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BEHAVIOR OF NOZZLES AND ACOUSTIC LINERS IN THREE-DIMENSIONAL ACOUSTIC FIELDS

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PROGRESS DURING REPORT PERIOD

A. Summary

Theoretical values of the admittances of various nozzles have been computed and compared with the corresponding experimental values. The existing data reduction scheme has been corrected and all available experimental data has been rechecked and corrected whenever necessary; the updated experimental admittance values are presented in this report. An analysis associated with the frequency sensitivity of experimental admittance values has been initiated. The Analog-To-Digital Data Reduction Program has become operational. Fourteen nozzle tests have been conducted during this report period.

B. Theoretical Studies

Theoretical values of the nozzle admittance have been computed based on the three dimensional nozzle admittance theory of Crocco.[1] The development of a computer program which employs this theory to predict nozzle admittances has been completed; this program was then used to predict the admittance values for all the nozzles tested to date. Before presenting the results, a brief description of the theory used in developing this computer program will now be given.

According to Crocco's theory[1], the admittance Y is given by the expression

$$Y = \frac{-Z}{q^2 Z + is} \tag{1}$$

where

$$Z = \frac{\text{axial dependence of the axial velocity perturbation}}{\text{axial dependence of the radial velocity perturbation}}$$

q = nondimensionalized mean flow velocity

s = nondimensionalized frequency

Once Z is known and q and s are specified, the admittance can be found from Eq. (1). The problem is to compute Z. Values of this parameter can be determined by numerically integrating the following complex, nonlinear equation (called the Riccati Equation):

$$\frac{dZ}{d\Phi} = A(\Phi)Z - B(\Phi) - Z^2 \tag{2}$$

where the independent variable Φ is the steady state flow potential, and $A(\Phi)$ and $B(\Phi)$ are coefficients whose form depends upon s and the mean flow properties in the converging section of the nozzle. The major difficulty in integrating Eq. (2) is that Z can take on very large values whenever the radial velocity approaches zero. These large values can occur for the nozzles under investigation, and can cause numerical instabilities in the integration scheme. This problem is circumvented by transforming the dependent variable as follows:

$$T = \frac{1}{Z} \tag{3}$$

Thus, when Z becomes large T becomes small. Substituting for Z in Eq. (2) gives the following Riccati Equation for T:

$$\frac{dT}{d\Phi} = 1 - A(\Phi)T + B(\Phi)\ T^2 \tag{4}$$

In order to avoid numerical instabilities in the computer program which predicts theoretical admittance values, the following procedure is used. Starting at the nozzle throat, Eq. (2) is integrated until the magnitude of Z becomes larger than a specified value at a certain value of Φ; T is then found from Eq. (3) and Eq. (4) is integrated. Similarly, when $|T|$ exceeds a certain value, Z is computed from Eq. (3) and the integration is carried out using Eq. (2).

This process is repeated until Φ equals the value at the nozzle entrance. The admittance is then determined from Eq. (1) using the value of Z or T at that point.

When the theoretical admittance values were computed it was found that a discrepancy existed between the theoretical predictions and the experimental results. This discrepancy was traced to the improper interpretation of the incident and reflected waves in the theory used for the reduction of the experimental data. The discrepancy was corrected and all the experimental data that had been previously taken was rerun. While correcting the data reduction scheme, it was found that the equations presented in the last quarterly report remain unchanged with the exception of the expression for the real part of the admittance whose corrected form is given by Eq. (5). The corrected admittance data indicates that increasing the mean flow Mach number decreases the value of the real part of the admittance for three dimensional modes which is in agreement with nozzle admittance theory. Data presented in earlier reports shows the opposite trend. In addition, the signs of the corrected values of the imaginary parts of the nozzle admittance are the negative of the values reported earlier.

The comparisons of the experimental admittances with the corresponding theoretical predictions are presented in figures 1 through 24. Except for figures 3 and 7 the theory and experiment are in qualitative agreement. Before any conclusions, concerning the validity of the theory or the experimental data, are drawn, further analysis of these results will be performed. Included in this analysis will be the study of the accuracy of the frequency measurements and its effect upon the experimental results. The findings of this analysis will be reported in the next progress report.

Figures 3 and 7 show that the experimental values for the real part of the admittance approach large positive numbers whereas the theory predicts large negative values. This discrepancy could be due to the inability of the present data reduction scheme to determine the proper sign of α. This point may become clearer if one considers the following equations:

$$Y_r = \frac{S\sqrt{S^2 - S_{mn}^{\,2}(1-\bar{M}^2)}\ \tanh \pi\alpha\ \sec^2\pi\beta \mp S_{mn}^{\,2} M}{(S^2 + S_{mn}^{\,2} M^2)\ (\tanh^2\pi\alpha + \tan^2 \pi\beta)} \qquad (5)$$

where

$$e^{-2\pi\alpha} = \left(\frac{\text{reflected wave amplitude}}{\text{incident wave amplitude}}\right)_{\text{nozzle entrance}}$$

$\pi(1 + 2\beta)$ = phase change of the incident wave upon reflection

r_c = chamber radius

S_{mn} = 0 for longitudinal modes
= 1.8413 for transverse modes

M = chamber Mach number ~~(5)~~

In order for the theoretical and experimental admittances, in Figs. 3 and 7, to agree α must take on negative values. However, the present data reduction scheme is not capable of determining the sign of α from the perturbation pressure amplitude measurements at various locations along the tube. The sign of α can, however, be determined from perturbation pressure phase measurements; as a matter of fact the phase measurements can be used to determine both the sign and magnitude of α.

A computer program using the Nonlinear Regression Technique for the computation of α, β, and the admittance from phase measurements taken at discrete points along the tube is in preparation. This program is currently undergoing preliminary checkouts and admittance values obtained from this program will be presented in the next report.

The checkout of the analog-to-digital data reduction program has been completed and the program is operational at this time. The principal motivation for the development of the A-to-D program was the desire to obtain accurate phase data, which is an important consideration for both the present nozzle testing program and the anticipated acoustic liner work. Other advantages associated with the use of the A-to-D program are: (1) the data reduction time is reduced by several orders of magnitude; (2) the frequency resolution is improved; and (3) the possibility of human errors affecting the data accuracy are virtually eliminated.

A brief description of the use of the A-to-D program follows. First, the analog data taken during the test must be digitized. This is accomplished by a 14 channel Analog-To-Digital Conversion System manufactured by the Radiation Corporation. This unit is made available, free-of-charge, to users of the Rich Electronic Computer Center, which is an integral part of Georgia Tech. The unit has been programmed to sample 25,000 samples/second. For ten channels of analog data (viz., two frequency channels and eight dynamic pressure transducer channels), this sample rate provides 2,500 samples/second/channel, which represents 0.4 milliseconds between samples on each channel. The maximum frequency recorded on the analog tape is 1,000 Hz; however, the maximum frequency of the Conversion System is restricted to 250 Hz at this sample rate for ten channels. Consequently, the analog tape recorder speed must be reduced by 4:1 during the playback into the A-to-D Conversion System. This selection of sample rate and maximum frequency insures that the signal with the shortest period (viz., the real-time frequency of 1,000 Hz) will be sampled 10 times during the period, which is considered to be an absolute minimum for good statistical confidence. The minimum frequency is not limited by the Conversion System but is limited by the available core size associated with the computer that is used to process the digitized data. In this case, the computer is a Univac 1108 that has a total available core of 60,000 words. This amount of core results in a minimum real-time frequency of 56 Hz, which implies that this period is sampled 179 times during one cycle by the Conversion System. The frequency limits can be summarized as follows:

$$\text{Real-time;}\quad 56 \le f,\ \text{Hz} \le 1{,}000$$

$$\text{Reduced-time;}\quad 14 \le f,\ \text{Hz} \le 250$$

The end product of the A-to-D conversion is a tape of digitized test data.

The digitized test data is then transferred to the Univac 1108 system where it is used to determine all needed information. The data reduction program is written in the Fortran V compiler and executed by the Univac 1108. After this program reads a block of digitized data, it proceeds to determine the frequency associated with that block of data. This is accomplished by checking for the zero-crossings of a reference (sinusoidal) frequency signal. Inasmuch as the frequency signal will not be digitized at the exact instant when the signal is identically zero, the instant when the signal crosses the zero line must be interpolated by using the last two positive values and the first two negative values. The use of an interpolation routine suggests that an error might be introduced. A checkout of the interpolation schemed showed that it produces a maximum error of 0.5 Hz, which represents a 0.05% error.

The frequency that has just been determined is the frequency of the driven oscillation at that instant of time during the test. Therefore, it represents the fundamental frequency for that block of digitized pressure data. For one period of the fundamental mode, the Fourier Series representation of the time-dependent signal is given by:

$$p(t) = A \cos \omega t + B \sin \omega t$$

where

$p(t)$: time-dependent pressure amplitude, psi

ω : angular frequency, radians/sec

$$A = \frac{2}{T} \int_0^T p(t) \cos \omega t \, dt$$

$$B = \frac{2}{T} \int_0^T p(t) \sin \omega t \, dt$$

T : period of the fundamental mode, seconds

The program determines the Fourier Coefficients A and B for each of the pressure signals. The signal amplitude is determined from the expression:

$$\text{Amplitude} = (A^2 + B^2)^{1/2}$$

and the phase is determined from the expression:

$$\text{Phase} = \tan^{-1}(B/A)$$

Each test can be divided into 500 data reduction points. After the frequency, amplitude, and phase have been determined for the entire digital tape, this information is fed into a special subroutine that uses this data to compute the nozzle admittance and related data. An example of the data reduction results is presented in Appendix A.

The data reduction program was checked out with and without a digitized tape data. The first checkout was without a digitized tape data. In this case, signals of known frequency, amplitude, and phase were generated using a sine function. These continuous signals were synthetically digitized in a manner similar to that used by the Conversion System when it digitizes the analog data. This data was processed by the program and the program results were compared to the input values. For both simple periodic signals and complex periodic signals (i.e., signals composed of a sum of a fundamental oscillation and its various harmonics), the error in amplitude and phase appeared as a "round-off" error, which represents an error of less than 0.2%. For a nonperiodic signal (i.e., two periodic signals whose frequencies are not related by an integer constant), the amplitude error was less than 5% and the phase error was approximately 5° for the case when the two signal amplitudes were equal. This case approximates conditions when the signal-to-noise ratios equal to one. These errors decreased rapidly as the signal-to-noise ratio approached 10:1.

The second checkout of the program involved the use of digitized data obtained from an actual test. A comparison of the program's results with the results obtained by the previous data reduction method disclosed that there was general agreement between the two methods. The concensus of opinion is that the new data reduction scheme is more accurate than the one used to date; furthermore, the new program is considerably more efficient.

C. Experimental Investigations

During this report period fourteen tests have been run. One test was conducted for checking the analog-to-digital data reduction program. All of the nozzles fabricated thus far were retested in order to include the entire frequency range for 1T modes ($1.84 < s < 3.05$) and most of the longitudinal frequency range ($.1 < s < 1.84$). The results of these tests are included in figures 1 through 24. In addition, two tests were run with a quasi-steady nozzle and two more with a nozzle whose half-angle is 45° and radius of curvature of 2.5 inches. The Mach number of the latter nozzle was increased to a value of .20. The data obtained in these tests is being reduced and it will be presented in the next progress report.

Other efforts have resulted in the improvement of the precision of the frequency measurements. This improvement allowed a significant increase in the number of data points taken per run.

EXPECTED PROGRESS DURING NEXT REPORT PERIOD

During the next quarter, two more microphones will be added to the data acquisition system. This addition will bring the number of pressure amplitudes sampled along the standing wave pattern to ten. This will improve the accuracy of the admittance values by providing more information about the wave structure.

The nozzle with a half-angle of 45° and radius of curvature of 2.5 inches will be tested at various Mach numbers starting at $M = .24$ and proceeding to $M = .32$. These series of tests will be conducted to determine whether there are any unexpected problems associated with testing at higher Mach numbers. Assuming that no major problems are encountered, the other nozzles will be tested and the experimental admittance values along with the corresponding theoretical predictions will be determined. These results will be compared in the next quarterly report.

REFERENCES

1. Crocco, L., Sirignano, W. A., "Behavior of Supercritical Nozzles Under Three Dimensional Oscillatory Conditions," AGARDograph 117, 1967.

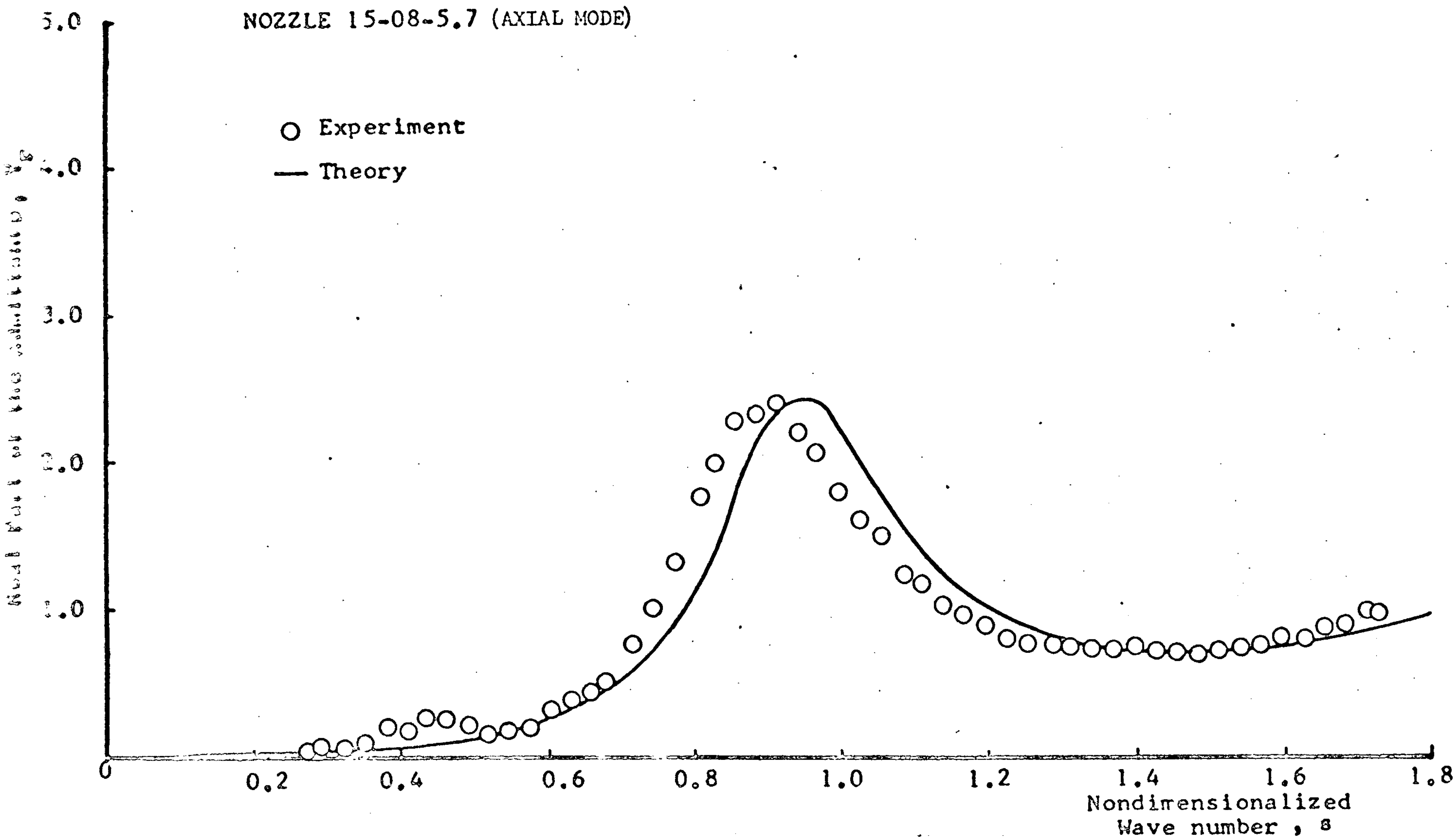

Figure 1. Comparison of the theory and experimental values of the real part of the admittance for the nozzle with a half-angle of 15 degrees, entrance Mach number of .08, and radii of curvature at the throat and entrance of 5.7 inches.

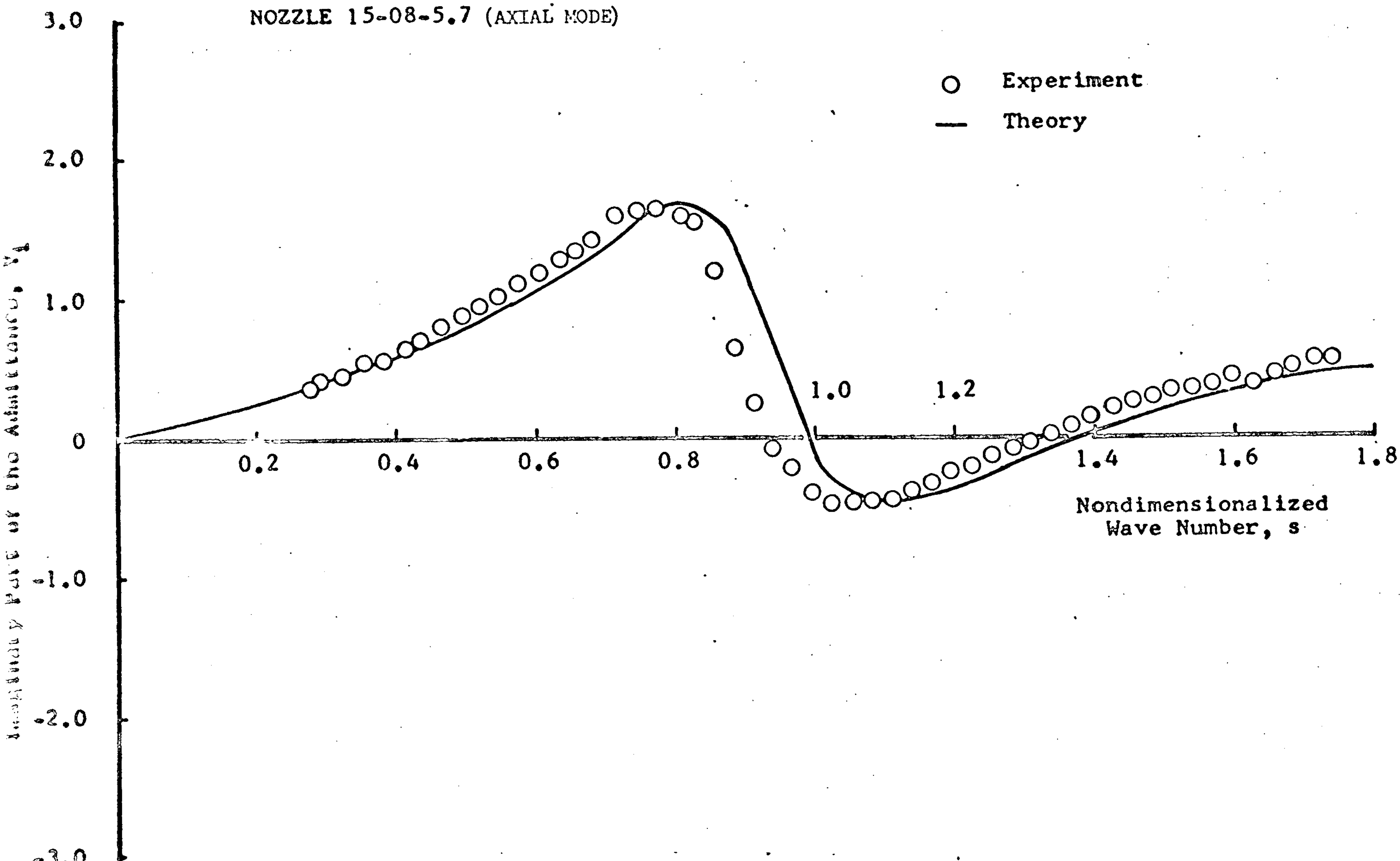

Figure 2. Comparison of the theory and experimental values of the imaginary part of the admittance for the nozzle with a half-angle of 15 degrees, entrance Mach number of .08, and radii of curvature at the throat and entrance of 5.7 inches.

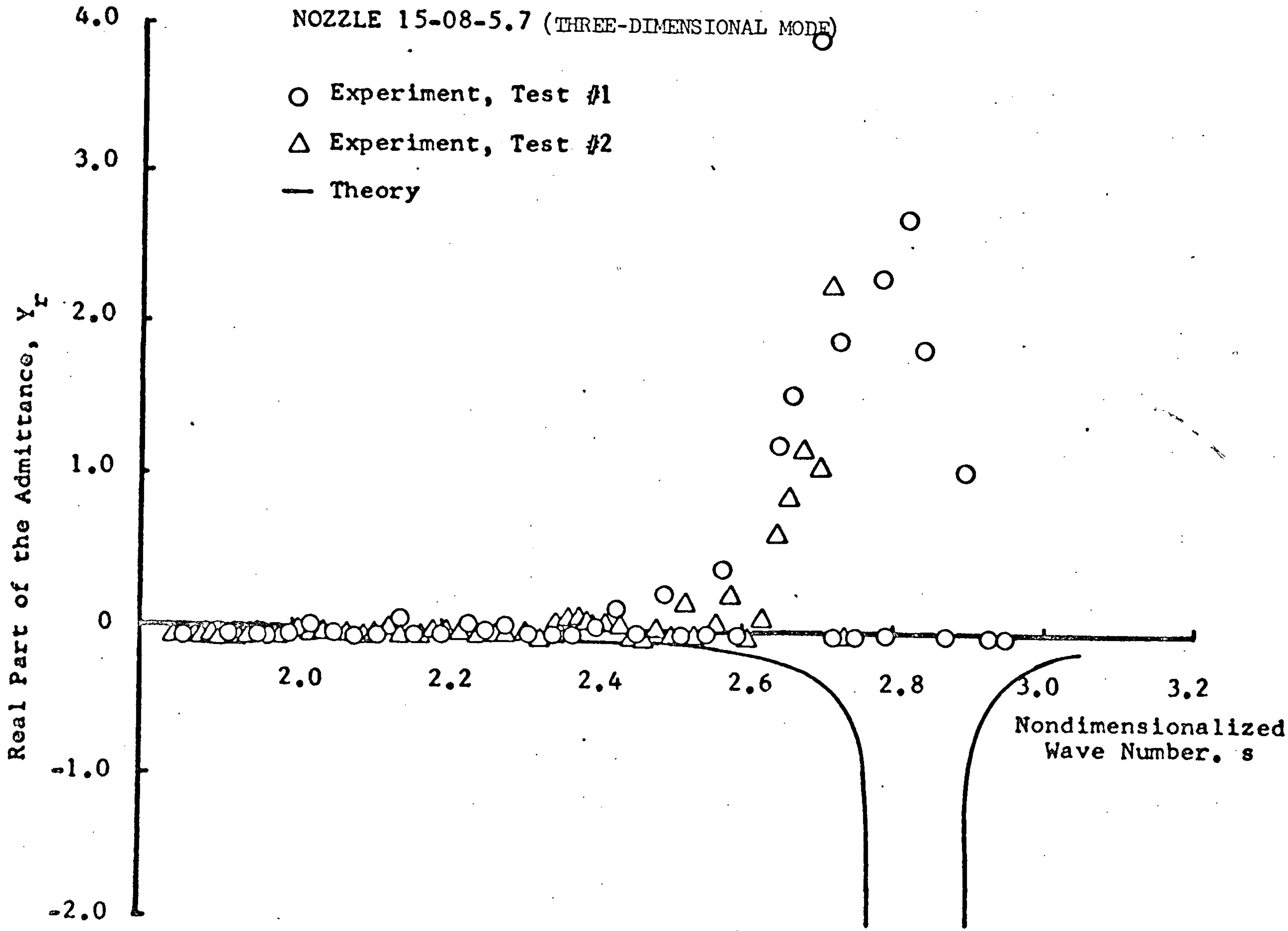

Figure 3. Comparison of the theory and experimental values of the real part of the admittance for a nozzle with a half-angle of 15 degrees, entrance Mach number of .08, and radii of curvature at the throat and entrance of 5.7 inches.

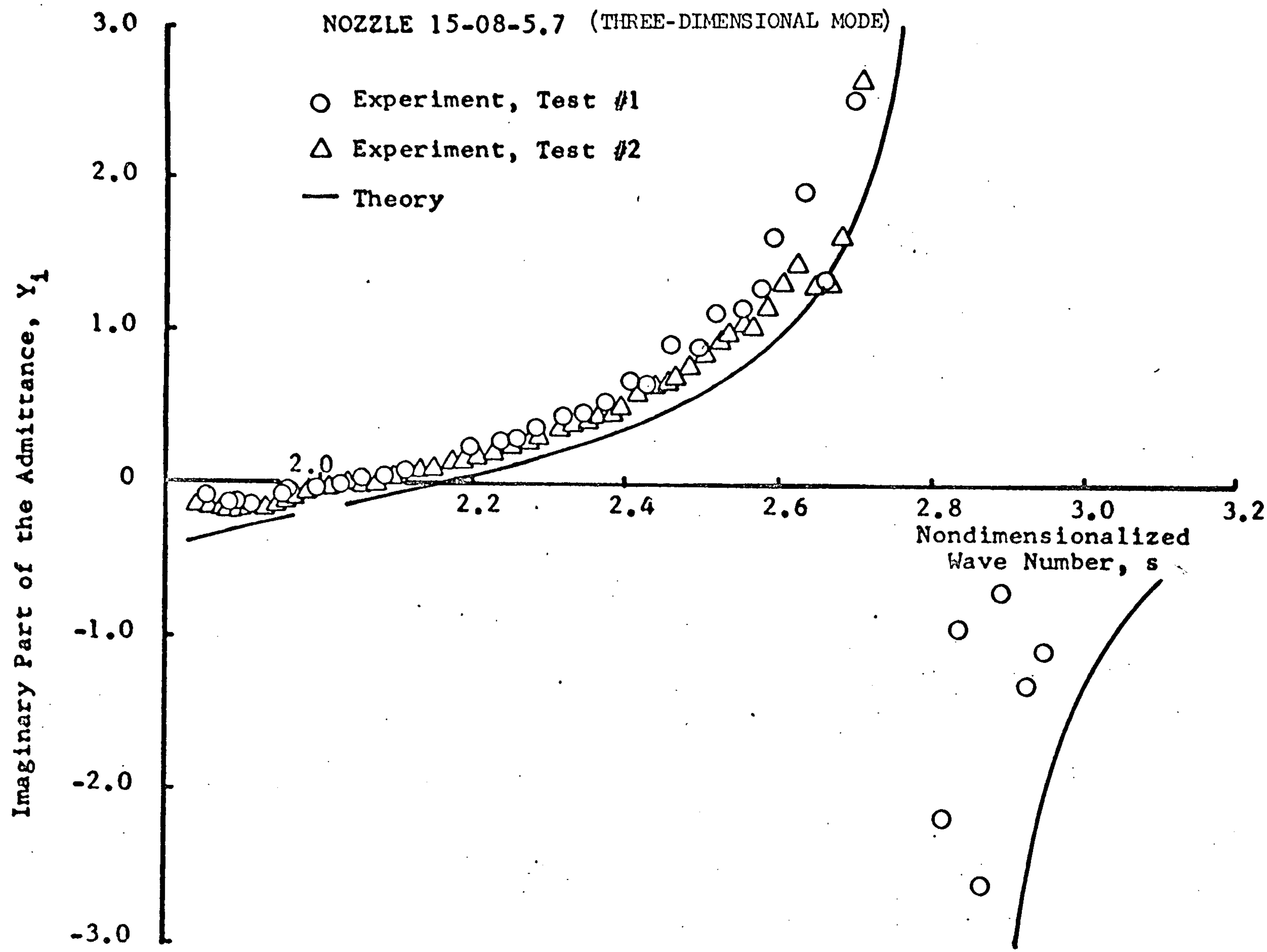

Figure 4. Comparison of the theoretical and experimental values of the imaginary part of the admittance for a nozzle with a half-angle of 15 degrees, entrance Mach Number of .08, and radii of curvature at the throat and entrance of 5.7.

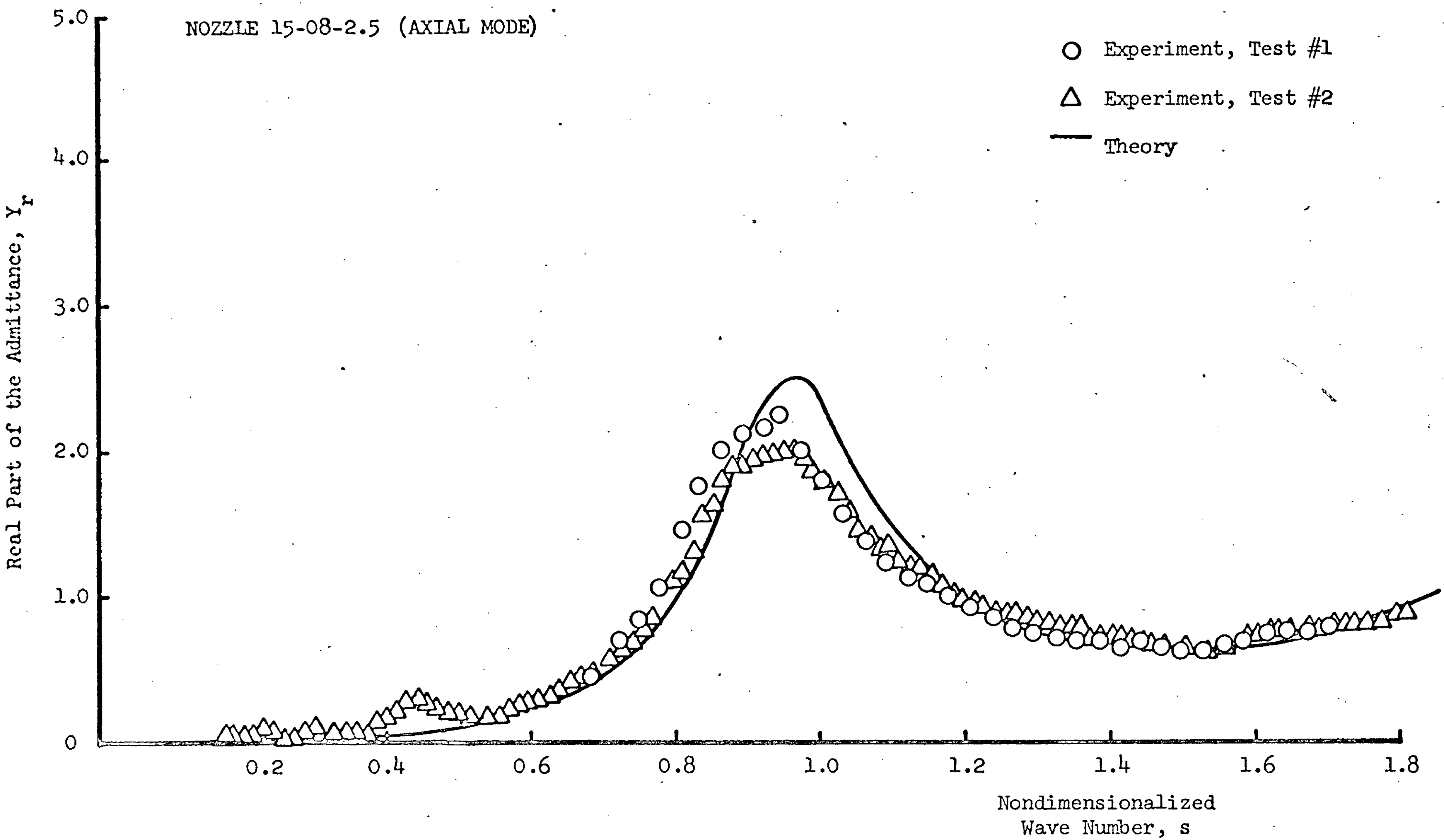

Figure 5. Comparison of the theoretical and experimental values of the real part of the admittance for a nozzle with a half-angle of 15 degrees entrance Mach number of .08 and radii of curvature at the entrance and throat of 2.5 inches.

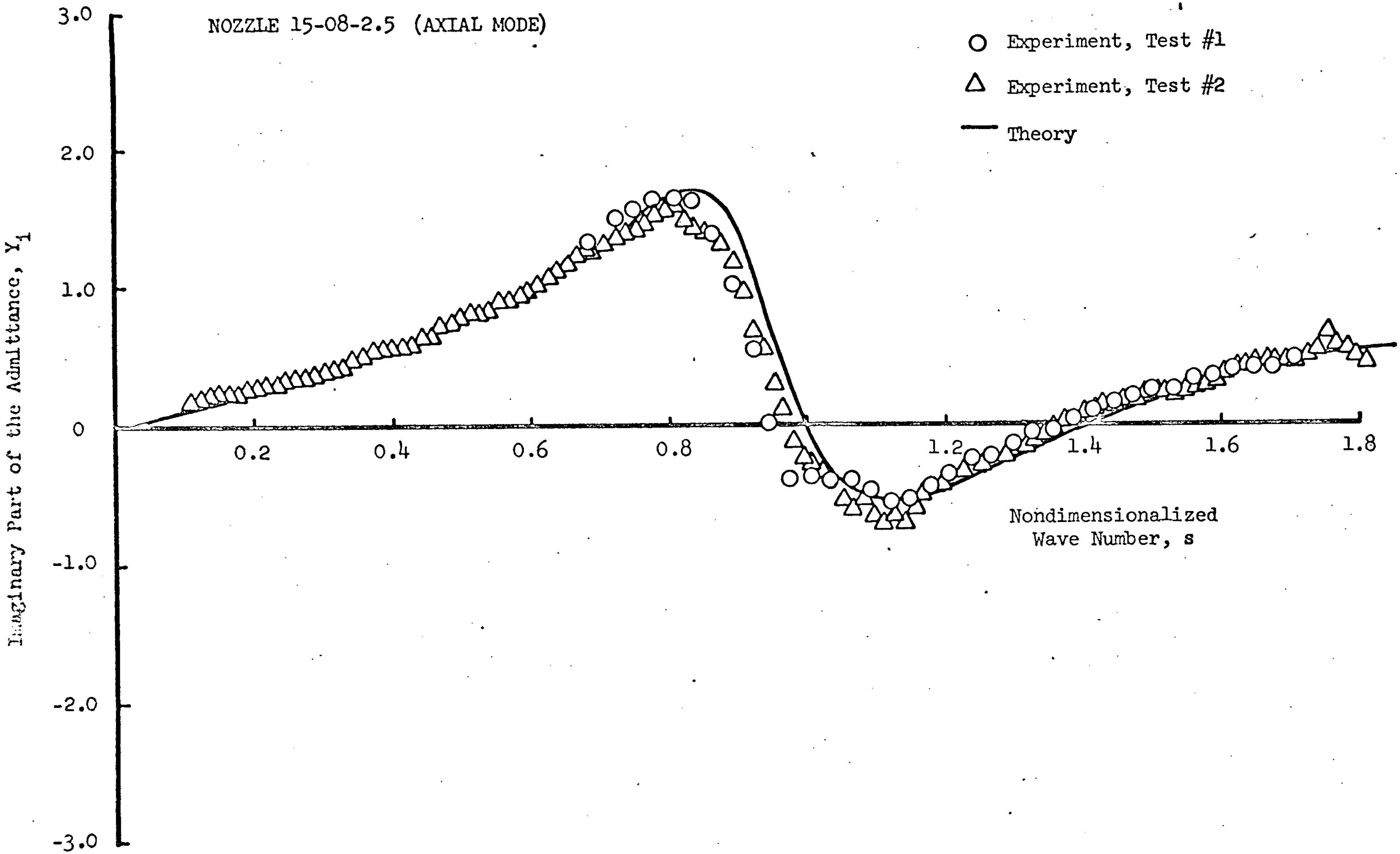

Figure 6. Comparison of the theoretical and experimental values of the imaginary part of the admittance for a nozzle with a half-angle of 15 degrees, entrance Mach number of .08 and radii of curvature at the entrance and throat of 2.5 inches.

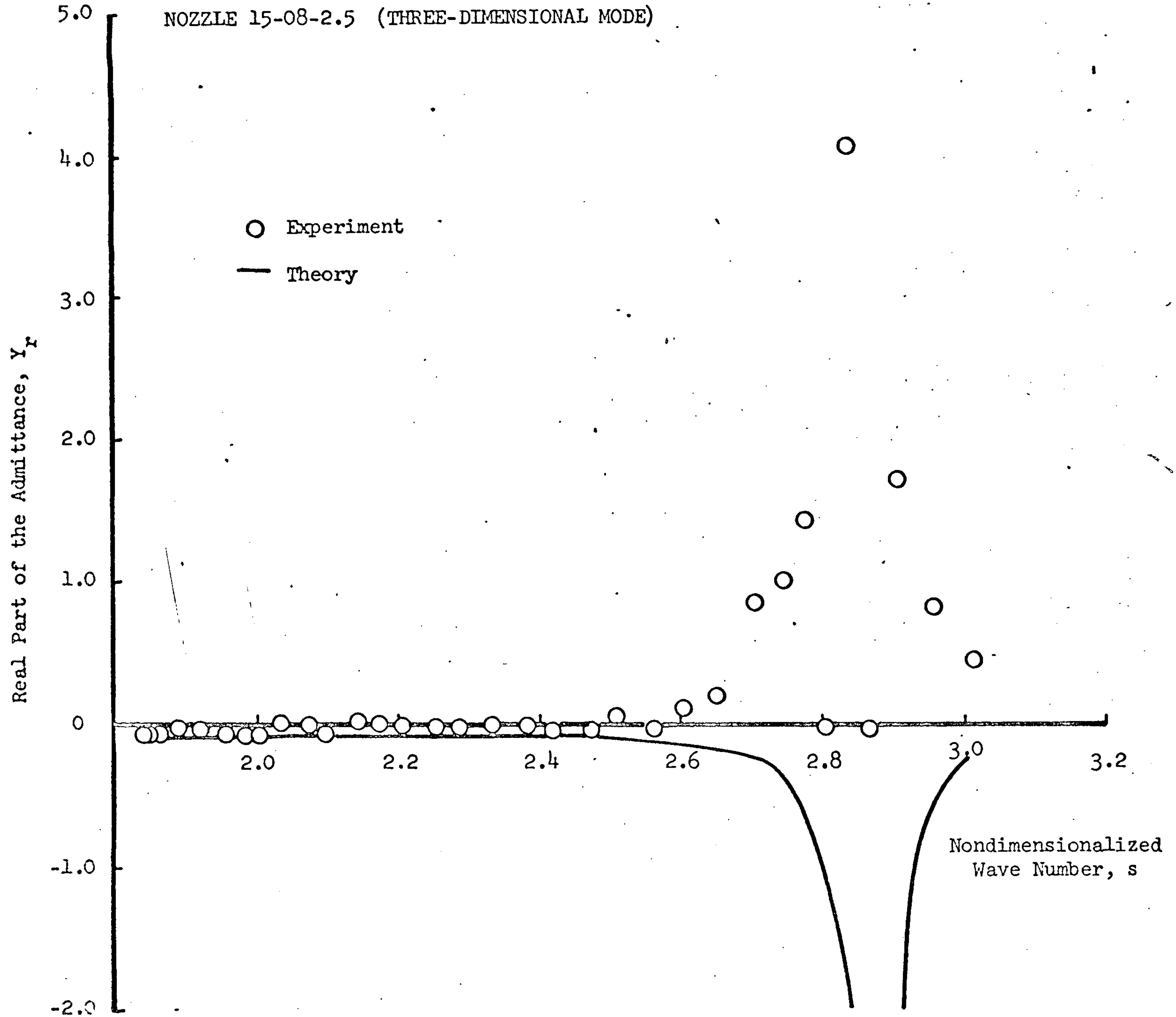

Figure 7. Comparison of the theoretical and experimental values of the real part of the admittance for a nozzle with a half-angle of 15 degrees, entrance Mach number of .08, and radii of curvature at the throat and entrance of 2.5 inches.

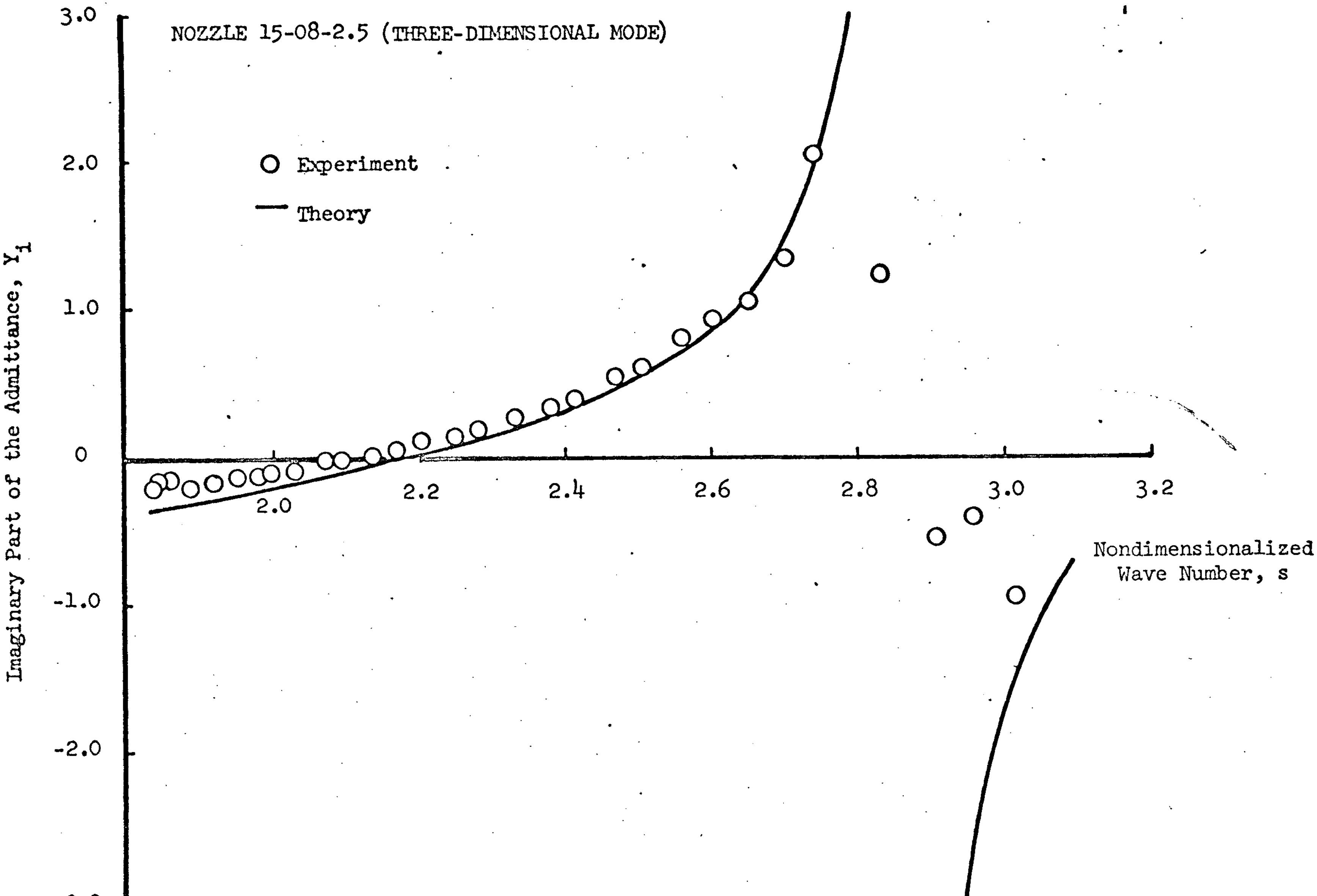

Figure 8. Comparison of the theoretical and experimental values of the imaginary part of the admittance for a nozzle with a half-angle of 15 degrees, entrance Mach number of .08, and radii of curvature at the throat and entrance of 2.5 inches.

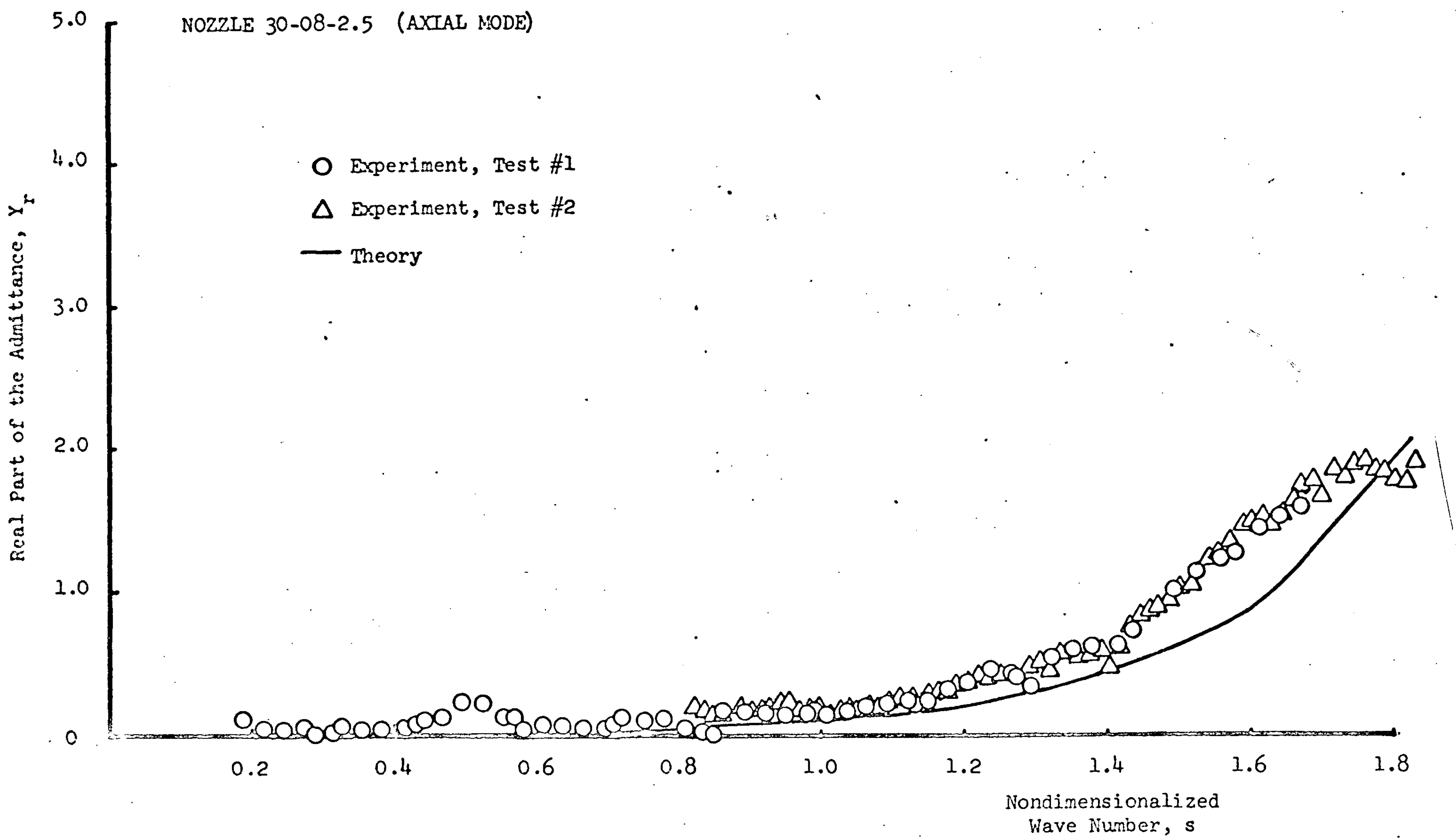

Figure 9. Comparison of the theoretical and experimental values of the real part of the admittance for a nozzle with a half-angle of 30 degrees, entrance Mach number of .08, and radii of curvature at the throat and entrance of 2.5 inches.

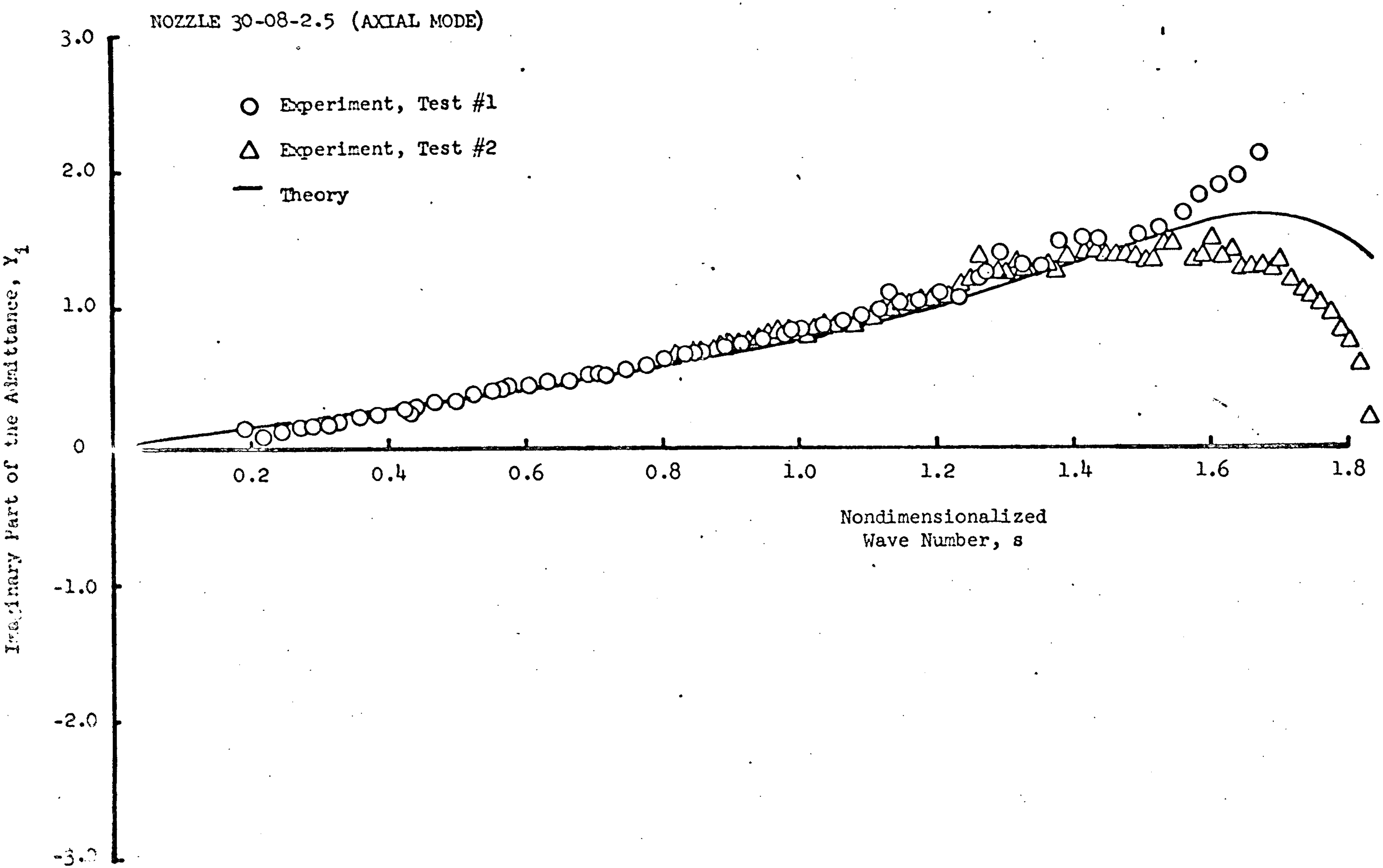

Figure 1[illegible]. Comparison of the theoretical and experimental values of the imaginary part of the admittance for a nozzle with a half-angle of 30 degrees, entrance Mach number of .08, and radii of curvature at the throat and entrance of 2.5 inches.

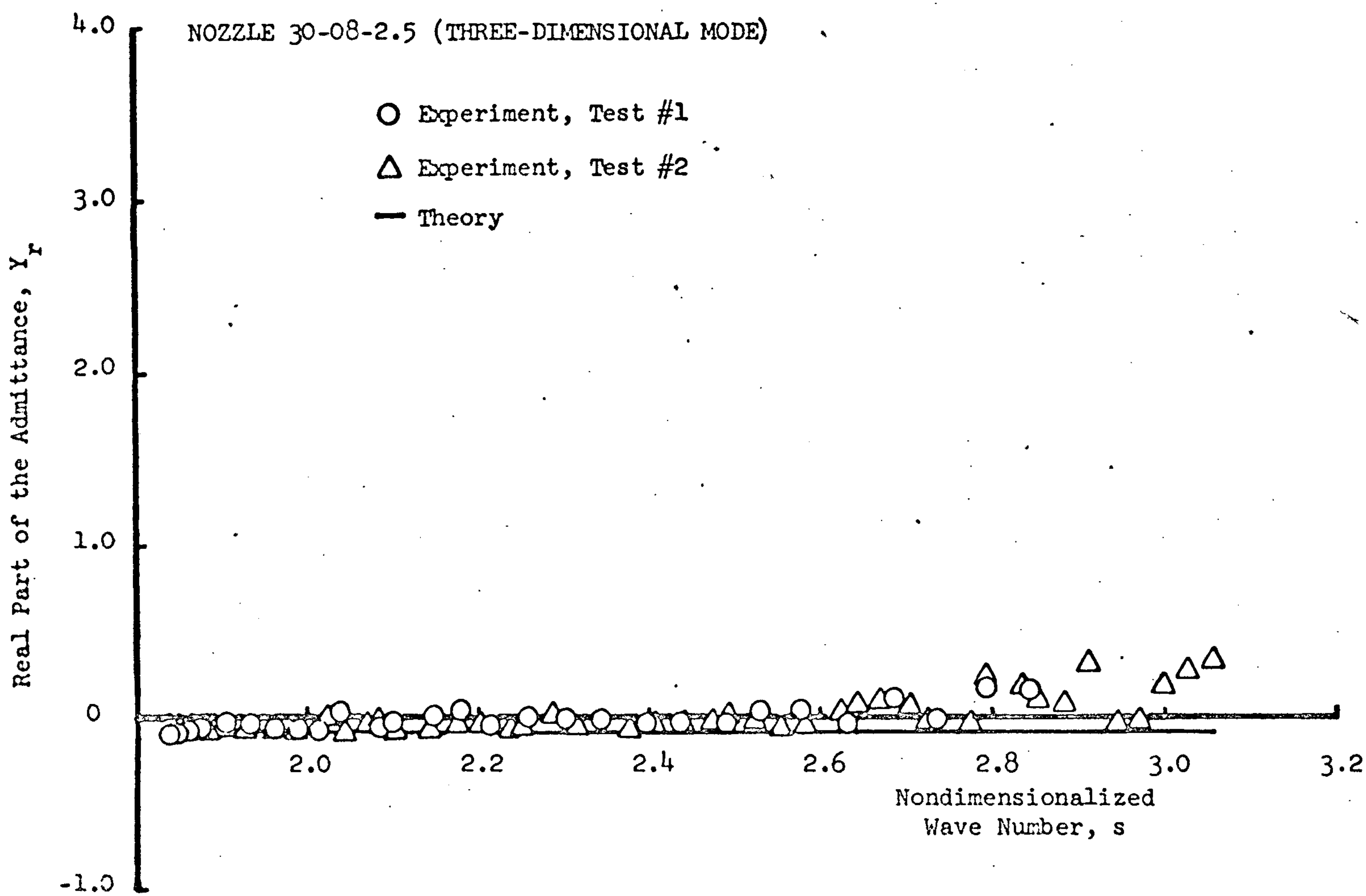

Figure 11. Comparison of the theoretical and experimental values of the real part of the admittance for a nozzle with a half-angle of 30 degrees, entrance Mach number of .08, and radii of curvature at the throat and entrance of 2.5 inches.

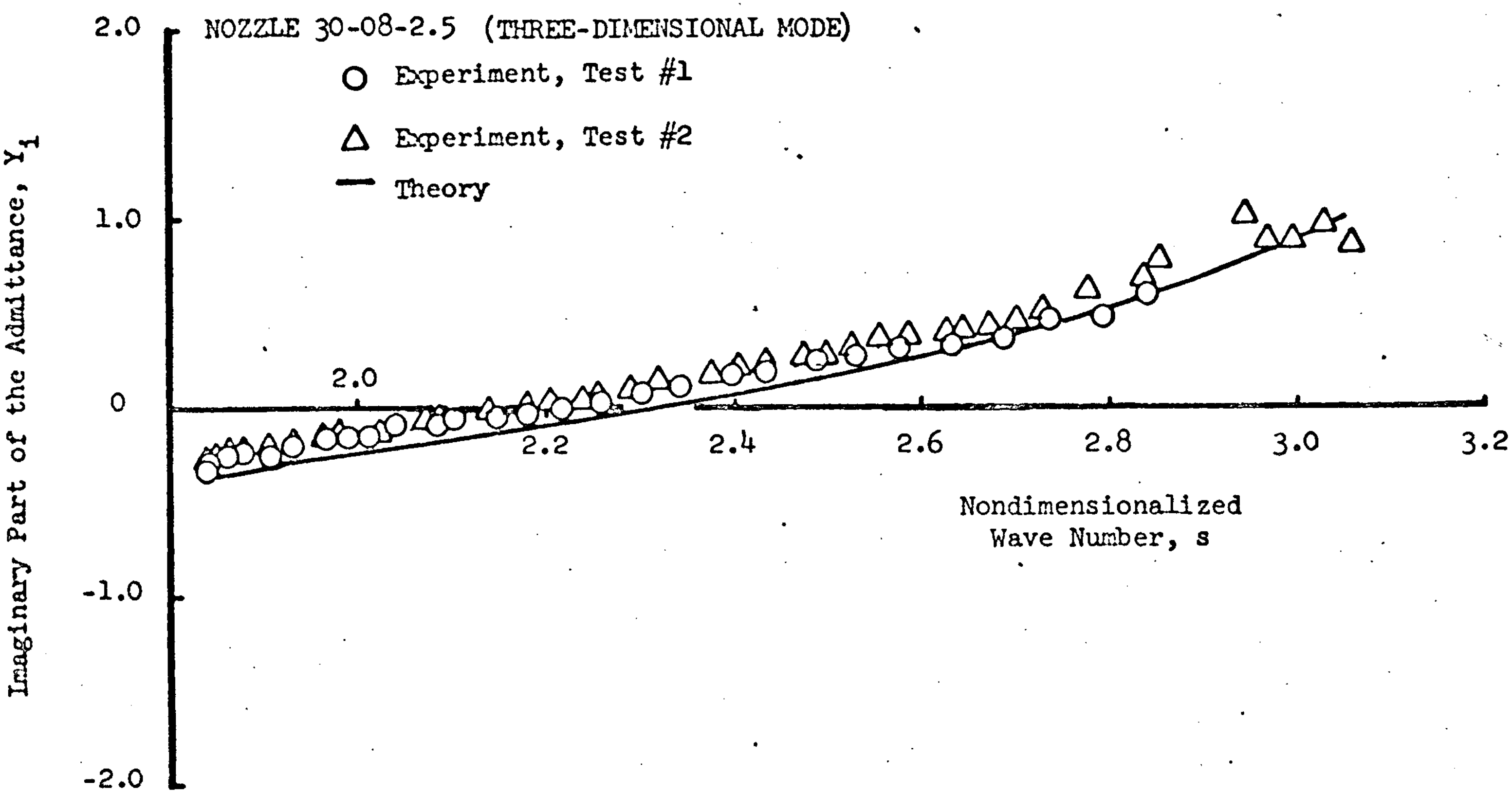

Figure 12. Comparison of the theoretical and experimental values of the imaginary part of the admittance for a nozzle with a half-angle of 30 degrees, an entrance Mach number of .08, and radii of curvature at the throat and entrance of 2.5 inches.

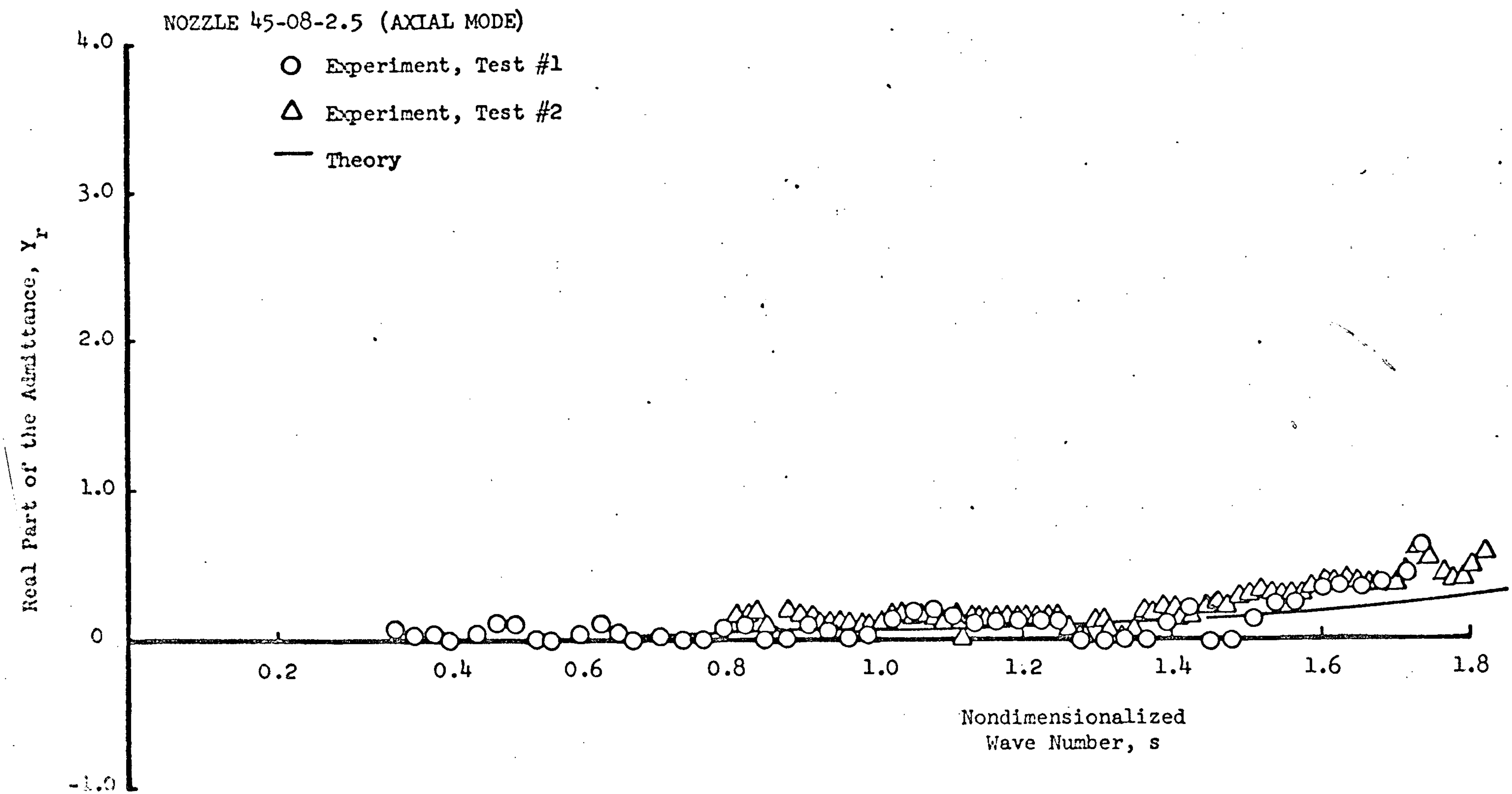

Figure 13. Comparison of the theoretical and experimental values of the real part of the admittance for a nozzle with a half-angle of 45 degrees, entrance Mach number of .08, and radii of curvature at the throat and entrance of 2.5 inches.

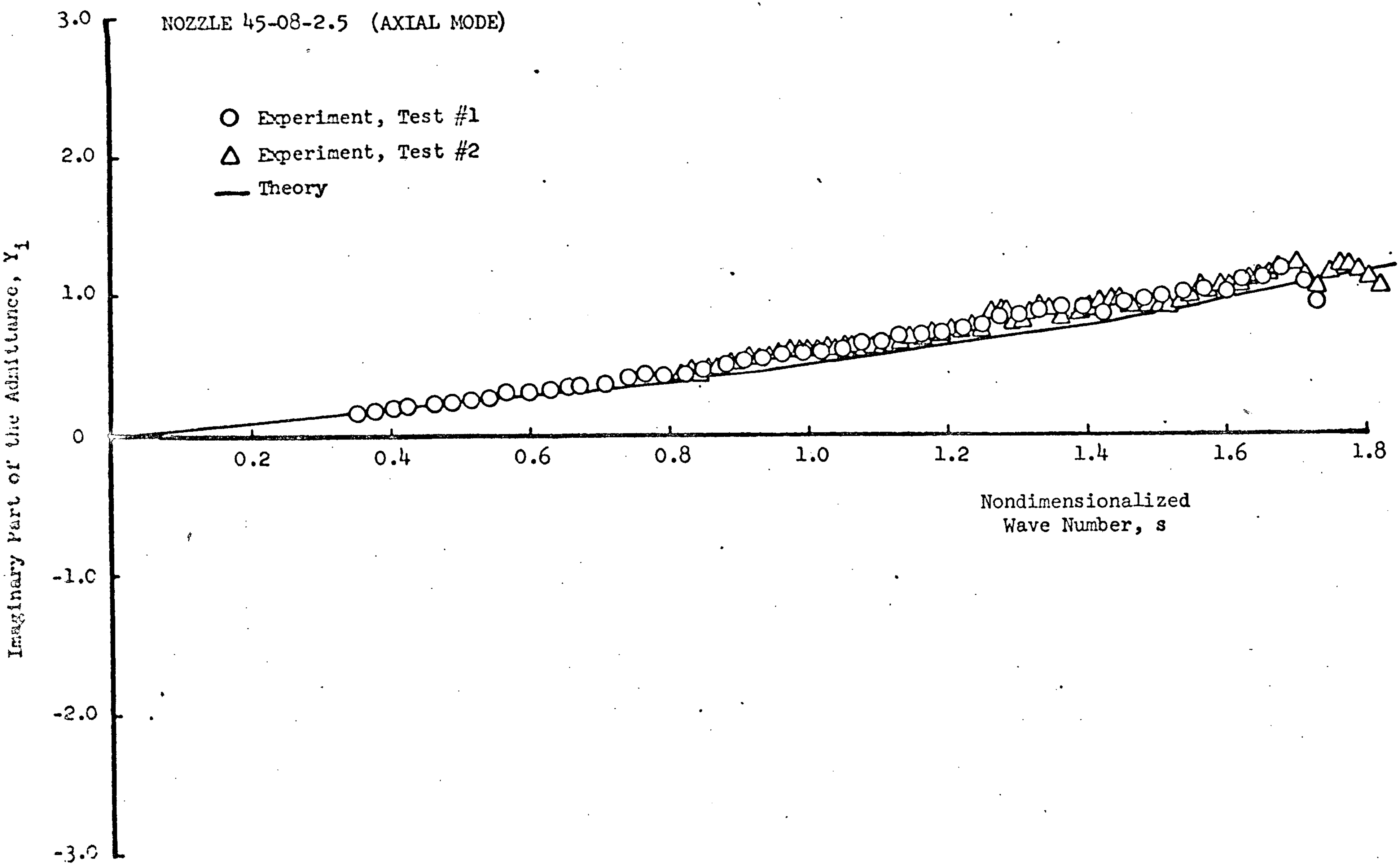

Figure 14. Comparison of the theoretical and experimental values of the imaginary part of the admittance for a nozzle with an entrance Mach number of .08, half-angle of 45 degrees, and radii of curvature at the throat and entrance of 2.5 inches.

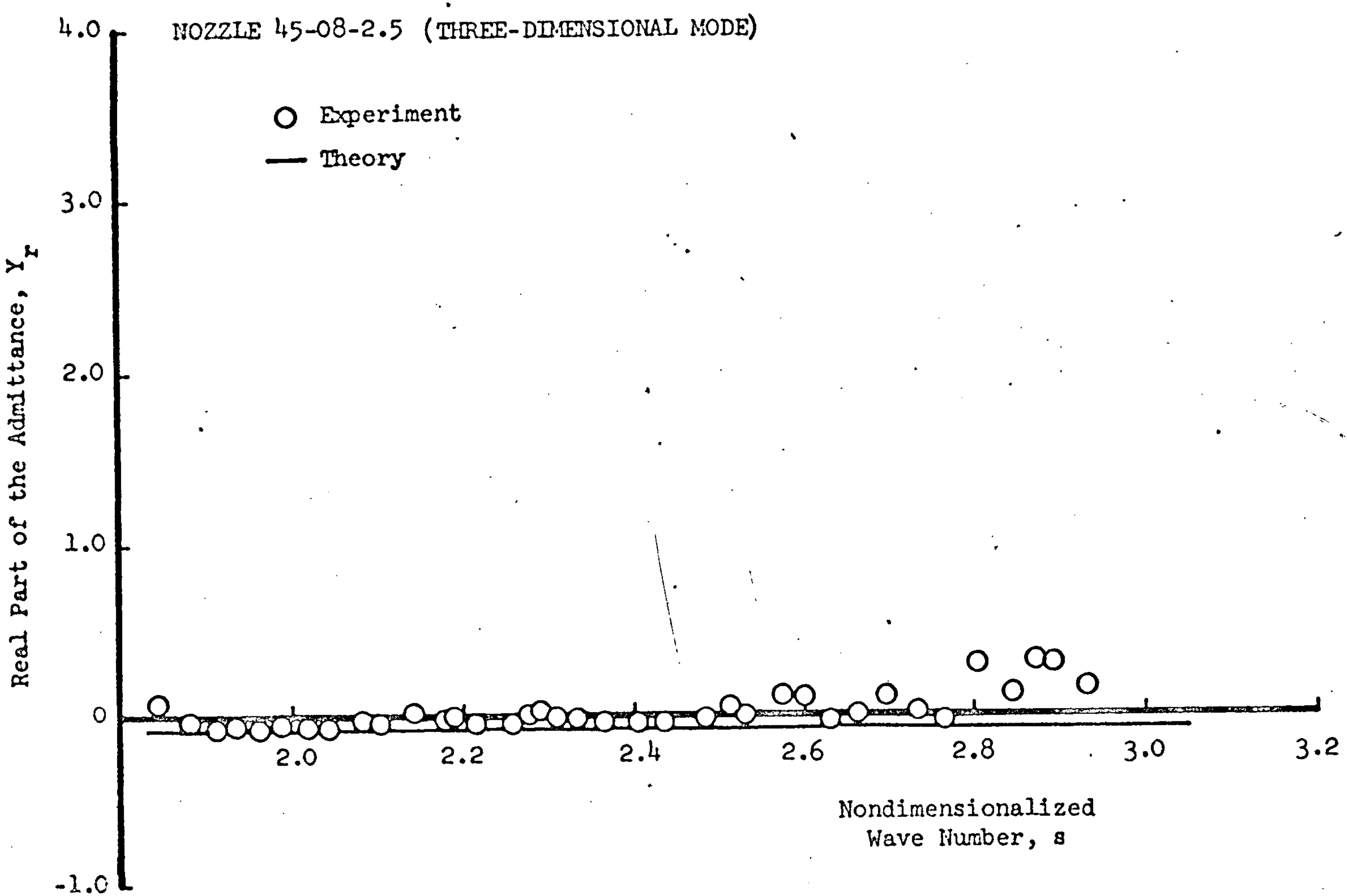

Figure 15. Comparison of the theoretical and experimental values of the real part of the admittance for a nozzle with a half-angle of 45 degrees, entrance Mach number of .08, and radii of curvature at the throat and entrance of 2.5 inches.

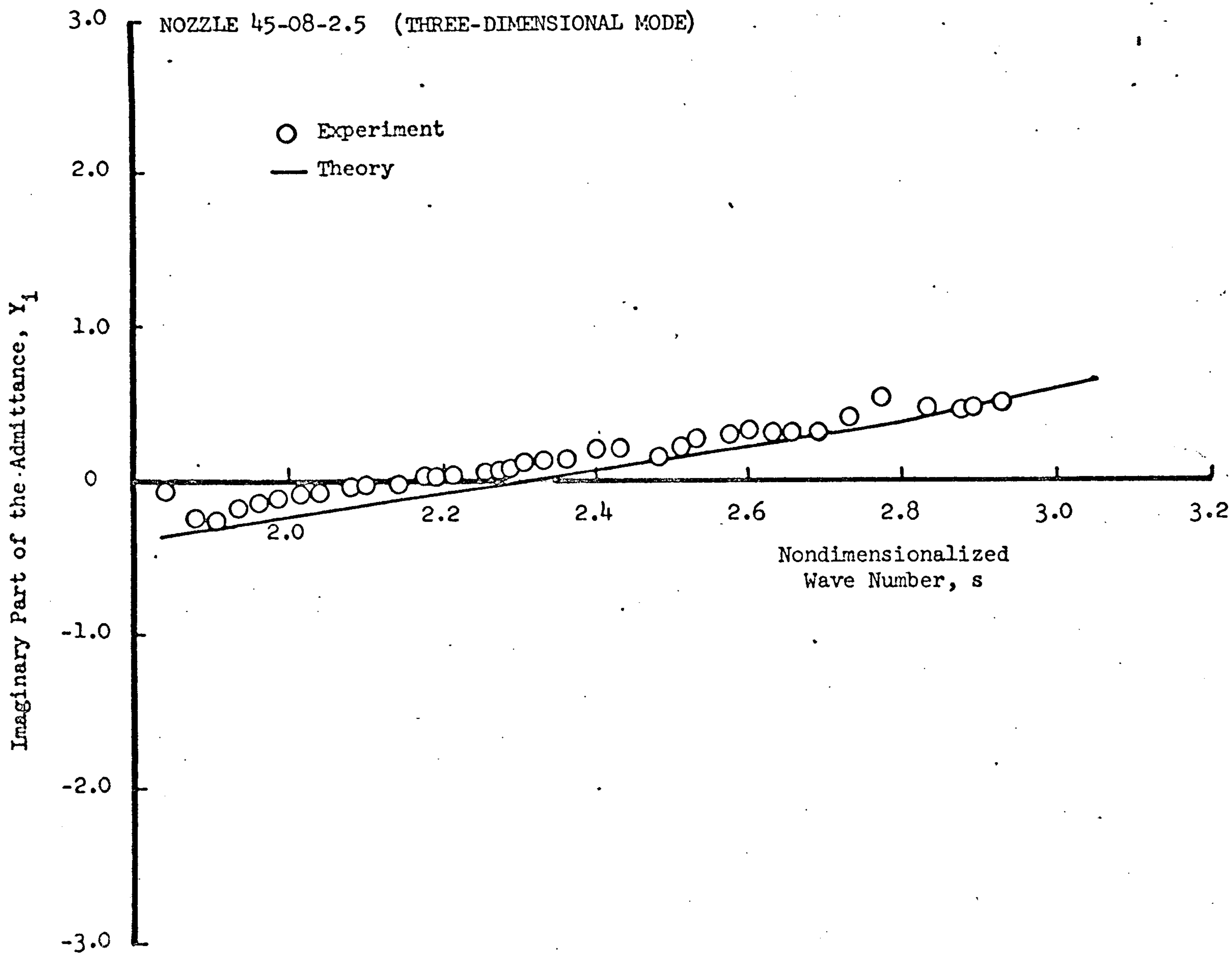

Figure 16. Comparison of the theoretical and experimental values of the imaginary part of the admittance for a nozzle with an entrance Mach number of .08, half-angle of 45 degrees, and radii of curvature at the throat and entrance of 2.5 inches.

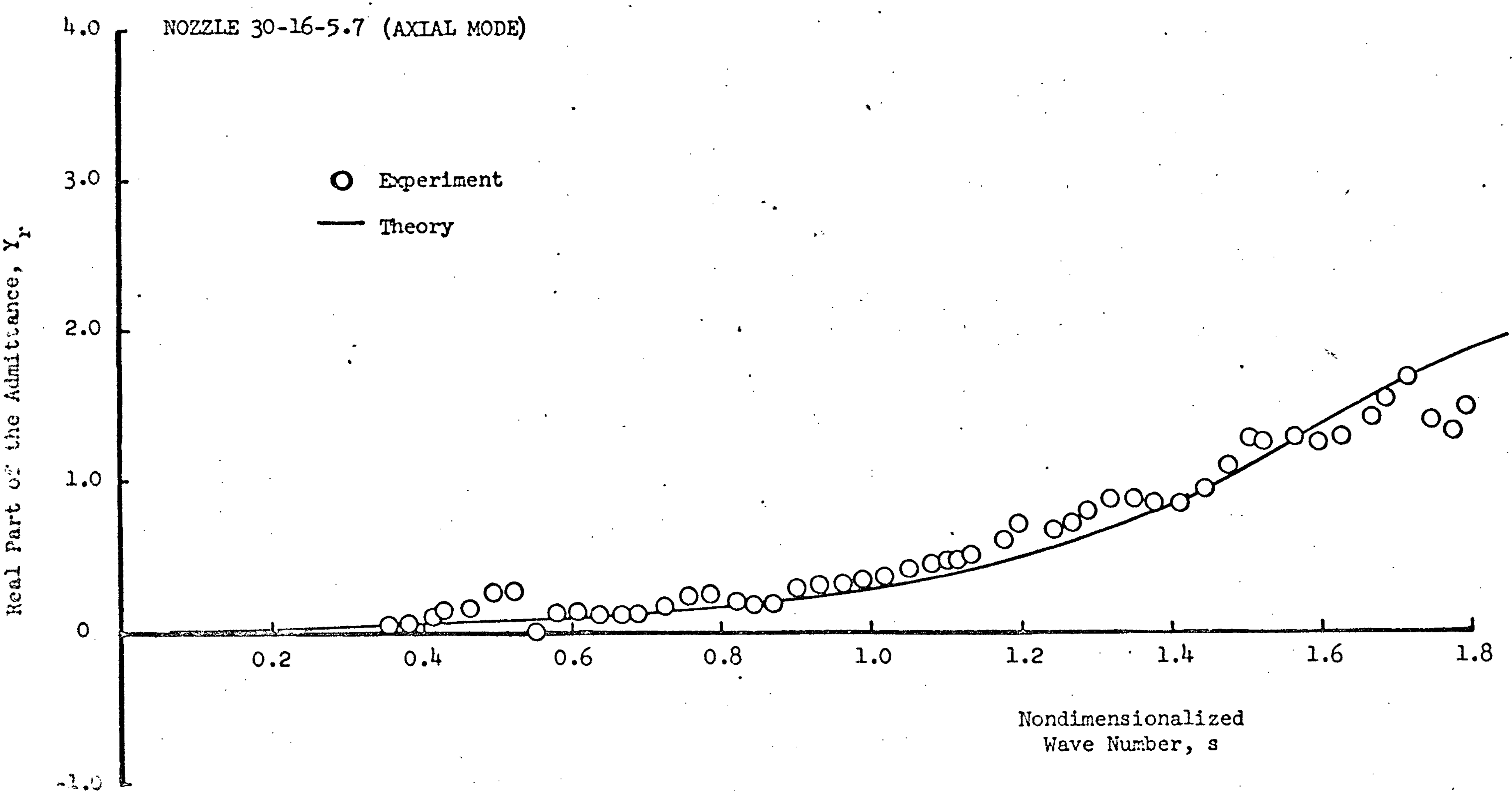

Figure 17. Comparison of the theoretical and experimental values of the real part of the admittance for a nozzle with a half-angle of 30 degrees, entrance Mach number of .16, and radii of curvature at the entrance and throat of 5.7 inches.

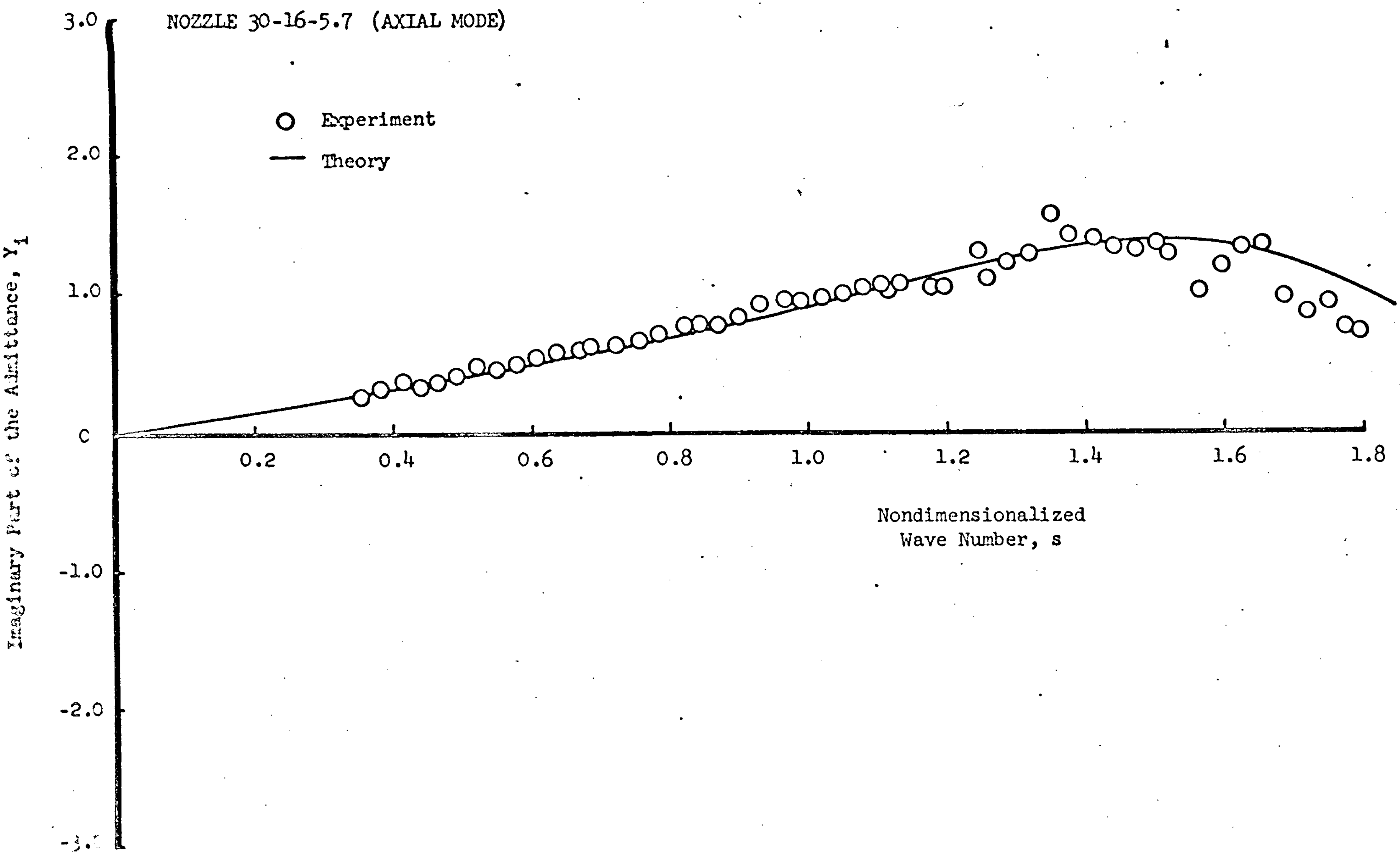

Figure 18. Comparison of the theoretical and experimental values of the imaginary part of the admittance for a nozzle with a half-angle of 30 degrees, entrance Mach number of .16, and radii of curvature at the throat and entrance of 5.7 inches.

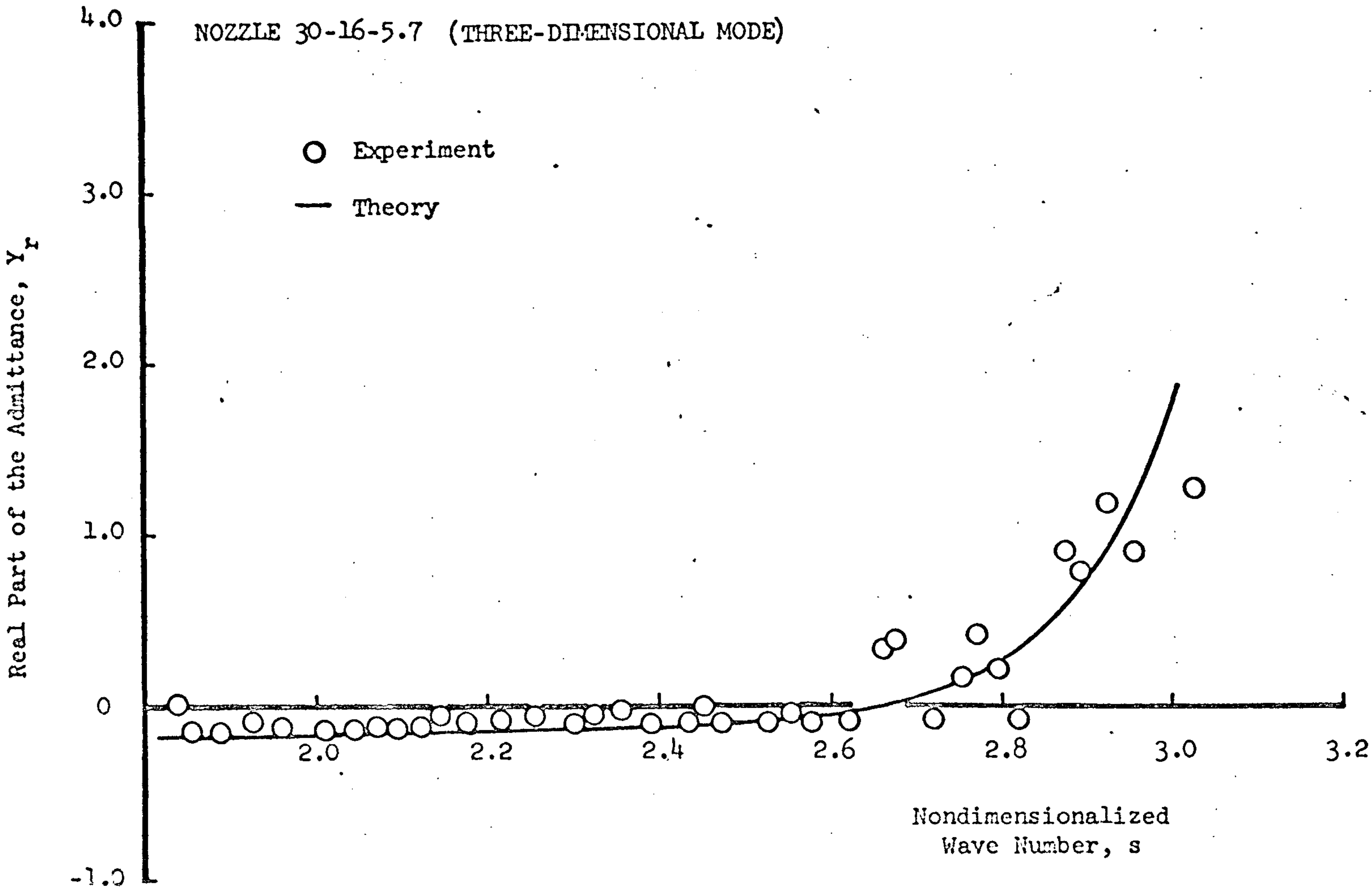

Figure 19. Comparison of the theoretical and experimental values of the real part of the admittance for a nozzle with a half-angle of 30 degrees, entrance Mach number of .16, and radii of curvature at the throat and entrance of 5.7 inches.

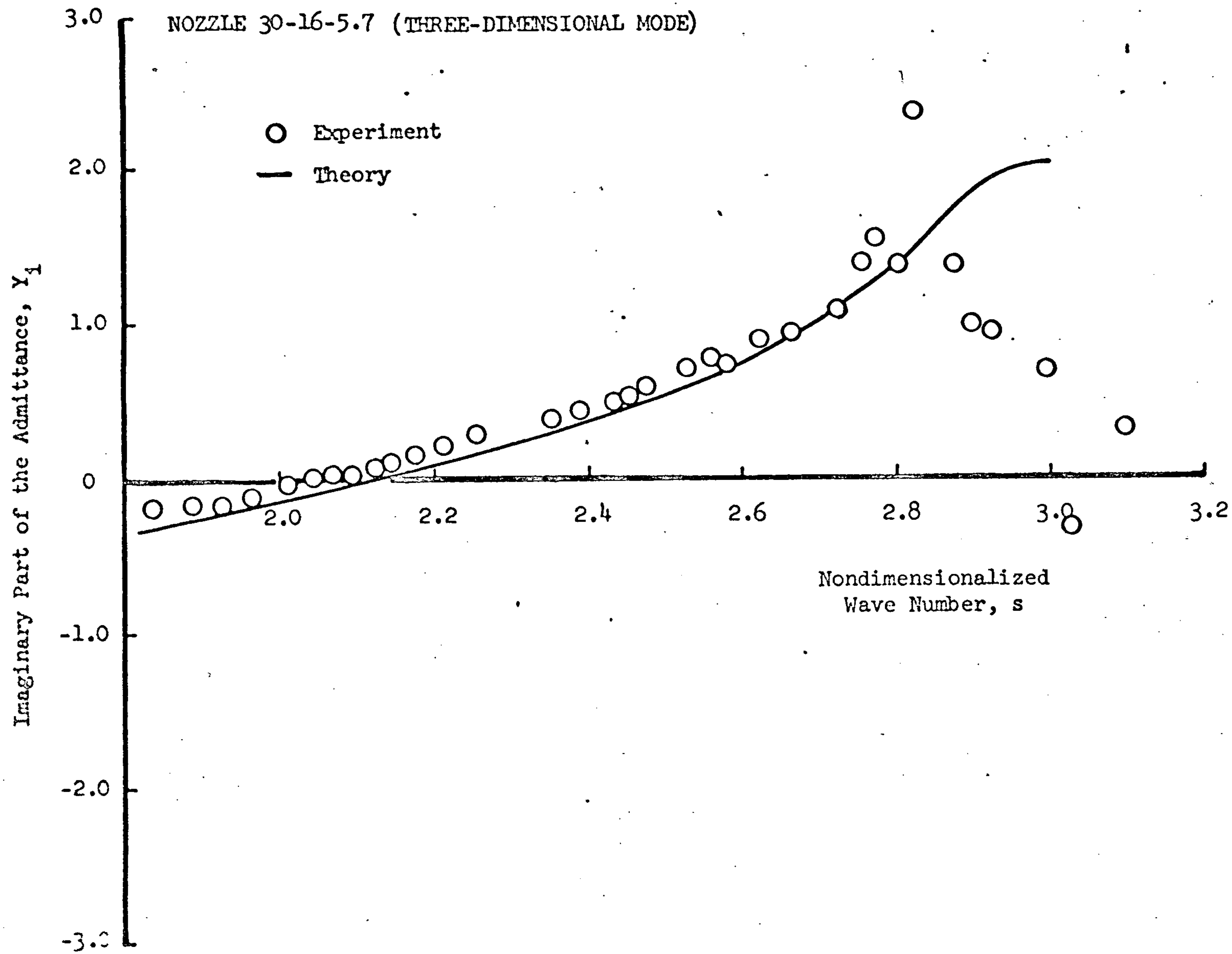

Figure 2[illegible]. Comparison of the theoretical and experimental values of the imaginary part of the admittance for a nozzle with a half-angle of 30 degrees, entrance Mach number of .16, and radii of curvature at the throat and entrance of 5.7 inches.

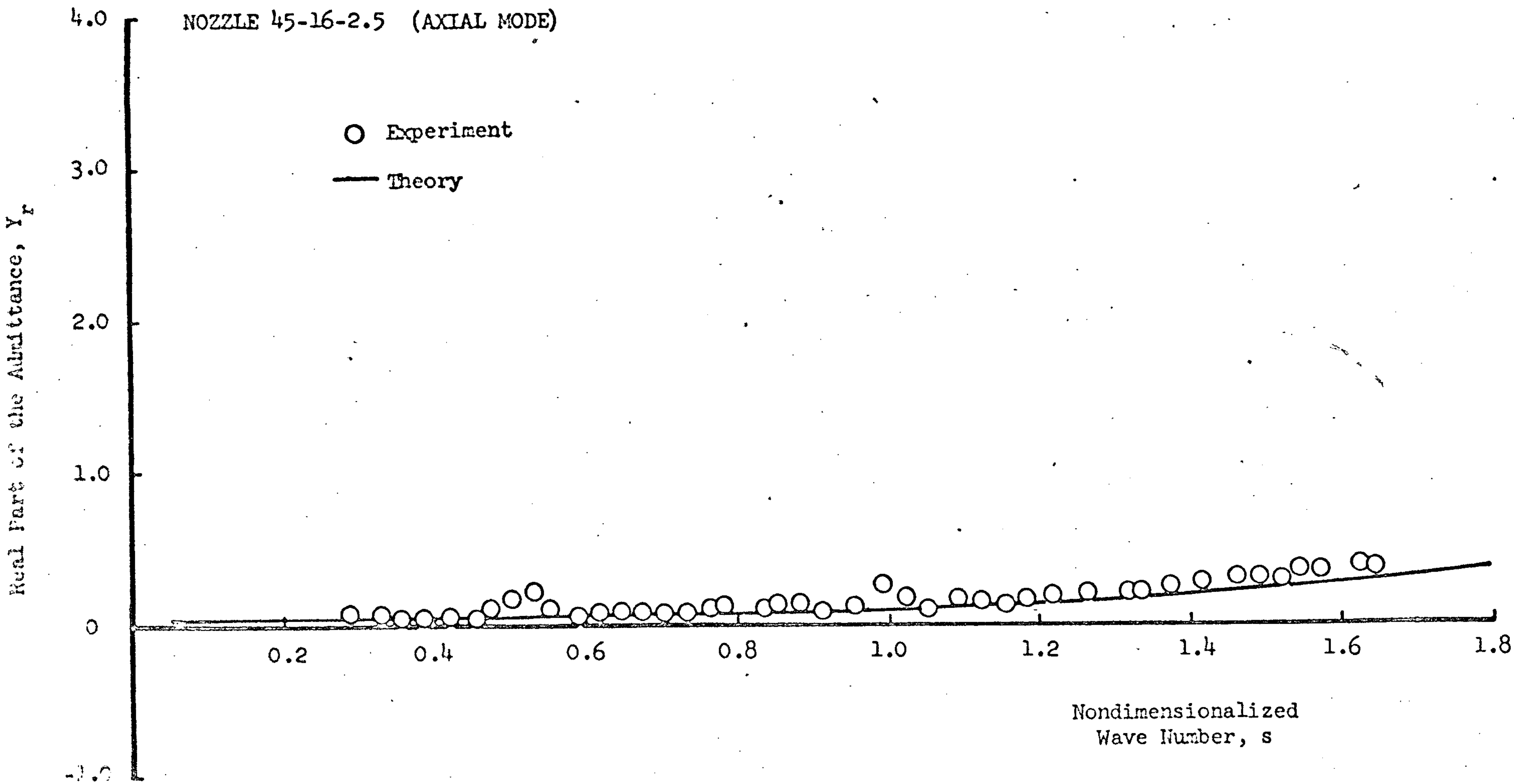

Figure 21. Comparison of the theoretical and experimental values of the real part of the admittance for a nozzle with a half-angle of 45 degrees, entrance Mach number of .16, and radii of curvature at the throat and entrance of 2.5 inches.

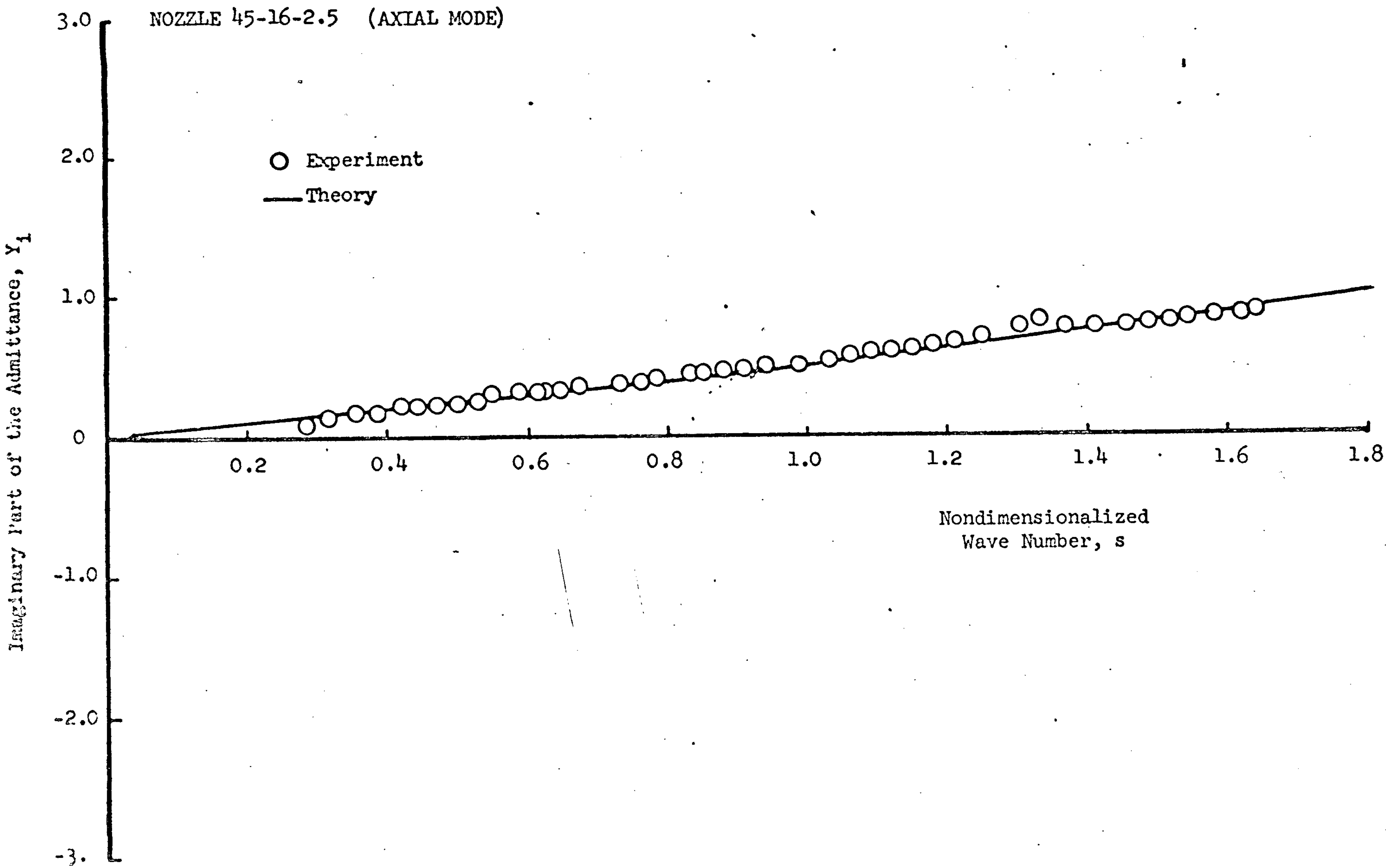

Figure 22. Comparison of the theoretical and experimental values of the imaginary part of the admittance for a nozzle with a half-angle of 45 degrees, entrance Mach number of .16, and radii of curvature at the throat and entrance of 2.5 inches.

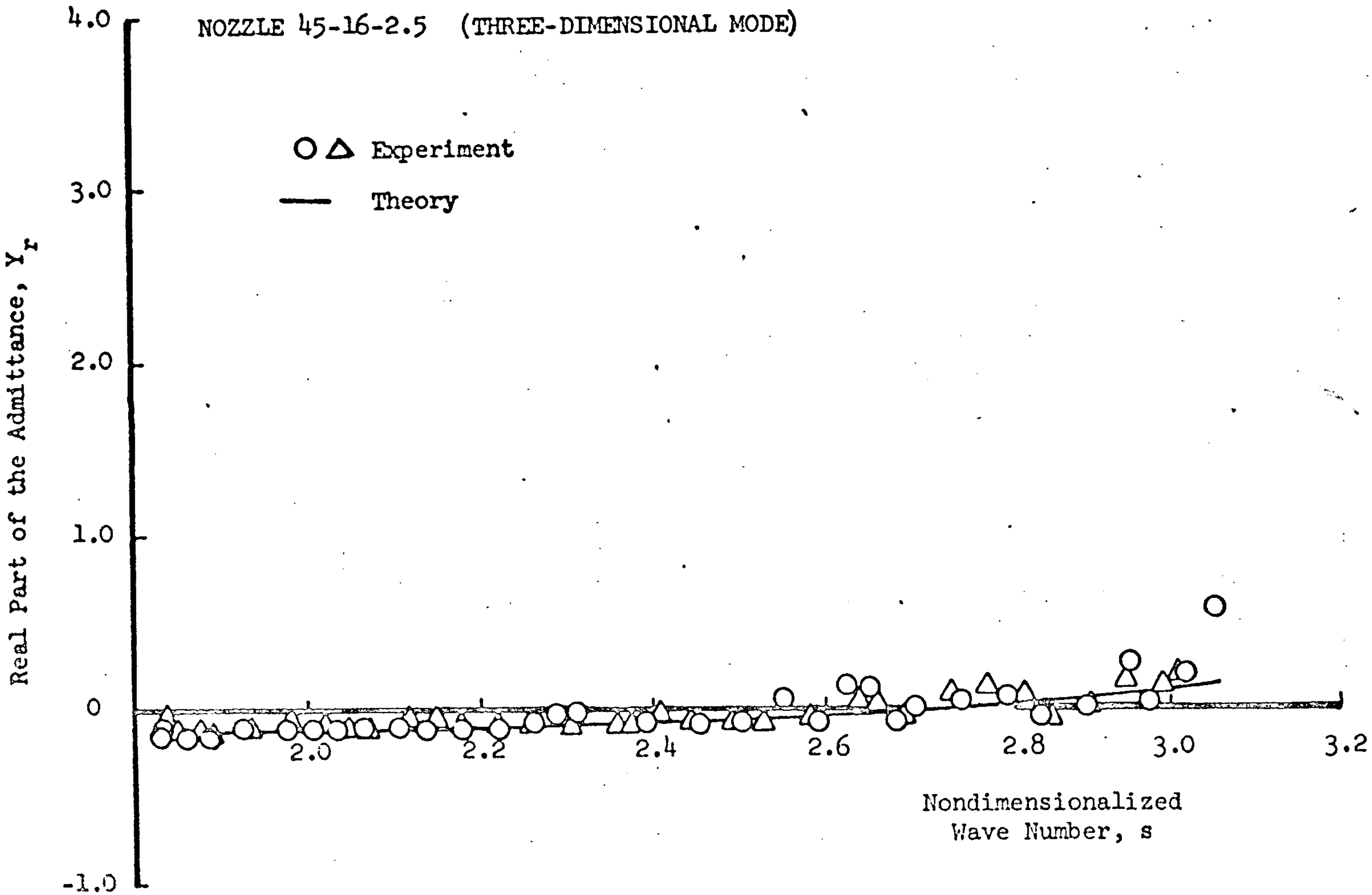

Figure 23. Comparison of the theoretical and experimental values of the real part of the nozzle admittance of a nozzle with a half-angle of 45 degrees, entrance Mach number of .16, and radii of curvature at the throat and entrance of 2.5 inches.

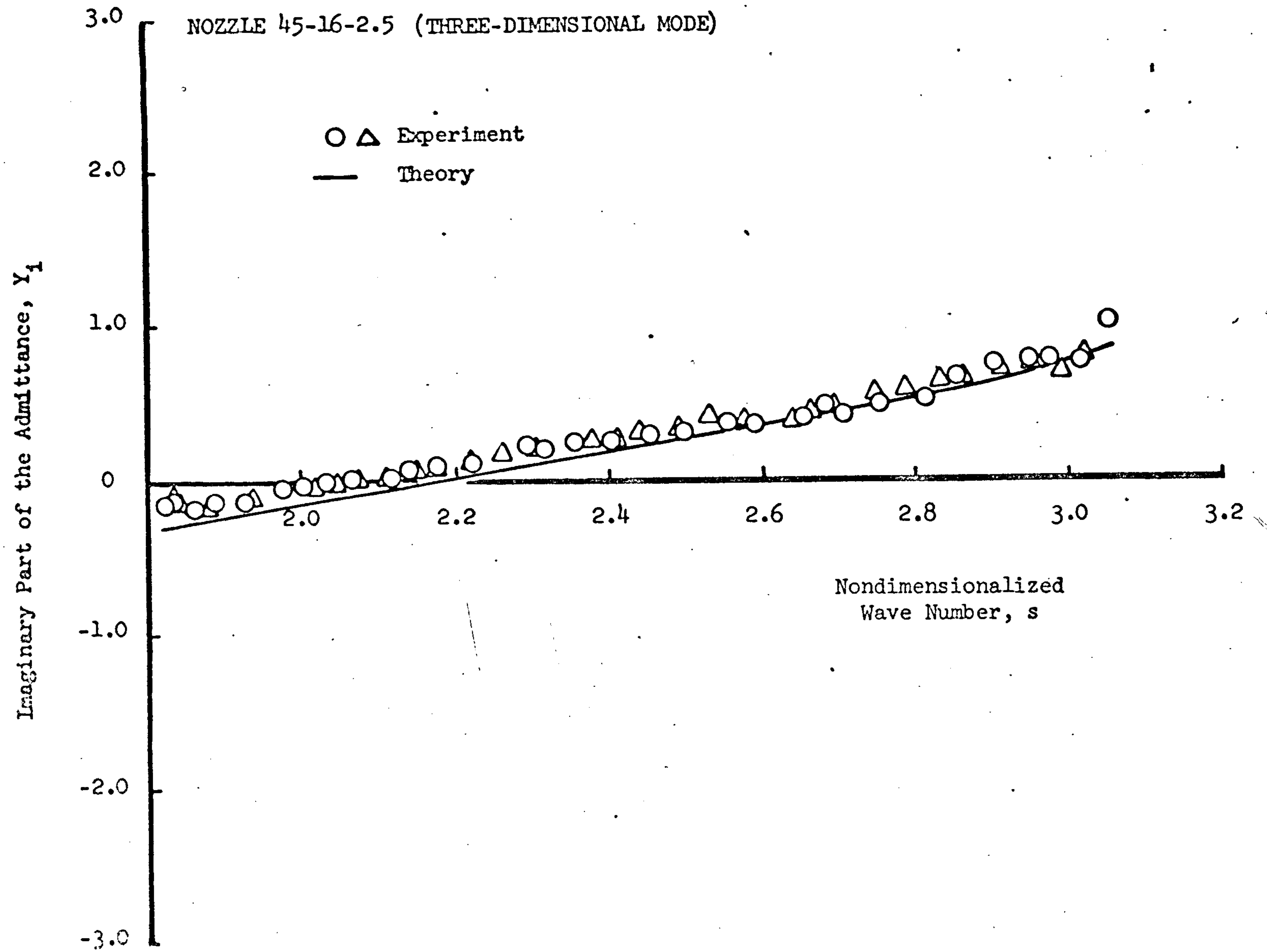

Figure 24. Comparison of the theoretical and experimental values of the imaginary part of the admittance for a nozzle with a half-angle of 45 degrees, entrance Mach number of .16, and radii of curvature at the throat and entrance of 2.5 inches.

APPENDIX A: OUTPUT OF ANALOG-TO-DIGITAL DATA REDUCTION PROGRAM

FOURIER ANALYSIS RESULTS OF A-TO-D DATA, EXAMPLE CASE, A-TO-D PROGRAM AEDPP, TEST B214-61

	HF-FREQ	HF- 8/9	HF-33/9	HF-19/9	HF-40/9	HF-FREQ	HF-35/9	HF-24/9	HF-17/9	HF- 3/9
FREQUENCY = 1000.0, HZ RUN POINT 1										
AMPLITUDE, SPL(DB) =	.99	160.00	160.00	160.00	160.00	.99	160.00	160.00	160.00	160.00
PHASE, DEGREES =	.00	231.86	237.65	175.14	234.60	3.85	258.10	274.64	219.10	331.18
FREQUENCY = 609.1, HZ RUN POINT 2										
AMPLITUDE, SPL(DB) =	1.00	124.28	124.06	100.00	100.00	1.00	128.70	127.54	120.95	134.17
PHASE, DEGREES =	.00	40.46	113.40	68.75	75.07	3.49	126.26	120.12	109.22	10.88
FREQUENCY = 616.7, HZ RUN POINT 3										
AMPLITUDE, SPL(DB) =	.99	131.64	131.62	100.00	100.00	1.00	128.95	121.00	100.00	124.08
PHASE, DEGREES =	.00	214.81	219.08	112.47	32.12	3.87	222.58	219.90	284.46	241.05
FREQUENCY = 625.0, HZ RUN POINT 4										
AMPLITUDE, SPL(DB) =	1.00	124.50	100.00	100.00	125.37	1.00	121.55	124.87	100.00	128.61
PHASE, DEGREES =	.00	275.73	344.24	348.98	37.72	3.53	42.20	332.25	110.17	345.26
FREQUENCY = 632.6, HZ RUN POINT 5										
AMPLITUDE, SPL(DB) =	1.00	130.95	130.74	100.00	130.93	1.00	132.32	129.14	100.00	129.83
PHASE, DEGREES =	.00	169.99	10.58	34.70	44.43	3.31	43.90	351.11	124.97	211.59
FREQUENCY = 640.7, HZ RUN POINT 6										
AMPLITUDE, SPL(DB) =	1.00	127.65	126.52	100.00	126.43	1.00	126.40	100.00	127.51	100.00
PHASE, DEGREES =	.00	77.37	290.09	98.95	22.82	4.14	328.85	88.34	105.09	129.33
FREQUENCY = 648.1, HZ RUN POINT 7										
AMPLITUDE, SPL(DB) =	1.00	126.70	133.30	131.73	127.71	1.01	133.67	131.78	133.90	125.91
PHASE, DEGREES =	.00	152.39	148.13	122.13	146.09	3.58	168.95	145.98	148.77	145.01
FREQUENCY = 656.1, HZ RUN POINT 8										
AMPLITUDE, SPL(DB) =	1.00	126.48	136.71	100.00	129.28	1.01	136.17	137.06	100.00	100.00
PHASE, DEGREES =	.00	313.62	155.64	148.80	140.76	3.78	172.20	163.44	147.18	60.74
FREQUENCY = 663.5, HZ RUN POINT 9										
AMPLITUDE, SPL(DB) =	.99	127.78	137.25	135.89	136.58	.99	139.04	136.57	134.75	132.10
PHASE, DEGREES =	.00	335.97	194.30	215.74	194.43	4.10	208.94	218.60	236.64	351.91
FREQUENCY = 671.5, HZ RUN POINT 10										
AMPLITUDE, SPL(DB) =	1.00	133.74	139.31	140.34	136.02	1.00	139.34	139.58	141.89	126.07
PHASE, DEGREES =	.00	329.99	.20	332.77	27.04	3.89	24.74	351.38	4.24	315.21
FREQUENCY = 678.9, HZ RUN POINT 11										
AMPLITUDE, SPL(DB) =	1.00	160.45	165.06	163.36	162.99	1.00	165.66	164.15	163.20	157.92
PHASE, DEGREES =	.00	112.69	146.70	129.51	155.57	4.04	162.80	154.56	147.79	127.85
FREQUENCY = 687.1, HZ RUN POINT 12										
AMPLITUDE, SPL(DB) =	1.00	170.14	165.44	170.65	156.13	1.00	164.52	159.48	171.00	167.93
PHASE, DEGREES =	.00	339.97	23.78	358.56	47.53	4.17	42.59	23.63	15.31	358.25
FREQUENCY = 693.7, HZ RUN POINT 13										
AMPLITUDE, SPL(DB) =	1.00	168.98	156.54	165.21	162.84	1.01	160.64	160.82	167.54	167.56
PHASE, DEGREES =	.00	142.51	9.61	163.94	22.14	3.91	26.64	189.71	180.59	160.03

FOURIER ANALYSIS RESULTS OF A-TO-D DATA, EXAMPLE CASE, A-TO-D PROGRAM AEDPP, TEST 8214-61

	HF-FREQ	HF- 8/9	HF-33/9	HF-19/9	HF-40/9	HF-FREQ	HF-35/9	HF-24/9	HF-17/9	HF- 3/9
FREQUENCY = 702.2, HZ RUN POINT 14										
AMPLITUDE, SPL(DB) =	1.00	166.89	164.58	158.70	164.38	1.00	156.12	144.38	152.98	165.30
PHASE, DEGREES =	.00	247.01	114.03	268.96	127.34	4.19	132.66	113.87	286.21	264.29
FREQUENCY = 710.0, HZ RUN POINT 15										
AMPLITUDE, SPL(DB) =	.99	165.77	167.29	100.00	162.97	.98	167.71	151.24	159.81	167.14
PHASE, DEGREES =	.00	346.07	210.84	23.43	221.65	4.32	228.08	214.83	25.51	5.35
FREQUENCY = 717.1, HZ RUN POINT 16										
AMPLITUDE, SPL(DB) =	1.00	164.80	165.49	155.52	153.79	1.00	164.64	164.26	145.99	166.29
PHASE, DEGREES =	.00	93.90	314.06	286.70	321.98	4.13	330.89	317.99	209.78	112.87
FREQUENCY = 725.0, HZ RUN POINT 17										
AMPLITUDE, SPL(DB) =	1.03	163.96	163.31	162.83	148.44	1.04	160.12	156.94	158.73	165.54
PHASE, DEGREES =	.00	161.69	21.01	358.10	234.95	4.56	39.72	24.19	18.66	181.24
FREQUENCY = 732.8, HZ RUN POINT 18										
AMPLITUDE, SPL(DB) =	1.00	161.49	153.80	164.63	158.91	1.00	100.00	166.32	162.29	165.03
PHASE, DEGREES =	.00	269.56	129.77	110.25	326.39	4.06	320.01	134.59	129.90	289.82
FREQUENCY = 740.6, HZ RUN POINT 19										
AMPLITUDE, SPL(DB) =	1.00	155.64	147.30	163.01	159.60	1.00	155.71	162.75	161.81	162.90
PHASE, DEGREES =	.00	315.78	2.56	154.99	12.56	4.51	16.86	180.35	173.79	335.23
FREQUENCY = 749.3, HZ RUN POINT 20										
AMPLITUDE, SPL(DB) =	1.03	157.17	161.87	158.55	165.46	1.02	165.84	165.30	167.92	167.56
PHASE, DEGREES =	.00	29.04	67.07	223.08	79.25	4.74	84.94	248.62	242.19	44.45
FREQUENCY = 756.2, HZ RUN POINT 21										
AMPLITUDE, SPL(DB) =	.94	144.67	160.34	163.24	158.96	.95	162.46	159.10	163.26	169.93
PHASE, DEGREES =	.00	129.41	152.72	307.72	168.08	3.91	171.98	335.57	326.33	129.67
FREQUENCY = 764.2, HZ RUN POINT 22										
AMPLITUDE, SPL(DB) =	.98	132.57	161.32	162.31	156.31	.99	162.54	154.11	162.94	160.00
PHASE, DEGREES =	.00	168.88	180.35	336.29	195.95	4.38	199.66	7.79	354.93	155.84
FREQUENCY = 771.8, HZ RUN POINT 23										
AMPLITUDE, SPL(DB) =	1.00	151.17	168.59	167.87	156.48	1.00	168.60	150.26	169.35	165.12
PHASE, DEGREES =	.00	25.27	256.49	52.90	271.98	4.71	276.67	91.85	71.84	233.22
FREQUENCY = 781.1, HZ RUN POINT 24										
AMPLITUDE, SPL(DB) =	1.00	150.16	159.85	158.43	100.00	1.00	158.35	139.08	160.83	156.22
PHASE, DEGREES =	.00	105.23	335.38	130.55	110.83	4.54	357.19	330.61	149.97	314.62
FREQUENCY = 787.6, HZ RUN POINT 25										
AMPLITUDE, SPL(DB) =	1.00	152.09	157.84	155.85	147.96	1.00	154.10	148.90	159.55	153.80
PHASE, DEGREES =	.00	133.04	358.39	154.86	185.94	5.22	19.77	356.30	173.88	331.13
FREQUENCY = 794.4, HZ RUN POINT 26										
AMPLITUDE, SPL(DB) =	1.00	160.40	162.23	158.91	159.99	1.00	154.05	161.12	164.29	167.13
PHASE, DEGREES =	.00	168.49	42.55	201.07	237.97	5.21	67.06	44.59	219.78	21.42

FOURIER ANALYSIS RESULTS OF A-TO-D DATA, EXAMPLE CASE, A-TO-D PROGRAM AEDPP, TEST 8214-61

	HF-FREQ	HF- 8/9	HF-33/9	HF-19/9	HF-40/9	HF-FREQ	HF-35/9	HF-24/9	HF-17/9	HF- 3/9
FREQUENCY = 802.3, HZ RUN POINT 27										
AMPLITUDE, SPL(DB) =	1.00	155.91	153.10	148.02	157.03	1.00	132.48	158.38	157.58	153.65
PHASE, DEGREES =	.00	280.97	158.65	322.62	349.04	5.00	277.32	153.33	333.14	130.55
FREQUENCY = 810.3, HZ RUN POINT 28										
AMPLITUDE, SPL(DB) =	1.00	153.96	139.97	135.82	153.91	1.00	145.66	155.71	150.97	147.39
PHASE, DEGREES =	.00	305.79	185.16	53.53	9.97	5.18	9.24	172.78	358.81	150.99
FREQUENCY = 817.6, HZ RUN POINT 29										
AMPLITUDE, SPL(DB) =	.96	156.23	142.27	142.73	156.50	.95	154.31	158.96	150.61	150.01
PHASE, DEGREES =	.00	316.90	12.08	132.90	28.98	4.72	32.39	191.58	16.84	173.99
FREQUENCY = 825.0, HZ RUN POINT 30										
AMPLITUDE, SPL(DB) =	1.00	165.46	158.44	156.94	162.79	1.00	164.80	166.61	150.47	153.75
PHASE, DEGREES =	.00	68.84	114.93	266.91	136.93	4.72	138.08	304.68	137.53	289.89
FREQUENCY = 834.[illegible], HZ RUN POINT 31										
AMPLITUDE, SPL(DB) =	1.00	155.78	152.29	149.50	150.45	1.00	155.85	155.79	121.20	142.20
PHASE, DEGREES =	.00	113.12	167.51	320.02	191.14	5.01	189.75	350.73	101.82	324.55
FREQUENCY = 840.5, HZ RUN POINT 32										
AMPLITUDE, SPL(DB) =	1.00	154.42	152.61	150.54	143.94	1.00	155.09	153.51	141.04	135.43
PHASE, DEGREES =	.00	125.33	178.52	325.30	205.05	5.01	200.89	3.10	330.09	29.77
FREQUENCY = 849.5, HZ RUN POINT 33										
AMPLITUDE, SPL(DB) =	1.02	159.43	158.88	157.57	139.39	1.01	159.79	158.29	152.02	131.95
PHASE, DEGREES =	.00	145.37	195.77	352.17	209.87	4.76	216.60	24.52	14.52	79.95
FREQUENCY = 855.9, HZ RUN POINT 34										
AMPLITUDE, SPL(DB) =	.97	163.06	162.25	161.33	140.38	.98	162.00	160.40	156.86	142.65
PHASE, DEGREES =	.00	276.48	328.64	120.88	139.08	5.33	350.82	155.08	138.01	275.17
FREQUENCY = 863.3, HZ RUN POINT 35										
AMPLITUDE, SPL(DB) =	.99	153.45	152.54	153.13	143.47	1.00	150.04	148.54	150.62	139.13
PHASE, DEGREES =	.00	298.95	351.66	143.43	186.54	5.05	15.38	182.71	164.33	310.48
FREQUENCY = 872.6, HZ RUN POINT 36										
AMPLITUDE, SPL(DB) =	1.00	152.16	151.35	152.32	143.86	1.00	147.97	145.37	150.48	139.02
PHASE, DEGREES =	.00	311.94	1.58	147.31	199.51	4.74	26.45	178.87	166.60	328.33
FREQUENCY = 880.6, HZ RUN POINT 37										
AMPLITUDE, SPL(DB) =	1.00	157.07	154.24	157.24	152.34	1.00	146.73	143.10	156.22	145.94
PHASE, DEGREES =	.00	327.00	22.08	170.18	209.98	5.17	54.72	207.90	101.65	337.73
FREQUENCY = 888.0, HZ RUN POINT 38										
AMPLITUDE, SPL(DB) =	1.00	162.20	157.24	161.48	158.03	1.00	144.51	138.15	160.81	151.65
PHASE, DEGREES =	.00	100.64	152.76	302.88	343.26	5.66	206.71	38.42	322.89	113.56
FREQUENCY = 894.9, HZ RUN POINT 39										
AMPLITUDE, SPL(DB) =	1.01	140.54	143.34	151.72	146.86	1.00	131.33	100.00	151.75	140.72
PHASE, DEGREES =	.00	115.07	184.35	327.80	6.82	5.39	322.74	108.65	351.72	130.83

FOURIER ANALYSIS RESULTS OF A-TO-D DATA, EXAMPLE CASE, A-TO-D PROGRAM AEDPP, TEST B214-61

	HF-FREQ	HF- 8/9	HF-33/9	HF-19/9	HF-40/9	HF-FREQ	HF-35/9	HF-24/9	HF-17/9	HF- 3/9
FREQUENCY = 902.5, HZ RUN POINT 40										
AMPLITUDE, SPL(DB) =	1.00	149.12	135.34	148.52	145.45	1.01	139.34	138.70	149.94	143.00
PHASE, DEGREES =	.00	126.25	182.56	331.28	24.99	5.42	31.89	191.61	356.18	146.66
FREQUENCY = 910.6, HZ RUN POINT 41										
AMPLITUDE, SPL(DB) =	1.00	150.30	124.97	149.20	147.11	1.00	146.48	145.45	151.85	146.53
PHASE, DEGREES =	.00	138.34	322.86	340.02	30.15	5.44	32.56	187.59	1.24	144.91
FREQUENCY = 916.4, HZ RUN POINT 42										
AMPLITUDE, SPL(DB) =	1.00	161.79	150.82	160.21	155.73	1.00	160.11	158.66	163.22	157.15
PHASE, DEGREES =	.00	219.19	78.83	63.84	110.87	5.32	110.54	271.72	84.67	236.62
FREQUENCY = 925.3, HZ RUN POINT 43										
AMPLITUDE, SPL(DB) =	1.01	149.57	144.79	145.42	139.42	1.02	149.72	147.37	150.57	145.17
PHASE, DEGREES =	.00	293.80	155.11	148.26	205.18	5.10	186.15	349.09	171.93	322.58
FREQUENCY = 933.6, HZ RUN POINT 44										
AMPLITUDE, SPL(DB) =	.99	141.86	141.08	138.57	128.39	.97	144.47	140.37	144.43	140.78
PHASE, DEGREES =	.00	318.28	176.93	148.64	202.15	5.95	198.99	353.48	169.60	339.43
FREQUENCY = 940.5, HZ RUN POINT 45										
AMPLITUDE, SPL(DB) =	.99	142.10	145.35	136.85	100.00	.98	147.26	145.25	149.27	142.61
PHASE, DEGREES =	.00	307.39	172.58	189.55	218.52	5.81	199.69	2.97	190.17	330.78
FREQUENCY = 948.1, HZ RUN POINT 46										
AMPLITUDE, SPL(DB) =	.99	147.86	151.80	137.21	140.47	.99	152.58	152.61	151.25	150.35
PHASE, DEGREES =	.00	329.72	198.08	172.20	31.40	5.84	224.96	34.39	203.70	349.27
FREQUENCY = 956.0, HZ RUN POINT 47										
AMPLITUDE, SPL(DB) =	1.00	143.95	148.37	100.00	142.74	1.00	146.44	148.81	147.89	148.84
PHASE, DEGREES =	.00	111.24	344.70	289.09	173.55	5.31	13.60	161.83	327.65	132.38
FREQUENCY = 964.0, HZ RUN POINT 48										
AMPLITUDE, SPL(DB) =	1.00	137.40	138.17	100.00	135.78	1.00	133.19	139.99	137.65	143.17
PHASE, DEGREES =	.00	112.95	343.26	99.66	160.56	6.17	35.63	174.28	345.97	136.05
FREQUENCY = 970.3, HZ RUN POINT 49										
AMPLITUDE, SPL(DB) =	1.01	135.51	133.99	100.00	137.13	1.01	128.61	138.43	138.50	141.13
PHASE, DEGREES =	.00	138.95	350.04	222.83	176.14	6.01	56.60	185.25	332.44	129.90
FREQUENCY = 977.7, HZ RUN POINT 50										
AMPLITUDE, SPL(DB) =	1.00	122.87	143.37	135.27	138.81	1.01	136.36	135.67	130.34	142.91
PHASE, DEGREES =	.00	197.21	20.54	141.02	200.57	6.15	62.80	171.73	345.67	140.55
FREQUENCY = 986.1, HZ RUN POINT 51										
AMPLITUDE, SPL(DB) =	.96	140.59	149.42	149.10	149.77	.97	133.92	150.46	135.54	153.27
PHASE, DEGREES =	.00	175.03	71.94	209.03	266.90	6.00	136.78	249.51	80.87	208.49

DATA REDUCTION FINISHED, EXAMPLE CASE, A-TO-D PROGRAM AEDPP, TEST B214-61

EXAMPLE CASE, A-TO-D PROGRAM AEDPP, TEST 8214-61 MACH NUMBER = .080, SVN = 1.841

RUN	FREQ	S	****ANGLES****		*******ADMITTANCES*******			*ERROR*	***********PRESSURE DIFFERENCES, DP***********								COMBIN-
POINT	HZ		ALPHA	BETA	RE(Y/YS)	IM(Y/YS)	YS	PRMS	1	2	3	4	5	6	7	8	ATIONS
11	678.9	1.8485	.1133	.0396	.3392	.0938	.1555	.241	.3	-.2	-.2	.0	.4	-.3	.1	-.1	35
12	687.1	1.8715	.1288	.1515	.3059	.2071	.1556	.210	.2	-.2	.0	.0	.2	-.2	.2	-.3	35
13	693.7	1.8902	.0000	.2113	.0755	.3037	.1565	.410	.5	-.3	.0	.0	-.2	-.7	.3	.4	35
14	702.2	1.9142	.0121	.2473	.0953	.2864	.1565	.265	.1	-.4	-.3	.0	.1	.0	.4	.1	35
15	710.0	1.9352	.0000	.2899	.0719	.2458	.1564	.193	-.1	-.1	.0	.0	.4	-.1	-.1	-.1	20
16	717.1	1.9561	.0274	.3185	.1120	.2100	.1564	.134	-.2	-.1	-.1	.0	.2	.2	.0	.0	35
17	725.0	1.9782	.0594	.3571	.1526	.1713	.1563	.259	-.3	.1	.2	.0	.2	.3	-.2	-.3	35
18	732.3	1.9999	.0246	.3964	.1014	.1325	.1563	.035	.1	-.0	.0	.0	.0	-.0	.0	-.0	20
19	740.6	2.0218	.0000	.4149	.0660	.1143	.1562	.390	-.5	-.1	.3	.0	-.6	.0	.6	.2	35
20	749.3	2.0461	.0000	.4330	.0644	.0939	.1562	.479	-.5	-.9	.4	.0	-.1	.3	.5	.3	35
21	756.2	2.0655	.0000	.4671	.0633	.0474	.1562	.383	-.1	-.7	.4	.0	-.1	.3	.5	-.3	35
22	764.2	2.0876	.0000	.4714	.0619	.0427	.1561	.459	-.1	-.7	.2	.0	-.0	.7	.4	-.5	35
23	771.3	2.1092	.0219	.4927	.0944	.0112	.1561	.273	.0	-.5	.2	.0	.1	-.0	.4	-.2	35
24	781.1	2.1353	.0000	.4872	.0592	.0205	.1560	2.274	4.6	-.5	.3	.0	-.2	-3.4	.7	-1.5	35
25	787.6	2.1535	.0453	-.4839	.1319	-.0259	.1560	1.438	1.9	-.0	.9	.0	-.3	-2.3	1.4	-1.7	35
26	794.4	2.1724	.0359	-.4530	.1183	-.0782	.1560	.537	.5	-.0	.4	.0	-.1	-.7	.6	-.7	35
27	802.3	2.1945	.0000	-.4645	.0561	-.0962	.1559	.632	1.0	.3	-.3	.0	-.1	-.3	.6	-1.1	35
28	810.3	2.2171	.0217	-.4384	.0944	-.1090	.1559	1.072	1.6	.4	-.1	.0	-1.0	.4	.6	-1.9	35
29	817.5	2.238[illegible]	.0283	-.4275	.1072	-.1310	.1559	.639	.3	-1.1	.8	.0	.1	.2	.5	-.8	35
30	825.0	2.258[illegible]	.0303	-.3904	.1150	-.2059	.1558	.753	1.1	-1.0	-.2	.0	.4	.3	.5	-1.1	35
31	834.3	2.2842	.0000	-.3921	.0518	-.2090	.1558	.489	1.1	-.4	-.3	.0	.2	-.4	-.0	-.3	35
32	840.5	2.3014	.0232	-.3641	.1037	-.2715	.1558	.426	.7	-.4	-.2	.0	.5	-.6	-.0	.0	35
33	849.5	2.3263	.0128	-.3402	.0818	-.3354	.1557	.291	.0	-.6	-.2	.0	.3	.2	.2	-.0	35
34	855.9	2.3447	.0290	-.3379	.1229	-.3423	.1557	.303	.5	-.6	-.2	.0	.0	.2	.1	-.0	35
35	863.3	2.3654	.0198	-.2985	.1082	-.4503	.1557	.439	-.0	-.7	.1	.0	-.5	.6	.6	-.1	35
36	872.6	2.3914	.0457	-.3167	.1756	-.4028	.1556	.333	-.4	-.4	-.1	.0	.3	.0	.6	-.1	35
37	880.6	2.4135	.0355	-.2833	.1640	-.5118	.1556	.286	-.2	-.3	-.0	.0	.5	-.3	.3	.0	35
38	888.0	2.4346	.0000	-.2981	.0456	-.4815	.1556	1.140	.0	-.8	-.7	.0	2.2	-1.3	-.4	1.0	35
39	894.3	2.4535	.0000	-.2906	.0449	-.5169	.1555	.915	-1.3	-.8	.9	.0	-.2	.0	1.4	-.0	20
40	902.5	2.4753	.0000	-.2679	.0441	-.5972	.1555	.905	.0	-.1	-.3	.0	-1.7	-.1	.6	1.5	35
41	910.6	2.4979	.0000	-.2538	.0433	-.6599	.1555	.800	-.1	-.2	-1.0	.0	-.8	.3	.2	1.5	35
42	918.4	2.5193	.0000	-.2481	.0426	-.6912	.1554	.314	-.0	-.2	-.3	.0	-.4	.2	.4	.4	35
43	925.3	2.5391	.0000	-.2139	.0419	-.8658	.1554	.617	1.0	.2	-.9	.0	.0	-.9	.5	.1	35
44	933.6	2.5624	.0570	-.2160	.3845	-.7742	.1554	1.051	-.1	.3	-.3	.0	.6	-2.3	1.1	.7	35
45	940.5	2.5820	.0000	-.1811	.0406	-1.0964	.1554	.634	-.6	.6	.1	.0	1.2	-.5	-.3	-.6	35
46	948.1	2.6033	.0000	-.1603	.0390	-1.2834	.1553	.520	-.3	-.6	-.2	.0	.3	-.2	1.1	-.2	35
47	956.0	2.6254	.2251	-.0779	1.1036	-.2596	.1553	1.059	-1.3	-.5	.0	.0	-.8	.1	2.0	.4	20
48	964.0	2.6480	.0960	.1382	.8883	1.0130	.1553	1.067	-.4	-1.3	.0	.0	-.7	1.7	1.2	-.5	20
49	970.3	2.6655	.0002	.1260	.0404	1.7295	.1553	2.657	-.3	-2.7	.0	.0	-2.2	3.1	4.0	-2.2	20
50	977.7	2.6863	.0000	-.0853	.0375	-2.6523	.1552	3.775	-5.5	2.7	-.5	.0	5.9	-4.9	1.2	1.0	35
51	986.1	2.7100	.0287	-.0973	.8531	-2.3480	.1552	1.056	2.1	-1.0	.5	.0	.0	-.2	-1.5	.1	35
									.1	-.3	-.0	.0	.1	-.2	.5	-.1	

```
NORMAL EXIT.  EXECUTION TIME:        28933 MILLISECONDS.

@FIN

     RUNID:  0188     REF. NO: 51E16617          NAME: SMITH-A-J
        LOAD U399N  4/2 A-J           -1 0188
     1-0188*MSG: PLEASE ANSWER G TO ALL TAPE ERRORS
     1
     TIME: 00:00:28.946    IN: 27      OUT: 0        PAGES:   8
     INITIATION  TIME:    10:08:46-DEC  3,1971
     TERMINATION TIME:    10:13:15-DEC  3,1971
       0188   FIN 28.945 8 0
```