

UNCLASSIFIED

AD NUMBER
AD011504
NEW LIMITATION CHANGE
TO Approved for public release, distribution unlimited
FROM Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; 15 MAY 1953. Other requests shall be referred to Office of Naval Research, Arlington, VA 22203.
AUTHORITY
ONR ltr dtd 26 Oct 1977

THIS PAGE IS UNCLASSIFIED

Reproduced by

Armed Services Technical Information Agency DOCUMENT SERVICE CENTER

KNOTT BUILDING, DAYTON, 2, OHIO

AD -

11504

UNCLASSIFIED

**Best
Available
Copy**

AD NO. **11504**
ASTIA FILE COPY

Incipient-Cavitation Scaling Experiments

for

Hemispherical and 1.5-Caliber Ogive-Nosed Bodies

A Joint Study by

**The Hydrodynamics Laboratory
California Institute of Technology**

and

**Ordnance Research Laboratory
The Pennsylvania State College**

May 15, 1953

Serial No. NOrd 7958-264

Copy No. **31**

Department of the Navy

Office of Naval Research
Contract Nour-24433 NR 062-124

Bureau of Ordnance
Contract NOrd-7958

Incipient-Cavitation Scaling Experiments

for

Hemispherical and 1.5-Caliber Ogive-Nosed Bodies

A Joint Study by

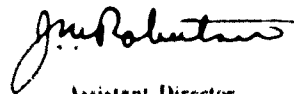
The Hydrodynamics Laboratory
California Institute of Technology

and

Ordnance Research Laboratory
The Pennsylvania State College

May 15, 1953

Approved for Distribution



Assistant Director
Ordnance Research Laboratory
The Pennsylvania State College

By
Blaine R. Parkin
J. W. Hall



The Hydrodynamics Laboratory
California Institute of Technology

Distribution List

Chief, Bureau of Ordnance (Reb) Department of the Navy Washington 25, D. C.	2 copies	Westinghouse Electric Corporation Sharon, Pennsylvania	1 copy
Chief, Bureau of Ordnance (Ad3) Department of the Navy Washington 25, D. C.	2 copies	Via: Development Contract Administrator Westinghouse Electric Corporation Sharon, Pennsylvania	
British Joint Services Mission (Navy Staff) Room 4930, Main Navy Building 18th & Constitution Avenue Washington 25, D. C.	3 copies	Aerojet Corporation Azusa, California	1 copy
Via: Bureau of Ordnance (Ad8) Department of the Navy Washington 25, D. C.		Via: Bureau of Aeronautics Representative 15 South Raymond Street Pasadena, California	
Commander U. S. Naval Ordnance Test Station, Inyokern China Lake, California	1 copy	National Advisory Committee for Aeronautics 1724 "F" Street, N. W. Washington, D. C.	1 copy
Commander U. S. Naval Ordnance Test Station 1202 East Foothill Pasadena Activity Pasadena 8, California	1 copy	Director, Experimental Towing Tank Stevens Institute of Technology 711 Hudson Street Hoboken, New Jersey	1 copy
Director, Ordnance Research Laboratory Pennsylvania State College State College, Pennsylvania	1 copy	Via: Inspector of Naval Material Naval Industrial Reserve Shipyard Building 13 Port Newark, New Jersey	
Via: Development Contract Administrator Ordnance Research Laboratory Pennsylvania State College State College, Pennsylvania		Director, Hydrodynamics Laboratory California Institute of Technology Pasadena, California	1 copy
Commander U. S. Naval Ordnance Laboratory White Oak Silver Spring 19, Maryland	2 copies	Via: Inspector of Naval Material 1206 South Santee Street Los Angeles 15, California	
Commanding Officer U. S. Naval Underwater Ordnance Station Newport, Rhode Island	2 copies	Chief, Bureau of Ships Department of the Navy Washington 25, D. C.	1 copy
Director, Applied Physics Laboratory University of Washington Seattle, Washington	1 copy	Chief, Bureau of Aeronautics Department of the Navy Washington 25, D. C.	1 copy
Via: Inspector of Naval Material 412 Lyon Building 607 Third Avenue Seattle 4, Washington		Johns Hopkins University (Mr. Wiscelcenus) Baltimore, Maryland	1 copy
Commanding Officer and Director David Taylor Model Basin Carderock, Maryland	1 copy	Via: Inspector of Naval Material 401 Water Street Baltimore 2, Maryland	
Chief of Naval Research Department of the Navy Washington 25, D. C.	1 copy	Brush Development Company 1405 Perkins Avenue Cleveland 14, Ohio	1 copy
Director U. S. Naval Research Laboratory Washington 25, D. C.	1 copy	Via: Inspector of Naval Material 1620 Euclid Avenue, 3rd Floor Cleveland 15, Ohio	
Chief of Naval Operations (OP 316) Department of the Navy Washington 25, D. C.	1 copy	Chief of Naval Research c/o Technical Information Division Library of Congress Washington 25, D. C.	2 copies
General Electric Company Pittsfield, Massachusetts	1 copy	University of Minnesota Hydrodynamics Laboratory Minneapolis, Minnesota	1 copy
Via: Naval Inspector of Ordnance Schenectady, New York		Hydrodynamics Laboratory Massachusetts Institute of Technology Cambridge, Massachusetts	1 copy
General Electric Company Schenectady, New York	1 copy	Illinois Institute of Technology Chicago, Illinois	1 copy
Via: Naval Inspector of Ordnance Schenectady, New York		Physics Department (Mr. Lindsay) Brown University Providence, Rhode Island	1 copy

DISTRIBUTION LIST CONTINUED
(Contract N6onr-24435)

Chief of Naval Research (N482) Office of Naval Research Department of the Navy Washington 25, D. C.	11 copies	Director, Office of Naval Research Chicago Branch American Fore Building 844 North Rush Street Chicago 11, Illinois	1 copy
Director, Office of Naval Research Boston Branch 495 Summer Street Boston 10, Massachusetts	1 copy	Aerojet Engineering Corporation 332 North Irwindale Road Azusa, California Attention: C. Gongwer	1 copy
Director, Office of Naval Research 346 Broadway New York 13, New York	2 copies	Commander, Naval Ordnance Test Station, Inyokern China Lake, California Attention: Technical Library, Code 5507	1 copy
Office of Naval Research London Branch Office of Asst. Naval Attache for Research American Embassy, Navy 100 Fleet Post Office New York, New York	2 copies	Officer-in-Charge, Pasadena Annex Naval Ordnance Test Station, Inyokern 3202 East Foothill Boulevard Pasadena, California Attention: Pasadena Annex Library, Code P5507	2 copies
Director, Office of Naval Research Los Angeles Branch 1030 East Green Street Pasadena 1, California	2 copies	Commander, Submarine Development Group Two Box 70, U. S. Naval Submarine Base New London, Connecticut	1 copy
Director, Office of Naval Research San Francisco Branch 801 Donahue Street San Francisco 24, California	1 copy	Dr. F. C. Lindvall California Institute of Technology 1201 East California Street Pasadena 4, California	1 copy

Abstract

THIS REPORT presents the results of the joint experimental program on cavitation scale effects conducted at the Ordnance Research Laboratory, The Pennsylvania State College, and the Hydrodynamics Laboratory, California Institute of Technology. Two families of axially symmetric bodies were tested in the Garfield Thomas Water Tunnel at ORL and in the High-Speed Water Tunnel at CIT. One family of bodies consisted of models with hemispherical noses while the other geometrically similar family had 1.5-caliber ogive noses.

It was found that in spite of differences in the test facilities, such as the resorber in the High-Speed Water Tunnel circuit, the measurements for incipient cavitation taken at CIT and ORL showed good agreement. The dependence of the incipient cavitation number upon free-stream velocity and model size, previously observed at CIT, was verified. In addition, the range of model sizes was extended to larger scale for the ORL experiments. It was found that the values for the incipient cavitation number for each family of models could be represented as a function of the product of the flow velocity and the square root of the model size. These results show that for cavitation tests of small models it is not correct to assume that the incipient cavitation number equals the negative of the minimum pressure coefficient.



Contents

	PAGE
Introduction.....	1
Test Procedure.....	2
Reduction of Data.....	4
Discussion of Results.....	6
Dependence of σ_i on V_0	6
Dependence of σ_i on Reynolds Number.....	13
Dependence of σ_i on $Vd^{1/2}$	13
Conclusions.....	19
Appendix A.....	21
Models and Test Configurations.....	21
Appendix B.....	24
Corrections for Tunnel Constraint.....	24
Appendix C.....	26
Tables of Experimental Data.....	26
References.....	33

Illustrations

	PAGE
Fig. 1. Noise Generated by Cavitation on 1-1/8-Inch Hemisphere - ORL Data.....	3
Fig. 2. Incipient Cavitation Number vs Free-Stream Velocity for 1/4-Inch Hemisphere - CIT and ORL Data.....	7
Fig. 3. Incipient Cavitation Number vs Free-Stream Velocity for 3/8-Inch Hemisphere - CIT and ORL Data.....	7
Fig. 4. Incipient Cavitation Number vs Free-Stream Velocity for 1/2-Inch Hemisphere - CIT and ORL Data.....	8
Fig. 5. Incipient Cavitation Number vs Free-Stream Velocity for 1-1/8-Inch Hemisphere - CIT and ORL Data.....	8
Fig. 6. Incipient Cavitation Number vs Free-Stream Velocity for 2-Inch Hemisphere - CIT and ORL Data.....	9

	PAGE
Fig. 7. Incipient Cavitation Number vs Free-Stream Velocity for 4-Inch Hemisphere - CIT and ORL Data	9
Fig. 8. Incipient Cavitation Number vs Free-Stream Velocity for 8-Inch Hemisphere - ORL Data	10
Fig. 9. Incipient Cavitation Number vs Free-Stream Velocity for 1/2-Inch Ogive - CIT and ORL Data	10
Fig. 10. Incipient Cavitation Number vs Free-Stream Velocity for 1-Inch Ogive - CIT and ORL Data	11
Fig. 11. Incipient Cavitation Number vs Free-Stream Velocity for 2-Inch Ogive - CIT and ORL Data	11
Fig. 12. Incipient Cavitation Number vs Free-Stream Velocity for 4-Inch Ogive - CIT and ORL Data	12
Fig. 13. Effect of Free-Stream Velocity upon Incipient Cavitation for All Hemisphere and Ogive Models	12
Fig. 14. Effect of Model Size upon Incipient Cavitation for Several Values of the Free-Stream Velocity	13
Fig. 15. Incipient Cavitation Number vs Reynolds Number - ORL Data	14
Fig. 16. Incipient Cavitation Number vs Reynolds Number - CIT Data	14
Fig. 17. Correlation of ORL Hemisphere Data with $v_0 \sqrt{d}$	16
Fig. 18. Correlation of CIT Hemisphere Data with $v_0 \sqrt{d}$	16
Fig. 19. Correlation of ORL Ogive Data with $v_0 \sqrt{d}$	17
Fig. 20. Correlation of CIT Ogive Data with $v_0 \sqrt{d}$	17
Fig. 21. A Comparison of $v_0 \sqrt{d}$ Correlations Obtained at CIT and ORL	18
Fig. A-1. ORL Arrangement for Supporting 4-Inch Hemisphere ...	21
Fig. A-2. The 4-Inch 1.5-Caliber Ogive Model Installed in the High-Speed Water Tunnel	23
Fig. B-1. Experimentally Determined Blockage Correction Factors	25
Fig. B-2. Pressure Distribution Around 4-Inch Hemisphere Nose in the High-Speed Water Tunnel	25
Fig. B-3. Comparison of CIT and ORL Data for 4-Inch Hemisphere with Iowa and CIT Blockage Corrections Applied to CIT Data	25
Fig. B-4. Effect of Tunnel Walls upon the Pressure Distribution of 1.5-Caliber Ogive Noses	25

Introduction

EXPERIMENTS at the Hydrodynamics Laboratory, California Institute of Technology^{1, 2*}, have shown that the inception of cavitation on geometrically similar bodies in steady rectilinear liquid flow is definitely influenced by the size of the body and the free-stream velocity. Further, it has been found theoretically that if Reynolds-number effects are neglected, the inception of cavitation still depends upon both free-stream velocity and model size³. For the experiments performed at CIT, the largest body in any geometrically similar family of axially symmetric models was two inches in diameter. Consequently, it was desirable to extend the range to larger sizes. Further, no other laboratory had attempted to confirm the trends observed at CIT. Therefore, the Ordnance Research Laboratory at The Pennsylvania State College and the Hydrodynamics Laboratory at CIT have been cooperating in a joint research program to extend observations of incipient cavitation to larger models and to compare the results obtained when a given series of models is tested in two different test facilities. This report presents the results of the joint research program which was carried out in the 14-inch High-Speed Water Tunnel of the Hydrodynamics Laboratory, CIT, and the 48-inch Garfield Thomas Water Tunnel at ORL.

Throughout this report we shall use the term "incipient cavitation number", σ , to designate that state of liquid flow in which cavitation disappears as the static pressure is slowly increased at constant free-stream velocity.** We shall also include that state in which small wisps of cavitation occur only intermittently near the point of lowest pressure on the model. This definition is only one of several ways by which the inception conditions could be determined. For example, it might seem more logical to require that the

pressure be lowered from the noncavitating flow state to determine incipient cavitation. However, experience has shown that the present definition enables one to obtain reproducible data for that flow state at the highest free-stream static pressure for which cavitation can occur at a given velocity on smooth bodies. If the pressure is lowered to this value, cavitation may or may not occur, and its occurrence depends in a random manner upon the time during which the pressure is held at the lower value. Thus, the present definition offers the engineering advantage that conservative values can be found, and it simplifies the problem by excluding any time dependence as well as giving reproducible experimental results. We use the customary definition for the cavitation number, σ , namely,

$$\sigma = \frac{p_0 - p_v}{\frac{1}{2} \rho V_0^2}$$

where p_0 is the free-stream static pressure, p_v is the liquid vapor pressure, ρ is the liquid density, and V_0 is the free-stream velocity.

In this investigation we have confined ourselves to determining visually the incipient cavitation number of two families of geometrically similar axially symmetric bodies in steady rectilinear flows at various free-stream velocities and at several values of dissolved-air content. The two model shapes consist of right circular cylindrical bodies with hemispherical noses for one family and with 1.5-caliber ogive noses for the other family. The family of hemispheres includes models 1/4, 3/8, 1/2, 1-1/8, 2, 4 and 8 inches in diameter while the family of 1.5-caliber ogives includes models 1/2, 1, 2 and 4 inches in diameter. Except for the four- and eight-inch models, the hemispheres were among those tested by Kermeen² at CIT. More detailed descriptions of the models and the test arrangements are given in Appendix A of this report.

* Superscripted numbers refer to the list of references.

** Kermeen² calls this flow state "intermittent incipient cavitation".

Test Procedure

The general test procedures for the tests at ORL and CIT were essentially the same for all models. The tunnel velocity was held constant and the free-stream static pressure was lowered until cavitation was established around the entire nose. The pressure was then raised until incipient cavitation was seen to exist (usually on top of the model near the lowest-pressure point). The free-stream static pressure measurement was then recorded and free-stream velocity readings were taken in terms of the pressure differentials across the water-tunnel nozzles. At both CIT and ORL, tunnel pressure fluctuations caused the conditions for incipient cavitation to be unsteady. The test conditions at ORL, and occasionally at CIT, would change from too much cavitation to incipient cavitation and then to no cavitation. The entire cycle repeated itself in various orders. At CIT, where the fluctuations were less severe, a random pressure rise would often cause the incipient cavitation to vanish. The cavitation would not return even though the pressure would fall again to a low value, so that cavitation had to be completely re-established. Therefore, it was necessary to correlate the inception conditions with the static pressure readings by recording only those static pressure readings which were observed when incipient cavitation was seen on the body. The methods used for measuring the free-stream velocity were slightly different at the two laboratories. At ORL, sequences of differential pressure readings were recorded during every observation period. These pressure differences were then averaged so that an average velocity could be calculated for each period when incipient cavitation observations were made. At CIT, the differential pressures were averaged in this way only for tunnel speeds in excess of 60 fps. For lower velocities, the static and differential pressure readings were taken simultaneously when incipient cavitation was seen on the model.

During the ORL experiments, each observer noted the cavitation condition at each velocity.

Thus at least two points were obtained for each velocity and a check was made on "personal constants" for identifying incipient cavitation. In practically all cases the two readings agreed very closely. For those models and velocities where very low working-section pressures were required, air came out of solution and the resulting entrained air obscured the model and made data impossible to obtain if the very low static pressure was held for too long a time. This difficulty was overcome by making a measurement as quickly as possible after the free-stream static pressure had been lowered. Then the working-section pressure would be raised to 40 psia and held there for ten minutes to redissolve the entrained air before another reading was taken. It was usually at the end of these high-pressure periods that water samples were collected for a Van Slyke analysis of the dissolved air concentration. In addition to the sample which was taken from the nozzle section, samples were sometimes also taken from the diffuser section and the lower leg of the tunnel. This procedure was followed to check the homogeneity of the water samples. The air-content readings of such triple samples were found to agree within five per cent.

At CIT, the resorber⁴ in the High-Speed Water Tunnel circuit allows for continuous operation without appreciable air entrainment so that special techniques were not required. The determinations of air content, with a Van Slyke apparatus, for the CIT experiments followed the procedure outlined by Kermeen².

In addition to visual observations, some sound measurements were made with the ORL acoustic apparatus⁵. As with the visual observations, the velocity was held constant and the pressure was lowered until the nose cavitated all over. The static pressure was then gradually raised through the cavitation range while the hydrophone acoustic pressure readings and the working-section static pressure readings were

correlated by the observers. The result of such measurements for the 1-1/8-inch-diameter hemisphere is shown in figure 1. The shape of the curve is like that given in reference 2, figure 4, although the curve of figure 1 does not have as sharp a peak. If the maximum point is arbitrarily taken as the point of inception, we find a value of 0.64 for the incipient cavitation number at a free-stream velocity of 51 fps. This value shows good agreement with ORL visual value of 0.646 (figure 5). For the larger bodies, the difference in hydrostatic pressure from the bottom to the top of the model allows various degrees of cavitation to be distributed around the nose, from nearly incipient at the bottom, say, to more profuse cavitation at the top. This hydrostatic effect tends to make the sound peak more gradual for models which are larger than two inches in diameter. Thus, the acoustic determination loses its usefulness if the point of maximum acoustic pressure is to be used to define incipient cavitation.

For the smaller models tested at both ORL and CIT a noticeable "hysteresis" in the cavitation phenomenon was observed. When the pressure was lowered rather quickly below the inception point, cavitation would not occur immediately. When cavitation finally appeared, its state was more highly developed than the incipient state of the maximum of figure 1, and it was then necessary to increase the pressure to attain incipient conditions. As mentioned previously,

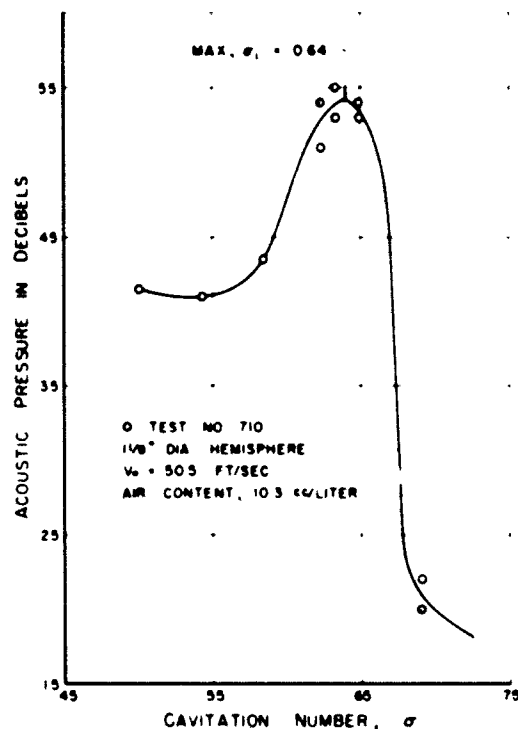


FIG. 1. NOISE GENERATED BY CAVITATION ON 1-1/8-INCH HEMISPHERE - ORL DATA

the general procedure of first establishing cavitation and then raising the pressure to its value for visual incipient cavitation has been found to be the most practicable for this study, as this procedure avoids the above difficulty and allows reproducible data to be obtained easily.

Reduction of Data

The cavitation number, σ , is a convenient parameter for describing cavitating flows. From the procedure outlined above, it is clear that p_0 and V_0 , which enter in the expression for σ , were not measured directly. Therefore, p_0 and V_0 must be obtained from the measured quantities by taking account of elementary flow laws and certain empirically derived corrections. The corrections employed here include the correction for the streamwise loss in static pressure due to the growth of the boundary layer in the working section; and for the larger models, the static pressure loss from the model centerline to the top of the model, plus a correction to the free-stream velocity to account for blockage or tunnel wall effects.* Further, all ORL data were corrected to account for the change in the velocity due to the growth of the boundary layer so that the final value of V_0 represents the effective free-stream velocity along the centerline of the model.

If p_0 is the measured working-section static pressure taken from taps located at the upstream end of the test section, Δp_1 is the loss in static pressure due to the growth of the boundary layer along the working section between the piezometer ring and the model nose, and Δp_2 is the loss in pressure from the model centerline to the top of the model, then

$$p_0 = p - \Delta p_1 - \Delta p_2^{**}$$

* Details of the blockage corrections are given in Appendix B.

** At the present time the High-Speed Water Tunnel, CIT, has an uncertainty factor within ± 2 per cent for $(p - \Delta p_1) / \frac{1}{2} \rho V_0^2$.

The mean velocity in the free stream $\bar{V}_0$ is given by

$$\bar{V}_0 = k\sqrt{\Delta}$$

where Δ is the pressure differential across the nozzle and k is a constant of proportionality. For example, for the ORL tunnel, if Δ is in inches of mercury and $\bar{V}_0$ is in feet per second, $k = 5.2 \text{ ft/sec (inches of Hg)}^{1/2}$.

If V_0 is the free-stream velocity in the center of the tunnel without blockage corrections, then for the ORL data

$$\bar{V}_0 = 0.99V_0$$

while for the CIT data

$$\bar{V}_0 = V_0$$

The blockage correction factor is defined as

$$\frac{V_0^2 \text{ (without walls)}}{(V_0^2) \text{ (with walls)}} = N \quad (\text{cf. Appendix B})$$

If account is taken of all these factors, the incipient cavitation number can be written as

$$\sigma = \frac{p - \Delta p_1 - \Delta p_2 - p_1}{\frac{1}{2} \rho V_0^2} = \frac{1}{N} \left[\frac{p - p_1}{\frac{1}{2} \rho V_0^2} - C_1 - C_2 \right]$$

where

$$C_f = \frac{\Delta p_f}{\frac{1}{2} \rho V_o^2}$$

and

$$C_h = \frac{\Delta p_h}{\frac{1}{2} \rho V_o^2}$$

are dimensionless coefficients for the pressure losses due to the growth of the boundary layer in the working section and the difference in elevation from the centerline to the top of the model, respectively. It has been assumed that consistent units are employed for all quantities which form the last equation so that no conversion factors need be explicitly indicated. For most of the

data $N=1$. At ORL, blockage corrections were applied to the data on the eight-inch-diameter hemisphere only, while at CIT, blockage corrections were applied to data from both the four-inch-diameter hemisphere and the four-inch-diameter ogive. Of course, C_h is important only for the larger models or for very low velocities.

After all data had been reduced as outlined above, they were arranged in tabular forms. These tables are presented in Appendix C. Mr. R. W. Kermeeen has kindly permitted the authors to use those portions of his experimental data which apply to the present study. Since he has given no tables of data in reference 2, we have included these data with our own test results in Appendix C.

Discussion of Results

Dependence of σ_i on V_0

The CIT and ORL data are presented in figures 2 through 12, where the incipient cavitation number for each model size is shown as a function of the free-stream velocity. The average air content for each model is also shown in the figures. The eight-inch-diameter hemisphere was not tested at CIT.

Except for the one-fourth-inch hemisphere (figure 2), the CIT data shown in figures 2 through 12 are generally slightly higher than the ORL data. In most cases, this difference appears to be well within the experimental error one would expect in the two test facilities. In addition to dissimilarities in instrumentation and control, a resistor⁴ is employed in the circuit of the High-Speed Water Tunnel to redissolve entrained air, whereas the ORL tunnel is not equipped for this. In view of these differences in the facilities and those in the test procedure, the over-all agreement of the test results is very satisfactory.

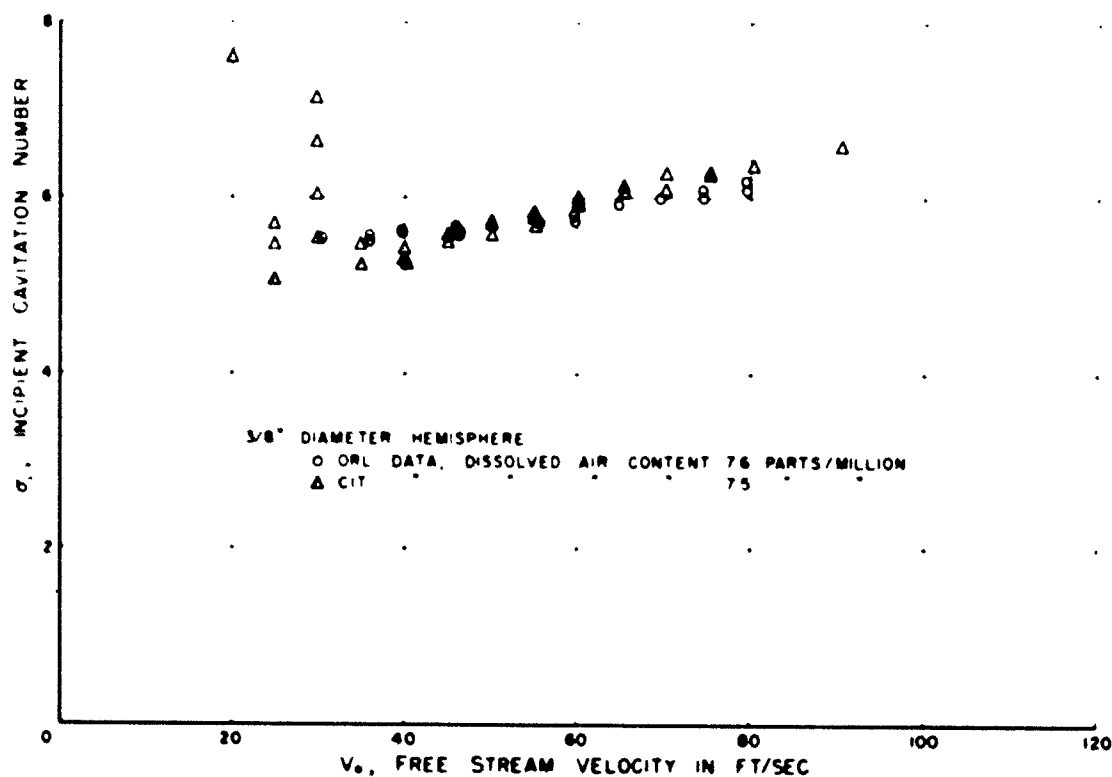
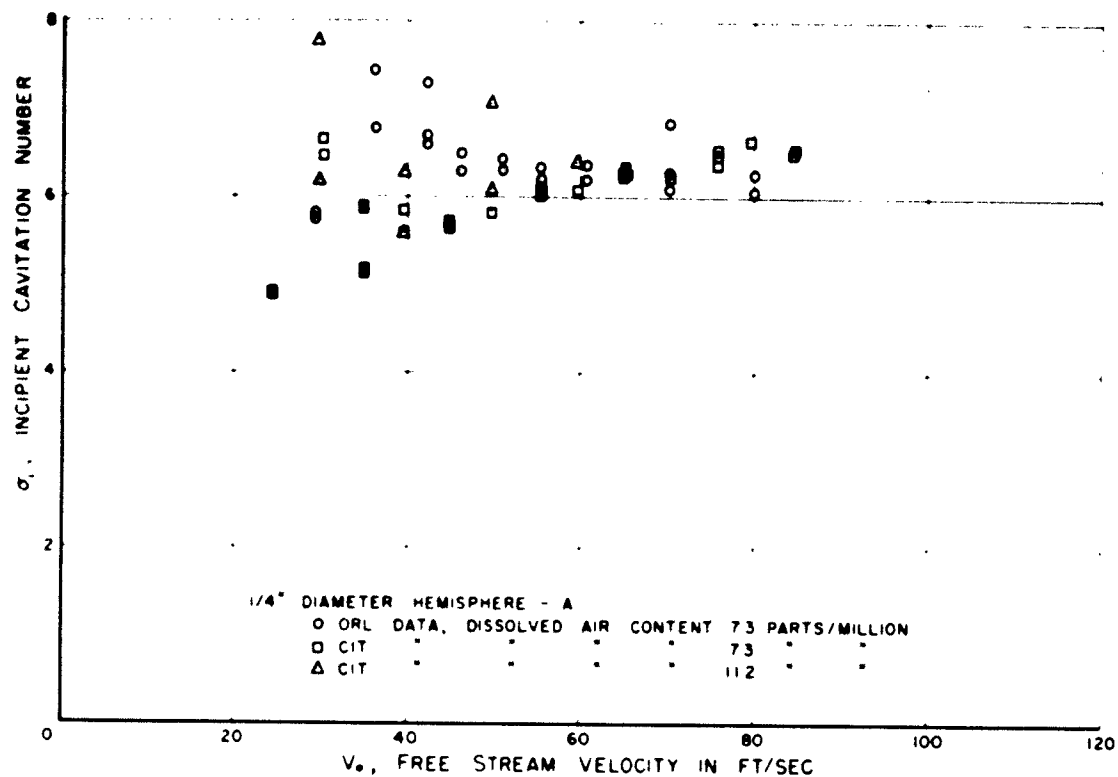
Curves were faired through the data of figures 3 through 12 and the accumulative results are given in figure 13. Because of the wide spread in the data for the one-fourth-inch hemisphere, no attempt was made to obtain a faired curve. Except for the smaller hemispheres at low velocities, figure 13 shows that the incipient cavitation number increases with both velocity and size. The cross plot of figure 13 excluding the low velocity range is shown in figure 14.

It is customary to assume that $\sigma_i = |C_{p,min}|$ on the body, and hence for comparison purposes, the absolute value of the minimum pressure coefficient is shown in figure 13 for both the hemispheres and ogives. These values of the minimum pressure coefficient are for Reynolds number in

the supercritical range⁶. Except for the eight-inch hemisphere, all values of σ_i are below $|C_{p,min}|$. This shows that the conventional method of calculating the incipient cavitation index is not valid.

It was observed both at ORL and at CIT that wide variations in the dissolved air content made no systematic differences in the test results (except in the case of the one-fourth-inch hemisphere at very low velocities). The nondependence of the incipient cavitation number upon air content is typified by the CIT data plotted in figure 10 for the one-inch-diameter 1.5-caliber ogive.

The data obtained from the tests on the one-fourth-inch hemisphere are shown in figure 2. In particular, the CIT data become more scattered as the velocity, V_0 , decreases, and the data taken at the higher air content tend to lie above the data for the lower air content. Also, these data show a reversal of the general trend exhibited by figures 5 through 12 in that for the low velocity range, σ_i increases with a decrease in the velocity. This trend is also shown by the CIT data for the three-eighths-inch and one-half-inch hemispheres in figures 3 and 4. In contrast to the data for the smaller hemispheres, the ogive data do not show a reversal of the general trend in the low velocity range. However, the ogive data do not extend far enough into the low velocity range to justify definitely concluding that a reversal of the general trend does not exist. Kermeen² found that by employing a special test procedure, clear cavities up to 23 model diameters in length could be established on small hemispheres at very low velocities. In some cases, the cavities were maintained at cavitation numbers as high as 4.8. This phenomenon, which was apparently due to air diffusion, may account for the reversal of the general trend shown by



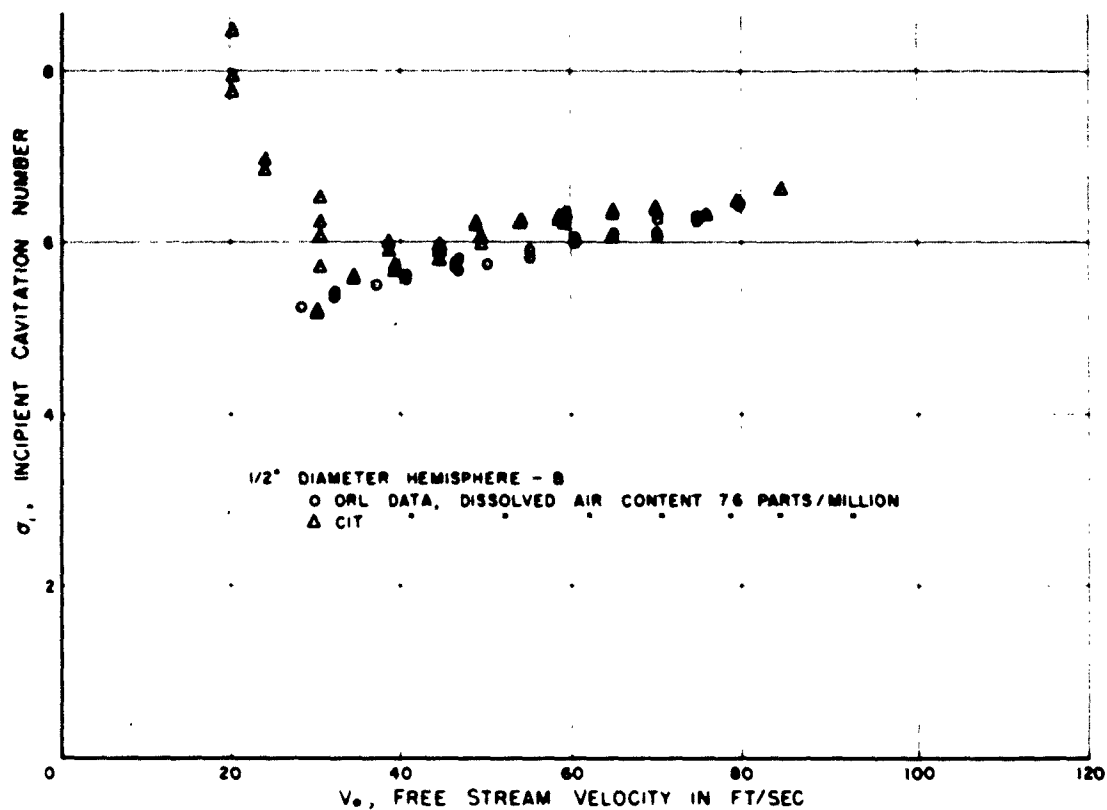


FIG. 4. INCIDENT CAVITATION NUMBER VS FREE-STREAM VELOCITY FOR 1/2-INCH HEMISPHERE - CIT AND ORL DATA

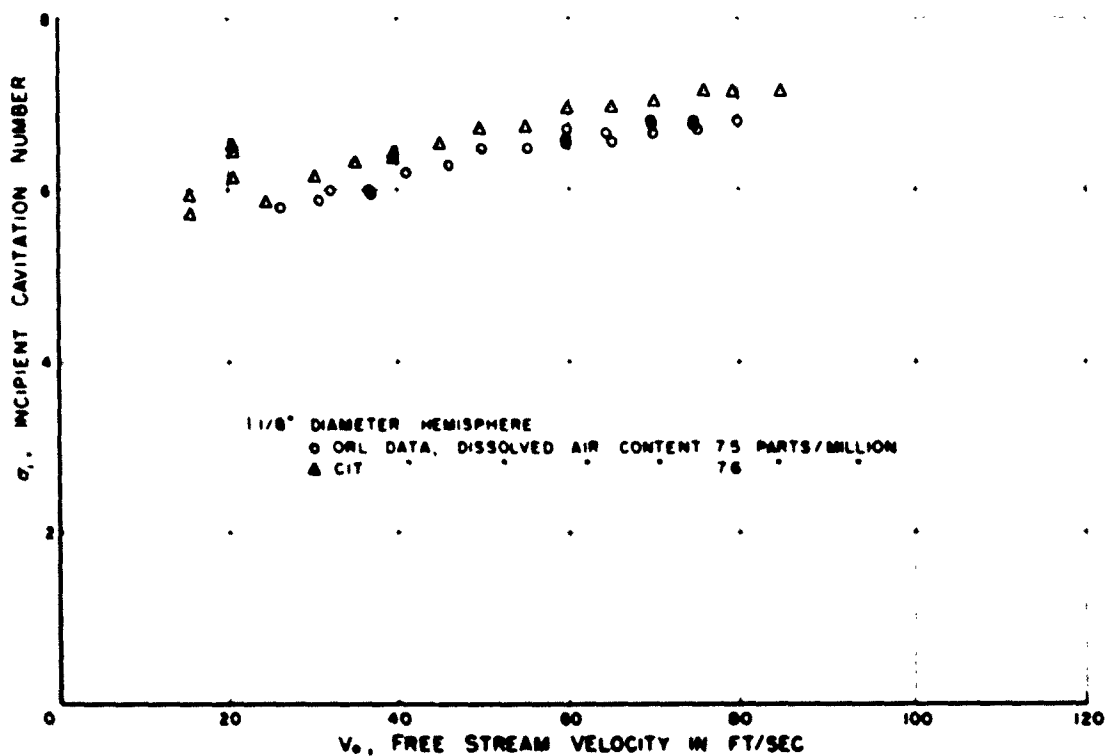


FIG. 5. INCIDENT CAVITATION NUMBER VS FREE-STREAM VELOCITY FOR 1 1/8-INCH HEMISPHERE - CIT AND ORL DATA

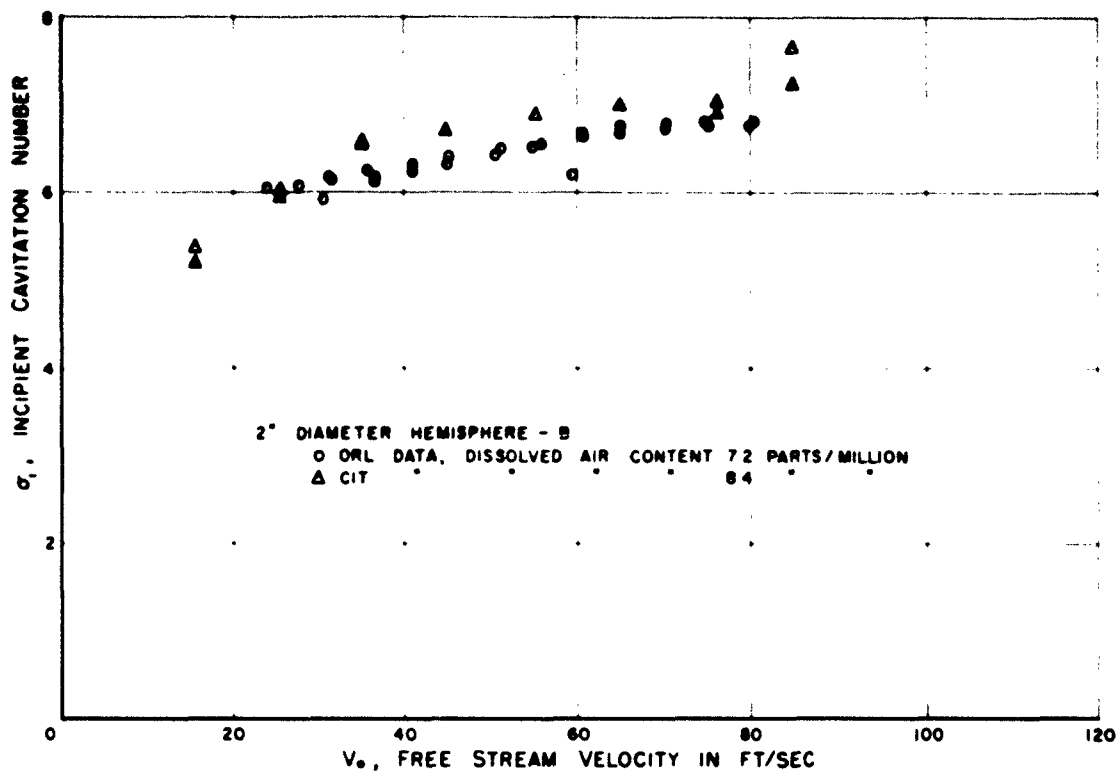


FIG. 6. INCIPIENT CAVITATION NUMBER VS FREE-STREAM VELOCITY FOR 2-INCH HEMISPHERE - CIT AND ORL DATA

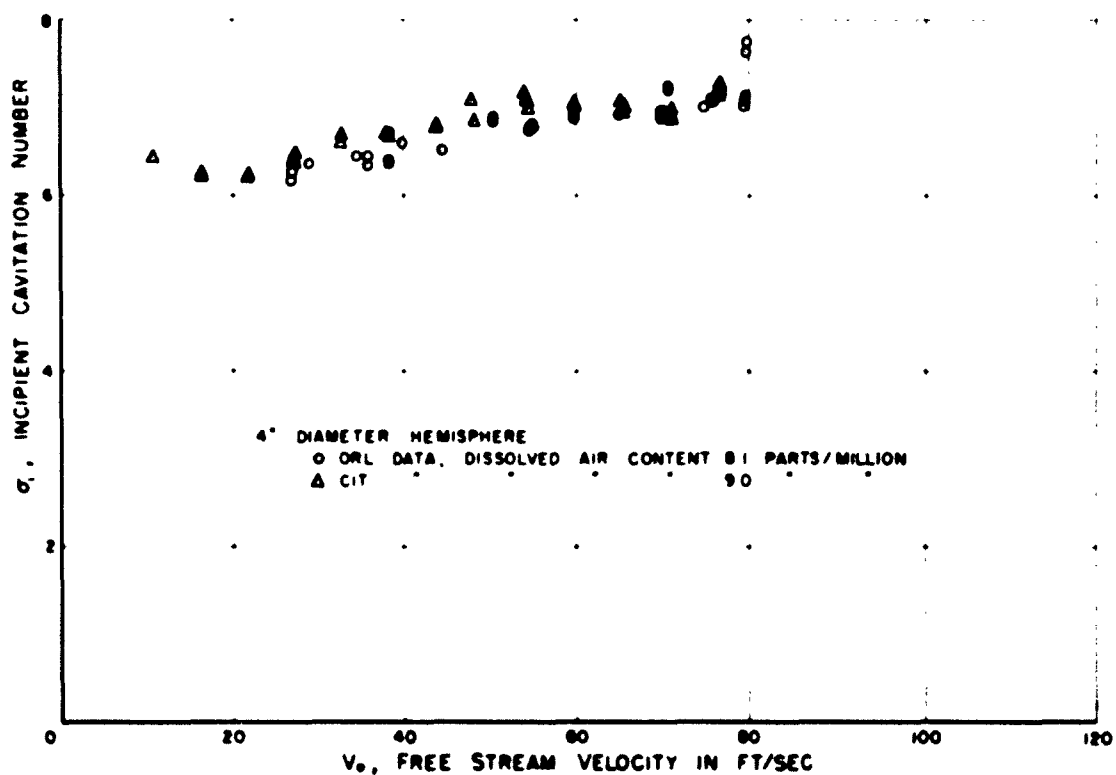


FIG. 7. INCIPIENT CAVITATION NUMBER VS FREE-STREAM VELOCITY FOR 4-INCH HEMISPHERE - CIT AND ORL DATA

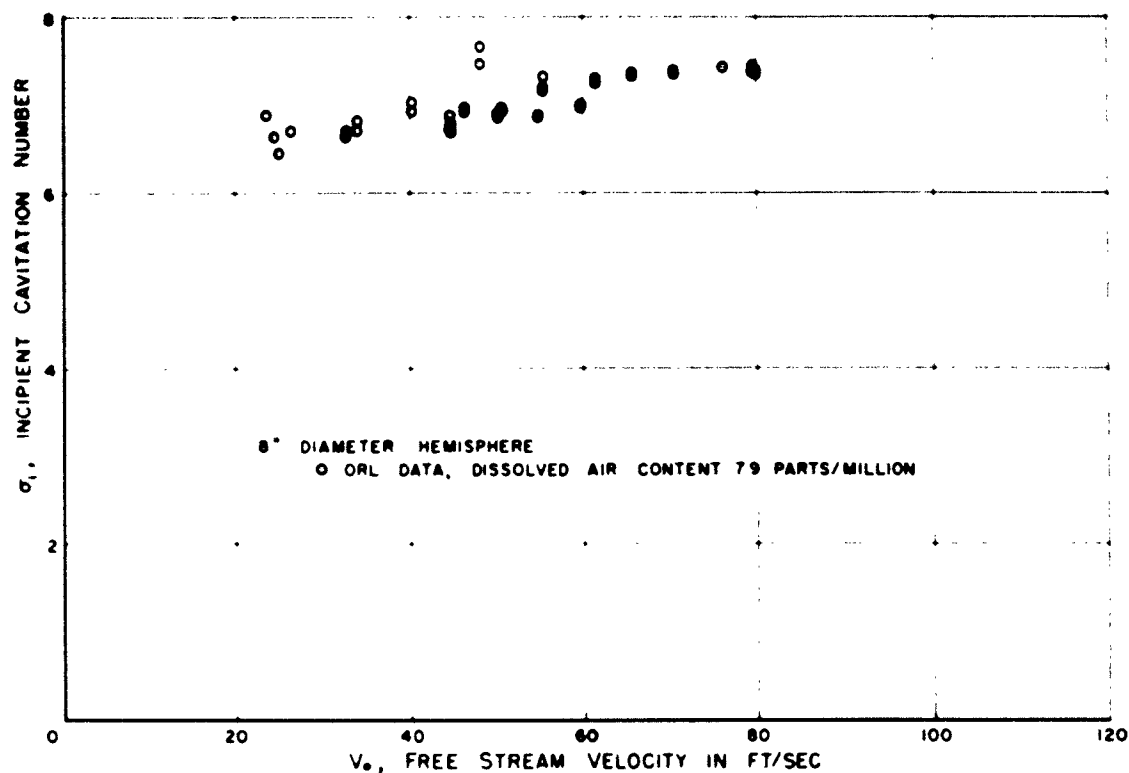


FIG. 4. INCIPIENT CAVITATION NUMBER VS FREE-STREAM VELOCITY FOR 8-INCH HEMISPHERE - ORL DATA

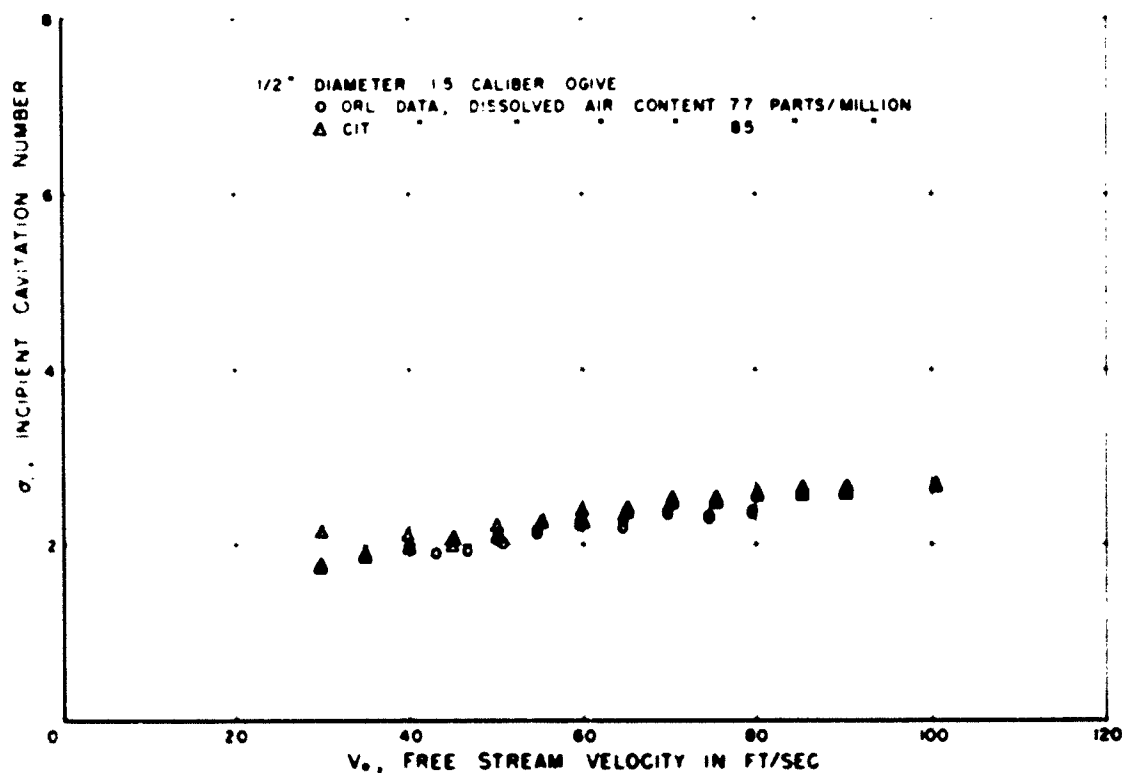


FIG. 5. INCIPIENT CAVITATION NUMBER VS FREE-STREAM VELOCITY FOR 1/2-INCH OGIVE - CIT AND ORL DATA

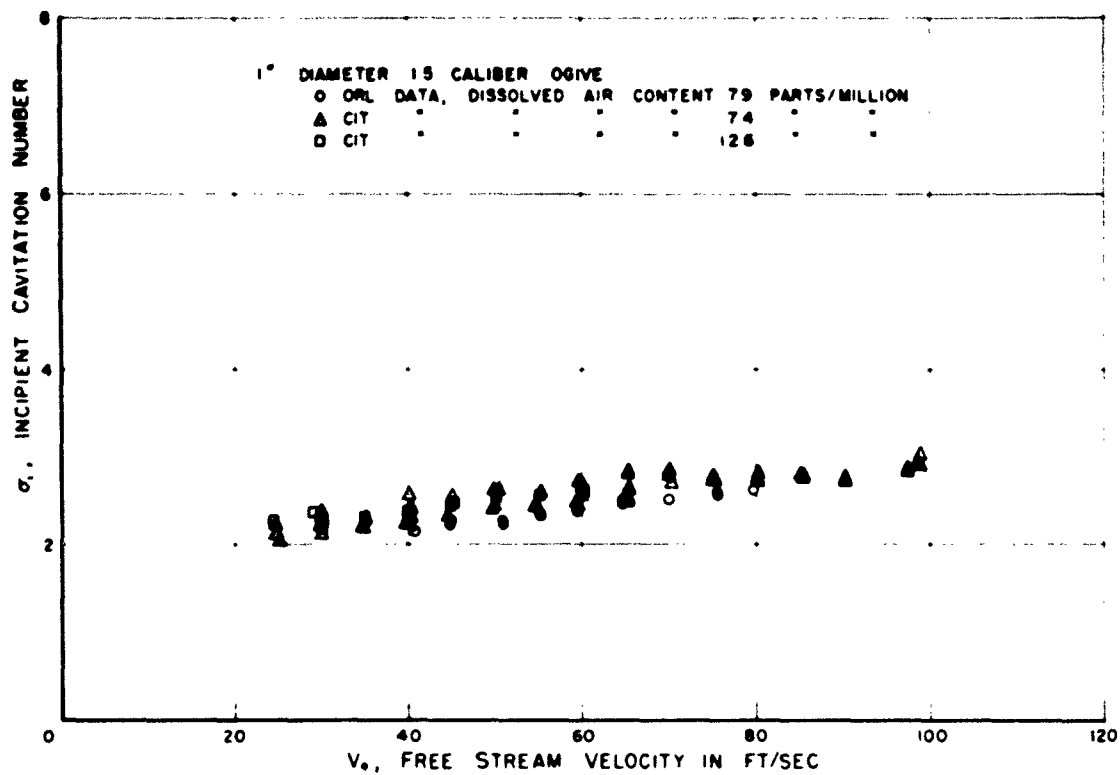


FIG. 10. INCIPIENT CAVITATION NUMBER VS FREE-STREAM VELOCITY FOR 1-INCH OGIVE - CIT AND ORL DATA

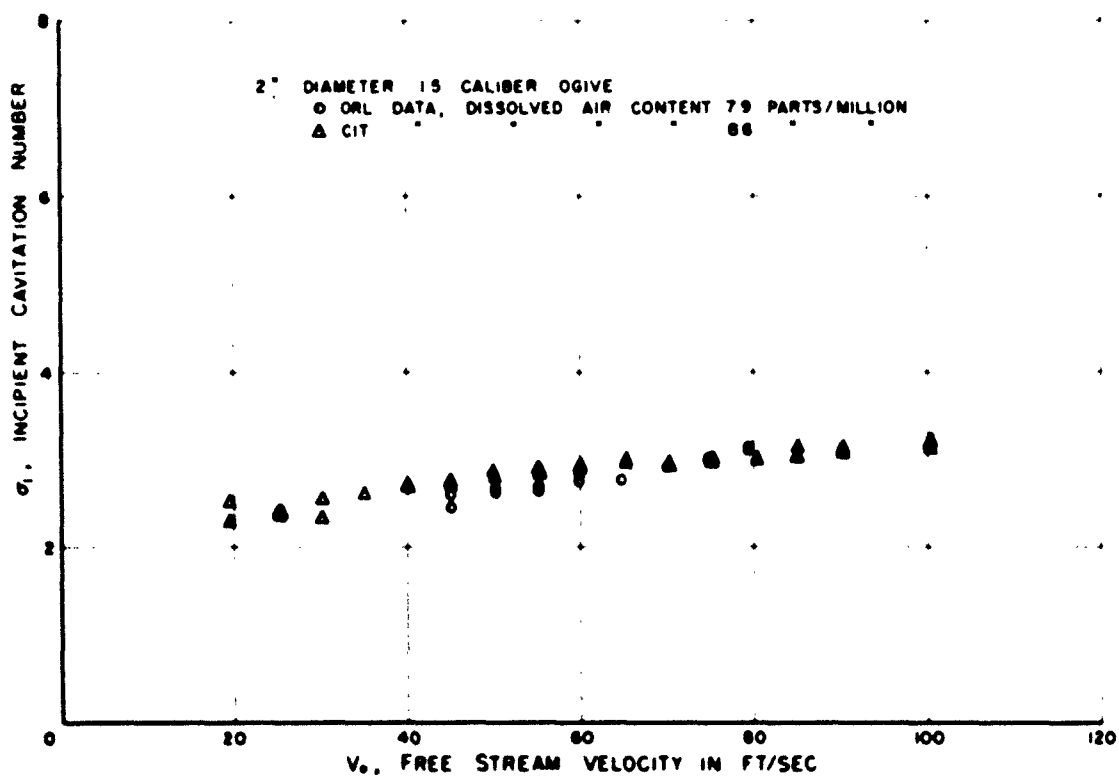


FIG. 11. INCIPIENT CAVITATION NUMBER VS FREE-STREAM VELOCITY FOR 2-INCH OGIVE - CIT AND ORL DATA

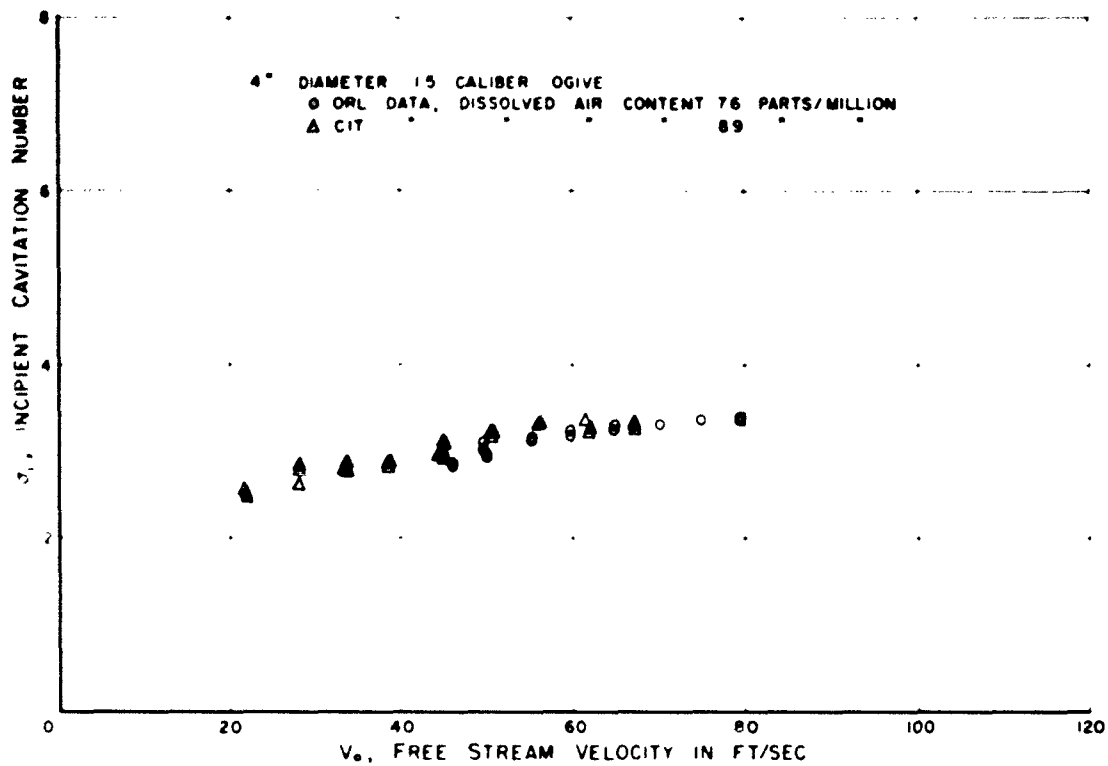


FIG. 12 INCIPIENT CAVITATION NUMBER VS FREE STREAM VELOCITY
 FOR 4 INCH OGIVE - CIT AND ORL DATA

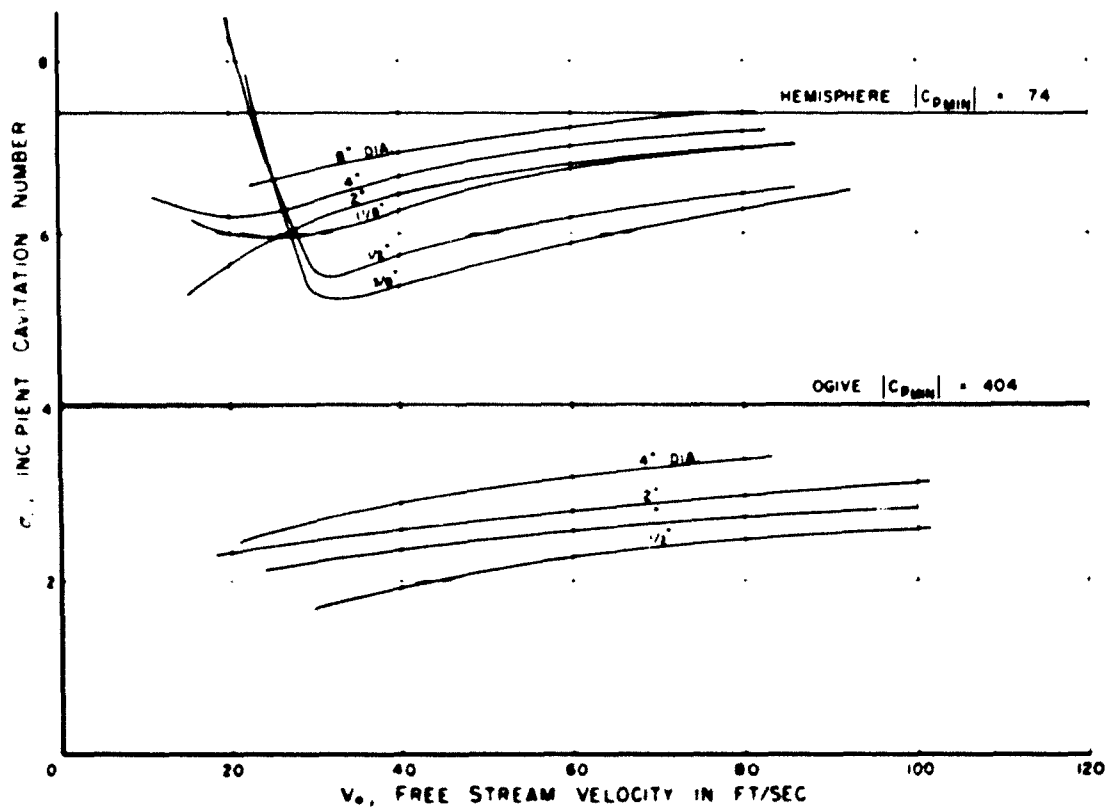


FIG. 13 EFFECT OF FREE STREAM VELOCITY UPON INCIPIENT CAVITATION NUMBER FOR ALL HEMISPHERE AND OGIVE MODELS

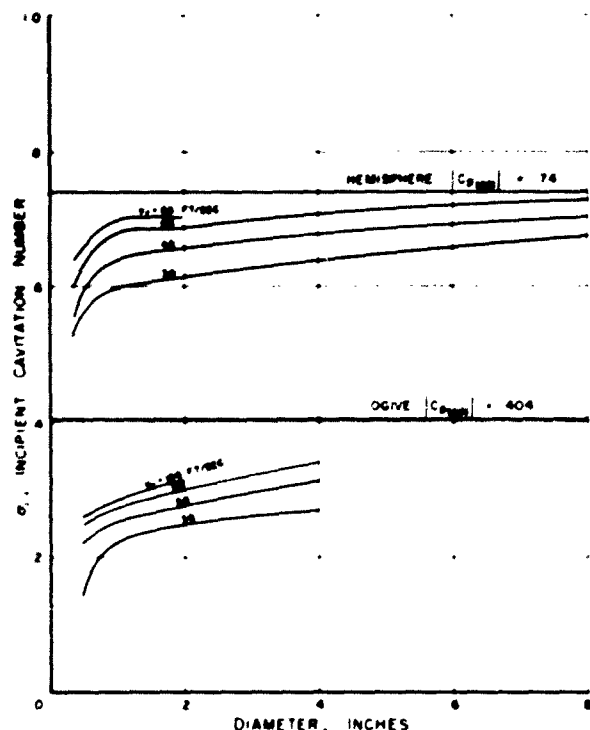


FIG. 14 EFFECT OF MODEL SIZE UPON INCIDENT CAVITATION FOR SEVERAL VALUES OF THE FREE-STREAM VELOCITY

the one-fourth-inch, three-eighths-inch, and one-half-inch hemispheres.

Part of the scatter shown by the ORL data for the one-fourth-inch hemisphere may be due to difficult conditions of observation in the 48-inch tunnel. In order to see cavitation on the model in the test section, it was necessary to look through some two feet of water. In addition, the reflection of intense highlights from the shiny surface of the model hindered visual observation, so that incipient cavitation was difficult to define. However, the ORL data for the one-fourth-inch nose have less scatter than the corresponding CIT data. But at CIT, since the test section is much smaller, visual observations were not difficult. Hence, we may conclude that the trend so clearly shown by the data represents an actual difference in the nature of incipient cavitation when the model size and free-stream velocity are sufficiently reduced.

The spread in the data for the eight-inch hemisphere was due to surface roughness and entrained air. Small diamond-shaped cavitation zones apparently due to very small rough spots became fixed at random points on the nose for a long time before they were swept away. In some cases these points of apparent roughness seemed to shift to another spot. These diamond-shaped cavitation patches were also characteristic of

the four-inch hemisphere; however, they were less severe than those for the eight-inch hemisphere. Recent tests of a two-inch-diameter hemisphere having a somewhat rough finish showed that similar diamond-shaped patches appeared at high velocities. Possibly this is due to the boundary layer becoming thinner as the velocity is increased, with the resulting protrusion of large roughnesses causing cavitation. Polishing the eight-inch hemisphere appeared to help somewhat, but did not completely remove the small diamond-shaped cavitation zones. When such zones were near the top of the model, the observation of inception conditions was difficult. Further, at low pressures the cavitation zone around the eight-inch model was confused by growing air bubbles and entrained air, so that observations of the inception of cavitation were made more uncertain. This type of air-bubble growth was observed to be more pronounced as the nose size was increased, probably because the larger the model the greater the time available for the air bubbles to grow at any given free-stream velocity. The situation was improved by raising the pressure to 40 psia for ten minutes (as mentioned under Test Procedure, page 2) to drive the entrained air back into solution. Then the pressure was lowered and readings were taken before air came out of solution. We believe that the greater scatter shown by the test results for the eight-inch model (figure 8) is largely due to the above effects.

Dependence of σ_i on Reynolds Number

The ORL and CIT data for incipient cavitation number are shown as a function of Reynolds number in figures 15 and 16, respectively. Referring to figure 15, the ORL data indicate that the incipient cavitation number is not a unique function of Reynolds number, for a distinct curve could be drawn for each model size. This trend is also shown by the CIT data in figure 16. Although there may be some Reynolds-number effects, we do not yet understand their full significance. We believe that such effects could influence the bubble growth required to produce incipient cavitation by their influence upon the time available for the occurrence of such growth³.

Dependence of σ_i on $Vd^{1/2}$

On the basis of a dimensional analysis, J. W. Holl concluded that it might be useful to express the incipient cavitation number as a function of the Weber number based upon the model diameter. Thus, if σ is the surface tension of the water, v_∞ is the free-stream velocity, ρ is

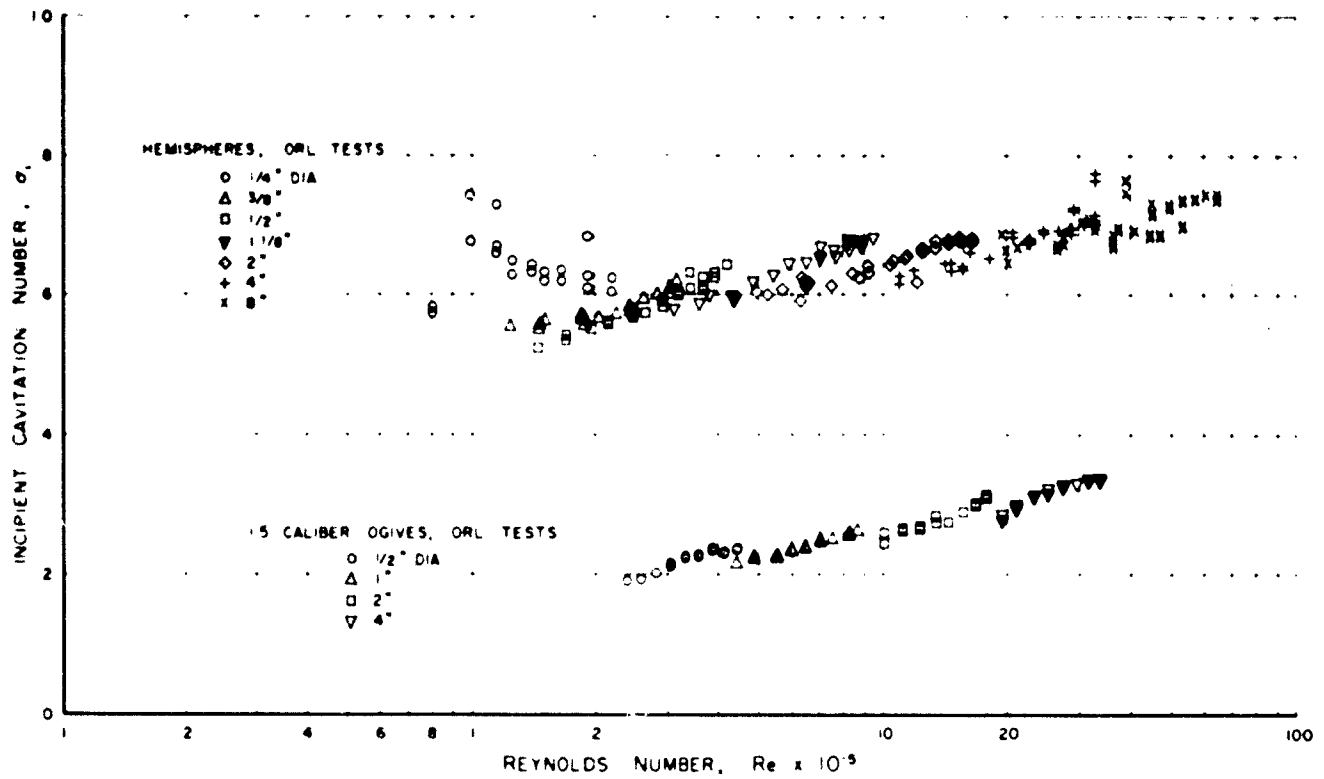


FIG. 15. INCIDENT CAVITATION NUMBER VS REYNOLDS NUMBER—ORL DATA

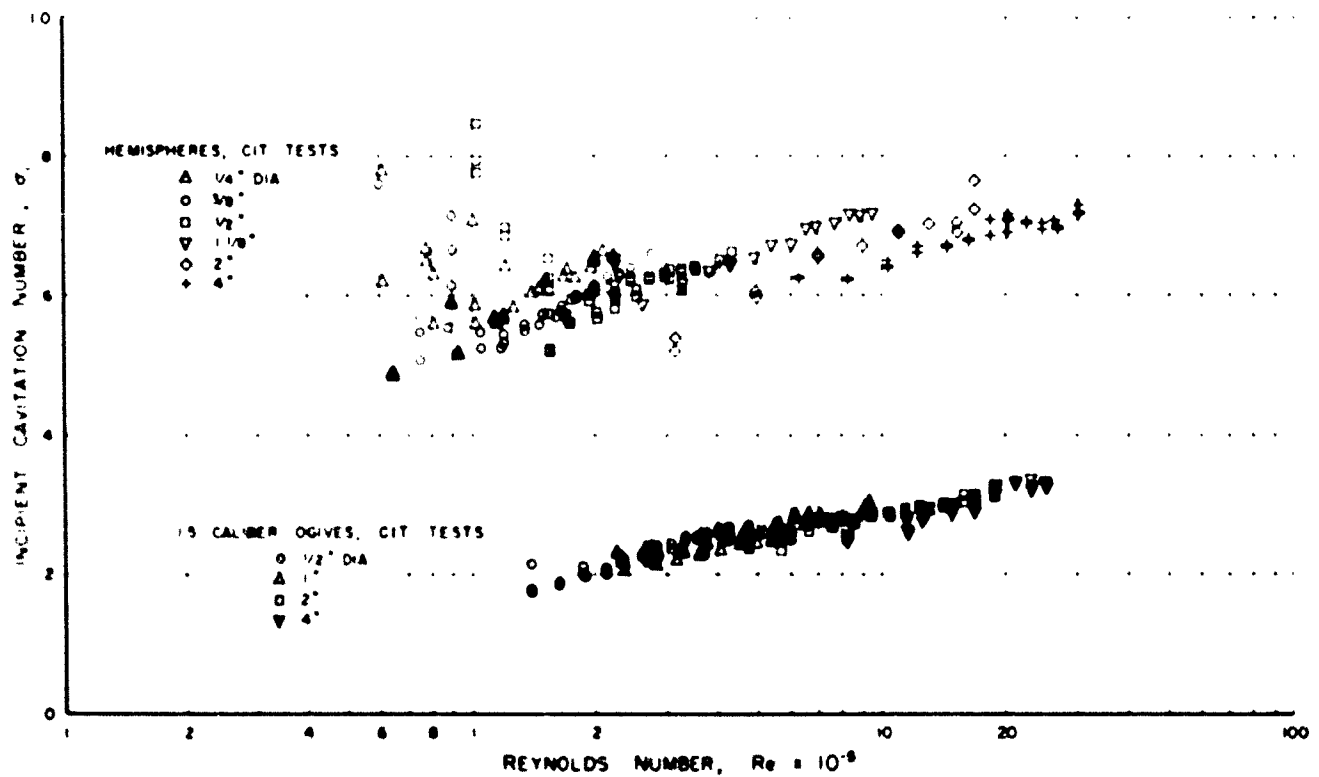


FIG. 16. INCIDENT CAVITATION NUMBER VS REYNOLDS NUMBER—CIT DATA

the liquid density and σ is the maximum diameter of the body, the Weber number of interest here is given by

$$W_0 = \frac{V_0 \sqrt{\sigma}}{\sqrt{\gamma/\rho}}$$

However, the correlation of the experimental data for σ_i with W_0 would imply a more general result than can actually be inferred from these Water Tunnel tests, because the ratio γ/ρ was not significantly altered during these experiments.

For example, table I below shows only a 3.38-percent variation in γ/ρ when the water temperature is changed from 70 to 100 degrees F. Actually the temperature variation encountered in the course of the present experiments was somewhat less than 70 to 100 degrees F, so that the variation in the ratio, γ/ρ , was less than 3.38 per cent. Such a variation is not of engineering significance.

The ORL data for incipient cavitation number were plotted as a function of Weber number, and the results showed that σ_i could be represented by a single curve for each model shape. How-

ever, as shown previously, the ratio γ/ρ was not varied significantly, so that one could only conclude that σ_i was a function of $V\sqrt{\sigma}$. The ORL and CIT data were then plotted as a function of $V\sqrt{\sigma}$, and the results are shown in figures 17 through 20. The hemisphere data obtained at ORL and CIT are shown in figures 17 and 18, respectively. Although there is some scatter in the data, we see that, for the most part, there are no consistent variations in the data because of changes in model size. The ORL and CIT data for the 1.5-caliber ogives given in figures 19 and 20 show the same correlation as did the hemisphere data, but in this case, there is less scatter** in the data. Thus it appears possible to represent the data by a single curve for each of the four figures. For comparison purposes, a curve was faired through the experimental points for each of figures 17 through 20, and from these faired curves figure 21 was constructed. The over-all trends for the ogive and hemisphere experiments are very much alike for both laboratories. The more detailed differences in the curves of figure 21 appear to be within the experimental scatter of the plots in figures 17 through 20.

From the foregoing it is clear that the present experiments indicate a correlation between the incipient cavitation number σ_i and the parameter $V_0 \sqrt{\sigma}$. We regret that the ratio of surface tension to density, γ/ρ , could not also be varied so that the dependence of σ_i upon Weber number could be investigated. We believe that it may be profitable to perform similar cavitation studies in different liquids to investigate the Weber-number dependence.

Table I - Values of γ/ρ as a Function of Water Temperature*

Water Temperature (degrees F)	γ/ρ (ft^3/sec^2)
50	0.002619
60	0.002595
70	0.002569
80	0.002544
90	0.002518
100	0.002485
120	0.002430

* Values of σ were taken from reference 7.

** Deviations from the theoretical body shape would not be so critical in the case of the ogives because of the flatter pressure distribution; hence, this would probably account for the smaller amount of scatter in the data.

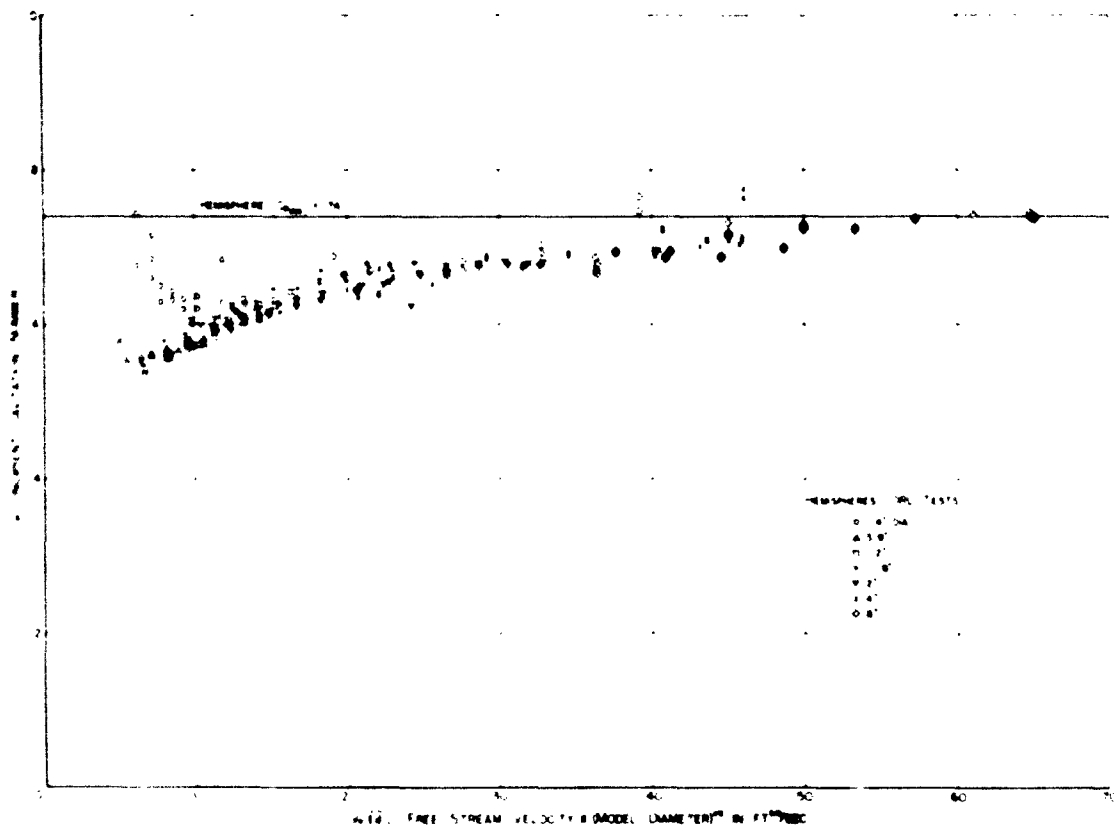


FIG. 17. CORRELATION OF ORL HEMISPHERE DATA WITH $V\sqrt{D}$

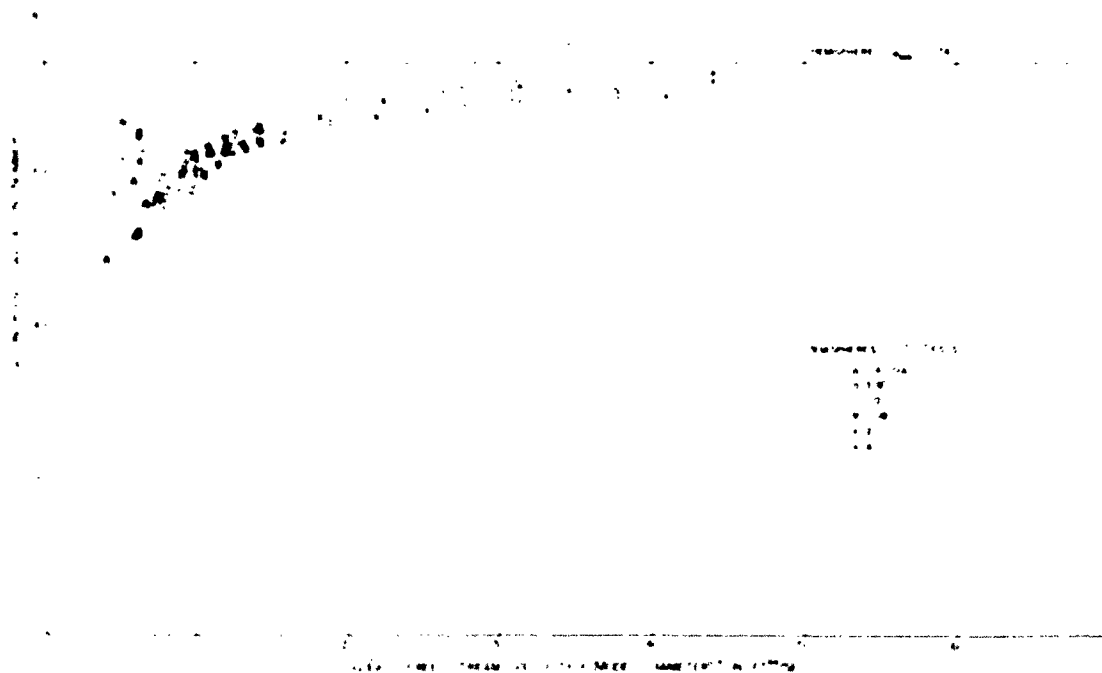


FIG. 18. CORRELATION OF CIT HEMISPHERE DATA WITH $V\sqrt{D}$

FIG. 19



FIG. 19 CORRELATION OF ORIGINATIVE DATA WITH $V_0 V_2$

FIG. 20

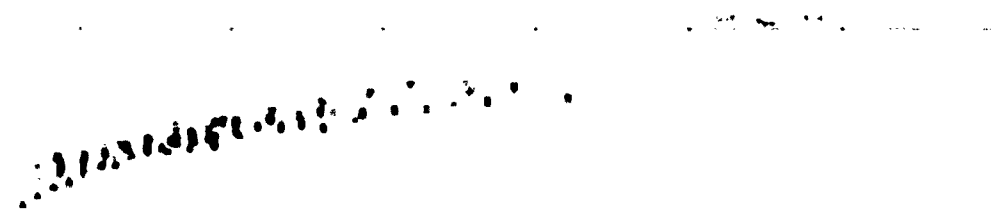


FIG. 20 CORRELATION OF ORIGINATIVE DATA WITH $V_0 V_2$

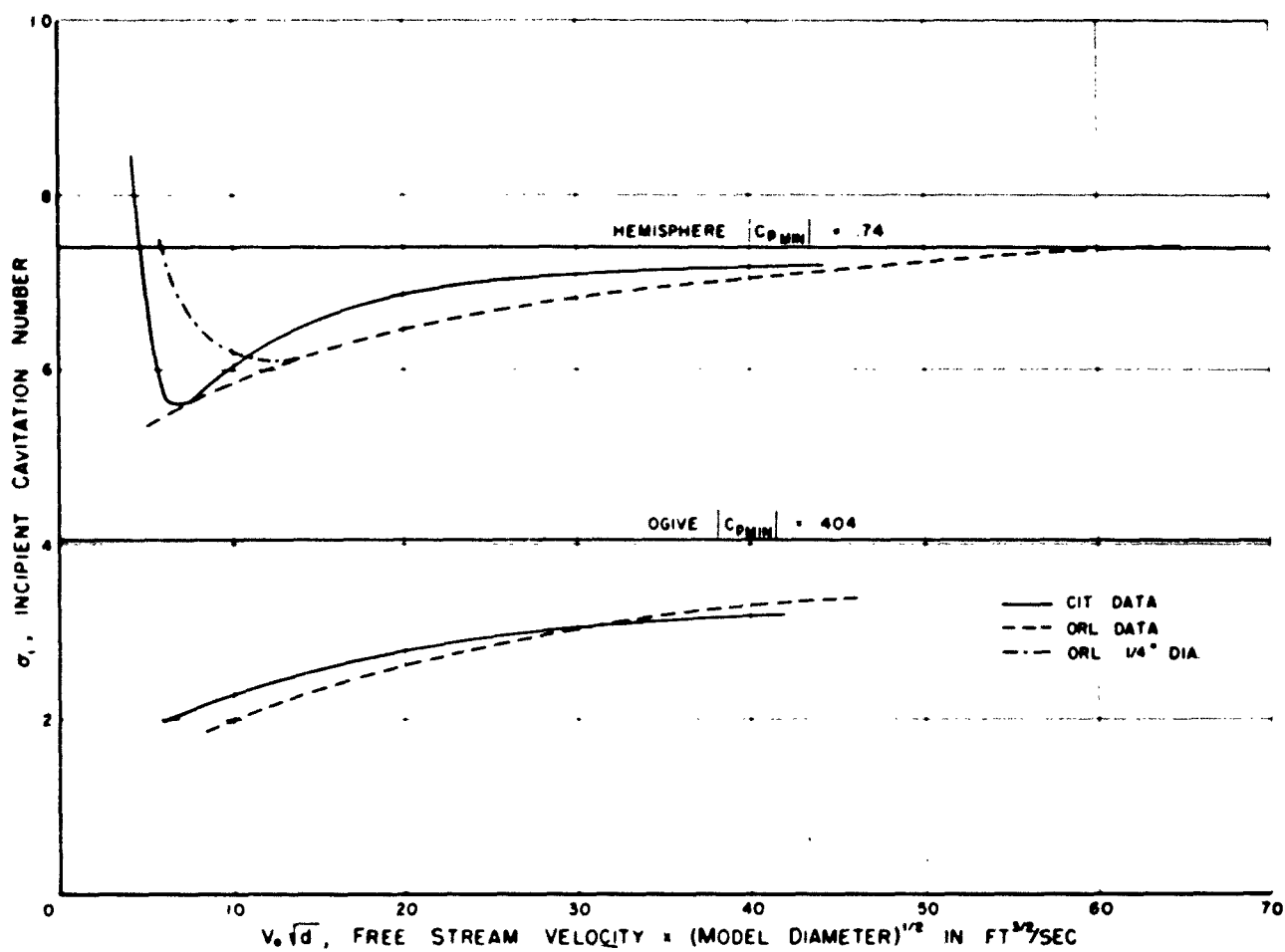


FIG. 21. A COMPARISON OF $V_\infty \sqrt{d}$ CORRELATIONS OBTAINED AT CIT AND ORL

Conclusions

The ORL experiments verify the CIT findings which show that the inception of cavitation in a steady rectilinear flow of a liquid past a body depends upon the free-stream velocity and the body size. This result was found to hold for hemisphere-nosed bodies up to eight inches in diameter, while the largest bodies tested before were two inches in diameter. In general, it was verified that the incipient cavitation number increases with body scale and free-stream velocity. Except for the largest body at higher flow velocities, the measured values of the incipient cavitation number are not as great as the incipient cavitation number which would be found by the customary calculation procedure. Hence, at the inception point, the pressure external to the cavities is not in general equal to the vapor pressure as is so often assumed. However, for full-scale work, it is safe to assume that $\sigma_c \approx |C_{p_{min}}|$.

Except for the smaller hemispheres at the lower velocities (less than 30 fps) no consistent variations of the incipient cavitation number with air content were observed.

The results for the smaller hemispheres at lower velocities showed a tendency for the incip-

ient cavitation number to increase with increasing dissolved air content. Also, in the low velocity range, the incipient cavitation number increased with a decrease in the velocity. This phenomenon was a reversal of the general trend characteristic of the larger hemispheres and all of the 1.5-caliber ogives. Evidently, this exceptional behavior is caused by air diffusion from the liquid into the cavitation bubbles. Data having sizable scatter and poor reproducibility are characteristic of tests made on small models at low velocities; consequently, these test conditions should be avoided when the results of model tests are used for predicting the performance of larger scale bodies.

It has been found possible to represent the data from the present experiments as a function of the parameter $V_0 \sqrt{d}$ for each family of shapes tested. Of course, the data are also representable in terms of the Weber number, $V_0 \sqrt{d} / \sqrt{\gamma/\rho}$, because the ratio of surface tension to density, γ/ρ , was not significantly varied in these experiments. Further experiments with other liquids should be undertaken to see if the more general correlation of the incipient cavitation number with Weber number is meaningful.

Appendix A

Models and Test Configurations

Seven hemispherical heads and four 1.5-caliber ogive heads were used in these experiments. The pertinent details concerning these headforms are given in table A-1. The designations A and B for the two-inch, one-half-inch, and one-fourth-inch hemispheres correspond to those used in references 1 and 2. The Ordnance Research Laboratory has two four-inch hemispheres designated A and B, and as shown in table A-1, nose B was used in these studies. The eight-inch hemisphere was not tested at CIT.

At ORL the one-fourth-inch to two-inch noses were supported in the Tunnel on a two-inch cylindrical brass body with a conical tail. The four-inch and eight-inch noses were supported on a four-inch cylindrical brass body with a conical

tail and with a wooden fairing to fair the eight-inch nose into the four-inch supporting body. These bodies were supported from the Tunnel floor by a thin aluminum strut so that the axis of the models coincided with the centerline of the Tunnel test section. A pictorial description of the mounting arrangements of the various noses is given in table A-2. In this table, "L" refers to the straight section behind the nose, which was measured from the point where the nose joins the straight section. The B arrangement is typified by the four-inch hemisphere with its supporting structure, shown in figure A-1.

At CIT the test arrangement for the one-half-inch, one-inch, and two-inch ogives was



FIG. A-1 ORL ARRANGEMENT FOR SUPPORTING 4 INCH HEMISPHERE

Table A-1 Hemispheres and Ogives

<u>Diameter (inches)</u>	<u>Type</u>	<u>Material</u>	<u>Made by</u>	<u>Maximum Deviation from Theoretical Shape</u>
8	Hemisphere	Brass	ORL	Not inspected
4 (B)	"	Brass	ORL	Not inspected
2 (B)	"	Stainless Steel	CIT	Not given in Ref. 2
1 1/8	"	Stainless Steel	CIT	"
1/2 (B)	"	Stainless Steel	CIT	"
3/8	"	Stainless Steel	CIT	"
1/4 (A)	"	Stainless Steel	CIT	0.0003" (Ref. 2)
4 (1.5 caliber)	Ogive	Brass	ORL	Not inspected
2 (1.5 caliber)	"	Stainless Steel	CIT	0.0020"
1 (1.5 caliber)	"	Stainless Steel	CIT	0.0020"
1/2 (1.5 caliber)	"	Stainless Steel	CIT	0.0010"

Table A-2 - Mounting Arrangements

O. R. L. Experiments

<u>Nose Size and Type</u>	<u>Arrangement</u>	<u>L/D</u>
1/4" Hemisphere	A	8
3/8" "	A	8
1/2" "	A	8
1 1/8" "	A	3
2" "	B	5.5
4" "	B	4.5
8" "	C	1.5
1/2" Ogive	A	4
1" "	A	1.5
2" "	B	5.5
4" "	B	4.5

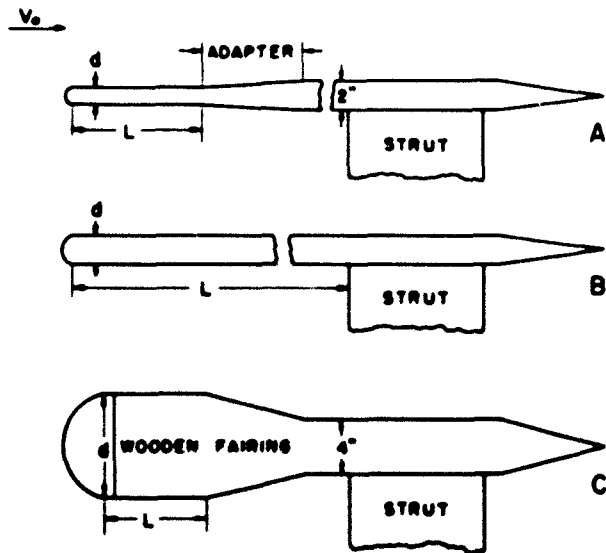




FIG. A-2 THE 4-INCH 1.5-CALIBER OGIVE MODEL INSTALLED IN THE HIGH-SPEED WATER TUNNEL

equivalent to the arrangements used at ORL. The models were supported from the bottom of the High-Speed Water Tunnel test section. The data for the one-fourth-inch to two-inch hemispheres were taken by R. W. Kermeen. A sting support was used for all models in his experiments. The details of his setup are given in ref-

erence 2. The CIT cavitation tests for the four-inch hemisphere and ogive were made on models which were supported as shown in figure A-2. This method of support was also used for the pressure distribution tests which were run to determine wall-effect correction factors (Appendix B).

Appendix B

Corrections for Tunnel Constraint

The elementary ideas behind the tunnel blockage corrections are described in Appendix A of reference 1. It was found that the blockage correction factor, N , could be defined by

$$N = \frac{C'_{p,min}}{C_{p,min}} = \left(\frac{V_0}{V'_0} \right)^2$$

where V_0 and $C_{p,min}$ are the free-stream velocity and minimum pressure coefficient, respectively, for unconstrained flow. The quantities V'_0 and $C'_{p,min}$ are the corresponding free-stream velocity and minimum pressure coefficient as measured in the water tunnel where the flow is constrained. The blockage correction factor, N , is defined so that for equal free-stream static pressures, the minimum static pressure is the same for both flows. For incipient cavitation, it follows that

$$\sigma_c = \frac{\sigma'_c}{N}$$

where σ_c is the incipient cavitation number for the constrained water-tunnel flow and σ'_c is the incipient cavitation number in the equivalent unconstrained flow.

When a systematic series of pressure distributions for various degrees of blockage on a given shape is available, the blockage factor N is easily determined. Such experimental pressure distributions have been reported by the Iowa Institute of Hydraulic Research⁸ for a family of hemispheres. The correction factors derived from the Iowa tests are plotted against the model diameter to working section diameter ratio, d/D , in figure B-1.

Pressure distribution tests for a four-inch-diameter hemisphere were made at CIT to check the Iowa results. The averaged and faired results of these tests are shown in figure B-2.

The blockage correction factor, N , calculated from the minimum C_p of figure B-2 is shown by the square symbol in figure B-1.

The incipient-cavitation data for the four-inch-diameter hemisphere taken at CIT was corrected for blockage by using both the Iowa and CIT correction factors. A comparison of the corrected CIT data with the ORL data for the four-inch hemisphere is shown in figure B-3. One can see that the CIT data corrected by the Iowa correction factor agree more closely with the ORL results, which needed no correction. Consequently, the CIT data for the four-inch hemisphere presented in this report were corrected by the Iowa blockage factor.

Blockage data were not available for the ogive noses, so a series of pressure distribution experiments was made at CIT. The average pressure distributions for 1.5-caliber ogive noses of two-inch, three-inch and four-inch diameter are shown in figure B-4. The C_p curve for the two-inch model corresponds to unconstrained flow, and the minimum C_p obtained from the curve is -0.398, while a similar Iowa result⁶, obtained by interpolation, gives -0.410 for the minimum C_p . For computing N , a value of -0.404 was taken for the minimum C_p in unconstrained flow. The resulting blockage corrections for the 1.5-caliber ogives are shown as a solid curve in figure B-1. We see that the wall-effect curves for the two nose shapes intersect in figure B-1. The blockage theory of Lock and Johansen⁹ indicates that we may expect the correction curve for the ogives to have a slightly greater slope than the hemisphere correction curve, but certainly not an intersection as shown in figure B-1. It is estimated that the CIT values for the minimum C_p have a total uncertainty from all causes which is less than ± 3 per cent. The precision of the Iowa data is not known.

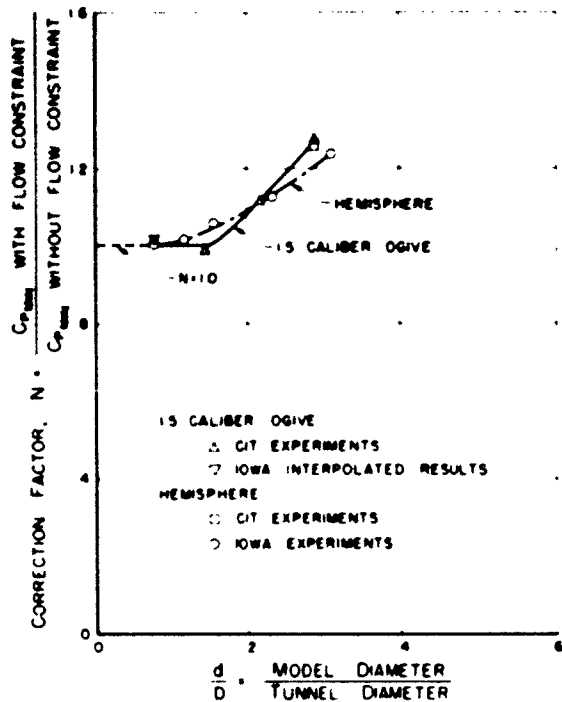


FIG. B-1 EXPERIMENTALLY DETERMINED BLOCKAGE CORRECTION FACTORS

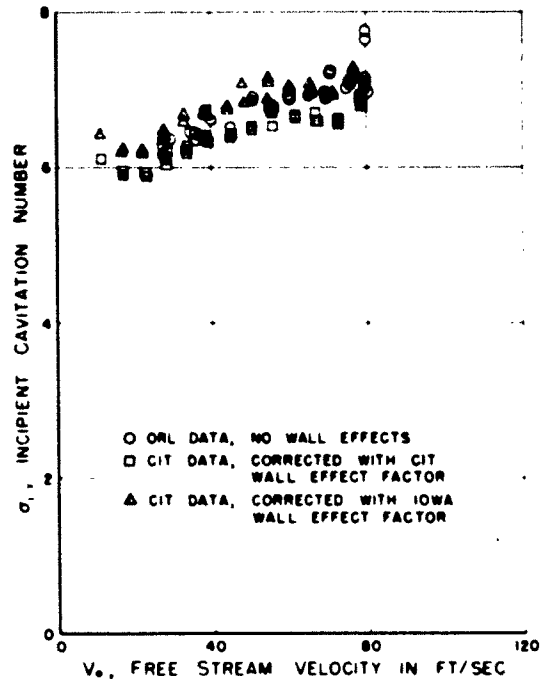


FIG. B-3 COMPARISON OF CIT AND ORL DATA FOR 4-INCH HEMISPHERE WITH IOWA AND CIT BLOCKAGE CORRECTIONS APPLIED TO CIT DATA

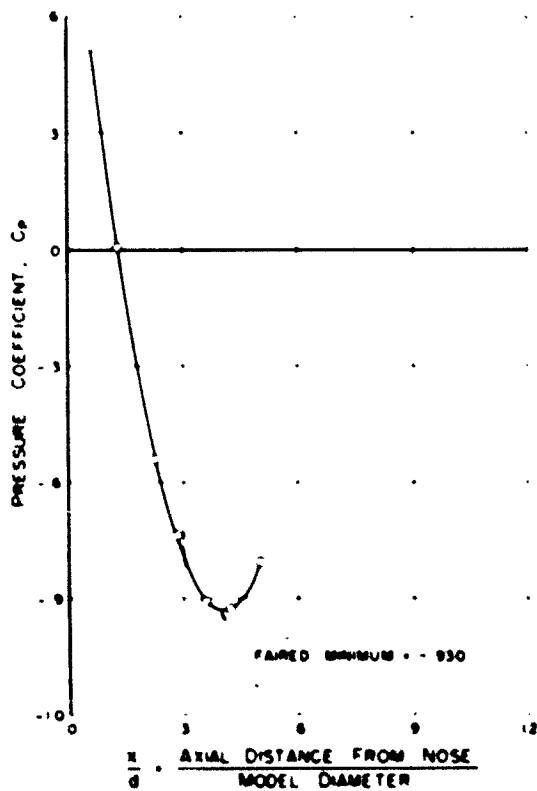


FIG. B-2 PRESSURE DISTRIBUTION AROUND 6-INCH HEMISPHERE NOSE IN THE HIGH-SPEED WATER TUNNEL

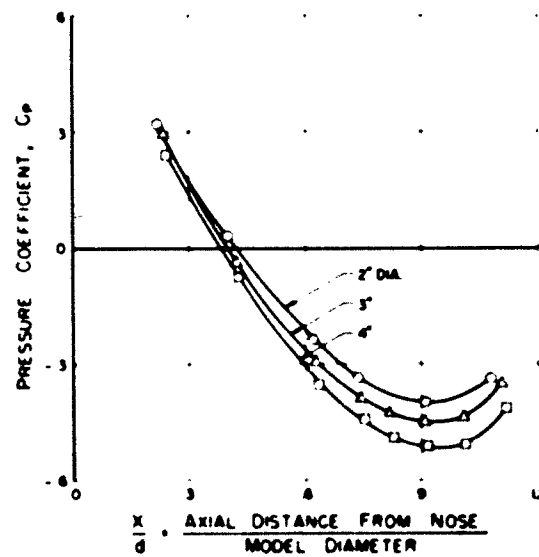


FIG. B-4 EFFECT OF TUNNEL WALLS UPON THE PRESSURE DISTRIBUTION OF 1.5-CALIBER OGIVE NOSES

Appendix C

Tables of Experimental Data

The attached tables give the values of the incipient cavitation numbers which were found from visual observations of the flow. The values

given here have been corrected in accordance with the procedure outlined in the section entitled Reduction of Data, page 4.

1 4"-Diameter Hemisphere - August 8, 1952
O. R. L. Test No. 726

Time	V_1	V_0	$V_0 \sqrt{d}$	$R_0 \times 10^{-5}$	Air Content*	
					As Measured	Corrected
1555	582	29.1	4.91	801	1.2	7.2
1553	576	29.1	4.91	801		
1551	570	29.1	4.91	801		
1549	577	36.2	6.09	990		
1548	566	36.2	6.09	990		
1546	590	42.2	7.10	1.15		
1545	579	42.2	7.10	1.15		
1543	569	42.2	7.10	1.15		
1542	429	46.1	7.76	1.26		
1541	559	46.1	7.76	1.26		
1540	532	50.9	8.11	1.60		
1539	561	50.9	8.11	1.60		
1538	520	55.2	9.29	1.51		
1537	511	55.2	9.29	1.51		
1536	516	60.6	10.2	1.66		
1535	629	60.6	10.2	1.66		
1534	599	70.1	11.8	1.92		
1533	628	70.1	11.8	1.92		
1532	619	70.1	11.8	1.92		
1531	606	79.9	13.6	2.19	5.0	7.2
1530	626	79.9	13.6	2.19		
1529					5.2	7.6

1 8"-Diameter Hemisphere - August 8, 1952
O. R. L. Test No. 726

Time	V_1	V_0	$V_0 \sqrt{d}$	$R_0 \times 10^{-5}$	Air Content*	
					As Measured	Corrected
1547	554	10.6	5.41	1.24		
1546	554	10.6	5.41	1.24		
1550	551	16.1	6.30	1.46		
1554	558	16.1	6.30	1.46		
1555	562	19.7	7.02	1.61		
1556	561	19.7	7.02	1.61		
1621					4.1	7.0
1622	568	45.9	8.12	1.66		
1623	564	45.9	8.12	1.66		
1626	566	50.4	8.91	2.04		
1627	566	50.4	8.91	2.04		
1628	572	55.6	9.81	2.25		
1631	572	55.6	9.81	2.25		
1632	576	59.7	10.6	2.42		
1636	582	59.7	10.6	2.42		
1636	594	64.7	11.6	2.62	5.6	7.6
1639	594	64.7	11.6	2.62		
1640	601	69.6	12.3	2.82		
1642	601	69.6	12.3	2.82		
1644	601	74.6	13.2	3.02		
1647	610	74.6	13.2	3.02		
1649	621	79.9	16.1	3.15		
1651	621	79.9	16.1	3.15		
1655	556	46.1	8.10	1.09		
1657	562	46.1	8.10	1.09		
1659					5.6	7.6

* All air contents are in parts per million. The values of air content for the O.R.L. tests were corrected to account for water vapor on the mercury column of the Van Slyke apparatus.

1 1/2" Diameter Hemisphere - August 6, 1952
O. R. L. Test No. 725

Time	σ_1	V_o	$V_o \sqrt{d}$	$R_g \times 10^{-5}$	Air Content	
					As Measured	Corrected
0954	.524	28.5	5.82	1.46		
0957	.524	28.5	5.82	1.46		
1011					3.7	7.5
1016	.535	32.4	6.61	1.71		
1016	.542	32.4	6.61	1.71		
1035					4.2	7.8
1039	.550	37.2	7.59	1.96		
1040	.550	37.2	7.59	1.96		
1042	.562	40.7	8.30	2.14		
1045	.550	40.7	8.30	2.14		
1100					3.7	7.4
1104	.500	46.8	9.55	2.47		
1108	.540	46.8	9.55	2.47		
1110	.574	50.5	10.3	2.64		
1111	.574	50.5	10.3	2.64		
1114	.583	55.2	11.3	2.90		
1116	.591	55.2	11.3	2.90		
1118	.600	60.4	12.3	3.19		
1120	.606	60.4	12.3	3.19		
1125	.619	65.0	13.3	3.42		
1125	.633	65.0	13.3	3.42		
1126	.600	70.1	14.3	3.69		
1126	.611	70.1	14.3	3.69		
1130	.626	70.1	14.3	3.69		
1133	.625	74.8	15.3	3.93		
1134	.632	74.8	15.3	3.93		
1136	.643	79.8	16.3	4.21		
1140	.644	79.8	16.3	4.21		
1140	.674	84.6	9.51	2.45		
1143	.677	84.6	9.51	2.45		

1 1/2" Diameter Hemisphere - August 7-8, 1952
O. R. L. Tests Nos. 726 and 725

Time	σ_1	V_o	$V_o \sqrt{d}$	$R_g \times 10^{-5}$	Air Content	
					As Measured	Corrected
1510	.620	40.9	12.5	4.85	3.2	7.2
1510						
1521	.629	45.9	14.3	5.45		
1525	.646	49.8	15.2	5.91		
1530					3.1	7.1
1550	.647	55.0	16.8	6.53		
1601	.670	59.7	18.3	7.09		
1607	.656	65.0	19.9	7.72		
1610	.664	69.9	21.4	8.29		
1616	.670	75.0	23.0	8.89		
1619	.681	79.7	24.6	9.46		
1623	.680	79.7	24.6	9.46		
1624	.676	76.6	22.8	8.84		
1627	.679	76.6	22.8	8.84		
1628	.677	66.7	21.3	8.27		
1632	.680	69.7	21.3	8.27		
1636	.664	64.4	19.7	7.65	2.8	6.9
1636	.664	64.4	19.7	7.65		
1642	.653	59.5	18.2	7.06		
1643	.650	59.5	18.2	7.06		
1643					3.2	7.3

Test No. 725						
0822					4.7	8.1
0825	.990	36.4	11.1	4.31		
0840					4.7	8.2
0843	.990	32.1	9.81	3.81		
0857					4.3	7.8
0904	.970	26.1	7.99	3.10		
0907	.980	30.6	9.37	3.60		
0907	.980	30.6	9.37	3.60		
0908	.990	36.7	11.2	4.35		
0909	.990	36.7	11.2	4.35		
0911					3.9	7.5
0923					3.7	7.6

2" Diameter Hemisphere - August 6-7, 1952
O. R. L. Tests Nos. 722, 723, 724

Test No. 722						
Time	σ_1	V_o	$V_o \sqrt{d}$	$R_g \times 10^{-5}$	Air Content As Measured	Corrected
1320					3.2	6.8
1328	.614	31.5	12.9	6.49		
1346	.600	25.5	10.4	5.24		
1400					2.8	6.6
1413	.592	30.5	12.4	6.28		
1430					2.7	6.6
1434	.618	36.5	14.9	7.50		
1455					2.5	6.4
1521	.643	50.5	20.6	10.4	3.6	7.5
1528	.632	44.9	18.3	9.24	3.6	7.5
1550	.608	27.4	11.3	5.68	3.4	7.4
1605	.625	30.7	12.5	6.33		
1615					3.1	7.1
1623	.624	41.0	16.7	8.72		
1625	.652	54.8	22.4	11.3		
1631	.620	59.3	24.2	12.2		
1638	.648	65.0	26.5	13.4		
1643	.674	70.1	28.6	14.4		
1648	.682	74.6	30.4	15.3		
1651	.681	80.3	32.8	16.5		

Test No. 723						
0855	.632	40.9	16.7	8.42	4.8	7.8
0902	.641	45.1	18.4	9.28		
0908	.650	51.2	20.9	10.6		
0913	.656	55.8	22.8	11.5		
0919	.668	60.6	24.7	12.5		
0933	.664	60.8	24.8	12.5	4.1	7.3
0941	.677	65.0	26.5	13.4		
0947	.679	70.2	28.6	14.4		
0952	.677	75.0	30.6	15.4		
0956	.676	79.8	32.6	16.4		
1010					3.4	6.8
1055					3.7	7.2
1145					3.4	7.0

Test No. 724						
1330					4.2	7.7
1336	.606	24.0	9.79	4.94		
1355					3.9	7.6
1401	.618	31.2	12.7	6.42		
1410					3.6	7.4
1414	.612	36.5	14.9	7.50		
1430					3.56	7.4

6"-Diameter Hemisphere - August 12, 1952
O. R. L. Tests Nos. 729 and 730

Test No. 729 -						Air Content	
Time	V_1	V_0	$V_0 \sqrt{d}$	$R_0 \times 10^{-5}$		As Measured	Corrected
0910						5.3	8.6
0924	.605	50.4	29.1	28.7			
0926	.606	50.4	29.1	28.7			
0927	.676	55.0	31.7	22.7			
0929	.678	55.0	31.7	22.7			
0930	.609	50.8	34.5	24.6			
0932	.601	50.8	34.5	24.6			
0934	.601	65.0	37.5	26.7			
0936	.601	65.0	37.5	26.7			
1002					4.6		8.1
1008	.724	70.5	40.7	29.0			
1010	.721	70.5	40.7	29.0			
1011	.700	75.6	43.6	31.1			
1013	.710	75.6	43.6	31.1			
1015	.703	79.3	45.7	32.6			
1017	.703	79.3	45.7	32.6			
1017	.600	55.4	32.0	22.7			
1022	.600	55.4	32.0	22.7			
1023	.600	55.4	32.0	22.7			
1025					5.0		8.5
1049					4.4		8.0
1051	.675	54.6	31.5	22.4			
1055	.677	54.6	31.5	22.4			
1056	.696	70.2	40.5	28.8			
1059	.696	70.2	40.5	28.8			
1101	.775	79.7	46.0	32.8			
1104	.764	79.7	46.0	32.8			
1107	.764	79.7	46.0	32.8			
1110					4.4		8.1
1115	.652	64.6	25.6	18.2			
1116	.652	64.6	25.6	18.2			
1118	.617	50.3	22.1	15.7			
1118	.672	50.3	22.1	15.7			
1121	.617	50.3	22.1	15.7			
1121	.641	50.3	22.1	15.7			
1151					4.2		8.0
Test No. 730							
1124					4.9		8.6
1132	.601	59.9	23.0	16.4			
1133	.601	59.9	23.0	16.4			
1134	.615	55.9	20.7	14.7			
1134	.646	55.9	20.7	14.7			
1134	.645	55.9	20.7	14.7			
1131	.627	27.0	15.6	11.0			
1131	.616	27.0	15.6	11.0			
1134					4.6, 4.5		8.4, 8.1
1134					4.2, 4.4		8.0, 8.1
1134					4.5, 4.3		8.1, 8.2
1134							Lower Log
1144	.636	29.0	16.7	11.9			
1145	.636	29.0	16.7	11.9			
1146	.605	34.6	20.0	14.2			
1149	.645	34.6	20.0	14.2			
1152	.600	49.7	40.2	28.6			
1156	.600	49.7	40.2	28.6			
1156	.600	49.7	40.2	28.6			
1159	.701	70.6	43.1	30.7			
1151	.701	70.6	43.1	30.7			
1153	.714	70.5	45.9	32.7			
1156	.700	70.5	45.9	32.7			

8"-Diameter Hemisphere - August 11, 1952
O. R. L. Tests Nos. 727 and 728

Test No. 727 -						Air Content	
Time	V_1	V_0	$V_0 \sqrt{d}$	$R_0 \times 10^{-5}$		As Measured	Corrected
0914						5.7	8.6
1002						4.5	7.7
1012	.725	61.2	50.0	49.8			
1014	.730	61.2	50.0	49.8			
1016	.726	61.2	50.0	49.8			
1021	.737	65.4	53.4	53.2			
1022					4.6		8.0
1024	.734	65.4	53.4	53.2			
1026	.736	70.2	57.3	57.1			
1029	.738	70.2	57.3	57.1			
1030	.743	74.8	61.1	60.7			
1032	.743	74.8	61.1	60.7			
1034	.745	79.3	64.8	64.5			
1034	.739	79.3	64.8	64.5			
1104					4.2		7.7
1115	.732	55.2	45.1	44.9			
1113	.716	55.2	45.1	44.9			
1116	.718	55.2	45.1	44.9			
1118	.695	50.5	41.2	41.1			
1122	.694	50.5	41.2	41.1			
1123	.695	50.5	41.2	41.1			
Test No. 728 -							
1130					4.2		7.7
1132	.737	79.7	65.1	64.8			
1135	.740	79.7	65.1	64.8			
1140	.672	44.5	36.3	36.3			
1142	.688	44.5	36.3	36.3			
1144	.703	40.1	32.7	32.6			
1145	.703	40.1	32.7	32.6			
1147	.693	40.1	32.7	32.6			
1149	.682	33.8	27.6	27.5			
1151	.671	33.8	27.6	27.5			
1150					4.3		8.0
1154	.670	32.6	26.6	26.5			
1157	.664	32.6	26.6	26.5			
1415					3.8		7.6
1422	.664	24.3	19.8	19.8			
1453					4.0		7.9
1511	.688	23.4	19.1	19.0			
1528	.646	24.9	20.6	20.2			
1551	.670	26.3	21.5	21.4			
1553	.693	46.1	37.6	37.5			
1555	.696	46.1	37.6	37.5			
1557	.747	48.0	39.2	39.0			
1557	.766	48.0	39.2	39.0			
1605					3.6		7.6
1615	.688	50.1	40.9	40.7			
1615	.686	50.1	40.9	40.7			
1624	.688	54.6	44.6	44.4			
1624	.687	54.6	44.6	44.4			
1627	.700	59.6	48.7	48.5			
1627	.698	59.6	48.7	48.5			
1633	.648	44.6	36.4	36.3			
1633	.678	44.6	36.4	36.3			
1635					4.8		8.1

1/4" Diameter Hemisphere "A"

P_1	V_0	$R_0 \times 10^{-5}$	$V_0 \sqrt{t}$	Dissolved Air Content P.P.M.	Water Temp. °F	Run
.665	30.2	.776	5.00	7.01	91.0	16
.667	30.2	.776	5.00			
.689	30.8	.804	5.06		91.6	"
.686	34.8	.894	5.06			"
.699	39.5	1.02	6.05			"
.686	39.5	1.02	6.05			"
.662	44.7	1.15	7.51			"
.661	44.7	1.15	7.51			"
.668	44.8	1.13	7.53		89.6	"
.665	44.8	1.13	7.53			"
.681	49.7	1.27	8.37		91.0	"
.682	55.1	1.41	9.27	7.24		"
.617	55.5	1.52	10.0		91.0	"
.625	65.1	1.60	11.0		91.0	"
.623	70.8	1.81	11.8		92.0	"
.637	75.7	1.97	12.7		92.6	"
.662	79.3	2.29	13.3		93.0	"
.614	84.7	2.23	14.3		93.2	"
.652	84.5	2.22	14.2	7.24	93.0	17
.652	84.5	2.22	14.2			"
.653	75.7	2.29	12.7		93.8	"
.667	75.7	2.29	12.7			"
.628	84.9	1.72	10.9		94.0	"
.636	84.9	1.72	10.9			"
.621	84.9	1.72	10.9			"
.620	84.9	1.72	10.9			"
.608	55.2	1.47	9.28		94.2	"
.609	55.2	1.47	9.28			"
.670	64.8	1.19	7.54		94.3	"
.665	64.8	1.19	7.54			"
.612	55.0	.912	5.88		94.3	"
.617	55.0	.912	5.88			"
.687	28.3	.646	4.28		94.3	"
.684	28.3	.646	4.28			"
.649	59.5	1.21	10.0		92	"
.704	69.6	1.51	8.34		92	"
.649	69.6	1.51	8.34		92	"
.657	59.6	9.81	6.64		92	"
.629	59.6	3.81	6.64		92	"
.619	29.7	3.41	6.99		92	"
.677	29.7	0.61	6.99		92	"

* Data from B. W. Kermack² This data was taken during the period April 1951 to January 1952

1/8" Diameter Hemisphere "B"

P_1	V_0	$R_0 \times 10^{-5}$	$V_0 \sqrt{t}$	Dissolved Air Content P.P.M.	Water Temp. °F	Run
.552	30.0	.88	5.39	6.0	69.6	26
.522	40.1	1.18	7.09			"
.557	50.1	1.67	8.85		69.7	"
.592	60.2	1.77	10.6			"
.567	55.2	1.62	9.75			"
.759	70.1	.60	1.56	7.5	71.2	27
.608	25.0	.75	6.62			"
.566	25.0	.75	6.62			"
.566	25.0	.75	6.62			"
.661	20.0	.95	5.29		71.3	"
.611	20.0	.95	5.29			"
.715	20.0	.95	5.29			"
.623	15.0	1.05	6.17		71.4	"
.546	15.0	1.05	6.17			"
.562	10.0	1.20	7.06		71.5	"
.561	10.0	1.20	7.06			"
.557	45.0	1.34	7.95		71.6	"
.568	65.0	1.36	7.95			"
.571	50.0	1.50	8.86		71.7	"
.571	50.0	1.50	8.86			"
.603	55.0	1.67	9.72		71.8	"
.576	55.0	1.67	9.72			"
.904	60.0	1.82	10.6			"
.900	60.0	1.82	10.6			"
.600	65.0	2.00	11.5	7.5	72.6	28
.613	65.0	2.00	11.5			"
.607	65.0	2.00	11.5			"
.626	70.2	2.15	12.6			"
.600	70.2	2.15	12.6			"
.670	70.1	2.31	13.4			"
.627	75.1	2.31	13.4			"
.637	80.0	2.60	14.2			"
.606	80.0	2.77	15.0			"

* Data from B. W. Kermack² This data was taken during the period April 1951 to January 1952

1/2" Diameter Hemisphere "C"

P_1	V_0	$R_0 \times 10^{-5}$	$V_0 \sqrt{t}$	Dissolved Air Content P.P.M.	Water Temp. °F	Run
.776	20.6	1.83	6.16	7.7	88.0	18
.804	20.6	1.83	6.16			"
.793	20.6	1.83	6.16			"
.697	26.2	1.22	6.94			"
.684	26.2	1.22	6.94			"
.652	30.7	1.55	6.27			"
.608	30.7	1.55	6.27			"
.571	30.7	1.55	6.27			"
.623	36.7	1.55	6.27			"
.568	36.7	1.75	7.08			"
.559	34.7	1.75	7.08			"
.600	38.6	1.95	7.88		90.0	"
.591	38.6	1.95	7.88			"
.591	38.6	1.95	7.88			"
.591	44.7	2.26	9.10			"
.594	44.7	2.26	9.10			"
.580	44.7	2.26	9.10			"
.597	44.7	2.26	9.10			"
.623	48.9	2.47	9.98		90.2	"
.620	48.9	2.47	9.98			"
.624	54.2	2.75	11.1		90.4	"
.623	54.2	2.75	11.1			"
.630	58.7	2.98	12.0			"
.626	58.7	2.98	12.0			"
.629	58.7	2.98	12.0			"
.608	64.9	3.28	13.2			"
.637	64.9	3.28	13.2			"
.633	64.9	3.28	13.2			"
.615	70.0	3.57	14.3		90.6	"
.637	70.0	3.57	14.3			"
.640	69.9	3.52	14.2		90.6	"
.633	75.8	3.86	15.5	7.3		"
.649	79.5	4.07	16.2		91.0	"
.662	84.6	4.34	17.3		91.4	"
.634	59.4	3.05	12.1	7.7	91.6	15
.622	59.4	3.05	12.1			"
.607	49.4	2.55	10.2		91.8	"
.597	49.4	2.55	10.2			"
.566	39.4	2.03	8.04		91.8	"
.574	39.4	2.03	8.04			"
.520	30.2	1.56	6.16			"
.519	30.2	1.56	6.16			"

* Data from B. W. Kermack² This data was taken during the period April 1951 to January 1952

1-1/8" Diameter Hemisphere "D"

P_1	V_0	$R_0 \times 10^{-5}$	$V_0 \sqrt{t}$	Dissolved Air Content P.P.M.	Water Temp. °F	Run
.592	15.6	1.69	4.72	7.5	87.0	11
.571	15.6	1.69	4.72			"
.613	20.6	2.24	6.25			"
.641	20.6	2.24	6.25			"
.651	20.6	2.24	6.25			"
.585	24.6	2.67	7.65			"
.616	30.1	3.30	8.54			"
.612	34.9	3.83	10.7			"
.643	39.4	4.31	12.0			"
.641	39.4	4.31	12.0			"
.652	44.7	4.91	13.7			"
.670	49.4	5.65	15.2			"
.672	54.9	6.81	16.8		87.2	"
.694	59.7	6.54	18.3	7.7	87.4	"
.690	65.0	7.90	19.9		87.8	"
.702	64.0	7.74	22.4		88.0	"
.715	75.7	8.41	23.2		88.2	"
.713	70.1	8.87	24.2		88.8	"
.716	84.7	9.52	25.9		89.8	"

* Data from B. W. Kermack² This data was taken during the period April 1951 to January 1952

2" Diameter Hemisphere - "B" -

σ_1	V_o	$R_o \times 10^{-5}$	$V_o \sqrt{d}$	Dissolved Air Content P.P.M.	Water Temp- °F	Run
765	86.7	16.93	34.6	8.6	89.6	10
723	86.7	16.93	34.6			"
723	86.7	16.93	34.6			"
704	75.0	15.27	30.9			"
691	75.0	15.27	30.9			"
703	66.9	13.09	26.4		90.0	"
703	66.9	13.09	26.4			"
689	55.2	11.05	22.5		89.3	"
690	55.2	11.05	22.5			"
649	46.8	8.96	18.3			"
679	46.8	8.96	18.3			"
650	35.0	7.01	14.3			"
655	35.0	7.01	14.3			"
595	26.5	6.96	10.0		90.2	"
601	26.5	6.96	10.0			"
517	15.5	3.14	6.34			"
519	15.5	3.14	6.34			"

Data from R. W. Kermack. This data was taken during the period April 1951 to January 1952

1/2" Diameter 1.5-Calibre Optive - August 14, 1952
O.R.L. Test No. 733

Time	σ_1	V_o	$V_o \sqrt{d}$	$R_o \times 10^{-5}$	Air Content	
					As Measured	Corrected
1330					4.0	7.6
1405					3.6	7.1
1414	.191	42.9	8.76	2.39		
1416	.191	42.9	8.76	2.39		
1422	.193	44.5	9.40	2.50		
1423	.193	44.5	9.40	2.50		
1430	.202	50.5	10.3	2.81		
1430	.202	50.5	10.3	2.81		
1433	.212	54.6	11.1	3.04		
1434	.216	54.6	11.1	3.04		
1438	.226	59.6	12.2	3.31		
1440	.223	59.6	12.2	3.31		
1442	.229	64.5	13.2	3.59		
1444	.228	64.5	13.2	3.59		
1446	.234	69.6	14.2	3.87		
1448	.230	69.6	14.2	3.87		
1450	.230	74.4	15.2	4.13		
1452	.233	74.4	15.2	4.13		
1455	.236	79.5	16.2	4.42		
1455	.230	79.5	16.2	4.42		
1519					4.5	8.3

1" Diameter 1.5-Calibre Optive - August 14, 1952
O.R.L. Test No. 734

Time	σ_1	V_o	$V_o \sqrt{d}$	$R_o \times 10^{-5}$	Air Content	
					As Measured	Corrected
0837					5.2	8.1
1102					4.6	7.8
1105	.223	50.8	14.6	5.52		
1106	.227	50.8	14.6	5.52		
1109	.235	55.0	15.9	5.97		
1110	.233	55.0	15.9	5.97		
1112	.240	59.4	17.1	6.44		
1114	.230	59.4	17.1	6.44		
1115	.247	64.6	18.6	7.01		
1116	.250	64.6	18.6	7.01		
1119	.251	69.8	20.1	7.56		
1120	.251	69.8	20.1	7.56		
1122	.257	75.6	21.8	8.29		
1124	.259	75.6	21.8	8.29		
1126	.262	79.6	23.0	8.62		
1127	.262	79.6	23.0	8.62		
1131	.226	64.8	12.9	6.05		
1132	.222	64.8	12.9	6.05		
1136	.215	60.6	11.7	4.40		
1137	.215	60.6	11.7	4.40		
1144					4.5	7.8

4" Diameter Hemisphere - October 16, 1952
C.I.T. Test

σ_1	V_o	$R_o \times 10^{-5}$	$V_o \sqrt{d}$	Dissolved Air Content P.P.M.
695	65.6	26.6	37.8	Av 9.0
707	65.1	26.6	37.6	
702	65.6	26.7	37.8	
705	59.0	22.6	34.6	
701	59.9	22.6	34.6	
710	54.3	20.4	31.4	
716	54.1	20.4	31.2	
690	54.4	20.5	31.4	
700	54.4	20.5	31.4	
700	47.9	18.5	27.6	
681	48.2	18.6	27.8	
677	41.0	16.5	25.3	
680	41.0	16.5	25.3	
680	41.0	16.5	25.3	
649	30.2	10.6	22.0	
671	30.6	10.4	21.9	
669	12.8	12.3	18.9	
660	12.0	12.4	18.9	
660	12.7	12.3	18.9	
669	27.4	10.4	15.0	
639	27.4	10.4	15.0	
641	27.3	10.4	15.0	
634	21.0	8.3	12.6	
634	21.0	8.3	12.6	
642	21.0	8.3	12.6	
645	16.5	6.3	9.5	
646	16.5	6.3	9.5	
660	16.0	6.1	6.2	
680	71.0	27.0	41.0	
690	71.0	27.0	41.0	
696	71.0	27.0	41.0	
715	70.6	30.2	44.1	
715	70.6	30.2	44.1	
710	70.6	30.2	44.1	
700	70.6	30.2	44.1	
700	70.6	30.2	44.1	

2" Diameter 1.5-Calibre Optive - August 13, 1952
O.R.L. Test No. 733

Time	σ_1	V_o	$V_o \sqrt{d}$	$R_o \times 10^{-5}$	Air Content	
					As Measured	Corrected
1507					4.3	8.6
1513	.260	45.0	18.4	10.00		
1520	.245	45.0	18.4	10.00		
1528	.267	50.1	20.4	11.2		
1531	.262	50.1	20.4	11.2		
1536	.269	55.0	22.4	12.3		
1541	.264	55.0	22.4	12.3		
1545	.275	59.8	24.4	13.4		
1547	.284	59.8	24.4	13.4		
1549	.275	64.6	26.4	14.4		
1551	.275	64.6	26.4	14.4		
1543	.291	69.9	28.5	15.7		
1550	.291	69.9	28.5	15.7		
1550	.301	74.8	30.5	16.80		
1559	.299	74.8	30.5	16.80		
1602	.310	79.3	32.6	17.80		
1603	.314	79.3	32.6	17.80		
1620					6.1	7.8

6" Diameter 1.5-Calibre Ogive - August 13, 1952
O.B.L. Test Nos. 731 and 732

Test No. 731					
Time	σ_1	V_o	$V_o \sqrt{d}$	$R_o \times 10^{-5}$	Air Content As Measured Corrected
0900					4.6 7.0
0925	.310	69.9	28.0	21.1	
0942	.300	69.9	28.0	21.1	
0950	.312	55.2	31.0	23.3	
1000	.310	55.2	31.0	23.3	
1020					4.3 7.6
1026	.317	59.6	34.4	25.2	
1031	.323	59.6	34.4	25.2	
1038	.324	64.7	37.3	27.3	
1045	.329	64.7	37.3	27.3	
1055	.330	70.0	40.4	29.5	
1103	.330	70.0	40.4	29.5	
1110					3.9 7.5
1112	.336	74.7	43.1	31.5	
1120	.336	74.7	43.1	31.5	
1130	.330	79.1	45.8	33.5	
1140	.334	79.1	45.8	33.5	
1141					3.6 7.3
1144	.290	69.0	28.7	21.0	
1146	.293	69.0	28.7	21.0	

Test No. 732					
1132					4.3 7.9
1136	.286	65.9	26.5	19.4	
1140	.278	65.9	26.5	19.4	
1144	.286	65.9	26.5	19.4	
1157					4.0 7.7
1210					4.0 7.7

1 1/2" Diameter 1.5-Calibre Ogive - October 15, 1952
C.I.T. Test

σ_1	V_o	$R_o \times 10^{-5}$	$V_o \sqrt{d}$	Air Content 0.5 P.P.M.
.266	100.4	4.75	20.5	
.265	100.4	4.75	20.5	
.260	100.4	4.75	20.5	
.257	90.2	4.26	18.4	
.265	90.2	4.26	18.4	
.261	90.2	4.26	18.4	
.256	85.2	4.03	17.4	
.259	85.2	4.03	17.4	
.264	85.2	4.03	17.4	
.258	85.2	4.03	17.4	
.253	80.1	3.79	16.1	
.250	80.1	3.79	16.1	
.254	80.1	3.79	16.1	
.247	75.2	3.56	15.3	
.252	75.2	3.56	15.3	
.248	75.2	3.56	15.3	
.249	70.1	3.32	14.3	
.252	70.1	3.32	14.3	
.247	70.1	3.32	14.3	
.236	65.1	3.00	13.1	
.241	65.1	3.00	13.1	
.242	65.1	3.00	13.1	
.239	59.0	2.81	12.2	
.227	59.7	2.82	12.2	
.226	59.9	2.83	12.2	
.225	55.1	2.61	11.2	
.226	55.1	2.61	11.2	
.220	50.0	2.36	10.2	
.210	50.0	2.37	10.2	
.210	50.1	2.37	10.2	
.190	44.8	2.12	9.10	
.207	44.9	2.12	9.10	
.206	44.9	2.12	9.10	
.211	39.7	1.80	8.10	
.190	40.0	1.80	8.10	
.197	44.0	1.80	9.10	
.200	34.0	1.64	7.10	
.200	34.0	1.64	7.10	
.210	29.0	1.41	6.10	
.175	29.0	1.41	6.00	
.176	29.0	1.41	6.00	

1" Diameter 1.5-Calibre Ogive - October 8-14, 1952
C.I.T. Test

σ_1	V_o	$R_o \times 10^{-5}$	$V_o \sqrt{d}$	Air Content
.210	29.7	2.72	8.56	
.221	29.7	2.72	8.56	
.219	34.6	3.17	9.90	
.219	34.7	3.18	10.0	
.227	39.7	3.64	11.4	
.225	39.7	3.63	11.4	
.232	44.6	4.09	12.9	
.232	44.6	4.08	12.9	
.240	49.6	4.54	14.3	
.245	49.8	4.56	14.4	
.244	49.6	4.55	14.3	
.243	54.7	5.01	15.8	
.243	54.5	4.99	15.7	
.248	59.1	5.43	17.1	
.246	59.5	5.44	17.2	
.254	64.7	5.92	18.7	
.251	64.7	5.92	18.7	
.248	65.1	5.96	18.8	
.255	65.1	5.96	18.8	
.252	65.1	5.96	18.8	7.4 Av.
.287	97.4	8.92	28.1	
.283	97.4	8.92	28.1	
.277	90.2	8.26	26.0	
.277	90.2	8.26	26.0	
.276	85.3	7.81	24.6	
.278	85.3	7.81	24.6	
.274	80.2	7.35	23.2	
.274	80.2	7.35	23.2	
.274	75.3	6.90	21.7	
.276	75.3	6.90	21.7	
.269	70.2	6.43	20.3	6.2
.270	70.2	6.43	20.3	
.263	65.4	5.99	18.9	
.265	65.4	5.99	18.9	
.265	60.2	5.52	17.4	
.230	30.0	2.75	8.65	
.231	29.9	2.74	8.62	
.256	40.1	3.67	11.6	
.249	40.0	3.67	11.5	
.228	24.4	2.26	7.04	13.0 Av.
.237	29.0	2.68	8.36	
.230	28.9	2.67	8.34	
.224	30.0	2.78	8.65	
.220	29.9	2.77	8.63	
.228	35.1	3.24	10.1	
.232	34.9	3.22	10.1	
.230	40.0	3.70	11.5	
.235	40.1	3.71	11.6	
.248	45.1	4.17	13.0	
.244	44.9	4.15	13.0	
.248	45.0	4.16	13.0	
.255	50.1	4.63	14.4	
.250	50.0	4.62	14.4	
.257	55.0	5.00	15.9	
.256	55.0	5.00	15.9	
.257	60.1	5.56	17.3	
.240	60.1	5.56	17.3	
.261	65.1	5.95	17.3	12.3
.284	65.2	6.15	18.0	
.283	65.2	6.15	18.0	
.279	65.2	6.15	18.0	
.285	70.0	6.61	20.2	
.281	70.0	6.61	20.2	
.279	70.0	6.61	20.2	
.278	75.2	7.10	21.7	8.5
.274	75.2	7.10	21.7	
.278	75.2	7.10	21.7	
.276	80.2	7.57	23.2	
.273	80.2	7.57	23.2	
.282	80.2	7.57	23.2	
.276	85.2	8.06	24.6	

1"-Diameter 1.5-Calibre Ogive - October 8-14, 1952
C.I.T. Test (Continued)

v_1	V_0	$R_0 \times 10^{-5}$	$V_0 \sqrt{d}$	Air Content
.200	99.2	8.94	24.6	8.9
.201	98.9	9.33	24.6	"
.201	98.9	9.33	24.6	"
.200	98.9	9.33	24.6	"
.204	98.6	9.28	24.9	"
.204	98.6	9.28	24.9	"
.273	98.3	8.90	24.0	"
.274	98.3	8.90	24.0	"
.273	98.3	8.90	24.0	"
.212	24.7	2.32	7.13	"
.223	24.7	2.32	7.13	"
.204	25.1	2.36	7.24	"
.213	30.0	2.82	8.65	"
.229	30.0	2.82	8.65	"
.228	30.0	2.82	8.65	"
.230	35.1	3.30	10.1	"
.232	35.1	3.31	10.1	"
.243	40.0	3.77	11.5	"
.243	40.2	3.79	11.6	"
.241	40.2	3.78	11.6	"
.249	45.2	4.25	13.0	"
.254	45.1	4.25	13.0	"
.262	49.8	4.69	14.4	"
.260	50.2	4.73	14.5	"
.260	50.1	4.72	14.5	"
.259	55.1	5.19	15.9	"
.259	55.2	5.19	15.9	"
.272	59.6	5.61	17.2	"
.264	59.9	5.64	17.3	"
.269	60.0	5.65	17.3	"

2"-Diameter 1.5-Calibre Ogive - October 15, 1952
C.I.T. Test (continued)

v_1	V_0	$R_0 \times 10^{-5}$	$V_0 \sqrt{d}$	Air Content
.232	30.0	5.71	12.3	8.6
.239	25.1	4.78	10.2	"
.234	25.0	4.76	10.2	"
.240	25.0	4.76	10.2	"
.250	19.5	3.71	7.96	"
.229	19.6	3.73	8.00	"

2"-Diameter 1.5-Calibre Ogive - October 15, 1952
C.I.T. Test

v_1	V_0	$R_0 \times 10^{-5}$	$V_0 \sqrt{d}$	Air Content
.319	100.3	10.91	42.1	8.6
.318	100.3		42.1	"
.314	100.3		42.1	"
.310	90.2	17.00	36.8	"
.307	90.2	17.00	36.8	"
.312	90.2	17.00	36.8	"
.313	84.9	16.00	34.6	"
.303	84.9	16.00	34.6	"
.302	84.9	16.00	34.6	"
.300	80.3	15.1	32.0	"
.299	80.3	15.1	32.0	"
.300	80.3	15.1	32.0	"
.297	75.2	14.2	30.7	"
.296	75.2	14.2	30.7	"
.300	75.2	14.2	30.7	"
.296	70.2	13.2	28.6	"
.294	70.2	13.2	28.6	"
.291	70.2	13.2	28.6	"
.294	64.2	12.4	26.6	"
.297	64.2	12.4	26.6	"
.297	64.2	12.4	26.6	"
.289	60.1	11.4	24.6	"
.291	60.0	11.4	24.6	"
.292	60.0	11.4	24.6	"
.282	56.1	10.5	22.9	"
.289	56.1	10.5	22.9	"
.288	56.9	10.6	22.4	"
.280	49.0	9.60	20.4	"
.280	49.0	9.62	20.4	"
.274	40.0	8.90	18.0	"
.272	40.0	8.90	18.0	"
.269	40.0	7.97	16.3	"
.268	40.0	7.61	16.3	"
.261	30.0	6.00	14.3	"
.260	30.9	6.00	14.3	"
.263	30.0	5.71	12.3	"

4"-Diameter 1.5-Calibre Ogive - October 16, 1952
C.I.T. Test

v_1	V_0	$R_0 \times 10^{-5}$	$V_0 \sqrt{d}$	Air Content
.320	67.0	25.4	38.6	9.0
.323	67.0	25.4	38.6	"
.331	67.0	25.2	38.6	"
.325	62.0	23.4	35.8	"
.319	61.0	23.3	35.6	"
.336	61.4	23.2	35.4	"
.319	61.0	23.3	35.6	"
.331	56.1	21.2	31.0	"
.330	56.0	21.2	31.7	"
.330	56.0	21.2	31.7	"
.321	50.5	19.0	29.2	"
.322	50.4	19.0	29.1	"
.315	50.3	19.0	29.0	"
.320	50.5	19.0	29.2	"
.307	44.9	17.0	25.9	"
.306	43.1	17.0	26.0	"
.294	44.7	16.9	25.8	"
.289	44.0	16.9	25.0	"
.290	44.0	16.9	25.0	"
.315	44.0	16.9	25.0	"
.290	39.1	14.9	22.6	"
.284	39.2	14.9	22.6	"
.295	39.2	14.9	22.6	"
.296	39.2	14.9	22.6	"
.275	33.7	12.7	19.4	"
.284	33.7	12.7	19.4	"
.284	33.6	12.7	19.4	"
.283	33.6	12.7	19.4	"
.299	28.2	10.7	16.3	"
.284	28.1	10.6	16.2	"
.284	28.1	10.6	16.2	"
.277	28.2	10.7	16.3	"
.282	28.0	10.6	16.2	"
.284	21.0	8.3	12.6	"
.286	22.1	8.3	12.8	"
.280	22.1	8.3	12.8	"

References

1. Parkin, Blaine R. Scale Effects in Cavitating Flow - A Preliminary Report. Report 21-7, Hydrodynamics Laboratory, CIT, December 28, 1951.
2. Kermeen, R. W. Some Observations of Cavitation on Hemispherical-Head Models. Report E-35.1, Hydrodynamics Laboratory, CIT, June 1952.
3. Parkin, Blaine R. Scale Effects in Cavitating Flow. Report 21-8, Hydrodynamics Laboratory, CIT, July 31, 1952.
4. Brown, F. Barton. Air Resorption in Water Tunnels. Report N-62, Hydrodynamics Laboratory, CIT, March 1949.
5. Power, R. B., Robertson, J. M., Ross, Donald, and Water Tunnel staff. Garfield Thomas Water Tunnel Operation. ORL report NOrd 7958-211, May 1, 1951.
6. Rouse, H., McNown, J. S., and Hsu, E. Summary of Cavitation Tests on a Systematic Series of Round Torpedo Heads. Final Report - Contract OEMsr 1353 (Declassified), Iowa Institute of Hydraulic Research, State University of Iowa, Iowa City, May 31, 1945, or Rouse, H., and McNown, J. S. Cavitation and Pressure Distribution - Head Forms at Zero Angle of Yaw. Bulletin 32, State University of Iowa, Studies in Engineering.
7. Rouse, H. Engineering Hydraulics. John Wiley and Sons, 1950, page 1011.
8. McNown, J. S., and Lamb, C. A. Cavitation Tests on a Systematic Series of Torpedo Heads - Effect of Model Size. Report 14, Iowa Institute of Hydraulic Research, State University of Iowa, Iowa City, April 1947.
9. Lock, C. N. H., and Johansen, F. C. Wind-Tunnel Interference on Streamline Bodies. R and M 1451, Aeronautical Research Committee, 1931.