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NACA AIRCRAFT ENGINE RESEARCH LABORATORY

MEMORANDUM REPORT

for the

Air Materiel Command, Army Air Forces

THE EFFECT OF LIQUID AND ICE PARTICLES ON THE EROSION OF A SUPERCHARGER-INLET COVER AND DIFFUSER VANES

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INTRODUCTION

During the course of a laboratory investigation requested by the Air Materiel Command, Army Air Forces, of ice formation and elimination in a carburetor and supercharger assembly, it was found by inspection that serious erosion of the surface of the cast magnesium-alloy supercharger cover plate and diffuser vanes had apparently been caused by the constant injection of fuel, the introduction of water to simulate operation in rain, and the passing of ice particles through the supercharger during induction system de-icing.

The increasing use of water injection to boost the power output of aircraft engines made it advisable to conduct additional accelerated erosion tests to determine the separate effects of the passage of fuel, water, and ice particles through the supercharger. The erosion of the supercharger-inlet cover and diffuser vanes, which was observed in the icing tests of reference 1, and the results of the tests reported herein to determine the effect of liquids and ice particles on supercharger erosion are discussed and several suggestions for minimizing erosion are presented.

APPARATUS AND TESTS

All tests were conducted on the laboratory setup fully described in reference 2. The icing tests that caused the initial erosion were conducted at the following conditions: air-flow rates simulating normal rated power, maximum cruise power, and 60-percent normal rated power; charge-air temperatures ranging from 35° to 100° F; moisture content of the air ranging from 10 percent relative humidity without water to 100 percent relative humidity with simulated-rain injection at rates up to 1000 grams per minute. During these tests ice formations in the carburetor or supercharger-inlet elbow had generally been cleared by raising the carburetor-air temperature and allowing the ice to pass through the supercharger.

Two accelerated erosion tests, each of $8\frac{1}{4}$-hour duration, were made at conditions simulating take-off power. In the first test, the injected water-fuel ratio was 0.6 at a fuel-air ratio of 0.08 and, in the second test, the same amount of water was injected without fuel. Liquid and carburetor-air temperatures for these tests were maintained at approximately 75° F, which is above the limit of induction-system icing; erosion therefore can be attributed solely to the action of the liquids.

A third $8\frac{1}{4}$-hour test to determine the effect of ice particles on erosion of the supercharger-inlet cover was made at the same rates of water and fuel injection as the two previous tests with a carburetor-air temperature of 0° F and a liquid temperature of 75° F. The saturated carburetor air at 0° F fell within the icing region for this induction system and the tests consisted of alternately icing and de-icing the system.

Replacement supercharger-inlet-cover assemblies were used in the first two accelerated erosion tests and a reconditioned assembly was used for the third test. The supercharger-inlet cover and diffuser vanes are cast in one piece of magnesium alloy and appear to be protected from corrosion by the conventional potassium-dichromate dip treatment. This type of surface protection is not abrasion nor erosion resistant and, when worn off, exposes the metal to corrosion. The inner surfaces of the supercharger are normally coated with an oily residue which provides insufficient erosion resistance.

RESULTS AND DISCUSSION

During an overhaul of the setup used for the icing investigations described in references 1 and 3, the inner surface of the supercharger-inlet cover in close proximity to the impeller was observed to be badly eroded. Erosion reached a depth of approximately 0.030 inch and was much worse on the left side than on the right side of the inlet cover, as seen in figure 1(a). The deeper annular depression noted by the arrow was located just opposite the point where the steel inducer joins the aluminum impeller. The erosion was more uniform on the portion of the cover shown at the left of the photograph; ice that formed in the bottom of the elbow would first strike this area when loosened during the de-icing process because the supercharger impeller rotated in a clockwise direction as viewed from the front of the engine. The leading edges of two of the six diffuser vanes are shown in figure 1(b). Erosion removed about three-eighths inch of metal from the leading-edge portion of the diffuser vane near the curved surface of the cover.

Consideration of the seriousness of this problem prompted a survey of the running time and test conditions for the setup. It was found that the total running time for this setup prior to inspection had been 861 hours, which included 110 hours operation with rain ingestion simulated by spraying water into the air stream about $6\frac{1}{2}$ feet above the carburetor top deck at an average rate of 46.3 pounds per hour. During the determination of icing characteristics, $8\frac{1}{4}$ hours of the running time had been at simulated operation with water injection in the inlet elbow by means of a special nozzle large enough to accommodate the combined volume of fuel and water. These runs were made at air flows simulating take-off power with an average rate of water injection corresponding to a water-fuel ratio of 0.4. The amount of the observed erosion caused by passage of ice through the supercharger could not be determined.

In the attempt to isolate the causes of erosion, the next two tests were made at take-off power conditions for $8\frac{1}{4}$ hours during which the liquid and air temperatures were maintained at about 75° F to prevent ice formation in the system. The erosion effect of liquid injected at a rate corresponding to a fuel-air ratio of 0.08 and a water-fuel ratio of 0.6 is shown in figure 2. The erosion effect of water alone on another inlet cover injected at a rate of approximately 485 pounds per hour for $8\frac{1}{4}$ hours is shown in figure 3.

The results of the third accelerated erosion test of $8\frac{1}{4}$-hour duration (fig. 4) indicate that the passage of ice through the supercharger caused most of the damage. In this case the inlet cover had been reconditioned after the mild erosion shown in figure 3. Ice, alternately formed and shed upstream of the supercharger at low carburetor-air temperatures, is apparently responsible for most of the erosion shown in figure 1.

The results of these investigations indicate that a large part of the liquid entering the face of the impeller leaves the tip of the inducer at the junction with the impeller proper and flows along the surface of the inlet elbow, as evidenced by the fact that the erosion of the diffuser vanes by liquid is greater near this surface. (See figs. 1(b), 2(b), 3(b), and 4(b).) Another factor contributing to the erosion of the diffuser vanes is the effect of the water drops thrown off the tips of the impeller. It was also observed that, of the six diffuser vanes, erosion was greater on vanes 2 and 3, counting clockwise from the top looking from the front of the engine.

Erosion of the diffuser-vane leading edges may be prevented by use of an erosion-resistant metal. Elimination of the discontinuity where the steel inducer joins the rest of the supercharger would prevent grooving the cover at that point. A more durable corrosion-resistant surface would reduce inlet-cover erosion. Erosion caused by ice could be materially reduced by excluding water drops from the system before they reach the carburetor and by changing the method of fuel injection to prevent fuel-evaporation icing (reference 4). Erosion caused by water or water-alcohol injected with the fuel could be eliminated by injecting the water downstream of the supercharger. This factor may become increasingly important with extended use of water injection for increased power ratings of aircraft engines.

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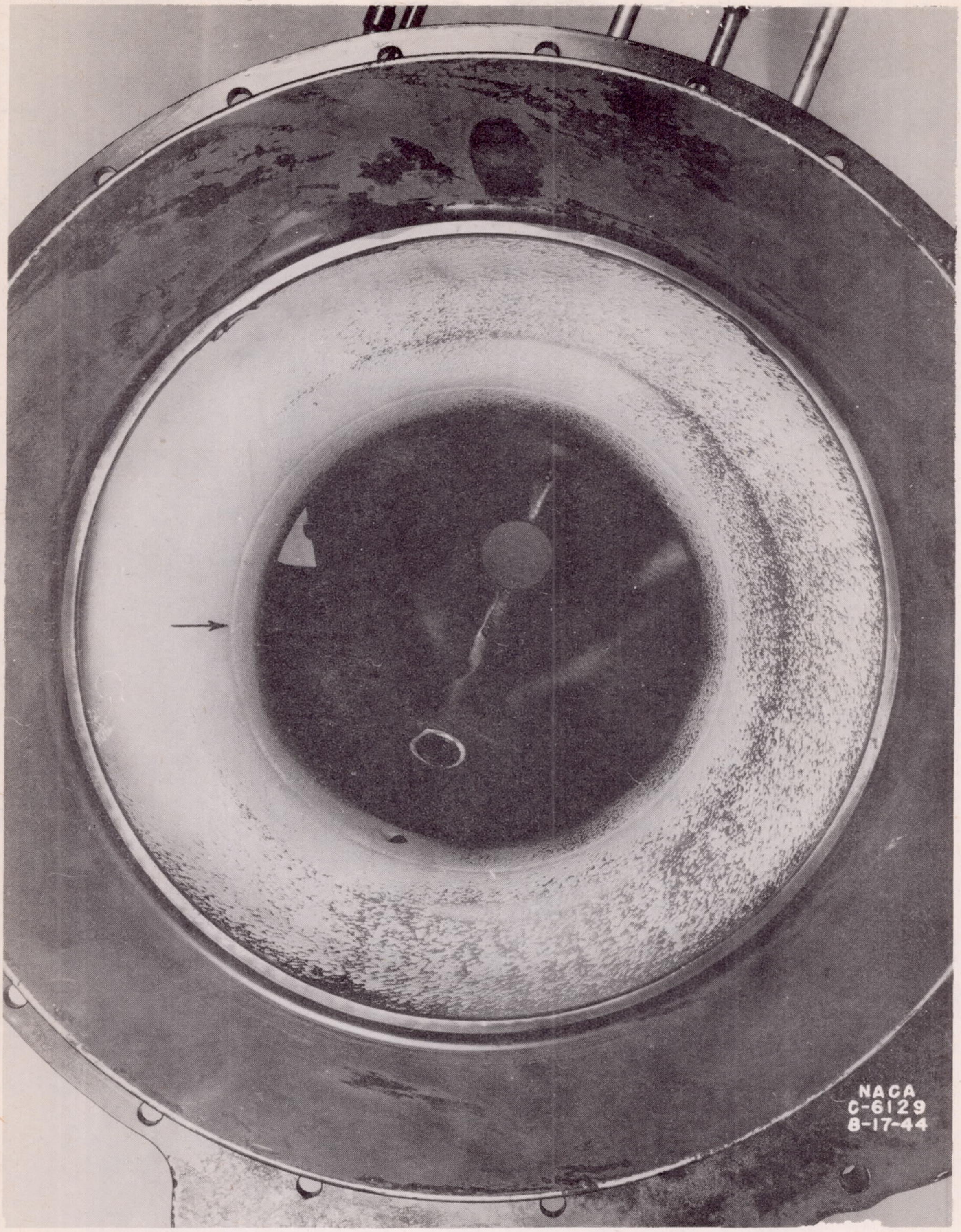

(a) Surface erosion at entrance to impeller.

Figure 1. - Effect of liquid and ice particles on erosion of supercharger-inlet cover resulting from 110 hours of operation under various icing conditions.

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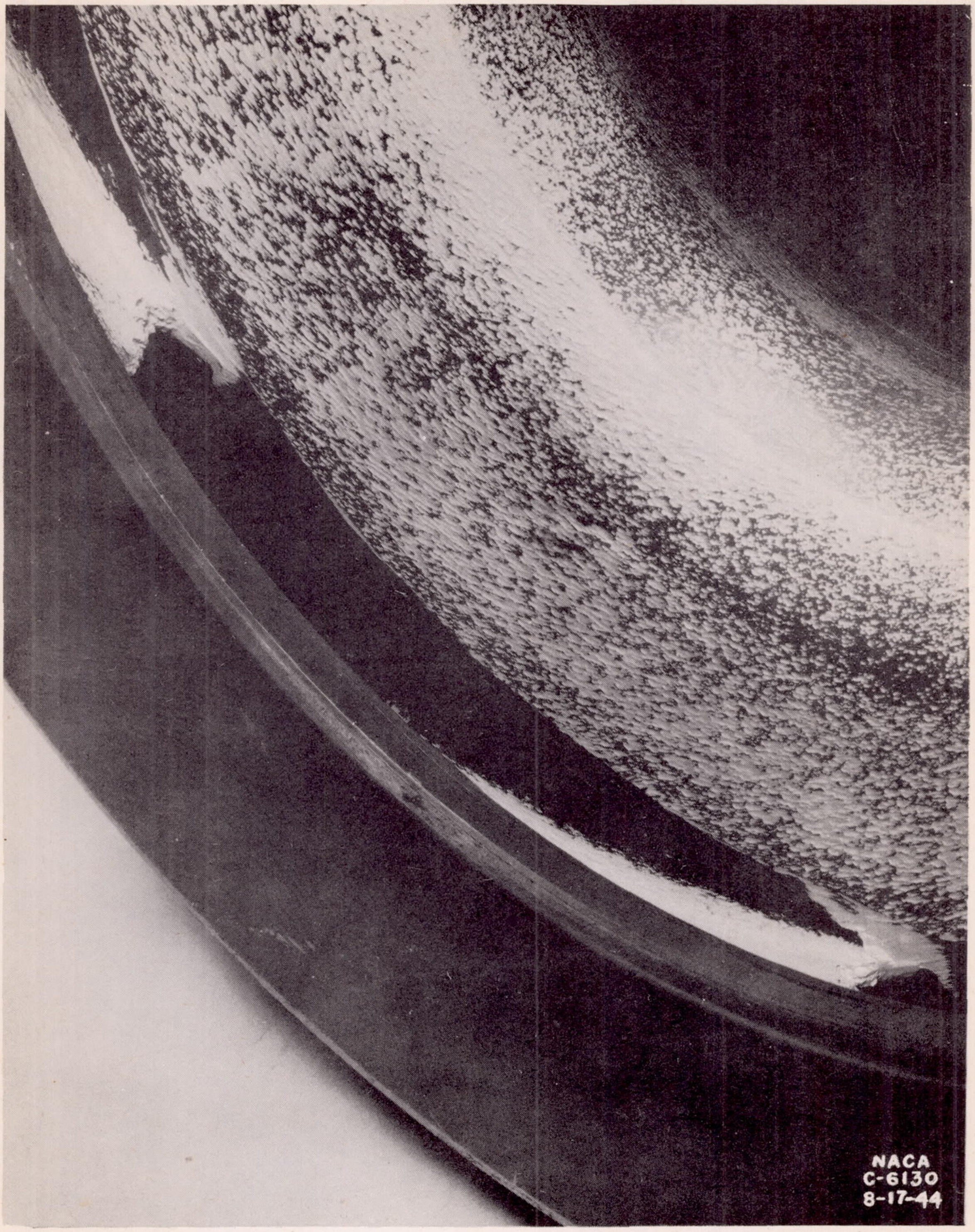
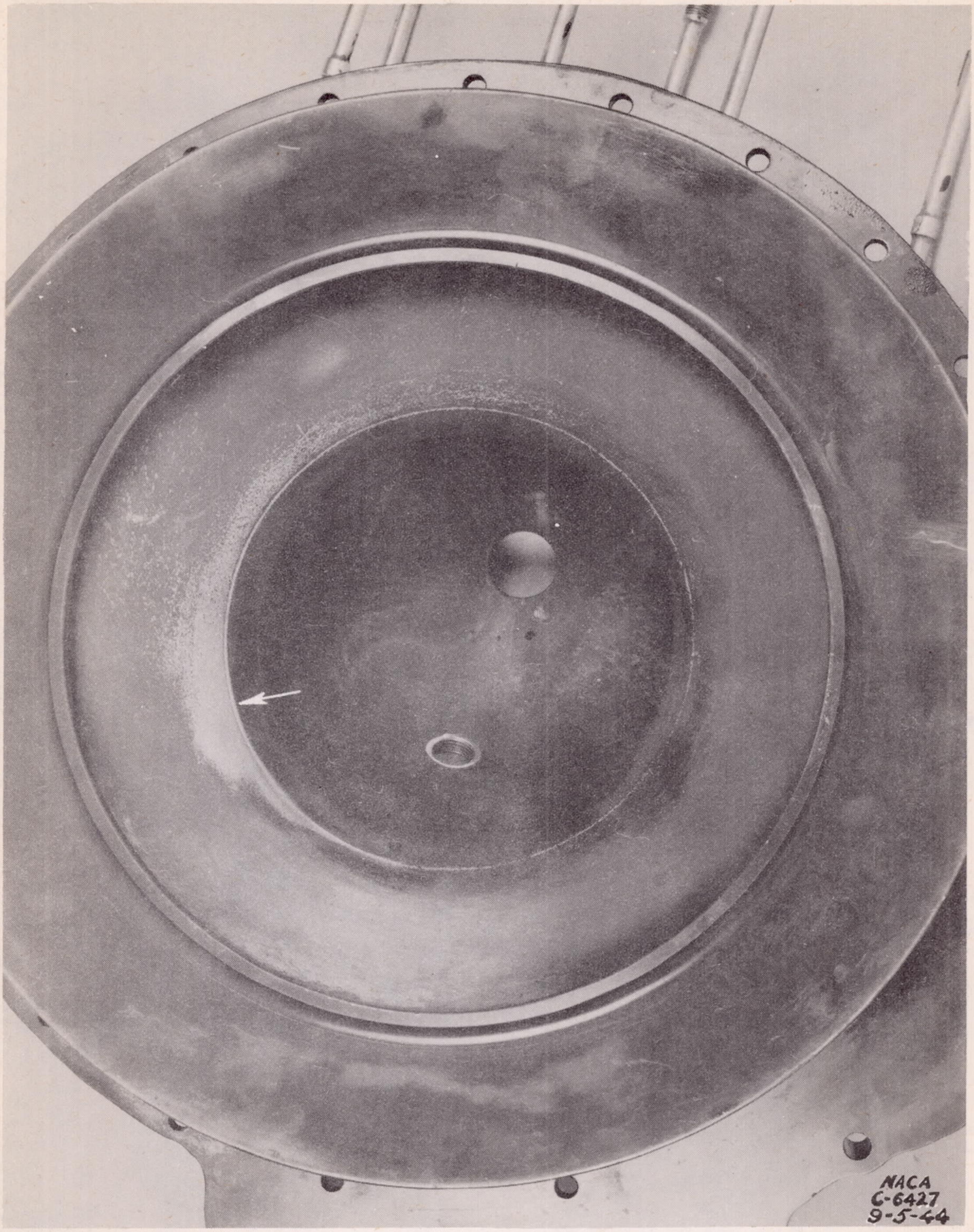


(b) Erosion of diffuser vanes 2 and 3.

Figure 1. - Concluded. Effect of liquid and ice particles on erosion of supercharger-inlet cover resulting from 110 hours of operation under various icing conditions.



(a) Surface erosion at impeller entrance.

Figure 2. - Erosion of supercharger-inlet cover caused by water and fuel injection. Rate of liquid injection, 1300 pounds per hour; duration of test, $8\frac{1}{4}$ hours.

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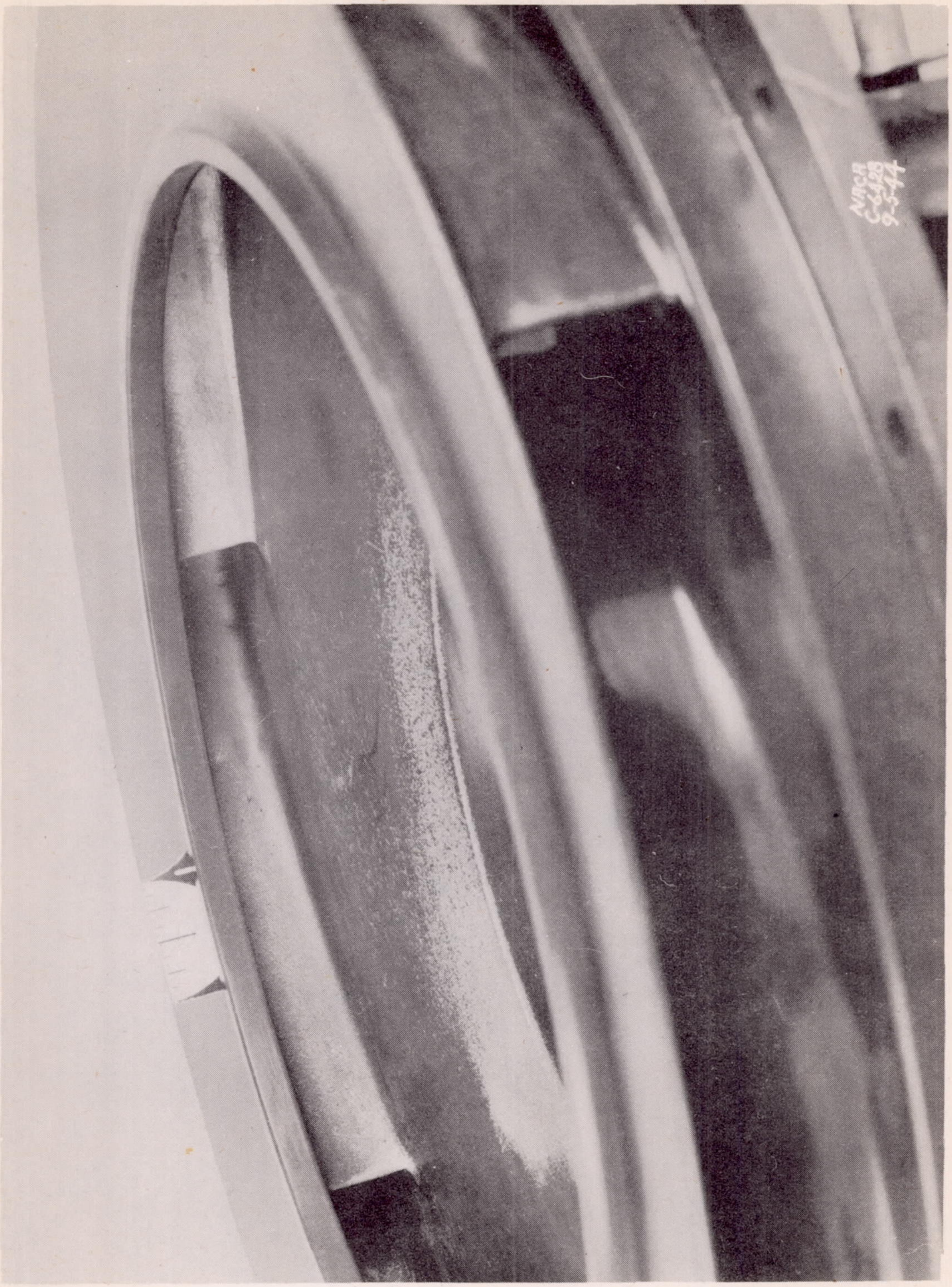

(b) **Erosion of diffuser vanes 5 and 6.**

Figure 2. - Concluded. Erosion of supercharger-inlet cover caused by water and fuel injection. Rate of liquid injection, 1300 pounds per hour; duration of test, $8\frac{1}{4}$ hours.

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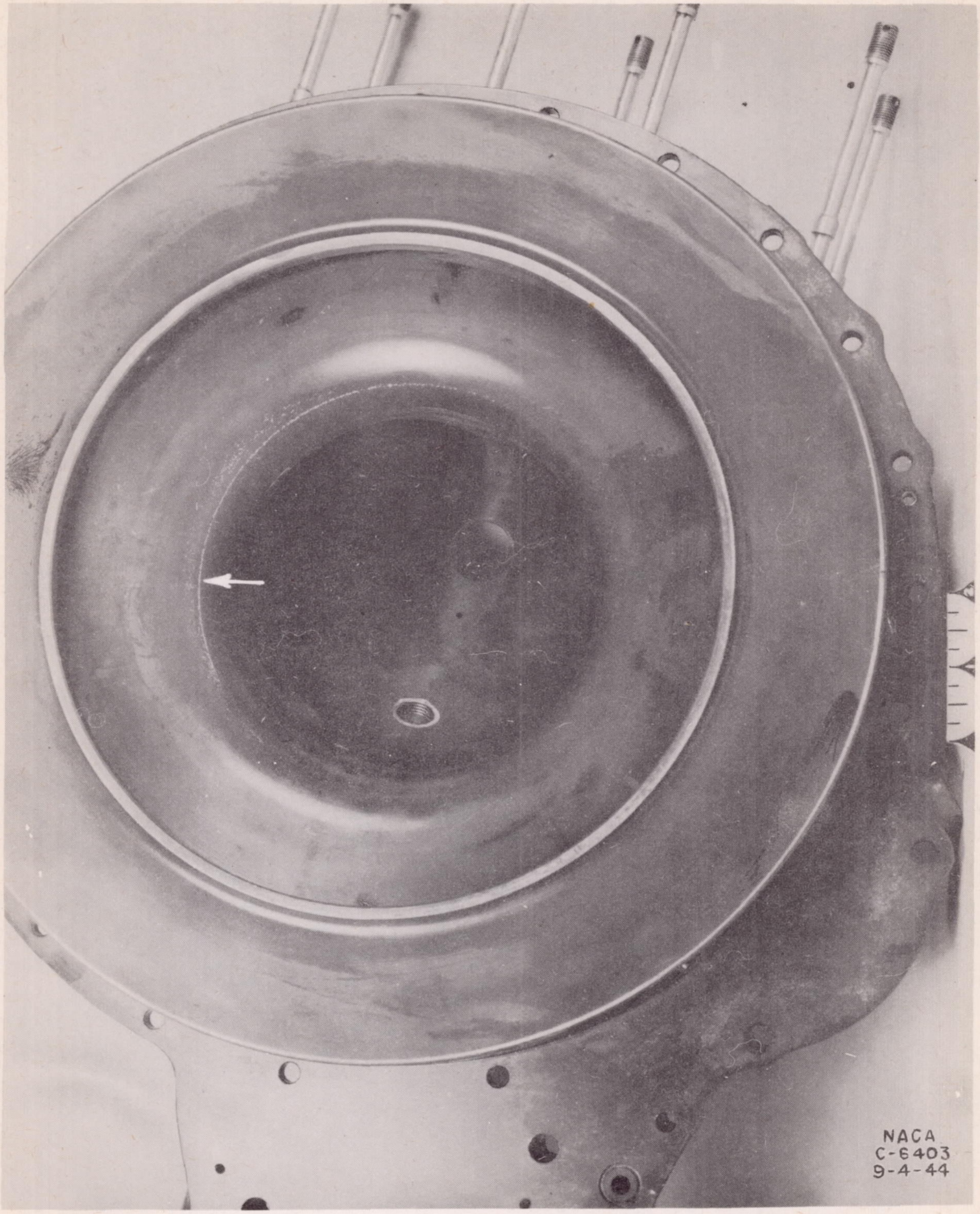

(a) Surface erosion at impeller entrance.

Figure 3. - Erosion of supercharger-inlet cover caused by water injection. Rate of water injection, 485 pounds per hour; duration of test, $8\frac{1}{4}$ hours.

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(b) Erosion of diffuser vanes 6 and 1.

Figure 3. - Concluded. Erosion of supercharger-inlet cover caused by water injection. Rate of water injection, 485 pounds per hour; duration of test, $8\frac{1}{4}$ hours.

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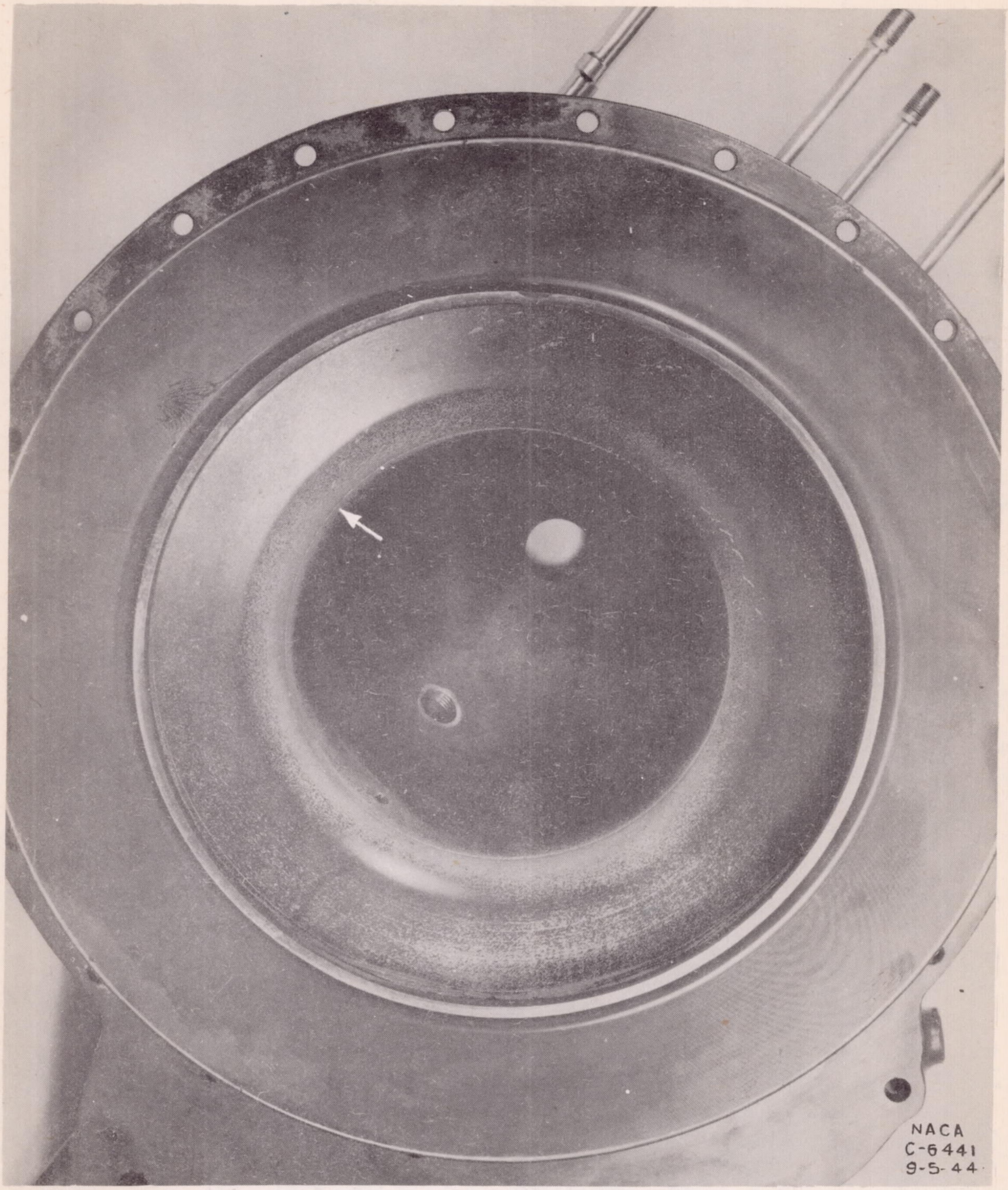
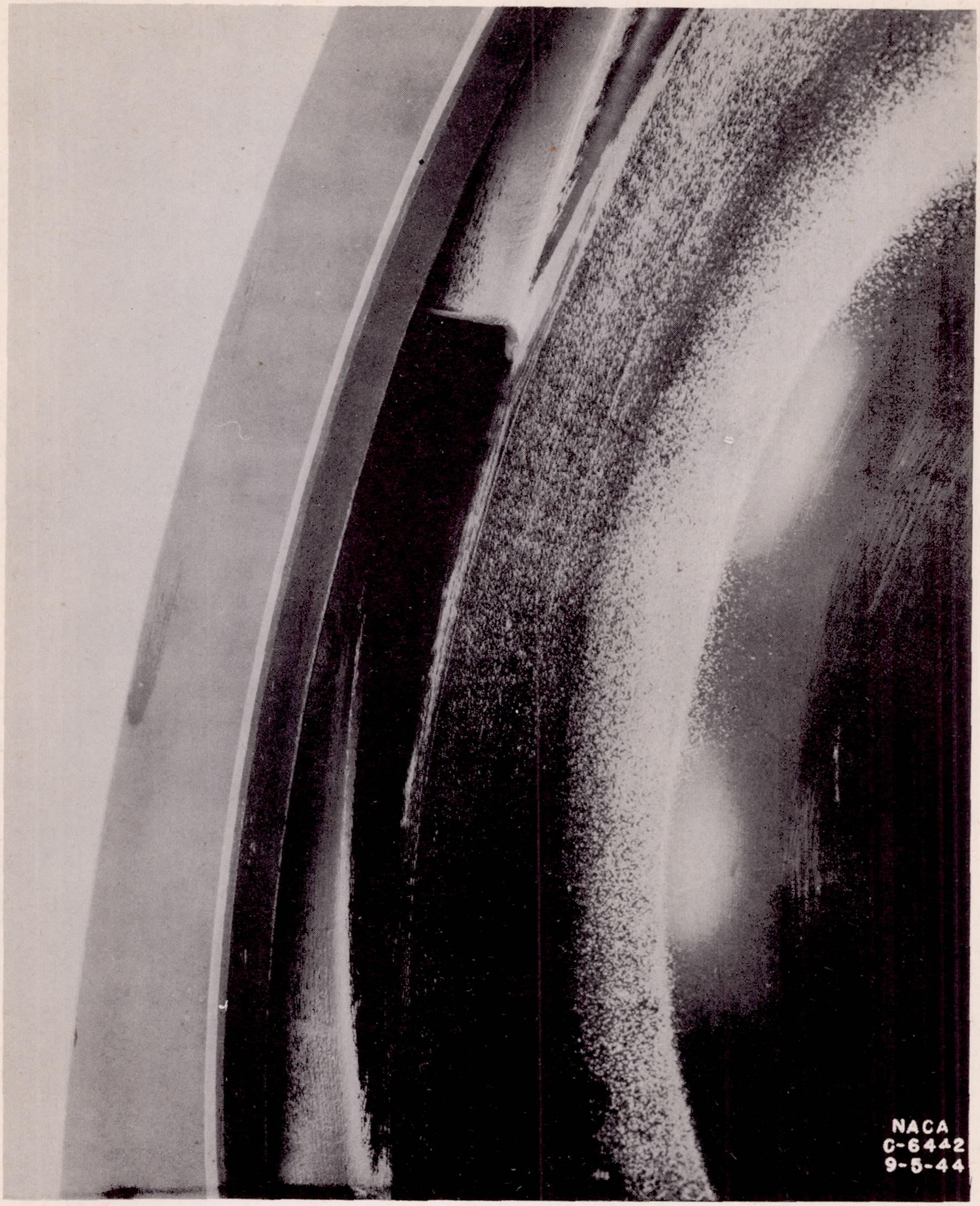


(a) Surface erosion at entrance to impeller.

Figure 4. - Erosion of supercharger-inlet cover caused by water and fuel injection and ice particles. Rate of liquid injection, 1300 pounds per hour; duration of test, $8\frac{1}{4}$ hours.



(b) Erosion of diffuser vanes 2 and 3.

Figure 4. - Concluded. Erosion of supercharger-inlet cover caused by water and fuel injection and ice particles. Rate of liquid injection, 1300 pounds per hour; duration of test, $8\frac{1}{4}$ hours.