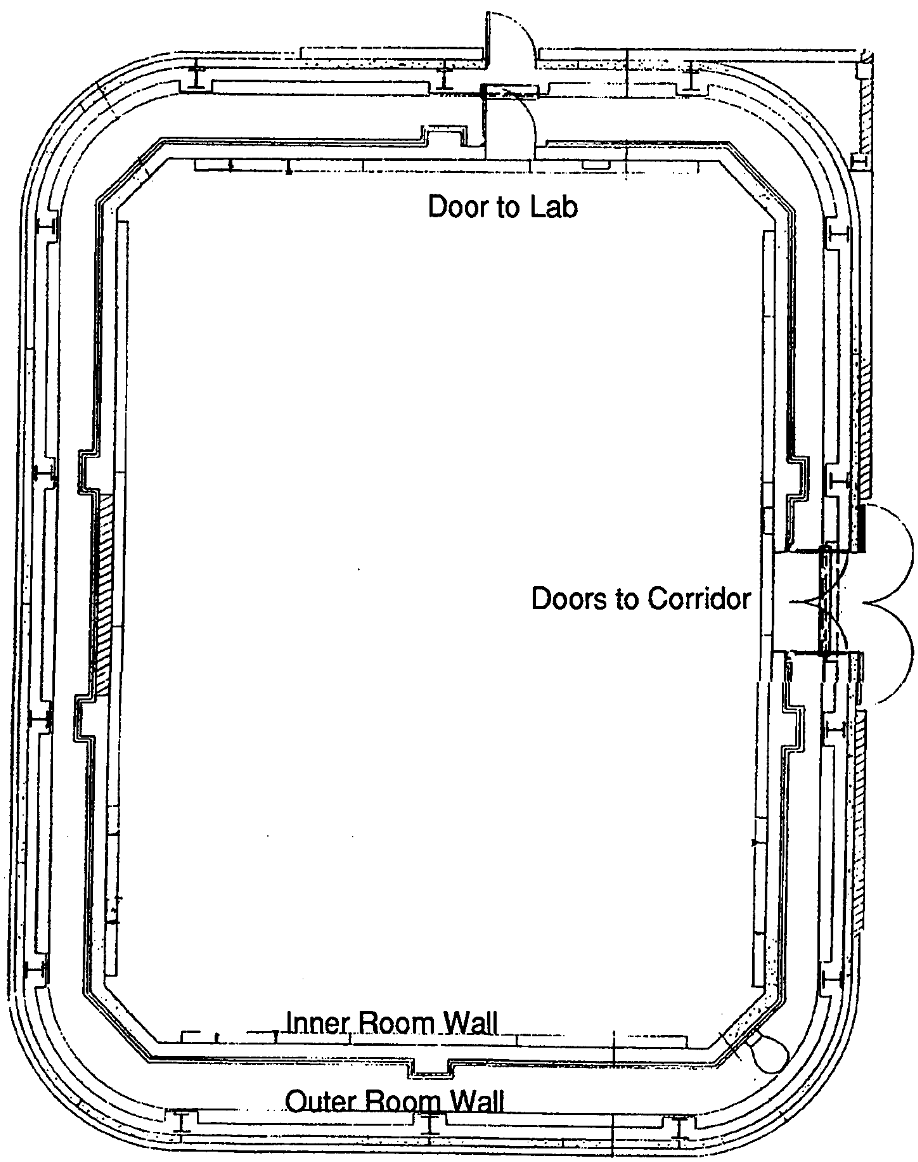


Figure 1: Anechoic Chamber Floor Plan

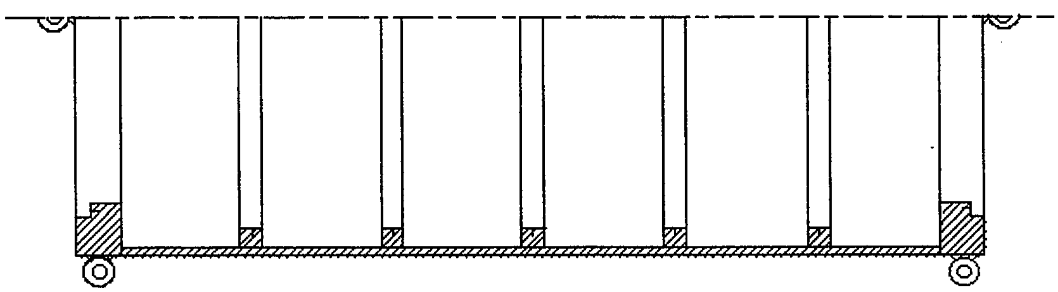

Figure 2: Half-Section Through Test Cylinder

The ring-stiffened cylinder's manufacture and detailed dimensions are given in [1]. Briefly, the cylinder consists of a 9.5mm thick tube with a nominal diameter of 762mm, with a weld seam running longitudinally along the entire lengthof 3.0 m. Five circumferential stiffeners were welded into the tube at equal intervals of 0.5 m. These stiffeners had a square 38.1mm $\times$ 38.1mm cross-section. Threaded 9.5mm radial holes facing inwards were also provided at 45° intervals on every ring stiffener to allow for the attachment of various pieces of equipment. Removable endcaps 76mm thick were constructed of nominal 3in plate and welded to the tube. The endcaps were of two pieces with a central 'hatch' roughly 600mm in diameter, 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 for handling of the cylinder and the endcaps. A half-section of the cylinder is shown in Figure 2 and a photograph of the cylinder (on its transport cradle) is shown in Figure 3.

Four 24-pin Envirocon marine connectors penetrated one endcap (called the *front* endcap) to permit the use of 48 accelerometers inside the cylinder. Two 3-pin connectors were installed to provide power and signals for an electromagnetic shaker. Two smaller connections were added to allow access to the signal cables from the shaker's integral accelerometer and force transducer.

Accelerometers (48) were mounted on blocks then installed on mounting studs previously welded to the stiffeners and skin on the interior of the cylinder. The accelerometers were installed in the positions shown in Figure 4. Position 1 was established as the 0° location and position 9 as the 90° location which defined the direction of increasing circumferential angle. The accelerometers used were Kistler Instruments Model 8632B50 piezobeam accelerometers with a nominal sensitivity of 100 mV/g. The accelerometers were powered by three Kistler Model 5128A 16-channel couplers.

A Wilcoxon Research Model F4/F7 combination electromagnetic/piezoelectric shaker was installed at the 0° point on the centre stiffener of the cylinder. The shaker uses its piezoelectric portion for high frequency excitation and, hence, this experiment only involved the use of the

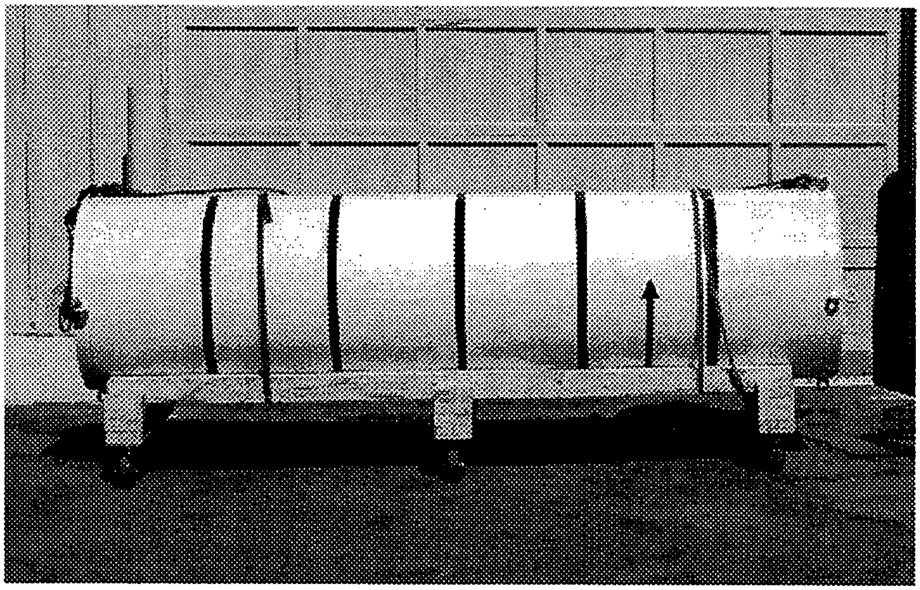

Figure 3: Test Cylinder

electromagnetic portion of the shaker. The shaker was equipped with an impedance head with which were measured the applied force to the cylinder and the resulting acceleration at that point. The force transducer had a voltage sensitivity of 17 mV/N and the accelerometer had a sensitivity of 12.9 mV/g.

Acoustic speakers were also used at various times to excite the cylinder. Four Klipsch Model KP301 200 W speakers driven by Bryston 7B NPB amplifiers were stacked together and located about 2.5 m from the cylinder during the natural frequency testing phase.

The cylinder was placed vertically on a turntable provided by DREA (see photograph in Figure 5. The turntable is driven by a stepper motor which was geared to be capable of rotating the cylinder in increments of 0.45° and which could be operated in a remote fashion.

All 48 accelerometers were wired through the 24-pin connectors and the cables were joined into a bundle which ran from the cylinder, through the wall of the anechoic chamber (through ports provided for such use), to the signal conditioners. The outputs from the signal conditioners then went to a set of analog filters. Individual channels were then selected for viewing on an HP35670A Spectrum Analyzer.

The radiated noise measurements were made using a B&K condenser microphone (Cartridge Type 4165) powered by a B&K Type 2619 preamplifier. For the circular directivity pattern testing, the microphone was mounted roughly at the cylinder midheight at a distance of 5.42m from the cylinder centre on a pipe mounted into one of the bayonet mounts in the chamber floor. For the vertical line directivity patterns, the microphone attached to the RPB's remote

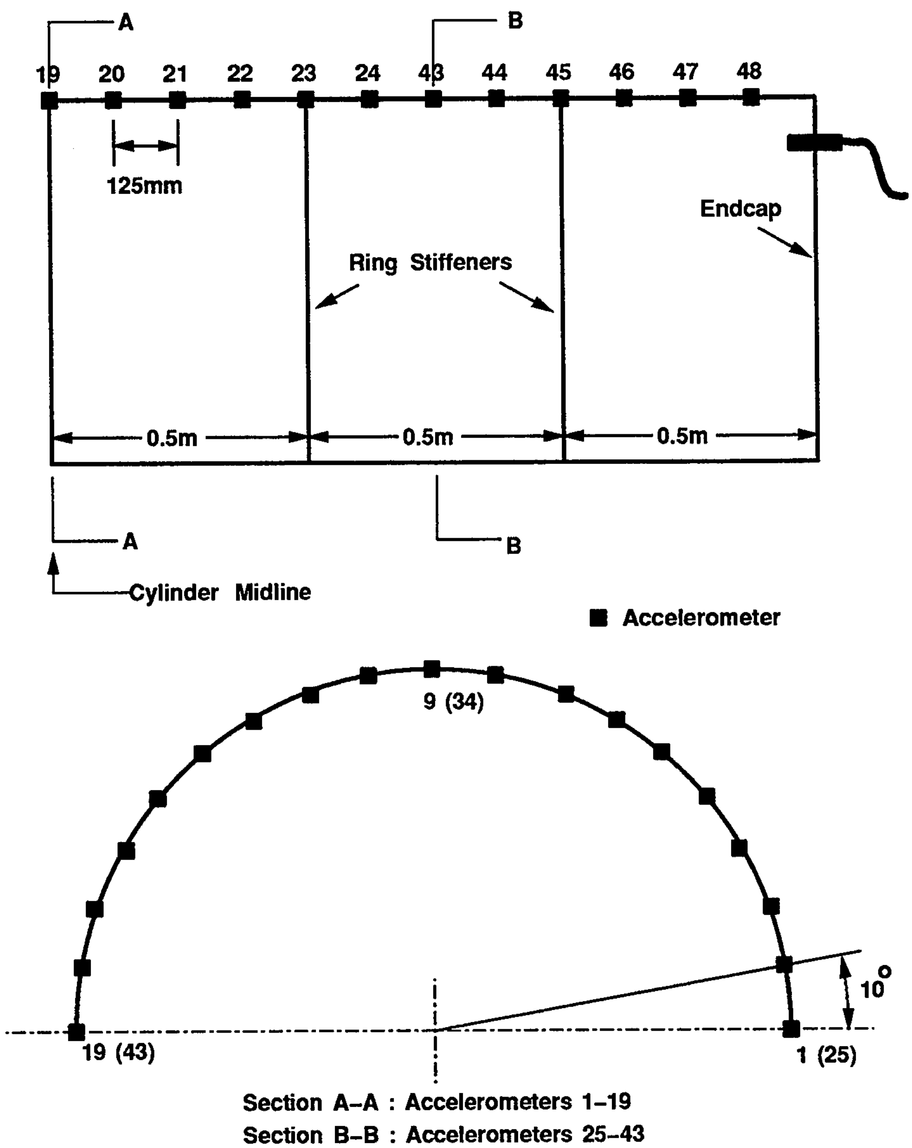


Figure 4: Accelerometer Positions

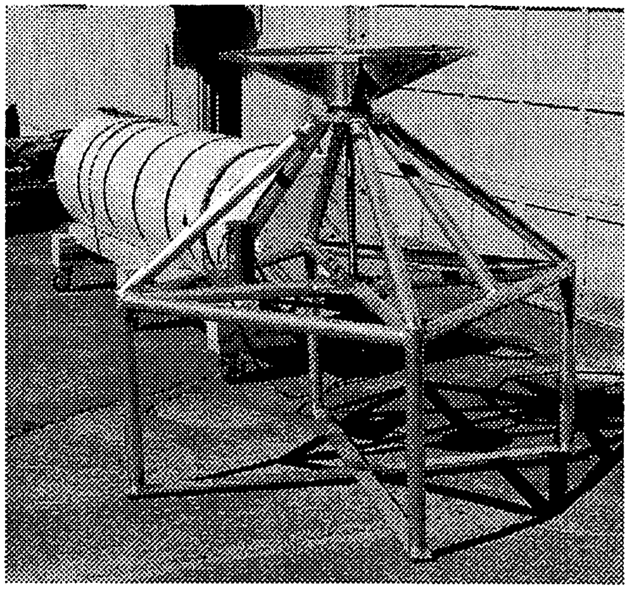

Figure 5: Turntable Support

five degree-of-freedom robotic system was used. The microphones were calibrated for use with the B&K Type 4228 pistonphone and the microphone output was viewed on the HP signal analyzer.

All amplifiers, power supplies, and other recording equipment were kept in the laboratory outside of the chamber. The chamber was monitored via a remote video camera.

# 3 In-Air Testing

## 3.1 Resonant Frequencies

The first set of tests involved determining the natural frequencies and mode shapes of the cylinder under the test conditions. The cylinder was first excited with the electromagnetic shaker using a random noise signal over a frequency band from 0 Hz to 800 Hz. The response power spectra of each accelerometer were examined using the HP signal analyzer and the natural frequencies were selected from the peaks of the response. With the shaker located at the cylinder midline, it is difficult to excite any modes which have nodes (longitudinally) at the midline, i.e., even longitudinal modes. To excite these modes, the four speakers were stacked in the anechoic chamber and driven with a swept sine signal over the same frequency range (to improve the signal to noise ratio). With both systems, the accelerometer signals were averaged over 30 sample periods to establish a stable response.

Modal damping factors can be determined from the response spectrums by examing the width of the resonant peak at the half-power point (3dB down). To establish good plots from which to measure these peaks, power spectrum responses were measured for 100 Hz wide bands around each resonance peak. Measurements were made with both the accelerometers and a microphone to attempt to establish clear response plots.

To try to determine the mode shapes of the selected peaks, frequency response trials were done comparing various accelerometers to each other with the cylinder being excited with a pure tone at the particular resonance. Either the shaker or the speaker were used, whichever seemed to give a better excitation to that resonance. Accelerometers 2 to 19 were compared to accelerometer 1 and accelerometers 26 to 43 were compared to 25 to establish circumferential mode numbers and the longitudinal accelerometers were also compared to accelerometer 19 to establish longitudinal mode shapes. This testing met with mixed success. Roughly one half the selected modes could be identified (mainly the lower frequency modes) while the measured shapes for the others were not readily identifiable.

Table 1 lists the natural frequencies found during the experiment using both the shaker and the speakers, as well as the damping factors and possible mode associated with each one. The letter N indicates the order of the circumferential mode (number of full sine waves) and M the longitudinal (number of half sine waves).

Further testing around the first mode at 186 Hz showed that, to precisely determine the resonant frequency, the frequency response with respect to the applied force should be examined, as opposed to the response of the accelerometer or microphone alone. It was initially assumed that the applied force was reasonably flat over the frequency range of interest, but further examination showed variations of up to 15 DB in the applied load in a narrow band around the resonance. This effect for the 186 Hz mode is shown in Figure 6 and, with higher frequency resolution, in Figure 7. The response was measured with a microphone and the two curves on each plot show the power spectrum of the microphone signal and the frequency response with respect to the signal from the force transducer.

Subsequent testing at DREA without the turntable (using the shaker and accelerometers only) showed no natural frequencies between 300 Hz and 400 Hz (there are four shown in Table 1). Further investigations by the staff at the RPB showed that these frequencies were primarily resonances of the triangular plate structures in the top of the turntable.

## 3.2 Directivity Patterns

Following the natural frequency measurements, directivity patterns were measured for the cylinder with the shaker providing excitation at selected frequencies. For the first set of tests, a fixed microphone was located at a distance of 5.42m from the centre of the cylinder at the same vertical height as the midline of the cylinder (3.15m from the floor of the chamber). A schematic of the chamber layout is shown in Figure 8. To measure the directivity patterns, the cylinder was excited using a pure tone and the power spectral output of the microphone was viewed on the signal analyzer. The signal analyzer was calibrated to give output in dB re 20$\mu$Pa and each

| No. | Experimental Frequency (Hz) | Excited By (sh, sp, b) | Possible Mode (N,M) | Damping Factor |
|---|---|---|---|---|
| 1 | 186 | b | 2,1 | 0.00168 |
| 2 | 231 | sh | 1,1 | 0.00277 |
| 3 | 274 | sh | 2,2 | 0.00086 |
| 4 | 291 | sp | 2,2 | 0.00297 |
| 5 | 357 | sp | ? | 0.00455 |
| 6 | 365 | sp | ? | 0.00367 |
| 7 | 374 | sp | ? | 0.00279 |
| 8 | 377 | sp | ? | 0.00274 |
| 9 | 452 | b | 2,3 | 0.00097 |
| 10 | 462 | b | 2,3 | 0.00133 |
| 11 | 465 | b | 3,1 | 0.00140 |
| 12 | 473 | b | ? | 0.00125 |
| 13 | 475 | b | 2,3 | 0.00156 |
| 14 | 488 | sp | 3,2 | 0.00183 |
| 15 | 506 | sh | 3,3 | 0.00038 |
| 16 | 541 | b | 3,3 | 0.00114 |
| 17 | 622 | sp | 3,4 | 0.00050 |
| 18 | 632 | b | 3,4 | 0.00079 |
| 19 | 669 | sp | 4,? | 0.00120 |
| 20 | 688 | b | 4,1 | 0.00134 |
| 21 | 695 | sh | 4,1 | 0.00151 |
| 22 | 703 | sp | 4,? | 0.00148 |
| 23 | 708 | sp | 5,1 | 0.00128 |
| 24 | 721 | b | ?,5 | 0.00097 |
| 25 | 737 | b | 3,5 | 0.00087 |
| 26 | 765 | b | 5,? | 0.00095 |

Table 1: Measured Natural Frequencies (Hz) of Cylinder

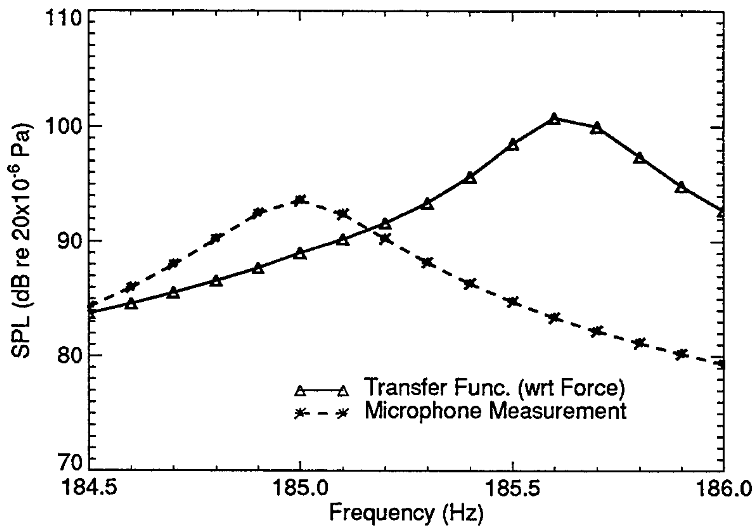


Figure 6: Frequency Response Around 185.00 Hz

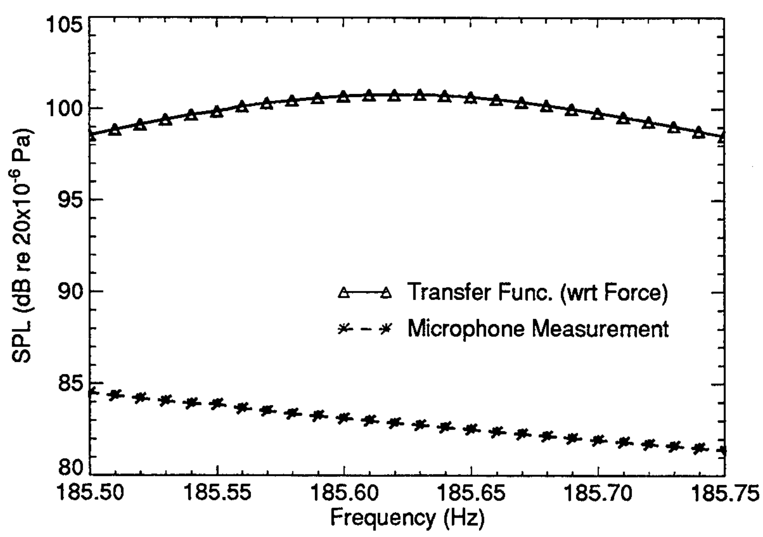


Figure 7: Frequency Response Around 185.00 Hz (High Resolution)

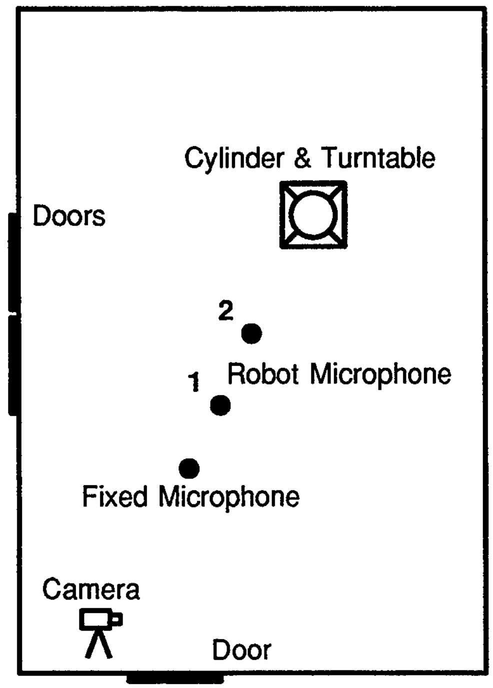


Figure 8: Microphone Positioning in Anechoic Chamber

measurement was an average of several sample periods. After each measurement the cylinder was rotated 10° using the powered turntable. Voltage levels on the force transducer were also recorded to determine the applied load for each pattern.

The discrete frequencies used were chosen based on two criteria: they had to be modes which could be excited easily by the shaker and they had to be dominant modes with strong signals. A listing of the tests done, the frequencies tested, and the applied force at each frequency is given in Table 2.

Test 01 involved measurements made around the first resonant peak at about 185.6 Hz to determine the extent of the drop in radiated sound close to the resonant frequency. The Test 02 runs were incomplete and are not reported here. Test 03 contained the majority of the tests run at selected resonances while Test 04 involved directivity patterns at off-resonant frequencies. As some of the Test 03 results were asymmetric or contained other irregularities, some frequencies were retested at 5° increments and are listed as Test 05 and Test 06. The directivity patterns for the above tests are shown in the next section.

For the next set of tests, the microphone attached to the RPB's overhead robotic control system was used. The microphone was initially positioned at a distance of 4.09m (Tests L1 and L2) from the centre of the cylinder with the 180° position of the cylinder facing the

| Frequency | Test Number | | | | |
|---|---|---|---|---|---|
| (Hz) | 01 | 03 | 04 | 05 | 06 |
| 185.00 | 99.43 | | | | |
| 185.50 | 12.00 | | | | |
| 185.60 | 7.92 | | | | |
| 185.70 | 7.55 | | | | |
| 185.66 | | 7.42 | | | |
| 231.44 | | 17.76 | | 54.14 | 54.14 |
| 273.59 | | 26.58 | | 50.94 | |
| 372.65 | | | | 46.13 | |
| 452.28 | | 33.12 | | | |
| 461.94 | | 36.23 | | 55.47 | |
| 465.34 | | 4.46 | | | |
| 473.66 | | 12.42 | | 25.44 | |
| 475.16 | | 8.75 | | 18.03 | |
| 541.47 | | 4.96 | | | |
| 632.81 | | 19.68 | | | |
| 740.13 | | 3.80 | | | |
| 200.00 | | | 54.18 | | |
| 325.00 | | | 47.32 | | |
| 400.00 | | | 45.40 | | |
| 525.00 | | | 41.26 | | |
| 600.00 | | | 36.27 | | |
| 150.00 | | | | 62.88 | |

Table 2: Cylinder Directivity Pattern Applied Forces ($N_{rms}$)

| Frequency (Hz) | Test Number | | | |
|---|---|---|---|---|
| | L1 | L2 | L3 | L4 |
| 150.00 | 63.32 | 59.85 | | |
| 185.66 | 14.13 | 2.52 | | 2.62 |
| 185.66* | | 13.55 | | |
| 231.44 | 31.92 | 4.47 | | |
| 273.59 | 51.23 | 8.68 | | |
| 372.65 | 46.13 | 7.64 | 7.74 | |
| 465.34 | | 1.44 | | |
| 473.66 | | 5.36 | 5.41 | |
| 541.47 | | 1.63 | 1.64 | 1.63 |
| 740.13 | | 1.11 | 2.62 | 1.09 |
| 740.13* | | 7.63 | | |

Table 3: Cylinder Directivity Pattern Applied Forces ($N_{rms}$)

microphone, i.e., the shaker pointed away from the microphone. For the directivity patterns, the microphone was traversed vertically ranging from 1.3m above to 1.3m below the cylinder midline. For the first test (L1), only the upper half of the cylinder was traversed. Test L2 covered the entire cylinder at the same distance over a broader range of frequencies. Another set of tests (Tests L3 and L4) was performed with the microphone moved to a distance of 2.89m from the cylinder centre. The positioning of the microphones is shown in Figure 8. Sound pressure levels were recorded every 100mm as the microphone was traversed down the length of the cylinder.

A listing of the tests done, the frequencies tested, and the applied force at each frequency is given in Table 3.

For Test L2, the frequencies marked with an asterisk were excited with a pure tone from a signal generator, while the remainder were excited simultaneously using a complex waveform generated by the LabView computer program.

The directivity patterns for the above tests are shown in the following section.

### 3.3 Directivity Pattern Plots

The following pages contain the directivity plots measured during the trials (Figures 9 to 59). For some of the circular plots, only half patterns were recorded due to time constraints. The first few vertical plots are also only half patterns (from the centreline to the top of the cylinder) for the same reason. The radial scales for the circular plots are sound pressure levels (SPL) in dB re 20$\mu$Pa.

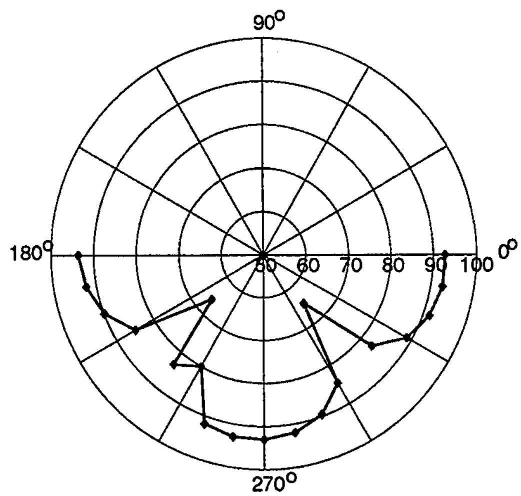


Figure 9: Test 01 Directivity Pattern at 185.0 Hz

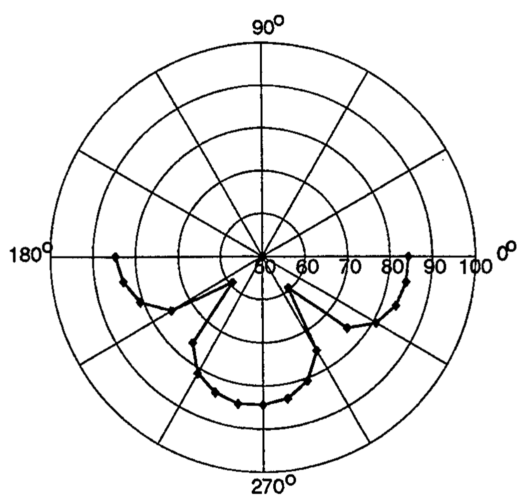


Figure 10: Test 01 Directivity Pattern at 185.5 Hz

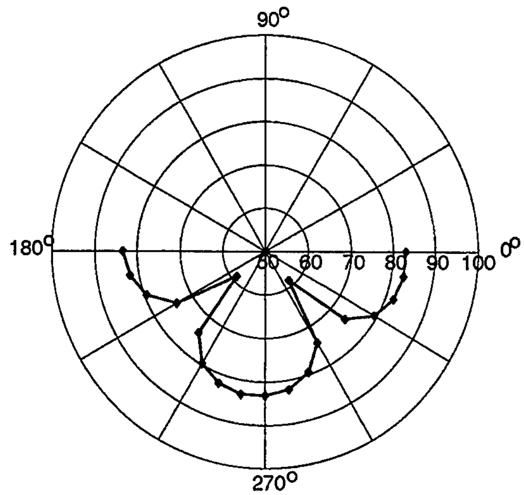


Figure 11: Test 01 Directivity Pattern at 185.6 Hz

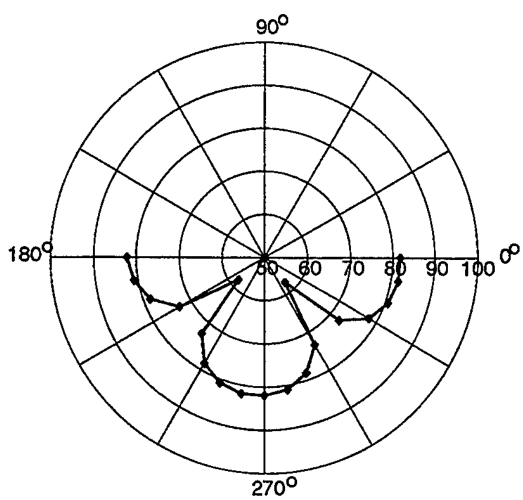


Figure 12: Test 01 Directivity Pattern at 185.7 Hz

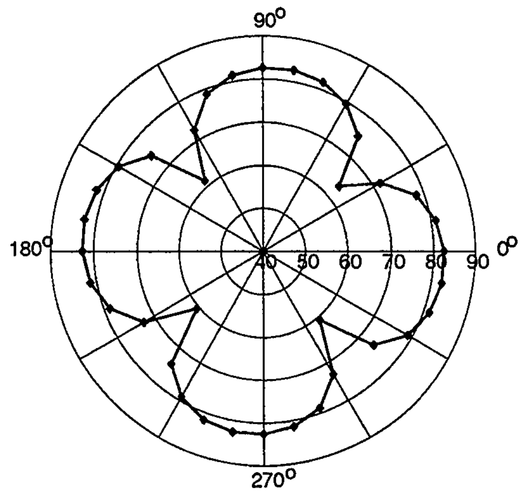


Figure 13: Test 03 Directivity Pattern at 185.66 Hz

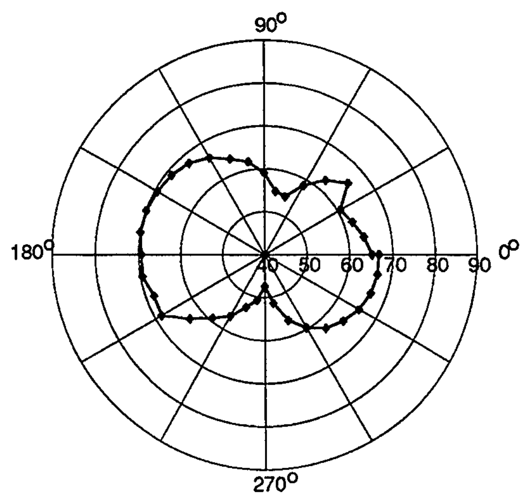


Figure 14: Test 03 Directivity Pattern at 231.44 Hz

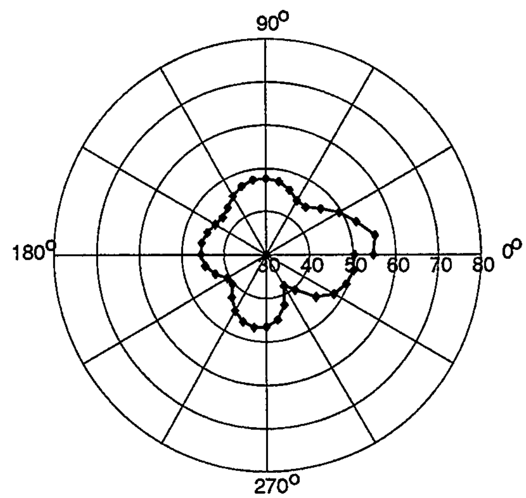


Figure 15: Test 03 Directivity Pattern at 273.59 Hz

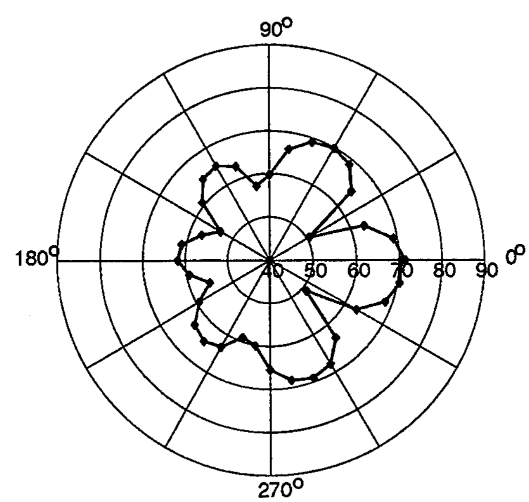


Figure 16: Test 03 Directivity Pattern at 452.28 Hz

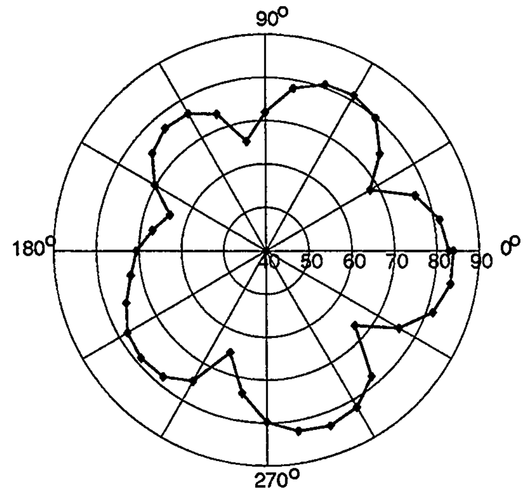


Figure 17: Test 03 Directivity Pattern at 461.94 Hz

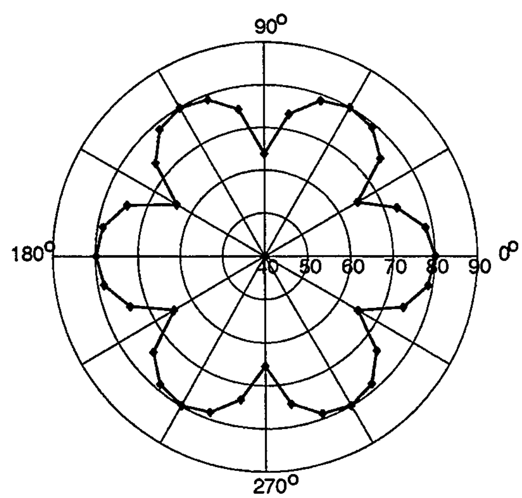


Figure 18: Test 03 Directivity Pattern at 465.34 Hz

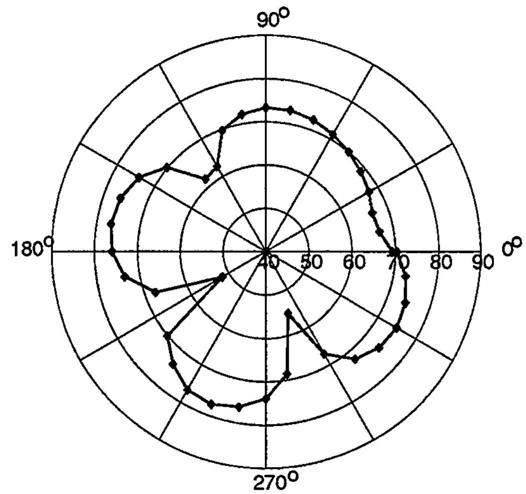


Figure 19: Test 03 Directivity Pattern at 473.65 Hz

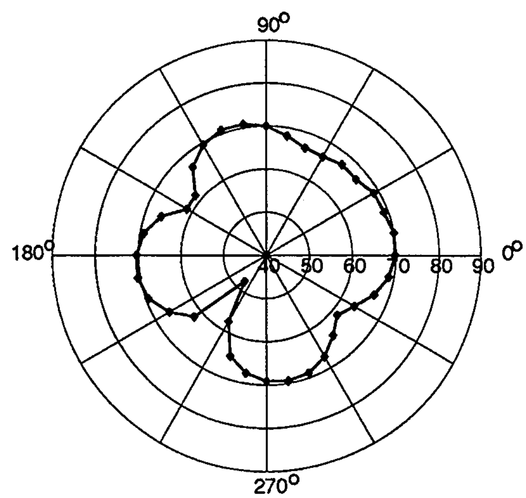


Figure 20: Test 03 Directivity Pattern at 475.16 Hz

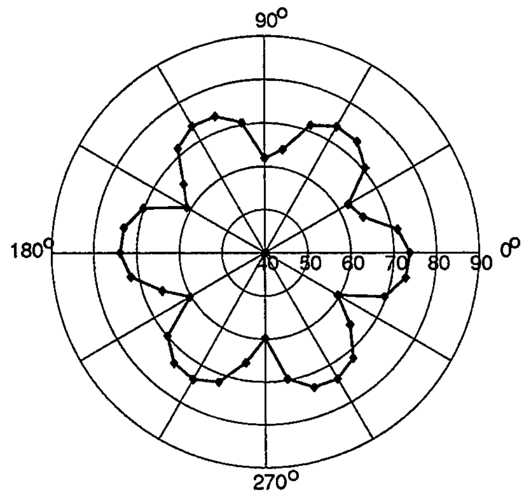


Figure 21: Test 03 Directivity Pattern at 541.47 Hz

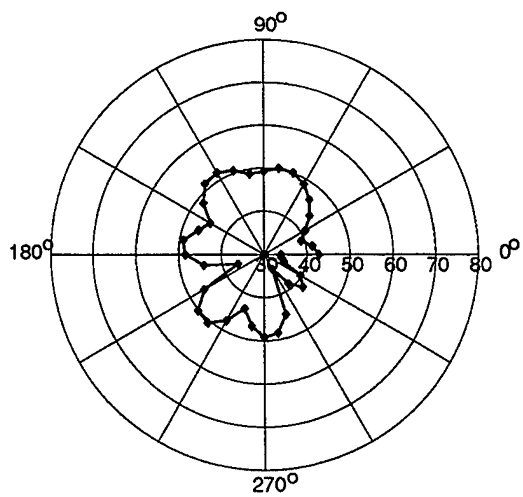


Figure 22: Test 03 Directivity Pattern at 632.81 Hz

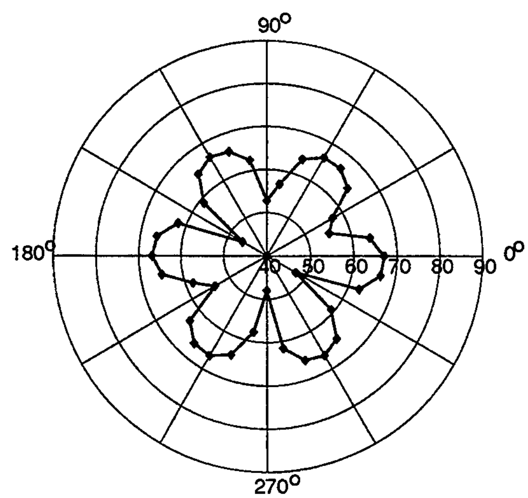


Figure 23: Test 03 Directivity Pattern at 740.13 Hz

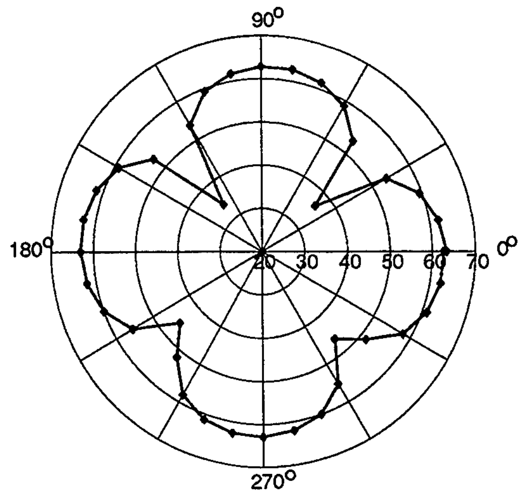


Figure 24: Test 04 Directivity Pattern at 200 Hz

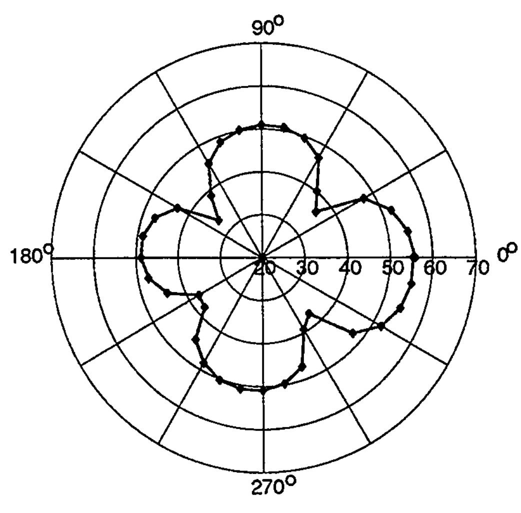


Figure 25: Test 04 Directivity Pattern at 325 Hz

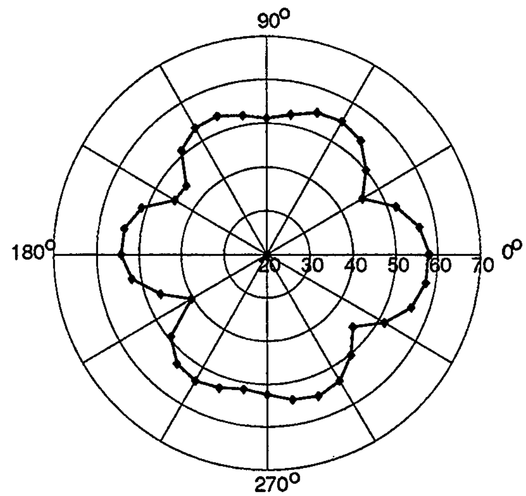


Figure 26: Test 04 Directivity Pattern at 400 Hz

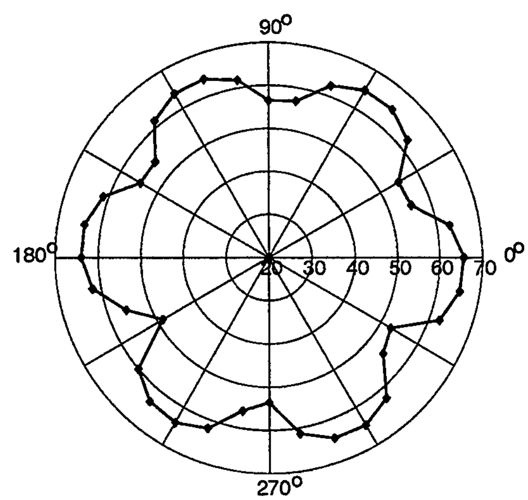


Figure 27: Test 04 Directivity Pattern at 525 Hz

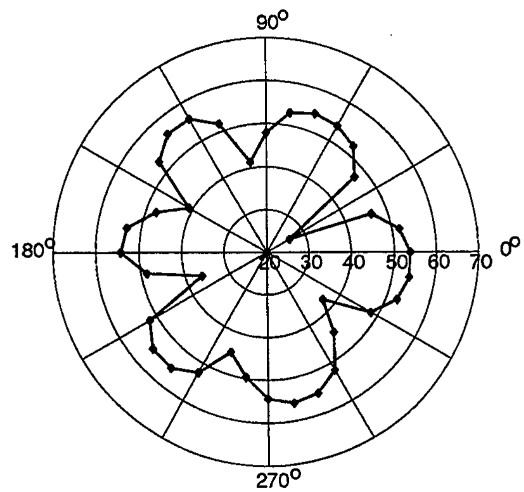


Figure 28: Test 04 Directivity Pattern at 600 Hz

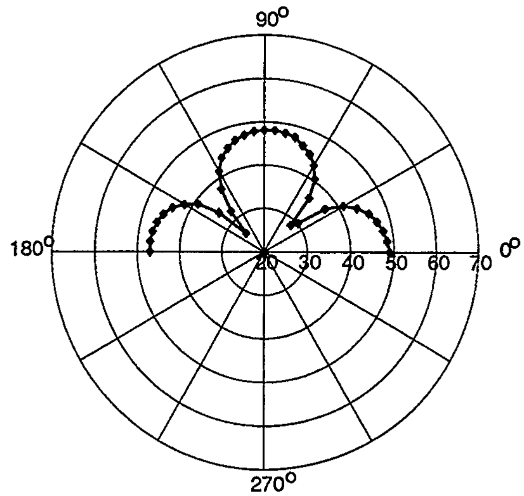


Figure 29: Test 05 Directivity Pattern at 150 Hz

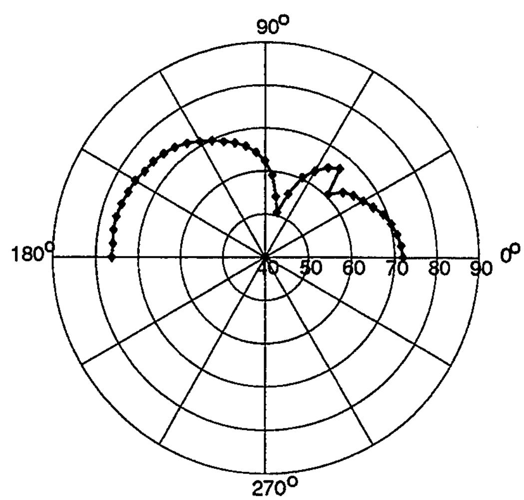


Figure 30: Test 05 Directivity Pattern at 231.44 Hz

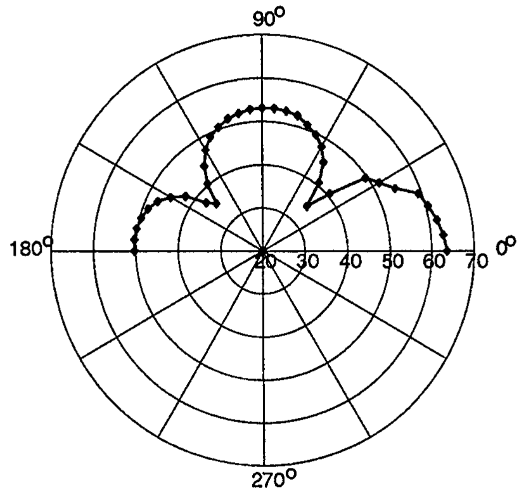


Figure 31: Test 05 Directivity Pattern at 273.59 Hz

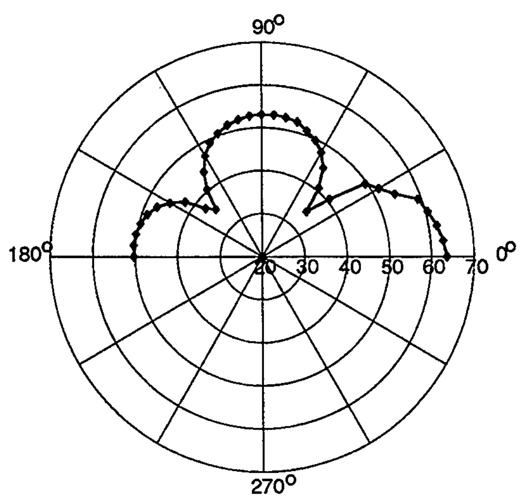


Figure 32: Test 05 Directivity Pattern at 372.65 Hz

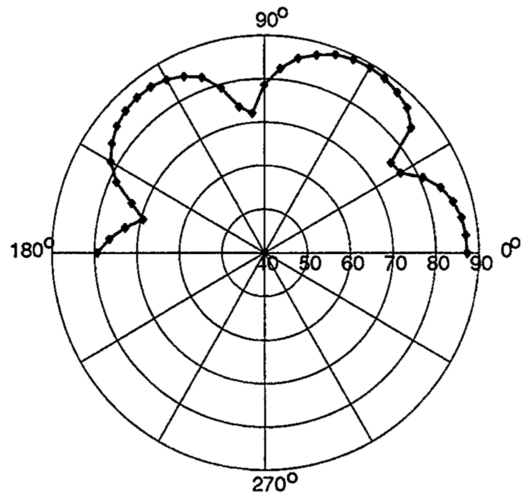


Figure 33: Test 05 Directivity Pattern at 461.94 Hz

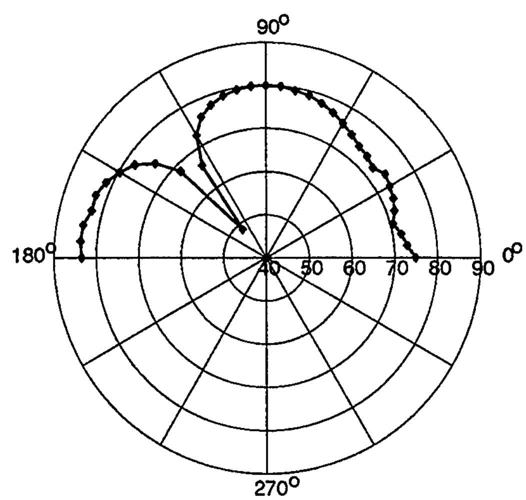


Figure 34: Test 05 Directivity Pattern at 473.66 Hz

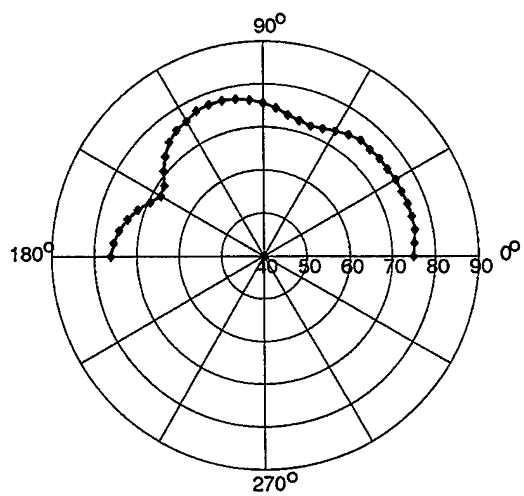


Figure 35: Test 05 Directivity Pattern at 475.16 Hz

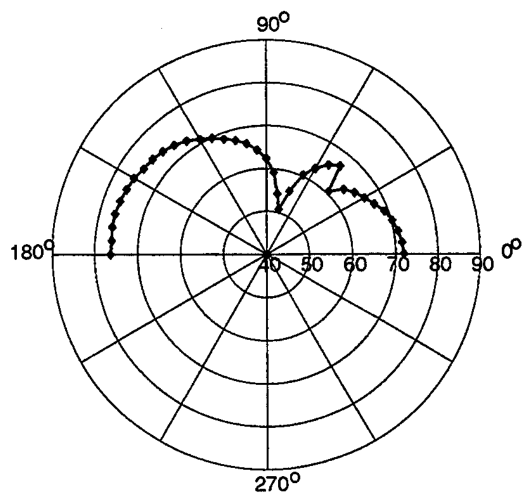


Figure 36: Test 06 Directivity Pattern at 231.44 Hz

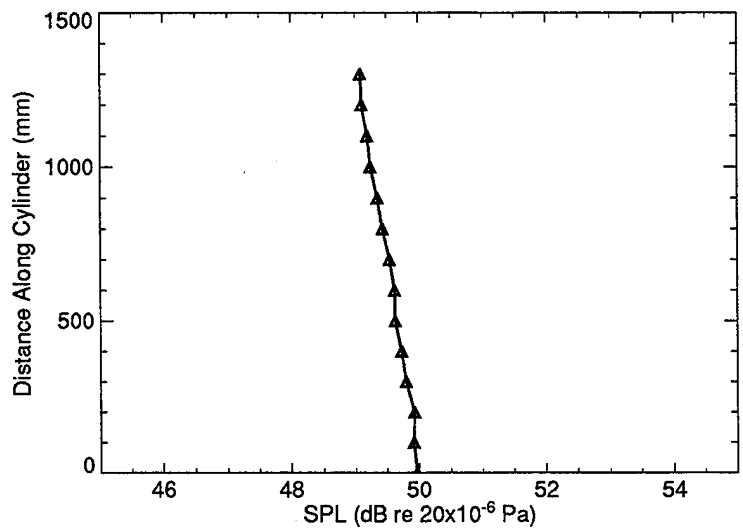


Figure 37: Test L1 Vertical Directivity Pattern at 150 Hz

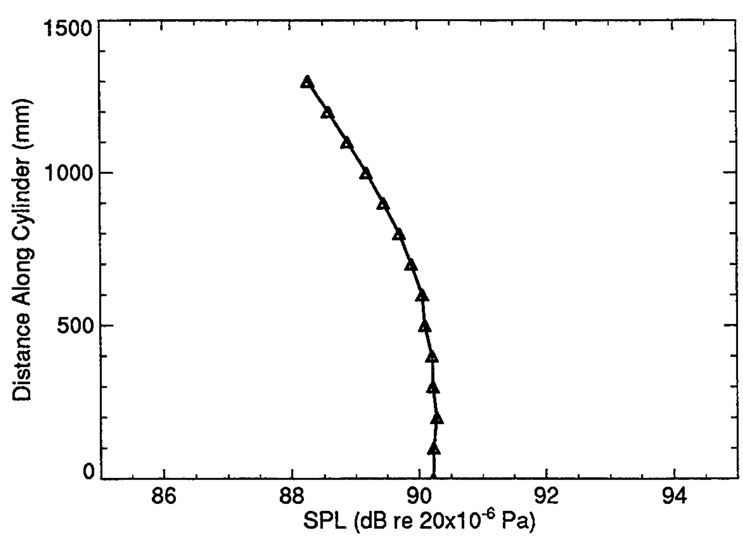


Figure 38: Test L1 Vertical Directivity Pattern at 185.66 Hz

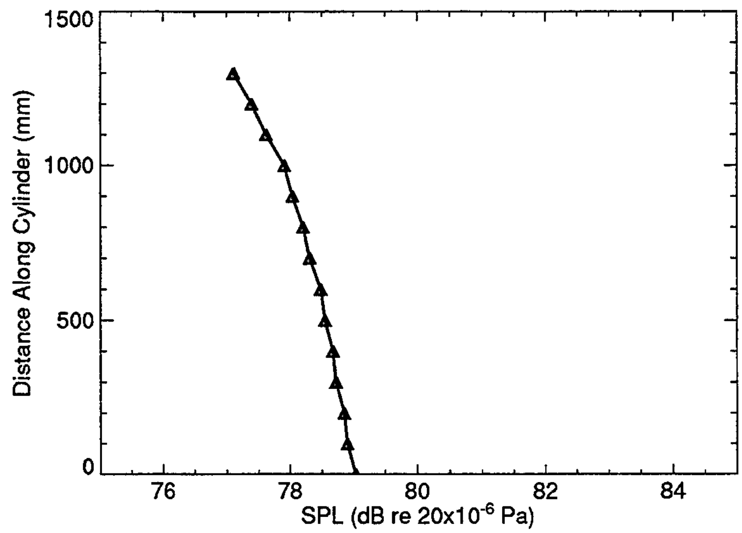


Figure 39: Test L1 Vertical Directivity Pattern at 231.44 Hz

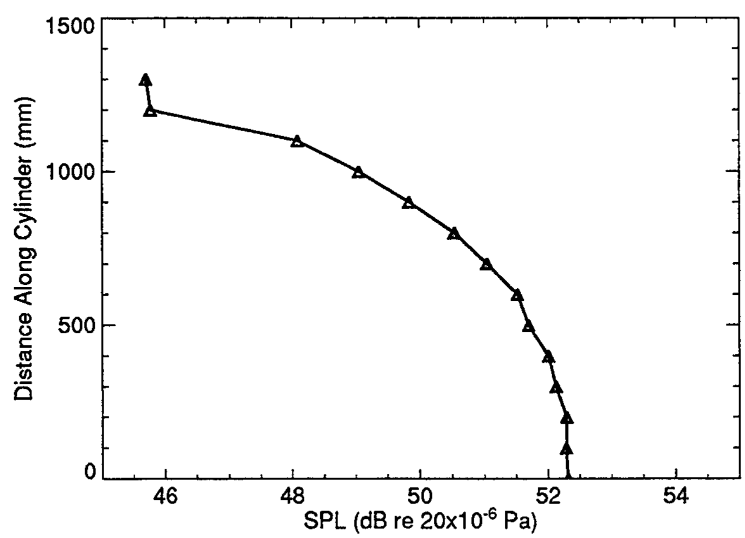


Figure 40: Test L1 Vertical Directivity Pattern at 273.59 Hz

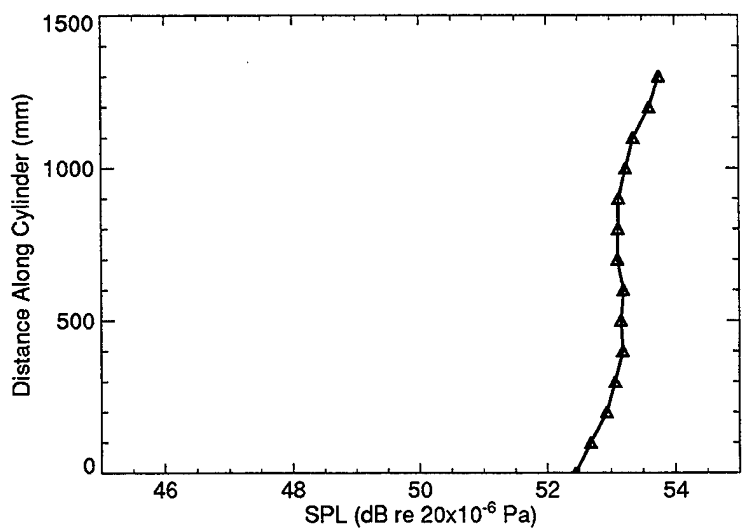


Figure 41: Test L1 Vertical Directivity Pattern at 372.65 Hz

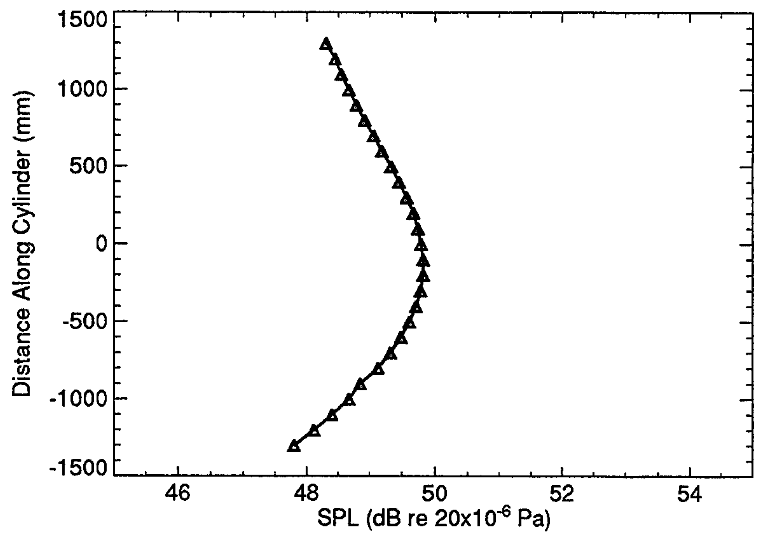


Figure 42: Test L2 Vertical Directivity Pattern at 150 Hz

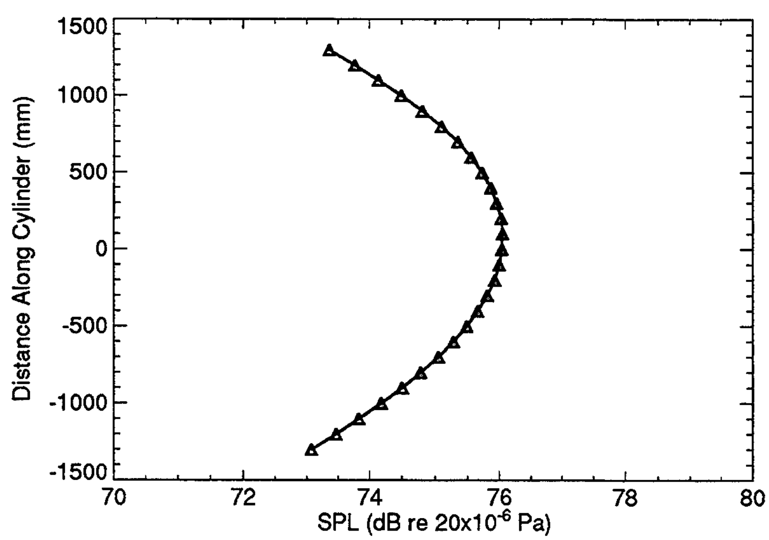


Figure 43: Test L2 Vertical Directivity Pattern at 185.66 Hz

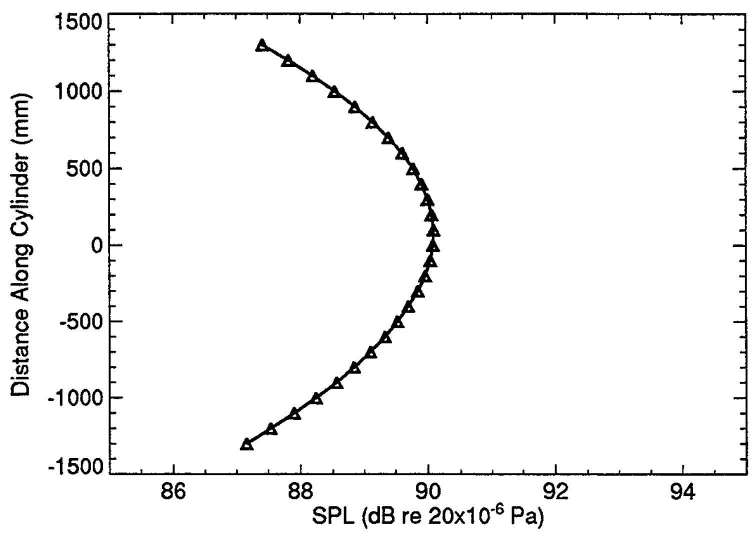


Figure 44: Test L2 Vertical Directivity Pattern at 185.66 Hz

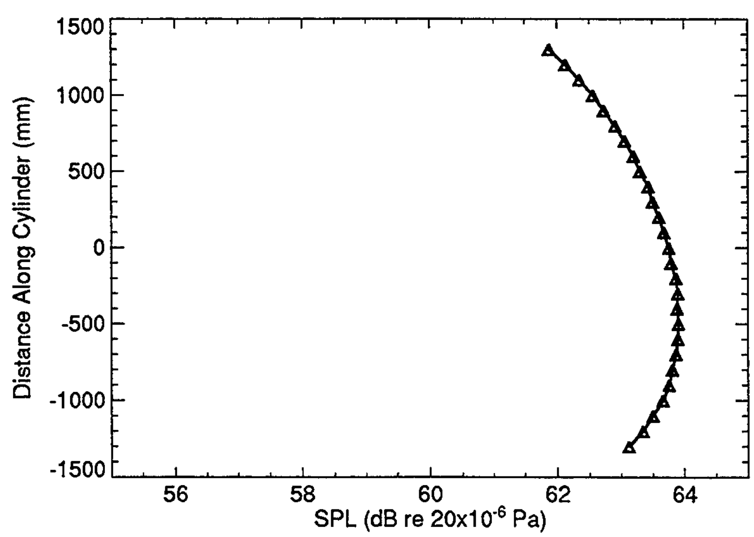


Figure 45: Test L2 Vertical Directivity Pattern at 231.44 Hz

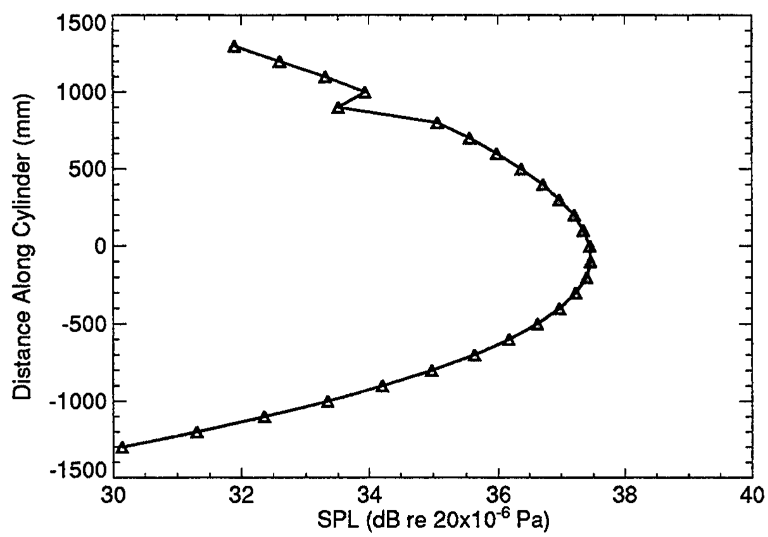


Figure 46: Test L2 Vertical Directivity Pattern at 273.59 Hz

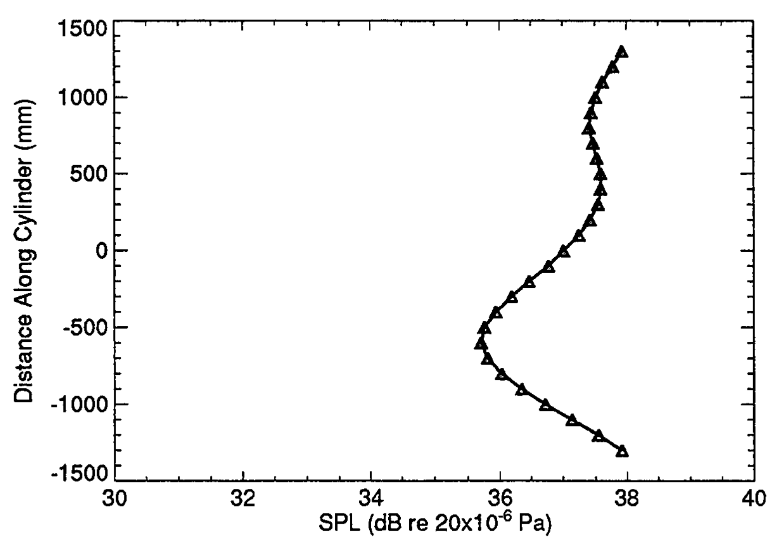


Figure 47: Test L2 Vertical Directivity Pattern at 372.65 Hz

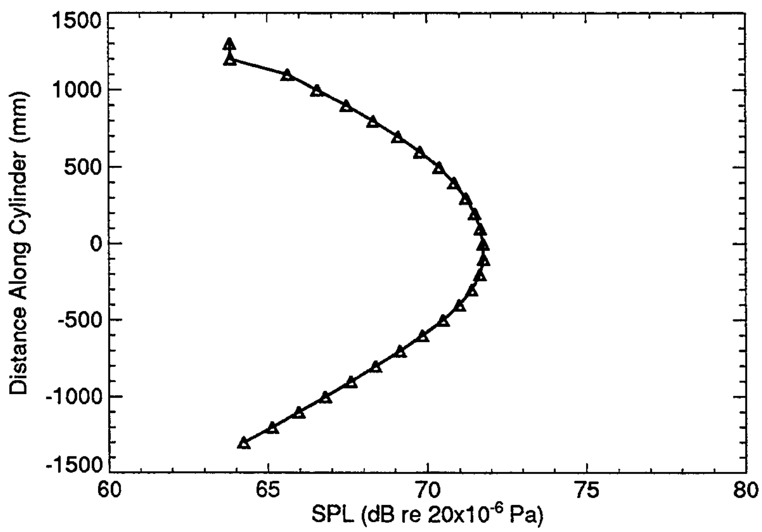


Figure 48: Test L2 Vertical Directivity Pattern at 465.34 Hz

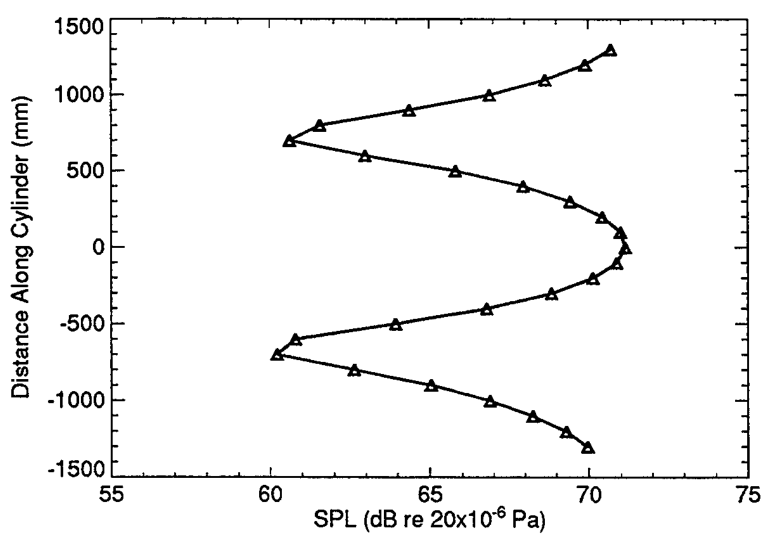


Figure 49: Test L2 Vertical Directivity Pattern at 473.66 Hz

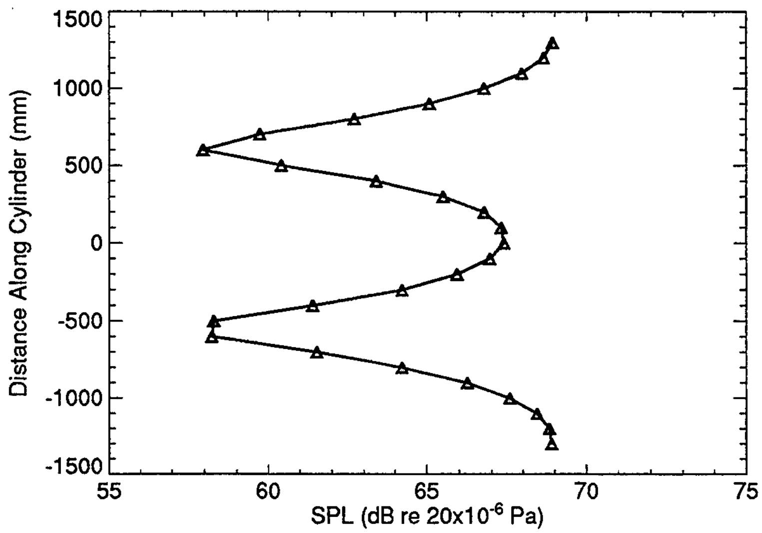


Figure 50: Test L2 Vertical Directivity Pattern at 541.47 Hz

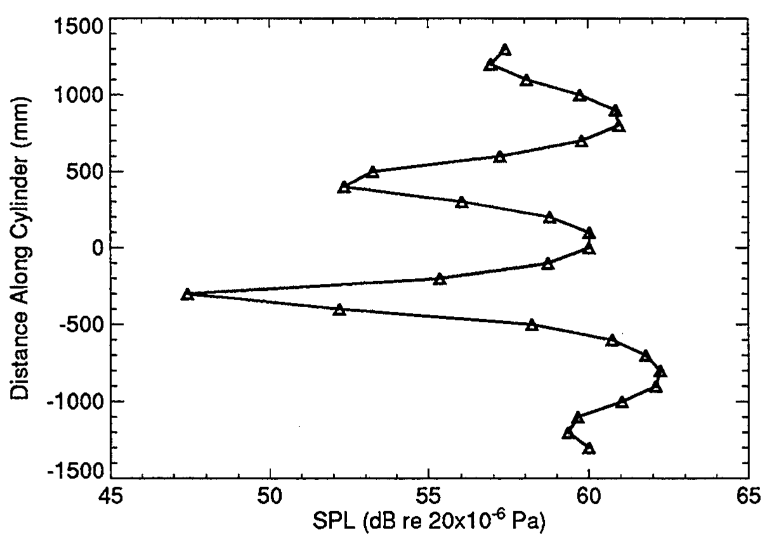


Figure 51: Test L2 Vertical Directivity Pattern at 740.13 Hz

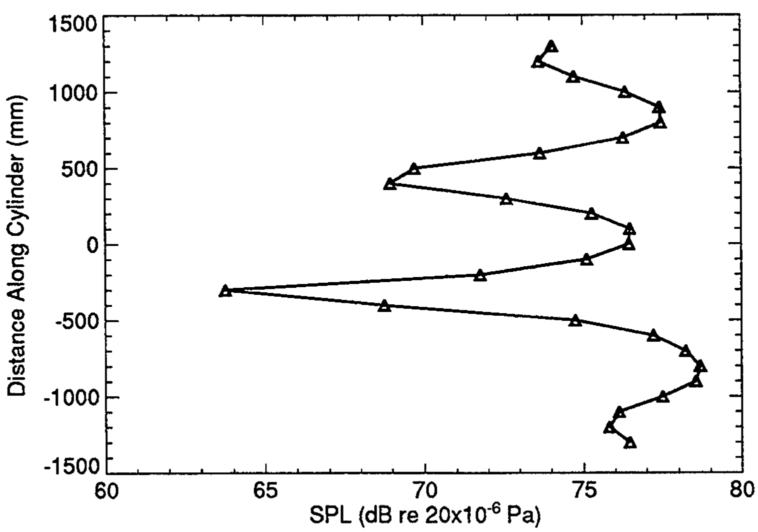


Figure 52: Test L2 Vertical Directivity Pattern at 740.13 Hz

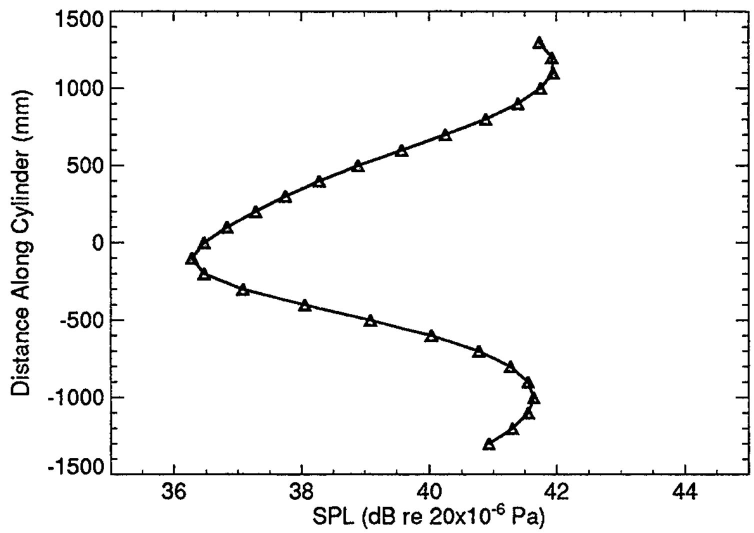


Figure 53: Test L3 Vertical Directivity Pattern at 372.65 Hz

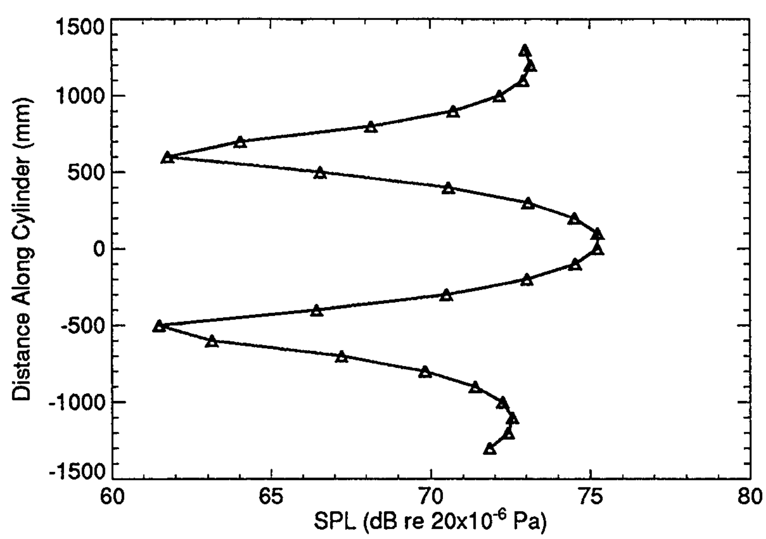


Figure 54: Test L3 Vertical Directivity Pattern at 473.66 Hz

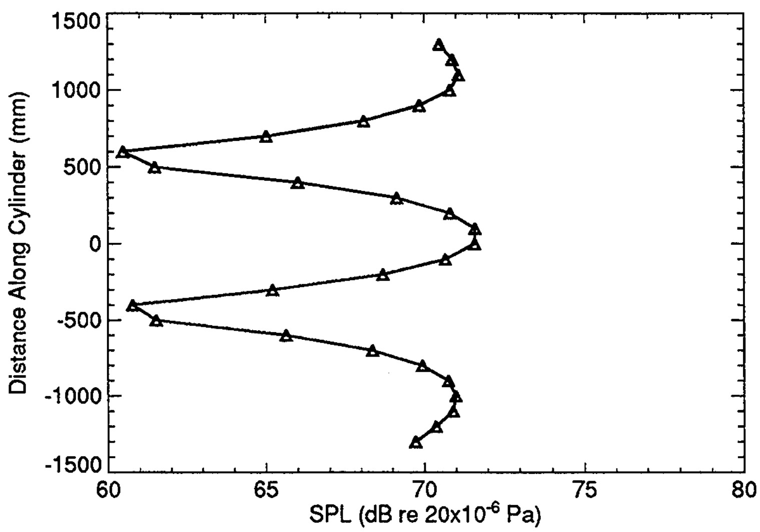


Figure 55: Test L3 Vertical Directivity Pattern at 541.47 Hz

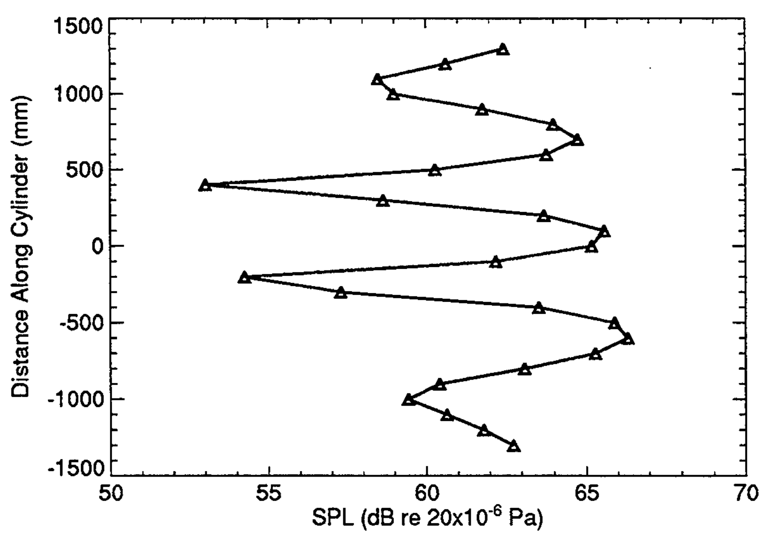


Figure 56: Test L3 Vertical Directivity Pattern at 740.13 Hz

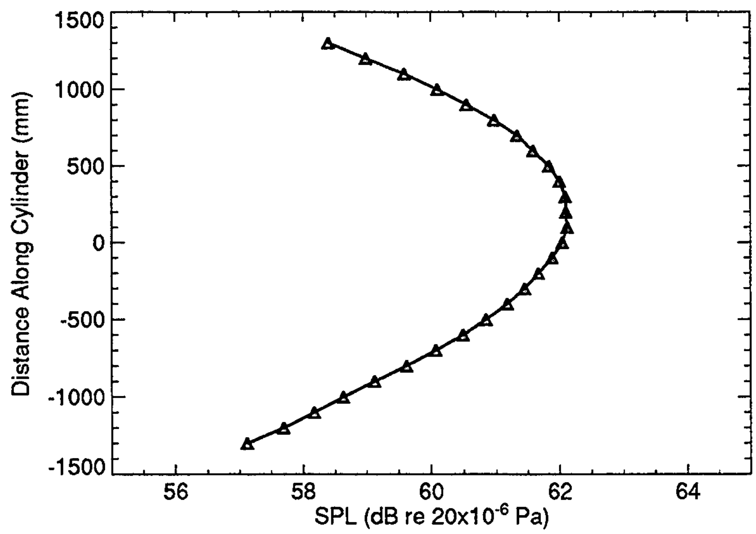


Figure 57: Test L4 Vertical Directivity Pattern at 185.66 Hz

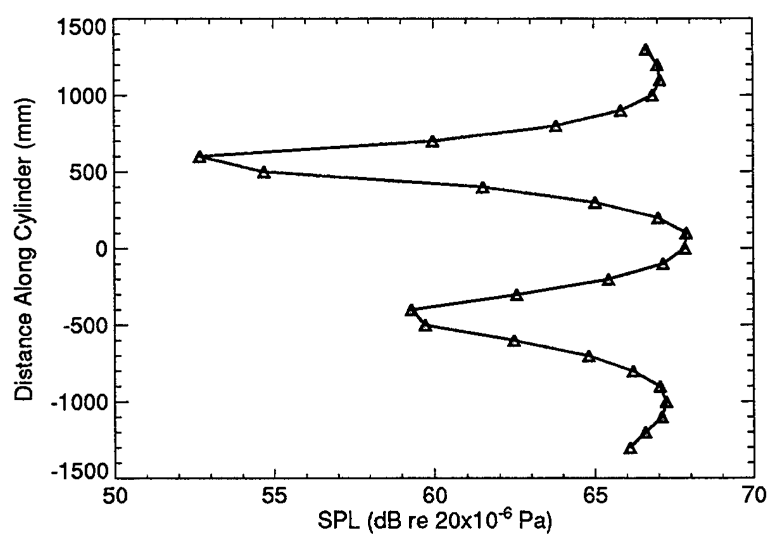


Figure 58: Test L4 Vertical Directivity Pattern at 541.47 Hz

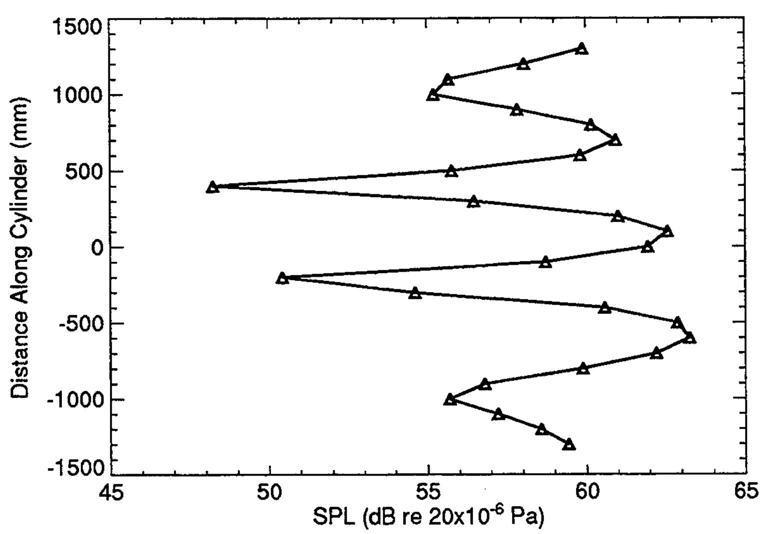


Figure 59: Test L4 Vertical Directivity Pattern at 740.13 Hz

# 4 Concluding Remarks

Experiments were performed at Health Canada's anechoic chamber at the Radiation Protection Bureau in Ottawa to measure the natural frequencies of a ring-stiffened cylinder and to measure acoustic radiation directivity patterns for the cylinder undergoing point-excitation. These experiments have provided data with which DREA structural and acoustic computer codes can be evaluated.

The testing was relatively successful, in that over 25 resonant frequencies of the cylinder were identified. Circumferential and longitudinal directivity patterns for a variety of frequencies were measured, but difficulties were encountered in identifying some modes (particularly the higher frequency modes). The Radiation Protection Bureau staff was quite helpful and their expertise was valuable in the smooth operation of the trial. The use of the anechoic chamber gave confidence that the data collected were of good quality and would be reproducible in any future experiments. Further investigations will be conducted at DREA to attempt to complete the identification of the resonant modes (in partiular, the higher frequency modes) using a finer grid for the accelerometers than was used in this trial.

# Bibliography


1. Gilroy, L.E., "Natural Frequency and Radiated Noise Measurements on a Ring-Stiffened Cylinder," DREA Technical Memorandum 93/215, October, 1993.

2. Gilroy, L.E., "Natural Frequency and Radiated Noise Measurements on a Ring-Stiffened Cylinder - Experimental Data Annex," DREA Technical Communication 93/313, December, 1993.

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Defence Research Establishment Atlantic (DREA), with the assistance of Health Canada, has conducted an experiment involving the measurement of radiated noise from a ring-stiffened cylinder subjected to a harmonic load in an anechoic chamber. This experiment was performed to provide validation data for structural acoustics computer codes being developed in-house and under contract.

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