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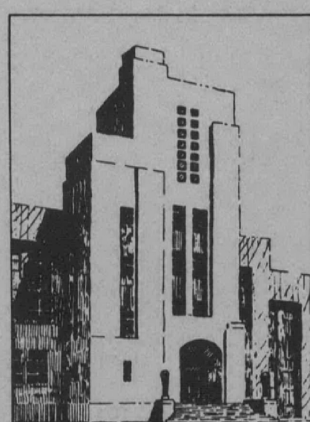
TESTING MAIN INJECTION SCOOPS AND OVERBOARD DISCHARGES IN RESTRICTED CHANNELS

by

Avis Borden, Ph.D



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NOTATION

a	Length of scoop opening
a_o	Stagnation point of flow into a sink
b	Width of scoop opening
C_E	Energy coefficient
C_Q	Discharge coefficient
d	Height of channel
E	Kinetic energy of flow
f	Width of channel
$f(y)$	$f(y) = z/t_o$
g	Acceleration due to gravity
$\overline{h}$	Average velocity head in entering core of water within the boundary layer
h_{FS}	Velocity head in free stream
K_n	Coefficient defined in Equation [31]
m	Sink strength
n	Exponent in power law velocity profile of boundary layer
Q	Quantity of flow through scoop
Q_o	Quantity of flow in channel upstream from scoop
q	Resultant velocity in restricted channel
q_o	Resultant velocity in unrestricted flow
r	Distance from a point in the stream to sink
r_{ij}	Distance from a point in the stream to the ij^{th} image sink
s	Exponent appearing in Equation [23]
t_o	Thickness of semielliptical core of water entering scoop
U	Free stream velocity in unrestricted flow
U_{FS}	Free stream velocity of Newport News tests
U'_{TH}	Average velocity in throat of scoop

U_∞	Channel velocity far upstream of scoop
$U_{-\infty}$	Channel velocity far downstream of scoop
u	Velocity component in x direction
$_{V}h'_{TH}$	An average velocity head in the scoop throat
v	Velocity component in y direction
w	Velocity component in z direction
w_o	Width of semielliptic core of water entering scoop
x	Coordinate in direction of flow
y	Coordinate normal to scoop opening and flow
z	Coordinate parallel to scoop opening and normal to flow
δ_o	Boundary layer thickness normal to surface
$\Delta_s h$	Head loss across the condenser
ρ	An average value of ρ_1 and ρ_2 defined in Equation [15]
ρ_1	Average distance of sinks in first frame to origin
ρ_2	Average distance of sinks in second frame to origin
σ	$\sigma = y/\frac{1}{2}w_o$

TESTING MAIN INJECTION SCOOPS AND OVERBOARD DISCHARGES IN RESTRICTED CHANNELS

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ABSTRACT

In an effort to evaluate the results obtained by testing main condenser circulating systems by drawing water from a restricted channel, the theory is developed for the flow into a point sink located on the centerline of one wall of a rectangular channel. Energy relations are derived to show how scoop performance depends upon boundary-layer parameters and the shape and size of the core of water entering the scoop.

INTRODUCTION

This commentary is written to clarify the theory of flow from a restricted channel into a main injection scoop and to evaluate the results of Newport News model tests of a circulating water system[1] on the basis of the new results. Much of the theory of scoop flow presented here is obtained from Dr. W. Spannhake's report.[2]

EFFECT OF A RESTRICTED CHANNEL ON THE FLOW INTO A SINK

The flow into a main injection scoop may be approximated by the flow into a sink at a point in an infinite plane. If the scoop is tested in the wall of a rectangular channel the flow is restricted by the walls and the flow lines are distorted, particularly near the scoop entrance. To study how the flow is distorted, the flow into a sink on the centerline of one wall of a channel will be compared with the flow in an unrestricted stream.

The potential function for the flow into a point sink in an infinite plane which is parallel to an unrestricted flow of velocity U in the negative x direction is

$$\phi = Ux - \frac{m}{r} \qquad [1]$$

where r is the distance from the sink to any point in the stream and m is the sink strength

$$r^2 = x^2 + y^2 + z^2 \qquad [2]$$

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[1]References are listed on page 14.

If $x = -a_o$ is the stagnation point

$$m = U\,a_o^2 \qquad [3]$$

The core of water entering the sink is semicircular in shape with radius $2a_o$ far upstream and $\sqrt{2}\,a_o$ at $x = 0$, see Figure 1.

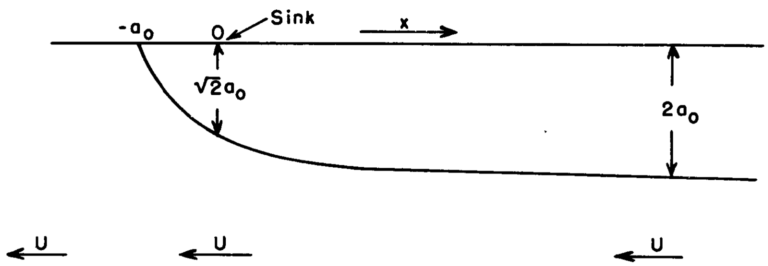

Figure 1 - Flow into a Sink from a Free Stream

The velocity components in the x,y,z directions respectively are

$$\begin{aligned} u &= -\frac{\partial \phi}{\partial x} = -U - \frac{m}{r^3}\,x \\ v &= -\frac{\partial \phi}{\partial y} = -\frac{m}{r^3}\,y \\ w &= -\frac{\partial \phi}{\partial z} = -\frac{m}{r^3}\,z \end{aligned} \qquad [4]$$

If the sink is located on the centerline of one wall of a rectangular channel of width f and height d, see Figure 2, the flow conditions are slightly altered. If the sink strength is the same the flow into the sink is

$$Q = 2\pi m = 2\pi a_o^2\,U_\infty \qquad [5]$$

where U_∞ is the average flow velocity far upstream. If Q_o is the total flow in the channel upstream of the sink, the velocity downstream is

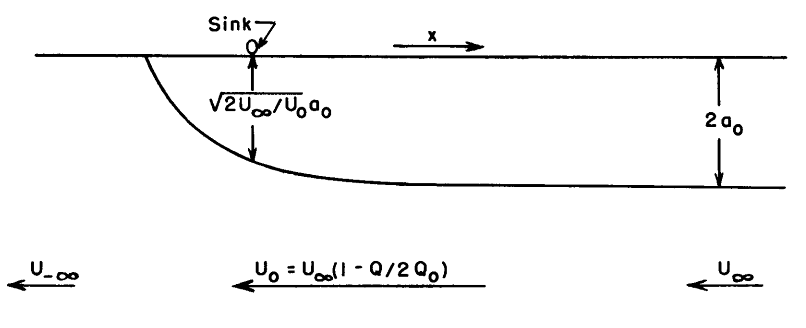

Figure 2 - Flow into a Sink from a Channel

$$U_{-\infty} = U_{\infty}(1 - Q/Q_0) \tag{6}$$

At x = 0, half the flow has entered the sink and the x component of velocity is

$$U_0 = U_{\infty}(1 - Q/2Q_0) \tag{7}$$

From continuity conditions the width of the core of water at x = 0 is $\sqrt{2U_{\infty}/U_0}\, a_0$ which is slightly larger than it is in a free stream at this point.

A theoretical expression for the flow into a sink in the wall of a rectangular channel is obtained by considering the additional flow produced by a whole field of image sinks induced in the four walls of the channel. In addition to the sink at the origin, image sinks are induced at y = 2id and z = jf where i and j take on all integral values from $-\infty$ to $+\infty$. The distance to the ijth sink from a point x,y,z in the channel is

$$r_{ij}^2 = x^2 + (y-2id)^2 + (z-jf)^2 \tag{8}$$

In analogy with Equation [4] the velocity components at any point in the channel are

$$u = -U_0 - mx \sum_{i=-\infty}^{\infty} \sum_{j=-\infty}^{\infty} \frac{1}{r_{ij}^3} \tag{9}$$

$$v = -m \sum_{i=-\infty}^{\infty} \sum_{j=-\infty}^{\infty} \frac{y - 2id}{r_{ij}^3} \tag{10}$$

$$w = -m \sum_{i=-\infty}^{\infty} \sum_{j=-\infty}^{\infty} \frac{z - jf}{r_{ij}^3} \tag{11}$$

The sums in [9], [10], and [11] are difficult to evaluate and must be summed termwise. For small values of y and z, however, the distance from x to the ijth image may be written

$$r_{ij}^2 = x^2 + 4i^2d^2 + j^2f^2 \tag{12}$$

In the sum of Equation [9] it will be convenient to find the average distance from the origin to the image sinks in the first and second frames of sinks; see Figure 3. An average distance ρ_1 of the 8 sinks in the first frame is found from the expression

$$\frac{8}{\rho_1^3} = \frac{2}{f^3} + \frac{2}{8d^3} + \frac{4}{(f^2 + 4d^2)^{3/2}} \tag{13}$$

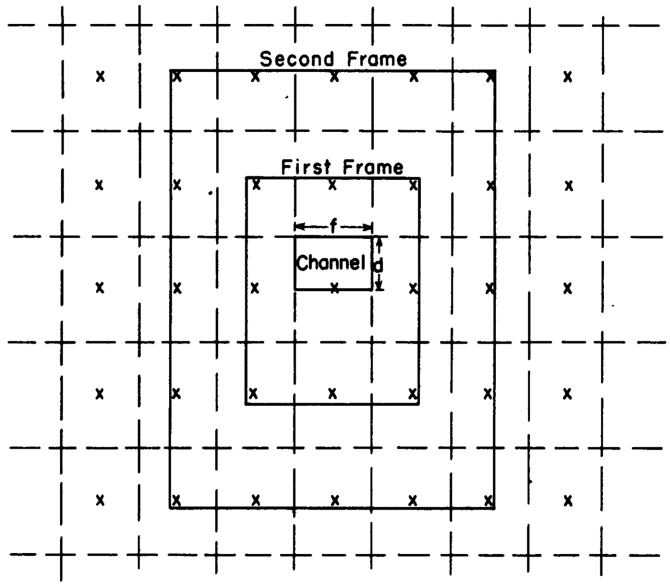

Figure 3 - Field of Image Sinks About a Single Sink in the Wall of a Rectangular Channel

In a similar manner an average distance ρ_2 of the 16 sinks in the second frame is found from the expression

$$\frac{16}{\rho_2^3} = \frac{2}{8f^3} + \frac{2}{64d^3} + \frac{4}{(f^2 + 16d^2)^{3/2}} + \frac{4}{(4f^2 + 4d^2)^{3/2}} + \frac{4}{(4f^2 + 16d^2)^{3/2}} \qquad [14]$$

If ρ_k for successive frames are calculated it will be found that $\rho_k/k > \rho_{k-1}/k-1 > \rho_1$ and ρ_k/k approaches a limiting value. Let $k\rho$ approximate the average distance to all the 8k sinks in the k^{th} frame, where ρ is obtained from the distances to the sinks in the first two frames. Thus

$$\frac{8}{\rho^3} + \frac{16}{8\rho^3} = \frac{8}{\rho_1^3} + \frac{16}{\rho_2^3}$$

or

$$\rho^3 = \frac{10\rho_1^3 \rho_2^3}{8\rho_2^3 + 16\rho_1^3} \qquad [15]$$

Using $k\rho$ in the sum of Equation [9]

$$u = -U_0 - \frac{mx}{r^3} - mx \sum_{k=1}^{\infty} \frac{8k}{(x^2 + k^2\rho^2)^{3/2}} \qquad [16]$$

The use of ρ in the sum yields a slight over-estimation of the flow induced by the image sinks. For values of $x \ll \rho$.

$$\sum_{k=1}^{\infty} \frac{8k}{(x^2 + k^2\rho^2)^{3/2}} = \sum_{k=1}^{\infty} \frac{8}{k^2\rho^3}\left[1 - \frac{3}{2}\left(\frac{x}{k\rho}\right)^2 + \ldots\right]$$
$$= \frac{13.16}{\rho^3} - 12.99\,\frac{x^2}{\rho^5} \qquad [17]$$

To the same degree of approximation the other sums in [10] and [11] with i and j in the numerator vanish. Substituting for U_0 from [7] and for the free stream sink strength from [3], the expressions for the velocity components become

$$\frac{u}{U_\infty} = -1 + \frac{Q}{2Q_0} - \frac{a_0^2 x}{r^3} - 13.16\,\frac{a_0^2 x}{\rho^3} + 12.99\,\frac{a_0^2 x^3}{\rho^5}$$

$$\frac{v}{U_\infty} = -\frac{a_0^2 y}{r^3} - 13.16\,\frac{a_0^2 y}{\rho^3} + 12.99\,\frac{a_0^2 x^2 y}{\rho^5} \qquad [18]$$

$$\frac{w}{U_\infty} = -\frac{a_0^2 z}{r^3} - 13.16\,\frac{a_0^2 z}{\rho^3} + 12.99\,\frac{a_0^2 x^2 z}{\rho^5}$$

The resultant velocity at any point xyz in the stream where $r \ll \rho$ is

$$\frac{q}{U_\infty} = \frac{\sqrt{u^2 + v^2 + w^2}}{U_\infty} = 1 - \frac{Q}{2Q_0} + \frac{a_0^2 x}{r^3}$$
$$+ 13.16\,\frac{a_0^2}{\rho^2}\left(\frac{x}{\rho} + \frac{a_0^2}{\rho r}\right) - 12.99\,\frac{a_0^2 x^2}{\rho^4}\left(\frac{2x}{\rho} + \frac{a_0^2}{\rho r}\right) \qquad [19]$$

In unrestricted flow

$$\frac{q_0}{U_\infty} = 1 + \frac{a_0^2 x}{r^3} + \ldots \qquad [20]$$

The change in velocity produced by the restriction of flow is

$$\frac{q - q_0}{q_0} = \frac{-\frac{Q}{2Q_0} + 13.16\,\frac{a_0^2}{\rho^2}\left(\frac{x}{\rho} + \frac{a_0^2}{\rho r}\right) - 12.99\,\frac{a_0^2 x^2}{\rho^4}\left(\frac{2x}{\rho} + \frac{a_0^2}{\rho r}\right)}{1 + \frac{a_0^2 x}{r^3}} \qquad [21]$$

The difference between u and $-U_\infty$ is

$$\frac{u + U_\infty}{U_\infty} = \frac{Q}{2Q_0} - \frac{a_0^2 x}{r^3} - 13.16\,\frac{a_0^2 x}{\rho^3} + 12.99\,\frac{a_0^2 x^4}{\rho^5} \qquad [22]$$

Values of the velocity corrections from Equations [21] and [22] are tabulated in Table 1 for different flow rates at the point at which measurements were made in the Newport News tests.[1] In these tests f = 13 in., d = 7 in., ρ = 15.25 in., x = 6.5 in., and y = 3.5 in. Although a scoop is not a point sink and no correction has been made for the boundary layer flow, the values of Table 1 indicate the orders of magnitude of velocity changes for different scoop flows.

TABLE 1

Percent Changes in Velocity Due to Restriction of Flow in a Rectangular Channel

Q/Q_o	x in.	y in.	a_o in.	$\frac{q-q_o}{q_o}$ percent	$\frac{u+U_\infty}{U_\infty}$ percent
0.05	6.5	3.5	0.854	-1.34	-0.12
0.10	6.5	3.5	1.207	-2.59	-0.26
0.15	6.5	3.5	1.48	-3.77	-0.38
0.20	6.5	3.5	1.71	-4.89	-0.49

The values in Table 1 show that although the x component of velocity does not change appreciably from U_∞ at this station the resultant velocity q is less than the unrestricted flow value. Although in unrestricted flow the velocity would normally be increasing to enter the sink at this point, in the restricted flow there has been very little change from the upstream conditions. Hence, the core of water, which has a radius $2a_o$ far upstream, does not diminish in size as fast as it does in the unrestricted flow. At x = 0, where the x component of velocity is constant across the channel, the area of the core of water is U_∞/U_o larger than the area of the core in unrestricted flow. Similarly, the stagnation point of the flow is slightly further downstream.

However, these differences in the size of the core of water near the scoop entrance do not affect the energy of the flow entering the scoop. The energy of the flow entering the scoop depends upon the velocity head in the core of water far upstream. Hence, for the same sink strength and an upstream velocity equal to the unrestricted free-stream velocity, free-stream conditions may be duplicated in a restricted channel.

A complete water circulating system, including inlet and overboard discharge, may be tested either in a single channel or in a double channel in which the water enters from one channel and empties into the other; see Figure 4. On the discharge side the flow is just the reverse of the flow into

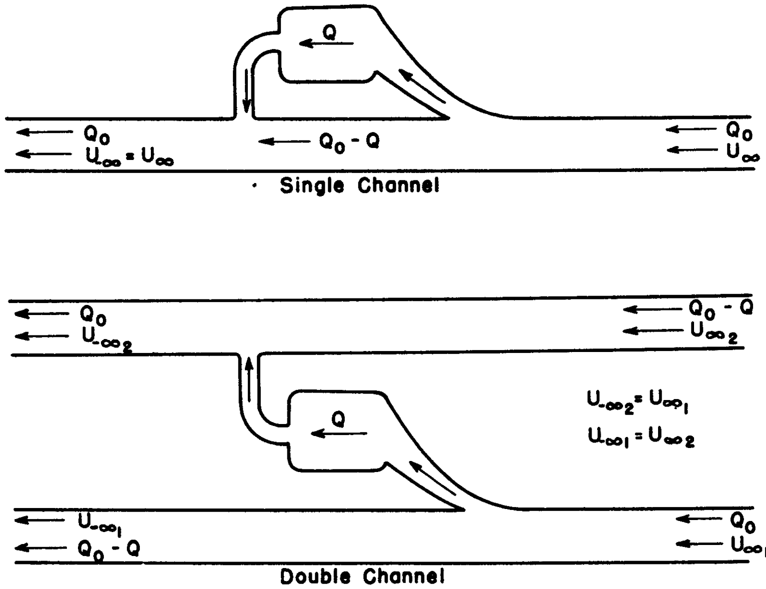

Figure 4 - Use of Single and Double Channels for Testing Main Condenser Circulating System

the scoop. The velocity far downstream from the overboard discharge becomes equivalent to the free-stream velocity and the velocity upstream from the overboard discharge is the same as the velocity downstream from the scoop. In a single channel these conditions are automatically satisfied but in a double channel it is necessary to adjust the velocities in the two ducts.

EFFECT OF BOUNDARY LAYER ON THE FLOW INTO A SCOOP

Since condenser scoops normally take water from the ship boundary layer, scoop performance depends upon the boundary-layer thickness and velocity profile as well as the free-stream velocity. Hence, for scoop tests, it is necessary to artificially stimulate a boundary layer similar to the ship boundary layer. In recent condenser scoop tests at Newport News successful attempts have been made to stimulate boundary layers of predetermined shapes and thicknesses by the use of small vanes across the channel near the wall. It is equally important to know the shape and size of the core of water which enters the scoop from upstream in order to know the energy of the fluid entering the scoop. This latter information may be obtained by making the flow visible by means of dye or air bubbles. Since it is probably sufficiently accurate to assume a semielliptic shape, it is sufficient to measure only the maximum width or thickness of the core of water; the other dimension may be obtained from the boundary-layer parameters.

It is believed that if the energy of the water in the entering core is known for one boundary layer, it may be computed for another. If all data are obtained in terms of the average velocity head in the entering core of water $\bar{h}$, they may be used to predict any scoop flow for which $\bar{h}$ is known. If this hypothesis could be well established by experiment, scoops could be tested without boundary-layer stimulation and the results could be adapted for any known boundary layer.

Although in the Newport News tests the condenser scoop was tested with four different boundary-layer profiles, no attempt was made to measure the entrance core of water. For convenience they assumed a rectangular shape with a width equal to the scoop width. Their results, however, expressed in terms of $\bar{h}$ for this area, showed no correlation. It is the purpose of the following analysis to test this hypothesis, using a more plausible shape for the entering core of water.

Experiments performed by Hewins and Reilly,[3] in which the flow in various parts of the scoop system was studied with the use of paints and dyes, indicate that there is considerable flow into the scoop from the sides and that the entering fluid comes from a region considerably wider than the scoop width. The exact shape and size of the entrance area are undoubtedly affected by the geometry of the scoop and quantity of flow as well as by the character of the boundary-layer flow. From the photographs in the report, the width of the stream entering the scoop is estimated to be approximately twice the scoop width. Furthermore, the shape of the section normal to the entering flow is more or less semielliptical. This means that the rectangular area assumed in the Newport News report includes too great a proportion of high velocity fluid. In the following paragraphs the results obtained in this report are analyzed on the basis of a semielliptical entrance core.

From an analysis of scoop performance recently completed by Dr. W. Spannhake[2] the following relations have been derived. The flow into the scoop is assumed to come from an entrance area of width w_o and thickness t_o. The shape of this area is given by the equation

$$\left(\frac{y}{\frac{1}{2}w_o}\right)^s + \left(\frac{z}{t_o}\right)^s = 1 \qquad [23]$$

When the exponent $s = \infty$ the shape is rectangular and when $s = 2$ it is elliptic. Intermediate shapes are represented by other values of s. Equation [23] may also be written as

$$f(y) = \frac{z}{t_o} = \left[1 - \sigma^s\right]^{1/s} \qquad [24]$$

where $\sigma = y/\frac{1}{2}w_o$.

Using the notation of the Spannhake report as far as possible, the velocity of flow in the boundary layer u may be represented by a power law in the form

$$\frac{u}{U_{FS}} = \left(\frac{z}{\delta_o}\right)^{1/n} \qquad [25]$$

where U_{FS} is the free-stream velocity and δ_o is the boundary-layer thickness. The rate of flow into the scoop from the entrance area is

$$Q = \int_{-w_o/2}^{w_o/2} dy \int_0^{t_o f(y)} u \, dz = C_Q \frac{n}{n+1} \left(\frac{t_o}{\delta_o}\right)^{1/n} w_o t_o U_{FS} \qquad [26]$$

The discharge coefficient is defined by the definite integral

$$C_Q = \int_0^1 \left[1 - \sigma^s\right]^{\frac{n+s}{ns}} d\sigma \qquad [27]$$

The rate of flow of energy into the scoop from the entrance area is

$$E = \frac{1}{2} \rho Q \bar{u}^2 = \int_{-w_o/2}^{w_o/2} dy \int_0^{t_o f(y)} \frac{\rho u^3}{2} \, dz = C_E \frac{n}{n+3} \left(\frac{t_o}{\delta_o}\right)^{3/n} \frac{1}{2} \rho w_o t_o U_{FS}^3 \qquad [28]$$

where ρ is the mass density of the fluid. The energy coefficient is defined by the definite integral

$$C_E = \int_0^1 \left[1 - \sigma^s\right]^{\frac{n+3}{ns}} d\sigma \qquad [29]$$

The ratio of the average velocity head in the entrance area to the velocity head in the free stream is obtained from Equations [26] and [28]

$$\frac{\bar{h}}{h_{FS}} = \frac{\overline{u^2}}{U_{FS}^2} = \frac{C_E}{C_Q} \frac{n+1}{n+3} \left(\frac{t_o}{\delta_o}\right)^{2/n} \qquad [30]$$

Since t_o cannot be estimated from the present experimental data it will be eliminated by the use of Equation [26]. Thus

$$\frac{\bar{h}}{h_{FS}} = \frac{C_E}{C_Q} \frac{n+1}{n+3} \left[\frac{1}{C_Q} \frac{n+1}{n} \frac{b}{w_o} \frac{a}{\delta_o} \frac{Q}{abU_{FS}}\right]^{\frac{2}{n+1}} \qquad [31]$$

or

$$\frac{\bar{h}}{h_{FS}} = K_n \left(\frac{b}{w_o}, \frac{a}{\delta_o}, s\right) \left[\frac{Q}{abU_{FS}}\right]^{\frac{2}{n+1}} \qquad [32]$$

where a and b are the length and width of the scoop opening in the hull and K_n is a function of b/w_o, a/δ_o, s, and n, and contains all the constants in Equation [31].

For a rectangular area, when $r = \infty$, $C_E = C_Q = 1$. For an elliptic area, $s = 2$, the values of C_E and C_Q for different values of n are tabulated

TABLE 2

Values of C_E and C_Q for Elliptic Entrance Areas (s=2)

n	C_E	C_Q
10	0.743	0.770
7	0.727	0.761
5	0.707	0.756

in Table 2. Values of K_n are recorded in Table 3 for several values of the ratio w_0/b for both rectangular and elliptic entrance areas. The values in the column $w_0/b = 1$ for the rectangular area are equivalent to those given in Equations [29], [30], and [31] of the Newport News report.

Pertinent data from the Newport News report, needed for computing $\bar{h}$ for different boundary-layer profiles as well as newly computed ratios are tabulated in Table 4.

A few numerical calculations were made to find $\bar{h}$ in an elliptic area using the Westinghouse boundary-layer distribution.[1] Since the layer in which the flow was appreciably retarded was very thin it was found that the new determinations of $\bar{h}$ would differ by no more than 2 percent from those computed for the rectangular area. Consequently, no effort was made to correct these data.

Curves similar to those of Figure 19 of the Newport News report, plotting $\bar{h}/h_{FS}$ against Q/abU_{FS} are shown in Figure 5 for elliptic areas in which w_0/b = 1.8, 2.0, and 2.2. Curves for the rectangular area $w_0/b = 1$ are included for comparison. It is seen that lower average velocity heads are obtained for wider entrance areas.

Since scoop performance may be independent of the boundary-layer distribution provided the average velocity head of the entering core of water is known, curves similar to those of Figure 21 of the Newport News report are drawn for a semielliptical core of water for which $w_0/b = 2.0$ in Figure 6. Here the ratio of the head loss across the condenser $\Delta_s h$ to $\bar{h}$ is plotted as a function of the ratio of the average velocity head in the throat

TABLE 3

Values of K_n for Different Stream Widths for Rectangular and Elliptic Entrance Areas

n \ w_0/b	Rectangular Area			Elliptic Area		
	1.0	1.5	2.0	1.8	2.0	2.2
10	1.051	0.978	0.928	0.957	0.939	0.923
7	1.099	0.993	0.924	0.970	0.945	0.923
5	1.172	1.024	0.930	0.989	0.955	0.925

TABLE 4

Experimental Data and Calculations Based on an Elliptic Entrance Area for which $w_o/b = 2$

a = 9.34 in. b = 3.92 in. δ_o = 2.79 in.

	n = 10				n = 7			
h_{FS}	6.00	5.76	5.81	5.76	5.70	5.70	5.67	5.67
$\Delta_s h$	4.00	3.76	3.97	3.81	3.16	2.75	3.02	3.00
$\nu h'_{TH}$	1.74	2.14	1.24	0.93	0.97	1.12	1.85	1.43
$\Delta_s h/h_{FS}$	0.667	0.653	0.683	0.662	0.554	0.482	0.533	0.530
Q/abU_{FS}	0.161	0.182	0.138	0.120	0.124	0.133	0.172	0.151
$[Q/abU_{FS}]^{2/(n+1)}$	0.718	0.734	0.698	0.680	0.593	0.604	0.644	0.623
K_n	0.939	0.939	0.939	0.939	0.945	0.945	0.945	0.945
$\bar{h}/h_{FS}$	0.674	0.689	0.655	0.639	0.560	0.571	0.608	0.589
$\bar{h}$	4.05	3.97	3.81	3.68	3.19	3.26	3.45	3.34
$\Delta_s h/\bar{h}$	0.989	0.947	1.043	1.035	0.990	0.843	0.875	0.898
$\nu h'_{TH}/\bar{h}$	0.430	0.539	0.326	0.253	0.304	0.344	0.536	0.428

	n = 5				
h_{FS}	5.57	5.57	5.57	5.57	5.57
$\Delta_s h$	2.69	2.59	2.83	2.60	2.76
$\nu h'_{TH}$	1.34	2.03	0.81	0.85	1.00
$\Delta_s h/h_{FS}$	0.483	0.465	0.508	0.467	0.496
Q/abU_{FS}	0.147	0.181	0.114	0.117	0.127
$[Q/abU_{FS}]^{2/(n+1)}$	0.528	0.566	0.485	0.489	0.503
K_n	0.955	0.955	0.955	0.955	0.955
$\bar{h}/h_{FS}$	0.504	0.541	0.463	0.467	0.480
$\bar{h}$	2.81	3.01	2.58	2.60	2.67
$\Delta_s h/\bar{h}$	0.957	0.860	1.097	1.000	1.034
$\nu h'_{TH}/\bar{h}$	0.477	0.674	0.314	0.327	0.375

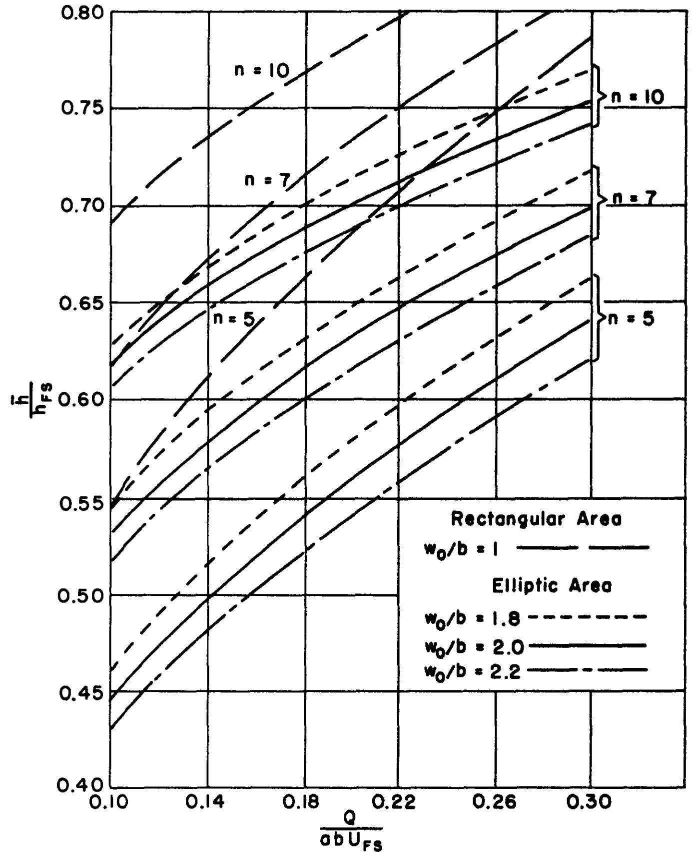

Figure 5 - Average Velocity Head in the Entrance Flow as a Function of Discharge Rate

${}_Vh'_{TH}$ to $\bar{h}$. The numerical values are listed in Table 4. Data for the Westinghouse boundary layer are also included.

Although there is considerable scatter in the points of Figure 6, a single curve has been drawn through them. The points for n = 7 appear to be consistently low and out of line with those for n = 5 and n = 10. If it were possible to estimate the size of the entering core of water with more precision some of the scatter in the points might be eliminated. Hence, more information is needed to accurately determine the width of the core of water and its variation with velocity and quantity of flow into the scoop.

DISCUSSION AND CONCLUSIONS

The analysis made in this report indicates that if scoop parameters are expressed in terms of the average velocity head in the entering core of water, scoop performance might be predicted for all boundary layers. If this hypothesis is substantiated in experiments in which the boundary layer is scaled and in which the size and shape of the entrance core of water are

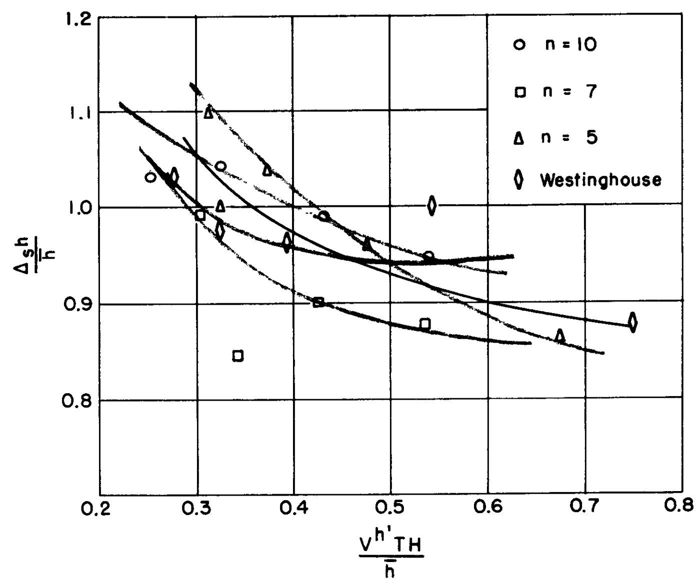

Figure 6 - Head Loss Across the Condenser as a Function of the Average Velocity Head in the Flow in an Elliptic Entrance Area, $w_o/b = 2$

measured, it may be possible to test scoops without boundary-layer simulation and convert the results to any desired boundary layer provided the size and shape of the entering core of water are known.

Until more data are available, condenser scoops should be tested in a scaled boundary layer. Since the effectiveness of the overboard discharge is also important for scoop performance, the boundary layer should be scaled just as carefully upstream from this opening. Here the average flow downstream is the equivalent free-stream velocity.

In so far as the head developed across the condenser of the scoop system depends only on the velocity head in the entering core of water far upstream, the tests are unaffected by the amount of flow Q drawn from the channel. For large flows, however, the walls distort the shape of the entering core of water from the free-stream shape. To predict the size and shape of the core of water in the boundary layer of a ship from model experiments it is necessary that the flow into the scoop be a small fraction of the total flow in the channel.

If drag measurements are to be made, as well as tests of scoop performance, the flow conditions should duplicate full-scale conditions as far as possible. The boundary layer should be carefully scaled at both the inlet and outlet and the channel should be large enough so that the shape of the entrance core of water is not appreciably distorted.

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