FINAL REPORT

Project No. A-573

THE EFFECTS OF RESONANT VIBRATIONS ON HEAT TRANSFER AT HIGH REYNOLDS NUMBERS

By

Thomas W. Jackson, Calvin C. Oliver
and Ian Eastwood

Covering the Period
13 June 1961 to 13 August 1961

Purchase Order 9184907

Lawrence Radiation Laboratory
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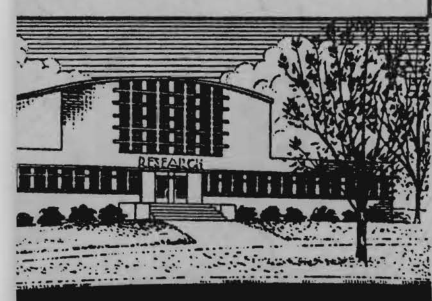

Engineering Experiment Station
Georgia Institute of Technology
Atlanta, Georgia

ENGINEERING EXPERIMENT STATION
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Submitted by:

Thomas W. Jackson, Project Director
and Chief, Mechanical Sciences Division

Released by:

for J. E. Boyd
Director

FOREWORD

This report contains a summary of results obtained from an experimental study of the effects of resonant acoustic vibrations on the local and overall convection heat transfer coefficients for an isothermal horizontal tube.

The results reported on herein were obtained through sponsorship of three agencies: the Aeronautical Research Laboratory at Wright Field; Georgia Institute of Technology; and, the University of California Lawrence Radiation Laboratory. Specifically, the equipment was constructed for research sponsored by the Aeronautical Research Laboratory, the capital items and some of the advanced research support were provided by Georgia Tech, and modifications to the inlet plenum chamber to obtain Reynolds numbers in the range of 80,000 to 200,000 was supported by the University of California.

ACKNOWLEDGEMENTS

The sponsorship of the University of California and the interest of Mr. E. Arbtin of the Lawrence Radiation Laboratory in obtaining support for this research is greatly appreciated.

ABSTRACT

Results are presented for a series of experiments conducted for the purpose of studying the local and overall effects of a resonant acoustic vibration on the heat transfer coefficient for air flowing through a constant temperature isothermal tube in the turbulent Reynolds number range, 16,000 to 200,000.

The local heat transfer coefficient is shown to vary periodically between the nodes and loops of the resonant sound wave. It is interesting to note that at Reynolds numbers below approximately 35,000 the maximum local Nusselt numbers occur at the velocity loops. Above 35,000 the maximum values of the Nusselt number shift to the velocity nodes. The reason for this shift is not apparent at this time. Tables of data are included for possible analytical investigations. Data are reported for two resonant frequencies 1,500 cps and 222 cps and for sound pressure levels to 164.5 decibels. At 1,500 cps the highest sound pressure level that could be obtained was 147.3 decibels.

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NOMENCLATURE

Latin

A	inside surface area of tube, ft^2
c_p	specific heat at constant pressure, BTU/lb °F
D	inside diameter of tube, ft
db	decibels
g	acceleration due to gravity, ft/hr^2
h	heat transfer coefficient of convection, BTU/hr ft^2 °F
h_{fg}	latent heat of vaporization, BTU/lb
k	thermal conductivity, BTU/hr ft °F
L	length, ft
m	mass of steam condensate, lb
$\dot{m}$	mass rate of flow, lb/hr
p	pressure, in. of Hg
Q	heat transfer, BTU
q	heat transfer rate, BTU/hr
SPL	sound-pressure-level, decibels - reference 0.0002 microbars
t	temperature, °F
V	volume, ft^3
$\bar{V}$	velocity, ft/hr
v	specific volume, ft^3/lb
w	width, ft
x	axial distance from tube entrance, ft

Greek

β	coefficient of volumetric expansion, $\frac{1}{°F}$
Δ	indicates an increment
γ	specific humidity, lb/lb

Greek (continued)

λ	wave length, ft
μ	dynamic viscosity, lb/ft hr
ν	kinematic viscosity, ft^2/hr
π	3.14159
ρ	density, lb/ft^3
Σ	indicates a summation of terms
τ	time, sec.

Subscript

a	refers to condition of air
d.b.	dry-bulb
i	number of condensate collection chamber, $i = 1, 2, 3, \ldots, 21$
lm	based on logarithmic mean conditions
o	based on inlet conditions
oa	based on conditions in inlet section of tube where condensate is not collected
s	based on conditions at inside surface of tube
x	based on local conditions

Moduli

Gr	Grashof, based on the tube diameter and wall properties, $\frac{\rho^2 g \beta \Delta t D^3}{\mu^2}$
Gz	Graetz, based on wall properties, $\dot{m} c_p / kx$
Nu	Nusselt, based on the tube diameter and wall properties, hD/k
Re	Reynolds, based on inlet conditions and tube diameter, $\bar{V}_o D / \nu_o$

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CHAPTER I

INTRODUCTION

The interest in the effects of resonant and non-resonant vibration on the heat transfer coefficient did not become important until recently. In the past several years many researchers have investigated the influence of sound on heat transfer. However, the basic phenomena which govern the effect are still not understood to a satisfactory degree. In 1958, under the sponsorship of the Aeronautical Research Laboratory, the Georgia Institute of Technology initiated a program of research in an attempt to give a more basic understanding to the problem. Equipment was built to study the effects of resonant acoustic vibrations in a uniform isothermal tube approximately 10 feet long and with an inside diameter of 3.86 inches. The first year's work on this equipment is reported in a WADC Technical Note (1). The first year's work dealt with only overall heat transfer coefficients and it was apparent that if meaningful data were to be obtained it would be necessary to determine the local heat transfer coefficients along the tube. To do this a second year's effort was initiated and this work is reported in an ARL Technical Report (2).

The equipment used to obtain the data reported in reference 2 was utilized with slight modifications to obtain the data reported on herein. In the interest of completeness this report encompasses data in excess of that obtained for the University of California Lawrence Radiation Laboratory. Data are reported for a range of Reynolds numbers from 16,100 to 209,000. It is believed that the results reported on herein are unique and indicate effects which would not normally be expected by researchers working in the field.

Descriptive sections of this report, concerned with the equipment and procedures utilized, are similar to those given in reference 2.

CHAPTER II

EXPERIMENTAL EQUIPMENT

The equipment used in these experiments consisted primarily of a steam heated test section and an electronic system for producing and measuring a stationary acoustic field. The entire apparatus was enclosed by an acoustic shield. The various components which comprised the test section, electronic system, and the acoustic shield are described in the following paragraphs and indicated schematically in Figures 1 and 2.

1. Heat Transfer Apparatus

a. Steam Heated Tube

The heat transfer test section was made from a 4.125 inch O.D. type K copper tube ten feet six inches long which was mounted concentrically within a 16-inch steel pipe. The annular region between the tube and the pipe, hereafter referred to as the steam chest, was filled with saturated steam from the laboratory low pressure steam line. Because the heat transfer coefficient between the air flowing through the copper tube and the tube itself was very much less than the heat transfer coefficient for condensing steam, the condensing steam produced essentially an isothermal test section. A drain shield over the test tube prevented any line condensate from dripping into the condensate collectors.

Three 24-gage copper-constantan thermocouples were installed to give the inlet tube wall temperature, the outlet tube wall temperature, and the saturation temperature of the steam. The inlet thermocouple was located 4-1/2 inches from the entrance of the test section and the outlet thermocouple was located 3 inches from the exit of the test section.

b. Condensate Collection System

The condensate collecting system had 21 collection chambers. The chambers were divided by diamond shaped partitions that were cut from 48-ounce soft-rolled copper sheet. The partitions were soldered to the

4.125-inch copper tube at three-inch intervals for the first two chambers and at six-inch intervals for the remaining nineteen chambers. The first chamber started 0.38 inches from the entrance of the test section. The chambers were completed by soldering a preformed 16-ounce copper collection pan in the shape of an inverted hollow pyramid to the bottom of each chamber. A hole at the bottom of each chamber allowed the condensate to drain into a 5/16-inch O.D. copper stand pipe 1-1/4 inches long. The drain lines ran horizontally through the steam chest and then ran through a brass head-plate at the entrance end of the chest section. One-fourth-inch O.D. copper tubing was used to run the drain lines from the head-plate to the outside wall of the acoustic shield and one-fourth-inch O.D. Neoprene tubing was used between the copper drain lines and the twenty-one transfer cups. The transfer cups were open to the atmosphere so that each drain line behaved as a U-tube manometer. Condensate from each transfer cup drained into a calibrated burette where it was measured as a function of time. In order to prevent extraneous condensate from being collected, a drip shield covered the condensate collection chambers.

c. Air Supply System

The air supply system consisted of an air filter, a throttling device, a centrifugal blower, an orifice plate, a mixing chamber, and an inlet plenum chamber. The blower and orifice were located outside the acoustic shield in the laboratory. The blower was 28-inches in diameter and was driven by a 15-horsepower electric motor. A cone shaped, variable throttling device was located on the intake side of the blower in a box with an air filter. The air from the laboratory passed over a hygrometer at the entrance to the blower which provided wet and dry bulb temperatures. The outlet of the blower was connected to a straight section of 6-inch diameter pipe which contained a thermometer well, straightening tubes, and a pressure tap. The pressure tap was connected to a 24-inch mercury manometer to give the air pressure upstream of the orifice. Slip-on flanges, with flange pressure taps and a standard ASME orifice plate, were connected at the end of the pipe. The pressure taps for the orifice were connected either to a 48-inch differential water manometer or to a micromanometer, depending on the flow rate. After the orifice, another straight section of pipe and an elbow passed the air through the wall of the acoustic shield into a mixing chamber where the air temperature was measured. From the mixing chamber the air passed through two 2-inch diameter pipes into an inlet plenum chamber. Provision was made in the connecting pipes for inserting various sized orifices for controlling the flow rate. The inlet plenum chamber was constructed of 3/4-inch plywood. The sound pressure level probe could be inserted through the plenum chamber to any desired position in the test section. The plenum chamber was well insulated to prevent changes in air temperature prior to entering the test section. A smooth bell-mouthed entrance section connected the inlet plenum chamber to the copper test tube. The bell was constructed of mahogany and was included to insulate the entering air from the hot head plate of the test section and to provide a uniform velocity profile at the tube entrance.

d. Thermocouples and Potentiometer

The thermocouples used in the test section were made from 24-gage copper-constantan thermocouple wire. The electromotive force produced by the thermocouples was measured with a Leeds and Northrup 8686 Millivolt Potentiometer. The air temperature in the mixing chamber was measured with a 24-gage iron-constantan thermocouple connected to a Leeds and Northrup Speedomax H direct reading temperature indicator.

2. Sound Generating Equipment

a. Drivers and Horn

Two PA-HF University drivers were connected by a 2YC-PA-HF University driver connector to produce the sound field in the test section. Sound pressure levels up to 164.5 db were obtained with this system. The PA-HF University drivers had a frequency response from 70 to 10,000 cps and a continuous duty power of 50 watts.

The conical horn used with the speakers was 18 inches long and had an outlet diameter of two inches. The inlet diameter of the horn matched the diameter of the 2YC-PA-HF connector. The horn was constructed of sheet metal. The drivers and horn were rigidly mounted on a plate which was connected to a rack assembly. The rack was positioned axially by a set of pinion gears which were turned by a hand crank. The horn was adjusted to the position which produced the greatest sound pressure level in the test section.

b. Audio Signal Generator and Amplifiers

The power supply for the drivers was a RCA Model WA-44B audio signal generator coupled to Bogen, Model CHA75, 75-watt amplifiers. An Eico, Model 425, push-pull oscilloscope and a Heathkit, Model AW-1, audio wattmeter were used in conjunction with the power supply. A Sorensen, Model 2501, voltage regulator supplied 115-volt 60-cycle power to all instrumentation. A schematic drawing of the sound generating equipment is given in Figure 2.

3. Sound Measuring Equipment

The sound pressure level in the test section was measured with a General Radio, Type 1551-A, sound level meter in conjunction with a General Radio, Type 1551-P1, condenser microphone system. The microphone system utilized an Altec, Type 21-BR-180, microphone. This microphone was calibrated periodically with a General Radio, Type 1552-B, sound level calibrator in conjunction with a General Radio, Type 1307-A, transistor oscillator. This calibrator produced a sound pressure level of 121 $\pm$ 1 db. In order to probe the sound field the microphone was mounted on the end of a 15 foot aluminum rod. With this rod, which passed through a packing gland on the sliding panel in the inlet plenum chamber, the sound pressure level in the test section was determined as a function of position.

4. Acoustic Shield

The acoustic shield, an eight by twenty foot room, eight feet high, was built to enclose the test apparatus in order to reduce the sound pressure level in the laboratory to a safe level. The room had a two by four wood framework with double layers of 3/8-inch sheetrock inside and outside. In the door facing the inlet air plenum chamber, a removable plug was inserted so that the sound pressure level probe could be inserted.

CHAPTER III

EXPERIMENTAL PROCEDURE

The experimental procedure consisted of the following three phases:

1. Calibration Tests Without Sound

Heat transfer runs without sound were conducted at various values of Reynolds number to determine the accuracy and reproducibility of the results obtained with the experimental apparatus. The steam pressure in the steam chest and the flow rate of air through the test section were adjusted until the desired settings were attained. In all tests, the apparatus was allowed to run an hour to establish thermal equilibrium before any data were recorded.

An individual test data run was initiated by first draining all burettes. Then a stopwatch was started and initial readings for each burette were recorded. The temperatures at all points in the system were read and recorded, including the tube wall temperatures, the inlet air temperature, and the steam temperature. Barometric pressure and the wet- and dry-bulb temperatures at the blower inlet were recorded. Other data included the pressure and temperature before the orifice and the pressure drop across the orifice. Each of these readings was recorded in the same sequence every half-hour for at least two hours. In this way, air flow rates, condensate collection rates for each chamber, pressures, and temperatures were measured for each half-hour period to provide a check on the steady-state behavior of the system. Unless erratic discrepancies occurred, these readings were averaged for the duration of the test run and the average values were used in the calculation procedure.

2. Preliminary Sound Field Tests

Before the simultaneous heat transfer and acoustic vibration tests were initiated, the sound field in the test section was studied at various frequencies. The sound generating equipment was adjusted to deliver resonant frequencies in the test section and the microphone probe was used to measure the sound pressure levels at small distance intervals along the tube length. The data from these tests were plotted as sound pressure levels in decibels versus distances measured from the entrance end of the test section. These data provided an understanding of the local sound pressure levels in the tube at various resonant frequencies. Figure 3 shows a typical plot of sound pressure level along the axis of the tube.

3. Test Runs with Heat Transfer and Acoustic Vibrations

These runs were conducted to determine the effects of resonant acoustic vibrations on heat transfer coefficients in the constant-temperature horizontal tube. The controlled variables were the sound pressure level, the frequency, and the air flow rates through the tube. Only steady-state effects were of interest. The sound runs differed from the no-sound runs only in the adjustment of the sound generating equipment before a run and in the sound measurement procedure during a run.

The sound generating equipment was adjusted prior to a test run to establish the desired frequency and sound pressure level in the test tube. During this adjustment procedure the microphone probe was positioned at a location in the tube where the first maximum sound pressure level occurred for the particular test frequency. Fine adjustments in frequency and signal level were then made to obtain the desired maximum sound pressure level in the tube. An actual data run was started in the same manner described for the no-sound tests after steady state conditions had been obtained. During the data runs, the microphone probe was removed from the tube and stored in a location in the entrance plenum box to minimize air flow distortion. A sound pressure level at the plenum box location of the microphone served as a reference during the run to monitor for steady state sound conditions in the tube. During the run, this box sound-pressure-level reading and the frequency reading were added to the data recorded each hour. At the end of the entire run (two hours or more), the tube was again probed to obtain a check on the maximum and minimum sound pressure level values in the tube. As in the case of the no-sound runs, average values for all data readings were used in the calculations.

CHAPTER IV

CALCULATION PROCEDURE AND NUMERICAL RESULTS

The test data include runs made with sound and without sound. A program was written to reduce the test data by use of a Burroughs 220 electronic digital computer. In the computer program, no distinction in computations for sound and no-sound runs were made, although the values of the acoustic parameters were included to be printed out with the final calculated results. This means that the basic heat transfer computation procedure was the same for the sound and no-sound runs. An outline of the computer program is included in the appendix of this report.

As mentioned previously, the first condensate collection chamber started at 0.38 inches downstream from the tube entrance. Because the heat transfer coefficient in forced convection approaches an infinite value at the tube entrance, it was decided that a correction should be made for the short section where data were not available. The correction applied was based on the Pohlhausen solution (3). The equation for the heat transfer rate was first written as

$$q_{oa} = 0.664\ k\ (\overline{V}_o L/\nu_o)^{1/2}\ (Pr)^{1/3}\ w(t_s - t_o) \tag{4a}$$

where

$$w = \pi D$$

Upon rearranging,

$$q_{oa} = 0.664\ k\ (\overline{V}_o D/\nu_o)^{1/2}\ (L/D)^{1/2}\ (Pr)^{1/3}\ \pi D(t_s - t_o) \tag{4b}$$

where

$$\bar{V}_o D/\nu_o = Re$$

$$L = 0.38/12 \text{ Ft.}$$

$$D = 0.3214 \text{ Ft.}$$

$$Pr = 0.70$$

and

$$q_{oa} = 0.1869\ k\ (Re)^{1/2}\ (t_s - t_o) \qquad (4c)$$

Thus the heat transfer rate computed from the data for the first chamber is corrected by the amount q_{oa} from Equation 4c.

The volume flow rate was obtained by use of the orifice equation for standard ASME orifice plates. All specifications (4) on construction, layout, measurement, and calculation were rigidly adhered to so that standard orifice coefficients could be employed.

For both the no-sound and sound runs, the condensate flow rates for each chamber, the air density, the air flow rate, the inlet air temperature, and the tube wall temperature were used to calculate the local temperature of the air in the tube corresponding to a total length from the inlet of the tube to the end of each chamber. These local temperatures were employed with the inlet air and tube wall temperatures to calculate an average log-mean temperature difference. Basing fluid properties on the tube wall temperature, local and overall values of Graetz, Nusselt, and Grashof numbers were calculated for each condensate collection chamber. The manner in which the computations were made is shown in the outline of the computer program in the appendix. In this investigation the Graetz and Grashof numbers were not utilized; however, they automatically came out of the digital computer and are shown in the tabulated data.

CHAPTER V

DISCUSSION OF RESULTS

At a Reynolds number of 16,100 and a frequency of 222 cps, the same trend that was noticed in reference 5 is apparent. This is that the local Nusselt numbers oscillate about the no-sound values in a periodic manner. The maximum values are at the velocity loops of the standing sound waves in the tube and the minimum values are at the velocity nodes. This periodic oscillation is shown in Figure 4a. If the average value of the sound run is compared to the average value of the no-sound run for the tube length, it is apparent from Figure 4a and Tables 2 and 4 that there is no overall effect of resonant vibrations at the Reynolds number, frequency, and sound pressure levels tested.

At a Reynolds number of 43,500 and a frequency of 222 cps, a very interesting effect takes place. Figure 4b indicates that the local Nusselt values still oscillate in a periodic manner; however, now it can be noted that the maximum values are at the velocity nodes of the standing wave instead of at the velocity loops. It is also interesting to note that the sound apparently suppresses the heat transfer since the local values of the Nusselt number with sound are considerably lower than those without sound. This effect was not expected and no explanation is available for it at this time. In reference to the average values, it is evident from Figure 4b and the tables that the average value is considerably lower with sound than without resonant vibrations in the tube.

For a Reynolds number of 81,000 and a frequency of 222 cps, the same effects that were noted for a Reynolds number of 43,500 are apparent. Figure 4c indicates that the sound is again suppressing the Nusselt number at a frequency of 222 cps. At 1,500 cps and a sound pressure level of 144.8 decibels no effect could be obtained. Higher sound pressure levels could not be obtained at this frequency and Reynolds number.

At a Reynolds number of approximately 203,000 no measureable effect of sound on the heat transfer coefficient could be determined. Sound pressure levels were limited to a maximum of 161.4 decibels at 222 cps and 147.3 decibels at 1,500 cps at this Reynolds number.

In an attempt to determine critical sound pressure levels, levels below which sound did not influence heat transfer, various experimental data which were available were utilized to plot sound pressure level versus the difference between the local Nusselt number with sound to that for no sound. By plotting values for various condensate collecting chambers and extrapolating to zero effect, it was found that a consistent set of critical sound pressure levels could be obtained. These are shown in Figure 5. Figure 5 is interesting because it indicates some sort of unknown transition taking place at a Reynolds number of approximately 35,000. There appears to be a definite break in the curve at this point. Also the experimental data reported on herein seem to confirm this discontinuity in the curve. At a Reynolds number of 16,100 the maximum values of the local Nusselt number occurred at the velocity loops of the resonant sound wave. At Reynolds numbers of 43,500 and 81,000 the maximum values occurred at the velocity nodes. If the curve in Figure 5 can be extrapolated to a Reynolds number of 200,000, then at a frequency of 222 cps one would not expect an effect below a sound pressure level of approximately 182 decibels. This investigation indicated, at a Reynolds number of approximately 200,000 and a sound pressure level to 161.4 decibels, no effect.

The experimental results reported on herein are extremely interesting because they indicate an area of heat transfer research where much work is yet to be done before an understanding of the mechanisms influencing the heat transfer is to be achieved.

CHAPTER VI

RESUME AND CONCLUSIONS

The experimental data reported on herein are for a limited number of Reynolds numbers, resonant frequencies, and sound pressure levels. Local and average heat transfer coefficients, as represented by the Nusselt numbers, were obtained for Reynolds numbers from 16,100 to 209,000, for frequencies of 222 cps and 1,500 cps, and for sound pressure levels to 164.5 decibels.

For the resonant conditions utilized, it was found that there were apparently two different types of mechanisms influencing the heat transfer. Below a Reynolds number of approximately 35,000 the maximum local Nusselt numbers occurred at the velocity loops of the resonant sound wave. Above a Reynolds number of 35,000 the maximum local Nusselt numbers occurred at the velocity nodes of the resonant sound wave. In addition, at low Reynolds numbers there was practically no change in the average Nusselt number for the whole tube with or without sound. At high Reynolds numbers, however, the sound apparently suppressed the heat transfer and reduced the average Nusselt number below that of the no-sound value.

It is apparent that additional experimental data and theoretical work will be required before a fundamental theory or understanding of the results reported on herein is available.

BIBLIOGRAPHY

1. "The Effects of Resonant Acoustic Vibrations on Heat Transfer to Air in Horizontal Tubes" by Jack M. Spurlock, Thomas W. Jackson, Kenneth R. Purdy, Calvin C. Oliver, and Harold L. Johnson, WADC Technical Note 59-330, June 1959.

2. "The Effects of Resonant Acoustic Vibrations on the Local and Overall Heat Transfer Coefficients for Air Flowing through an Isothermal Horizontal Tube" by T. W. Jackson, K. R. Purdy, C. C. Oliver and H. L. Johnson, ARL Technical Report 60-322, October, 1960.

3. "Principles of Engineering Heat Transfer" by Warren H. Giedt, D. Van Nostrand Co., Inc., 1st Edition, 1957.

4. "Flow Measurement with Orifice Meters" by R. F. Stearns, R. M. Jackson, R. R. Johnson, and C. A. Larson, D. Van Nostrand Co., Inc., New York, 1951.

5. "The Effects of Resonant Acoustic Vibrations on the Nusselt Numbers for a Constant Temperature Horizontal Tube" by T. W. Jackson, K. R. Purdy and C. C. Oliver, Paper No. 57, Part II, 1961. International Heat Transfer Conference, Boulder, Colorado, August, 1961.

6. "Thermodynamic Properties of Steam" by J. H. Keenan and F. G. Keyes, First Edition by John Wiley and Sons, Inc., New York, 1936.

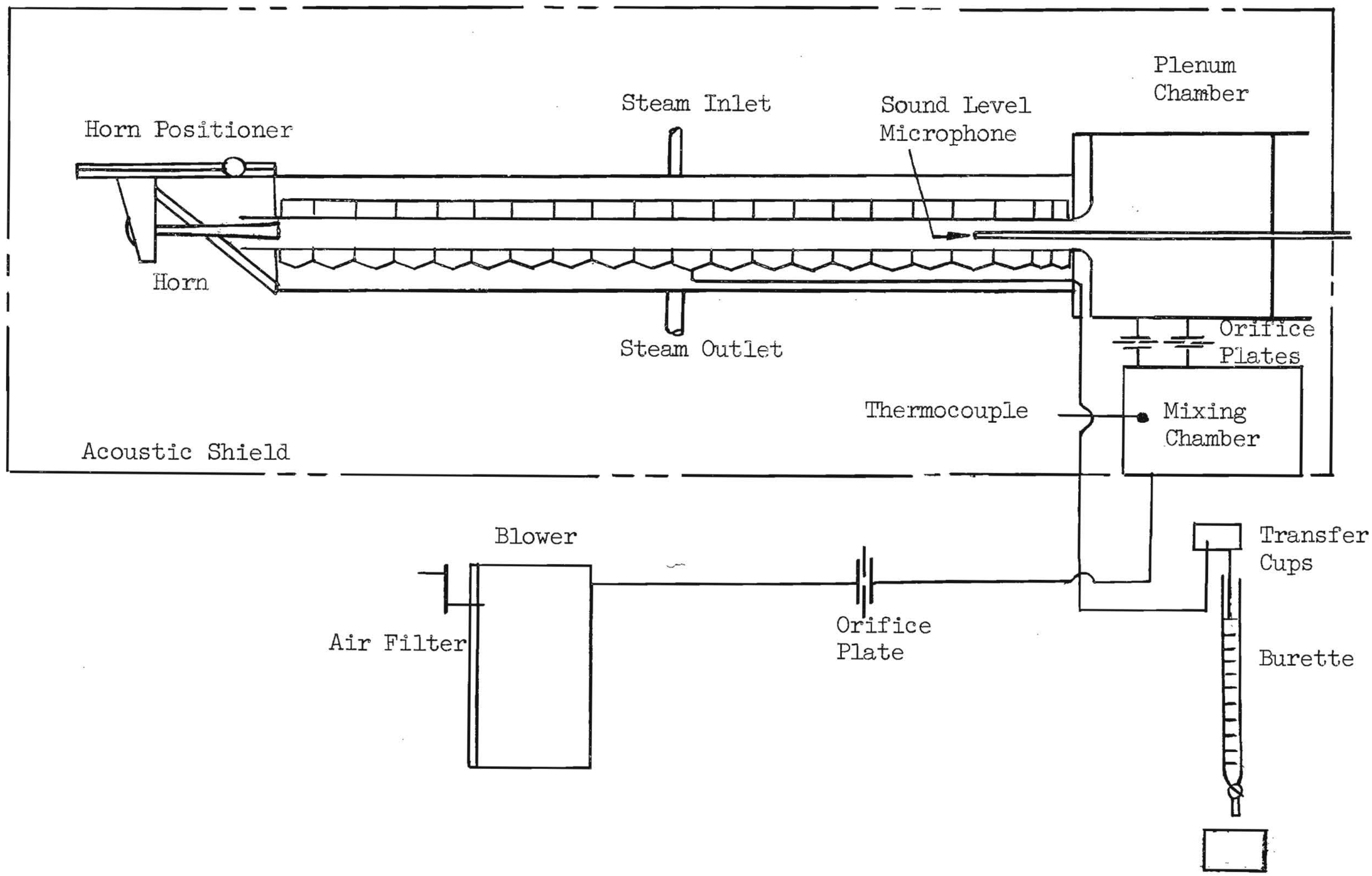

Figure 1. Schematic Diagram of Experimental Apparatus

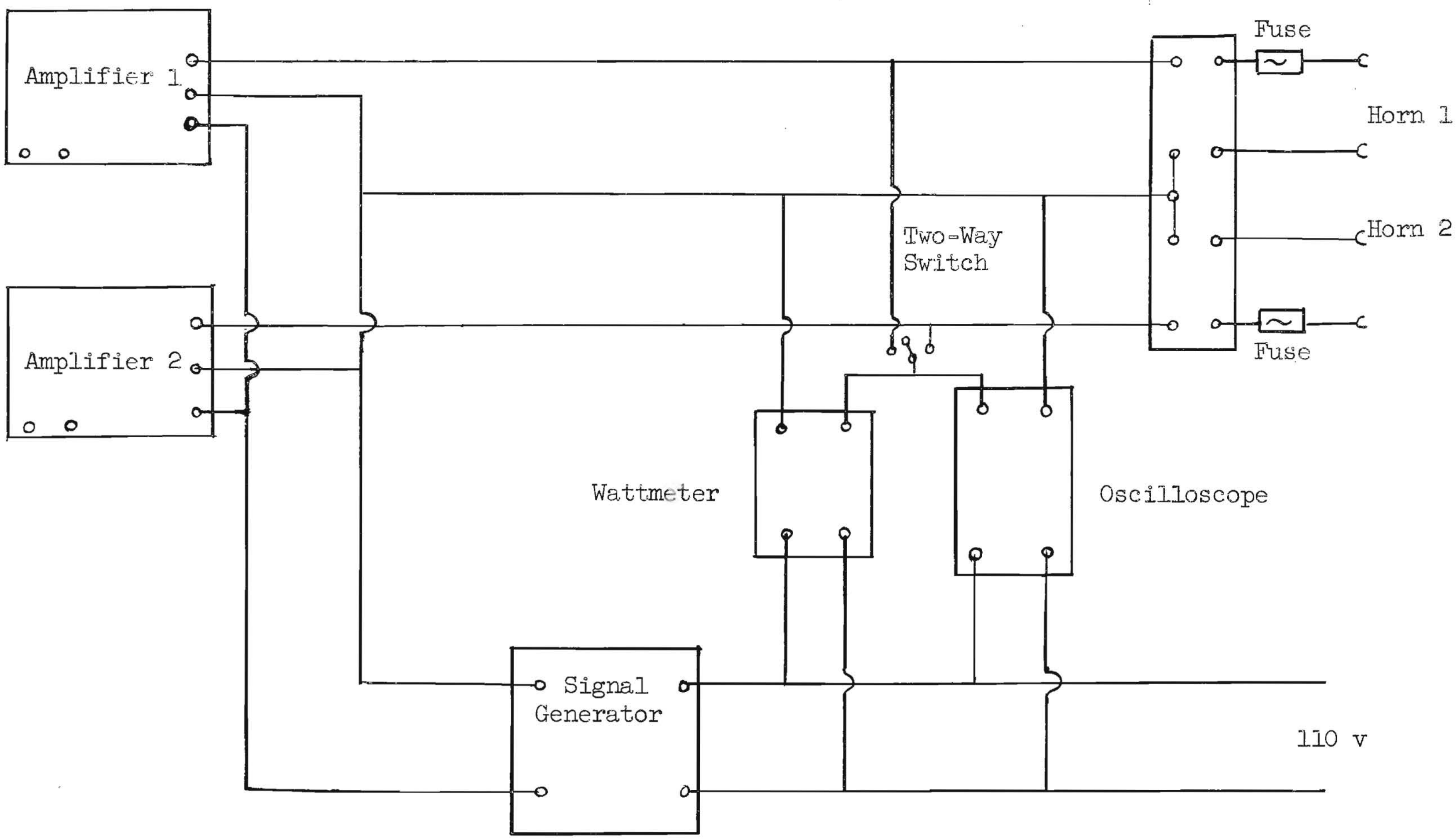

Figure 2. Schematic Diagram of Sound Generating Equipment

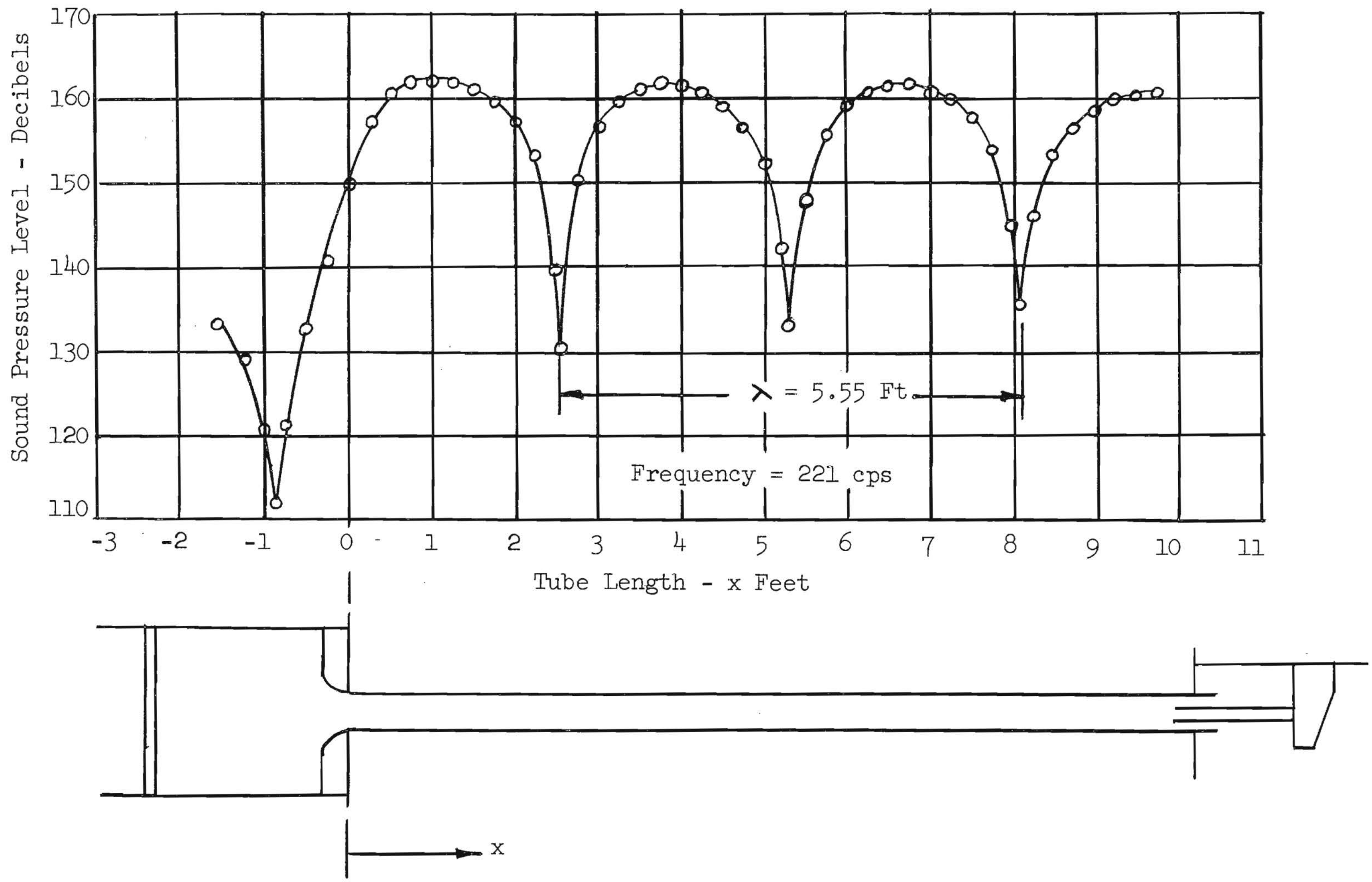

Figure 3. Sound Pressure Level Measured Along Axis of Tube

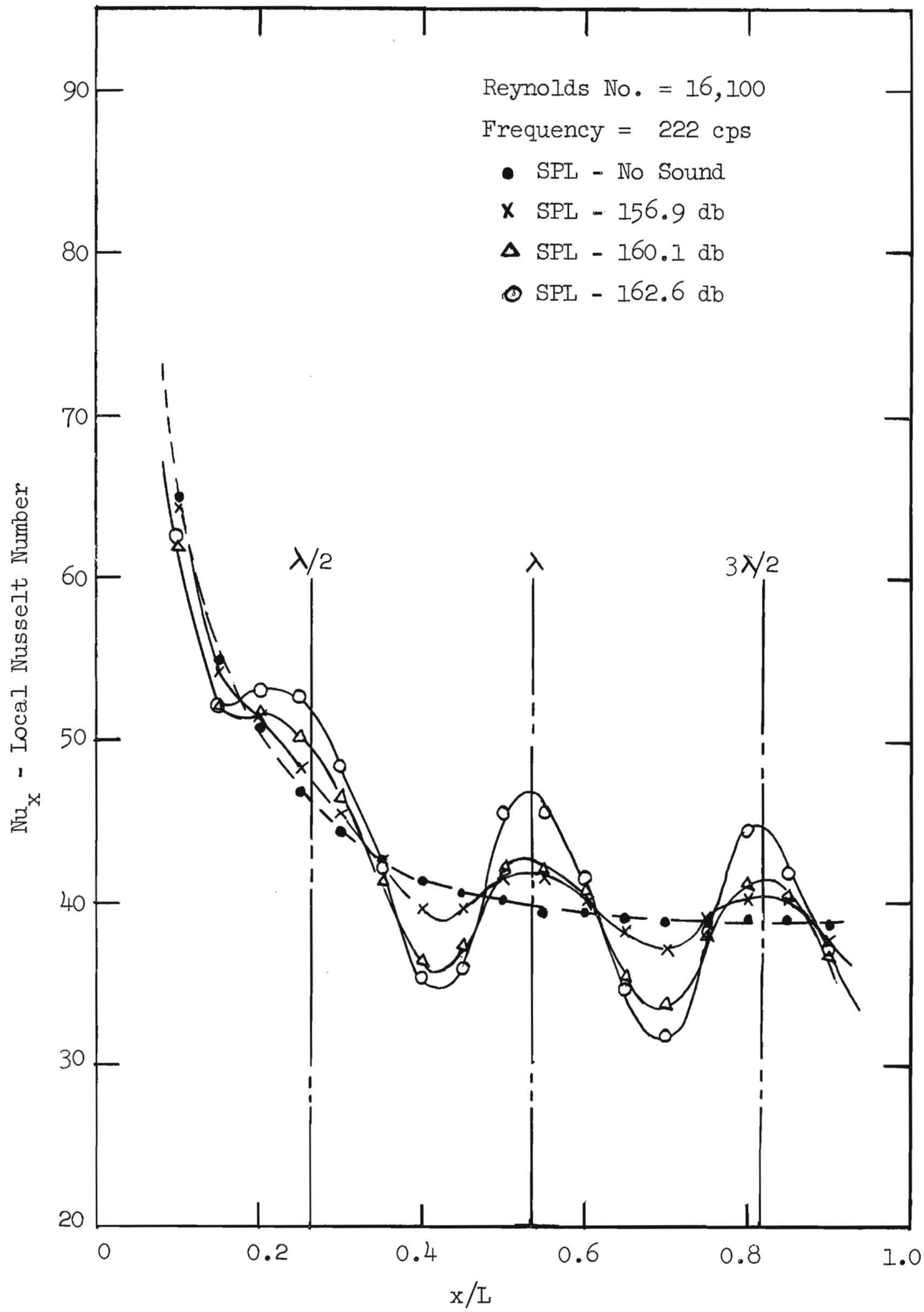

Figure 4a. Local Nusselt Number Versus x/L

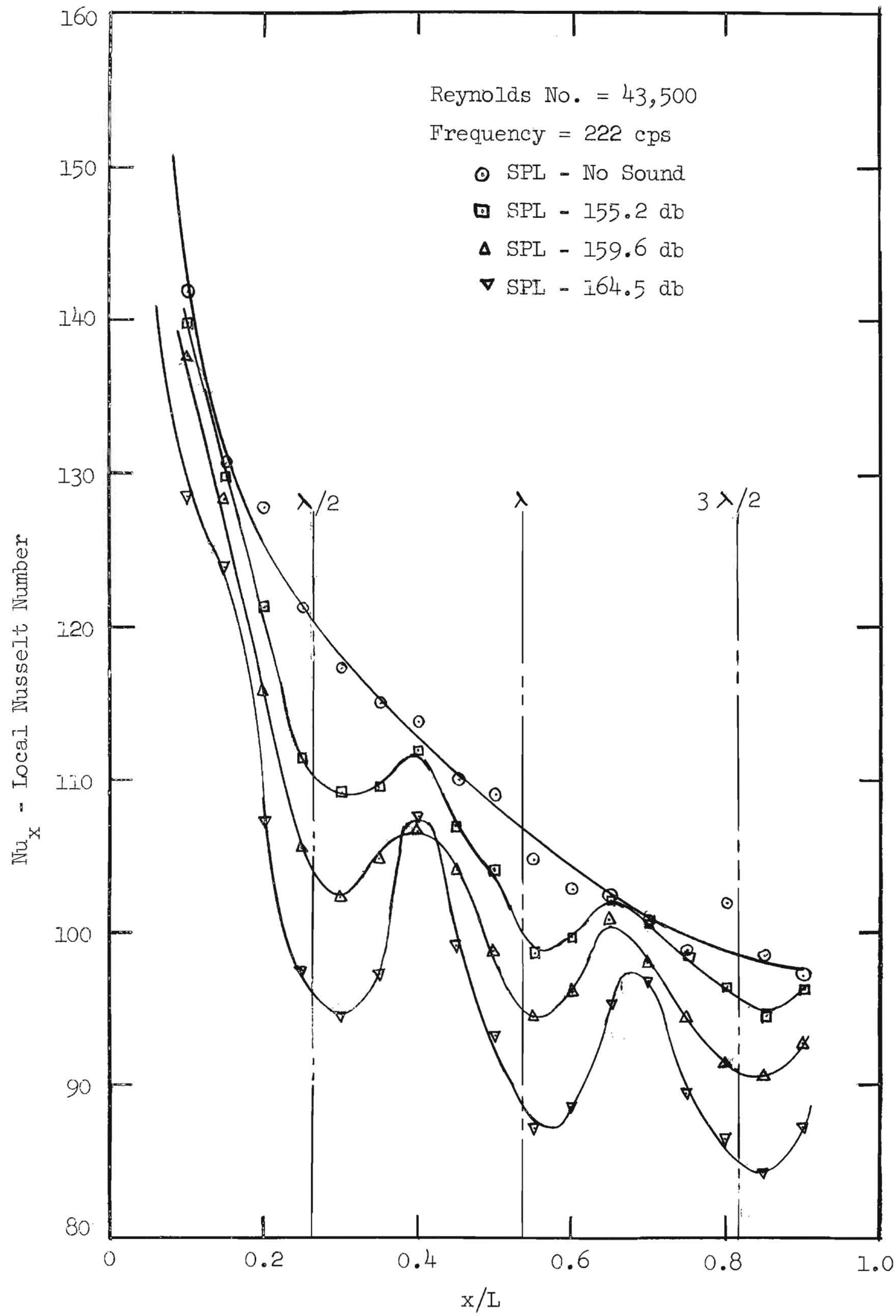

Figure 4b. Local Nusselt Number Versus x/L

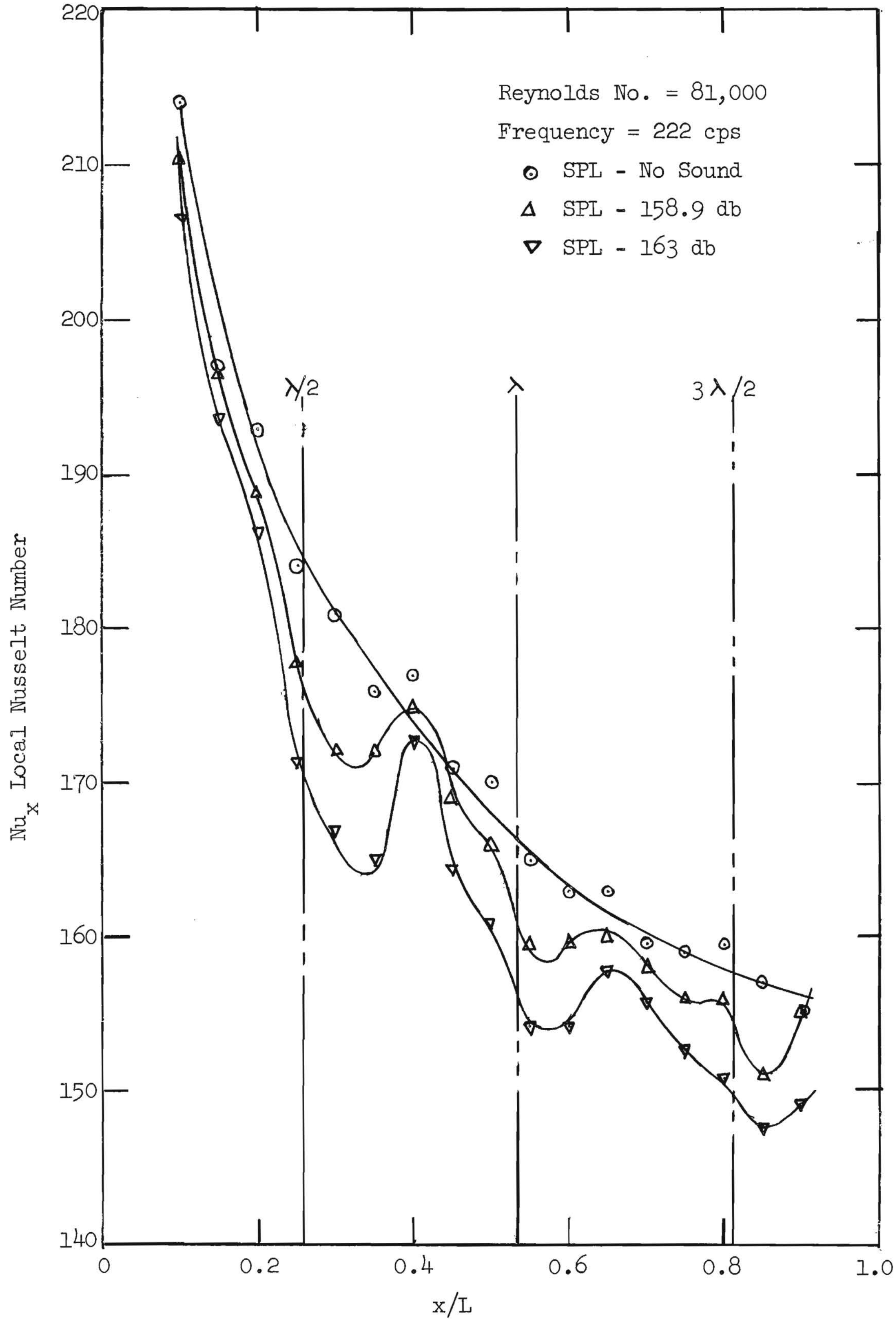

Figure 4c. Local Nusselt Number Versus x/L

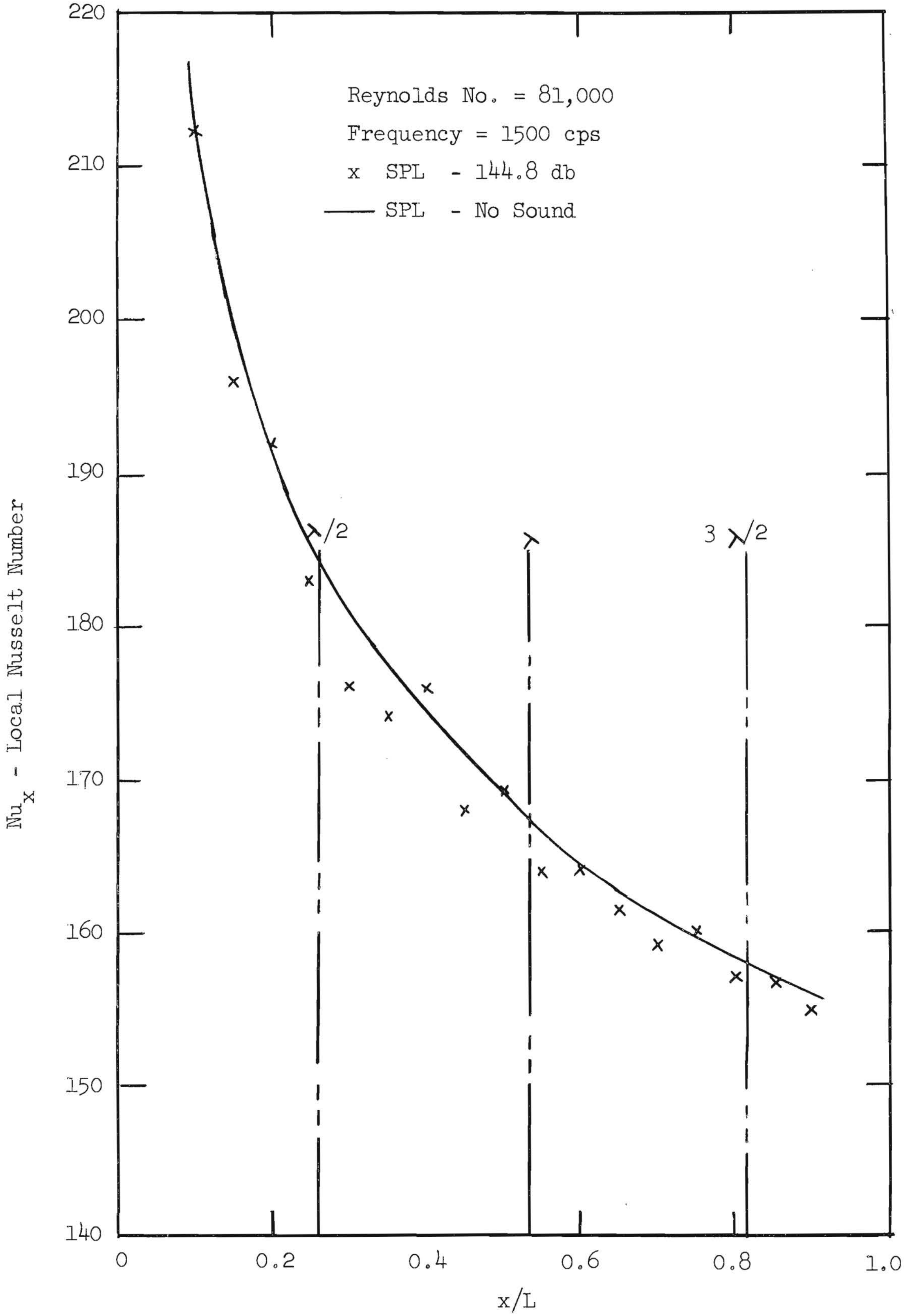

Figure 4d. Local Nusselt Number Versus x/L

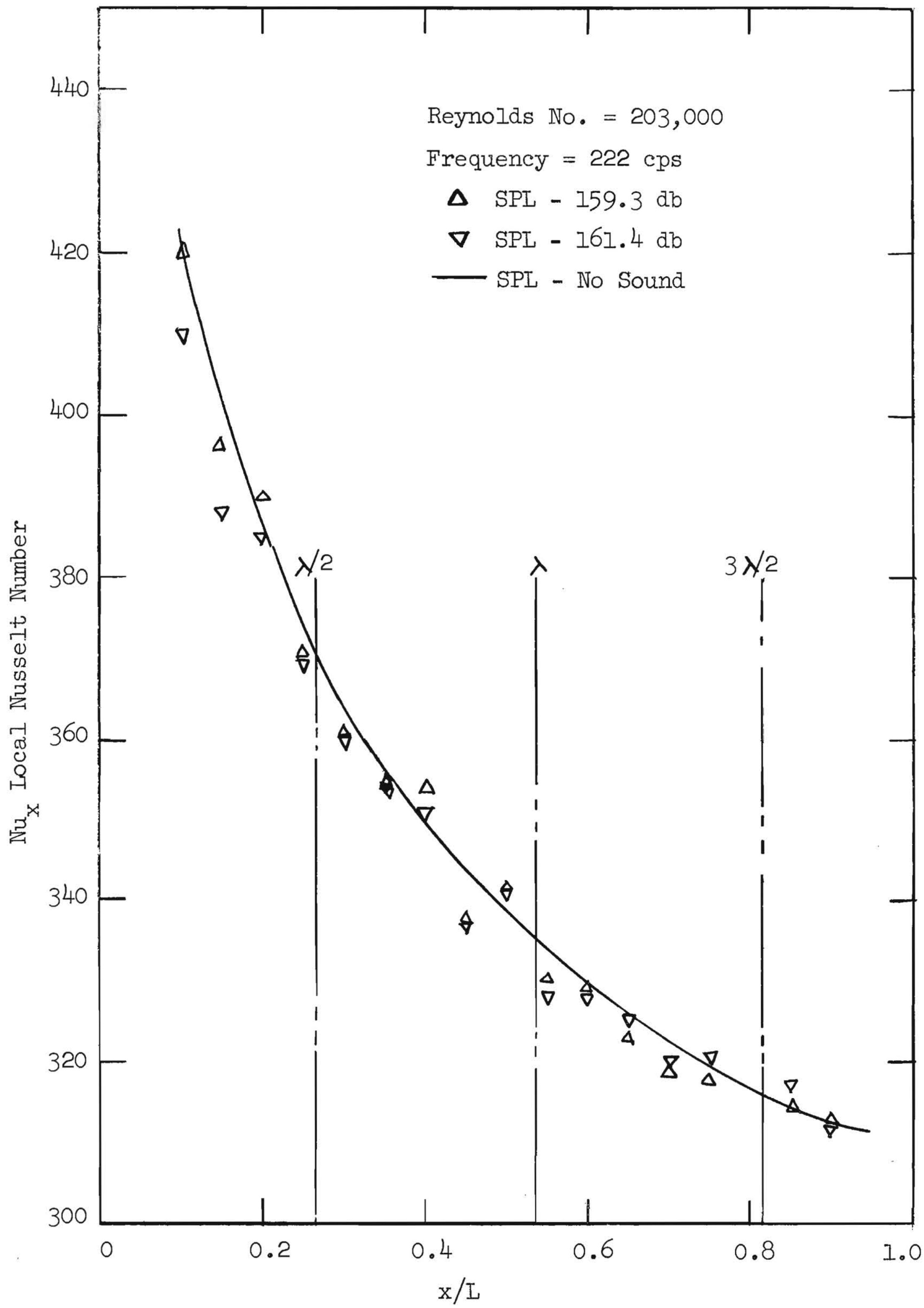

Figure 4e. Local Nusselt Number Versus x/L

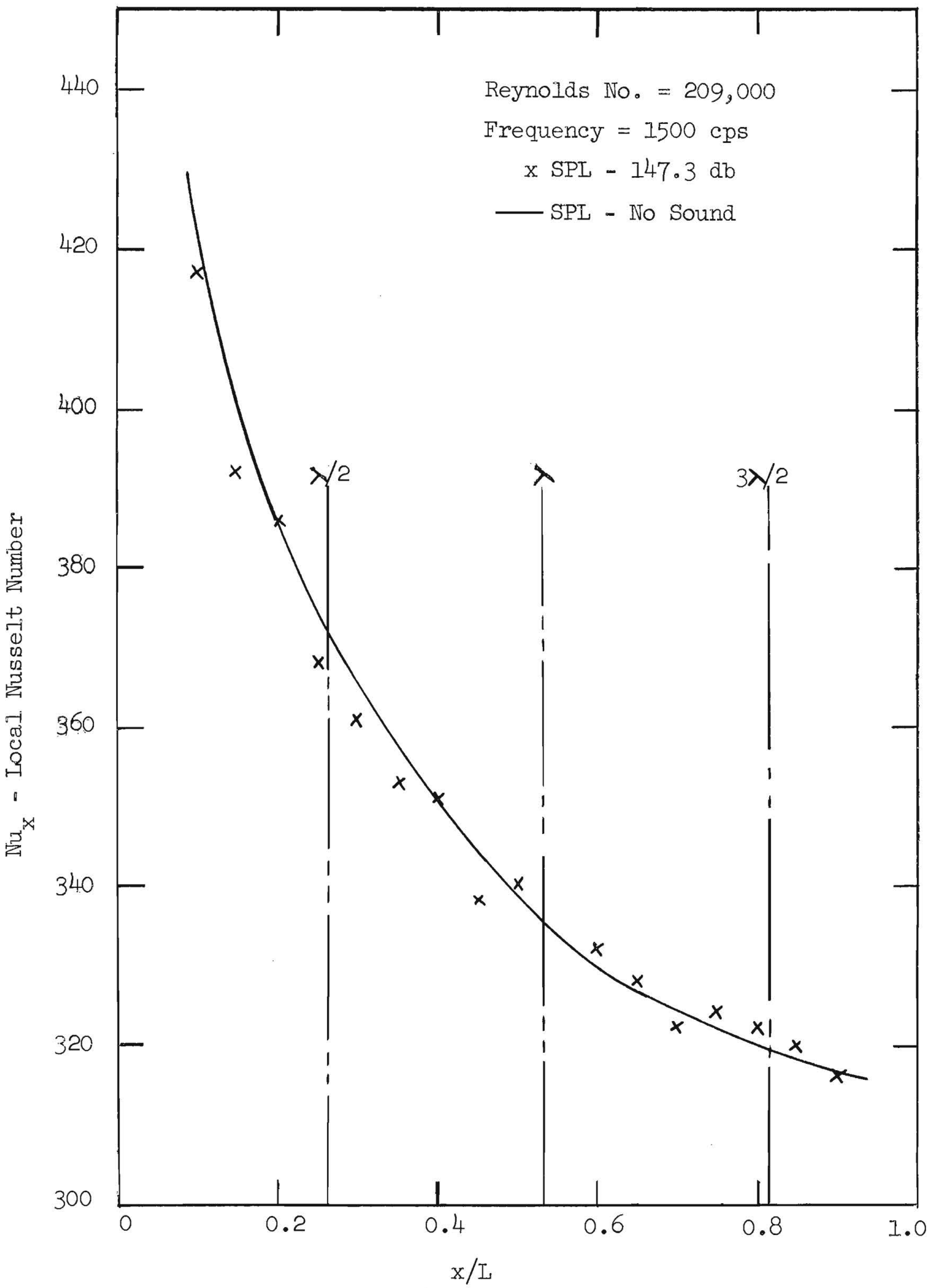

Figure 4f. Local Nusselt Number Versus x/L

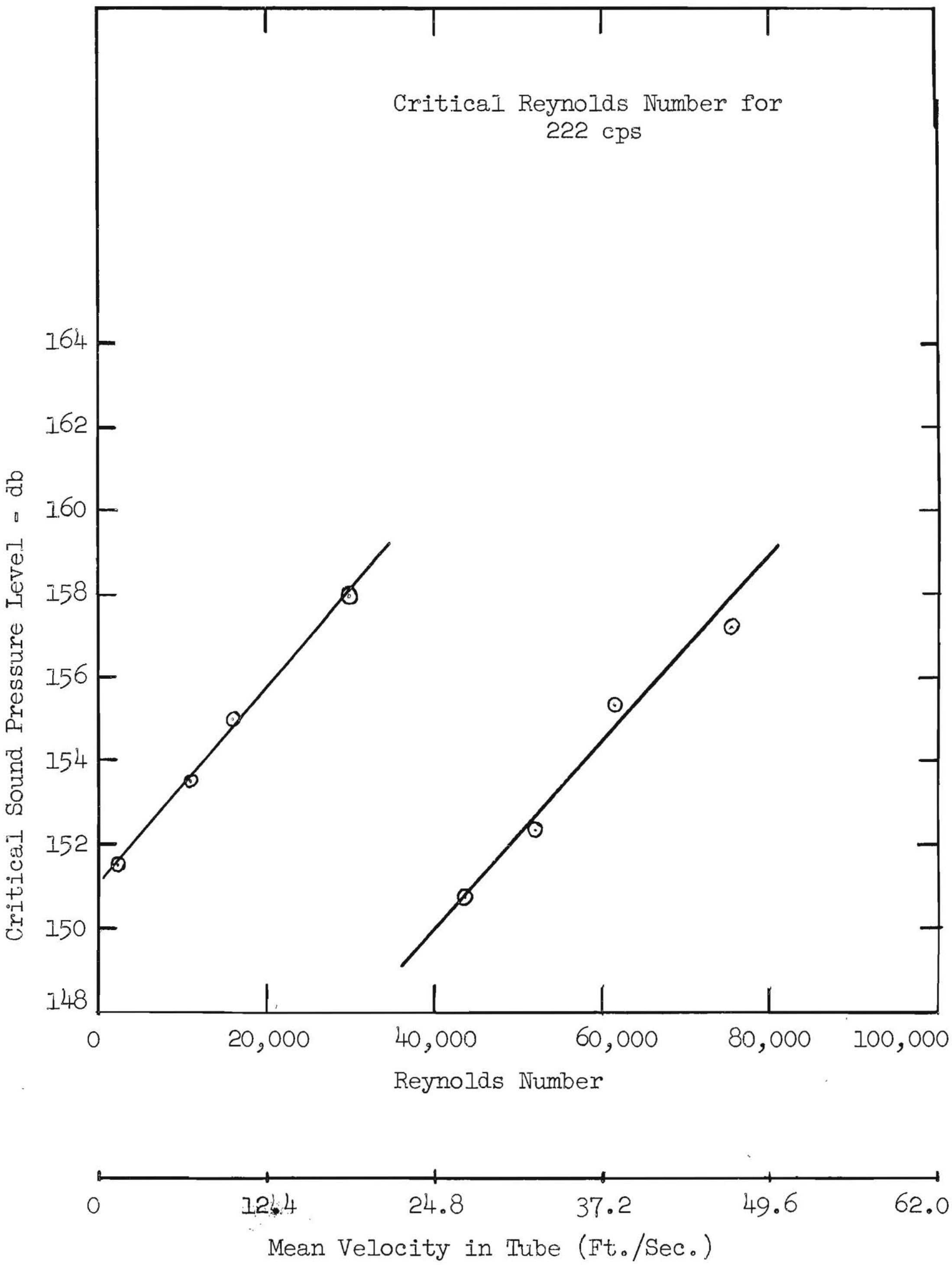

Figure 5. Critical Sound Pressure Versus Reynolds Number

TABLE 1

SUMMARY TABULATION OF LOCAL NO-SOUND DATA

REYNOLDS NUMBER = 15966.5 T SUBZERO = 120.90 F T SATURATED = 211.10 F

CHAMBER	T	H	NU	GZ	GR
1	126.27	10.134	177.98	27123.	2.2215
2	129.98	8.3354	146.39	6229.4	2.1062
3	133.14	3.6950	64.895	3239.6	2.0190
4	135.75	3.1271	54.921	1972.9	1.9458
5	138.05	2.8937	50.822	1418.4	1.8834
6	140.12	2.6699	46.892	1108.7	1.8279
7	142.03	2.5234	44.319	909.61	1.7775
8	143.85	2.4457	42.955	769.97	1.7302
9	145.52	2.3707	41.636	668.81	1.6859
10	147.18	2.3123	40.610	590.34	1.6436
11	148.73	2.2956	40.317	523.53	1.6029
12	150.22	2.2421	39.377	478.31	1.5642
13	151.69	2.2574	39.646	436.89	1.5266
14	153.11	2.2292	39.152	401.98	1.4899
15	154.48	2.2034	38.698	372.23	1.4545
16	155.80	2.1946	38.544	346.67	1.4203
17	157.12	2.2242	39.063	324.45	1.3869
18	158.40	2.2162	38.923	304.81	1.3539
19	159.64	2.1921	38.500	287.37	1.3219
20	161.00	2.4560	43.135	271.82	1.2889
21	162.40	2.6286	46.167	257.90	1.2539

TABLE 2

SUMMARY TABULATION OF AVERAGE NO-SOUND DATA

REYNOLDS NUMBER = 15966.5 T SUBZERO = 120.90 F T SATURATED = 211.10 F

CHAMBER	T	H	NU	GZ	GR
1	126.27	10.137	178.04	9106.6	2.2208
2	129.98	9.1992	161.56	4781.4	2.1724
3	133.14	6.5109	114.35	2462.6	2.1306
4	135.75	5.3853	94.581	1651.5	2.0956
5	138.05	4.7662	83.709	1246.2	2.0643
6	140.12	4.3475	76.355	1000.6	2.0360
7	142.03	4.0414	70.979	835.26	2.0096
8	143.85	3.8098	66.910	715.91	1.9842
9	145.52	3.6305	63.763	628.36	1.9606
10	147.18	3.4787	61.096	557.32	1.9371
11	148.73	3.3595	59.004	502.33	1.9148
12	150.22	3.2564	57.192	456.94	1.8932
13	151.69	3.1713	55.697	418.90	1.8717
14	153.11	3.0970	54.392	386.70	1.8508
15	154.48	3.0315	53.241	359.08	1.8304
16	155.80	2.9746	52.242	335.33	1.8106
17	157.12	2.9264	51.396	314.46	1.7908
18	158.40	2.8831	50.636	295.93	1.7712
19	159.64	2.8433	49.937	279.46	1.7521
20	161.00	2.8216	49.555	264.74	1.7311
21	162.40	2.8105	49.361	251.53	1.7091

TABLE 1

SUMMARY TABULATION OF LOCAL NO-SOUND DATA

REYNOLDS NUMBER = 43781.4   T SUBZERO = 121.00 F   T SATURATED = 210.52 F

CHAMBER	T	H	NU	GZ	GR
1	124.83	19.804	347.81	74330.	2.2161
2	127.74	17.612	309.33	17071.	2.1309
3	130.32	8.0832	141.96	8878.0	2.0615
4	132.66	7.4442	130.74	5406.6	1.9992
5	134.85	7.2775	127.81	3887.0	1.9420
6	136.87	6.9046	121.26	3038.3	1.8887
7	138.78	6.6836	117.38	2492.7	1.8389
8	140.63	6.5510	115.05	2110.0	1.7913
9	142.36	6.4887	113.96	1832.8	1.7461
10	144.07	6.2625	109.98	1617.7	1.7026
11	145.66	6.2109	109.08	1434.6	1.6608
12	147.17	5.9689	104.83	1310.7	1.6216
13	148.62	5.8540	102.81	1197.2	1.5842
14	150.04	5.8513	102.76	1101.6	1.5479
15	151.39	5.7322	100.67	1020.0	1.5128
16	152.69	5.6242	98.777	950.03	1.4793
17	154.00	5.8228	102.26	889.13	1.4463
18	155.24	5.6136	98.591	835.33	1.4140
19	156.44	5.5361	97.230	787.52	1.3831
20	157.69	5.8913	103.46	744.91	1.3521
21	159.15	7.0686	124.14	706.75	1.3179

TABLE 2

SUMMARY TABULATION OF AVERAGE NO-SOUND DATA

REYNOLDS NUMBER = 43781.4   T SUBZERO = 121.00 F   T SATURATED = 210.52 F

CHAMBER	T	H	NU	GZ	GR
1	124.83	19.807	347.87	24956.	2.2158
2	127.74	18.590	326.50	13103.	2.1783
3	130.32	13.453	236.27	6748.7	2.1446
4	132.66	11.447	201.05	4526.0	2.1137
5	134.85	10.405	182.74	3415.2	2.0846
6	136.87	9.7007	170.37	2742.2	2.0574
7	138.78	9.1899	161.40	2288.9	2.0314
8	140.63	8.8030	154.60	1961.9	2.0061
9	142.36	8.5112	149.48	1721.9	1.9821
10	144.07	8.2494	144.88	1527.2	1.9584
11	145.66	8.0417	141.23	1376.6	1.9359
12	147.17	7.8486	137.84	1252.2	1.9146
13	148.62	7.6774	134.83	1147.9	1.8938
14	150.04	7.5322	132.28	1059.7	1.8734
15	151.39	7.3992	129.95	984.04	1.8536
16	152.69	7.2778	127.81	918.95	1.8347
17	154.00	7.1834	126.16	861.76	1.8153
18	155.24	7.0873	124.47	810.98	1.7968
19	156.44	6.9976	122.89	765.84	1.7788
20	157.69	6.9360	121.81	725.50	1.7599
21	159.15	6.9388	121.86	689.31	1.7377

TABLE 1
SUMMARY TABULATION OF LOCAL NO-SOUND DATA

T SUBZERO = 123.10 F

REYNOLDS NUMBER = 81237.9 T SATURATED = 210.44 F

CHAMBER	T	H	NU	GZ	GR
1	126.00	28.425	499.24	*	2.1743
2	128.25	25.642	450.35	31731.	2.1090
3	130.34	12.195	214.18	16502.	2.0541
4	132.24	11.252	197.62	10049.	2.0036
5	134.03	11.003	193.25	7225.1	1.9568
6	135.71	10.501	184.44	5647.6	1.9129
7	137.32	10.286	180.65	4633.3	1.8713
8	138.87	9.9990	175.61	3922.0	1.8313
9	140.35	10.056	176.61	3406.7	1.7929
10	141.82	9.7271	170.83	3007.0	1.7556
11	143.20	9.6872	170.13	2666.7	1.7195
12	144.53	9.4232	165.49	2436.4	1.6851
13	145.83	9.3088	163.49	2225.4	1.6519
14	147.09	9.2877	163.11	2047.6	1.6195
15	148.31	9.0891	159.63	1896.0	1.5881
16	149.49	9.0641	159.19	1765.8	1.5578
17	150.65	9.0802	159.47	1652.6	1.5282
18	151.78	8.9246	156.74	1552.6	1.4992
19	152.87	8.8160	154.83	1463.8	1.4711
20	154.05	9.7417	171.09	1384.6	1.4423
21	155.43	11.608	203.87	1313.6	1.4099

TABLE 2
SUMMARY TABULATION OF AVERAGE NO-SOUND DATA

T SUBZERO = 123.10 F

REYNOLDS NUMBER = 81237.9 T SATURATED = 210.44 F

CHAMBER	T	H	NU	GZ	GR
1	126.00	28.428	499.28	46387.	2.1741
2	128.25	26.850	471.57	24355.	2.1451
3	130.34	19.680	345.64	12544.	2.1180
4	132.24	16.864	296.18	8412.7	2.0931
5	134.03	15.397	270.41	6348.1	2.0695
6	135.71	14.410	253.08	5097.2	2.0472
7	137.32	13.710	240.78	4254.6	2.0256
8	138.87	13.164	231.21	3646.7	2.0048
9	140.35	12.770	224.29	3200.7	1.9846
10	141.82	12.415	218.04	2838.8	1.9645
11	143.20	12.135	213.13	2558.7	1.9454
12	144.53	11.881	208.67	2327.5	1.9259
13	145.83	11.659	204.76	2133.7	1.9089
14	147.09	11.469	201.42	1969.7	1.8910
15	148.31	11.292	198.32	1829.1	1.8738
16	149.49	11.138	195.61	1708.1	1.8570
17	150.65	11.004	193.26	1601.8	1.8403
18	151.78	10.875	191.01	1507.4	1.8240
19	152.87	10.755	188.90	1423.5	1.8080
20	154.05	10.697	187.87	1348.5	1.7907
21	155.43	10.736	188.55	1281.2	1.7704

TABLE 1
SUMMARY TABULATION OF LOCAL NO-SOUND DATA

T SUBZERO = 119.60 F

REYNOLDS NUMBER =204570.7 T SATURATED = 211.10 F

CHAMBER	T	H	NU	GZ	GR
1	121.88	53.403	937.91	*	2.2905
2	123.71	49.247	864.92	79603.	2.2384
3	125.46	24.135	423.88	41398.	2.1930
4	127.09	22.508	395.31	25211.	2.1501
5	128.65	22.292	391.52	18125.	2.1097
6	130.11	21.230	372.87	14168.	2.0715
7	131.53	20.849	366.18	11623.	2.0350
8	132.88	20.164	354.14	9839.1	1.9999
9	134.19	20.289	356.33	8546.4	1.9662
10	135.47	19.378	340.34	7543.7	1.9333
11	136.70	19.531	343.03	6690.0	1.9015
12	137.87	18.858	331.21	6112.1	1.8710
13	139.04	18.854	331.13	5582.8	1.8414
14	140.17	18.654	327.62	5136.8	1.8123
15	141.26	18.254	320.59	4756.6	1.7841
16	142.33	18.253	320.58	4430.0	1.7568
17	143.39	18.386	322.92	4146.0	1.7298
18	144.42	18.075	317.45	3895.1	1.7033
19	145.43	17.863	313.73	3672.2	1.6775
20	146.58	20.897	367.01	3473.5	1.6501
21	147.88	23.940	420.46	3295.6	1.6190

TABLE 2
SUMMARY TABULATION OF AVERAGE NO-SOUND DATA

T SUBZERO = 119.60 F

REYNOLDS NUMBER =204570.7 T SATURATED = 211.10 F

CHAMBER	T	H	NU	GZ	GR
1	121.88	53.406	937.96	*	2.2904
2	123.71	50.941	894.67	61099.	2.2670
3	125.46	37.816	664.15	31469.	2.2443
4	127.09	32.694	574.20	21104.	2.2232
5	128.65	30.082	528.33	15925.	2.2028
6	130.11	28.293	496.91	12787.	2.1836
7	131.53	27.025	474.64	10673.	2.1648
8	132.88	26.014	456.88	9148.4	2.1467
9	134.19	25.286	444.10	8029.6	2.1292
10	135.47	24.595	431.96	7121.7	2.1119
11	136.70	24.075	422.82	6419.1	2.0953
12	137.87	23.585	414.22	5839.0	2.0792
13	139.04	23.175	407.01	5352.9	2.0633
14	140.17	22.811	400.64	4941.5	2.0477
15	141.26	22.472	394.67	4588.6	2.0326
16	142.33	22.180	389.54	4285.1	2.0177
17	143.39	21.932	385.18	4018.4	2.0029
18	144.42	21.693	380.99	3781.6	1.9883
19	145.43	21.469	377.06	3571.1	1.9741
20	146.58	21.427	376.32	3383.0	1.9576
21	147.88	21.539	378.30	3214.2	1.9390

TABLE 3

SUMMARY TABULATION OF LOCAL SOUND DATA

T SUBZERO = 118.20 F
REYNOLDS NUMBER = 16103.9 T SATURATED = 211.29 F
MAX. SPL = 156.9 DB FREQUENCY = 222.0 CPS

CHAMBER	T	H	NU	GZ	GR
1	123.67	10.062	176.72	27271.	2.3078
2	127.41	8.1555	143.23	6263.3	2.1902
3	130.63	3.6717	64.485	3257.3	2.1013
4	133.29	3.0885	54.244	1983.6	2.0262
5	135.69	2.9302	51.463	1426.1	1.9616
6	137.89	2.7571	48.423	1114.7	1.9028
7	139.91	2.5948	45.572	914.56	1.8490
8	141.75	2.4231	42.558	774.16	1.7996
9	143.40	2.2626	39.739	672.45	1.7550
10	145.07	2.2638	39.759	593.55	1.7127
11	146.72	2.3686	41.599	526.38	1.6702
12	148.34	2.3724	41.666	480.92	1.6284
13	149.87	2.2794	40.033	439.27	1.5881
14	151.30	2.1764	38.224	404.17	1.5504
15	152.65	2.1140	37.128	374.26	1.5149
16	154.03	2.2230	39.043	348.56	1.4800
17	155.42	2.2887	40.196	326.21	1.4446
18	156.79	2.2927	40.267	306.47	1.4094
19	158.04	2.1504	37.768	288.93	1.3759
20	159.41	2.4171	42.452	273.30	1.3424
21	160.89	2.6857	47.169	259.30	1.3060

TABLE 4

SUMMARY TABULATION OF AVERAGE SOUND DATA

T SUBZERO = 118.20 F
REYNOLDS NUMBER = 16103.9 T SATURATED = 211.29 F
MAX. SPL = 156.9 DB FREQUENCY = 222.0 CPS

1	123.67	10.065	176.77	9156.2	2.3071
2	127.41	9.0778	159.43	4807.4	2.2581
3	130.63	6.4371	113.05	2476.0	2.2151
4	133.29	5.3232	93.492	1660.5	2.1793
5	135.69	4.7283	83.042	1253.0	2.1466
6	137.89	4.3340	76.119	1006.1	2.1163
7	139.91	4.0418	70.987	839.81	2.0882
8	141.75	3.8069	66.861	719.81	2.0623
9	143.40	3.6150	63.490	631.78	2.0390
10	145.07	3.4595	60.759	560.35	2.0151
11	146.72	3.3494	58.825	505.07	1.9913
12	148.34	3.2588	57.234	459.43	1.9677
13	149.87	3.1752	55.767	421.18	1.9452
14	151.30	3.0967	54.387	388.81	1.9241
15	152.65	3.0248	53.125	361.04	1.9039
16	154.03	2.9702	52.166	337.16	1.8831
17	155.42	2.9263	51.394	316.17	1.8620
18	156.79	2.8875	50.713	297.54	1.8411
19	158.04	2.8452	49.970	280.98	1.8217
20	159.41	2.8213	49.550	266.18	1.8003
21	160.89	2.8131	49.406	252.90	1.7770

TABLE 3
SUMMARY TABULATION OF LOCAL SOUND DATA

REYNOLDS NUMBER = 16133.2 T SUBZERO = 117.10 F
T SATURATED = 211.16 F
MAX. SPL = 160.1 DB FREQUENCY = 222.0 CPS

CHAMBER	T	H	NU	GZ	GR
1	122.69	10.153	178.32	27225.	2.3199
2	126.44	8.1005	142.26	6252.6	2.2012
3	129.59	3.5383	62.142	3251.7	2.1135
4	132.18	2.9727	52.209	1980.2	2.0405
5	134.63	2.9494	51.800	1423.7	1.9764
6	136.94	2.8628	50.280	1112.8	1.9159
7	139.03	2.6488	46.522	913.00	1.8600
8	140.85	2.3537	41.339	772.84	1.8104
9	142.38	2.0812	36.552	671.30	1.7678
10	143.98	2.1296	37.403	592.54	1.7280
11	145.68	2.4077	42.287	525.48	1.6860
12	147.34	2.3931	42.030	480.09	1.6432
13	148.93	2.3265	40.860	438.51	1.6019
14	150.28	2.0241	35.550	403.48	1.5647
15	151.53	1.9244	33.798	373.62	1.5316
16	152.90	2.1718	38.143	347.96	1.4982
17	154.35	2.3459	41.201	325.66	1.4623
18	155.75	2.2947	40.301	305.95	1.4261
19	156.99	2.0960	36.812	288.44	1.3926
20	158.31	2.2804	40.051	272.83	1.3600
21	160.09	3.1814	55.874	258.86	1.3206

TABLE 4
SUMMARY TABULATION OF AVERAGE SOUND DATA

REYNOLDS NUMBER = 16133.2 T SUBZERO = 117.10 F
T SATURATED = 211.16 F
MAX. SPL = 160.1 DB FREQUENCY = 222.0 CPS

1	122.69	10.156	178.38	9140.6	2.3192
2	126.44	9.1002	159.82	4799.2	2.2702
3	129.59	6.3846	112.13	2471.8	2.2285
4	132.18	5.2503	92.211	1657.7	2.1938
5	134.63	4.6779	82.158	1250.9	2.1605
6	136.94	4.3142	75.770	1004.4	2.1288
7	139.03	4.0341	70.851	838.37	2.0999
8	140.85	3.7905	66.572	718.58	2.0745
9	142.38	3.5786	62.851	630.70	2.0529
10	143.98	3.4122	59.929	559.39	2.0302
11	145.68	3.3106	58.144	504.20	2.0058
12	147.34	3.2254	56.647	458.64	1.9817
13	148.93	3.1485	55.297	420.46	1.9586
14	150.28	3.0604	53.749	388.14	1.9388
15	151.53	2.9777	52.298	360.42	1.9202
16	152.90	2.9229	51.335	336.58	1.8997
17	154.35	2.8854	50.677	315.63	1.8778
18	155.75	2.8492	50.040	297.03	1.8566
19	156.99	2.8060	49.281	280.50	1.8375
20	158.31	2.7770	48.773	265.72	1.8171
21	160.09	2.7955	49.097	252.47	1.7892

TABLE 3
SUMMARY TABULATION OF LOCAL SOUND DATA

REYNOLDS NUMBER = 16034.0
MAX. SPL = 162.6 DB
T SUBZERO = 120.00 F
T SATURATED = 211.20 F
FREQUENCY = 222.0 CPS

CHAMBER	T	H	NU	GZ	GR
1	125.50	10.311	181.10	27208.	2.3059
2	129.22	8.2905	145.60	6248.7	2.1856
3	132.30	3.5730	62.753	3249.7	2.0970
4	134.80	2.9690	52.144	1979.0	2.0242
5	137.24	3.0321	53.253	1422.8	1.9598
6	139.59	3.0091	52.849	1112.1	1.8974
7	141.68	2.7547	48.381	912.43	1.8395
8	143.48	2.4045	42.230	772.36	1.7889
9	144.90	2.0074	35.255	670.88	1.7469
10	146.39	2.0570	36.128	592.17	1.7090
11	148.17	2.6026	45.710	525.15	1.6664
12	149.90	2.5887	45.465	479.79	1.6206
13	151.45	2.3665	41.563	438.24	1.5779
14	152.71	1.9817	34.805	403.23	1.5412
15	153.84	1.8035	31.675	373.39	1.5099
16	155.18	2.1927	38.511	347.75	1.4778
17	156.68	2.5327	44.483	325.45	1.4408
18	158.07	2.3786	41.776	305.76	1.4030
19	159.27	2.1123	37.098	288.26	1.3693
20	160.55	2.3067	40.513	272.66	1.3369
21	162.75	4.0995	71.999	258.69	1.2916

TABLE 4
SUMMARY TABULATION OF AVERAGE SOUND DATA

REYNOLDS NUMBER = 16034.0
MAX. SPL = 162.6 DB
T SUBZERO = 120.00 F
T SATURATED = 211.20 F
FREQUENCY = 222.0 CPS

1	125.50	10.315	181.16	9134.9	2.3051
2	129.22	9.2716	162.83	4796.2	2.2553
3	132.30	6.4896	113.97	2470.3	2.2134
4	134.80	5.3195	93.426	1656.6	2.1789
5	137.24	4.7502	83.427	1250.1	2.1450
6	139.59	4.4008	77.291	1003.7	2.1119
7	141.68	4.1237	72.424	837.85	2.0822
8	143.48	3.8745	68.047	718.13	2.0564
9	144.90	3.6434	63.989	630.31	2.0358
10	146.39	3.4615	60.795	559.04	2.0141
11	148.17	3.3740	59.258	503.89	1.9879
12	149.90	3.3006	57.968	458.36	1.9621
13	151.45	3.2207	56.566	420.19	1.9389
14	152.71	3.1239	54.864	387.90	1.9197
15	153.84	3.0281	53.183	360.19	1.9024
16	155.18	2.9713	52.186	336.37	1.8819
17	156.68	2.9424	51.677	315.44	1.8585
18	158.07	2.9076	51.067	296.85	1.8368
19	159.27	2.8621	50.267	280.33	1.8178
20	160.55	2.8315	49.730	265.56	1.7974
21	162.75	2.8926	50.803	252.31	1.7620

TABLE 3
SUMMARY TABULATION OF LOCAL SOUND DATA

T SUBZERO = 120.00 F
REYNOLDS NUMBER = 44138.8 T SATURATED = 210.25 F
MAX. SPL = 155.2 DB FREQUENCY = 222.0 CPS

CHAMBER	T	H	NU	GZ	GR
1	123.72	19.205	337.31	74892.	2.2102
2	126.46	16.578	291.16	17200.	2.1293
3	129.02	7.9661	139.90	8945.1	2.0630
4	131.35	7.3927	129.83	5447.4	2.0019
5	133.45	6.9062	121.29	3916.4	1.9466
6	135.32	6.3468	111.46	3061.3	1.8970
7	137.12	6.2163	109.17	2511.5	1.8510
8	138.90	6.2343	109.49	2125.9	1.8063
9	140.63	6.3739	111.94	1846.6	1.7625
10	142.31	6.0927	107.00	1630.0	1.7199
11	143.85	5.9239	104.04	1445.5	1.6795
12	145.29	5.6178	98.665	1320.6	1.6422
13	146.73	5.6815	99.784	1206.3	1.6062
14	148.16	5.8250	102.30	1109.9	1.5703
15	149.55	5.7312	100.65	1027.7	1.5351
16	150.86	5.6007	98.364	957.21	1.5014
17	152.12	5.4117	96.450	895.84	1.4692
18	153.34	5.3824	94.531	841.64	1.4382
19	154.56	5.4919	96.443	793.47	1.4077
20	155.82	5.8290	102.37	750.54	1.3767
21	157.28	6.9637	122.30	712.09	1.3426

TABLE 4
SUMMARY TABULATION OF AVERAGE SOUND DATA

T SUBZERO = 120.00 F
REYNOLDS NUMBER = 44138.8 T SATURATED = 210.25 F
MAX. SPL = 155.2 DB FREQUENCY = .0 CPS

1	123.72	19.208	337.36	25144.	2.2099
2	126.46	17.795	312.53	13202.	2.1749
3	129.02	12.987	228.09	6799.7	2.1419
4	131.35	11.118	195.27	4560.2	2.1116
5	133.45	10.066	176.79	3441.0	2.0841
6	135.32	9.3201	163.68	2763.0	2.0592
7	137.12	8.7958	154.47	2306.2	2.0351
8	138.90	8.4204	147.88	1976.7	2.0112
9	140.63	8.1615	143.34	1734.9	1.9877
10	142.31	7.9203	139.10	1538.8	1.9646
11	143.85	7.7170	135.53	1387.0	1.9433
12	145.29	7.5219	132.10	1261.6	1.9232
13	146.73	7.3637	129.32	1156.6	1.9030
14	148.16	7.2406	127.16	1067.7	1.8827
15	149.55	7.1283	125.19	991.48	1.8629
16	150.86	7.0233	123.35	925.90	1.8440
17	152.12	6.9243	121.61	868.27	1.8257
18	153.34	6.8300	119.95	817.10	1.8079
19	154.56	6.7522	118.58	771.63	1.7900
20	155.82	6.7003	117.67	730.98	1.7713
21	157.28	6.7097	117.84	694.52	1.7493

TABLE 3

SUMMARY TABULATION OF LOCAL SOUND DATA

	T SUBZERO =	121.70 F
REYNOLDS NUMBER = 43962.4	T SATURATED =	210.25 F
MAX. SPL = 157.6 DB	FREQUENCY =	222.0 CPS

CHAMBER	T	H	NU	GZ	GR
1	125.24	18.601	326.69	74751.	2.1741
2	127.85	16.019	281.35	17167.	2.0970
3	130.29	7.7030	135.28	8928.2	2.0337
4	132.53	7.1938	126.34	5437.1	1.9751
5	134.52	6.6359	116.54	3909.0	1.9222
6	136.28	6.0289	105.88	3055.5	1.8752
7	137.96	5.8874	103.39	2506.8	1.8321
8	139.66	6.0183	105.69	2121.9	1.7896
9	141.35	6.2792	110.28	1843.1	1.7472
10	142.96	5.8650	103.00	1626.9	1.7060
11	144.41	5.6331	98.933	1442.8	1.6676
12	145.78	5.3662	94.246	1318.1	1.6322
13	147.15	5.4404	95.549	1204.0	1.5979
14	148.52	5.5733	97.884	1107.8	1.5637
15	149.84	5.5026	96.642	1025.8	1.5299
16	151.08	5.3003	93.088	955.40	1.4978
17	152.27	5.2011	91.347	894.15	1.4674
18	153.44	5.1562	90.558	840.05	1.4378
19	154.61	5.2556	92.303	791.97	1.4086
20	155.83	5.6615	99.433	749.12	1.3786
21	157.27	6.8120	119.63	710.74	1.3452

TABLE 4

SUMMARY TABULATION OF AVERAGE SOUND DATA

	T SUBZERO =	121.70 F
REYNOLDS NUMBER = 43962.4	T SATURATED =	210.25 F
MAX. SPL = 157.6 DB	FREQUENCY =	.0 CPS

1	125.24	18.604	326.74	25097.	2.1738
2	127.85	17.217	302.39	13177.	2.1405
3	130.29	12.563	220.65	6786.9	2.1090
4	132.53	10.769	189.14	4551.5	2.0798
5	134.52	9.7376	171.02	3434.5	2.0537
6	136.28	8.9940	157.96	2757.7	2.0304
7	137.96	8.4698	148.75	2301.9	2.0079
8	139.66	8.1105	142.44	1973.0	1.9850
9	141.35	7.8780	138.36	1731.7	1.9620
10	142.96	7.6434	134.23	1535.9	1.9400
11	144.41	7.4390	130.65	1384.3	1.9199
12	145.78	7.2466	127.27	1259.2	1.9009
13	147.15	7.0914	124.54	1154.4	1.8817
14	148.52	6.9701	122.41	1065.7	1.8624
15	149.84	6.8610	120.49	989.60	1.8435
16	151.08	6.7540	118.62	924.15	1.8258
17	152.27	6.6539	116.86	866.63	1.8085
18	153.44	6.5623	115.25	815.56	1.7915
19	154.61	6.4865	113.92	770.17	1.7745
20	155.83	6.4398	113.10	729.60	1.7563
21	157.27	6.4547	113.36	693.21	1.7349

TABLE 3
SUMMARY TABULATION OF LOCAL SOUND DATA

T SUBZERO = 125.50 F
REYNOLDS NUMBER = 43617.8 T SATURATED = 210.34 F
MAX. SPL = 159.6 DB FREQUENCY = 222.0 CPS

CHAMBER	T	H	NU	GZ	GR
1	128.90	18.572	326.18	74548.	2.0873
2	131.37	15.306	277.61	17121.	2.0135
3	133.76	7.8451	137.78	8904.0	1.9525
4	135.94	7.3090	128.36	5422.4	1.8951
5	137.84	6.5903	115.74	3898.4	1.8439
6	139.52	6.0076	105.51	3047.2	1.7990
7	141.12	5.8232	102.27	2500.0	1.7578
8	142.74	5.9664	104.78	2116.2	1.7174
9	144.31	6.0895	106.94	1838.1	1.6773
10	145.87	5.9213	103.99	1622.5	1.6380
11	147.27	5.6144	98.606	1438.8	1.6010
12	148.58	5.3735	94.374	1314.6	1.5669
13	149.90	5.4690	96.051	1200.7	1.5338
14	151.25	5.7344	100.71	1104.8	1.5003
15	152.54	5.5813	98.024	1023.0	1.4671
16	153.75	5.3743	94.388	952.81	1.4359
17	154.89	5.2075	91.459	891.73	1.4063
18	156.01	5.1577	90.584	837.77	1.3779
19	157.14	5.2891	92.893	789.83	1.3497
20	158.33	5.7431	100.86	747.09	1.3206
21	159.74	7.0041	123.01	708.82	1.2879

TABLE 4
SUMMAPY TABULATION OF AVERAGE SOUND DATA

T SUBZERO = 125.50 F
REYNOLDS NUMBER = 43617.8 T SATURATED = 210.34 F
MAX. SPL = 159.6 DB FREQUENCY = .0 CPS

1	128.90	18.574	326.22	25029.	2.0870
2	131.37	17.103	300.38	13141.	2.0554
3	133.76	12.572	220.81	6768.5	2.0245
4	135.94	10.813	189.91	4539.2	1.9960
5	137.84	9.7595	171.40	3425.2	1.9710
6	139.52	9.0075	158.19	2750.3	1.9487
7	141.12	8.4706	148.76	2295.6	1.9272
8	142.74	8.1038	142.32	1967.6	1.9053
9	144.31	7.8492	137.85	1727.0	1.8839
10	145.87	7.6241	133.90	1531.7	1.8626
11	147.27	7.4199	130.31	1380.6	1.8433
12	148.58	7.2298	126.97	1255.8	1.8249
13	149.90	7.0784	124.31	1151.3	1.8064
14	151.25	6.9703	122.41	1062.8	1.7872
15	152.54	6.8667	120.60	986.92	1.7688
16	153.75	6.7642	118.79	921.65	1.7515
17	154.89	6.6639	117.03	864.28	1.7349
18	156.01	6.5718	115.42	813.35	1.7186
19	157.14	6.4973	114.11	768.08	1.7020
20	158.33	6.4543	113.35	727.62	1.6843
21	159.74	6.4779	113.77	691.33	1.6632

TABLE 3

SUMMARY TABULATION OF LOCAL SOUND DATA

T SUBZERO = 124.20 F
REYNOLDS NUMBER = 43424.4   T SATURATED = 210.44 F
MAX. SPL = 161.7 DB   FREQUENCY = 222.0 CPS

CHAMBER	T	H	NU	GZ	GR
1	127.62	18.265	320.78	74034.	2.1457
2	130.07	15.264	268.09	17003.	2.0711
3	132.43	7.5790	133.10	8842.6	2.0101
4	134.65	7.2130	126.68	5385.0	1.9520
5	136.52	6.3446	111.42	3871.5	1.9002
6	138.18	5.7772	101.46	3026.2	1.8554
7	139.76	5.5901	98.179	2482.7	1.8142
8	141.37	5.7613	101.18	2101.6	1.7737
9	143.01	6.1846	108.62	1825.5	1.7325
10	144.57	5.7838	101.58	1611.3	1.6918
11	145.97	5.4470	95.666	1428.9	1.6542
12	147.28	5.2012	91.348	1305.5	1.6199
13	148.59	5.2769	92.678	1192.4	1.5866
14	149.95	5.5379	98.139	1097.2	1.5527
15	151.29	5.6452	99.146	1016.0	1.5184
16	152.50	5.2204	91.686	946.25	1.4861
17	153.65	5.0774	89.174	885.58	1.4562
18	154.78	5.0344	88.419	832.00	1.4272
19	155.90	5.1452	90.365	784.38	1.3986
20	157.14	5.7696	101.33	741.94	1.3685
21	158.56	6.7831	119.13	703.93	1.3349

TABLE 4

SUMMARY TABULATION OF AVERAGE SOUND DATA

T SUBZERO = 124.20 F
REYNOLDS NUMBER = 43424.4   T SATURATED = 210.44 F
MAX. SPL = 161.7 DB   FREQUENCY = .0 CPS

1	127.62	18.267	320.83	24856.	2.1454
2	130.07	16.690	293.12	13050.	2.1138
3	132.43	12.232	214.83	6721.8	2.0829
4	134.65	10.553	185.35	4507.9	2.0537
5	136.52	9.5039	166.91	3401.6	2.0288
6	138.18	8.7573	153.80	2731.3	2.0065
7	139.76	8.2237	144.43	2279.8	1.9851
8	141.37	7.8632	138.10	1954.0	1.9632
9	143.01	7.6495	134.34	1715.1	1.9406
10	144.57	7.4316	130.52	1521.2	1.9190
11	145.97	7.2300	126.98	1371.1	1.8995
12	147.28	7.0417	123.67	1247.2	1.8810
13	148.59	6.8901	121.01	1143.3	1.8625
14	149.95	6.7854	119.17	1055.5	1.8431
15	151.29	6.6996	117.66	980.12	1.8237
16	152.50	6.5980	115.88	915.29	1.8062
17	153.65	6.5000	114.15	858.33	1.7894
18	154.78	6.4104	112.58	807.74	1.7728
19	155.90	6.3369	111.29	762.79	1.7561
20	157.14	6.3038	110.71	722.61	1.7376
21	158.56	6.3240	111.06	686.56	1.7163

TABLE 3

SUMMARY TABULATION OF LOCAL SOUND DATA

T SUBZERO = 124.20 F
REYNOLDS NUMBER = 43467.4 T SATURATED = 210.71 F
MAX. SPL = 163.4 DB FREQUENCY = 222.0 CPS

CHAMBER	T	H	NU	GZ	GR
1	127.58	17.991	315.98	74108.	2.1605
2	129.97	14.839	260.62	17020.	2.0870
3	132.29	7.4209	130.33	8851.4	2.0270
4	134.48	7.1116	124.90	5390.4	1.9695
5	136.32	6.2255	109.33	3875.3	1.9181
6	137.95	5.6095	98.518	3029.2	1.8740
7	139.49	5.4116	95.043	2485.2	1.8337
8	141.05	5.5570	97.597	2103.7	1.7942
9	142.69	6.1437	107.90	1827.3	1.7534
10	144.24	5.6631	99.460	1612.9	1.7128
11	145.58	5.2164	91.615	1430.3	1.6760
12	146.85	4.9859	87.567	1306.8	1.6427
13	148.13	5.0744	89.120	1193.6	1.6103
14	149.46	5.4230	95.243	1098.3	1.5771
15	150.77	5.4594	95.883	1017.0	1.5433
16	151.97	5.1283	90.067	947.18	1.5113
17	153.10	4.9028	86.108	886.46	1.4817
18	154.20	4.8328	84.879	832.82	1.4534
19	155.32	5.0354	88.437	785.16	1.4251
20	156.51	5.4575	95.850	742.68	1.3957
21	157.94	6.7888	119.23	704.63	1.3622

TABLE 4

SUMMARY TABULATION OF AVERAGE SOUND DATA

T SUBZERO = 124.20 F
REYNOLDS NUMBER = 43467.4 T SATURATED = 210.71 F
MAX. SPL = 163.4 DB FREQUENCY = .0 CPS

1	127.58	17.993	316.02	24881.	2.1602
2	129.97	16.348	287.12	13063.	2.1293
3	132.29	11.980	210.41	6728.5	2.0988
4	134.48	10.351	181.80	4512.4	2.0699
5	136.32	9.3227	163.73	3405.0	2.0453
6	137.95	8.5791	150.67	2734.0	2.0234
7	139.49	8.0457	141.30	2282.1	2.0025
8	141.05	7.6817	134.91	1956.0	1.9812
9	142.69	7.4853	131.46	1716.8	1.9586
10	144.24	7.2725	127.72	1522.7	1.9372
11	145.58	7.0641	124.06	1372.4	1.9184
12	146.85	6.8715	120.68	1248.4	1.9005
13	148.13	6.7174	117.97	1144.5	1.8824
14	149.46	6.6134	116.15	1056.5	1.8634
15	150.77	6.5267	114.62	981.09	1.8445
16	151.97	6.4306	112.94	916.20	1.8271
17	153.10	6.3323	111.21	859.18	1.8106
18	154.20	6.2408	109.60	808.55	1.7945
19	155.32	6.1707	108.37	763.55	1.7779
20	156.51	6.1301	107.66	723.32	1.7601
21	157.94	6.1593	108.17	687.24	1.7385

TABLE 3

SUMMARY TABULATION OF LOCAL SOUND DATA

T SUBZERO = 124.10 F
REYNOLDS NUMBER = 43442.6   T SATURATED = 210.59 F
MAX. SPL = 164.5 DB   FREQUENCY = 222.0 CPS

CHAMBER	T	I	NU	GZ	GR
1	127.46	17.903	314.43	74055.	2.1528
2	129.82	14.648	257.27	17008.	2.0801
3	132.12	7.3202	128.56	8845.1	2.0210
4	134.29	7.0515	123.84	5386.6	1.9643
5	136.10	6.1045	107.21	3872.6	1.9137
6	137.71	5.5430	97.351	3027.1	1.8703
7	139.25	5.3792	94.474	2483.4	1.8304
8	140.80	5.5295	97.114	2102.2	1.7912
9	142.45	6.1393	107.82	1826.0	1.7505
10	143.99	5.6343	98.955	1611.7	1.7101
11	145.36	5.3129	93.310	1429.3	1.6731
12	146.63	4.9585	87.086	1305.9	1.6396
13	147.90	5.0460	88.623	1192.8	1.6074
14	149.24	5.4210	95.209	1097.5	1.5743
15	150.56	5.5074	96.726	1016.3	1.5405
16	151.76	5.0916	89.424	946.52	1.5085
17	152.89	4.9250	86.497	885.83	1.4789
18	153.98	4.7881	84.093	832.23	1.4507
19	155.09	4.9580	87.077	784.61	1.4228
20	156.35	5.7697	101.33	742.15	1.3928
21	157.77	6.7276	118.15	704.13	1.3587

TABLE 4

SUMMARY TABULATION OF AVERAGE SOUND DATA

T SUBZERO = 124.10 F
REYNOLDS NUMBER = 43442.6   T SATURATED = 210.59 F
MAX. SPL = 164.5 DB   FREQUENCY = .0 CPS

1	127.46	17.905	314.47	24863.	2.1525
2	129.82	16.213	284.75	13054.	2.1220
3	132.12	11.862	208.34	6723.7	2.0921
4	134.29	10.253	180.07	4509.2	2.0634
5	136.10	9.2188	161.90	3402.6	2.0393
6	137.71	8.4828	148.98	2732.1	2.0178
7	139.25	7.9600	139.80	2280.4	1.9971
8	140.80	7.6044	133.55	1954.6	1.9759
9	142.45	7.4169	130.26	1715.6	1.9533
10	143.99	7.2086	126.60	1521.6	1.9321
11	145.36	7.0159	123.22	1371.5	1.9129
12	146.63	6.8252	119.87	1247.5	1.8952
13	147.90	6.6726	117.19	1143.7	1.8772
14	149.24	6.5719	115.42	1055.8	1.8582
15	150.56	6.4916	114.01	980.40	1.8392
16	151.76	6.3954	112.32	915.55	1.8219
17	152.89	6.3006	110.65	858.57	1.8054
18	153.98	6.2084	109.03	807.97	1.7895
19	155.09	6.1359	107.76	763.01	1.7732
20	156.35	6.1133	107.36	722.81	1.7545
21	157.77	6.1404	107.84	686.76	1.7331

TABLE 3
SUMMARY TABULATION OF LOCAL SOUND DATA

REYNOLDS NUMBER = 81124.0   T SUBZERO = 122.25 F
T SATURATED = 211.28 F
MAX. SPL = 144.8 DB   FREQUENCY = 1500.0 CPS

CHAMBER	T	H	NU	GZ	GR
1	125.23	28.541	501.26	*	2.2900
2	127.51	25.513	448.08	31643.	2.2211
3	129.63	12.083	212.22	16456.	2.1635
4	131.56	11.196	196.64	10021.	2.1105
5	133.38	10.924	191.86	7205.0	2.0614
6	135.08	10.417	182.96	5631.9	2.0153
7	136.69	10.023	176.03	4620.4	1.9721
8	138.26	9.9227	174.27	3911.1	1.9306
9	139.77	10.008	175.77	3397.3	1.8902
10	141.25	9.5865	168.36	2998.7	1.8511
11	142.66	9.6366	169.24	2659.3	1.8133
12	144.01	9.3222	163.72	2429.6	1.7773
13	145.33	9.3269	163.80	2219.2	1.7423
14	146.61	9.1659	160.97	2041.9	1.7083
15	147.85	9.0517	158.97	1890.8	1.6753
16	149.06	9.0937	159.71	1760.9	1.6433
17	150.24	8.9593	157.35	1648.0	1.6121
18	151.39	8.9129	156.53	1548.3	1.5817
19	152.51	8.8030	154.60	1459.7	1.5520
20	153.71	9.6907	170.19	1380.7	1.5216
21	155.13	11.704	205.55	1310.0	1.4873

TABLE 4
SUMMARY TABULATION OF AVERAGE SOUND DATA

T SUBZERO = 122.25 F
REYNOLDS NUMBER = 81124.0   T SATURATED = 211.28 F
MAX. SPL = 144.8 DB   FREQUENCY = 1500.0 CPS

1	125.23	28.544	501.31	46258.	2.2898
2	127.51	26.851	471.58	24287.	2.2594
3	129.63	19.626	344.70	12509.	2.2310
4	131.56	16.810	295.23	8389.3	2.2048
5	133.38	15.337	269.36	6330.5	2.1800
6	135.08	14.345	251.95	5083.0	2.1567
7	136.69	13.613	239.08	4242.8	2.1345
8	138.26	13.070	229.56	3636.5	2.1126
9	139.77	12.682	222.74	3191.8	2.0913
10	141.25	12.321	216.39	2830.9	2.0704
11	142.66	12.046	211.56	2551.6	2.0504
12	144.01	11.790	207.08	2321.0	2.0311
13	145.33	11.577	203.33	2127.8	2.0119
14	146.61	11.384	199.94	1964.3	1.9933
15	147.85	11.210	196.89	1824.0	1.9752
16	149.06	11.064	194.32	1703.3	1.9573
17	150.24	10.927	191.91	1597.3	1.9399
18	151.39	10.803	189.73	1503.2	1.9227
19	152.51	10.686	187.68	1419.5	1.9058
20	153.71	10.628	186.66	1344.7	1.8876
21	155.13	10.675	187.49	1277.7	1.8659

TABLE 3
SUMMARY TABULATION OF LOCAL SOUND DATA

REYNOLDS NUMBER = 80935.2 T SUBZERO = 123.50 F
T SATURATED = 211.28 F
MAX. SPL = 158.9 DB FREQUENCY = 222.0 CPS

CHAMBER	T	H	NU	GZ	GR
1	126.43	28.461	499.85	*	2.2579
2	128.65	25.064	440.19	31614.	2.1905
3	130.71	11.967	210.18	16441.	2.1345
4	132.63	11.197	196.66	10012.	2.0824
5	134.39	10.720	188.28	7198.4	2.0343
6	136.02	10.085	177.13	5626.8	1.9900
7	137.57	9.8170	172.41	4616.3	1.9484
3	139.11	9.7893	171.92	3907.6	1.9079
9	140.59	9.9477	174.71	3394.2	1.8685
10	142.06	9.6143	168.85	2995.9	1.8298
11	143.43	9.4316	165.64	2656.9	1.7928
12	144.72	9.0860	159.57	2427.4	1.7579
13	146.00	9.0812	159.49	2217.2	1.7242
14	147.26	9.1007	159.83	2040.0	1.6910
15	148.48	9.0084	158.21	1889.1	1.6586
16	149.66	8.8925	156.17	1759.3	1.6273
17	150.81	8.8834	156.01	1646.5	1.5968
18	151.91	8.6031	151.09	1546.9	1.5673
19	153.03	8.8598	155.60	1458.4	1.5382
20	154.23	9.7115	170.56	1379.5	1.5080
21	155.63	11.696	205.41	1308.8	1.4739

TABLE 4
SUMMARY TABULATION OF AVERAGE SOUND DATA

REYNOLDS NUMBER = 80935.2 T SUBZERO = 123.50 F
T SATURATED = 211.28 F
MAX. SPL = 158.9 DB FREQUENCY = 222.0 CPS

1	126.43	28.463	499.90	46216.	2.2577
2	128.65	26.600	467.17	24265.	2.2282
3	130.71	19.442	341.45	12498.	2.2005
4	132.63	16.686	293.06	8381.7	2.1746
5	134.39	15.194	266.85	6324.7	2.1506
6	136.02	14.166	248.80	5078.4	2.1283
7	137.57	13.429	235.86	4238.9	2.1068
8	139.11	12.894	226.46	3633.2	2.0854
9	140.59	12.520	219.90	3188.9	2.0646
10	142.06	12.180	213.92	2828.4	2.0438
11	143.43	11.899	208.98	2549.3	2.0244
12	144.72	11.636	204.36	2318.9	2.0058
13	146.00	11.415	200.49	2125.9	1.9874
14	147.26	11.230	197.23	1962.5	1.9691
15	148.48	11.064	194.32	1822.3	1.9512
16	149.66	10.914	191.68	1701.8	1.9340
17	150.81	10.782	189.36	1595.9	1.9169
13	151.91	10.648	187.01	1501.8	1.9004
19	153.03	10.543	185.17	1418.2	1.8836
20	154.23	10.494	184.30	1343.5	1.8655
21	155.63	10.547	185.24	1276.5	1.8441

TABLE 3
SUMMARY TABULATION OF LOCAL SOUND DATA

T SUBZERO = 121.25 F
REYNOLDS NUMBER = 80389.0 T SATURATED = 211.28 F
MAX. SPL = 159.3 DB FREQUENCY = 222.0 CPS

CHAMBER	T	H	NU	GZ	GR
1	124.29	28.521	500.92	*	2.3153
2	126.57	24.932	437.87	31311.	2.2456
3	128.70	11.907	209.13	16284.	2.1879
4	130.66	11.086	194.71	9916.7	2.1344
5	132.49	10.719	188.27	7129.5	2.0849
6	134.16	10.013	175.87	5572.9	2.0392
7	135.75	9.6924	170.22	4572.1	1.9966
8	137.30	9.5913	168.45	3870.2	1.9555
9	138.82	9.8239	172.53	3361.7	1.9153
10	140.31	9.4544	166.04	2967.3	1.8758
11	141.72	9.4095	165.25	2631.5	1.8379
12	143.05	8.9821	157.75	2404.2	1.8020
13	144.37	9.0363	158.70	2196.0	1.7674
14	145.66	9.0010	158.08	2020.5	1.7334
15	146.90	8.8865	156.07	1871.0	1.7002
16	148.12	8.8983	156.27	1742.5	1.6680
17	149.31	8.8669	155.72	1630.8	1.6365
18	150.45	8.5903	150.87	1532.1	1.6060
19	151.57	8.6171	151.34	1444.4	1.5764
20	152.84	9.9189	174.20	1366.3	1.5451
21	154.38	12.371	217.28	1296.3	1.5085

TABLE 4
SUMMARY TABULATION OF AVERAGE SOUND DATA

T SUBZERO = 121.25 F
REYNOLDS NUMBER = 80389.0 T SATURATED = 211.28 F
MAX. SPL = 159.3 DB FREQUENCY = 222.0 CPS

1	124.29	28.524	500.97	45774.	2.3151
2	126.57	26.570	466.65	24033.	2.2847
3	128.70	19.397	340.68	12378.	2.2562
4	130.66	16.621	291.91	8301.5	2.2297
5	132.49	15.144	265.98	6264.2	2.2048
6	134.16	14.112	247.85	5029.8	2.1819
7	135.75	13.364	234.71	4198.3	2.1599
8	137.30	12.810	224.99	3598.5	2.1383
9	138.82	12.432	218.34	3158.4	2.1169
10	140.31	12.084	212.23	2801.3	2.0958
11	141.72	11.810	207.42	2524.9	2.0758
12	143.05	11.545	202.78	2296.8	2.0567
13	144.37	11.329	198.97	2105.5	2.0377
14	145.66	11.142	195.69	1943.7	2.0190
15	146.90	10.974	192.74	1804.9	2.0008
16	148.12	10.830	190.22	1685.5	1.9829
17	149.31	10.702	187.97	1580.6	1.9652
18	150.45	10.572	185.68	1487.4	1.9482
19	151.57	10.458	183.68	1404.7	1.9313
20	152.84	10.424	183.08	1330.7	1.9122
21	154.38	10.515	184.67	1264.3	1.8887

TABLE 3

SUMMARY TABULATION OF LOCAL SOUND DATA

T SUBZERO = 126.00 F
REYNOLDS NUMBER = 80013.9 T SATURATED = 211.20 F
MAX. SPL = 161.9 DB FREQUENCY = 222.0 CPS

CHAMBER	T	H	NU	GZ	GR
1	128.90	28.849	506.67	*	2.1833
2	131.06	24.950	438.19	31369.	2.1173
3	133.07	11.883	208.69	16313.	2.0630
4	134.95	11.261	197.79	9934.9	2.0123
5	136.68	10.779	189.31	7142.6	1.9652
6	138.24	9.9083	174.01	5583.1	1.9223
7	139.71	9.5127	167.07	4580.4	1.8828
8	141.18	9.5566	167.84	3877.3	1.8445
9	142.63	9.9712	175.12	3367.9	1.8064
10	144.05	9.4797	166.49	2972.7	1.7690
11	145.37	9.3319	163.89	2636.3	1.7333
12	146.61	8.9034	156.37	2408.6	1.6999
13	147.85	8.9435	157.07	2200.0	1.6676
14	149.08	9.1536	160.76	2024.2	1.6354
15	150.30	9.1830	161.27	1874.4	1.6034
16	151.45	8.9499	157.18	1745.7	1.5725
17	152.56	8.7417	153.52	1633.8	1.5430
18	153.64	8.5867	150.80	1534.9	1.5145
19	154.71	8.6808	152.46	1447.1	1.4865
20	155.88	9.7329	170.93	1368.8	1.4573
21	157.27	11.807	207.36	1298.6	1.4240

TABLE 4

SUMMARY TABULATION OF AVERAGE SOUND DATA

T SUBZERO = 126.00 F
REYNOLDS NUMBER = 80013.9 T SATURATED = 211.20 F
MAX. SPL = 161.9 DB FREQUENCY = 222.0 CPS

1	128.90	28.852	506.73	45857.	2.1831
2	131.06	26.751	469.82	24077.	2.1545
3	133.07	19.479	342.10	12401.	2.1277
4	134.95	16.732	293.87	8316.7	2.1024
5	136.68	15.243	267.71	6275.7	2.0788
6	138.24	14.171	248.88	5039.0	2.0575
7	139.71	13.383	235.05	4206.0	2.0372
8	141.18	12.822	225.20	3605.1	2.0169
9	142.63	12.460	218.83	3164.2	1.9965
10	144.05	12.111	212.71	2806.4	1.9766
11	145.37	11.827	207.72	2529.5	1.9578
12	146.61	11.554	202.93	2301.0	1.9401
13	147.85	11.329	198.97	2109.4	1.9223
14	149.08	11.154	195.90	1947.3	1.9044
15	150.30	11.006	193.31	1808.2	1.8867
16	151.45	10.864	190.80	1688.6	1.8698
17	152.56	10.726	188.38	1583.5	1.8534
18	153.64	10.594	186.07	1490.2	1.8374
19	154.71	10.483	184.11	1407.2	1.8214
20	155.88	10.438	183.32	1333.1	1.8037
21	157.27	10.500	184.41	1266.6	1.7826

TABLE 3
SUMMARY TABULATION OF LOCAL SOUND DATA

REYNOLDS NUMBER = 82073.2 T SUBZERO = 121.00 F
T SATURATED = 211.10 F
MAX. SPL = 163.0 DB FREQUENCY = 222.0 CPS

CHAMBER	T	H	NU	GZ	GR
1	123.98	28.495	500.45	*	2.2991
2	126.21	24.771	435.06	31957.	2.2315
3	128.27	11.761	206.56	16619.	2.1758
4	130.19	11.021	193.56	10121.	2.1242
5	131.96	10.609	186.33	7276.5	2.0763
6	133.57	9.7643	171.48	5687.8	2.0324
7	135.10	9.5055	166.94	4666.3	1.9917
8	136.60	9.3955	165.01	3949.9	1.9523
9	138.11	9.8335	172.70	3431.0	1.9133
10	139.56	9.3556	164.31	3028.4	1.8749
11	140.92	9.1618	160.90	2685.7	1.8384
12	142.21	8.7775	154.15	2453.7	1.8041
13	143.47	8.7714	154.05	2241.2	1.7711
14	144.74	8.9823	157.75	2062.2	1.7381
15	145.98	8.8667	155.72	1909.5	1.7056
16	147.15	8.6880	152.58	1778.4	1.6743
17	148.30	8.5797	150.68	1664.4	1.6442
18	149.41	8.4067	147.64	1563.7	1.6150
19	150.51	8.4817	148.96	1474.2	1.5864
20	151.72	9.5276	167.33	1394.4	1.5564
21	153.17	11.728	205.97	1323.0	1.5219

TABLE 4
SUMMARY TABULATION OF AVERAGE SOUND DATA

REYNOLDS NUMBER = 82073.2 T SUBZERO = 121.00 F
T SATURATED = 211.10 F
MAX. SPL = 163.0 DB FREQUENCY = 222.0 CPS

1	123.98	28.497	500.50	46717.	2.2989
2	126.21	26.482	465.10	24528.	2.2696
3	128.27	19.282	338.64	12633.	2.2421
4	130.19	16.522	290.17	8472.6	2.2165
5	131.96	15.043	264.20	6393.3	2.1924
6	133.57	13.982	245.56	5133.5	2.1706
7	135.10	13.225	232.26	4284.9	2.1496
8	136.60	12.663	222.41	3672.6	2.1289
9	138.11	12.304	216.09	3223.5	2.1081
10	139.56	11.959	210.04	2859.0	2.0877
11	140.92	11.673	205.02	2576.9	2.0686
12	142.21	11.403	200.28	2344.1	2.0504
13	143.47	11.176	196.29	2148.9	2.0323
14	144.74	11.000	193.20	1983.8	2.0140
15	145.98	10.841	190.40	1842.1	1.9962
16	147.15	10.692	187.79	1720.2	1.9791
17	148.30	10.555	185.38	1613.2	1.9623
18	149.41	10.423	183.06	1518.1	1.9460
19	150.51	10.310	181.07	1433.6	1.9297
20	151.72	10.263	180.26	1358.1	1.9117
21	153.17	10.330	181.43	1290.3	1.8898

TABLE 3

SUMMARY TABULATION OF LOCAL SOUND DATA

REYNOLDS NUMBER =209347.1 T SUBZERO = 114.10 F
T SATURATED = 211.06 F
MAX. SPL = 147.3 DB FREQUENCY = 1500.0 CPS

CHAMBER	T	H	NU	GZ	GR
1	116.47	53.253	935.29	*	2.4245
2	118.38	49.327	866.33	80900.	2.3702
3	120.19	23.796	417.93	42072.	2.3232
4	121.87	22.334	392.25	25621.	2.2790
5	123.48	21.991	386.22	18420.	2.2373
6	124.99	20.972	368.33	14398.	2.1978
7	126.45	20.560	361.10	11812.	2.1603
8	127.86	20.098	352.98	9999.4	2.1239
9	129.21	19.992	351.11	8685.7	2.0889
10	130.54	19.244	337.98	7666.6	2.0550
11	131.82	19.356	339.96	6799.0	2.0220
12	133.05	18.820	330.53	6211.7	1.9903
13	134.27	18.906	332.05	5673.8	1.9592
14	135.46	18.695	328.34	5220.5	1.9287
15	136.61	18.339	322.09	4834.1	1.8991
16	137.74	18.430	323.68	4502.2	1.8702
17	138.85	18.354	322.36	4213.5	1.8419
18	139.94	18.205	319.74	3958.6	1.8140
19	141.01	18.000	316.13	3732.0	1.7867
20	142.21	20.725	363.99	3530.1	1.7580
21	143.61	24.652	432.96	3349.3	1.7251

TABLE 4

SUMMARY TABULATION OF AVERAGE SOUND DATA

REYNOLDS NUMBER =209347.1 T SUBZERO = 114.10 F
T SATURATED = 211.06 F
MAX. SPL = 147.3 DB FREQUENCY = 1500.0 CPS

1	116.47	53.256	935.34	*	2.4243
2	118.38	50.900	893.95	62095.	2.3999
3	120.19	37.632	660.92	31982.	2.3766
4	121.87	32.513	571.03	21448.	2.3547
5	123.48	29.873	524.66	16184.	2.3337
6	124.99	28.075	493.08	12995.	2.3139
7	126.45	26.795	470.61	10847.	2.2946
8	127.86	25.808	453.27	9297.4	2.2758
9	129.21	25.070	440.30	8160.4	2.2578
10	130.54	24.388	428.32	7237.8	2.2399
11	131.82	23.871	419.24	6523.7	2.2227
12	133.05	23.396	410.91	5934.2	2.2059
13	134.27	23.006	404.05	5440.1	2.1892
14	135.46	22.659	397.95	5022.0	2.1729
15	136.61	22.336	392.29	4663.3	2.1570
16	137.74	22.064	387.52	4354.9	2.1413
17	138.85	21.821	383.25	4083.9	2.1258
18	139.94	21.597	379.30	3843.2	2.1105
19	141.01	21.386	375.59	3629.3	2.0955
20	142.21	21.339	374.78	3438.1	2.0784
21	143.61	21.491	377.45	3266.6	2.0584

TABLE 3
SUMMARY TABULATION OF LOCAL SOUND DATA

T SUBZERO = 115.40 F
REYNOLDS NUMBER =208507.6 T SATURATED = 211.06 F
MAX. SPL = 159.3 DB FREQUENCY = 220.0 CPS

CHAMBER	T	H	NU	GZ	GR
1	117.74	53.017	931.13	*	2.3920
2	119.63	49.606	871.22	80717.	2.3384
3	121.43	23.933	420.33	41977.	2.2916
4	123.11	22.540	395.87	25564.	2.2476
5	124.72	22.227	390.38	18379.	2.2060
6	126.22	21.108	370.71	14366.	2.1666
7	127.66	20.547	360.86	11786.	2.1294
8	129.06	20.159	354.05	9976.9	2.0935
9	130.40	20.140	353.72	8666.1	2.0587
10	131.72	19.287	338.75	7649.3	2.0250
11	132.99	19.452	341.64	6783.6	1.9923
12	134.20	18.863	331.29	6197.7	1.9609
13	135.40	18.729	328.94	5661.0	1.9303
14	136.56	18.396	323.09	5208.7	1.9006
15	137.68	18.186	319.40	4823.2	1.8717
16	138.78	18.105	317.97	4492.0	1.8436
17	139.87	18.312	321.62	4204.0	1.8158
18	140.94	17.964	315.50	3949.6	1.7885
19	141.98	17.812	312.84	3723.6	1.7619
20	143.17	20.698	363.53	3522.1	1.7337
21	144.49	23.658	415.51	3341.7	1.7018

TABLE 4
SUMMARY TABULATION OF AVERAGE SOUND DATA

T SUBZERO = 115.40 F
REYNOLDS NUMBER =208507.6 T SATURATED = 211.06 F
MAX. SPL = 159.3 DB FREQUENCY = 220.0 CPS

1	117.74	53.020	931.18	*	2.3919
2	119.63	50.905	894.04	61955.	2.3676
3	121.43	37.700	662.13	31910.	2.3444
4	123.11	32.627	573.02	21400.	2.3226
5	124.72	30.016	527.17	16148.	2.3016
6	126.22	28.216	495.55	12966.	2.2819
7	127.66	26.911	472.64	10822.	2.2629
8	129.06	25.916	455.16	9276.4	2.2443
9	130.40	25.182	442.27	8142.0	2.2263
10	131.72	24.492	430.16	7221.4	2.2086
11	132.99	23.974	421.06	6508.9	2.1914
12	134.20	23.494	412.63	5920.8	2.1749
13	135.40	23.081	405.37	5427.8	2.1585
14	136.56	22.706	398.78	5010.7	2.1427
15	137.68	22.369	392.86	4652.8	2.1271
16	138.78	22.074	387.68	4345.1	2.1119
17	139.87	21.827	383.36	4074.6	2.0966
18	140.94	21.588	379.15	3834.5	2.0816
19	141.98	21.367	375.28	3621.1	2.0670
20	143.17	21.321	374.45	3430.3	2.0501
21	144.49	21.424	376.28	3259.2	2.0311

TABLE 3

SUMMARY TABULATION OF LOCAL SOUND DATA

REYNOLDS NUMBER =207454.2 T SUBZERO = 117.10 F

T SATURATED = 211.07 F

MAX. SPL = 160.3 DB FREQUENCY = 220.0 CPS

CHAMBER	T	H	NU	GZ	GR
1	119.41	53.143	933.34	*	2.3496
2	121.26	49.148	863.19	80481.	2.2969
3	122.99	23.447	411.80	41854.	2.2515
4	124.63	22.281	391.33	25489.	2.2088
5	126.20	22.025	386.82	18325.	2.1682
6	127.68	21.126	371.03	14324.	2.1296
7	129.10	20.557	361.05	11751.	2.0929
8	130.48	20.097	352.97	9947.6	2.0575
9	131.81	20.264	355.90	8640.6	2.0232
10	133.11	19.244	337.98	7626.8	1.9899
11	134.37	19.669	345.44	6763.7	1.9576
12	135.57	18.947	332.77	6179.5	1.9263
13	136.77	18.983	333.40	5644.4	1.8960
14	137.92	18.618	326.99	5193.4	1.8663
15	139.04	18.329	321.92	4809.0	1.8375
16	140.11	18.051	317.02	4478.8	1.8098
17	141.20	18.522	325.30	4191.7	1.7824
18	142.27	18.300	321.40	3938.0	1.7551
19	143.26	17.169	301.54	3712.7	1.7291
20	144.44	20.865	366.46	3511.8	1.7016
21	145.75	23.715	416.51	3331.9	1.6701

TABLE 4

SUMMARY TABULATION OF AVERAGE SOUND DATA

REYNOLDS NUMBER =207454.2 T SUBZERO = 117.10 F

T SATURATED = 211.07 F

MAX. SPL = 160.3 DB FREQUENCY = 220.0 CPS

1	119.41	53.146	933.39	*	2.3495
2	121.26	50.758	891.47	61773.	2.3258
3	122.99	37.392	656.71	31816.	2.3034
4	124.63	32.335	567.90	21337.	2.2821
5	126.20	29.747	522.44	16101.	2.2617
6	127.68	28.003	491.82	12928.	2.2422
7	129.10	26.735	469.55	10791.	2.2234
8	130.48	25.756	452.36	9249.2	2.2051
9	131.81	25.057	440.08	8118.1	2.1873
10	133.11	24.377	428.13	7200.2	2.1699
11	134.37	23.891	419.60	6489.9	2.1528
12	135.57	23.426	411.44	5903.4	2.1365
13	136.77	23.040	404.64	5411.9	2.1201
14	137.92	22.684	398.40	4996.0	2.1043
15	139.04	22.359	392.69	4639.1	2.0888
16	140.11	22.061	387.46	4332.3	2.0739
17	141.20	21.829	383.38	4062.7	2.0587
18	142.27	21.609	379.52	3823.3	2.0437
19	143.26	21.351	375.00	3610.5	2.0298
20	144.44	21.314	374.34	3420.3	2.0130
21	145.75	21.421	376.22	3249.7	1.9943

TABLE 3

SUMMARY TABULATION OF LOCAL SOUND DATA

	T SUBZERO = 121.70 F
REYNOLDS NUMBER =203614.9	T SATURATED = 211.18 F
MAX. SPL = 161.4 DB	FREQUENCY = 220.0 CPS

CHAMBER	T	H	NU	GZ	GR
1	123.92	52.970	930.30	*	2.2448
2	125.69	48.842	857.81	79533.	2.1941
3	127.36	23.378	410.59	41361.	2.1504
4	128.92	22.123	388.54	25188.	2.1093
5	130.42	21.910	384.80	18109.	2.0704
6	131.84	21.004	368.90	14155.	2.0333
7	133.20	20.493	359.92	11613.	1.9980
8	134.52	19.913	349.74	9830.4	1.9640
9	135.78	19.991	351.10	8538.9	1.9312
10	137.03	19.199	337.20	7537.0	1.8994
11	138.23	19.413	340.95	6684.0	1.8683
12	139.37	18.708	328.57	6106.7	1.8386
13	140.50	18.714	328.67	5577.9	1.8096
14	141.61	18.530	325.45	5132.2	1.7812
15	142.68	18.232	320.20	4752.4	1.7536
16	143.72	18.254	320.59	4426.1	1.7267
17	144.76	18.347	322.22	4142.3	1.7002
18	145.77	18.031	316.68	3891.7	1.6742
19	146.76	17.789	312.43	3668.9	1.6489
20	147.73	17.942	315.12	3470.4	1.6240
21	148.94	22.708	398.82	3292.6	1.5962

TABLE 4

SUMMARY TABULATION OF AVERAGE SOUND DATA

	T SUBZERO = 121.70 F
REYNOLDS NUMBER =203614.9	T SATURATED = 211.18 F
MAX. SPL = 161.4 DB	FREQUENCY = 220.0 CPS

1	123.92	52.972	930.35	*	2.2447
2	125.69	50.525	887.37	61045.	2.2219
3	127.36	37.238	654.02	31441.	2.2003
4	128.92	32.181	565.19	21086.	2.1800
5	130.42	29.602	519.91	15911.	2.1603
6	131.84	27.864	489.37	12775.	2.1416
7	133.20	26.608	467.32	10664.	2.1235
8	134.52	25.622	449.99	9140.3	2.1060
9	135.78	24.906	437.42	8022.5	2.0890
10	137.03	24.237	425.68	7115.4	2.0722
11	138.23	23.741	416.96	6413.4	2.0559
12	139.37	23.268	408.66	5833.9	2.0403
13	140.50	22.872	401.71	5348.2	2.0248
14	141.61	22.523	395.57	4937.1	2.0095
15	142.68	22.202	389.94	4584.5	1.9947
16	143.72	21.928	385.13	4281.3	1.9801
17	144.76	21.693	381.00	4014.8	1.9655
18	145.77	21.466	377.00	3778.2	1.9512
19	146.76	21.250	373.22	3568.0	1.9373
20	147.73	21.066	369.99	3380.0	1.9234
21	148.97	21.136	371.21	3211.4	1.9060

Table 5

Chambers Dimensions

Chamber No.	x_i (ft)	A_i (ft^2)	A_{x_i} (ft^2)
1	0.267	0.279	0.279
2	0.527	0.532	0.247
3	1.023	1.033	0.495
4	1.526	1.540	0.502
5	2.022	2.041	0.496
6	2.518	2.542	0.496
7	3.017	3.046	0.498
8	3.520	3.554	0.502
9	4.010	4.049	0.490
10	4.521	4.565	0.511
11	5.016	5.065	0.494
12	5.514	5.568	0.498
13	6.015	6.974	0.500
14	6.516	6.579	0.500
15	7.017	7.085	0.501
16	7.514	7.587	0.496
17	8.013	8.091	0.498
18	8.515	8.597	0.501
19	9.017	9.104	0.501
20	9.518	9.610	0.501
21	10.018	10.115	0.499

APPENDIX

CALCULATION PROCEDURES

Outline of Burroughs 220 Computer Program

Input Data: t_s, t_o, τ, V_a, t_{db}, V_i

p, p_o, h_{fg},* γ (Test Data)

Run Number, Sound or No-Sound, SPL, Frequency, Date

(Data for Designation - Not Involved in Computations)

D, A_i, x_i, A_{x_i} (Apparatus Design Data - See Table 5 for values)

Calculations:

$$v = \frac{53.35 + 85.58\,\gamma}{1 + \gamma} \cdot \frac{t_{db} + 460}{70.73\,p}$$

$$c_p = \frac{0.240 + 0.446\,\gamma}{1 + \gamma}$$

$$\dot{m} = \frac{3600\,Va}{\tau \cdot v}$$

$$\mu = 0.0407 + 0.0000562\,t_o{}^{**}$$

$$Re = \frac{4\,\dot{m}}{\pi D \mu}$$

$$m_i = \frac{V_i}{\tau}$$

$$Q_i = m_i\,h_{fg}$$

$$k = 0.0132 + 0.000025\,t_s{}^{**}$$

$$Q_{oa} = 0.1869\,k\,(Re)^{1/2}\,(t_s - t_o)$$

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*From Reference 6 at t_s.

**Equation obtained from data in Table A-2, Reference 3.

$$Q_1 \text{ (corrected)} = Q_1 + Q_{oa}$$

$$\sum Q_i = Q_1 \text{ (corrected)} + Q_2 + \ldots + Q_i$$

$$\Delta t_i = \frac{\sum Q_i}{\mathring{m}\, c_p}$$

$$t_i = t_o + \Delta t_i$$

$$\Delta t_{lm_i} = \frac{-\Delta t_i}{\ln \dfrac{t_s - t_i}{t_s - t_o}}$$

$$h_{lm_i} = \frac{\sum Q_i}{A_i\, \Delta t_{lm_i}}$$

$$Nu_{lm_i} = \frac{h_{lm_i} \cdot D}{k}$$

$$Gz_i = \frac{\mathring{m}\, c_p}{k\, x_i}$$

$$\frac{\rho^2 \beta g}{\mu^2} = \left[2.85 - 0.011\, t_s\right] \times 10^{6*}$$

$$Gr_i = \frac{\rho^2 \beta g}{\mu^2}\, D^3\, \Delta t_{lm_i} \left(\frac{p_o}{29.92}\right)^2$$

$$t_{am_i} = \frac{(t_s - t_{i-1}) + (t_s - t_i)}{2}$$

$$h_{x_i} = \frac{Q_i}{A_{x_i} \cdot \Delta t_{am_i}}$$

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*Equation obtained from data in Table A-2, Reference 3.

$$Nu_{x_i} = \frac{h_{x_i} D}{k}$$

$$Gz_{x_i} = \frac{\dot{m}\, c_p}{k\, x_i}$$

$$Gr_{x_i} = \frac{\rho^2 \beta g}{\mu^2} \quad D^3 \quad \frac{(t_s - t_i) + (t_s - t_{i-1})}{2} \quad \left(\frac{p_o}{29.92}\right)^2$$

Output Data:

Run Number, Sound or No-Sound, SPL, Frequency, Date

(Data for Designation)

t_i, h_{lm_i}, Nu_{lm_i}, Gz_i, Gr_i, Re, (Average Data)

h_{x_i}, Nu_{x_i}, Gz_{x_i}, Gr_{x_i} (Local Data)