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FLIGHT INVESTIGATION OF WING-GUN FAIRINGS ON A FIGHTER TYPE AIRPLANE

By J. M. Nissen and M. D. White

Langley Memorial Aeronautical Laboratory
Langley Field, Va.

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FLIGHT INVESTIGATION OF WING-GUN FAIRINGS

ON A FIGHTER TYPE AIRPLANE

By J. M. Nissen and M. D. White

SUMMARY

Flight tests were conducted on a Navy fighter airplane to determine methods for fairing the wing-gun installation so as to retain the maximum lift of the clean wing insofar as possible.

The unfaired-gun installation increased the stalling speed over that of the clean wing by approximately 5 knots with flaps down, power off and by approximately 3 knots with flaps down, power on.

Two arrangements of fairings were developed that restored the lift of the wing. One arrangement consisted of engine cowl-type fairings for both projecting and submerged guns. This arrangement provided an annular opening between the gun barrel and the fairing lip for cooling the guns. The flush arrangement consisted of the engine cowl-type fairings for the projecting guns and faired wing openings for the submerged guns. Successful operation of this latter type of fairing, however, required that no air be admitted around the submerged guns. All arrangements of fairings as well as the unfaired guns improved the stalling characteristics of the airplane as compared with the clean-wing condition. It also appeared that the gun-fairing arrangements eliminated the ground-looping tendencies of the airplane that were attributed to wing stalling. This was evidenced by a series of landings made with the wing guns faired and the small tail wheel installed in which no ground-looping tendencies were noted.

On the basis of data from the full-scale wind tunnel, it appears that no reduction in top speed need be anticipated with the four projecting fairings ventilated for cooling as compared with the unfaired gun condition. With the combination of projecting fairings and faired wing openings with no air admitted, the top speed may actually be increased 3 miles per hour as compared with the unfaired gun condition.

INTRODUCTION

At the request of the Bureau of Aeronautics, flight tests have been conducted on a fighter type airplane by the NACA at Langley Field. The purpose of these tests was to determine the modifications required to correct certain undesirable characteristics of the airplane. The investigation started on April 15, 1941 was suspended only for an interval from May 28 to June 16, during which check tests and necessary structural changes were made on the airplane by the Navy at Anacostia and Norfolk.

The present report covers the flight tests of gun fairings designed to correct the detrimental effects of the projecting and submerged wing guns on the airplane. These effects, a 5-knot increase in stalling speed as compared with the clean-wing condition, and a more pronounced tendency of the airplane to ground-loop in landings, were believed to be due to early and unsymmetrical wing stalling produced by the wing-contour irregularities of the gun installation. The belief that wing stalling influenced the ground-looping tendencies is based on flight tests of other airplanes that showed that violent ground-looping tendencies were caused by unsymmetrical wing stalling in a three-point attitude.

THE AIRPLANE AND INSTRUMENT INSTALLATION

The airplane on which the investigation was carried out is a Grumman F4F-3 single-place midwing monoplane fighter (fig. 1). Airplane No. 2538, which was delivered to the NACA for the test, was a standard service model except for the following modifications. The tail wheel of the test airplane was equipped with a pneumatic tire that raised the tail approximately 6 inches as compared with the hard-rubber tail wheel used on service models. By this substitution the airplane ground angle was reduced about 2°. This modification, which apparently is not suited to deck operation, was adopted during early tests to prevent ground-looping until specific investigation of that problem was undertaken. Wheel brakes of greater capacity than those in service models were also substituted on the test airplane to provide additional ground control.

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During the tests the airplane center-of-gravity position was maintained at approximately 28.5 percent M.A.C., the location at which it was generally flown in service. The starting weight for each flight varied from 6425 to 6735 pounds, the greatest part of the variation (275 pounds) being due to the removal or replacement of the four guns. This weight variation corresponds to a difference in stalling speed of approximately 1.5 knots; for simplicity in analysis all the stalling speeds reported have been corrected to a gross weight of 6725 pounds.

The instruments used in all the tests were a recording air-speed meter installed on the airplane air-speed line and a three-element control-position recorder recording the movements of the elevator, rudder, and ailerons. Tufts were installed on the upper surfaces of the wings and in some cases in the immediate vicinity of the gun fairings to aid in the study of the behavior of the airplane at the stall.

The locations of the two 0.50-caliber machine guns in each wing are illustrated in figure 2. Figures 3 through 7 are photographs of the various types of gun fairings tested. In figure 3(a) are shown the submerged gun in its unfaired condition and the projecting gun fitted with the fairing submitted by the Grumman Company. The Grumman fairing resembles an engine cowl in appearance except that the space between the gun barrel and the fairing was sealed with rubber grommet. Figure 3(b) shows the projecting gun in its unfaired condition with the submerged gun removed. The Grumman fairing which was the only fairing used on the projecting guns was at first tested as submitted. In later tests the grommet was removed and the edge of the opening was bent in so as to provide an annular space about 1/8 inch in width around the gun barrel for the entry of cooling air.

Several fairings for the submerged gun, designated for brevity No. 1, No. 2, No. 3, and "faired opening," are illustrated, respectively, in figures 4, 5, 6, and 7. Fairing No. 1 is a modified version of the Grumman fairing, being somewhat more oval in cross section as compared with the flat sides of the latter. Fairings Nos. 2 and 3, which are shorter versions of the No. 1 fairing, differ from each other only in width, No. 3 being the narrower. The faired opening shown in figure 7 is faired into a tube that encircles the gun barrel for a distance back from the gun muzzle of about 6 inches, and an annular space about 1/8

inch wide is provided between this tube and the gun barrel to permit the passage of cooling air. Similar annular spaces are provided between blast tube and fairing for the other fairings.

TESTS, RESULTS, AND DISCUSSION

Stall Characteristics

The results of the stall tests with various arrangements of gun fairings are presented in table I for the two flight conditions investigated. These flight conditions were the landing condition, power off, flaps down, and gear down, and the carrier-approach condition 23.5 inches of mercury manifold pressure and 2350 rpm, flaps down and gear down. In these flight conditions continuous records were obtained of stalls approached gradually in a laterally level attitude, the pilot noting the violence of the stall, the response of the airplane to the ailerons and to power application in the stall, and the tuft behavior in the stall approach.

The results tabulated in table I may be briefly summarized as follows:

1. In the power-off, flap-down flight condition each set of unfaired guns, projecting or submerged, alone effected a 3-knot increase in stalling speed over the clean-wing condition while in combination the increase was 5 knots. With power on, flaps down all arrangements of unfaired guns increased the stalling speeds by about 3 knots (tests 1, 2, 3, and 5).

2. A fairing arrangement consisting of the Grumman fairing on the projecting gun and the No. 1 fairing on the submerged gun (fig. 4 and test No. 7) effected an improvement over the unfaired-gun condition in the following respects:

   (a) The stalling speed in the carrier-approach condition was reduced by 1 or 2 knots as compared with the unfaired-gun condition and the landing-condition stalling speed was reduced to the clean-wing values.

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(b) The stalling characteristics were improved over the clean-wing condition as indicated by the milder roll at the stall and the increased responsiveness of the airplane to aileron movement or power application at the stall. Conclusions regarding the controllability in the stall as listed in table I are based on tests in which, immediately after the stall, ailerons were applied against the roll or power was applied and the stick moved forward only enough to prevent a sharp rise of the nose.

3. Another gun-fairing arrangement consisting of the Grumman fairing on the projecting gun and the faired wing opening for the submerged gun (fig. 7 and tests Nos. 14 and 15) gave results similar to those listed under paragraph (2), under restricted conditions; that is, the effective functioning of this arrangement required that no air flow be permitted through the fairings. (Compare tests Nos. 11 and 14.) If it is necessary that air be admitted to cool the guns during firing, then in order to utilize this arrangement in service, provision would have to be made for opening and closing an air seal around the gun in flight.

4. None of the other arrangements listed in table I was considered satisfactory. It is of interest to note, however, that at least one of the other fairings for the submerged guns was effective when tested alone with the projecting gun removed, but was entirely ineffective in combination with a fairing on the projecting gun (tests Nos. 8 and 9). Apparently detrimental interference effects result from the close proximity of the two guns to each other, especially with power on.

In addition to the results tabulated in table I, information was obtained from tuft studies that is considered of interest. The tuft observations indicated that even in the clean-wing condition the initial breakdown of flow occurs in the vicinity of the gun locations. This fact explains to some extent why the gun-fairing design was critical. The tufts showed too that, in general, the character of the stall corresponded with the rate and extent of spanwise progress of the flow breakdown. A sharp break and fast roll in the stall, for example, occurred

when the flow breakdown spread rapidly to the wing tip as in the clean-wing condition; on the other hand, a mild roll resulted when the flow progressed only to a station somewhat inboard of the ailerons as in the unfaired-gun conditions and as with the recommended fairings.

From the above, it is evident that the troubles experienced following the installation of unfaired guns on the clean wing were due not to their harmful effects on stalling characteristics but only to the increased stalling speeds that they produced. The mild rolls that followed the early advent of the stall would cause disturbing moments on the ground which, combined with the inherently unstable landing-gear arrangement, resulted in violent ground loops.

Tests with tufts in the immediate vicinity of the fairings showed mainly that it was the fairing for the submerged gun that suffered from interference, while the flow about the other fairing appeared to be maintained satisfactorily. Check tests made with and without the tufts near the fairings indicated the effects of the tufts to be negligible.

Following firing tests conducted on the recommended fairing arrangements by a squadron at Norfolk, it was reported that a 1/8-inch-wide annular space between gun or blast tube and fairing gave adequate gun cooling. No firing tests were conducted with openings sealed.

Drag Estimate

On the basis of full-scale wind-tunnel tests conducted on another airplane, it is estimated that there will be no reduction in top speed due to the projecting fairing as compared with the unfaired guns. The use of the faired-wing opening with the flow sealed off would actually increase the top speed by about 3 miles per hour as compared with the unfaired guns.

Ground-Looping Tests

Previous tests on other airplanes have shown that frequently objectionable ground-looping tendencies are associated with an unsymmetrical, early stalling of the wing in the ground run. As was stated earlier, it was

with the idea of reducing the ground angle of the airplane below the decreased stalling angle of the unfaired-gun arrangement that a pneumatic tail wheel was installed on the airplane.

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This tail wheel reduced the ground angle by about 2°. It is calculated that in the power-off condition the lift recovered by the recommended gun fairings corresponds to an increase in stalling angle as compared with the unfaired-gun condition of 3°. With the gun fairings on, therefore, the ground angle could be increased by as much as 3° without exceeding the stalling angle; hence, the pneumatic tail wheel no longer seemed necessary.

To verify this conclusion, a series of landings was made with the original hard-rubber tail wheel installed and the guns faired with the Grumman and the No. 1 fairing. No ground-looping tendency was noted in any of the landings. From these landings it is evident that the aerodynamic sources of ground-looping tendencies were eliminated by the gun fairings. It should be noted, however, that this modification in no way affected the natural tendencies of the airplane to ground-loop; in fact, the landing-gear arrangement of this airplane appears less satisfactory from this standpoint than do many others.

GENERAL REMARKS

The problems associated with the installation of wing guns in the subject airplane appear to be of a rather general nature. For example, the difficulties that necessitated the present investigation were due largely to the introduction of discontinuities in what is known to be the most critical portion of the wing chord, that is, the upper surface of the wing in the immediate vicinity of the leading edge.

Corrective measures that might logically be employed in future designs would be: (1) to lower the gun within the wing possibly by turning the gun on its side so that it would project below the stagnation point, or (2) to provide a faired opening with an air seal that can be opened and closed in flight if it is considered necessary to admit cooling air to the guns. From the standpoint of simplicity of design and installation, the former alterna-

tive recommends itself. For ready adaptation, however, the installation should be incorporated in the original design since structural limitations will generally prevent relocation of the guns once the airplane has been constructed, as in the present instance.

The second alternative has the disadvantage that it might require the added complication of a movable air seal. This disadvantage would be compensated for, to a considerable extent, however, by the reduced drag of this installation as compared with the first and by the protection from adverse weather conditions that it affords the gun.

Regardless of the fairing installation employed, provision must be made for bore-sighting the guns. This could be accomplished most readily by first bore-sighting the guns and then installing the fairings so that the guns are centered in the openings. Another problem that merits attention in connection with wing-gun installations is that of minimizing the size of leading-edge opening required to cover different settings of the gun. In this connection, consideration might logically be given the possibility of changing the angle of the gun about the muzzle instead of about the front support. Whatever the means employed, however, it appears desirable that some steps be taken in this direction.

CONCLUSIONS

As a result of the flight investigation of wing-gun fairings on a fighter type airplane, the following conclusions may be stated:

1. The installation of unfaired guns on the otherwise clean wing resulted in a premature stall that increased the stalling speed in the carrier-approach and landing conditions of flight.

2. By suitably fairing the guns it was possible to reduce the stalling speeds to very nearly the values corresponding to the clean wing and at the same time eliminate the objectionable stalling characteristics associated with the clean-wing condition.

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3. For immediate adoption on airplanes now in service, a gun-fairing arrangement consisting of the Grumman fairing on the projecting gun and a modification of this fairing for the submerged gun recommends itself largely because of its simplicity.

4. An alternative and equally effective arrangement consisting of the Grumman fairing for the projecting gun and a faired wing opening for the submerged gun depended for its effectiveness on the sealing off of cooling air around the gun, so that in service means might have to be provided for opening and closing an air seal in flight.

5. In a series of landings made with the original hard-rubber tail wheel installed and the guns faired, no ground-looping tendency was noted. The landing-gear arrangement on this airplane, however, appears less satisfactory from a ground-looping standpoint than do many others.

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

Test	Condition: Guns Projecting	Condition: Guns Submerged	Condition: Fin / Rudder Travel		Landing Condition - Flaps + Gear Down, Power Off: V_{stall}, Knots (IND.) 1.	Direction of Roll at Stall	Aileron Against Roll	Power Application Fly-out at Stall		Carrier Approach Condition - Flaps + Gear Down, 23" Hg. Man. Press., 2400 RPM: V_{stall} (IND.) (Knots)	Direction of Roll at Stall	Aileron Against Roll	Power Application Fly-out at Stall	
1	Removed	Removed	Original / Original		62.5	Right Sharp Break	N.G.	N.G.		52-53.5	Left Sharp Break	N.G.	N.G.	
2	Unfaired	Unfaired	Original / Original		66.5-68.5	Right Mild	O.K.	O.K. + N.G.		55-57.5	Left Mild	N.G.	O.K. -30" N.G. -35"	
3	Grumman Fairing Closed	Unfaired	Original / Original	Fig 2a	64.5-66.5	Right Mild	O.K.	N.G.		55-57.5	Left Mild	O.K.	O.K. 35" + 38"	
4	Grumman Fairing Closed	Removed	Original / Original		60.5-61.5	Left Sharp Break	N.G.	N.G.		50.5-53.5	Left Sharp Break	N.G.	N.G.	
5	Unfaired	Removed	Original / Original	Fig. 2b.	65.5	Right Mild	O.K.	N.G.		56.5-57.5	Left Mild	O.K.	—	
6	Removed	Removed	Offset / Increased		63	Right Sharp Break	N.G.	N.G.		51.5-53.5	Left Sharp Break	N.G.	N.G.	
7.	Grumman Fairing Vented For Cooling	Fairing No.1 / Vented For Cooling	Offset / Increased	Fig. 3	62-63	Left Mild	O.K	O.K		55.5-56	Left Mild	O.K.	O.K.	
8	Grumman Fairing Vented For Cooling	Fairing No.2 (Wide) Vented For Cooling	Offset / Increased	Fig. 4	63.5-64.5	Left Mild	O.K.	O.K		55-58	Left Mild	N.G		
9	Removed	Fairing No.2 (Wide) Vented For Cooling	Offset / Increased		63.5-64	Right Mild	O.K at start of roll	O.K		51-53	Left Mild	N.G.	N.G.	

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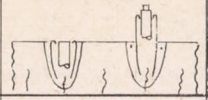
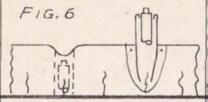
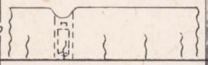
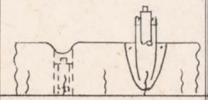
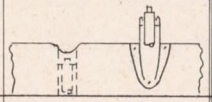
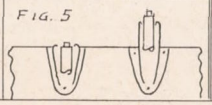
Table 1

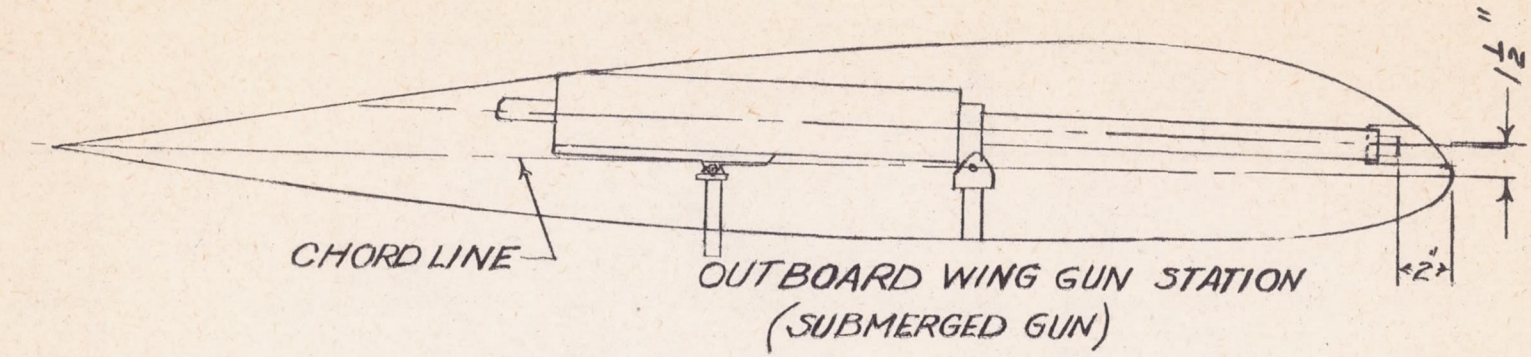
Test	Condition: Guns Projecting	Guns Submerged	Fin Rudder Travel		Landing Condition – Flaps + Gear Down, Power Off: V_{stall}, Knots (IND.) 1.	Direction of Roll at Stall	Aileron Against Roll	Power Application Fly-out at Stall		Carrier Approach Condition – Flaps + Gear Down, 23" Hg. Man. Press., 2400 RPM: V_{stall} (IND.) (Knots)	Direction of Roll at Stall	Aileron Against Roll	Power Application Fly-out at Stall	
10	Grumman Fairing Vented For Cooling [Tufted 2]	Fairing No. 3 (Narrow) Vented For Cooling	Offset — Increased		64.5-65	Right	O.K	O.K		57-57.5	Left Mild	N.G.	O.K -32" N.G-More Than 32"	
11	Grumman Fairing Vented For Cooling [Tufted 2]	Faired Opening Open	Offset — Increased	Fig. 6 	66-67	Variable	O.K	O.K		57.5	Left Mild	O.K	O.K	
12	Removed [Tufted 2]	Faired Opening Open	Offset — Increased		67	Variable	O.K	O.K		58-59	Left Mild	O.K	O.K	
13	Removed [Tufted 2]	Faired Opening Sealed	Offset — Increased		64-65.5	Right Mild	Fair	O.K		53.5-54.5	Left	N.G	N.G.	
14	Grumman Fairing Sealed [Tufted 2]	Faired Opening Sealed	Offset — Increased		62.5-63.5	Left Mild	O.K	O.K.		53.5-55.5	Left Mild	Uncertain	O.K	
15	Grumman Fairing Sealed	Faired Opening Sealed	Original — Increased		61.5-62.5	Left Mild	O.K	O.K		54.5-55	Left Mild	Uncertain	O.K	
16	Grumman Fairing Vented For Cooling	Fairing No. 3 (Narrow) Vented For Cooling	Offset — Increased	Fig. 5 	65.5	Right Mild	O.K	O.K		57-57.5	Left Mild	O.K. at Start N.G later	O.K	

1. Stalling speeds recorded from airplane airspeed head and corrected to gross weight of 6725 pounds.
2. Tests marked "Tufted" indicate tufts installed in immediate vicinity of fairings.

Table I. Results of stall tests with various gun fairings on Grumman F4F-3 airplane.

Table 1 concluded

Figure 1.- Three-fourths front view of Grumman F4F-3 airplane with pneumatic tail wheel installed. No guns installed.



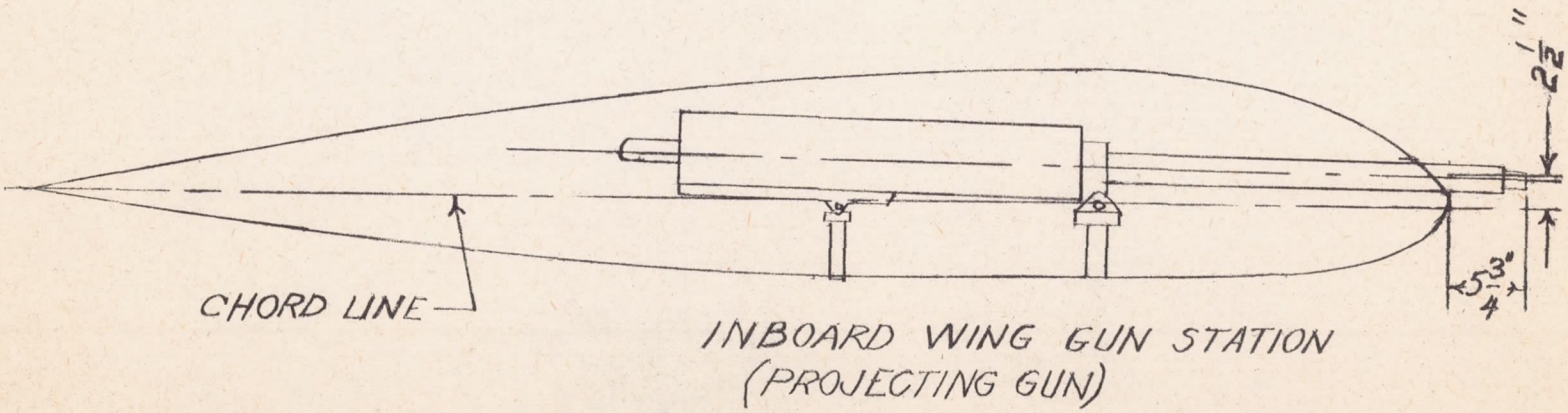


Figure 2.- Present locations of .50-caliber machine guns in wing of F4F-3 airplane.

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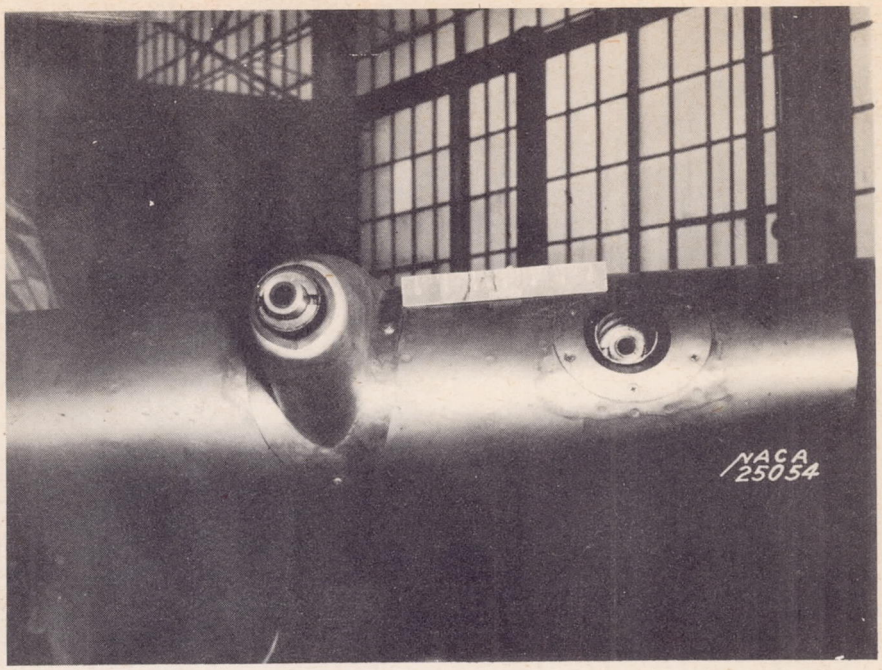

Figure 3a.- View of submerged gun in unfaired condition and projecting gun with Grumman fairing. Rubber grommets installed around edges of fairing and wing opening.

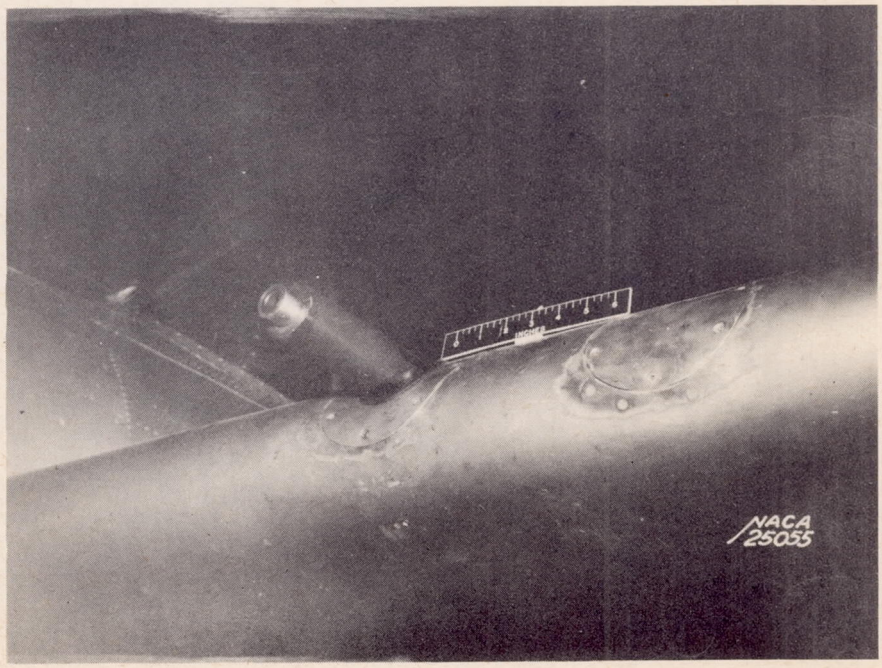

Figure 3b.- View of projecting gun in unfaired condition with submerged gun removed.

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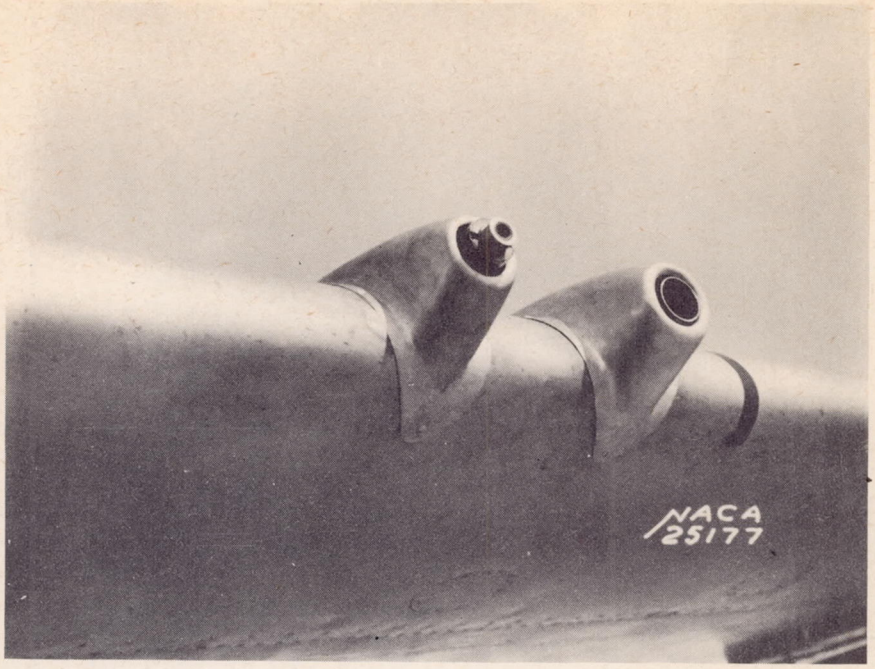

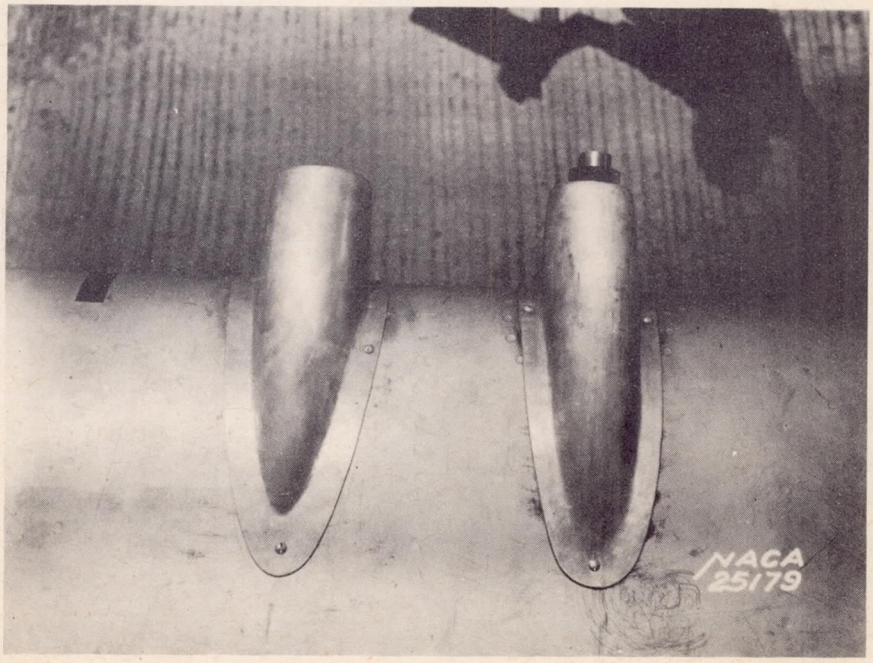

Figure 4.- Views of No. 1 fairing on submerged gun and Grumman fairing on projecting gun. Both fairings provide annular space about 1/8" wide around gun barrel or blast tube for cooling air.

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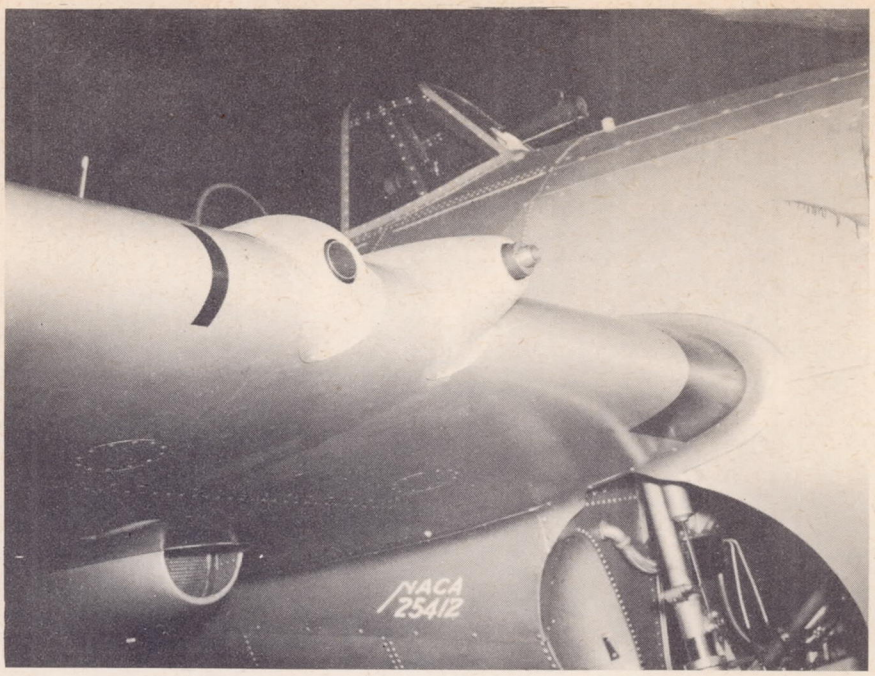

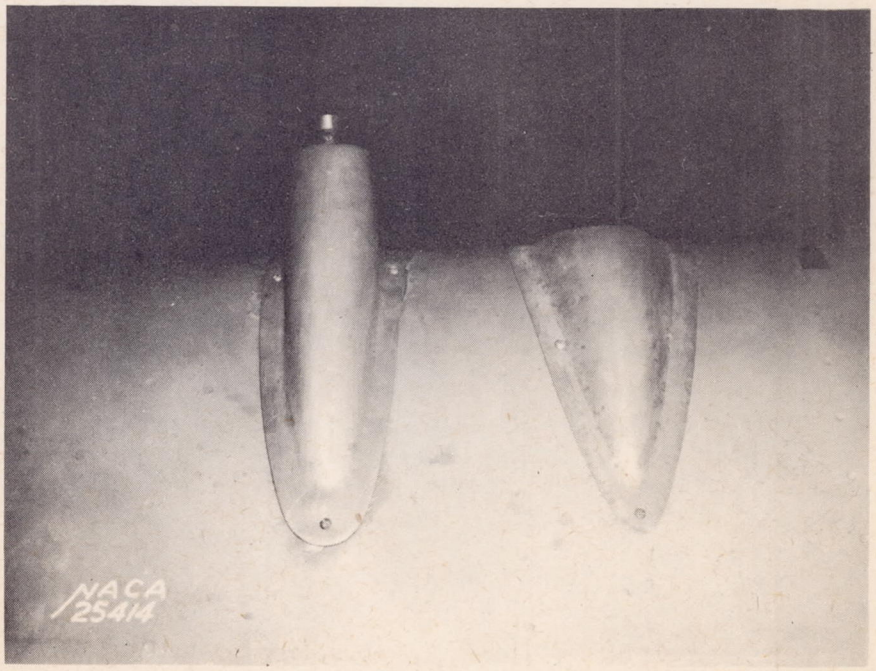

Figure 5.- Views of No. 2 (wide) fairing on submerged gun and Grumman fairing on projecting gun. Both fairings provide annular space about 1/8" wide around gun barrel or blast tube for cooling air.

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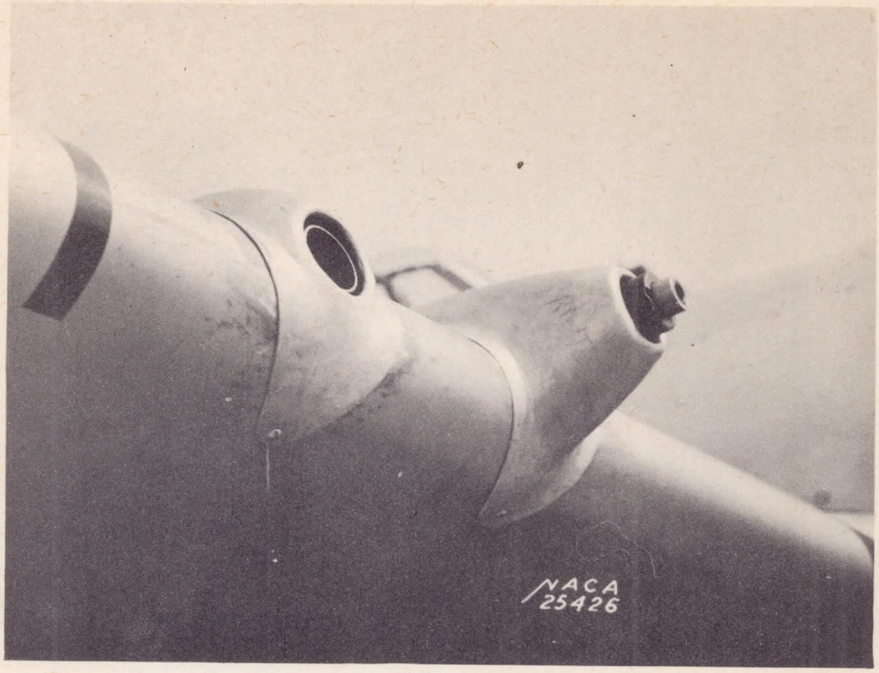


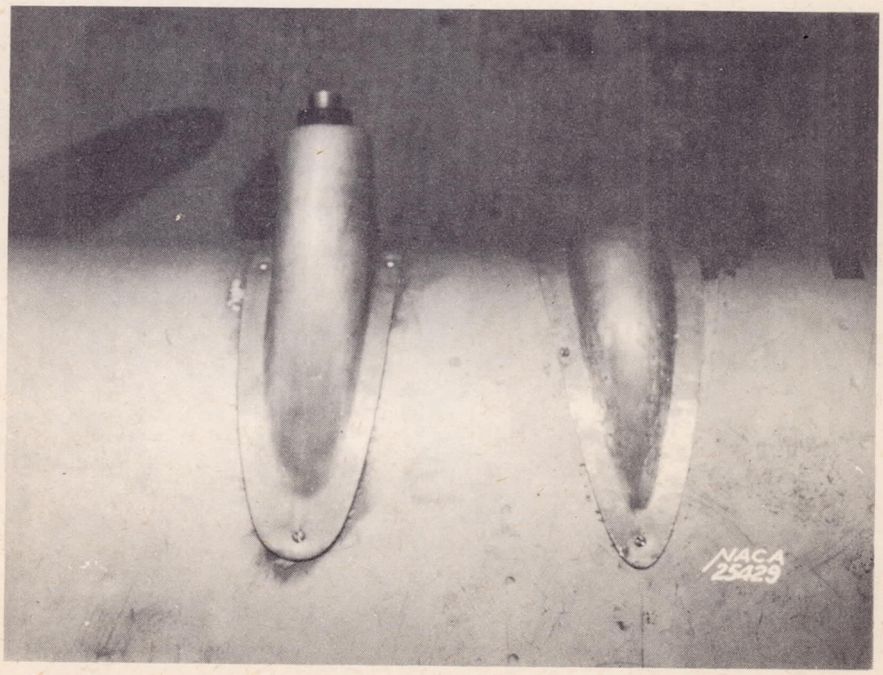
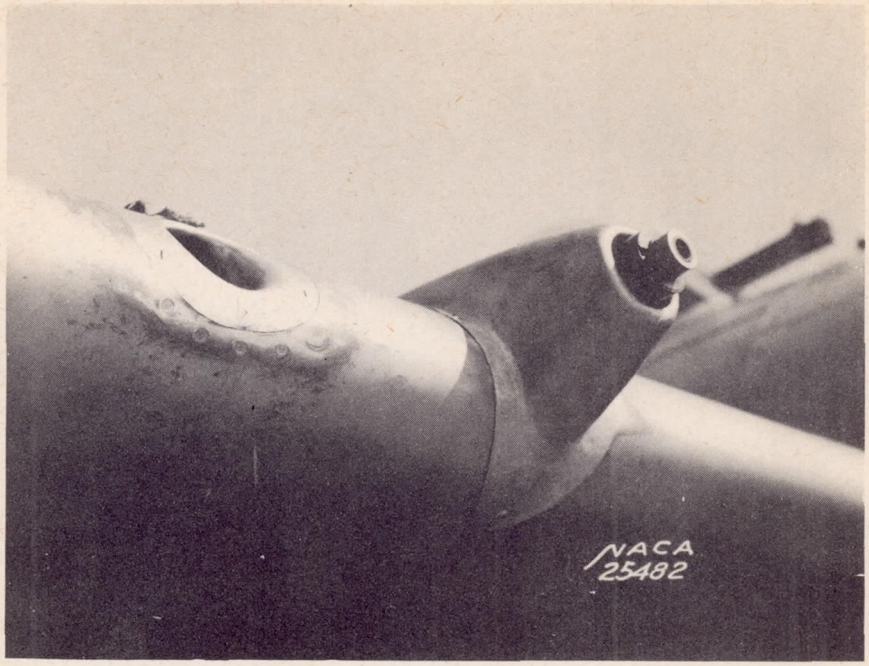


Figure 6.- Views of No. 3 (narrow) fairing on submerged gun and Grumman fairing on projecting gun. Both fairings provide annular space about 1/8" wide around gun barrel or blast tube for cooling air.



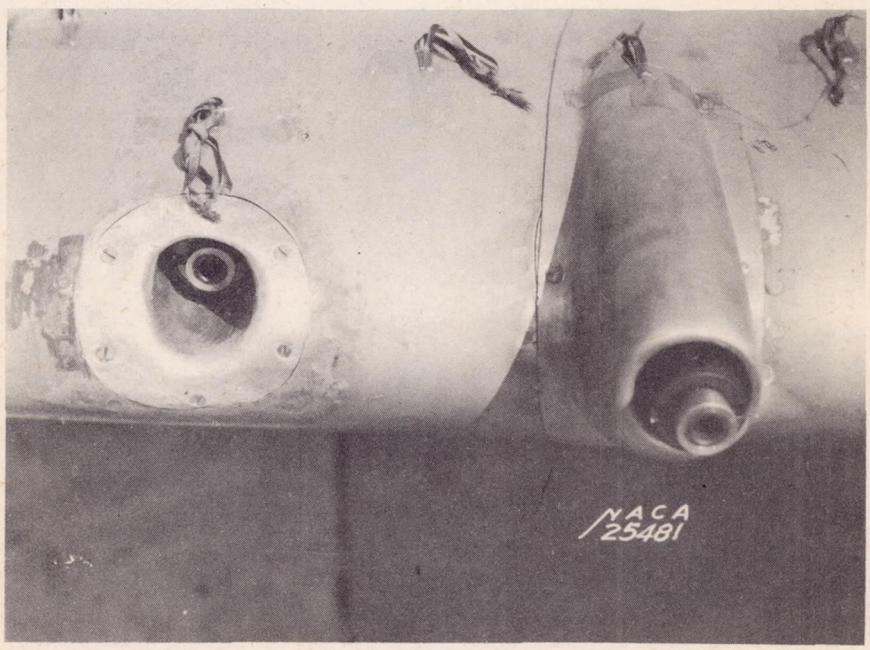


Figure 7.- Views of faired wing opening for submerged gun and Grumman fairing on projecting gun. Both fairings provide annular space about 1/8" wide around gun barrels for cooling air.