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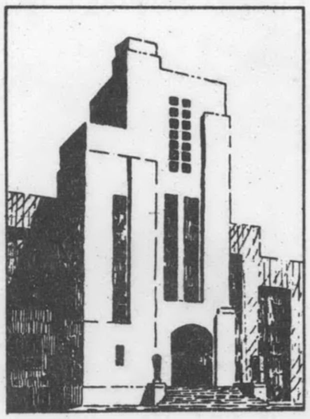
PROGRESS REPORT
RESEARCH ON MAIN INJECTION SCOOPS AND OVERBOARD DISCHARGES

By

John P. Breslin
and
William M. Ellsworth, Jr.



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PROGRESS REPORT

RESEARCH ON MAIN INJECTION SCOOPS AND OVERBOARD DISCHARGES

By

John P. Breslin and William M. Ellsworth, Jr.

ABSTRACT

This report is an account of the work accomplished on project NS643-028 entitled "Research and Tests on Main Injection Scoops and Overboard Discharges" which was initiated at the David Taylor Model Basin in March 1948. The program of the Advisory Committee on Scoop Design as interpreted by the Model Basin is given. A very brief discussion of the hydrodynamics of scoop flow is given and reference is made to a complete treatment written by W. Spannhake. An analysis of available ship and ship-model boundary layer data is presented and the influence of the boundary layer momentum thickness and shape parameter on the flow to the scoop is discussed. An account of the equipment built at the Model Basin for this project is rendered by reference to sketches, figures and working plans. Three families of scoops have been derived mathematically from three different parent designs. No test data have been obtained because of the low priority assigned this work and it is therefore concluded that the entire project be re-evaluated and contracted to another laboratory in order to accomplish the desired test work.

The program of research as outlined by the Advisory Committee on Scoop Design is given in the Appendix.

INTRODUCTION

A project was initiated (1)* at the David Taylor Model Basin in March 1948 to determine the relationship between the developable head, flow capacity and drag of a series of main injection scoops. This project was an outgrowth of a test program begun in 1940 but abandoned during World War II. Plans for the new project were formulated by the Advisory Committee on Scoop Design which met at the Model Basin on 27 April 1948 and laid out a broad program (2) for the guidance of the Model Basin. It is the purpose of this report to state the problems set forth and the progress which has been made on this project.

The basic purpose of a marine condenser scoop-overboard discharge system is to supply sufficient sea water to the main condensers to effect proper condenser action which maintains a high vacuum on the steam turbine discharge. The efficiency of the steam plant then depends upon the performance of the scoop system. Perhaps it is to insure a high efficiency that present design practices lead to over-sized scoops.

To design an efficient scoop which must compare favorably with the efficiency of a circulating pump it is necessary to know the effects of various parameters on scoop flow and drag. Because such data are not available the Advisory Committee on Scoop Design was formed. This Committee which is made up of representatives of the Bureau of Ships and of many firms in the marine industry advocated that a systematic series of scoop designs be tested in model scale.

To comply with the suggestions of the Advisory Committee, test equipment for both two- and three-dimensional studies of scoop flow has been built. Investigations of methods for deriving families of scoops from the three designs selected by the Committee have been made and an extensive theoretical study has been completed by W. Spannhake which will be published soon as a TMB Report (3). No test work has been accomplished as all the experimental and much of the theoretical work on this project has moved slowly because of the low priority assigned since December 1948. The prospects of future work on this project at this activity are poor because of the competition of a large number of other problems with higher TMB priority.

RESEARCH PROGRAM

The program of research as proposed by the Advisory Committee on Scoop Design (2) is given in detail in the

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* Numbers in parentheses indicate references on page 14.

Appendix. In an effort to comply with this comprehensive plan the Taylor Model Basin has proceeded with the following initial program:

1. A study of the hydrodynamic theory of scoop flow.
2. A compilation of available ship boundary layer data.
3. Revision of existing equipment and construction of new apparatus for 2- and 3-dimensional tests.
4. Mathematical design of scoop families.

The progress made on this program is reviewed in the subsequent sections of this report.

Hydrodynamic Theory of Scoop Flow

A thorough treatment of the theory of scoop-system flow has been given by W. Spannhake (3). The theoretical analysis reveals that the drag of a scoop system and the pressure built up at the condenser inlet-water box depend upon four loss coefficients which are functions of the geometry of the scoop system, the boundary layer flow at the scoop and overboard discharge, and upon the operating conditions. Inasmuch as it is not yet possible to compute these variable coefficients, or even to estimate them with accuracy, recourse must be made to carefully controlled model tests for prediction of the performances of any particular scoop system.

Model tests will produce valid predictions only if all the important parameters of the flow are properly scaled. Since all the flow into a scoop-system comes from the ship boundary layer it is most important to impose a kinematically similar boundary layer on the model system. Ship boundary-layer characteristics depend upon the shape of the hull, the position on the girth , upon the Reynolds number based on the distance from the bow, and upon the Froude number. The dependence upon Froude number is more marked on high speed ships of small draft. It is common knowledge that ship-Reynolds numbers cannot be matched in model experiments. Therefore, the boundary layer kinematics must be reproduced in the neighborhood of the scoop and overboard discharge by means of some artifice. Experiments have been conducted and recently reported (4) by the Hydraulic Laboratory (Newport News Shipbuilding and Dry Dock Co.) in which faired strut forms were staggered at various distances from the boundary forward of a model scoop and overboard discharge to produce various boundary layer velocity distributions. These experiments show that the scoop flow characteristics depend upon the velocity distribution in the boundary layer and point up the need for scaling the estimated ship boundary layer conditions at the scoop and discharge.

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Ship Boundary Layer Data

Since the condenser-scoop flow comes entirely from the boundary layer of the ship it is imperative to know as much as possible about the actual flow which may be expected to exist near the hull. Such information is necessary for the preliminary design of a scoop system as well as for fixing the conditions on a model experiment for prediction of the performance of the prototype system.

Ship and model boundary-layer data have been assembled from a variety of sources. Needless to say, there is relatively very little information on the characteristics of ship boundary layer velocity distributions. On the other hand, the boundary layer on a flat plate has received much attention in the past 30 years and as a consequence is well formulated especially for Reynolds numbers below 10^8 for the case of zero pressure gradient.

The data presented in Tables 1 and 2 have been gleaned from experiments made by the U.S. Experimental Model Basin on the USS HAMILTON (EX-DD141) 1933-1935; from experiments reported by G. S. Baker (5), and from the calibration tests of the rod-meters on various naval vessels which were conducted by the Pitometer Log Corporation (6).

Analysis of these data has shown that in most instance the velocity distribution as measured on the ship and on ship models can be accurately specified by

$$u = U\left(\frac{y}{\delta}\right)^{1/n} \qquad [1]$$

where u is the boundary layer velocity at a distance y from the wall,
U is the velocity just outside the boundary layer
δ is the thickness of the boundary layer and
n is a dimensionless exponent.

It is advantageous to derive from the boundary layer velocity distributions a so-called momentum thickness θ, and a displacement thickness δ^* which are defined as follows:

$$\theta = \delta\int_0^1 \frac{u}{U}\left(1 - \frac{u}{U}\right)d\eta \qquad [2]$$

$$\delta^* = \delta\int_0^1 \left(1 - \frac{u}{U}\right)d\eta \qquad [3]$$

where $\eta = \left(\frac{y}{\delta}\right)$, a dimensionless parameter based on the normal distance from the surface

The displacement thickness, momentum thickness, and shape parameter (H) are evaluated in terms of δ and n for the velocity distribution given by Equation [1]. Thus

$$\delta^*/\delta = \frac{1}{n+1} \qquad [4]$$

$$\theta/\delta = \frac{n}{(n+1)(n+2)} \qquad [5]$$

$$H = \frac{\delta^*}{\theta} = 1 + \frac{2}{n} \qquad [6]$$

Values of θ/x, where x is the distance from the bow, obtained from ship and model data, are plotted against the x- Reynolds number in Figure 1. The spread in the ship and ship-model data is to be expected since the data have been taken at different positions on the girth. The relative height of the measuring points above the base line Z, for the HAMILTON data is given as a fraction of the draft, D, in Table 1. The values of θ/x, on the average, are seen to be higher for positions near the keel than for positions high on the girth.

For any body in a pressure field, the momentum thickness at a point is known to depend upon the integrated effect of the pressure distribution as well as the frictional drag of the surface upstream from the measuring point. For a flat plate with zero pressure gradient,

$$\theta/x = \tfrac{1}{2} C_D \qquad [7]$$

where C_D is the integrated frictional resistance coefficient over the distance x. For comparison with the data, one-half the value of the Schoenherr frictional-resistance coefficient has been plotted on Figure 1 as well as the dimensionless momentum thickness which is obtained by assuming that the boundary layer shape parameter is $H = 1.286$ (or $n = 7$). The agreement between the values of θ/x as derived from Hansen's data (7) and those calculated from Schoenherr's friction line is good, as should be expected. The lack of agreement of the ship and model data with these flat plate formulae is not surprising. However, it seems significant that the θ/x values for the HAMILTON model data are about the same as those for the ship when the values for geometrically similar locations are compared. Thus θ/x shows little dependence upon Reynolds number.

The vertical spread of the data may indicate dependence upon the Froude number and the geometrical position of the point of measurement in the pressure field of the body.

A comparative analysis of the shape parameter H derived from both ship and model experiments is given in Figure 2. There is seen to be little correlation between the shape parameters for the ship and model boundary layers at geometrically similar points. There seems to be some indication that the shape parameter for the model flow is somewhat higher than that for the ship. However, much more data from more carefully conducted experiments would have to be obtained before valid decisions concerning the effect of scale on θ/x and H can be made. In any event some idea of the bounds of H can be obtained from Figure 2.

These boundary layer parameters θ/x and H may, in the absence of specific data, be used to determine the various quantities which should be known in order to design a condenser scoop; that is such quantities as the mean velocity, the average head, the total kinetic energy, etc., available in that part of the boundary layer which is taken into the scoop.

It seems reasonable to follow Hewins and Reilly (8) in assuming that the shape of a section of that part of the boundary layer flow which passes into the scoop is nearly elliptical as shown in Figure 3. If the proportions of this section are known as well as the boundary layer velocity distribution and the rate of flow through the scoop, then the mean velocity, the average available total head, and the total kinetic energy of the flow may be computed. Formal integral expressions have been derived in reference 3.

In as much as the boundary layer parameters H and θ must be estimated it is important to know how the accuracy of the prediction of mean velocity, average available head, etc depend upon the accuracy of the estimates of H and θ. If, for simplicity, the section normal to the entry flow taken forward of the scoop is rectangular instead of elliptical, as shown in the sketch of Figure 3, the distance of the bounding streamline t_o from the hull is given by

$$\frac{t_o}{x} = \left(\frac{H+1}{2}\right)^{\frac{2}{H+1}} \left[\frac{H(H+1)\,\theta/x}{(H-1)}\right]^{\frac{H-1}{H+1}} \left(\frac{Q}{x w_o U}\right)^{\frac{2}{H+1}} \qquad [8]$$

where x is the distance from the bow to the flow section.
Q is the volume rate of flow into the scoop, and
w_o is the width of a rectangular flow section taken forward of scoop, similar to that shown in Figure 3.

Now it is not necessary to know θ and H to a high degree of accuracy in order to obtain reasonably accurate values of t_o. Thus, if for H = 1.286 (corresponding to n = 7), the value of θ selected from the curve of Figure 1 happens to be in error by 100 percent, the resulting error in t_o is only 9 percent. Since the values of H will always be contained in the interval $1.10 \leq h \leq 1.35$ the maximum error in selecting H is 32 percent. Now assuming no error in θ and the maximum error in H, it is found that for the design conditions on DD828 i.e., Q=76 ft /sec, w_o=4 ft. (twice scoop width*) θ = 0.13 ft. and U = 38.2 knots, the resulting error in t_o will be about 25 percent, if, however, a mean value of H be taken at 1.23 then the maximum error in t_o is only 5 percent. In practice some error will be involved in both θ and H but with judicious selections of these values from the data given in this report the inaccuracy in t_o should be small. Consequently, the mean velocity and the mean available head of this flow, calculated from the following expressions, give reasonable estimates of the flow.

$$\frac{\bar{U}}{U} = \frac{2}{H+1}\left[\frac{H-1}{H(H+1)}\right]^{\frac{H-1}{2}}\left(\frac{t_o}{\theta}\right)^{\frac{H-1}{2}} \qquad [9]$$

$$\frac{\bar{h}}{h} = \frac{H+1}{3H-1}\left[\frac{H-1}{H(H+1)}\right]^{H-1}\left(\frac{t_o}{\theta}\right)^{H-1} \qquad [10]$$

where $\bar{U}$ and $\bar{h}$ are the mean velocity and mean head respectively and $h = U^2/2g$, the free stream stagnation head.

Equipment for Two- and Three-Dimensional Tests

Despite the fact that scoop flow is essentially 3-dimensional it was felt that valuable hints as to the effectiveness of inlet shapes could be obtained from 2-dimensional studies conducted in the TMB bentonite channel. In this facility the flow may be observed by means of soluble dyes and fine threads. Variations in shape which show promise in such a test must be carefully checked by use of larger scale 3-dimensional models because the pressure distribution and flow diffusion characteristics are considerably different in the two cases.

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* It is shown in reference (7) that the use of a rectangular section of width equal to scoop opening width instead of an elliptic section as sketched in Figure 3, leads to inaccurate determination of mean available head. However, close agreement is achieved in the case of the DD828 scoop by assuming the section A_o is a rectangle having twice the width of the scoop opening.

Plastic models built for the 2-dimensional studies are shown in the photograph in Figure 4. Detailed dimensions of the models are given in reference (10).

A scoop-overboard discharge test compartment for experiments with 3-dimensional models was built for tests conducted at TMB in 1941-42. The test-section was designed to be attached to the carriage dynamometer for the purpose of determining the drag of scoops and discharges. The test apparatus has recently been modified so that the test section is now supported by flexures (11) from supports attached to the surrounding hull. The drag force may now be measured by means of a ring-strain-gage dynamometer. The photographs in Figures 5 and 6 show the changes which have been made. This drag dynamometer is calibrated (12) by applying known loads through the linkage shown in the photograph in Figure 6. A schematic wiring diagram is given with a calibration of the entire dynamometer system in Figure 7. Provision has been made to survey the boundary layer forward of the scoop and overboard discharge locations (13). Very small total head and static pressure tubes are positioned by means of a micrometer screw traversing mechanism (14) as shown in the sketch on Figure 8.

DESIGN OF SCOOP FAMILIES

The Scoop Advisory Committee requested that variations of three types of scoops, shown in Figure 9, be made up to form three families. The geometry of the testing apparatus and that of the scoop makes it extremely difficult to vary one parameter at a time to obtain a family with systematic variations of form. The analysis which follows is an attempt to define the scoop families by mathematical means to insure a systematic series of scoops.

Westinghouse Design

The Westinghouse design (15), designated as Scoop "A" is, in profile, made up of several circular arcs. Since there appears to be no advantage gained by the complexity of this construction, a revision of this design is proposed which might be used as a parent scoop of shape similar to the Westinghouse type. Using the notation indicated on the definition sketch in Figure 10 the following relations may be adopted:

Let $\alpha_1 = \ell/W$, the aspect ratio of the entrance*

$\epsilon_1 = A/A_1$, the expansion ratio of the entrance* or more appropriately, the area ratio

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* The definitions of aspect and expansion ratios referred to in the Scoop Committee's program apply to the throat section of the scoop. The definitions adopted here are more suitable for defining scoop shape.

where $\bar{w}_1$ is the mean width of the trapezoidal entrance at the hull
ℓ is the length of scoop opening at the hull
A_1 is the entrance area $\bar{w}_1 \ell$ as shown in Figure 3
$A = \pi r^2$ is the cross sectional area of the inboard end of the diffuser.

The entrance dimensions of the scoop may now be completely specified in terms of the aspect and expansion ratios and the other fixed quantities. Thus

$$\ell = \sqrt{\frac{\alpha_1 A}{\epsilon_1}} \qquad [11]$$

$$\bar{w}_1 = \sqrt{\frac{A}{\epsilon_1 \alpha_1}} \qquad [12]$$

and

$$L = \left[r - \frac{1}{2} \sqrt{\frac{A}{\epsilon_1 \alpha_1}} \right] \cot \varphi + \frac{1}{2} \; \frac{\alpha_1 A}{\epsilon_1} \qquad [13]$$

where L is the length shown in Figure 10.

The Westinghouse plan shows a rectangular entrance whereas a trapezoid is specified in this TMB proposal. Such a change in plan view not only makes it easier to set up mathematical formulae for the scoop boundaries but also provides for a smoother entrance by avoiding the sharp change in the width at the after edge of the opening. With points C and D located by means of Equations [11] and [13] the profile shape of the scoop in the longitudinal centerline plane is determined by a simple geometric construction of two circular arcs termed the upper and lower circles. The upper circle is constructed tangent to the baseline at C(L,0) and tangent to a line through B parallel to the scoop centerline at P(0,h). The lower circle is constructed to pass through the points A and D and be tangent to a line through A parallel to the scoop centerline at P. A graphical comparison between the profiles of the Westinghouse design (15) and this TMB proposed design is given in Figure 11. It is seen that the curves are close. In plan view the width is taken to change linearly so that the width w at any section is

$$w = \frac{2(\bar{w}_1 - 2r)x}{2L - \ell} + 2r \qquad [14]$$

The sections are taken normal to a circle drawn through P tangent to the scoop centerline and through the baseline at $x = L - \ell/2$. The section shape must change from rectangular to circular between points C and B. The corners are made with circular arcs which are specified by

$$r_u = r\sqrt{\frac{L-x}{L}} \qquad [15]$$

$$r_\ell = \begin{cases} r\sqrt{\frac{L-\ell-x}{L-\ell}}, & 0<x<L-\ell \\ 0, & L-\ell \le x \le L \end{cases} \qquad [16]$$

where r_u and r_ℓ are the radii of the upper and lower corners respectively

and r is the radius of the section at the inboard end of t diffuser.

Thus a scoop very similar to the Westinghouse design is completely specified by fixing ϵ_1, α_1, and φ. However, it is impossible to vary one parameter at a time. The divergence angle φ should be kept as small as possible i.e. close to 4°, but for a fixed diffuser discharge at P it is difficult to keep φ small while α_1 and ϵ_1 are separately varied. Variations of ϵ_1 and α_1 must necessarily be accompanied by variations in the angle φ otherwise abnormal scoop lengths will be obtained for small α_1 and large ϵ_1.

Newport News Scoop "C"

Scoop C, the design of the Newport News Shipbuilding and Dry Dock Company (16), is sketched in Figure 12. Here again it is expedient to modify the shape of the opening from rectangular to trapezoidal to make it more amenable to mathematical treatment.

Using the same notation as above the expressions for the dimensions of the hull opening, or entrance, in terms of the expansion and aspect ratios are given by Equations [11] and [12] and the width at any x is given by Equation [14]. If it is assumed that the line BC of Figure 12 is faired into the ship bottom by means of a circle of radius R which is tangent to the diffuser wall at some point C and tangent to the bottom at D, then the scoop length is given by

$$L = R\cot\left(\frac{\theta-\beta}{2}\right) + r\sin\theta - (h-r\cos\theta)\cot(\theta-\beta) \qquad [17]$$

Another expression for L is obtained from the plan view, viz,

$$L = \frac{1}{2}\sqrt{\frac{\alpha_1 A}{\epsilon_1}} + \left(r-\frac{1}{2}\sqrt{\frac{A}{\epsilon_1\alpha_1}}\right)\cot\varphi \qquad [18]$$

Now although r, θ, A and h are fixed, this scoop can be varied in shape in a number of different ways. The aspect and expansion ratios may be varied by changing the fairing radius R keeping the profile divergence angle β constant and allowing the length L and the angle φ to change. Conversely R may be kept constant and a family may be derived in which β, φ, and L are changed to give the desired variation of ϵ_1 and α_1. The transition from rectangular to circular cross section is made by permitting the corner radii to grow in accordance with the same arbitrary formulas as used for the family of Scoop A as given by Equations [15] and [16].

Newport News Scoop "D"

The third selection of the Scoop Committee for a parent model is designated as Newport News Scoop "D" (17) which is sketched in Figure 13. It is seen that this scoop consists in profile of a straight-wall diffuser and a straight section near the entrance which are faired together with circles of radii, R_1, R_2 and R_3. Here again the scoop may be varied in a number of ways. The most practical method which is suggested by the design itself is to hold the profile shape of the diffuser and vary the shape of the entrance from point C to J on Figure 13 in a systematic manner.

Let the points A, B, C, M and K on Figure 13 be fixed. The length ℓ and the mean width $\bar{w}_1$ are calculated from Equations [11] and [12]. For each pair of values of the aspect and expansion ratios, α_1, ϵ_1, the shape of the upper side in profile is determined by constructing the external tangent FG to the circular arcs having radii R_1 and R_2 with centers at $H(L,R_1)$ and $E(x_2,y_2)$ respectively. The coordinates of E are given in terms of the fixed parameters of the scoop by

$$x_2 = R_2 \sin(\theta-\beta) + (r-S\tan\beta)\sin\theta - S\cos\theta \qquad [19]$$

$$y_2 = h - S\sin\theta - (r-S\tan\beta)\cos\theta - R_2\cos(\theta-\beta) \qquad [20]$$

The entrance angle γ measured with respect to the vertical is given by

$$\gamma = \frac{\pi}{2} - \tan^{-1}\left(\frac{y_2-R_1}{L-x_2}\right) - \tan^{-1}\left[\frac{R_1-R_2}{\sqrt{(L-x_2)^2+(R_1-y_2)^2-(R_2-R_1)^2}}\right] \qquad [21]$$

Now the scoop length L is a function of α_1 and ϵ_1 only because with point K fixed, $L-\ell$ is a constant and ℓ is given entirely by these numbers from [11]. Thus, for fixed radii R_1 and R_2, the angle γ also depends only upon α_1 and ϵ_1 and the entire geometry of the scoop entrance is specified by these two parameters. It must be remembered that the diffuser angle ϕ will change and care should be taken to keep ϕ small.

At this point it should be remarked that the use of a circular arc tangent to a straight line does not provide a truly fair boundary since the radius of curvature at the point of tangency is discontinuous. The use of so-called easement curves to provide continuity in the second derivative of the boundary in the neighborhood of the juncture of the circle and straight line could be recommended. However for the sake of simplicity no such transition curves have been introduced in the derivation of any of the three scoop families. Modifications of this type could be made, say, on the best member of each family to determine if any further advantages may be gained from such a refinement in the scoop boundary.

CONCLUSIONS AND RECOMMENDATIONS

Although the test equipment for the condenser scoop program has been completed, it is highly improbable that any extensive test agenda could be effectively carried out in the near future at this activity because of the relatively low priority which is assigned to this work. It is recommended that the equipment be utilized by a contractor to conduct such tests as the Bureau of Ships and the Advisory Committee on Scoop Design deem advisable.

It is also strongly recommended that the program as originally planned be reviewed for practicability. Although the foregoing analyses indicate that consistent families of scoops may be derived, it appears to the authors that much more valuable information might be obtained to improve scoop performance by study of the effect of various techniques for control of the boundary layer flow in the neighborhood of the scoop. Thus, the flow through any scoop may be materially improved by the use of faired ramps to reduce side flow and by removal of the low energy boundary flow by suction slots both forward of the scoop and along the outboard side of faired deflectors or ramps. The beneficial effects of such artifices has been demonstrated by tests on aircraft scoops (see, for example, Reference (17)). The fact that each scoop system must be "tailored" to the machinery layout of the ship makes it most difficult to utilize the advantages which might be found from an extensive study of the effects of expansion and aspect ratios. It is recommended that the Advisory Committee on Scoop Design review the original program to decide on the best policy for the conduct of scoop-flow research.

ACKNOWLEDGEMENTS

Boundary layer data from the USS HAMILTON and the HAMILTON Model were obtained from earlier measurements made by Mr. Charles E. Janes. Compilations and analyses of these data, as presented herein, were made by Mr. John P. Breslin and Mr. John L. Power.

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APPENDIX

RESEARCH PROGRAM PROPOSED BY ADVISORY COMMITTEE ON SCOOP DESIGN

The program or research as proposed by the Advisory Committee on Scoop Design (2) listed these topics for investigation in the following order:

1. Three types of scoops to be tested initially, each in conjunction with the same overboard discharge known at TMB as Type "G".

   a. Type "A" scoop of the 1940-42 tests.
   b. Type "C" scoop of the 1940-42 tests with 36° angle.
   c. Type "D" scoop, a design prepared by the Newport News Shipbuilding and Dry Dock Co.

Profile sketches of each type are given in Figure 9.

2. Aspect and expansion ratios to be 1.5 in first models. Ratios to be varied either way from this point on subsequent tests.

3. Drag, flow and pressure measurements to be made.

4. Effect of sharp versus rounded longitudinal edges of scoops to be investigated.

5. Cavitation in scoops to be investigated.

6. Boundary layer investigation.

7. Hydrodynamics of flow in scoops to be studied.

8. Redesign of existing scoop testing apparatus.

9. Develop instrumentation to permit test work to be accomplished in the circulating water channel at the Taylor Model Basin.

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TABLE 1a

VALUES FOR BOUNDARY LAYER PARAMETERS OBTAINED FROM MEASUREMENTS OF VELOCITY DISTRIBUTION IN BOUNDARY LAYER ON USS HAMILTON (EX DD-141)

Pitot Tube Stat. No.	Dist. Aft of Bow x-feet	Ship Speed Knots	Reynolds Number R_x x 10^{-8}	$\frac{\delta}{x}$ x 10^2	$\frac{\delta^*}{x}$ x 10^3	$\frac{\theta}{x}$ x 10^3	Shape Factor H	Rel. Hght. of Station Z/D	Corresp. No. on Fig. 1
1	83	10.1	0.92	1.05	1.40	1.18	1.19	0.130	①**
		12.7	1.14	1.21	1.71	1.35	1.27		①
		15.8	1.42	0.84	1.30	1.00	1.29		①
		18.7	1.68	1.00	1.31	1.07	1.21		①
2	136	10.2	1.53	0.48	0.61	0.51	1.13	0.639	②
		12.9	1.93	0.46	0.61	0.46	1.28		②
		15.7	2.34	0.46	0.61	0.46	1.27		②
		18.6	2.78	0.41	0.48	0.43	1.25		②
3	171	9.97	1.85	1.00	1.20	0.97	1.24	0.491	③
		12.8	2.37	0.97	1.04	0.84	1.24		③
		15.8	2.94	0.73	0.99	0.79	1.26		③
		18.7	3.48	0.58	0.48	0.42	1.12		③
4	197	10.0	2.14	0.85	0.93	0.76	1.23	0.037	④
		12.5	2.68	0.55	0.67	0.56	1.20		④
		15.7	3.37	0.84	0.99	0.86	1.15		④
		18.6	3.99	0.55	0.86	0.67	1.29		④
5	242	10.3	2.70	0.96	1.29	1.10	1.10	0.287	⑤
		12.9	3.40	1.00	1.62	1.13	1.42		⑤
		15.7	4.14	0.79	1.08	1.03	1.05		⑤
		18.6	4.19	0.90	1.19	0.89	1.35		⑤
6	279	9.97	3.05	0.75	0.80	0.65	1.24	0.380	⑥
		12.8	3.87	0.54	0.69	0.56	1.24		⑥
		15.8	4.79	0.99	1.06	0.80	1.26		⑥
		18.7	5.67	0.72	0.78	0.65	1.21		⑥

** Circles around the numbers indicate full scale data. When numbers are the same for full scale and model then measurements were taken at the same values of Z/D where Z is the height ~~above~~ the keel and D is the draft.

TABLE 1b

VALUES FOR BOUNDARY LAYER PARAMETERS OBTAINED FROM MEASUREMENTS ON TMB MODEL OF USS HAMILTON

Pitot Tube Stat. No.	Dist. Aft of Bow x-feet	Ship Speed Knots	Reynolds Number R_x x 10^{-6}	$\frac{\delta}{x}$ x 10^2	$\frac{\delta^*}{x}$ x 10^3	$\frac{\theta}{x}$ x 10^3	Shape Factor H	Rel. Hght. of Station Z/D	Corresp. No. on Fig. 1
1	5.35	3.06	2.98	1.06	1.60	1.20	1.338	0.130	$\boxed{1}$**
2	8.77	3.15	5.02	0.53	0.60	1.50	1.238	0.639	$\boxed{2}$
3	11.03	3.03	4.01	0.68	1.00	0.70	1.316	0.491	$\boxed{3}$
4	12.71	3.02	6.97	0.85	0.90	0.60	1.175	0.037	$\boxed{4}$
4	12.71	2.85	4.77	0.85	1.20	0.90	1.292	0.037	$\boxed{4}$
5	15.61	2.71	7.69	0.99	1.30	1.00	1.267	0.287	$\boxed{5}$
6	18.00	2.69	5.81	1.18	1.70	1.30	1.302	0.380	$\boxed{6}$
7	9.74	2.32	2.60	0.75	0.70	0.60	1.183	0.694	$\boxed{7}$
8	9.74	2.50	2.81	0.82	1.00	0.80	1.242	0.241	$\boxed{8}$
9	9.74	2.53	2.84	1.63	2.40	1.70	1.294	0.556	$\boxed{9}$
10	16.64	1.76	3.37	2.55	3.90	2.90	1.332	0.843	$\boxed{10}$
11	16.64	2.03	3.89	1.20	1.50	1.20	1.261	0.213	$\boxed{11}$

** Squares around the numbers indicate model data. When numbers are the same for full scale and model then measurements were taken at the same value of Z/D, where Z is the height above the keel and D is the draft.

TABLE 2

VALUES FOR BOUNDARY LAYER PARAMETERS OBTAINED FROM MEASUREMENTS ON VARIOUS SHIPS AND MODELS

Ship or Model	Dist. Aft of Bow x-Feet	Ship Speed Knots	Reynolds Numbers $R_x \times 10^{-8}$	$\frac{\delta}{x} \times 10^2$	$\frac{\delta^*}{x} \times 10^3$	$\frac{\theta}{x} \times 10^3$	Shape Factor H	Corresp. No. on Figure
USS EDISON	60	35.4	2.40	0.65	0.74	0.59	1.250	⑫**
USS NOA	89	24.7	2.40	1.58	2.30	1.93	1.210	⑬
USS McDERMOT	92	15.2	1.53	0.64	0.77	0.60	1.275	⑭
SS AMERICA	210	21.6	5.36	1.19	1.29	1.03	1.245	⑮
USS SARATOGA	275	16.3	5.19	1.39	2.22	1.64	1.360	⑯
" "	275	34.5	11.0	1.09	1.72	1.27	1.350	⑰
USS YORKTOWN	314	17.6	6.39	0.58	0.46	0.30	1.150	⑱
" "	314	24.0	8.71	1.06	1.32	1.05	1.260	⑲
" "	314	30.0	10.9	1.09	1.44	1.12	1.280	⑳
SNAEFELL	196	20.4	5.0	0.76	0.91	0.73	1.248	㉑
"	196	20.4	5.0	0.76	0.90	0.73	1.248	㉒
Model Snaefell	10.70	7.96	0.071	0.78	1.28	0.93	1.370	$\boxed{23}$
" "	10.70	7.96	0.071	1.01	1.48	1.12	1.318	$\boxed{24}$
ASHWORTH	87	11.25	1.25	0.67	0.22	0.59	1.219	㉕
"	300	11.25	4.30	0.67	0.87	0.68	1.274	㉖

** See foot note tables 1a and 1b.

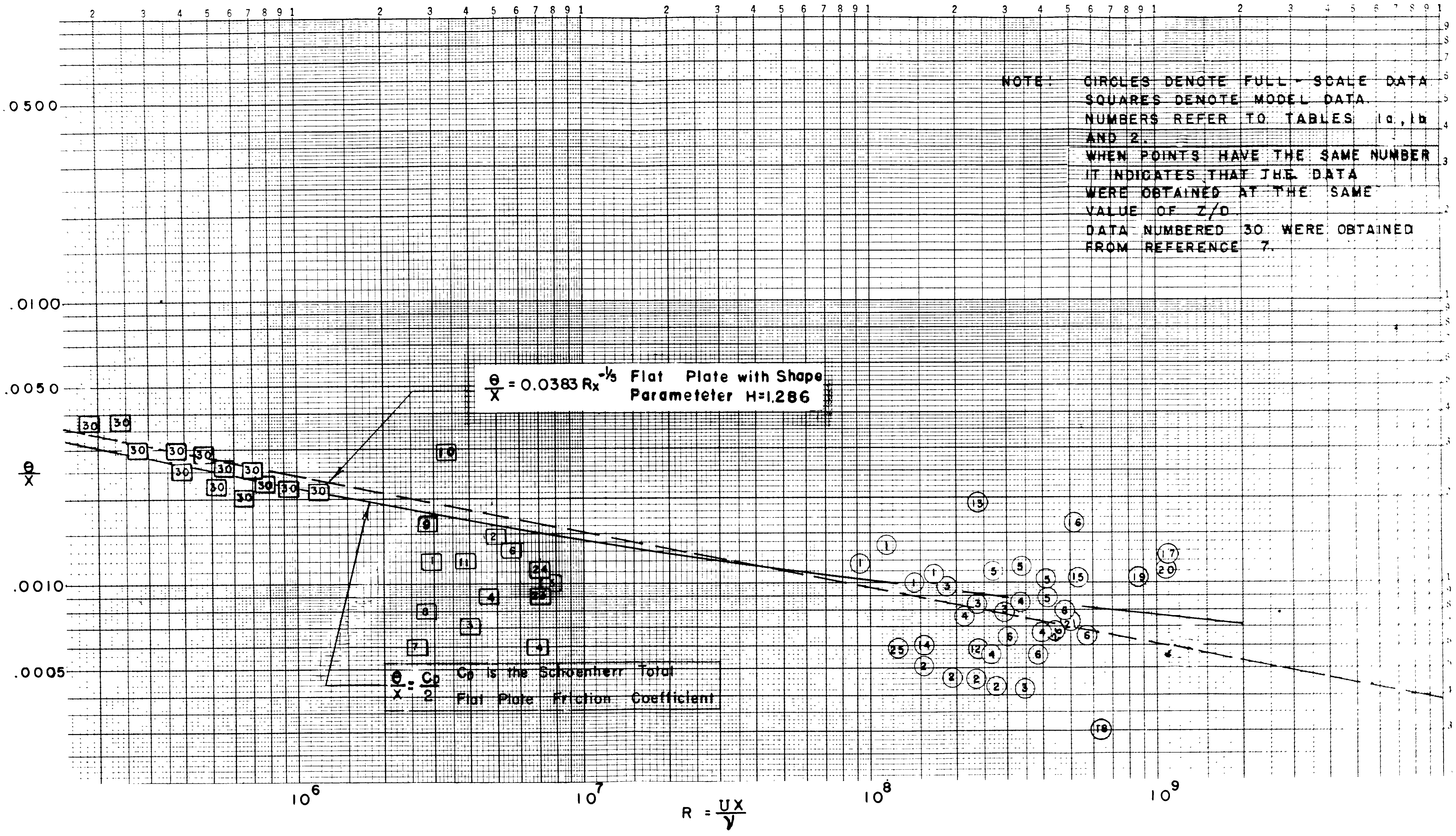
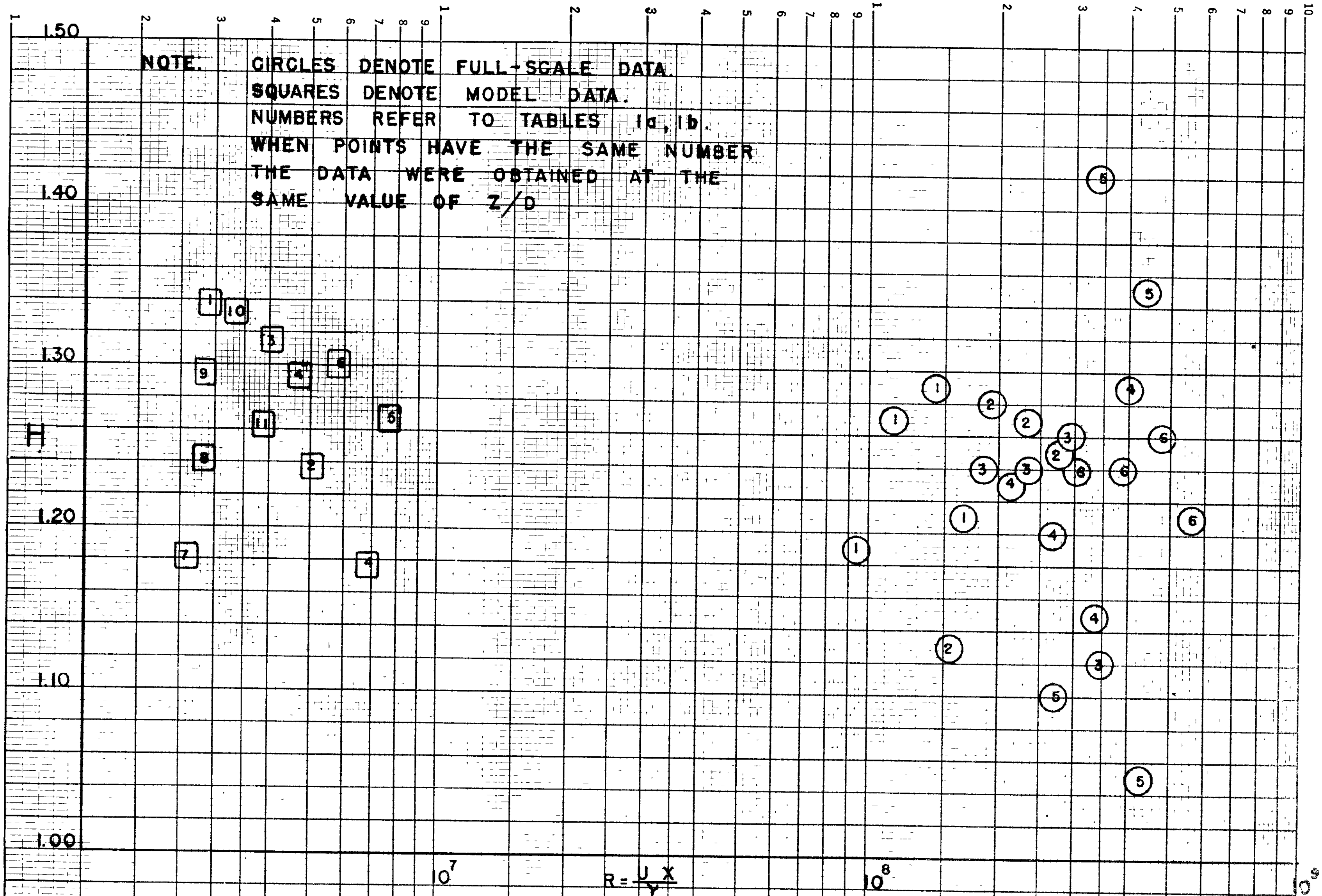


FIGURE I VARIATION OF MOMENTUM THICKNESS (EXPRESSED AS A FRACTION OF THE DISTANCE FROM THE BOW) WITH REYNOLDS NUMBER, FROM SHIP AND MODEL MEASUREMENTS.



NOTE: CIRCLES DENOTE FULL-SCALE DATA.
SQUARES DENOTE MODEL DATA.
NUMBERS REFER TO TABLES Ia, Ib.
WHEN POINTS HAVE THE SAME NUMBER THE DATA WERE OBTAINED AT THE SAME VALUE OF Z/D

FIGURE 2 VARIATION OF SHAPE PARAMETER (H) WITH REYNOLDS NUMBER FROM MEASUREMENTS ON U.S.S. HAMILTON (EX-DD141) AND ON 20-FOOT MODEL

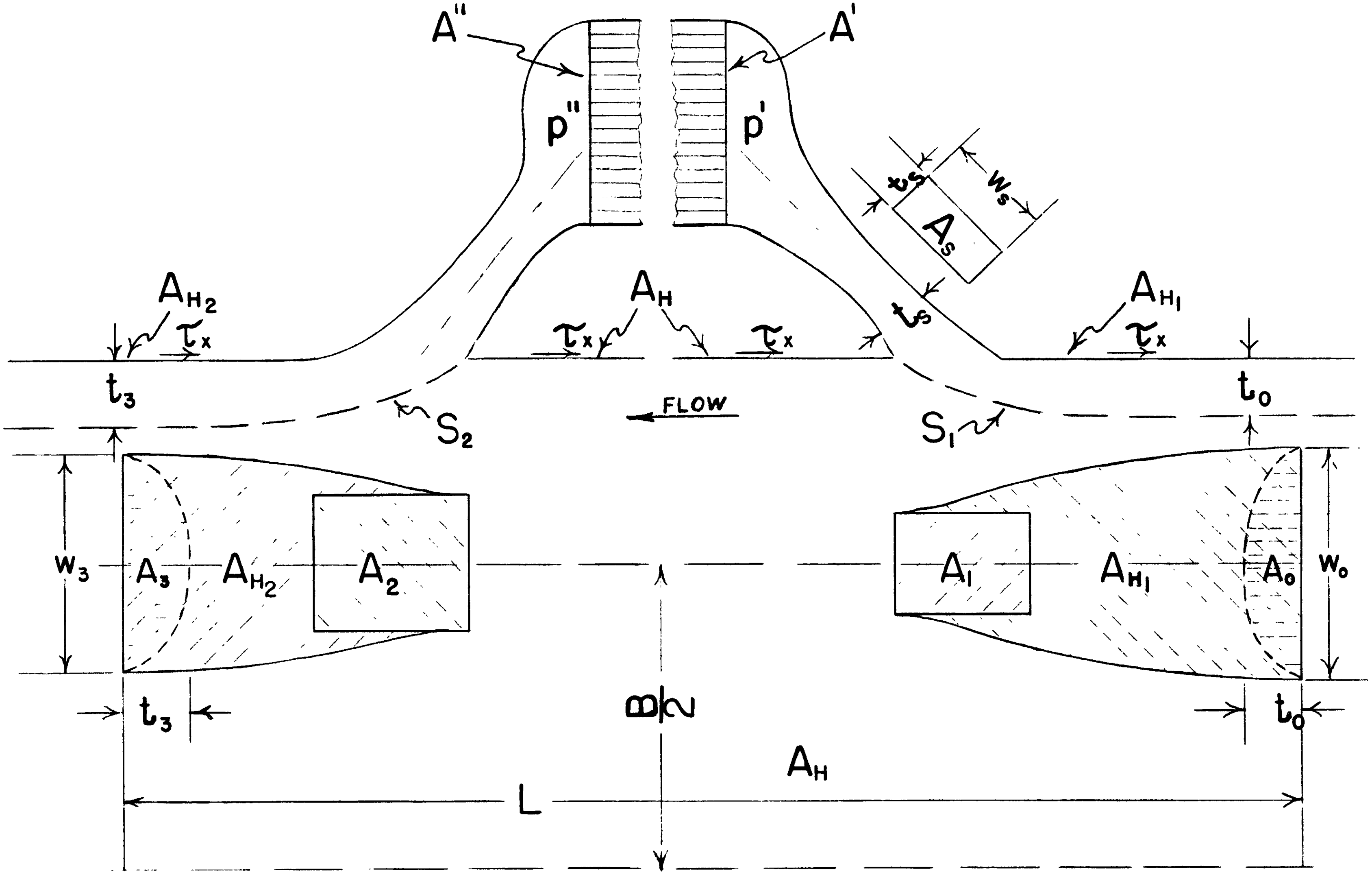


Figure 3 - Definition Sketch of Flow Through Condenser Scoop

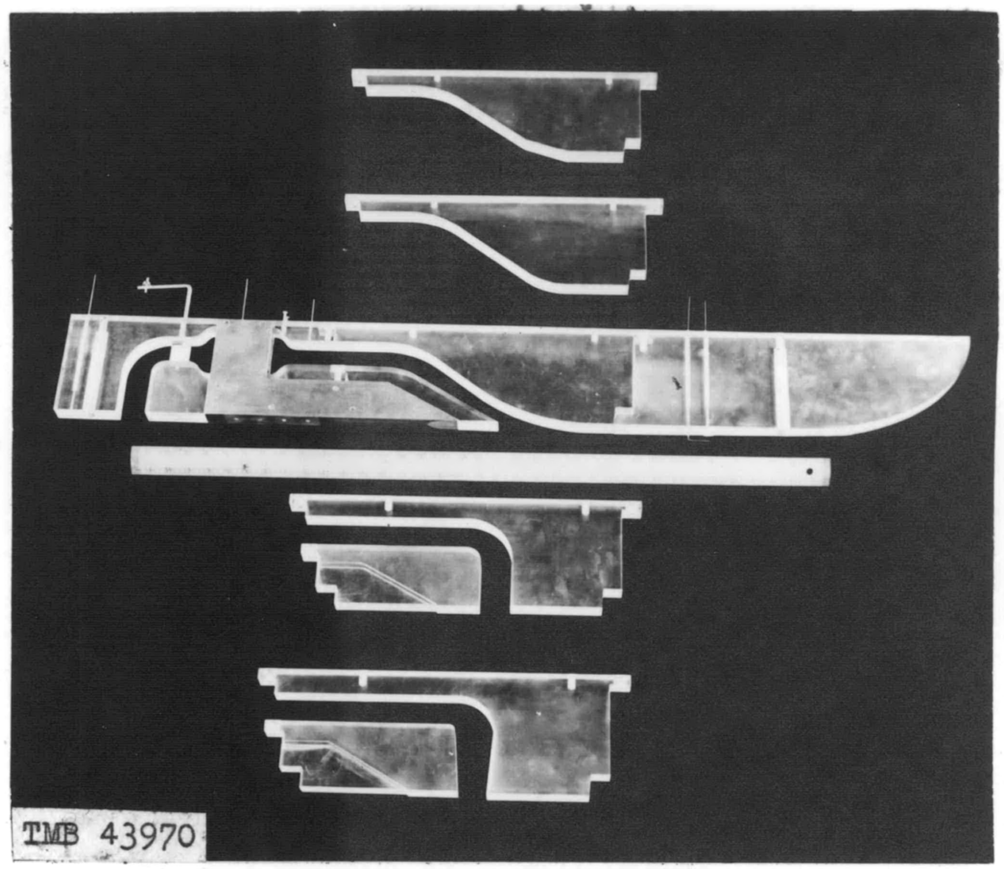


Figure. 4. Photograph of Scoop Profiles for a Two-Dimensional Study in TMB Bentonite Channel.

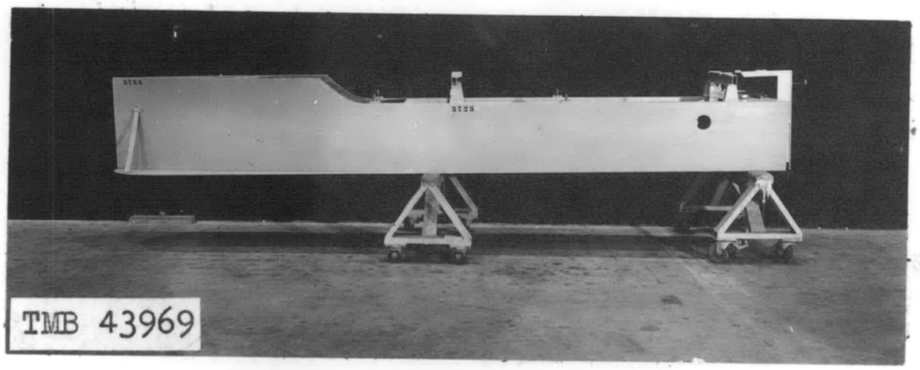
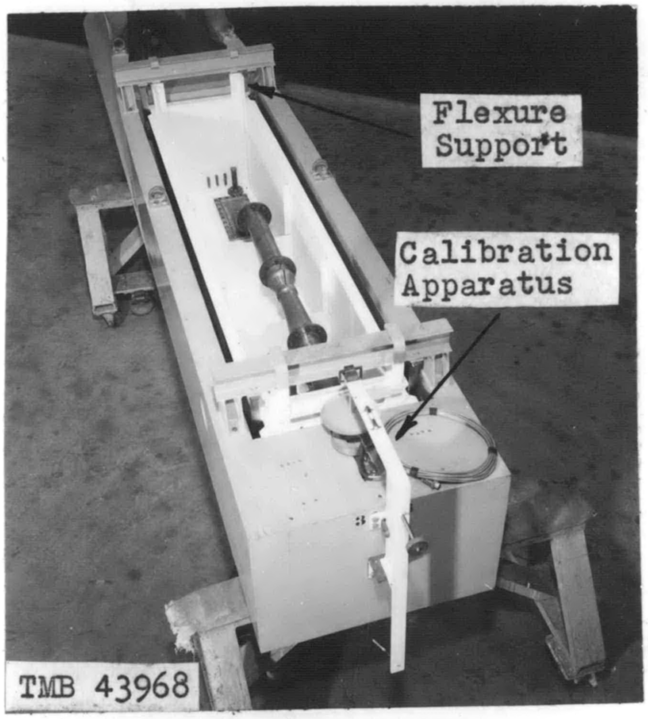
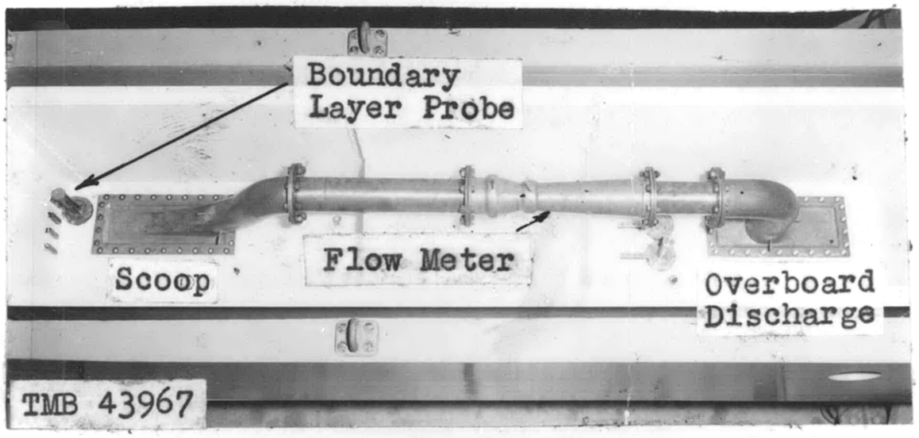


Figure 5. Photograph of Apparatus for Model Tests of Three-Dimensional Scoop System.

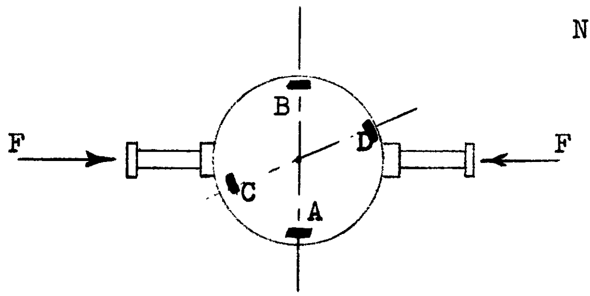


View of Stern Showing Calibration Apparatus



View from Above Showing Arrangement of Boundary Layer Probes, Scoop, Venturi Meter, and Overboard Discharge.

Figure 6 - Photographs of Model Scoop System Test Compartment



NOTES:
Gage Type A-21
A,B-Compression Gages
C,D-Tension Gages

Ring Dynamometer SR-4 Strain Gage Arrangement

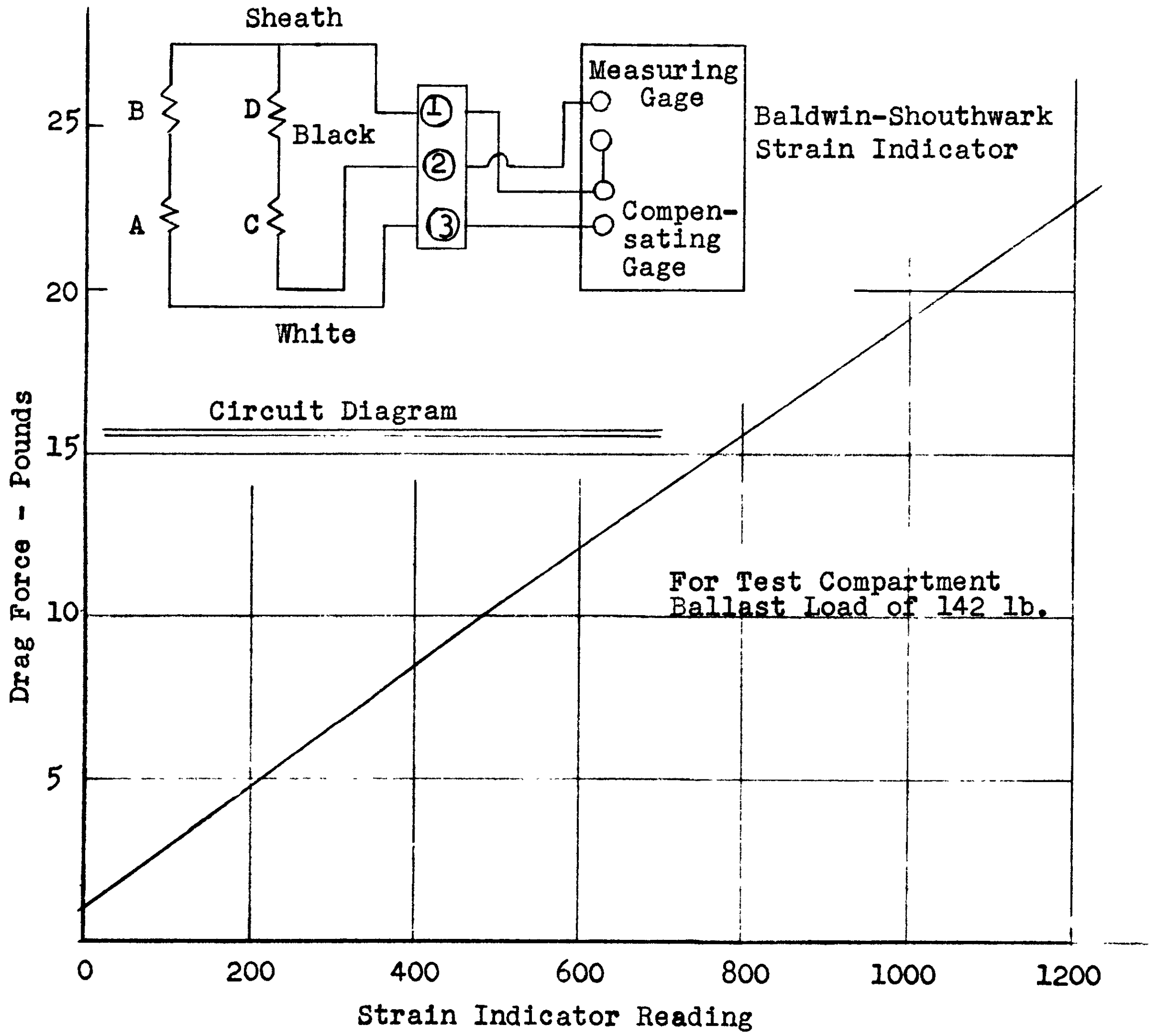
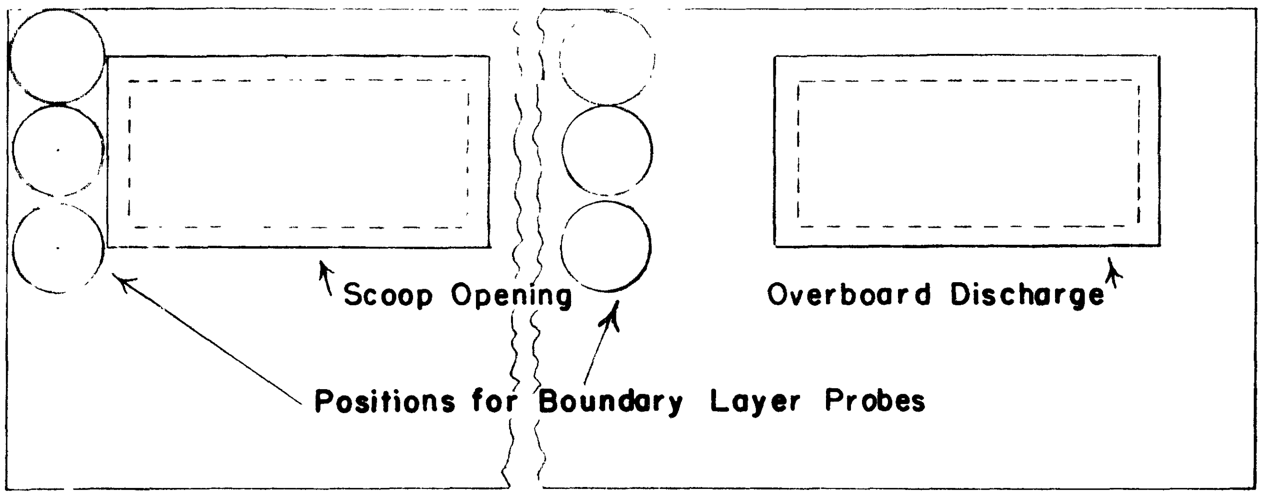
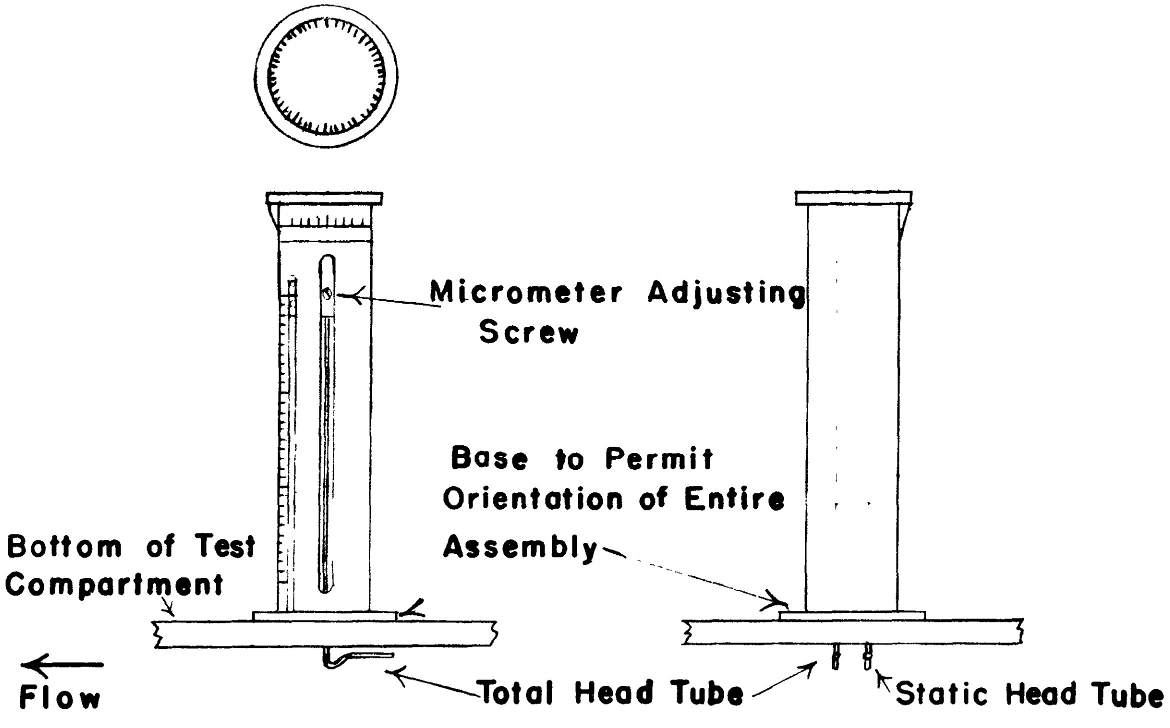


Figure 7 - Calibration and Wiring Diagram of Ring Dynamometer for Measurement of Drag Forces Acting on Condenser Scoop Test Compartment



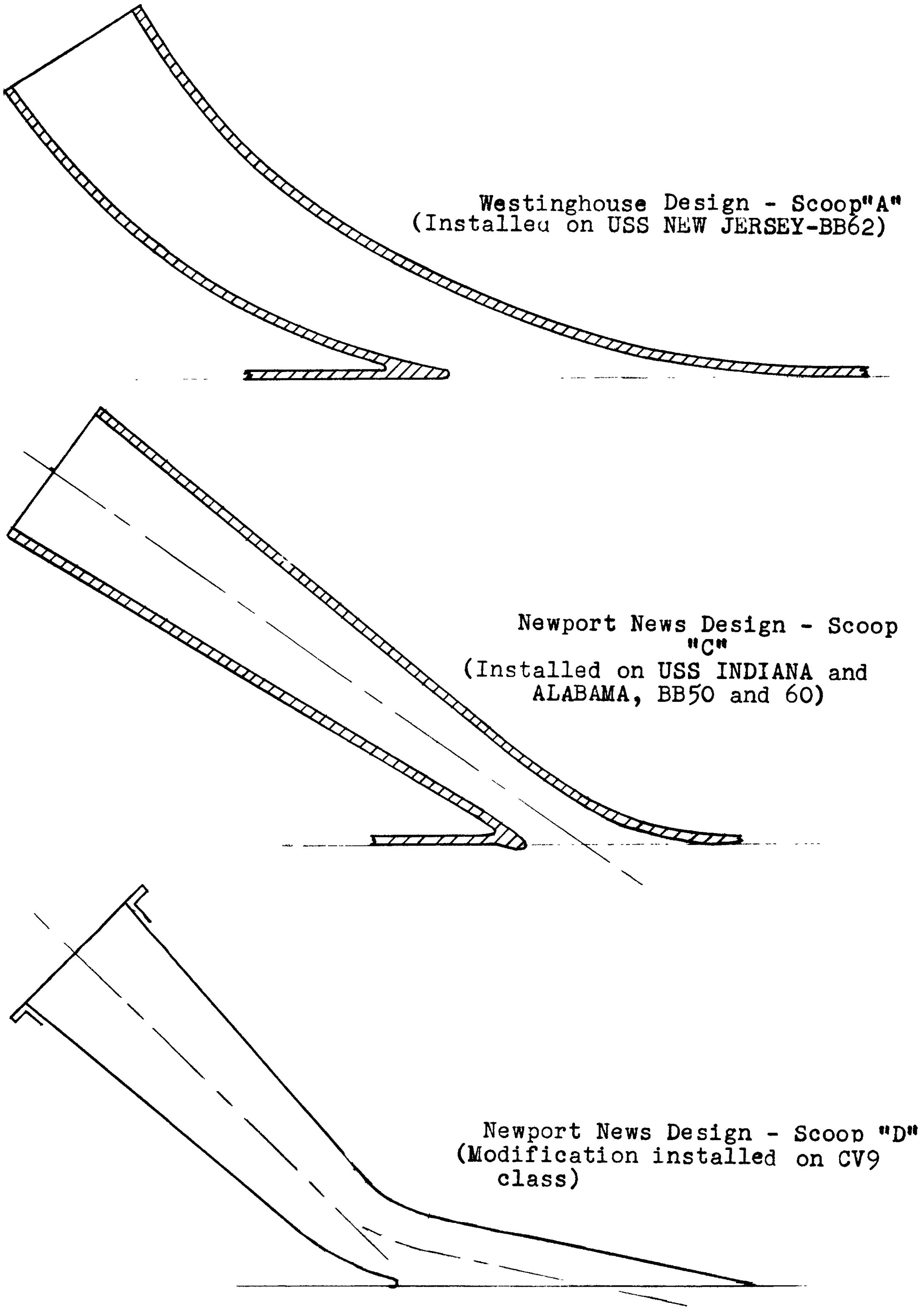
Plan View of Condenser Scoop Test Compartment



View Looking to Port View Looking Aft

Detailed Sketch of Boundary Layer Probes

Figure 8 - Location and Details of Probe for Measurements of Boundary Layer Velocity Distribution Forward of Scoop and Discharge



Westinghouse Design - Scoop "A"
(Installed on USS NEW JERSEY-BB62)

Newport News Design - Scoop "C"
(Installed on USS INDIANA and ALABAMA, BB50 and 60)

Newport News Design - Scoop "D"
(Modification installed on CV9 class)

Figure 9. Profiles of Scoops Selected as Parent Designs

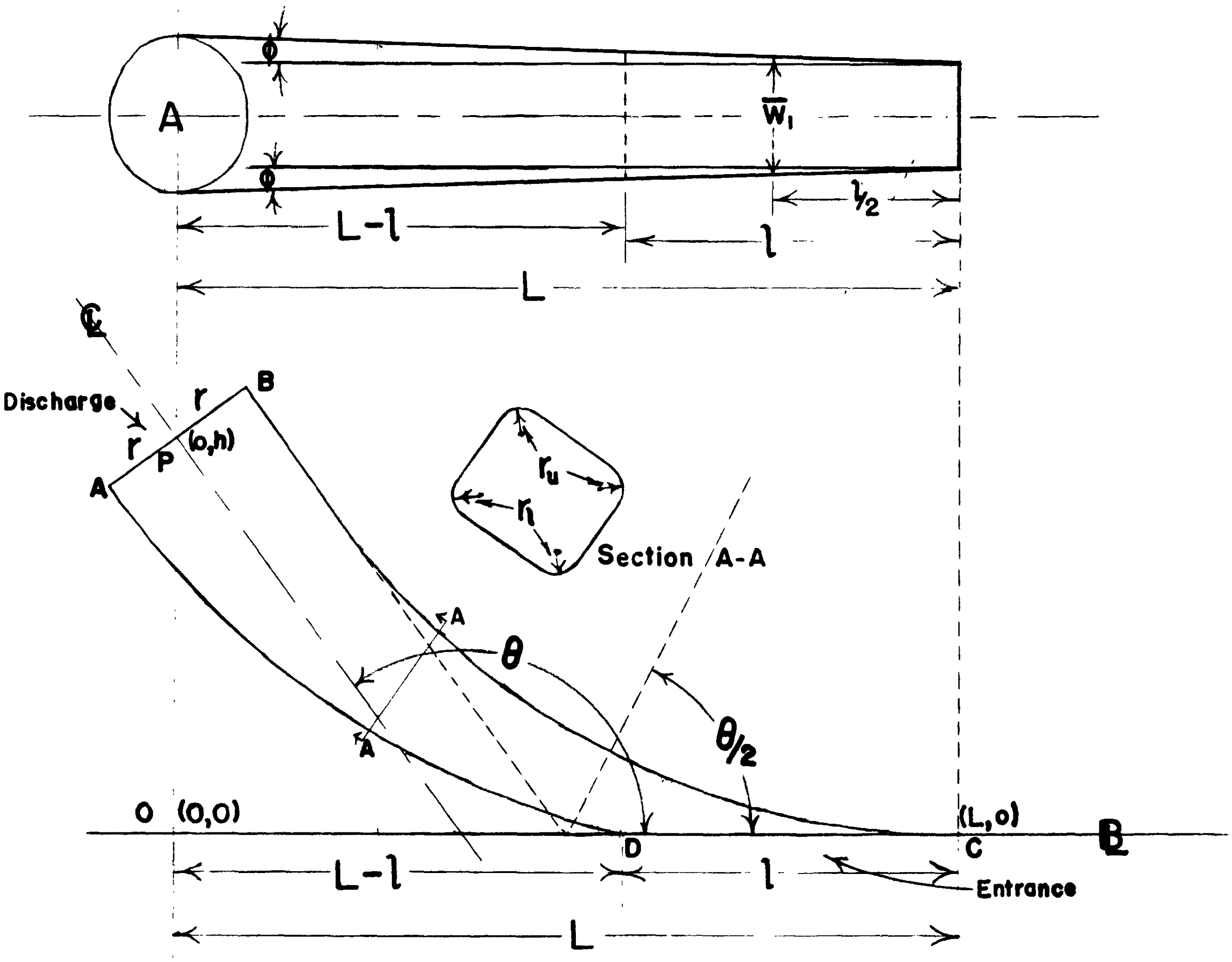
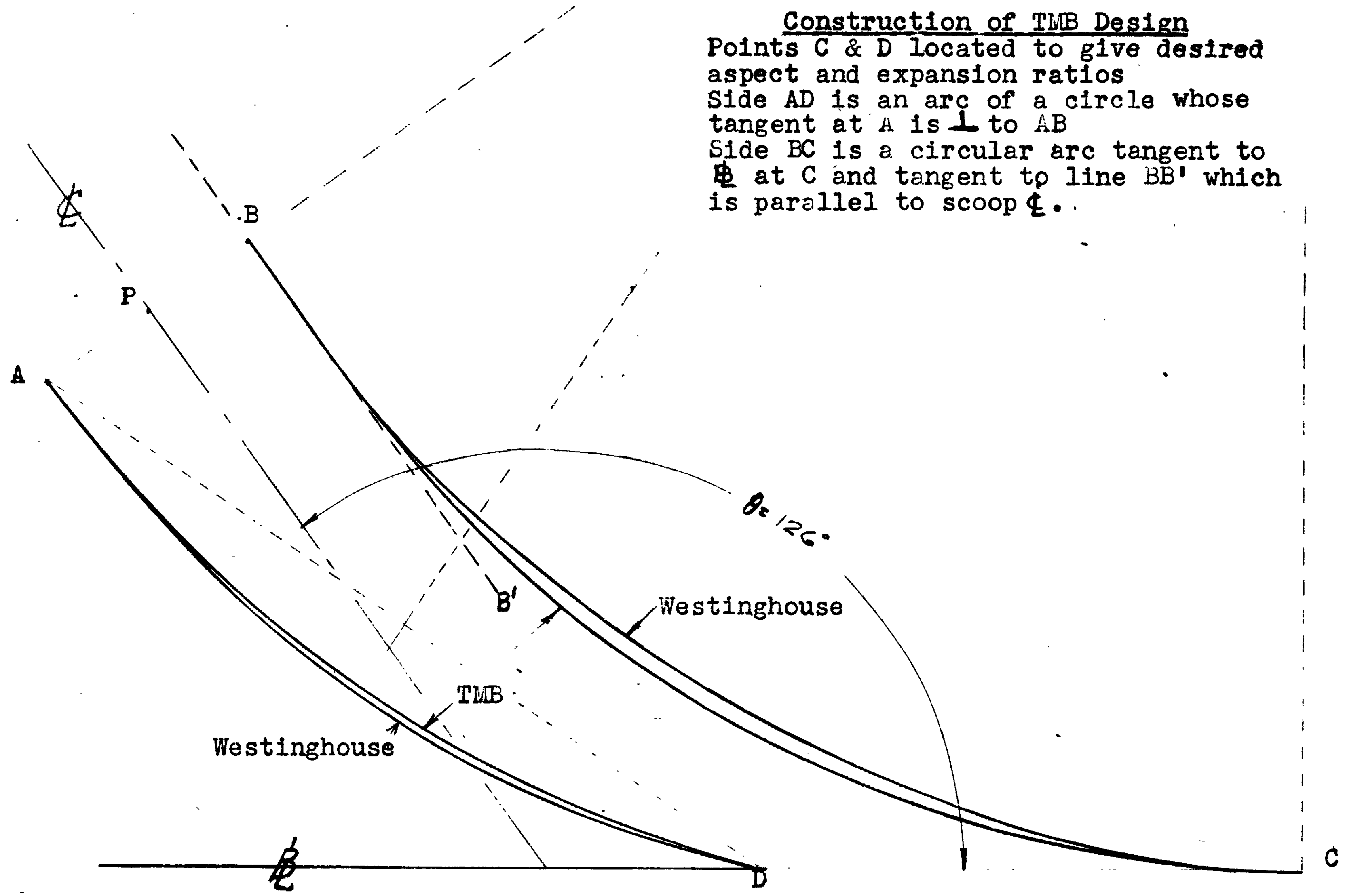


Figure 10 - Definition Sketch for Geometrical Construction of a Family of Scoops Similar to Westinghouse Scoop "A"



Construction of TMB Design

Points C & D located to give desired aspect and expansion ratios
Side AD is an arc of a circle whose tangent at A is ⊥ to AB
Side BC is a circular arc tangent to ℄ at C and tangent to line BB' which is parallel to scoop ℄.

Figure 11 - Comparison of Longitudinal Profiles of Westinghouse Scoop A and of a Proposed Design of a Parent Scoop Having a Simpler Geometrical Construction.

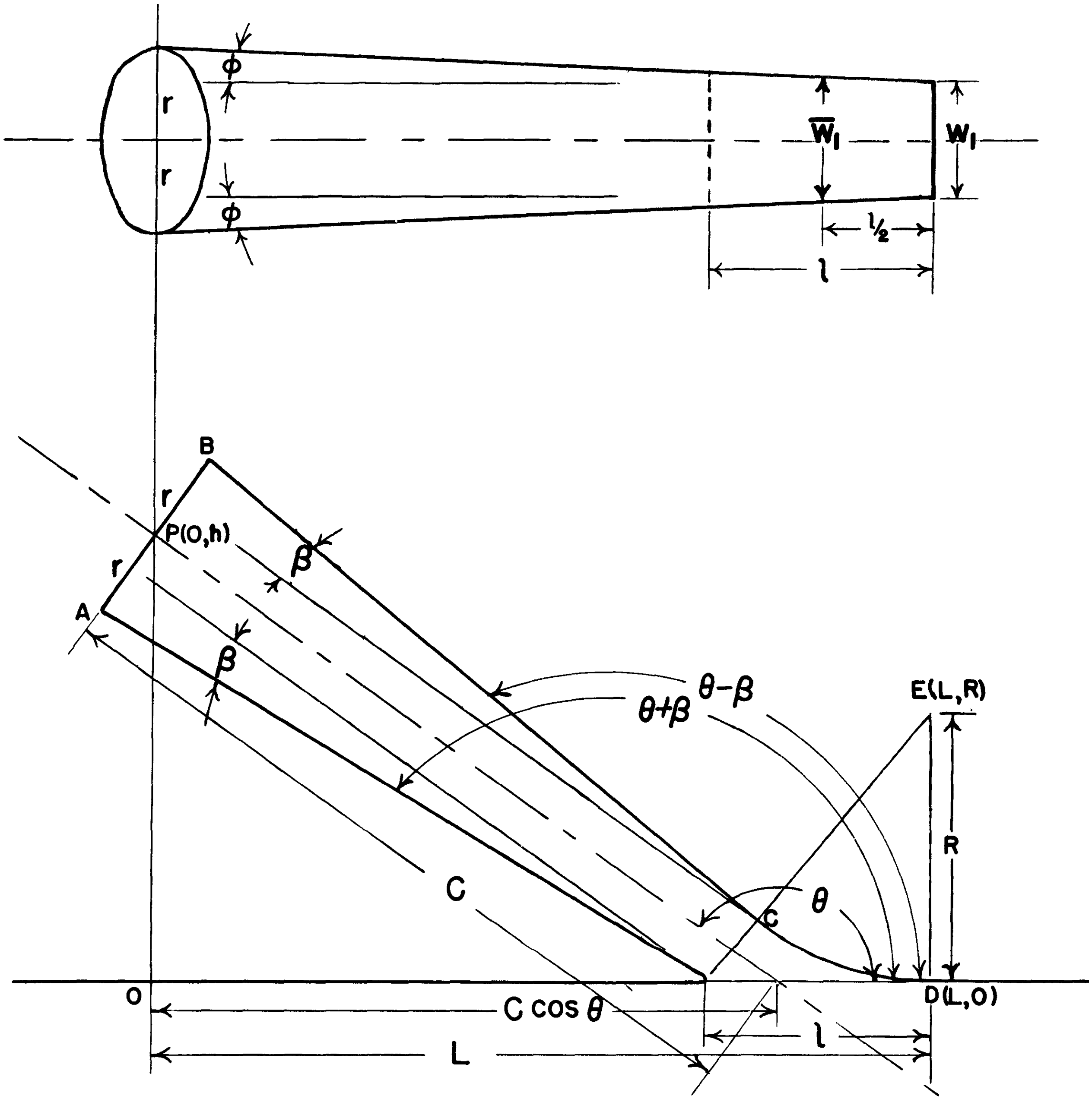


Figure 12. Definition Sketch for Geometrical Construction of a Family of Scoops Similar to Newport News Scoop "C"

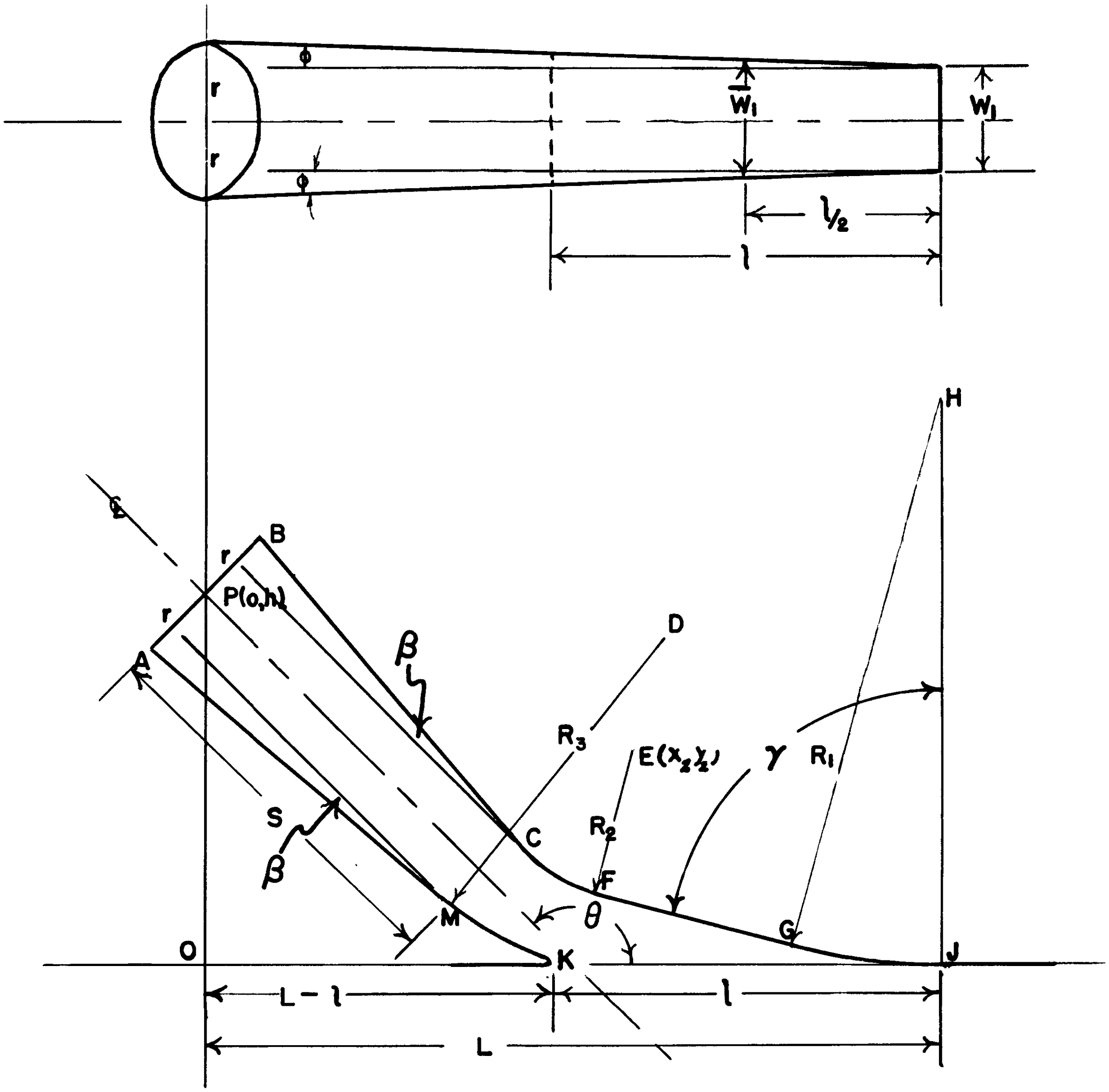


Figure 13 - Definition Sketch for Geometrical Construction of a Family of Scoops Similar to Newport News Scoop "D"