TECHNICAL NOTES

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No. 620

ENERGY LOSS, VELOCITY DISTRIBUTION, AND TEMPERATURE

DISTRIBUTION FOR A BAFFLED CYLINDER MODEL

By Maurice J. Brevoort
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SUMMARY

A study has been made of the important principles in-
volved in the operation of a baffle for an engine cylinder
and shows that the cooling can be improved 20 percent by
using a correctly designed baffle. Such a gain is as ef-
fective in cooling the cylinder with the improved baffle
as a 65-percent increase in pressure drop across the stand-
ard baffle, which had a 1/4-inch clearance between baffle
and fin tips.

INTRODUCTION

In the design of a cowling a certain pressure drop
across the cylinders of a radial air-cooled engine is made
available. Baffles are designed to make use of this avail-
able pressure drop for cooling.

The problem of cooling an air-cooled engine cylinder
has been treated, for the most part, from considerations
of a large heat-transfer coefficient. The knowledge of
the precise cylinder characteristics that give a maximum
heat-transfer coefficient should be the first considera-
tion. The next problem is to distribute this ability to
cool so that the cylinder cools uniformly.

Hartshorn (reference 1) has made some measurements on
energy loss and effect of baffle arrangement. His inter-
esting discussion of the problem might be read with profit
by anyone interested in the problem of engine cooling.
The tests made by Hartshorn suffer from incompleteness, no
doubt owing to the fact that the effect of baffle arrange-
ment was only one part of a large problem.

The subject report takes up the problem of the design
of a baffle for a model cylinder. The variables that af-

fect the design of the baffle and the several variables in
the baffle itself are studied. The results also show, to
some extent, the effect of fin spacing and cylinder diam-
eter.

Each actual engine-cylinder type is a separate prob-
lem that must be solved by tests in flight or in a large
wind tunnel. A simple case is studied to determine the
function and importance of each element in the baffle-
cylinder arrangement. The fundamental ideas brought out
in tests of the model cylinder will be of assistance in in-
telligently planning these tests and adjustments.

This study is not concerned with the cooling perform-
ance of the front of the cylinder. It has been shown in
reference 2 that the front of the cylinder is cooled by
large-scale turbulence. It follows, then, that the cool-
ing performance of the baffled part of the cylinder has no
relation to the cooling performance of the front of the
cylinder except for the fact that the air entering the
baffle is slightly heated by the front of the cylinder.

ANALYSIS OF THE PROBLEM

The energy loss of the air flow around the baffled
part of a finned cylinder as it is commonly installed on
an engine is of the same character as the energy loss
through a venturi tube.

Figure 1 shows a venturi tube with $P_0 V_0$ correspond-
ing to the entrance of the baffle where the stream veloc-
ity is, for all practical purposes, zero. The value of
$P_1 V_1$ corresponds to the finned part of the cylinder. It
is apparent that V_1 is large in this region and that
$P_1 + \frac{1}{2} \rho_1 V_1^2$ at the entrance to the fins is equal to P_0
assuming $V_0 = 0$. The value of P_1 varies throughout
the restricted passage. Near the exit

$$P_0 = P_1' + \frac{1}{2} \rho_1 V_1^2 + l\ f(V)$$

where $f(V)$ is the loss in energy per unit length due to
viscous friction and turbulence.

$$P_1 = P_1' + l\ f(V)$$

The expansion of the air to the condition $P_2 V_2$,
where V_2 is approximately zero, is the most troublesome
part of the operation, the object being to reconvert as
much as possible of the kinetic energy to potential en-
ergy. It is well known that if the tube is ended at
$P_1' V_1'$ the entire kinetic energy is lost. If a suitable
expansion of the fluid is accomplished, an appreciable
proportion of this energy may be reconverted to potential
energy. In the case of the actual engine, the front and
rear of the cylinder, corresponding to the regions $P_0 V_0$
and $P_2 V_2$, respectively, have a constant difference in
pressure for a given cowling and at a given air speed. If
by a suitable expansion V_2 is made small, the value of
$\frac{1}{2} \rho_2 V_2^2$ will be small. In the ideal case, where
$P_0 - P_2 = l\ f(V)$ and it is assumed that $V_2 = V_0 = 0$,
the air passes through the restricted tube with a rela-
tively large velocity and dissipates its entire available
energy in friction. This condition would correspond to
the maximum cooling possible on the baffled part of the
cylinder.

In the arrangement shown in figure 1 the chance of
approaching the ideal flow is considerably greater than in
an actual case. Figure 2(a) shows the essential parts of
the arrangement of the practical case. The entrance condi-
tions of an actual cylinder can be made as good as in the
simplified case, but from that point on the actual finned
cylinder operates at a disadvantage. Two streams or jets
come together from opposite directions at the point where
a complete expansion of the jets would take place if there
were no exit duct on the baffle. The two jets must come
together from opposite directions because the rear of the
cylinder must be cooled. It can be seen that, if the air
were permitted to leave the cylinder farther to the front,
the two jets could be brought together at a more acute an-
gle. Thus a smaller loss in energy would result because
the jets would not be required to make so sharp a turn and
the mixing loss might be less. After the two jets have
been united in a common exit, a considerable part of the
kinetic energy may be salvaged by a suitable expansion,
as in the ideal case. Any such improvement will serve
either to dissipate more heat on an undercooled engine or
to reduce the cost of cooling an adequately cooled engine.
In the tests reported herein the optimum conditions for
the combination of these two jets and their subsequent
expansion were determined.

The foregoing analysis considers the problem from considerations of realizing the maximum heat transfer on a given cylinder by the optimum choice of baffles. The problem is really somewhat more complicated than the mere determination of maximum heat transfer. All temperatures on the cylinder must be held below some specified maximum. One can readily visualize a situation in which part of the cylinder is overcooled while another part is undercooled. Such a condition may be controlled by proper baffling and finning, neither of which takes the place of the other. Finning is used to give the cylinder a large heat-transfer coefficient; and baffling to increase the air flow at a given Δp and to control the temperature distribution. This investigation is concerned only with baffling.

The study of correct baffle design is therefore made to determine not only the arrangements giving maximum average heat transfer with a given Δp but also those giving the lowest maximum temperature. The two conditions are not concomitant as it is necessary to sacrifice some of the over-all heat transfer to obtain a low maximum temperature.

APPARATUS AND TESTS

The pressure drop across the cylinder was made to simulate conditions in an actual engine. The cylinder was set in the side of a box so that the part corresponding to the front was open to the room and the baffled part was inside the box with the exit of the baffle discharging into the box (fig. 3(a)). The box was connected to the suction side of a blower. The pressure in the box could be varied from 0 to 24 inches of water below atmospheric pressure by the adjustment of a bypass and a cut-off valve. The pressure inside the box was measured by an open-end tube located in a position free from air currents. As only the baffled part of the cylinder was studied, all the essential characteristics of the practical case were reproduced by such a set-up. Small impact and static tubes (outside diameter, 0.015 inch) were placed in the fin spaces. All openings were along a given radius but not more than two tubes were in a given fin space. Five impact and five static tubes were thus located at suitable intervals along the center line between the fins. These tubes were used to give the velocity and total-head distribution in the fin spaces. As a check on these measurements a small platinum wire was located along the center

line of the fin space on the same radius as the openings
to the survey tubes. The current required to keep this
wire at a given temperature above the air stream gave a
measure of the cooling.

The cylinder was so arranged that it could be rotated
with reference to the baffle. Another group of survey
tubes made from 0.040-inch tubing was located in the exit-
duct opening to measure the energy and velocity distribu-
tion at that point.

Two cylinder diameters were used with two fin spac-
ings in the larger. For each arrangement the effect of
the baffle-exit width and the exit-duct length and flare
was studied. On one series the radius of curvature of the
baffle at the point where it leaves the cylinder and joins
the exit duct was varied. Figure 2(a) shows the general
arrangement of cylinder and baffle.

A single test run was usually made at two air speeds
for several angular positions around the cylinder. Such
test data made it possible to plot curves of velocity, en-
ergy loss, and cooling of the hot wire against angular
position around the cylinder. A series of tests in which
exit-duct length, flare, and baffle-exit width were sepa-
rately varied determined the optimum arrangement.

There are two sources of error: (1) an accidental
change in the geometry of the arrangement, easily detect-
ed by the usual cross plots of the data; and (2) a syste-
matic error due to making all the measurements on the cen-
ter line of the fin space. A systematic error of this
type causes no trouble for comparisons of a given fin
spacing but, if the error were large, comparisons of vari-
ous fin spacings would be difficult to make. Measure-
ments of velocity and energy loss across the fin space
show that the boundary layer is very thin and that the
measurements made on the center line will be in error by
only a few percent. In the range of fin spacings used
this error is not important. Each measurement can be made
with a high degree of accuracy.

As a check on the velocity and cooling tests of the
unheated cylinder, tests were made of an electrically
heated brass cylinder. This cylinder was 5-3/4 inches
high with an inside diameter of 5 inches and a cylinder
wall 1/4 inch thick. The fins were 1/32 inch thick and
3/4 inch wide with a 1/10-inch free-air space between fins.

The heater was wound on a soapstone core with about 1/4-inch gap between the cylinder wall and the coils. Heat transfer was principally by radiation from the heating coil to the cylinder wall.

The temperature of the cylinder wall was measured by ten thermocouples placed at 0°, 30°, 60°, 90°, 105°, 120° 135°, 150°, 165°, and 180° from the front of the cylinder on the six fins nearest the center of the cylinder. The hot junctions were made by peening constantan wires into the cylinder wall. A lead of the same material as that of the cylinder was joined at the cooling-air inlet to a constantan wire to form the cold junction. The thermocouples gave a practically straight-line calibration so that temperature differences measured in this manner are relatively free from error caused by small changes in cooling-air temperature.

A constant heat input of 3,100 watts was supplied to the heater. The cylinder was allowed to heat up for about 30 minutes under controlled conditions of heat input and pressure drop across the baffle. Readings on all thermocouples were taken at 5-minute intervals until approximate equilibrium had been attained. Equilibrium usually occurred about 50 minutes after the start of the test. The temperature distribution for the cylinder was then obtained.

It is obvious that, as only the rear of the cylinder was baffled in this study, the front of the cylinder would heat up excessively. On an actual cowled and baffled engine the front of the cylinder cools without difficulty owing to large-scale turbulence. In these tests it was found necessary to employ a baffle on the front of the cylinder, creating a flow toward the front (figs. 2(b) and 3(b)). The duct carrying the air away from this baffle discharged into the same box as the rear baffle and, accordingly, the same controlled Δp determined the flow through the front baffle. The front temperature remained fairly constant.

It was hoped that such an arrangement would give a front temperature independent of the rear baffle arrangement. This result was obtained when the rear baffle was tight-fitting, but loosely fitting rear baffles allowed a larger proportion of the cylinder to be cooled by the air flowing toward the front. As a result, the front temperature was higher with a loosely fitting rear baffle.

RESULTS

The detailed results, together with the method for evaluating them, are shown for a typical case; baffle arrangements used are shown in figure 2(a), and the basic results are plotted in figures 4 to 9. Figure 4 gives the distribution of total head along the center line of the fin space. Figure 5 gives the velocity distribution for the same position. The total head H_T and velocity V are presented in nondimensional forms in terms of Δp by using $H_T/\Delta p$ for total head and $\sqrt{\dfrac{H_T - H_S}{\Delta p}} = \dfrac{V}{V_H}$ for velocity where H_S is the static pressure and $H_T - H_S = q = \frac{1}{2} \rho V^2$.

The energy is given by $\int H_T V dA$ where A is the cross-sectional area. On a cylinder baffled as in figure 2(a), A is constant and V is approximately constant so that H_T can be considered a measure of the energy. Similarly $H_T/\Delta p$ can be considered as proportional to the energy.

The average values of $H_T/\Delta p$ and V/V_H are determined from an integration of the areas under the curves of figures 4 and 5. The value of V_A/V_H for a tightly fitting baffle must remain constant at all positions inside the baffle. The ratio $H_T/\Delta p$ becomes gradually smaller as the air moves around the cylinder and out the exit. Figure 6 shows a plot of the loss of $H_T/\Delta p$ against angle around the cylinder where 0° is the front and 180° the rear of the cylinder. Each curve is for a particular exit-duct opening. Figure 7 shows the effect of exit-duct opening on both the $H_T/\Delta p$ loss to the 150° position and the V_A/V_H. The peaks of the curves show the expansion that gives maximum cooling.

The curve for $I^2 - I_0^2$ also shown in figure 7 will now be discussed. The energy to heat the hot wire to a given temperature at any air speed is represented by KI^2 and, when the air speed is zero, the energy is KI_0^2. It follows, then, that the heat carried away by the air stream is proportional to $I^2 - I_0^2$. Figure 8 shows a plot of $I^2 - I_0^2$ against Δp. Separate curves are given for each angular position tested. The values of $I^2 - I_0^2$ are read from the curves at a value of $\Delta p = 10$ and plot-

ted against angle in figure 9. The values of $I^2 - I_0^2$
are read at the 150° position from the curves and plotted
against exit-duct opening (fig. 7). Figures 10, 11, and
12 show the loss in $H_T/\Delta p$ and the values of V_A/V_H and
$I^2 - I_0^2$ at the 150° position all plotted against exit-
duct length for several baffle openings. These results
are for the 7-inch cylinder, 1/16-inch fin spacing, and
3/4-inch fin width. The peaks of the curves determined in
this manner show the optimum conditions of the exit-duct
expansion. The choice throughout of 150° for the point of
comparison and of $\Delta p = 10$, at which all values of
$I^2 - I_0^2$ were plotted, was entirely arbitrary.

Figures 13, 14, and 15 present similar results for
the 1/4-inch spacing on the 7.00-inch cylinder; figures
16, 17, and 18 likewise present similar results for the
1/16-inch spacing on the 4.66-inch cylinder. Figures 10
to 18 give results that make it possible to choose the
best baffle-exit width and to determine the gain obtaina-
ble for a particular exit-duct length. Figure 19 shows
the optimum angle of expansion for each general arrange-
ment tested.

All the results from the three cylinder arrangements
tested have two characteristics in common: (1) A gain in
cooling can be secured by lengthening the exit duct; and
(2) the larger part of this gain can be secured by a rela-
tively short exit duct. It is to be noted that these re-
sults all apply to the 150° position on the cylinder.

Figures 20 and 21, in which $I^2 - I_0^2$ is plotted
against baffle-exit width for the various cylinder arrange-
ments tested, show their relative cooling performance.
The values appearing in figures 20 and 21 cannot be com-
pared because the platinum wire was destroyed between the
tests from which the two sets of data were taken. It is
at once apparent that the narrower baffle exit gives the
best cooling at the 180° position.

All the results presented except those in figure 21
were obtained from the tests made of a baffle having a
1/4-inch radius at the point of junction of the skirt and
baffle. A few tests were made to determine the effect of
a larger radius. Figures 22 and 23 show the results for
1.0-inch and 1.5-inch baffle exits where the radius was
varied and the exit-duct length remained at 7.00 inches
for all the tests. The cooling was improved 8 to 10 per-

cent by increasing the radius from 1/4 to 3/4 inch. Such
an improvement in cooling is to be expected in any design.

It has been pointed out that the cooling problem is
not merely a problem of securing a high heat-transfer co-
efficient but also a problem of obtaining a reasonable
uniformity of cylinder temperature. Some 40 baffle ar-
rangements were studied in these cooling tests. Table I
presents the results of 15 of these tests and gives a de-
scription of each of the 15 baffles. The results show the
change in temperature distribution and temperature when
the baffle entrance, baffle exit, baffle-exit radius, and
exit-duct length are varied.

Baffle 1 is representative of the most usual baffle
now in use. It was made with an entrance similar to that
shown in figure 2(a). The baffle exit was given a 1/4-
inch radius and was placed concentric with the test model
allowing a 1/4-inch clearance between fin tips and baffle.

Baffles 7 and 8 show the effect of the entrance open-
ing. Baffle 9 shows the effect of speeding up the air
very rapidly at the rear of the cylinder. Baffle 10 rep-
resents an attempt to accentuate the effect developed in
baffle 9. It was thought that the sharp break in the baf-
fle tended to set up turbulence. The addition of a tight-
ly fitting inner baffle, 1-1/2 inches wide, leaving a
1/2-inch opening ahead of the point where the baffle comes
in contact with the fins was expected further to increase
this turbulence. Such a baffle acts as an injector, in-
creasing the velocity between the fins and forcing cold
air between the fins at the point where the greatest cool-
ing is needed. Baffle 11 was developed to increase this
turbulence. This baffle had a 1/8-inch strip at the baf-
fle entrance and a 3/8-inch gap for the entrance of the
air. The 1-1/2 inch inner baffle was located the same as
in baffle 10. This arrangement failed to cool satisfac-
torily without the inner baffles. Later tests made it
relatively certain that a gap wider than 3/8 inch would
have further improved the cooling. Baffle 12 was tested
in an attempt to show that a greater improvement in cool-
ing would result from a very high flow velocity than from
an entrance designed to cause turbulence. The results
are indecisive. The addition of a 1-1/2 inch strip, with
a 3/4-inch opening between the strip and the baffle, sim-
ilar to that in baffle 10, gave very satisfactory cooling.
Baffle 13 shows the effect of an injector in the exit duct
near the baffle exit. There is a definite improvement in

cooling., which undoubtedlycould be further extended. The
benefit derived from such an arrangement, however; is
small in comparison with the complications of construc-
tion that such a baffle would involve. Baffle 14 is a
type which might be used for blower cooling. Baffle 15
was designed to show the improvement to be obtained by sep-
arating the two jets and should be compared with baffle
14. Each cools the entire cylinder, in contrast to the
previously discussed baffles. Note that both maximum and
average temperatures are 20° lower with baffle 15 than with
baffle 14. As indicated in figure 2(j), baffle 15 has an
interfin baffle. This interfin baffle was so fitted that
sufficient air was allowed to pass to give relatively good
cooling at the point of passage of the air. An adaptation
of this idea might prove advantageous for cooling half the
cylinder.

DISCUSSION

The loss in total head for the baffle arrangement is
conveniently divided into three parts: (1) the drop in
the fins; (2) the loss at the baffle exit, caused chiefly
by the necessarily sharp turn that the air flow must make;
and (3) the expansion loss that takes place in the exit
duct and the exit-duct opening. The first loss is the
only loss that can be utilized for cooling the cylinder.
Figure 16 shows the useful loss at the 150° position to be
0.275 $H_T/\Delta p$. The baffle extends to the 165° position.
Thus the loss in the baffle will be 0.36 $H_T/\Delta p$. Figure
17 shows that V_A/V_H for the same arrangement is 0.725.
From the thickness of the fins and the exit-duct expan-
sion angle it can be shown that the air is expanded to ap-
proximately half velocity before it reaches the exit-duct
opening where V_A/V_H will be about 0.36. The air at this
point has only $(V_A/V_H)^2$ energy remaining, or 0.13 $H_T/\Delta p$.
This value leaves approximately half of the original energy
to be accounted for at the turn and entrance to the exit
duct. Tests of an actual engine gave losses of $H_T/\Delta p$ of
0.2 in the baffle and 0.8 at the baffle exit.

These values are only approximate but are sufficient-
ly accurate to indicate how very inefficient the mechan-
ism of cooling really is, either on an actual engine or
with the more elaborate arrangement tested. There is still
a great opportunity for improvement. The present test re-
sults, however, seem to indicate that further improvement
in this direction will be slight and difficult unless the

general system of cooling now employed is changed to make
the useless losses small and the useful drop in total head
large. Closer fin spacing will increase this useful drop
in total head.

The results indicate that as long an exit duct as
possible should be used, with a radius of approximately
3/4 inch at the baffle exit. A smaller radius causes a
large loss in energy with a consequent lower velocity,
whereas a larger radius allows the flow to miss the rear
of the cylinder. The baffle should fit closely near the
baffle exit, gradually expanding toward the front.

The results for either the energy-loss study or the
tests of the heated cylinder show that, compared with the
standard baffle, an improvement of 20 to 25 percent of
the heat transfer of the cylinder can be realized by the
use of the best arrangement tested. Such an improvement
might not appear to be particularly interesting. It would
be necessary to increase the Δp 65 percent to obtain
such a gain when the standard baffle is used. The stand-
ard baffle, however, would require about double the power.

The best baffle tested, because it fits closely, re-
quires no more power at a given Δp than the poorest ar-
rangement. The good baffle has a higher velocity between
the fins, thus using more air where actual cooling is ac-
complished; the standard baffle has a lower velocity be-
tween the fins. The standard baffle, moreover, allows
air to escape without cooling. Thus the quantity of air
used is about the same for each baffle.

The function of the baffle in controlling temperature
distribution will now be considered. The temperature on
the cylinder would be expected to increase from the baffle
entrance to the baffle exit. Table I confirms this result
for every baffle tested. The effect is more pronounced if
the baffle has the same shape as the cylinder and less
pronounced when the baffle has some clearance at the en-
trance, gradually approaching the cylinder and coming in
contact with it just in advance of the exit. This perfect-
ly logical result is due to the heating of the air. It
could be predicted that the gradual increase in the veloc-
ity and the continued addition of cool air between the
fins would counteract to some extent the effect of the
heating of the air.

The problem, then, is to determine to what extent it

is possible to overcome this heating effect.   The results
show several arrangements that are particularly effective
in leveling off the temperature distribution.   Such ar-
rangements, of course, are only effective to the extent
that the maximum temperature is reduced.   Table I shows
several devices that appear to be equally good.   A more ex-
haustive series of tests would probably further improve
the cooling.   Such tests should be incidental to the fit-
ting of a baffle to an actual engine cylinder.*

CONCLUSIONS

1.   A 20-percent increase in cooling was obtained by
the use of a properly designed baffle exit.   This gain cor-
responds to that which can be obtained when the standard
baffle with a 65-percent increase in pressure drop across
the baffle is used.

2.   The baffle-exit radius and width and exit-duct
length were found to be the most critical parts of the
baffle.

3.   A baffle was developed that gave a relatively uni-
form temperature distribution around the cylinder.

Langley Memorial Aeronautical Laboratory,
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            Langley Field, Va., January 14, 1937.

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*Although the tests were run on a model of the cylinder
barrel of an actual engine, the results are directly ap-
plicable to the cylinder head.   The principles determined
in this study were applied to the baffling of a two-row
radial engine with a resultant improvement in cooling of
28 percent.

TABLE I

Temperature Difference, ^{o}F.

Baffle	Figure	Baffle-exit radius in.	Baffle-exit width in.	Baffle-entrance width in.	Exit-duct length in.	Exit-duct width in.	Flared to	Angular position around cylinder, degrees									
								0	30	60	90	105	120	135	150	165	180
1	–	0.25	1.875	0.25	0	–	–	126.5	113.5	109.5	116.5	124	132	139	150	160	167.5
2	2(a)	.25	1.875	close	0	–	–	126	114	110	113	119	125	132	140	148	155
3	2(a)	.75	1.875	do.	7	2.625	–	120	106	100	99	103	107.5	114	124	136	144
4	2(a)	.75	1.375	do.	7	2.25	–	119.5	106	100.5	101	106	109.5	115	122	128.5	136
5	2(a)	.25	1.875	do.	7	2.625	–	126.5	114	109	111.5	115	119.5	125	133	141	151
6	2(a)	.25	1.250	do.	7	2.625	–	127	113.5	109.5	112	117.5	122.5	128	135	140.5	147
7	2(c)	.75	1.250	0.50	7	2.25	–	121	109.5	103	107.5	110.5	114	115.5	120.5	126.5	133.5
8	2(c)	.75	1.250	1.00	7	2.25	–	122	107.5	103	108.5	112	114	117	119.5	125	132.5
9	2(d)	.75	1.250	1.00	7	2.625	–	132	120	117	124	127	129	130	133	135	142
10	2(e)	.75	1.250	2.00	7	2.25	–	130	117	116	124	126.5	126.5	126	126.5	130	134
11	2(f)	.75	1.250	2.625	7	2.25	–	141	128	125	127	138.5	126	125	125.5	127	131.5
12	2(g)	.75	1.250	1.25	7	2.25	1.00	131.5	116	113.5	120.5	125	125.5	126.5	128.5	130	134.5
13	2(h)	.75	1.375	.75	7	2.625	–	119	105	100	106	111	114	116.5	120	124	129.5
14	2(i)	.75	1.250	1.25	7	2.25	–	157.5	149.5	150	150.5	150	147	146	149	154.5	160
15	2(j)	–	.750	.625	7	1.25	–	132	132	132	135.5	140	136.5	127	128	128	132

P_0V_0 P_1V_1 $P_1'V_1'$ P_2V_2

Figure 1.- Ideal case.

Fig. 1

Fin width

Exit-duct length

Baffle exit

Baffle-exit radius

Baffle-entrance radius

Exit-duct width

(a)

(b)

Baffle-entrane opening

(c)

(d)
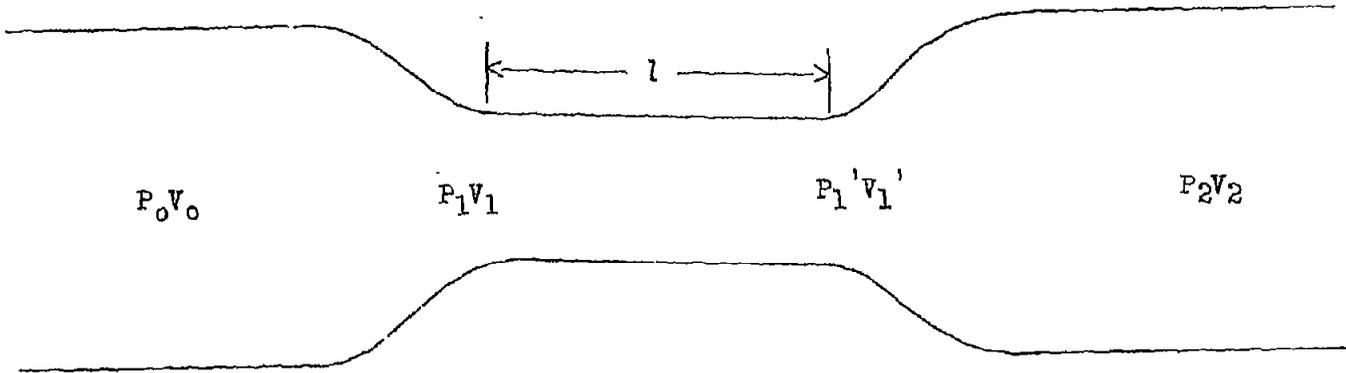
(e)
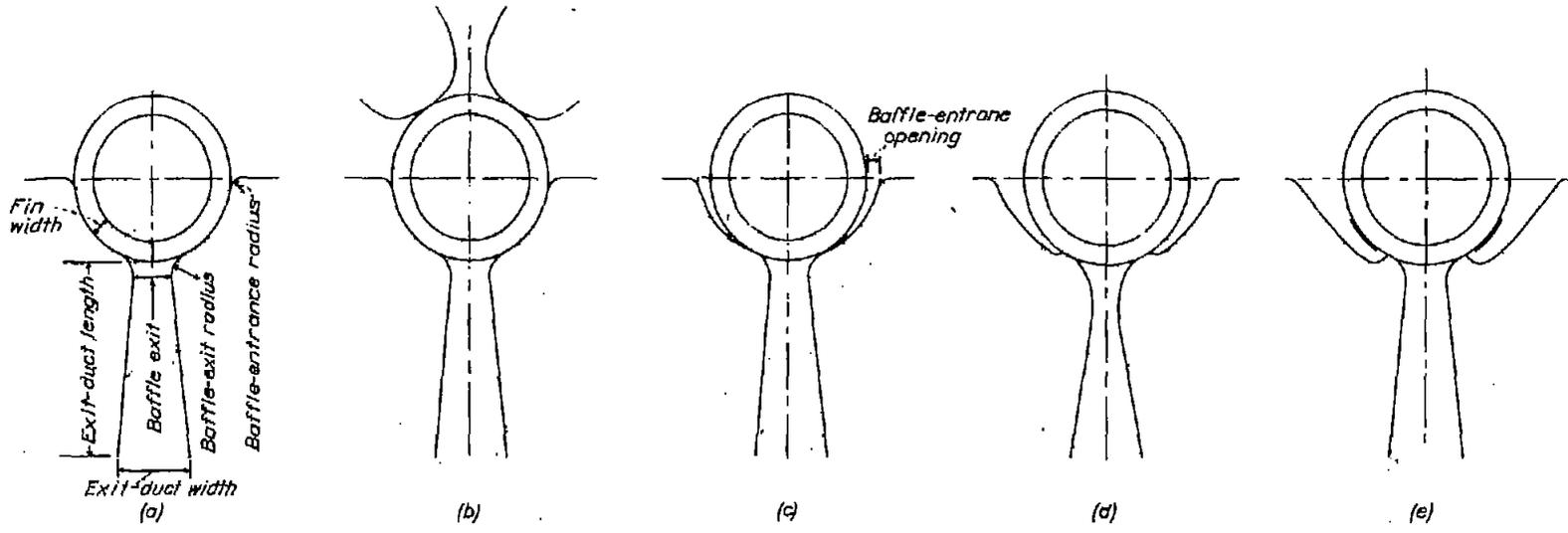
Fig:2.- Baffle arrangement.

(f)

(g)

(h)

(i)

(j)

Fig. 2

Fig. 3
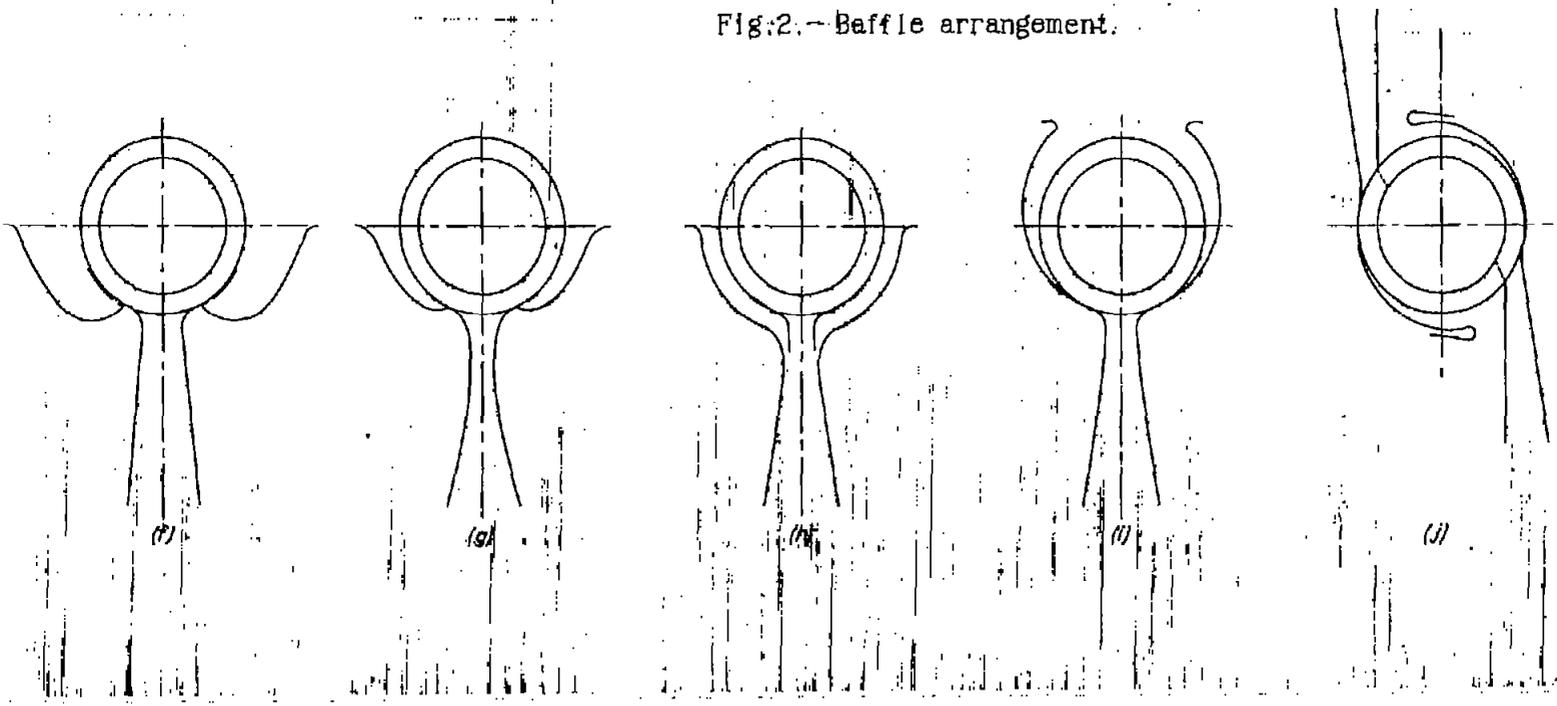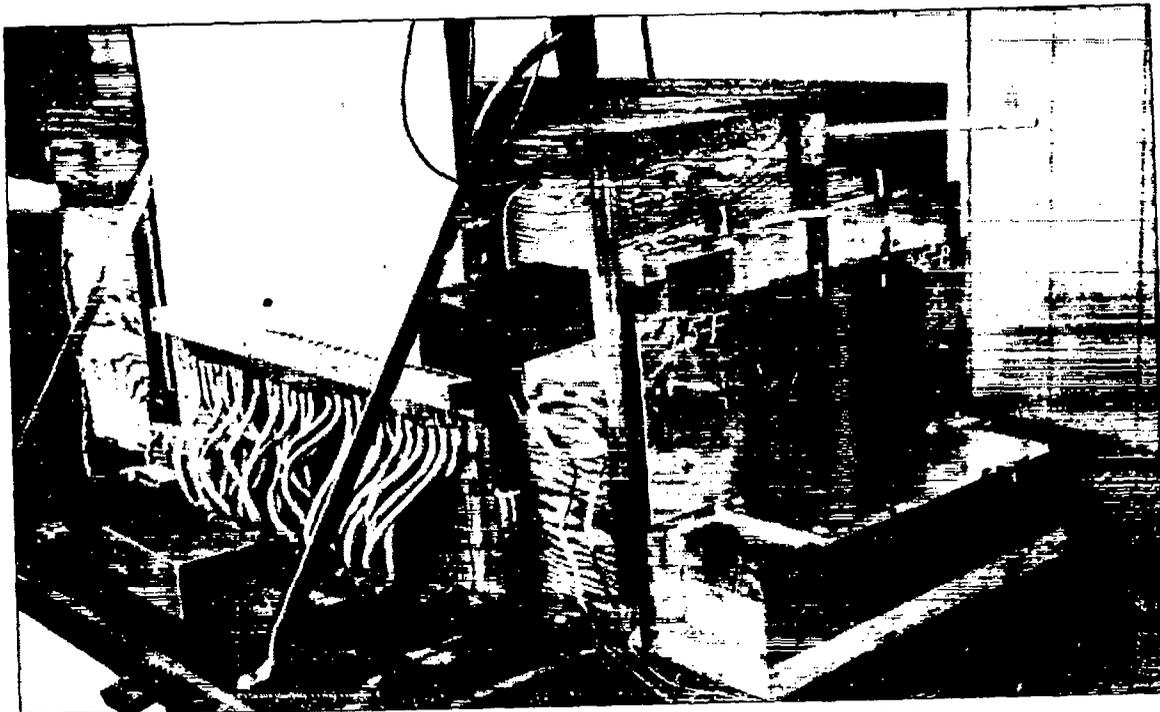
Figure 3(a).- Test arrangement for velocity study.
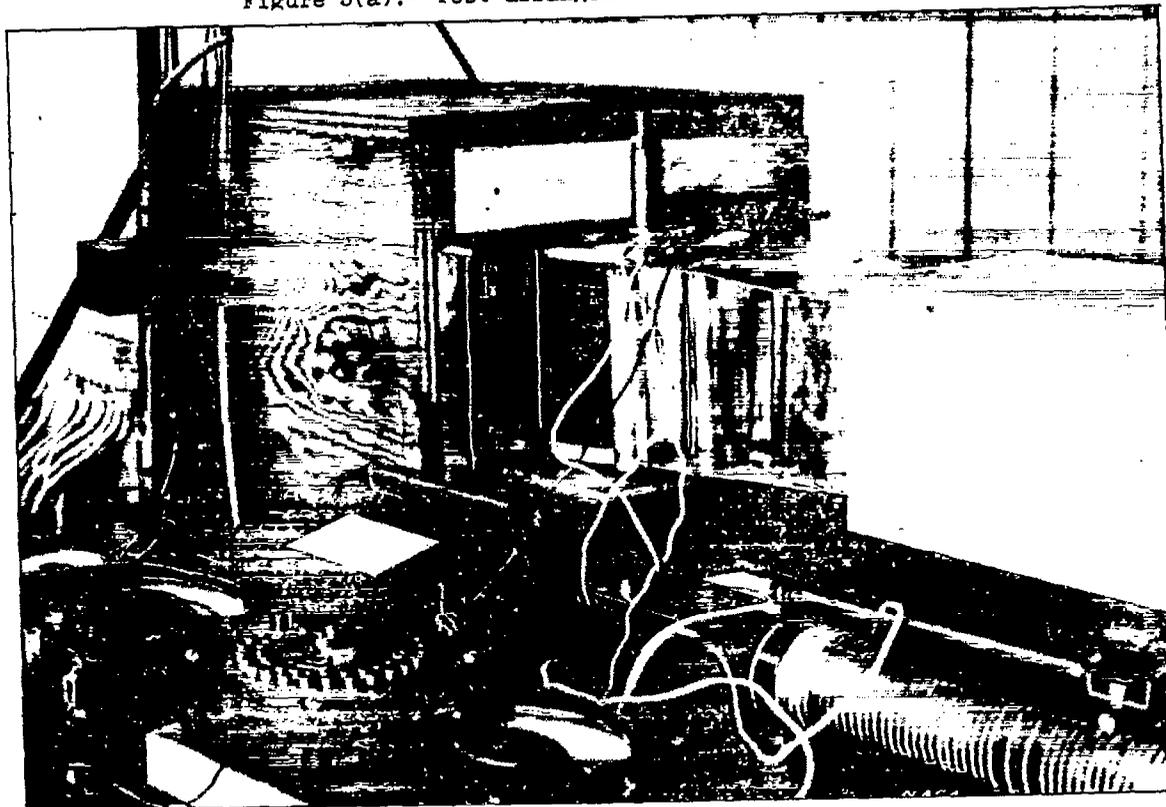
Figure 3(b).- Test arrangement for cooling with heated cylinder.

Fig. 4
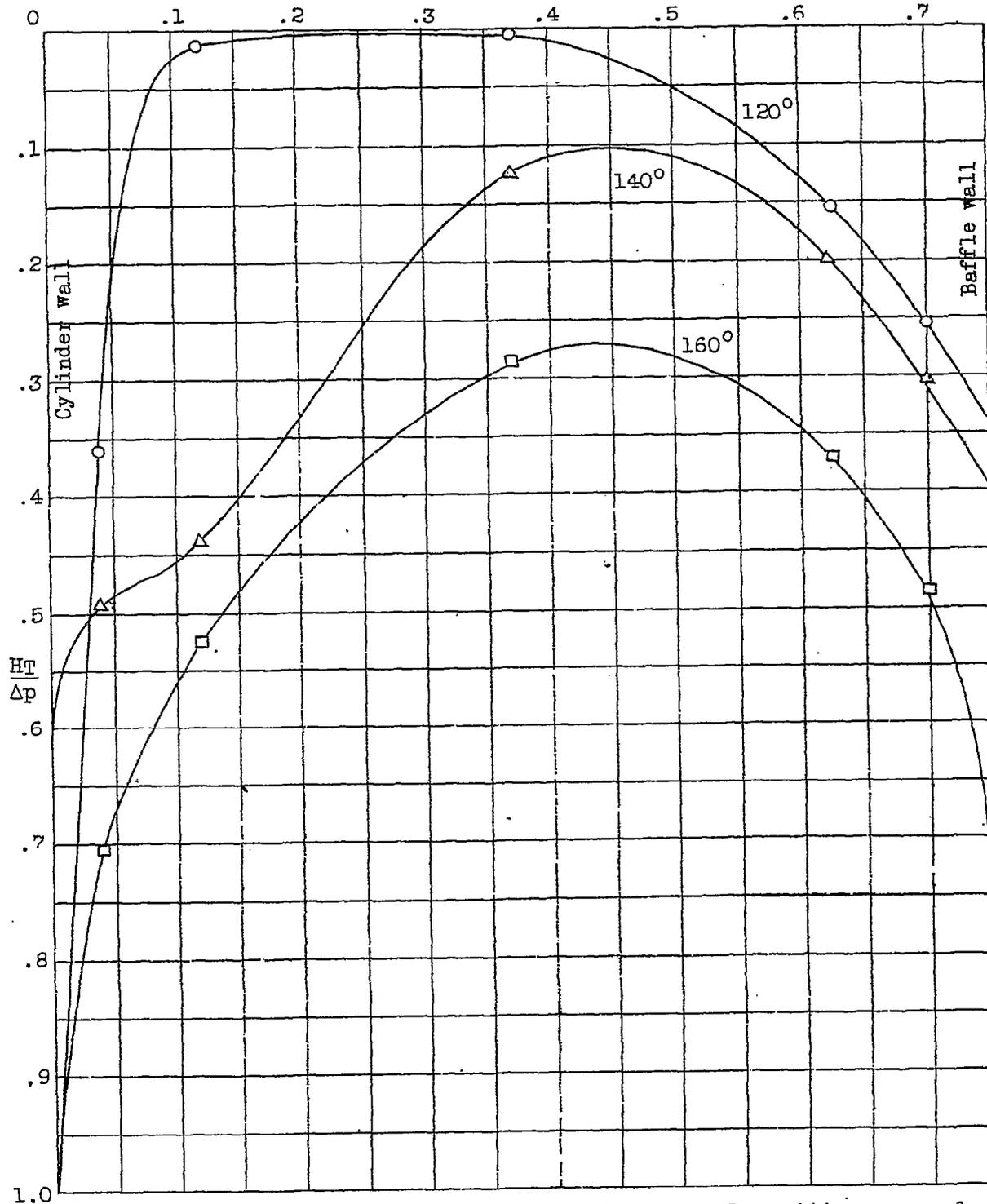
Figure 4.- Loss in total head between fins for several positions around
cylinder. Exit-duct length, 3.75 inches; exit-duct opening,
1.50 inches; baffle opening, 1.00 inch.
Cylinder diameter, 7.00 inches; fin space, 1/16 inch.

Fig. 5
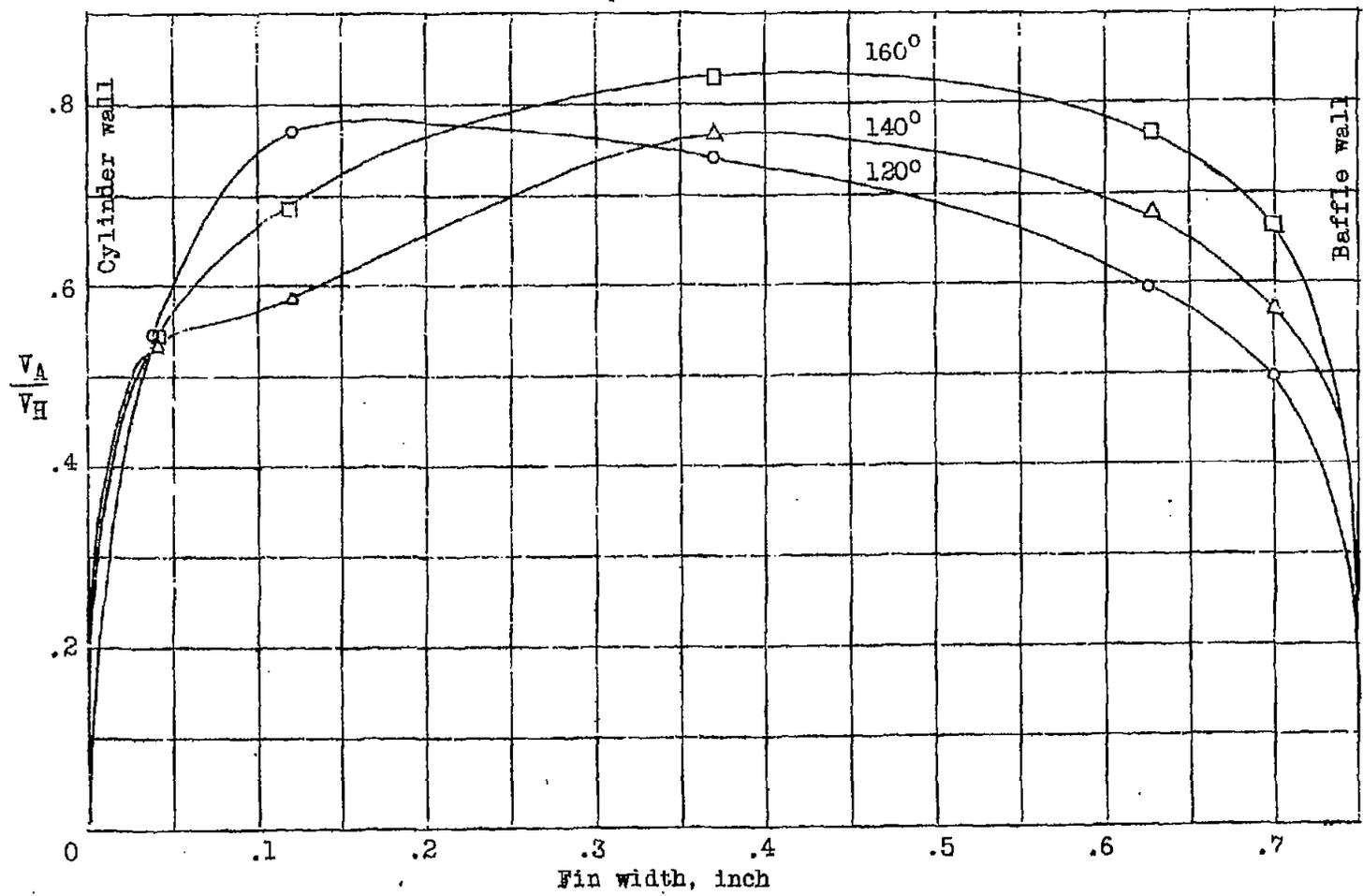
Figure 5.- Velocity distribution on center line of fin space. Exit-duct length, 3.75 inches; exit-duct opening, 1.50 inches; baffle opening, 1.00 inch.
Cylinder diameter, 7.00 inches; fin space, 1/16 inch.

Distance from front of cylinder, degrees

$$\frac{H_T}{\Delta p}$$

Exit-duct opening, inches

1.50
3.00
2.25
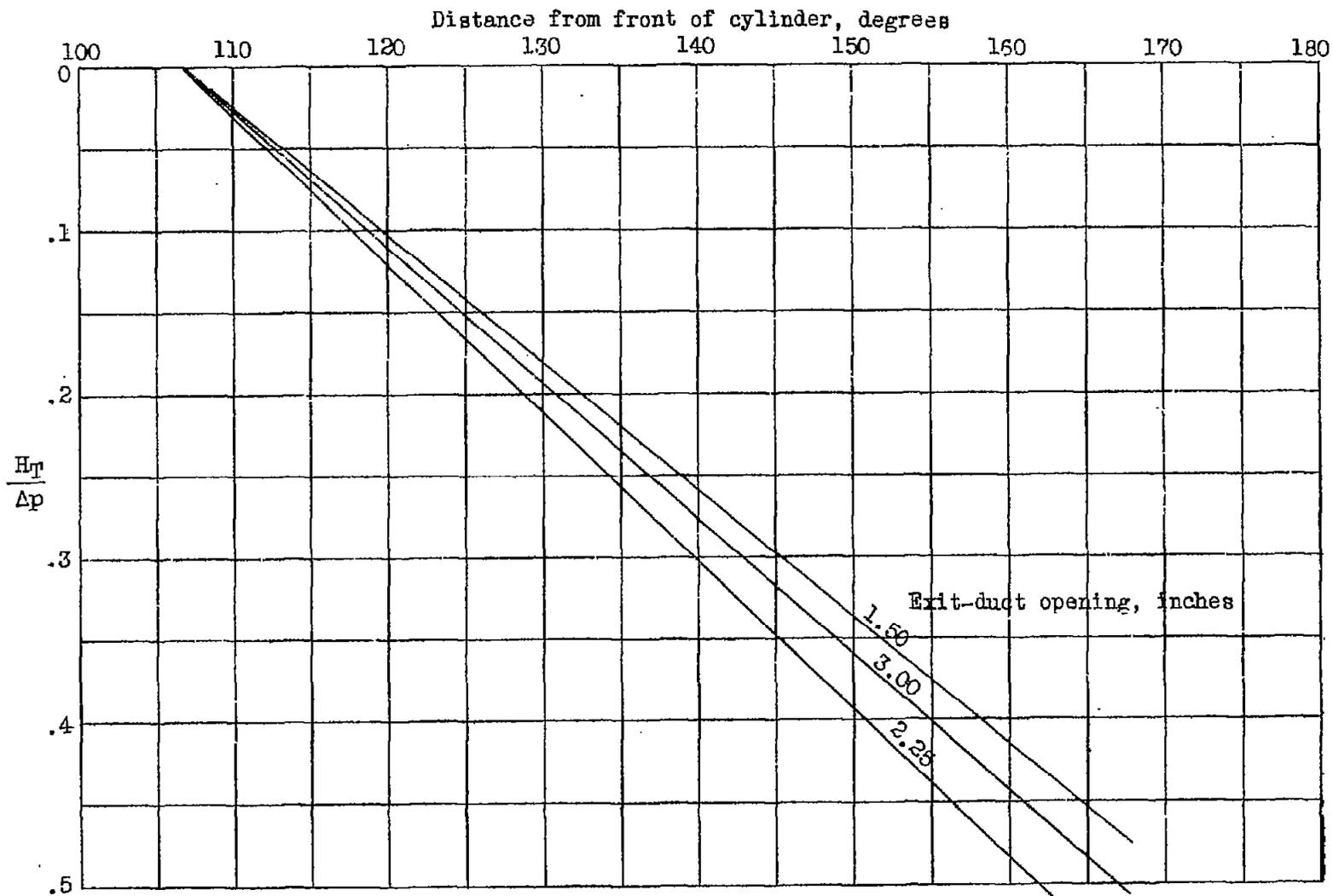
Figure 6.- Effect of position around cylinder on loss in total head for several exit-duct openings.
Exit-duct length, 3.75 inches; baffle opening, 1.00 inch;
Cylinder diameter, 7.00 inches; fin space, 1/16 inch.

Fig. 6
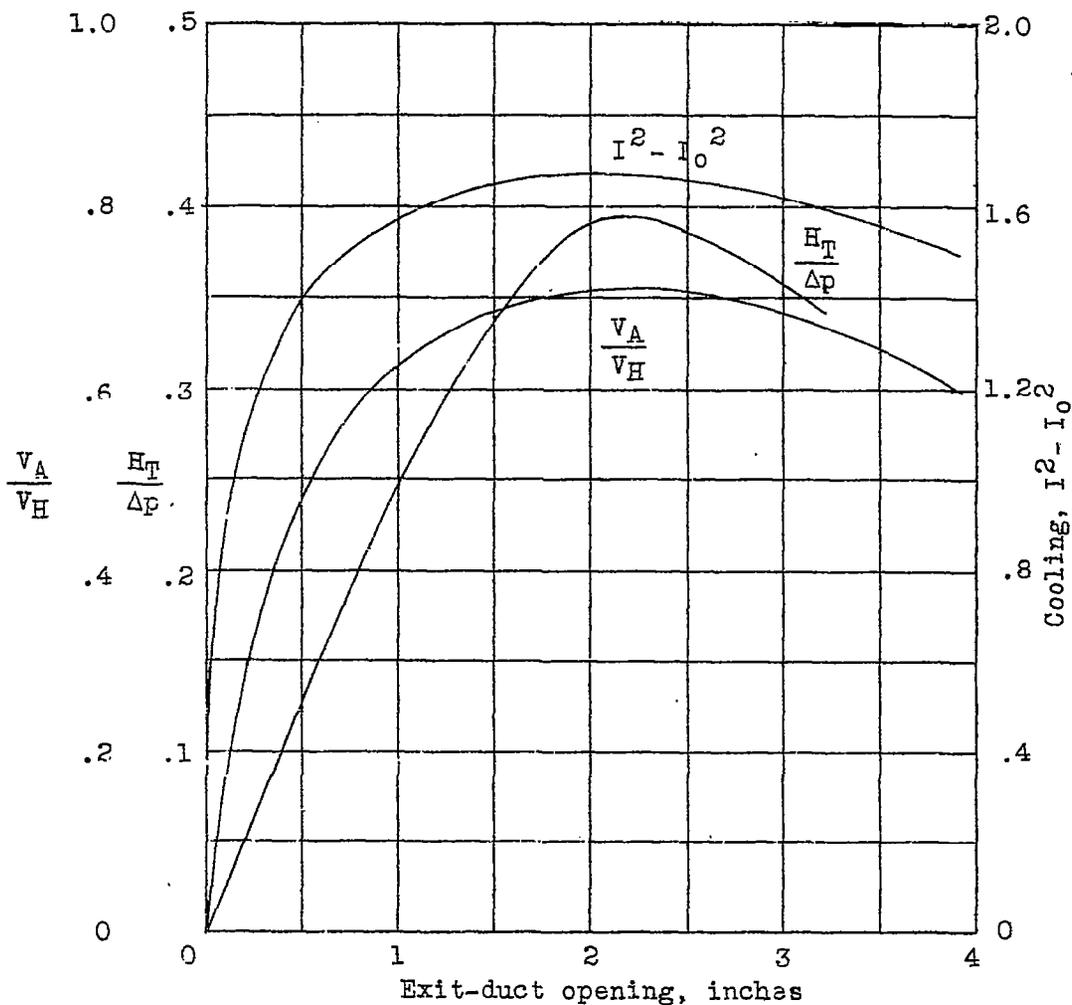
Figure 7.- Effect of exit-duct opening on $H_T/\Delta p$, V_A/V_H, and $I^2 - I_o^2$ at $150°$ from front of cylinder. Exit-duct length, 3.75 inches; baffle opening, 1.00 inch; Cylinder diameter, 7.00 inches; fin space, $1/16$ inch.
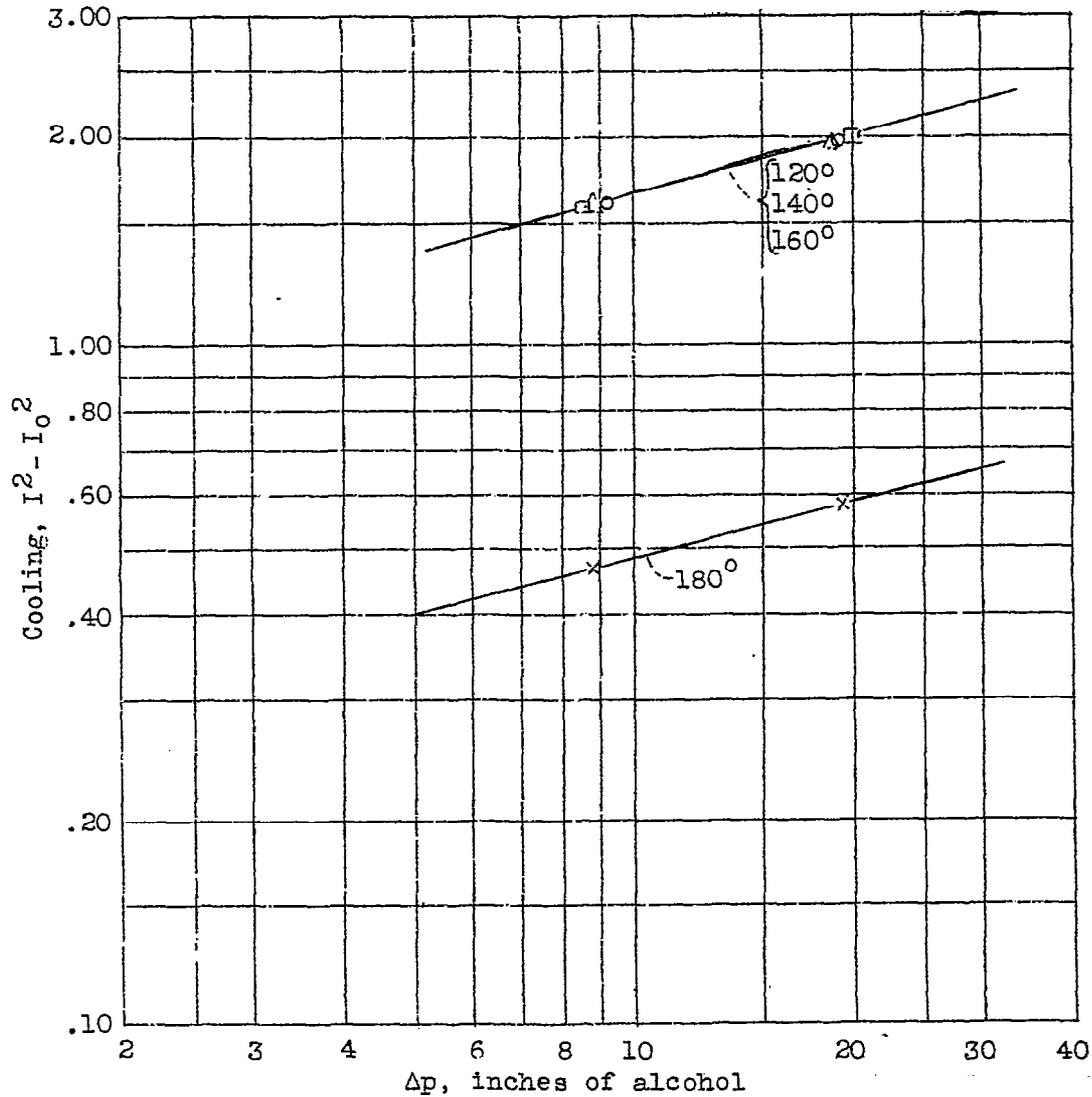
Figure 8.- Effect of Δp on cooling for several positions around
          the cylinder. Exit-duct length, 3.75 inches; exit-duct
opening, 1.50 inches; baffle opening, 1.00 inch.
Cylinder diameter, 7.00 inches; fin space, 1/16 inch.
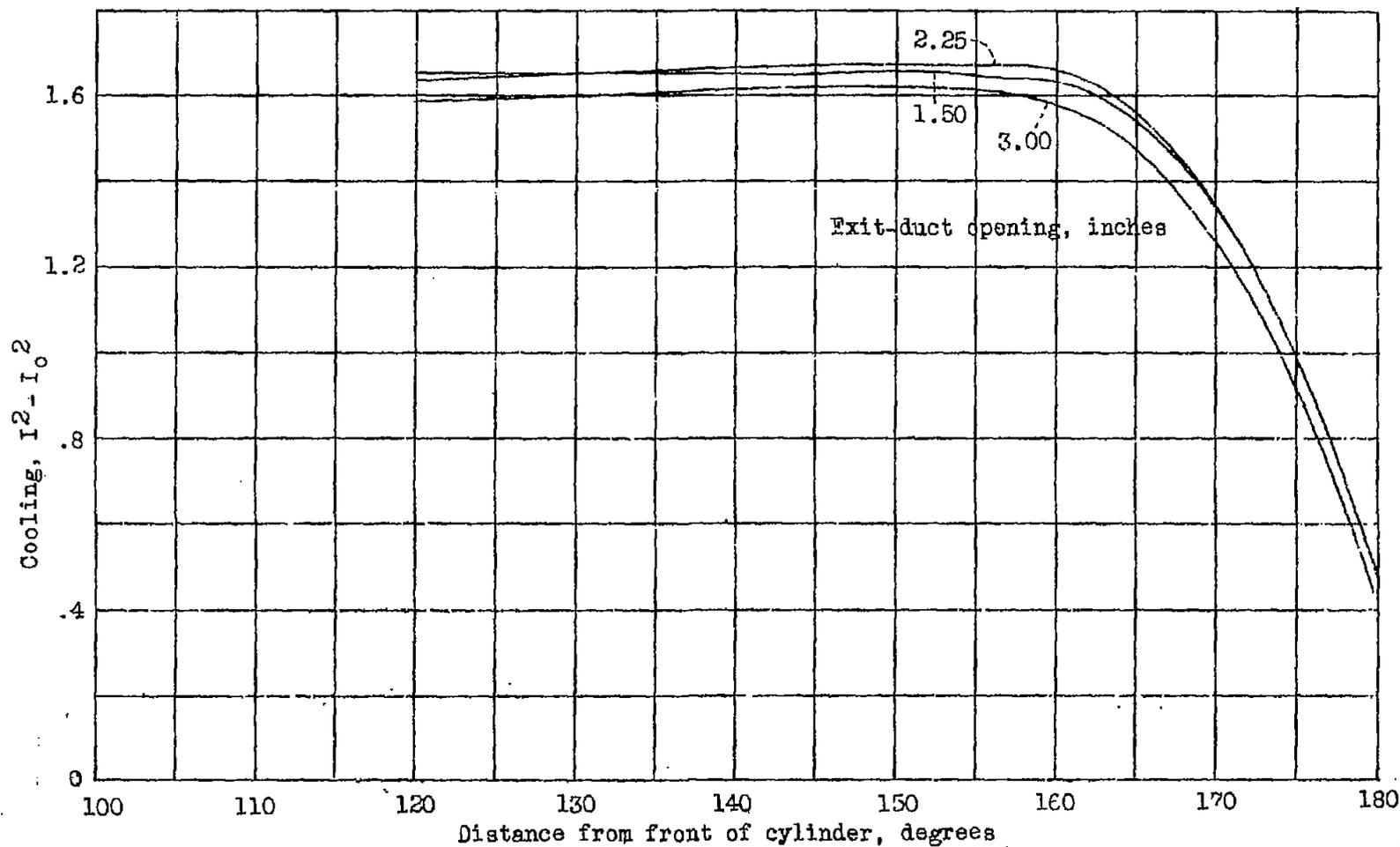
Figure 9.- Effect of position around cylinder on cooling for several exit-duct openings. Exit-duct length, 3.75 inches; baffle opening, 1.00 inch.
Cylinder diameter, 7.00 inches; fin space, 1/16 inch.

Fig. 9
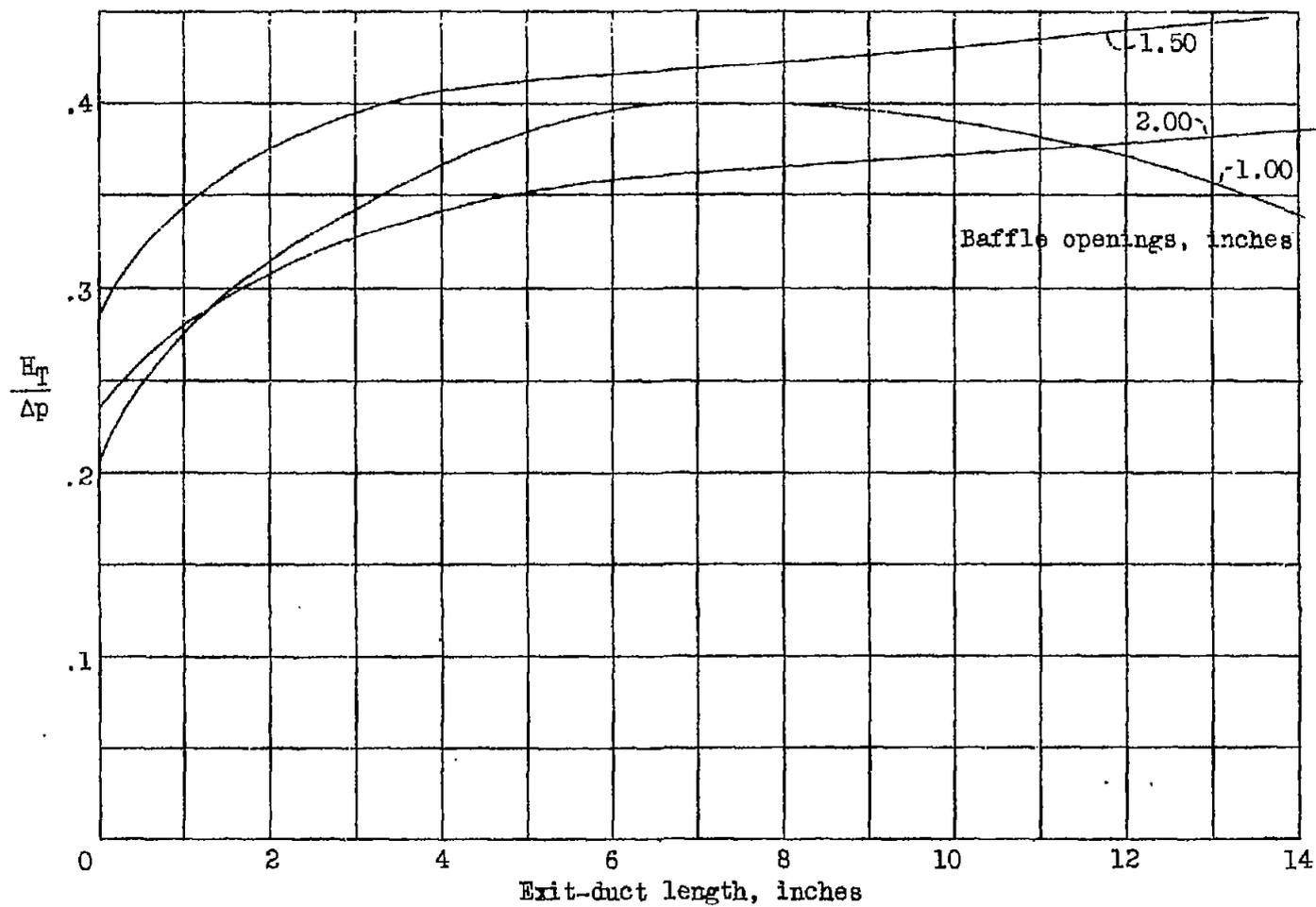
Figure 10.- Effect of exit-duct length on loss in total head at 150° from front of cylinder for several baffle openings at optimum exit-duct opening. Cylinder diameter, 7.00 inches; fin space, 1/16 inch

Fig. 10
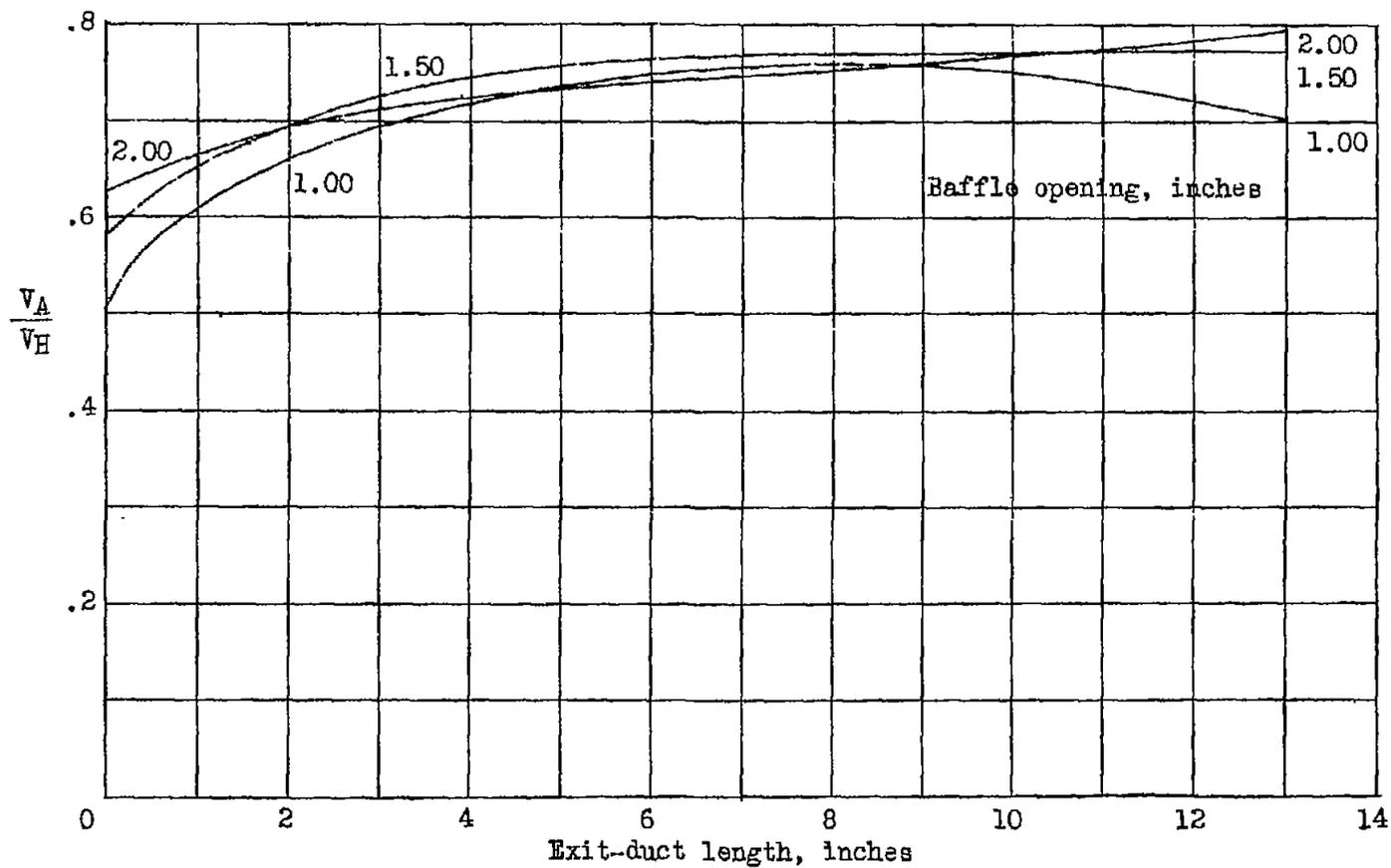
Figure 11.- Effect of exit-duct length on V_A/V_H at 150° from front of cylinder for several
baffle openings at optimum exit-duct opening.
Cylinder diameter, 7.00 inches; fin space, 1/16 inch.

Fig. 11
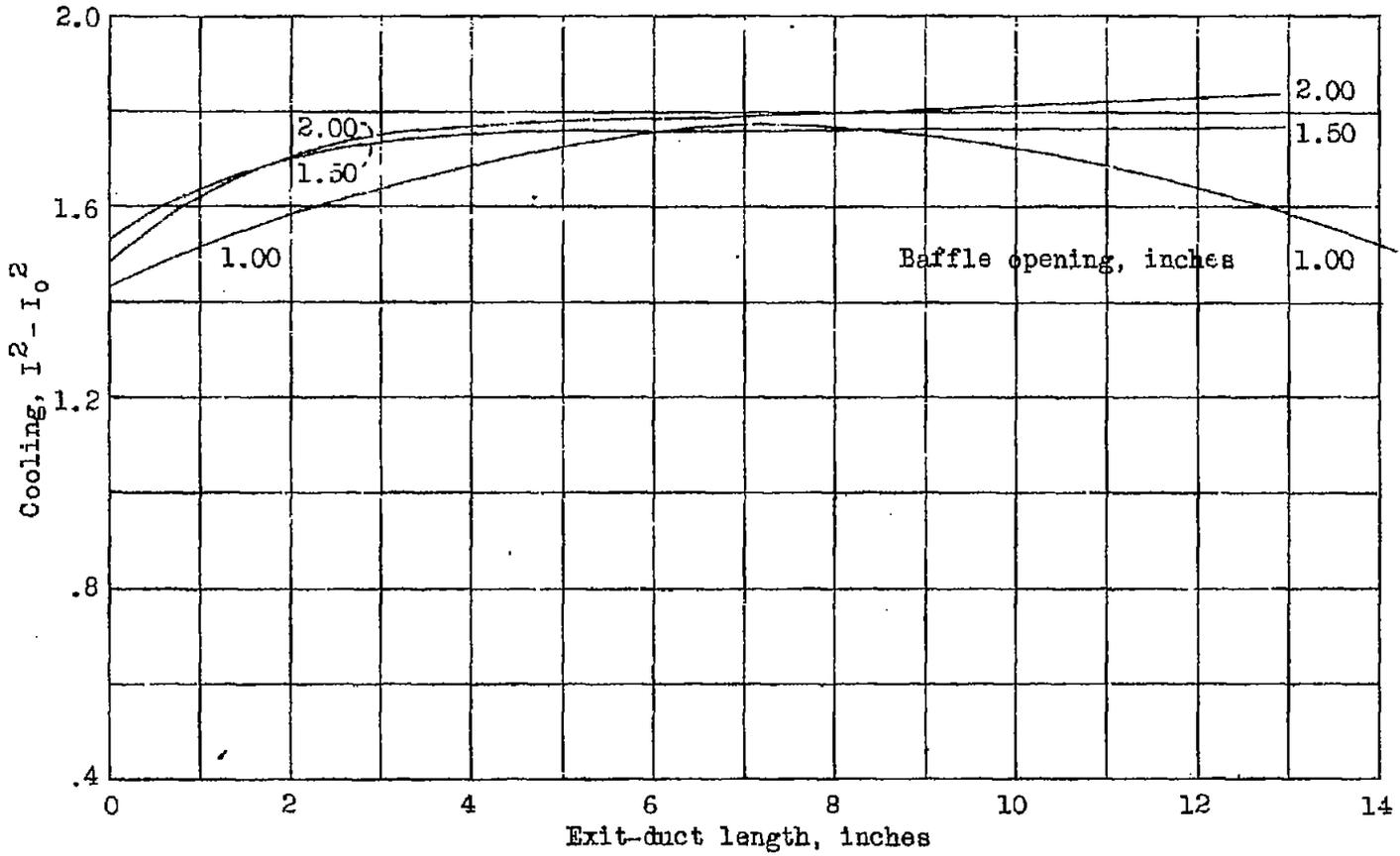
Figure 12.- Effect of exit-duct length on cooling at 150° from front of cylinder for several baffle openings at optimum exit-duct opening.
Cylinder diameter, 7.00 inches; fin space, 1/16 inch.

Fig. 12
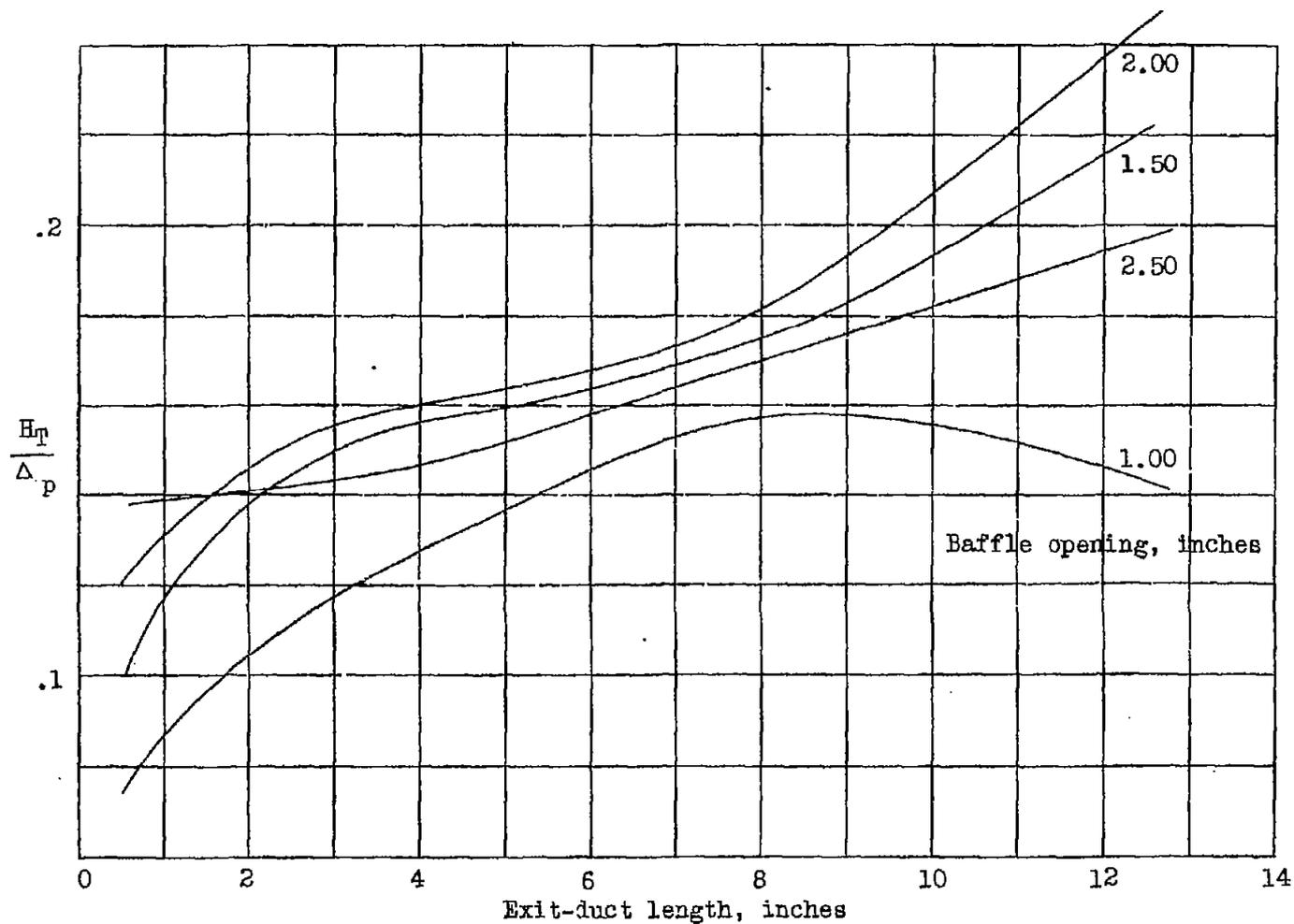
Figure 13.- Effect of exit-duct length on loss in total head at 150° from front of cylinder for several baffle openings at optimum exit-duct opening.
Cylinder diameter, 7.00 inches; fin space, 1/4 inch.

Fig. 13
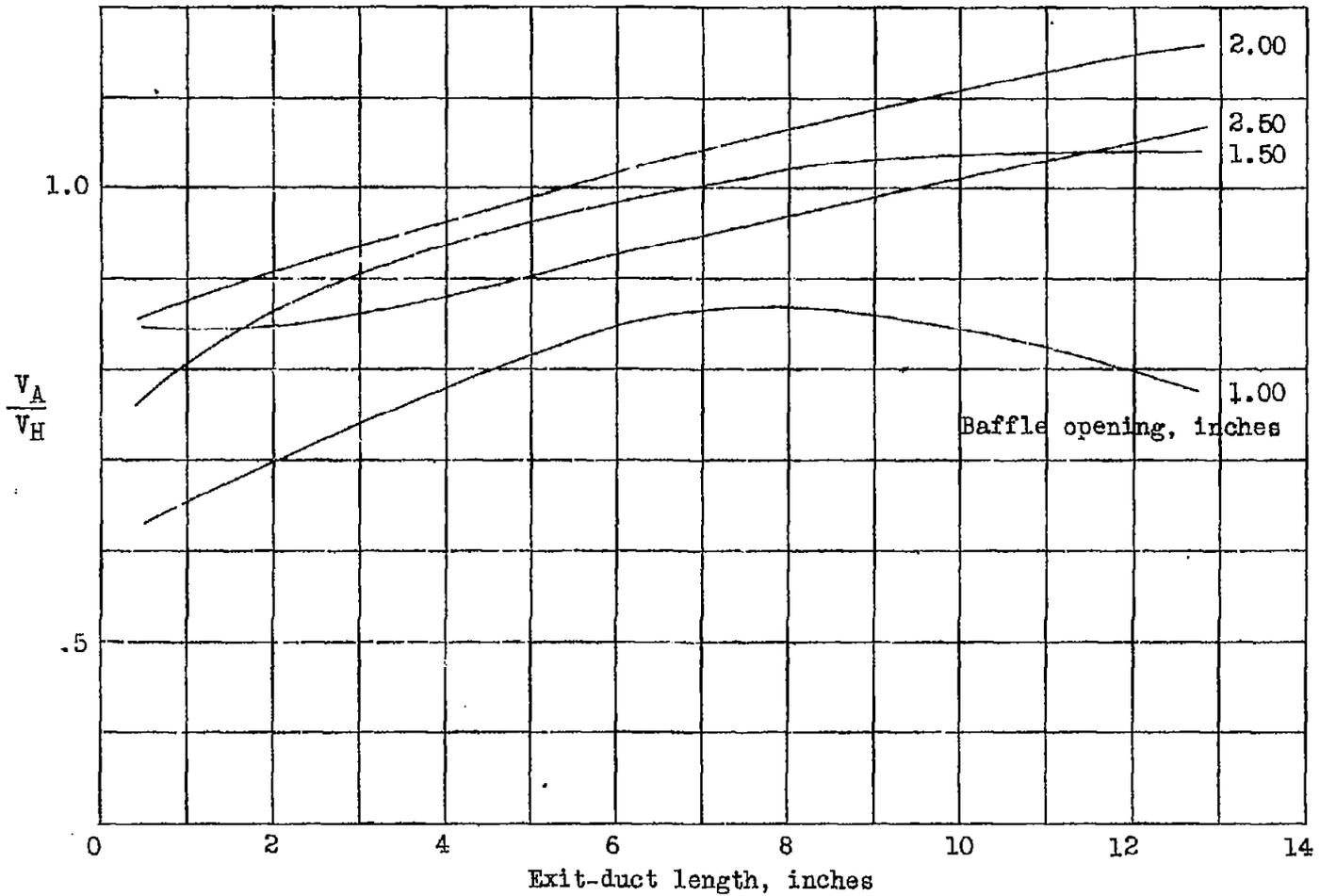
Figure 14.- Effect of exit-duct length on V_A/V_H at 150° from front of cylinder for several baffle openings at optimum exit-duct opening.
Cylinder diameter, 7.00 inches;   fin space, 1/4 inch.

Fig. 14
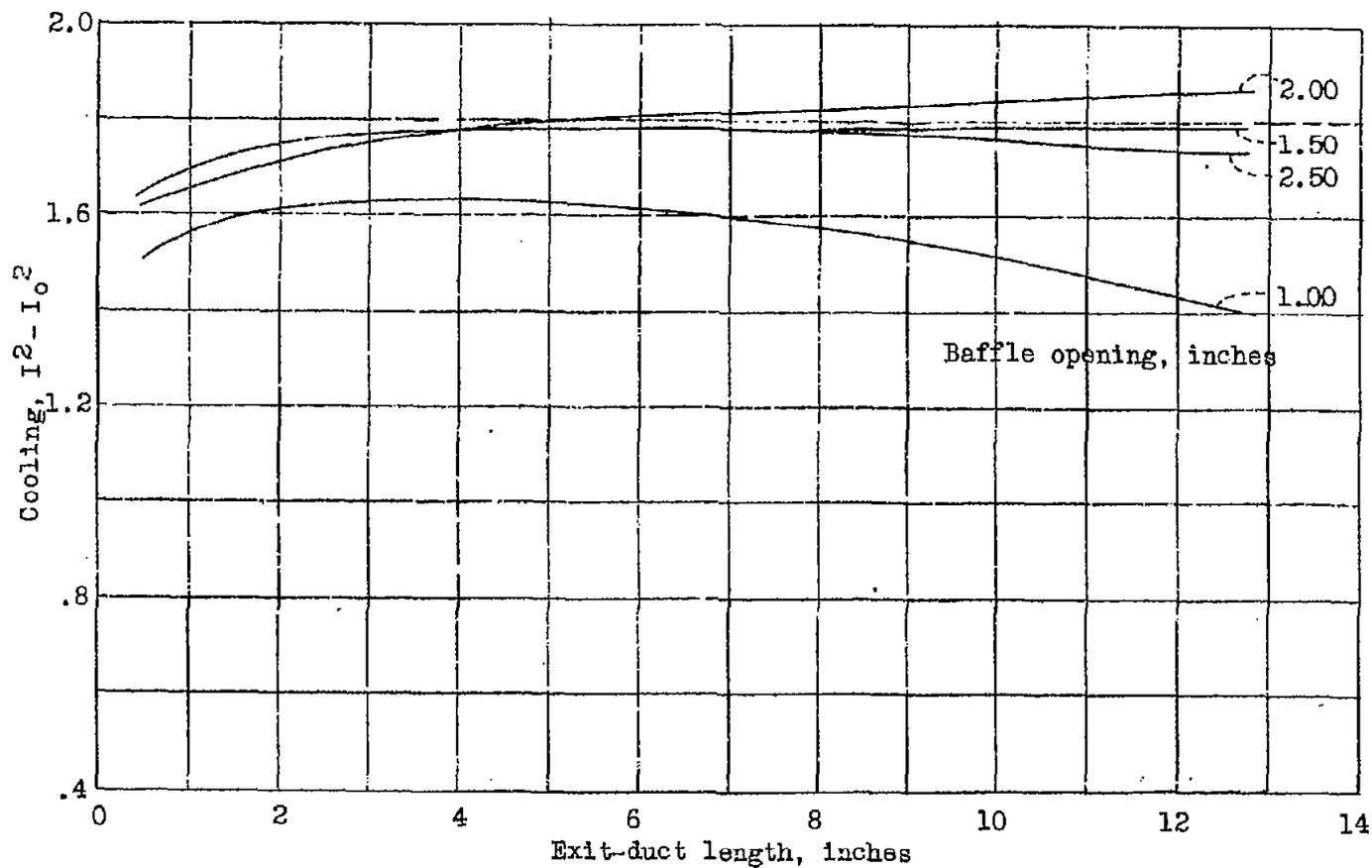
Figure 15.— Effect of exit-duct length on cooling at 150° from front of cylinder for several baffle openings at optimum exit-duct opening.
Cylinder diameter, 7.00 inches; fin space. 1/4 inch.

Fig. 15
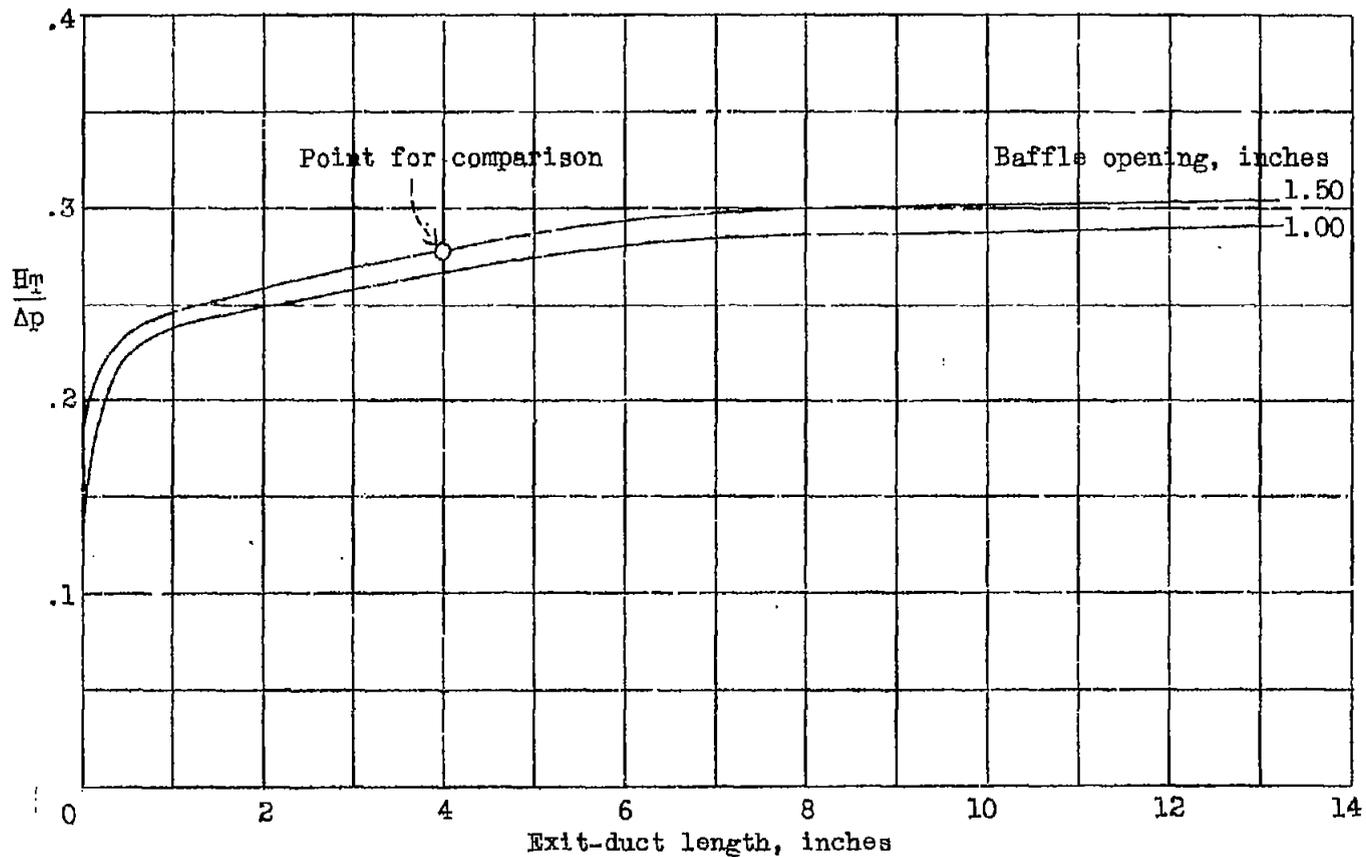
Figure 16.- Effect of exit-duct length on loss in total head at 150° from front of cylinder for different baffle openings at optimum exit-duct opening.
Cylinder diameter, 4.66 inches; fin space, 1/16 inch.

Fig. 16
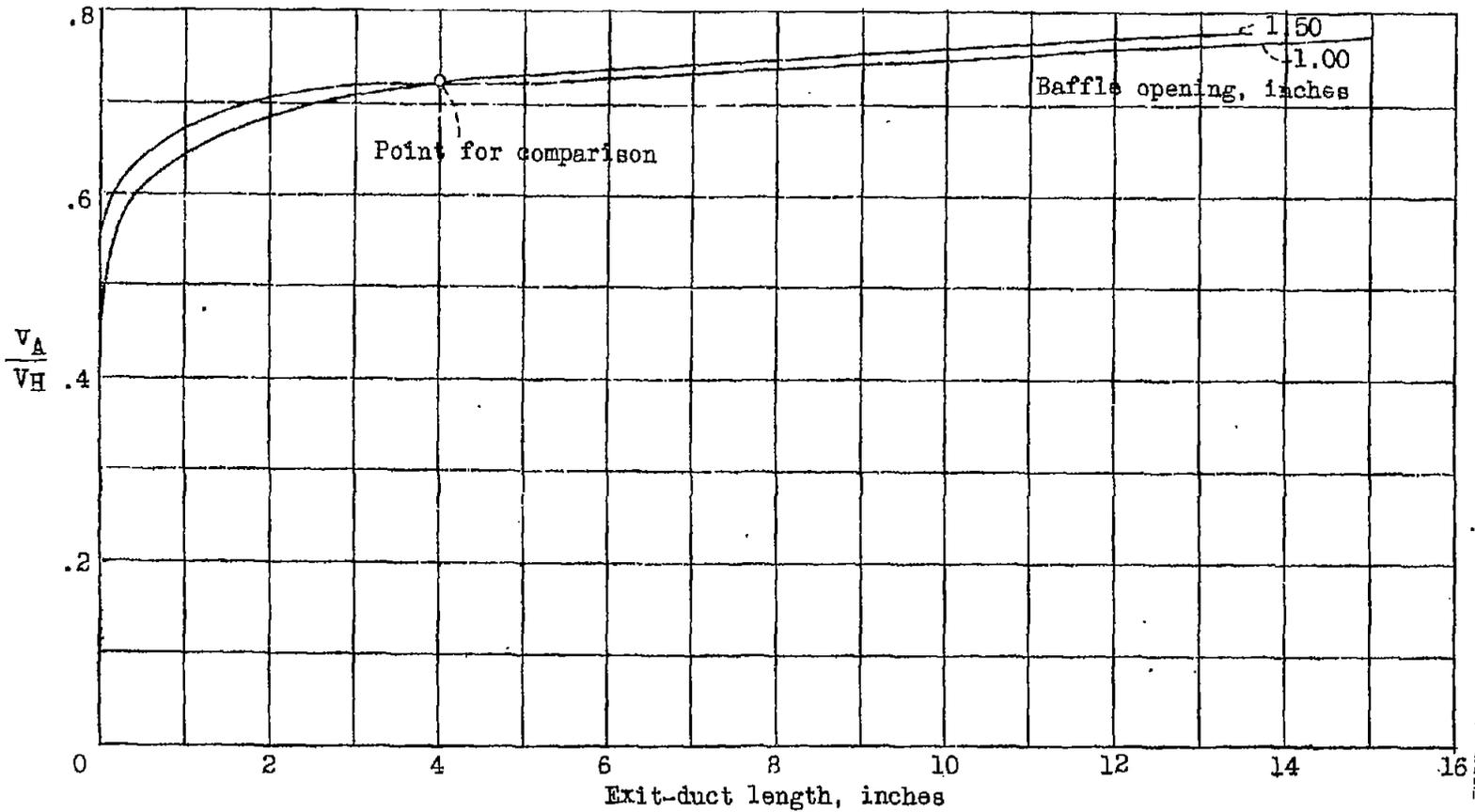
Figure 17.- Effect of exit-duct length on V_A/V_H at 150° from front of cylinder for different baffle openings at optimum exit-duct opening.
Cylinder diameter, 4.66 inches; fin space, 1/16 inch.

Fig. 17
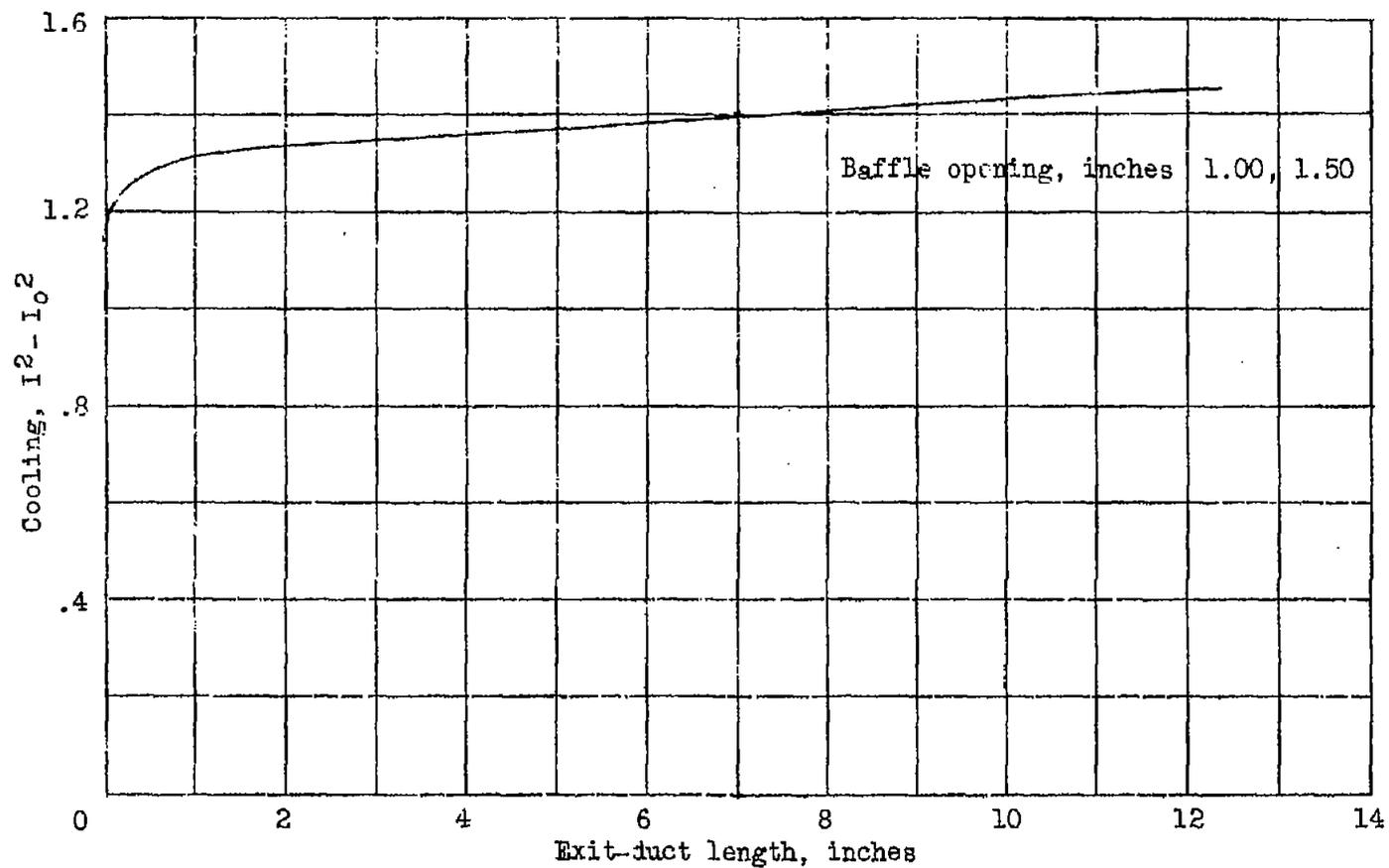
Figure 18.- Effect of exit-duct length on cooling at 150° from front of cylinder at optimum exit-duct opening.
Cylinder diameter, 4.66 inches; fin space, 1/16 inch.

Fig. 18

Curve	Cylinder diameter, inches	Fin space, inch
1	7.00	1/4
2	7.00	1/16
3	4.66	1/16
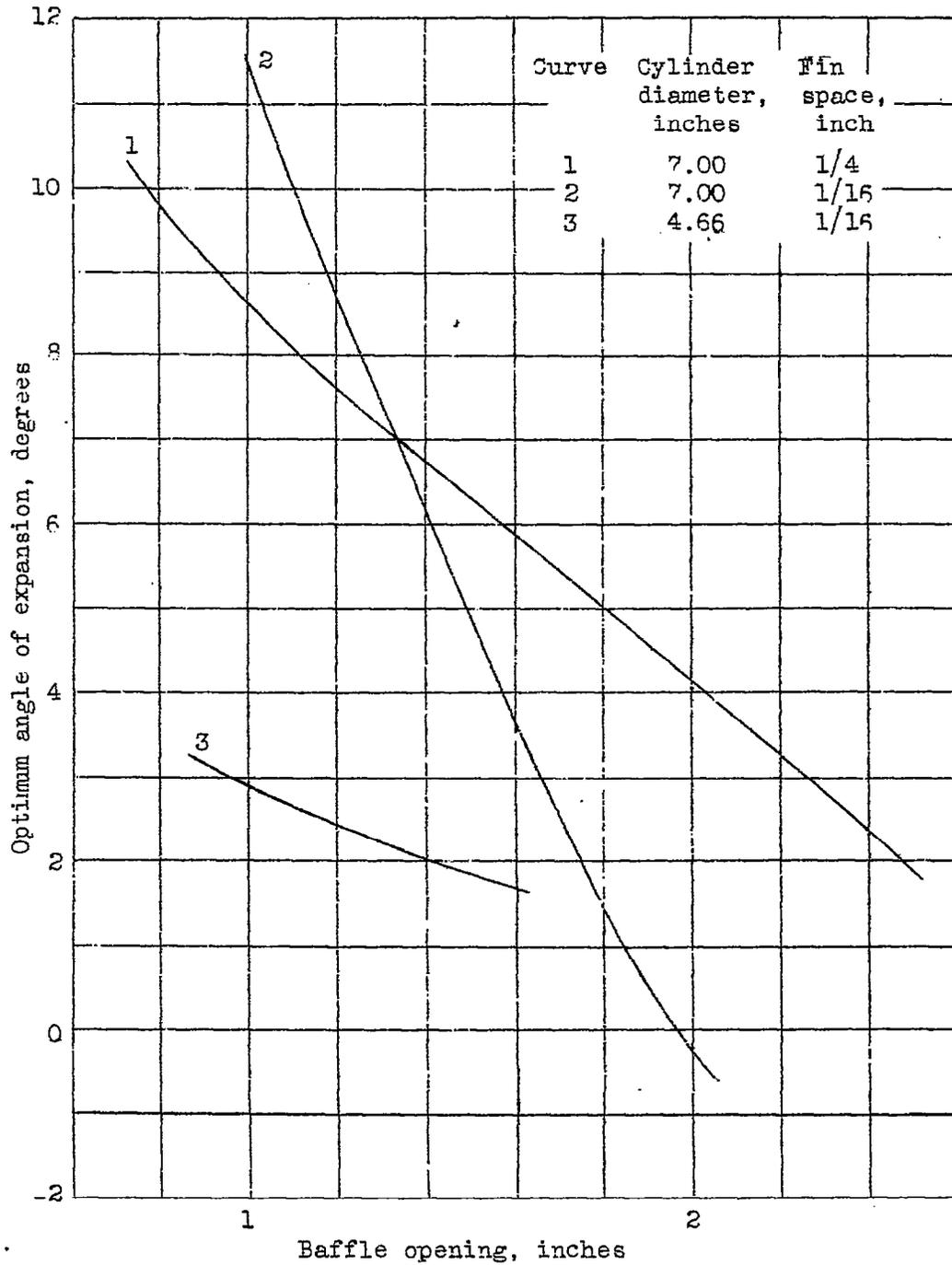
Figure 19.- Effect of baffle opening on optimum angle of expansion.
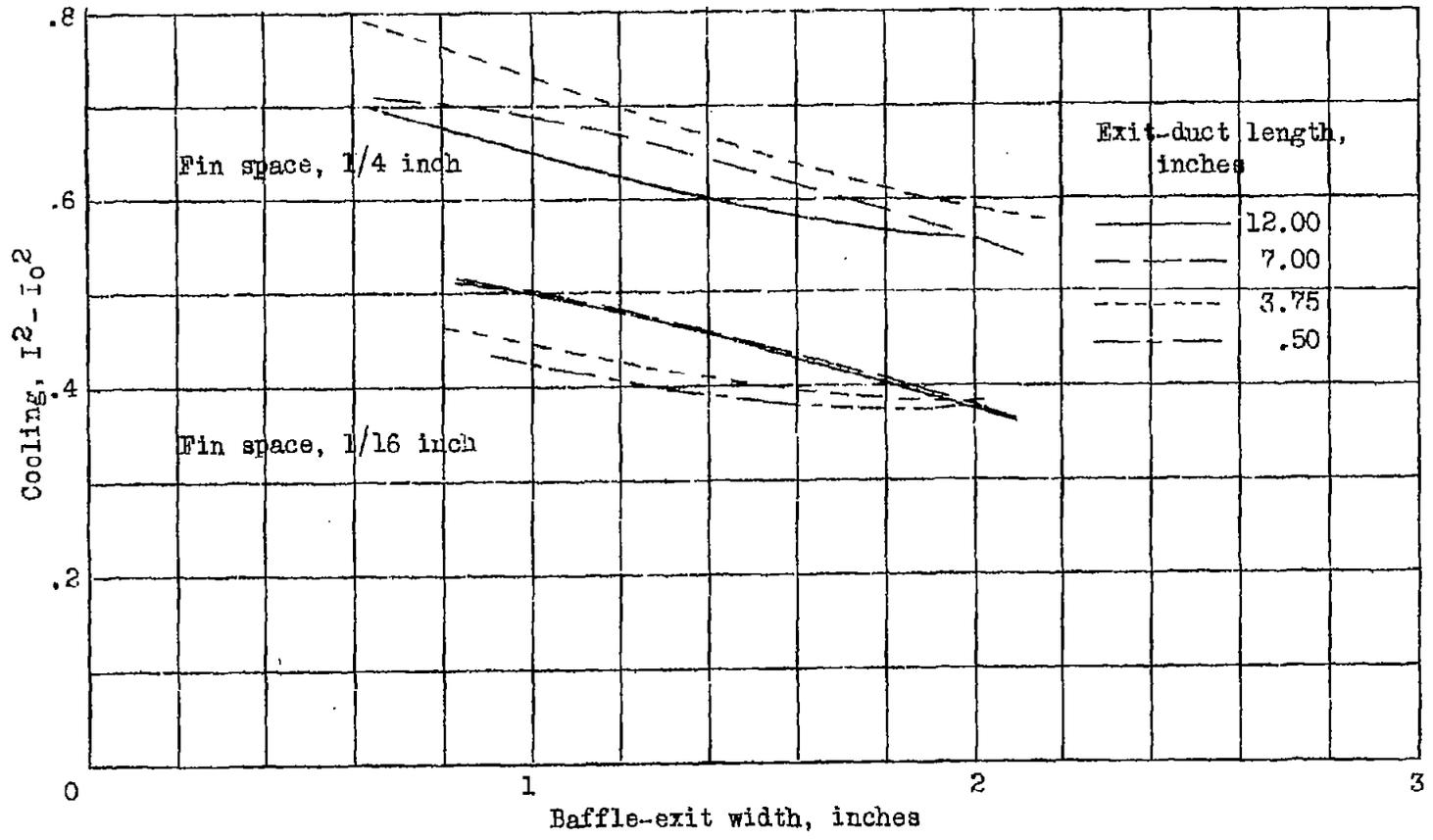
Figure 20.- Effect of baffle-exit width on cooling at rear of cylinder for two fin spacings and several exit-duct lengths at optimum exit-duct opening.
Cylinder diameter, 7.00 inches.

Fig. 20
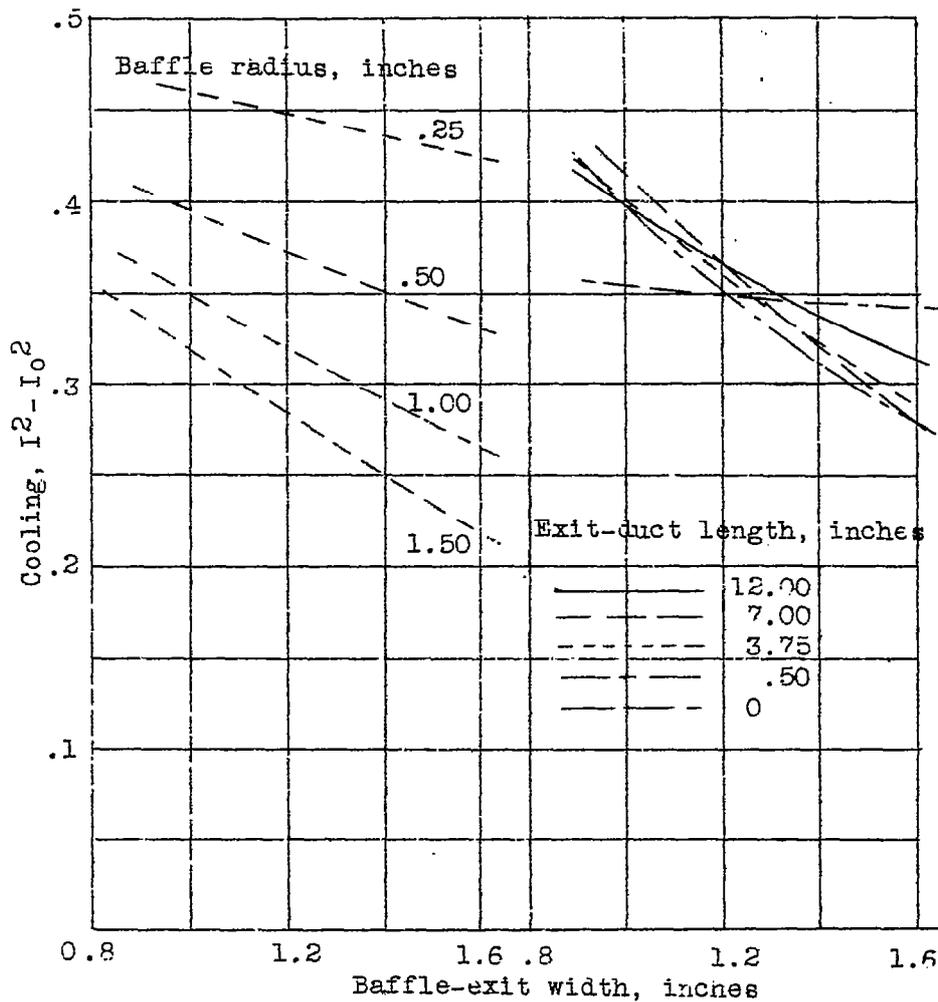
Figure 21.- Effect of baffle-exit width on cooling at rear of cylinder
         for several exit-duct lengths and baffle radii at optimum-
exit-duct opening.
Cylinder diameter, 4.66 inches; fin space, 1/16 inch.
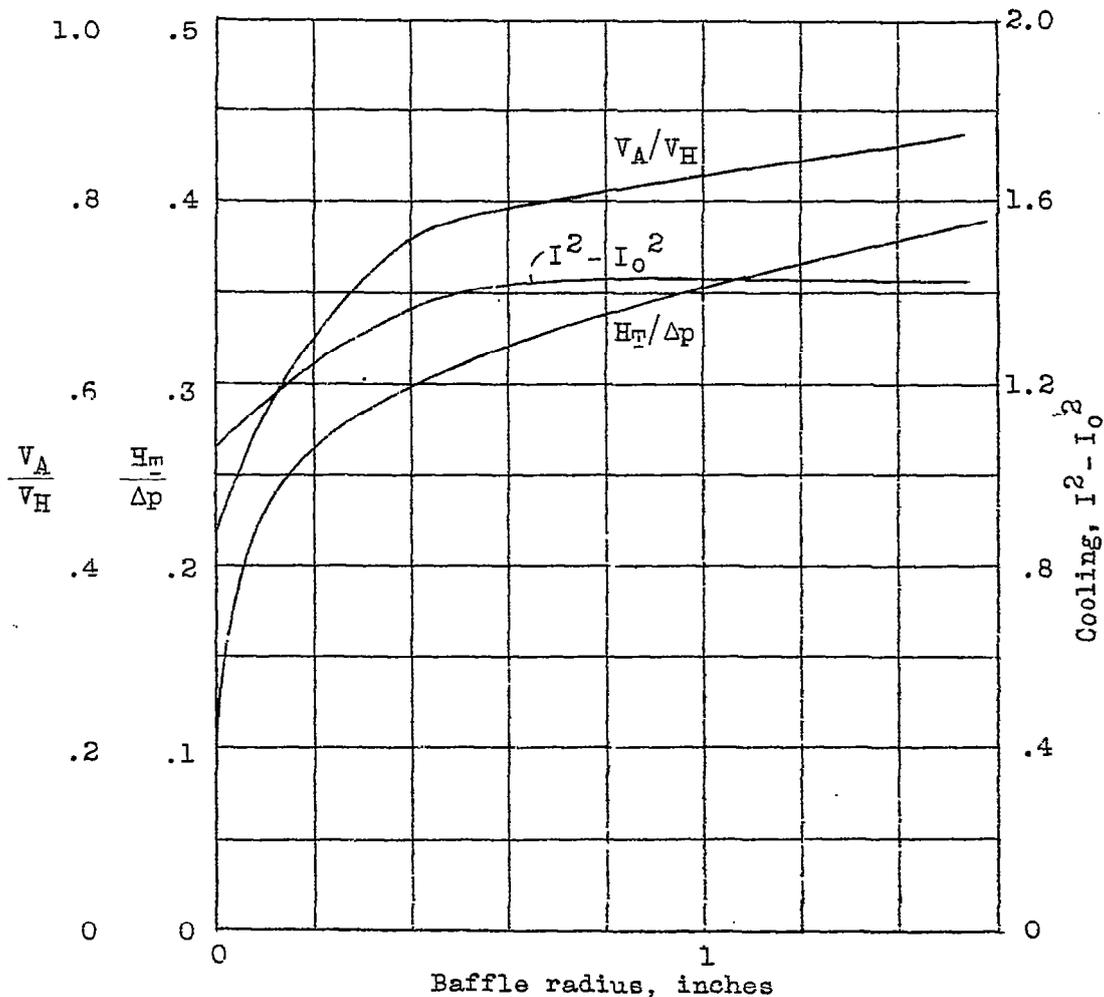
Figure 22.- Effect of baffle radius on $H_T/\Delta p$, V_A/V_H, and $I^2 - I_o^2$ at 150° from front of cylinder at optimum exit-duct opening. Baffle exit, 1.00 inch; exit-duct length, 7.00 inches. Cylinder diameter, 4.66 inches; fin space, 1/16 inch.
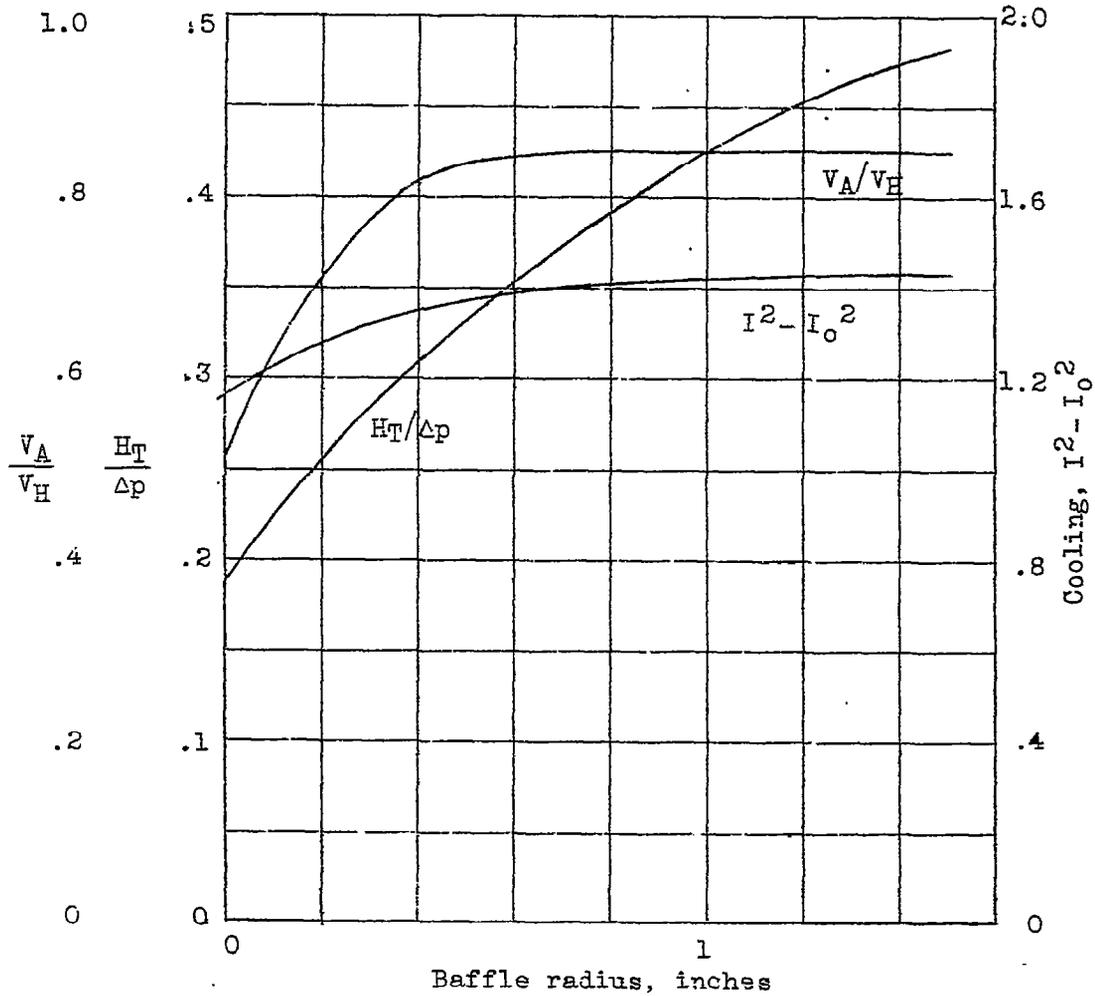
Figure 23.- Effect of baffle radius on $H_T/\Delta p$, V_A/V_H, and $I^2 - I_o^2$ at $150°$ from front of cylinder at optimum exit-duct opening. Baffle exit, 1.5 inches; exit-duct length, 7.00 inches. Cylinder diameter, 4.66 inches; fin spaces. 1/16 inch.