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No. 631

WIND-TUNNEL TESTS OF CARBURETOR-INTAKE RAMS

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By Frank H. Highley

SUMMARY

An investigation was conducted in the N.A.C.A. 20-foot wind tunnel of the ramming effect of three general types of carburetor-intake rams for radial engines, namely, the internal constant-area type, the external constant-area type, and the external expanding type. The rams were installed on a radial air-cooled engine nacelle and tests were made with and without the propeller operating.

The internal constant-area type secures air for the carburetor from within the engine cowling and forward of the engine cylinders. One entrance shape and five locations were investigated. The external constant-area type secures air for the carburetor from the air stream outside the engine cowling. Two entrance shapes and two locations were investigated. The external expanding type secures air at high velocity from the air stream outside the engine cowling and reduces its velocity and increases its pressure by an expanding tube before it reaches the carburetor. One entrance shape and two locations were investigated. This type is characterized by having a smaller frontal area than the external constant-area type. The results indicated that:

The external types having entrances near the front of the engine cowling gave the greatest ramming effect.

The propeller increased the ramming effect for the external types.

From considerations of ramming effect, the best entrance location for the external types was close to the nose of the engine cowling; for the internal type, the best location was in a plane perpendicular to the propeller shaft and immediately forward of the engine cylinders.

INTRODUCTION

A carburetor-intake ram is a device used to increase the carburetor-intake pressure through the use of the dy-

namic pressure due to forward motion. This increase in carburetor-intake pressure results in several increases in engine performance, namely, increased full-throttle power at the same altitude, increased critical altitude, and possible increased cruising altitude.

The use of carburetor intake rams is not new for many installations may be observed. The rams in use fall into two classes: the internal constant-area type and the external constant-area type. In general, the internal constant-area type consists of one or more ducts passing between the engine cylinders to the carburetor and having an entrance so located as to obtain air for the carburetor from within the forward portion of the engine cowling. Several entrance locations are in use, some near the nose of the cowling, some near the engine cylinders, some projecting forward, and some at an angle to the axis of the engine and cowling. The external constant-area type consists, in general, of a duct leading to the carburetor with an entrance located somewhere on the outside of the cowling. Here again, several entrance locations are used. Although most entrances are on the engine cowling itself, others are to be found on the forward portion of the fuselage or nacelle and a few in the leading edge of the wing, close to the fuselage or nacelle.

From the variety of installations observed and from the lack of published information, it is apparent that there is very little information available concerning the proper entrance location and the ramming effect of the various types of carburetor-intake rams.

The present investigation was made in conjunction with propeller tests conducted in the N.A.C.A. 20-foot wind tunnel.

If the effect of the propeller is neglected, it is apparent that the maximum pressure obtainable from the air stream is the dynamic pressure due to the forward velocity of the airplane. Not all of this dynamic pressure is available for increasing the carburetor-intake pressure, however, since losses occur in the carburetor-intake ram. Friction losses are present in every ram and cannot be eliminated. Another loss exists in the form of an entrance loss, part of which is due to the entrance shape and location and part to the fact that the velocity of the air entering the ram must be reduced from that of the air stream to the velocity required at the carburetor.

As this reduction in velocity occurs without expansion in the case of the external constant-area type, it is reasonable to expect losses due to spillage and turbulence to exist. If it were possible to take air into the ram at the velocity of the air stream and expand it until its velocity were reduced to that required at the carburetor, it should be possible to eliminate the losses due to spillage and turbulence.

Figures 1 and 2 show the pressure and velocity distribution on radial-engine cowling nose 6 of reference 1. Figure 2 shows that the highest velocity occurs near the nose of the cowling. The external expanding type was constructed to investigate the effect that may be obtained by reducing the velocity of the air and increasing its pressure by an expanding tube and the effect of placing the entrance in the high-velocity region of the cowling.

APPARATUS AND METHODS

The rams were constructed of sheet metal and were installed on a radial air-cooled engine nacelle (fig. 3). Flow conditions through a radial engine were simulated by means of a perforated plate. For the investigation of the effect of the propeller, power was supplied by a Curtiss Conqueror engine installed in the nacelle. The pitch angle of the nacelle was zero for all tests.

The internal constant-area type of ram was located inside the engine cowling (fig. 4). Five entrances, all having the same cross-sectional area and shape but different locations, were investigated. The velocity of the air through the ram was controlled by a manually operated damper valve. The velocity and pressure of the air in the ram were measured with three total-head tubes and one static-head tube.

The external constant-area type was located on the outside of the engine cowling and, because of its large size, was provided with a streamline fairing extending back over the nacelle (figs. 3 and 5). Two entrance shapes and two entrance locations were investigated. The velocity of the air through the ram was controlled by a manually operated damper valve. The velocity and pressure of the air in the ram were measured with five total-head tubes and one static-head tube.

The external expanding type (fig. 6) was installed on the outside of the engine cowling but, because of its small size, no fairing was provided. One entrance shape and two entrance locations were investigated. The total head and the static head existing in the ram were measured with three total-head tubes and one static-head tube. The air was not expanded in the ram but the effect of expansion was assumed to be such that the total head remained constant.

The total head and static head in the rams and the wind-tunnel velocity were measured.

Since the velocity of the air in the ram at the carburetor V_R and the velocity of the air stream V are both variable, it was found advantageous to plot p/q against the nondimensional quantity $(V_R/V)^2$ where

p is the increase in total head of the carburetor.

q, dynamic pressure due to the air-stream velocity V.

RESULTS AND DISCUSSION

Figures 7 to 9 show the effect of entrance location for the three types; the two external types were tested without the propeller and with the propeller operating. Figures 10 and 11 show the comparison between the best entrance locations for the three types tested, both with and without the propeller.

Figure 7 shows that entrance 1 of the internal constant-area type is superior to the other entrances tested throughout the entire range of values of $(V_R/V)^2$. Entrance 5 is definitely the worst entrance tested. Examination of figures 1 and 2 shows that this condition is to be expected, since entrance 1 is in a positive-pressure region and entrance 5 is located in a negative-pressure region. The fact that the curves of figure 7 are very nearly straight lines indicates that no entrance loss occurs with the internal constant-area type. This result is to be expected because the air inside the engine cowling has little or no velocity.

Figure 8 shows that, for the external constant-area type without propeller, entrance 1 is the best entrance

tested for most values of $(V_R/V)^2$. This result may be due in a large part to the fact that entrance 1 is slightly larger than entrances 2 and 3. Entrance losses seem to be very large, entrance 3 being affected the least.

Figure 9 shows that, for the external expanding type without propeller, the best entrance tested is entrance 2. The superiority of entrance 2 is probably due to the fact that there is some loss in energy in the air stream as it goes around the nose of the cowling; this loss results in less available total head at entrance 1 than at entrance 2.

Figure 8 shows that the effect of the propeller on the external constant-area type is to increase the ramming effect of all the entrances tested. The greatest increase is with entrance 3, probably because the increase in static pressure caused by the propeller is greatest close to the propeller.

Figure 9 shows that, with the external expanding type, the greatest increase in ramming effect due to the propeller is obtained with entrance 1. This result is probably due to the fact that the increase in static pressure caused by the propeller is partly offset, with entrance 2, by a change in the direction of the air flow around the nose of the cowling, thus making it impossible to obtain the full total head of the air stream in the entrance of the ram.

No tests of the effect of the propeller on the internal constant-area type were made, as recent tests in the 20-foot wind tunnel had shown the pressure immediately forward of the engine cylinders to be a function of so many variables that it was impractical to make such an investigation. In general, the effect of the propeller is to reduce slightly the pressure in the engine cowling. This result would tend to reduce slightly the ramming effect of the internal constant-area type with all entrances tested.

Figure 10 is a comparison of the three types of rams tested without the propeller. The external expanding type shows the highest ramming effect and the external constant-area type shows the lowest.

Figure 11 is a comparison of the three types of rams tested with the propeller operating. The external expanding type shows the highest ramming effect; for most values of $(V_R/V)^2$ the internal constant-area type shows the lowest.

As no tests were made of the internal constant-area type with the propeller operating, the curve for this type given in figure 11 is for the condition of no propeller. The effect of the propeller would be to place this curve lower than it is shown.

It should be noted that all the curves for the external expanding type are computed, each curve being based upon one experimental point. Since different points on the curves correspond to entrances of different size, the curves are based on the assumption that the entrance losses and friction losses are the same regardless of the size of entrance. It is also assumed that no loss occurs in the expanding portion of the ram. Possibly an actual installation of this type would not produce the ramming effect shown by the curves. The curves are included here to indicate the upper limit of the ramming effect for this type.

Factors other than the ramming effect should be considered in the selection of a carburetor-intake ram. An attempt was made to measure the drag of all the rams tested but the attempt was unsuccessful, since the drag was a small difference of two large numbers. It is reasonable to expect that the internal constant-area type has the least drag as it does not project into the air stream. By virtue of its smaller projected area the external expanding type should have less drag than the external constant-area type. The external expanding type gives the maximum ramming effect at only one speed. At speeds above this design speed, entrance losses would be apt to occur. At speeds below the design speed, the engine would be throttled by the ram. The constant-area types are not limited to one speed. If it were desired to develop full engine power at speeds below the design speed with the external expanding type, it would be necessary to furnish a secondary carburetor-air supply and some sort of valve mechanism for switching from this secondary supply to the ram. Because the air forward of the engine cylinders is heated by the cylinders, there is a possibility that the air furnished by the internal constant-area type might be too hot for proper operation of the engine.

CONCLUSIONS

1. Of the rams tested, the external types having entrances located near the nose of the engine cowling showed the greatest ramming effect.

2. The propeller increased the ramming effect appreciably for the external types.

3. From considerations of ramming effect, the best entrance location tested for the external types was close to the nose of the engine cowling at the point where the velocity was highest. The best entrance location tested for the internal type was in a plane perpendicular to the propeller shaft and immediately forward of the engine cylinders.

Langley Memorial Aeronautical Laboratory,
National Advisory Committee for Aeronautics,
Langley Field, Va., November 8, 1937.

REFERENCE

1. Theodorsen, Theodore, Brevoort, M. J., and Stickle, George W.: Full-Scale Tests of N.A.C.A. Cowlings. T.R. No. 592, N.A.C.A., 1937.

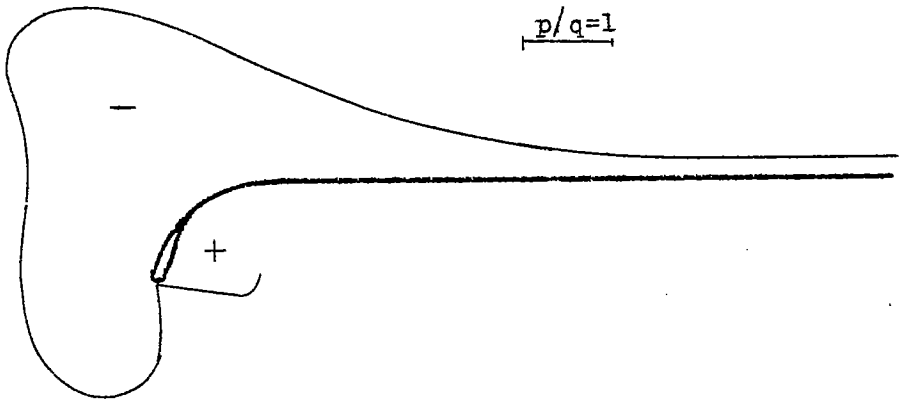

Figure 1.- Pressure distribution on nose 6 of reference 1, figure 13.

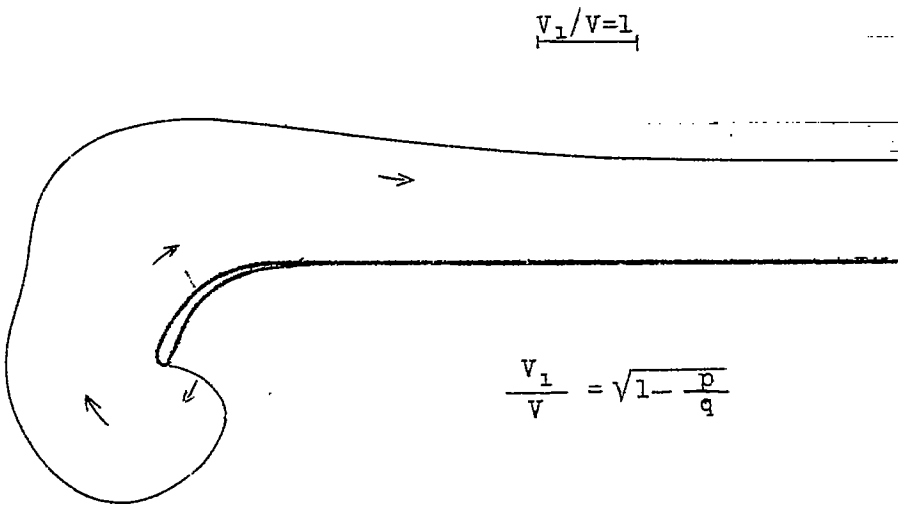

Figure 2.- Velocity distribution on nose 6 (computed from figure 1.)

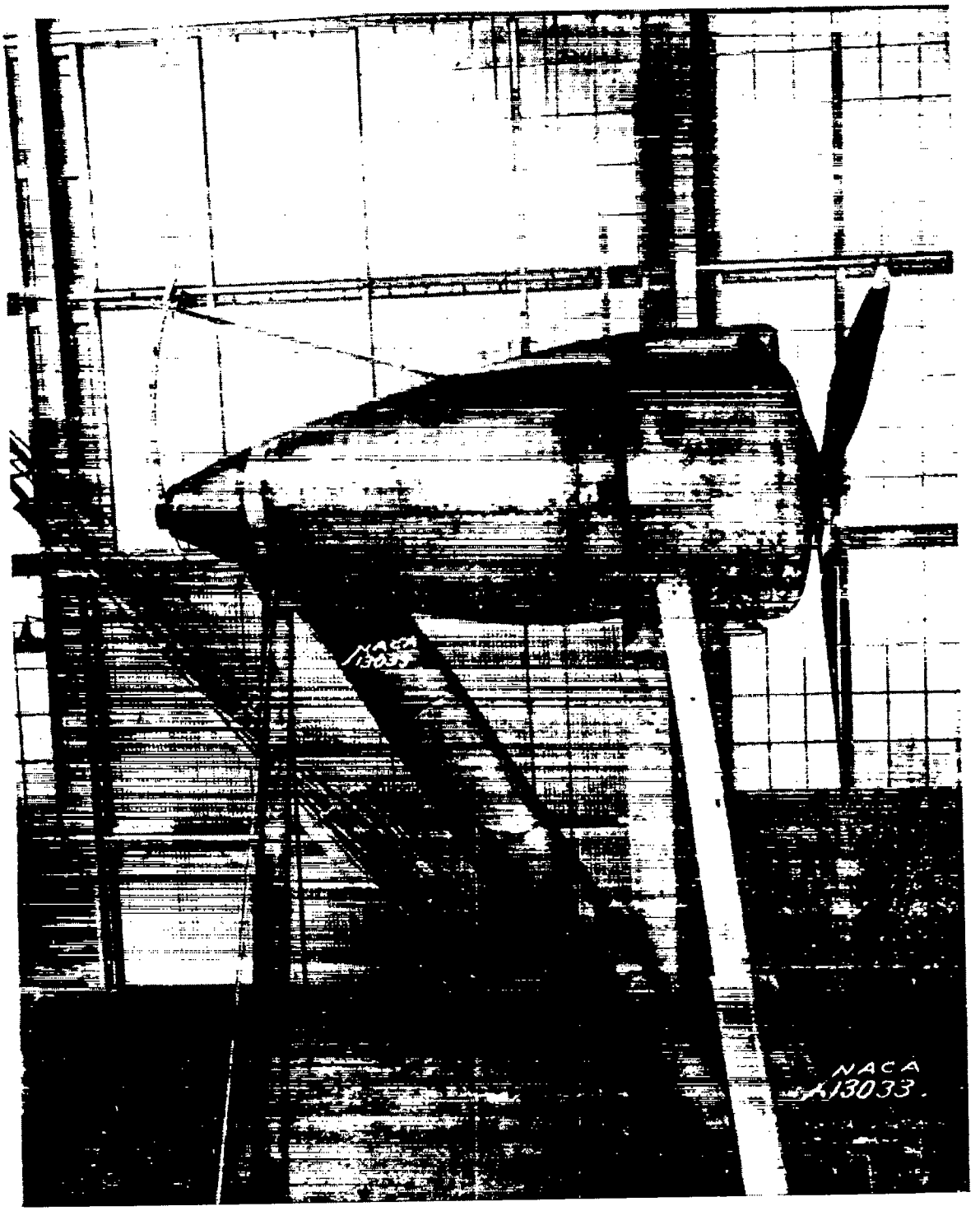

Figure 3.- External constant-area type, installed on the cowling of a radial air-cooled engine.

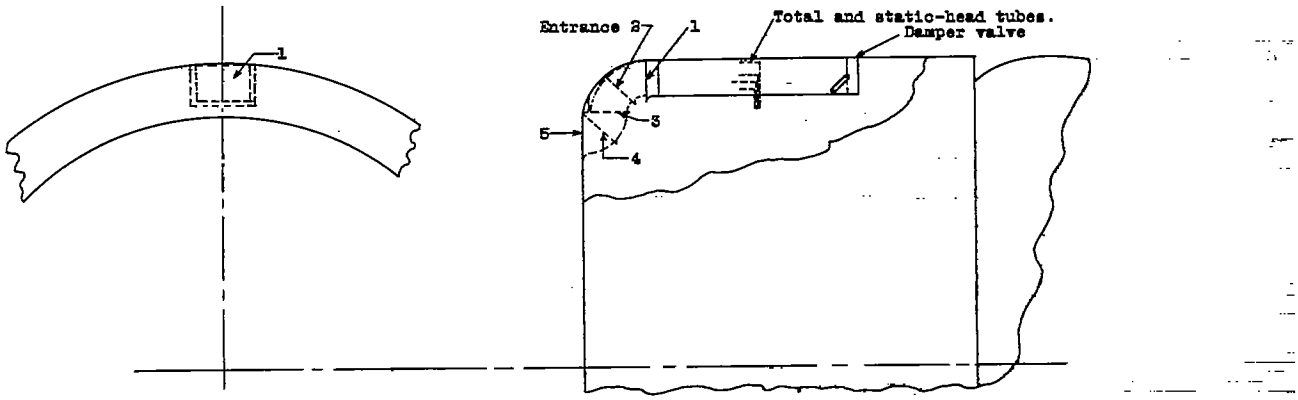

Figure 4.- Internal constant-area type of carburetor-intake ram.

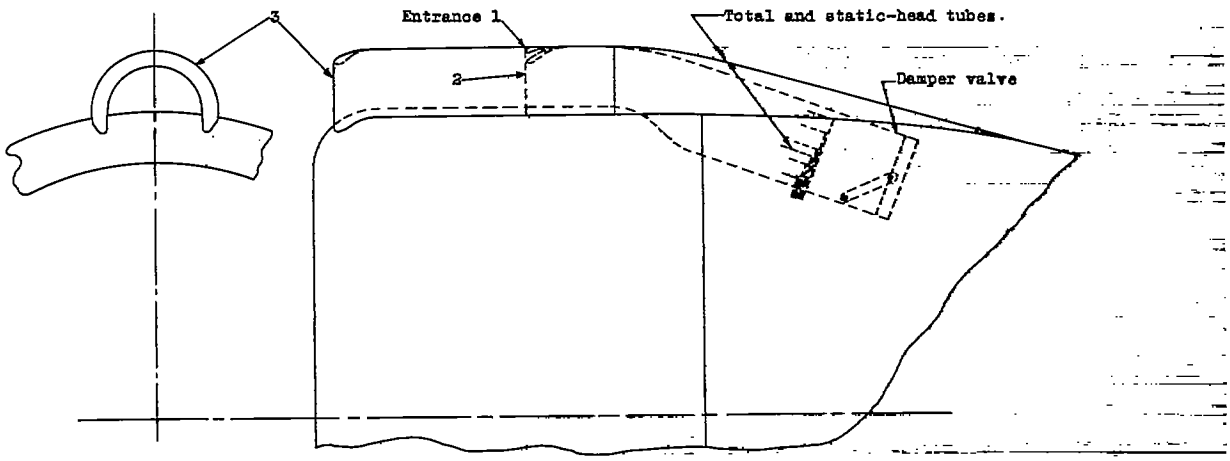

Figure 5.- External constant-area type of carburetor-intake ram.

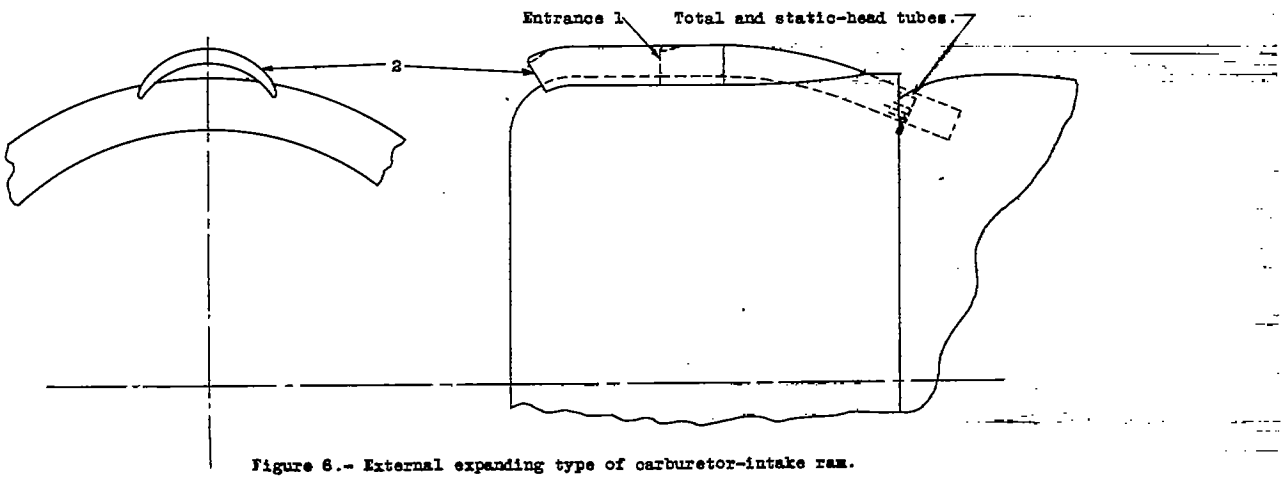

Figure 6.- External expanding type of carburetor-intake ram.

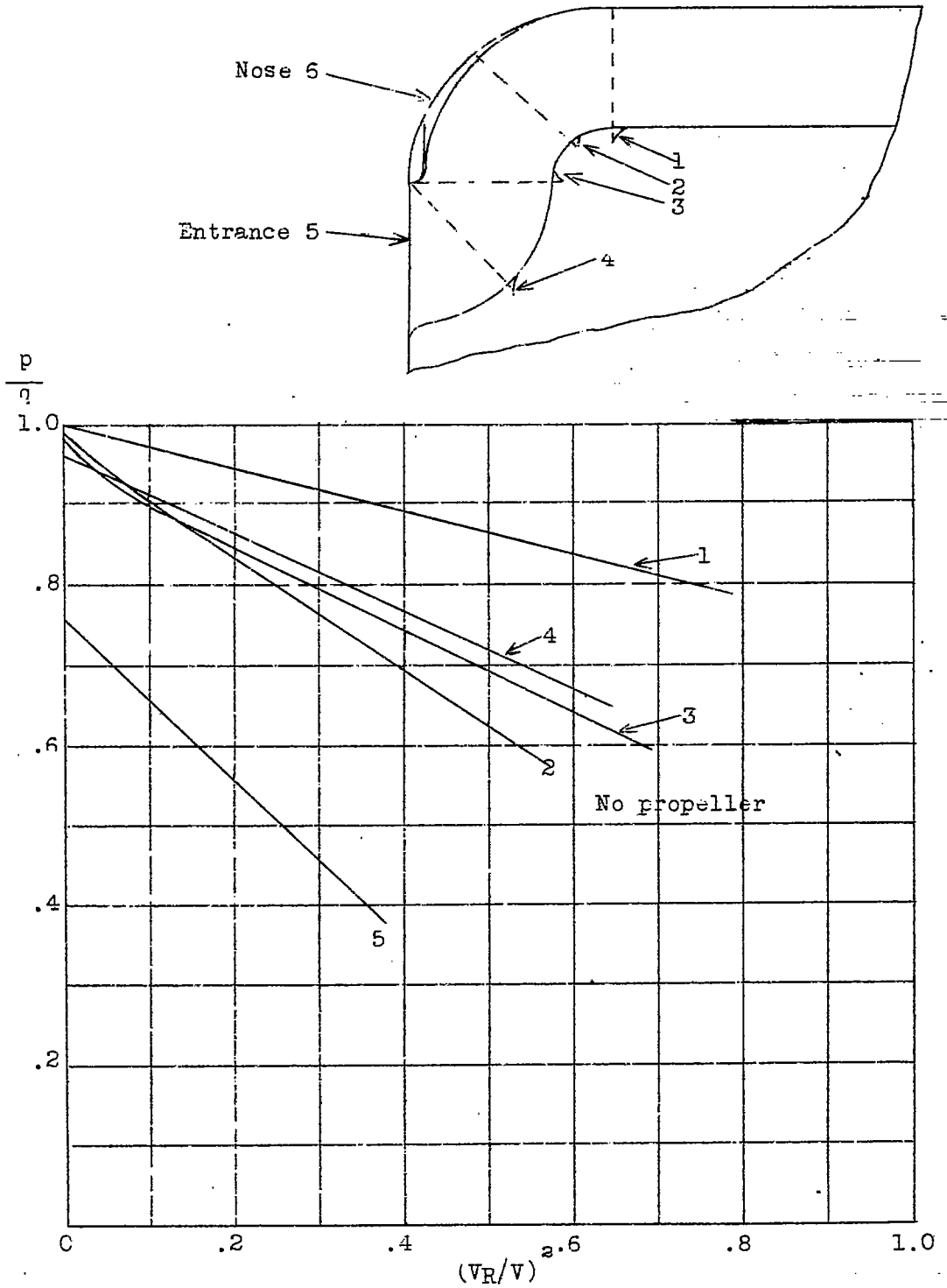

Figure 7.- Effect of entrance location on internal constant-area type of carburetor-intake ram.

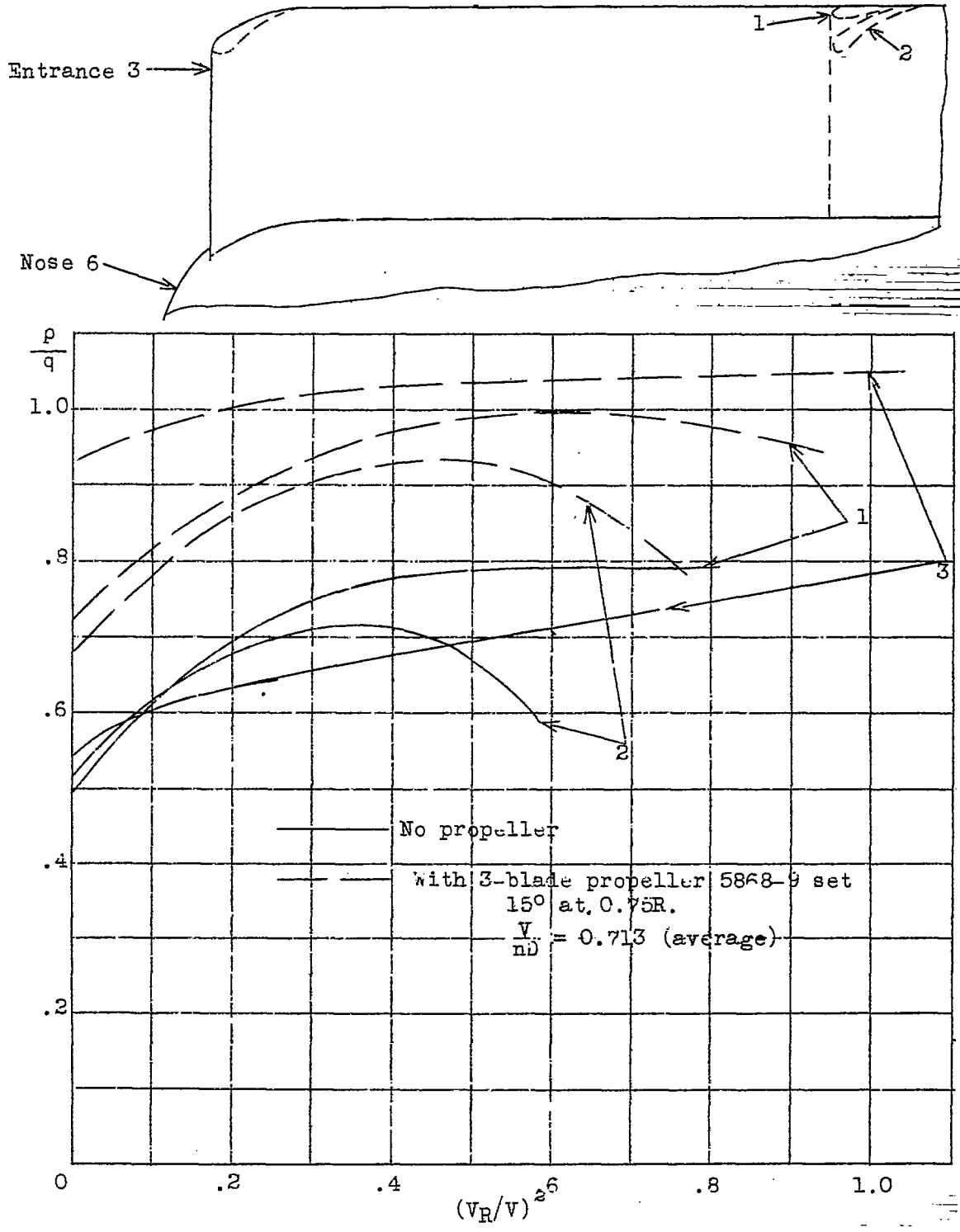

Figure 8.- Effect of entrance location on external constant-area type of carburetor-intake ram.

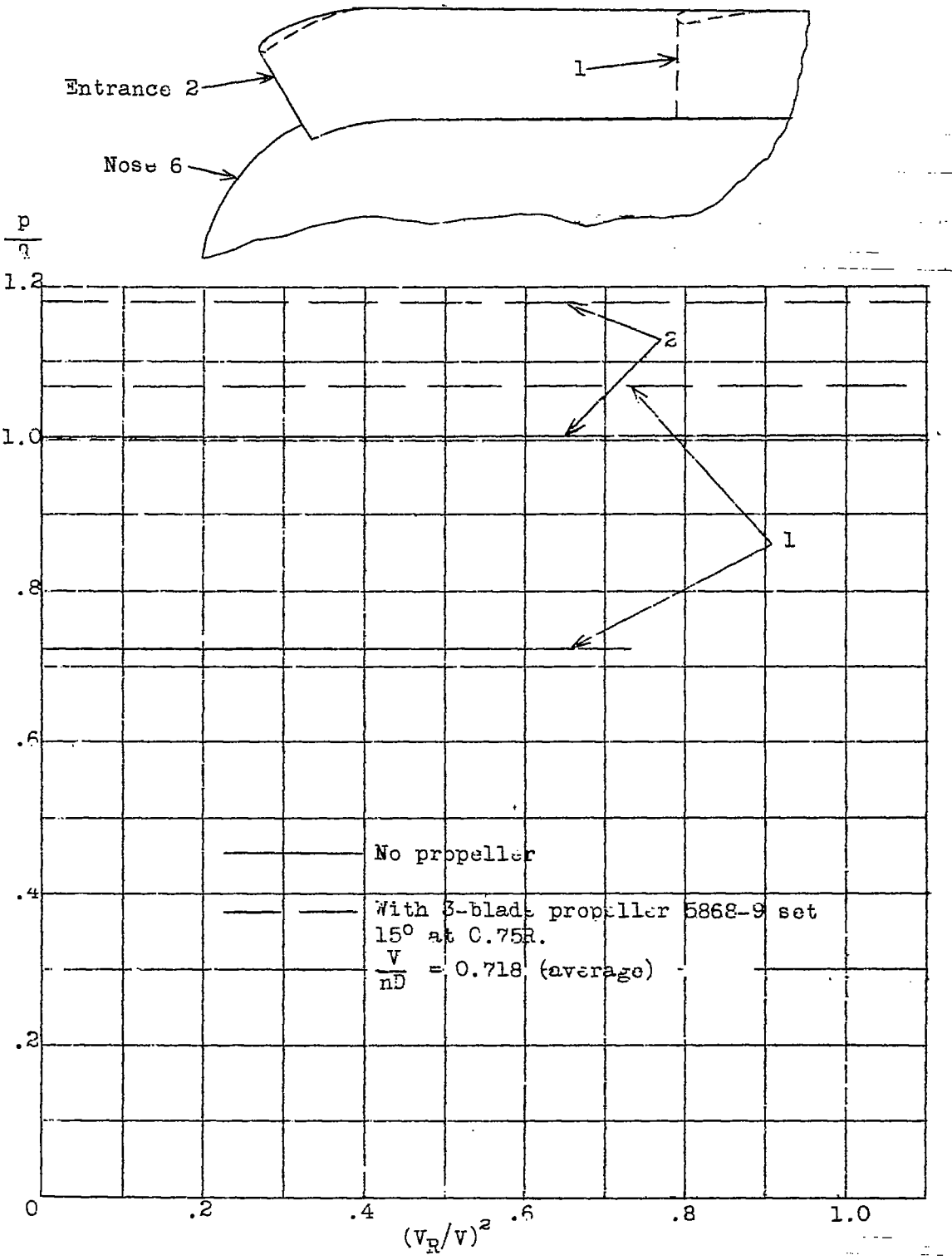

Figure 9.- Effect of entrance location on external expanding type of carburetor-intake ram.

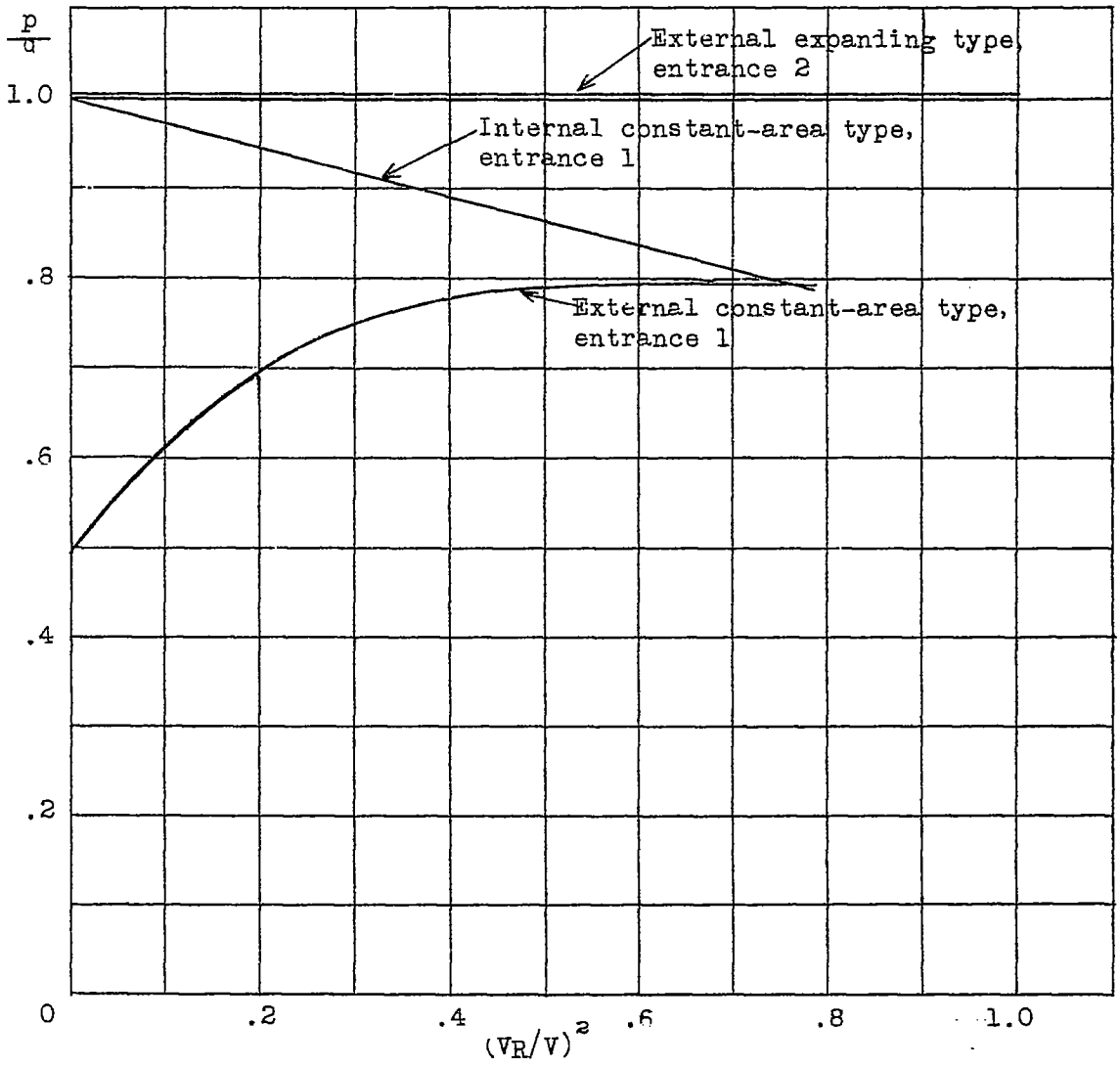

Figure 10.- Comparison of three types of carburetor-intake rams. Best entrance locations; no propeller.

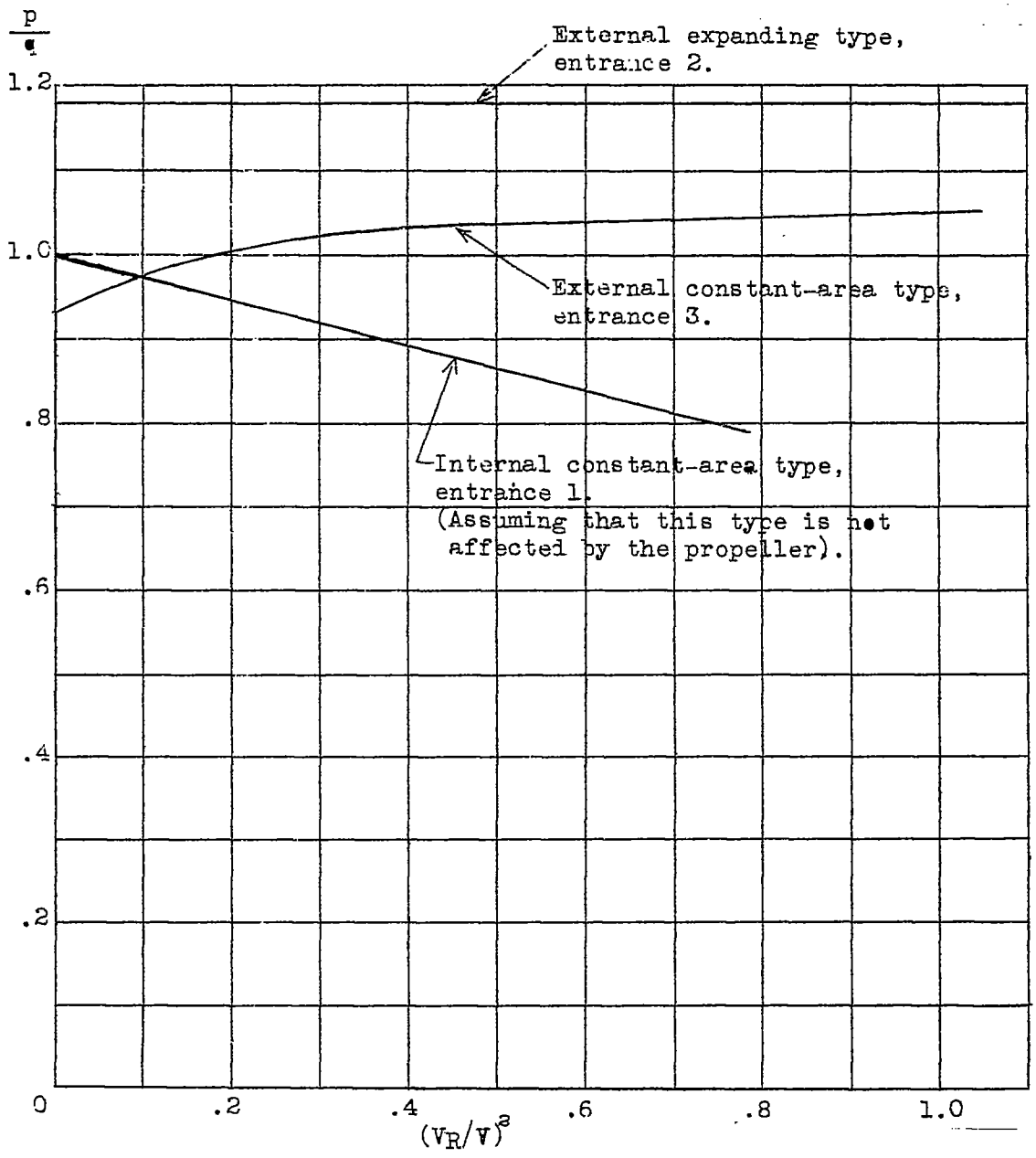

Figure 11.-Comparison of three types of carburetor-intake rams. Best entrance locations; 3-blade propeller 5868-9 set 15° at 0.75R; V/nD = 0.716 (average).