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FLUID DE-ICING TESTS ON A CHANDLER-EVANS 1900 CPB-3 CARBURETOR MOUNTED ON A PRATT & WHITNEY R-1830-C4 INTERMEDIATE REAR ENGINE SECTION

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NACA

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

ADVANCE RESTRICTED REPORT

FLUID DE-ICING TESTS ON A CHANDLER-EVANS 1900 CPB-3 CARBURETOR MOUNTED ON A PRATT & WHITNEY R-1830-C4 INTERMEDIATE REAR ENGINE SECTION

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INTRODUCTION

This report is the second in a series of three covering results of an investigation of the icing and de-icing characteristics of a Pratt & Whitney R-1830 engine induction system. The research was carried out by the NACA at the National Bureau of Standards in September and October 1943. The first report (reference 1) deals with the determination of limiting icing conditions and research on heated-air de-icing for this induction system, which includes a Chandler-Evans 1900 CPB-3 carburetor mounted on an R-1830-C4 intermediate rear engine section.

The present report covers a program to determine the most effective rate and method of injection of de-icing fluid to remove a heavy ice formation from the induction system. The third report in the series (reference 2) covers research on the icing characteristics of the induction system which includes a Bendix-Stromberg PD-12F5 carburetor.

The criterion of de-icing effectiveness employed in the investigation of fluid de-icing was the time required to recover 95 percent of the original air-flow rate after the engine power, as represented by the air flow, had been reduced owing to the formation of ice. Four de-icing fluids and three types of injection nozzle were investigated. In order to determine the effect of inlet-air temperature on the de-icing effectiveness of the fluids, tests were made at 25° F and 40° F; and, in order to determine the effect of engine operation, tests were made at simulated rated power (air-flow rate, 7000 lb/hr; fuel-air ratio, 0.100) and at simulated cruising power (air-flow rate, 4000 lb/hr; fuel-air ratio, 0.070).

APPARATUS AND DE-ICING FLUIDS

The test apparatus was that used in the icing tests described in reference 1 with the addition of the de-icing-fluid injection system shown in figure 1.

The three types of injection nozzle used in the tests were modified Army nozzles, standard Army nozzles, and Holley poppet valves. The modified Army nozzles are priming nozzles having the exit orifices drilled out with a No. 74 drill (0.0225 in.) to permit high fluid flows at the available pressures. The standard Army nozzles are also priming nozzles with No. 76 (0.020 in.) drilled exit orifices. The Holley poppet valves (provided by the Holley Carburetor Co.) are spring-loaded valves that open under light fluid pressure and produce a conical spray.

The de-icing fluids used were isopropyl alcohol, propyl alcohol, Shellacol, and Solox D-I. Shellacol is chiefly ethyl alcohol denatured with small quantities of methyl alcohol, ethyl acetate, methylisobutylketone, and gasoline; Solox D-I is a mixture of 90 percent ethyl alcohol and 10 percent methyl alcohol denatured with a small amount of a chemical rust inhibitor and with 1 gallon of gasoline added per 100 gallons of alcohol mixture.

TEST PROCEDURE

The test procedure consisted in setting the air-flow rate and the air temperature to the desired values for the test and humidifying the air to saturation. When air-flow rate, temperature, and humidity were correct, free water was injected above the carburetor at the rate of 500 grams per minute to simulate flight through rainfall. (This water injection should not be confused with water injection used to suppress knock.) Simultaneously with the injection of water, fuel flow at the rate necessary to give the desired fuel-air ratio was supplied. Icing was permitted to proceed until the air-flow rate was reduced to 2500 pounds per hour. When this condition was reached, the water-injection rate was reduced to 250 grams per minute and the de-icing fluid was injected at a predetermined rate. Readings of air flow and fuel flow were taken at frequent intervals until either recovery was complete or it became apparent that there would be no recovery. In one set of tests, this procedure was varied by using a different rate of free-water injection in each run.

A summary of the test conditions is presented in the following table:

Series	Simulated engine power condition	Carburetor-air temperature (°F)	Water-injection rate during de-icing (grams/min)	Type of injection nozzle	De-icing fluid	De-icing-fluid flow rate (lb/hr)
A	Cruising	40	250	Modified Army	Isopropyl alcohol	20 to 90
B	---do---	40	0 to 630	-----do-----	---do---	60
C	---do---	40	250	Holley	---do---	40 to 90
D	---do---	40	250	Standard Army	---do---	30 to 80
E	Rated	40	250	Modified Army	---do---	30 to 80
F	---do---	25	250	-----do-----	---do---	30 to 80
G	Cruising	25	250	-----do-----	---do---	20 to 80
H	---do---	40	250	-----do-----	Propyl alcohol	30 to 70
I	---do---	40	250	-----do-----	Shellacol	30 to 70
J	---do---	40	250	-----do-----	Solox D-I	30 to 70

RESULTS AND DISCUSSION

The results of the fluid de-icing tests are presented in table 1 and are plotted in figures 2 to 5. All of the fluids tested except propyl alcohol exhibited erratic and unreproducible recovery times for similar flow rates. Propyl alcohol failed to achieve 95-percent air-flow recovery at any of the flow rates used. The effect of the de-icing-fluid injection rate on the time for air-flow recovery for the other three fluids is shown in figure 2, which indicates that the recovery time tends to decrease with an increase in the de-icing-fluid injection rate when modified Army nozzles are used; the scatter of the points, however, does not permit the fairing of a curve.

The recovery times resulting from the use of the three types of injection nozzle are compared in figure 3. None of the injection nozzles showed any marked superiority in effectiveness and the rather erratic results do not permit the fairing of a curve. The tendency for the recovery time to decrease with an increased fluid-injection rate is apparent for all three types of injection nozzle.

The runs of series G were performed at a carburetor-air temperature of 25° F and the scatter of the results is shown in figure 4.

During the de-icing portions of the runs of series B, different water-injection rates were used while the other conditions were maintained constant throughout the series. The data points shown in figure 5 indicate that the recovery times showed little change with water-injection rates varying from 0 to 630 grams per minute.

Series E and F were run at simulated rated-power conditions; the results of the series E tests show recovery times about twice as long as the recovery times resulting from the tests at cruising power with similar de-icing-fluid injection rates and at the same carburetor-air temperature of 40° F. Simulated rated-power tests performed at an inlet-air temperature of 25° F (series F) gave no recovery at any of the de-icing-fluid injection rates tested.

The time required to obtain an operable fuel-air ratio in all tests was the same as that required for the recovery of air flow. (See table I.)

It was observed that the ice was never completely removed during any of the fluid de-icing tests. In comparison with the results of the heated-air de-icing tests of reference 1, in which air-flow-rate recovery times ranging from 0.5 to 0.2 minute were obtained for heated-air wet-bulb temperatures ranging from 80° F to 90° F, the air-flow recovery times resulting from the fluid de-icing tests cannot be considered satisfactory.

The apparent cause of the erratic results was that, as the ice formations were freed from the air-passage walls and the carburetor by the melting of the bond, they were caught by the turning vanes at the entrance to the impeller section and lodged there blocking the air passage until the ice had melted to a size small enough to pass between the vanes. De-icing would have been accomplished more rapidly if the loose pieces of ice had been drawn through an unobstructed air passage. (See reference 3.)

SUMMARY OF RESULTS

These results are strictly applicable only to the induction system consisting of a Chandler-Evans 1900 CPB-3 carburetor mounted on a Pratt & Whitney R-1830-C4 intermediate rear engine section and for the conditions tested.

1. There was no marked difference in air-flow recovery times obtained with similar injection rates of any of the fluids used with the exception of propyl alcohol, which showed no adequate recovery.

2. All three injection nozzles showed similar de-icing performance.

3. The recovery times obtained could not be reproduced under the same conditions at any de-icing-fluid injection rate.

4. In order to insure a 95-percent air-flow recovery under cruising-power conditions, de-icing-fluid injection rates of at least 50 to 60 pounds per hour were required.

5. The recovery times obtained for the runs made at rated-power conditions when the ice was formed at a carburetor-air temperature of 40° F were about double the recovery times obtained for the same de-icing-fluid injection rates for the cruising-power conditions.

6. Recovery could not be obtained within 5 minutes for de-icing-fluid flow rates up to 80 pounds per hour for the tests made at rated-power conditions when the ice was formed at a carburetor-air temperature of 25° F.

CONCLUSION

From the erratic results obtained in these tests, it is concluded that the use of de-icing fluids is inadequate as the sole means of de-icing this induction system when it is subjected to severe icing conditions.

Aircraft Engine Research Laboratory,
National Advisory Committee for Aeronautics,
Cleveland, Ohio.

REFERENCES

1. Essex, Henry A., and Galvin, Herman B.: A Laboratory Investigation of Icing and Heated-Air De-Icing of a Chandler-Evans 1900 CPB-3 Carburetor Mounted on a Pratt & Whitney R-1830-C4 Intermediate Rear Engine Section. NACA ARR No. E4J03, 1944.

2. Galvin, Herman B., and Essex, Henry A.: A Laboratory Investigation of the Icing Characteristics of the Bendix-Stromberg Carburetor Model PD-12F5 with the Pratt & Whitney R-1830-C4 Intermediate Rear Engine Section. NACA ARR No. E4J18, 1944.

3. Essex, Henry A.: De-Icing of an Aircraft-Engine Induction System. NACA ARR No. 3H13, 1943.

TABLE I - RESULTS OF FLUID DE-ICING TESTS ON A CHANDLER-EVANS 1900 CPB-3 CARBURETOR MOUNTED ON A PRATT & WHITNEY R-1830-C4 INTERMEDIATE REAR ENGINE SECTION

[Water-injection rate during icing, 500 grams/min]

Run	Icing			De-icing					
	Initial air-flow rate (lb/hr)	Carburetor-air temperature (°F)	Icing time (min)	Fluid-injection rate (lb/hr)	Water-injection rate (grams/min)	95-percent initial air-flow rate (lb/hr)	Time to recover 95-percent air flow rate (min)	Fuel-air ratio at 95-percent recovery	Maximum recovery (lb/hr)
Series A: initial operating conditions, cruising power; de-icing fluid, isopropyl alcohol; injection apparatus, modified Army nozzles									
1	4030	40	6.4	20	250	3830	--------	--------	3320
2	3980	40	8.0	30	250	3780	2.8	0.063	3900
3	4000	40	7.8	40	250	3800	2.9	.071	3900
32	4000	40	6.7	40	250	3800	2.0	.063	3910
33	4000	40	5.3	70	250	3800	.6	.070	3930
34	4000	40	7.9	70	250	3800	1.1	.072	3930
35	4000	40	4.6	40	250	3800	3.0	.071	3860
41	4000	40	13.8	80	250	3800	2.2	.071	3930
57	4000	40	4.6	30	250	3800	--------	--------	3520
58	4030	40	5.8	40	250	3830	4.0	.069	3880
59	4050	40	11.0	50	250	3850	2.7	.070	3900
60	4000	40	6.8	60	250	3800	1.5	.070	3950
61	4030	40	9.4	70	250	3830	1.9	.070	3930
62	4030	40	7.6	80	250	3830	1.5	.070	3950
Series B: initial operating conditions, cruising power; de-icing fluid, isopropyl alcohol; injection apparatus, modified Army nozzles									
60	4000	40	6.8	60	250	3800	1.5	0.070	3950
63	4030	40	5.6	60	630	3830	1.8	.071	3930
64	4030	40	6.9	60	0	3830	1.7	.070	3950
65	4000	40	7.3	60	100	3800	1.5	.070	3950
Series C: initial operating conditions, cruising power; de-icing fluid, isopropyl alcohol; injection apparatus, Holley poppet valves									
42	4000	40	5.9	40	250	3800	--------	--------	3710
43	4000	40	5.3	50	250	3800	2.6	0.070	3900
44	4000	40	7.1	60	250	3800	2.1	.077	3900
45	4000	40	5.8	70	250	3800	1.2	.068	3950
46	4030	40	6.1	80	250	3830	1.7	.068	3950
47	4030	40	5.7	90	250	3830	1.3	.072	3950

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TABLE I - RESULTS OF FLUID DE-ICING TESTS ON A CHANDLER-EVANS 1900 CPB-3 CARBURETOR MOUNTED ON A PRATT & WHITNEY R-1830-C4 INTERMEDIATE REAR ENGINE SECTION - Continued

	Icing			De-icing					
Run	Initial air-flow rate (lb/hr)	Carburetor-air temperature (°F)	Icing time (min)	Fluid-injection rate (lb/hr)	Water-injection rate (grams/min)	95-percent initial air-flow rate (lb/hr)	Time to recover 95-percent air-flow rate (min)	Fuel-air ratio at 95-percent recovery	Maximum recovery (lb/hr)
Series D: initial operating conditions, cruising power; de-icing fluid, isopropyl alcohol; injection apparatus, standard Army nozzles									
51	4030	40	6.1	30	250	3830	-------	-------	3520
52	4050	40	4.9	40	250	3850	2.9	0.075	3900
53	4030	40	5.3	50	250	3830	2.0	.072	3930
54	4050	40	5.1	60	250	3850	1.5	.071	3950
55	4030	40	4.8	70	250	3830	1.6	.071	3950
56	4030	40	5.4	80	250	3830	1.5	.071	3950
Series E: initial operating conditions, rated power; de-icing fluid, isopropyl alcohol; injection apparatus, modified Army nozzles									
66	6990	40	4.0	30	250	6640	-------	-------	5220
67	6860	40	3.3	40	250	6520	-------	-------	5350
68	7000	40	2.8	60	250	6650	5.0	0.088	6690
69	7000	40	3.1	70	250	6650	3.7	.093	6810
70	7000	40	3.7	80	250	6650	3.0	.099	6880
Series F: initial operating conditions, rated power; de-icing fluid, isopropyl alcohol; injection apparatus, modified Army nozzles									
71	7020	25	3.7	30	250	6670	-------	-------	6540
72	7000	25	4.5	40	250	6650	-------	-------	6590
73	7000	25	4.0	60	250	6650	-------	-------	6590
74	7000	25	4.9	80	250	6650	-------	-------	6500
Series G: initial operating conditions, cruising power; de-icing fluid, isopropyl alcohol; injection apparatus, modified Army nozzles									
75	4000	25	1.7	40	250	3800	3.8	0.071	3830
76	4000	25	1.9	30	250	3800	1.6	.065	3930
77	3990	25	1.2	20	250	3790	-------	-------	3600
78	4080	25	1.3	50	250	3680	3.3	.072	3960
79	4030	25	1.2	60	250	3830	1.1	.072	4000
80	4050	25	1.5	70	250	3850	2.9	.071	3930
81	4000	25	1.5	80	250	3800	1.4	.072	3960
82	4050	25	1.4	30	250	3850	-------	-------	3810

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TABLE I - RESULTS OF FLUID DE-ICING TESTS ON A CHANDLER-EVANS 1900 CPB-3 CARBURETOR MOUNTED ON A PRATT & WHITNEY R-1830-C4 INTERMEDIATE REAR ENGINE SECTION - Concluded

	Icing			De-icing					
Run	Initial air-flow rate (lb/hr)	Carburetor-air temperature (°F)	Icing time (min)	Fluid-injection rate (lb/hr)	Water-injection rate (grams/min)	95-percent initial air-flow rate (lb/hr)	Time to recover 95-percent air-flow rate (min)	Fuel-air ratio at 95-percent recovery	Maximum recovery (lb/hr)
Series H: initial operating conditions, cruising power; de-icing fluid, propyl alcohol; injection apparatus, modified Army nozzles									
83	4050	40	4.0	30	250	3850	--------	--------	3260
84	4050	40	5.9	50	250	3850	--------	--------	3630
85	4030	40	4.5	70	250	3830	--------	--------	3440
Series I: initial operating conditions, cruising power; de-icing fluid, Shellacol; injection apparatus, modified Army nozzles									
86	4050	40	4.6	30	250	3850	--------	--------	3810
87	4000	40	6.6	50	250	3800	2.3	0.071	3930
88	4030	40	6.0	70	250	3830	2.4	.073	3930
Series J: initial operating conditions, cruising power; de-icing fluid, Solox D-I; injection apparatus, modified Army nozzles									
89	4000	40	5.2	30	250	3800	1.8	0.070	3910
90	4030	40	4.5	50	250	3830	2.8	.072	3950
91	4030	40	6.1	70	250	3830	1.7	.073	4030

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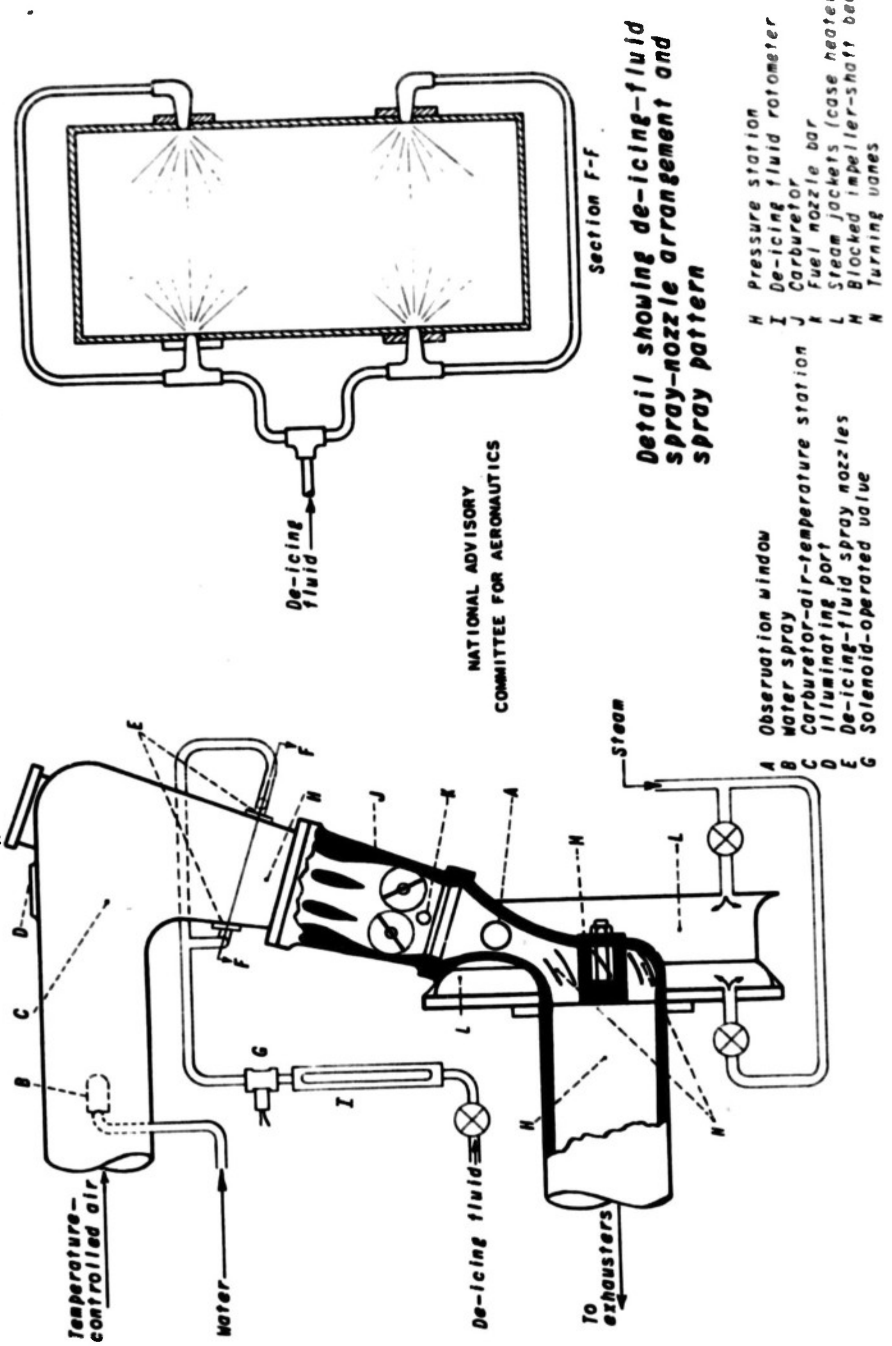

Figure 1. - Schematic diagram of test apparatus.

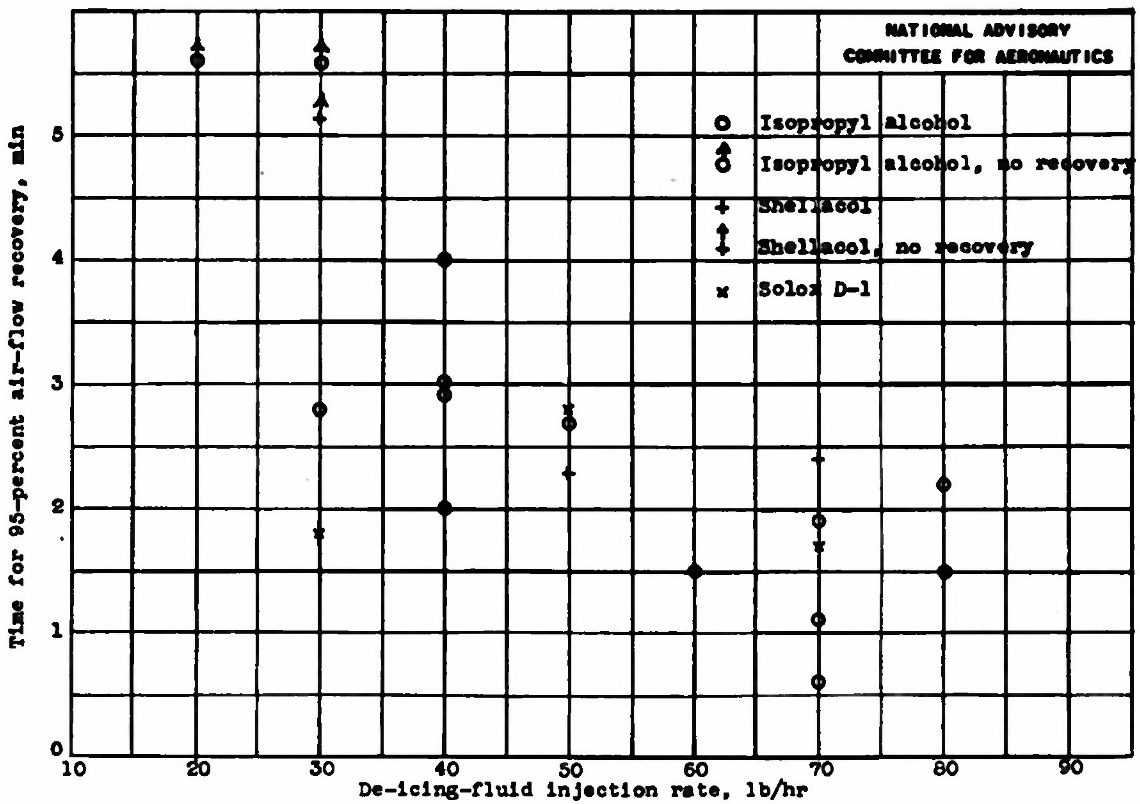

Figure 2. - Effect of de-icing-fluid injection rate on air-flow recovery time for three de-icing fluids. Injection apparatus, modified Army nozzles; carburetor-air temperature, 40° F; water-injection rate during de-icing, 250 grams per minute; initial air-flow rate, 4000 pounds per hour; initial fuel-air ratio, 0.070. Series A, I, and J.

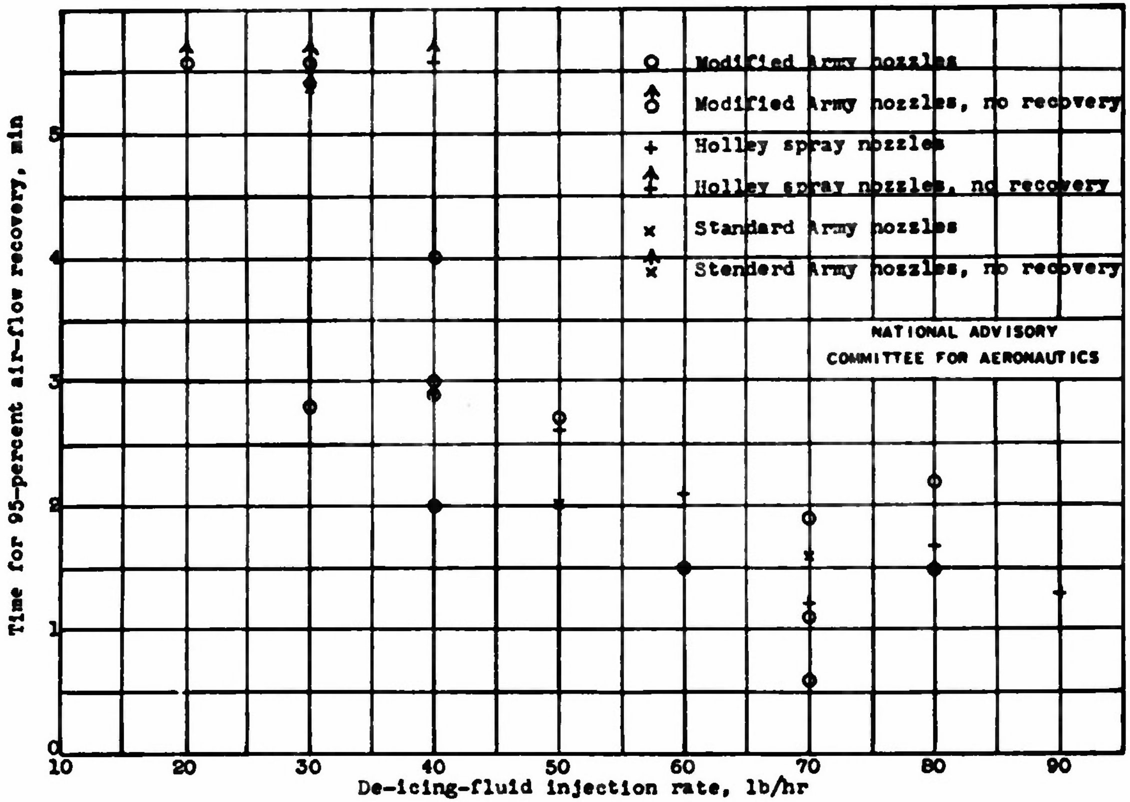

Figure 3. - Effect of de-icing-fluid injection rate on air-flow recovery time using three types of injection nozzle. De-icing fluid, isopropyl alcohol; carburetor-air temperature, 40° F; water-injection rate during de-icing, 250 grams per minute; initial air-flow rate, 4000 pounds per hour; initial fuel-air ratio, 0.070. Series A, C, and D.

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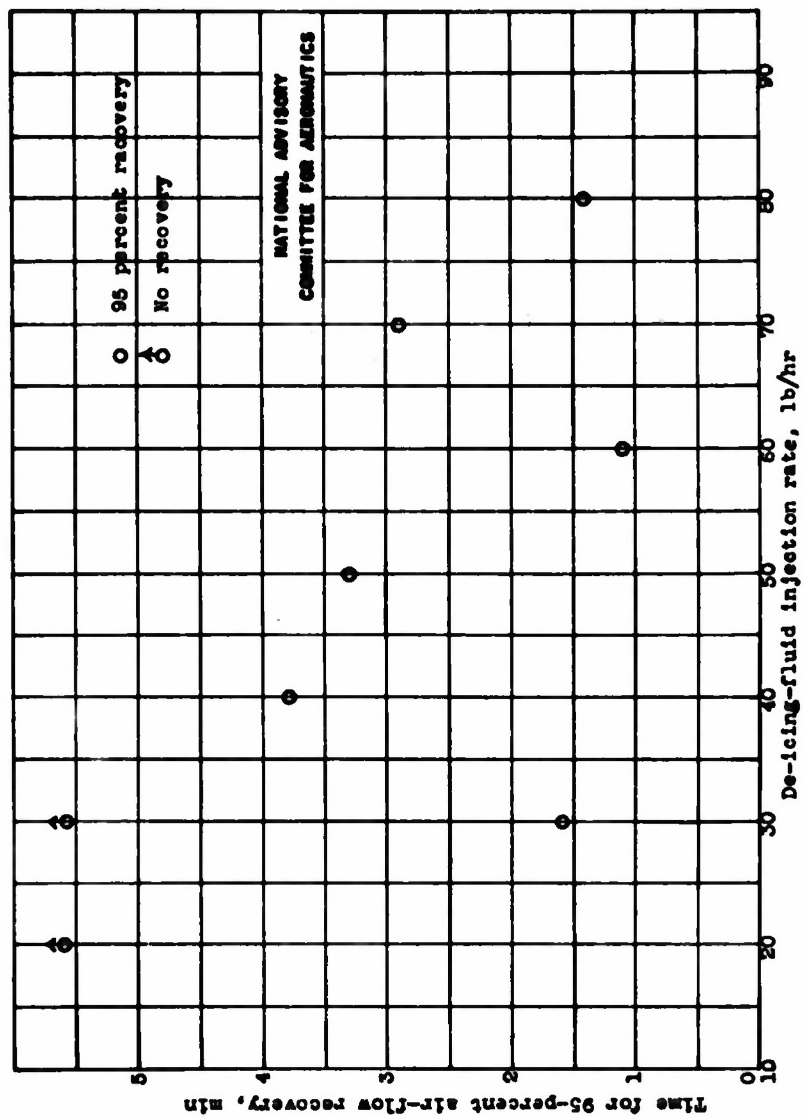

Figure 4. - Effect of de-icing-fluid injection rate on air-flow recovery time at low carburetor-air temperature (25° F). De-icing fluid, isopropyl alcohol; injection apparatus, modified Army nozzles; water-injection rate during de-icing, 250 grams per minute; initial air-flow rate, 4000 pounds per hour; initial fuel-air ratio, 0.070. Series G.

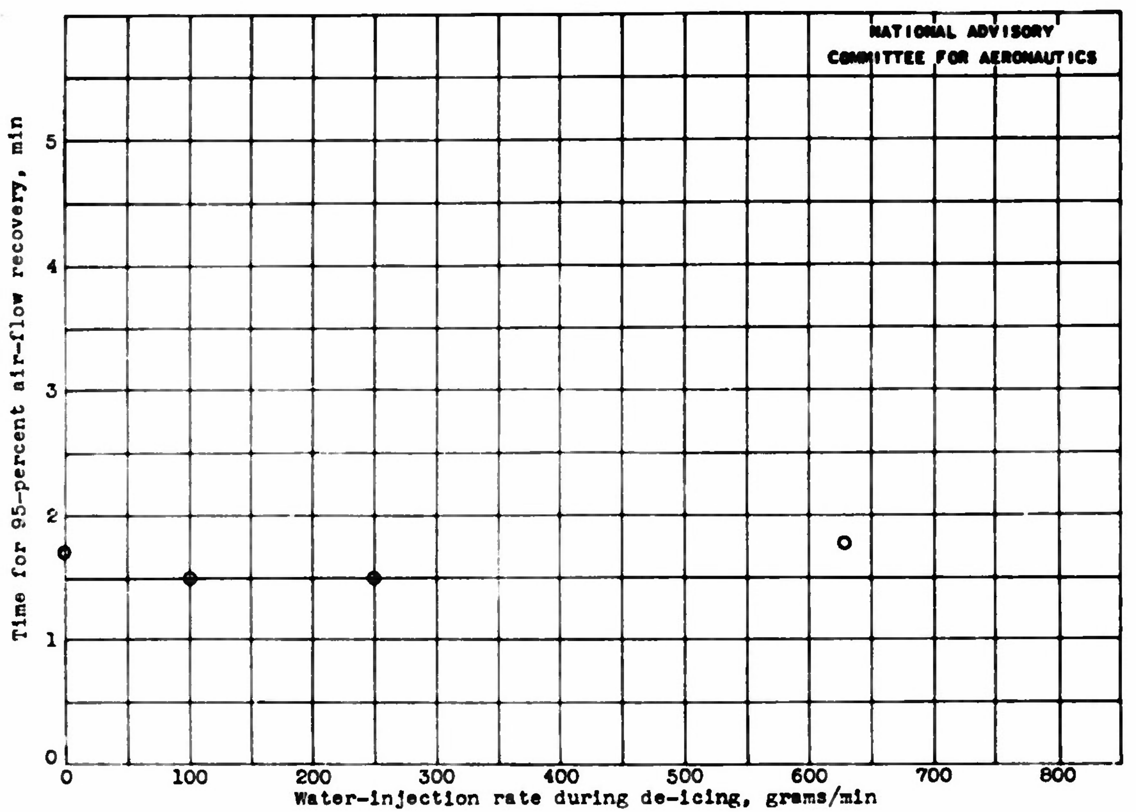

Figure 5. - Effect of water injection during de-icing on air-flow recovery time. De-icing fluid, isopropyl alcohol; de-icing-fluid injection rate, 60 pounds per hour; injection apparatus, modified Army nozzles; carburetor-air temperature, 40° F; initial air-flow rate, 4000 pounds per hour; initial fuel-air ratio, 0.070. Series B.

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ABSTRACT

Tests were conducted to determine most effective method of injecting de-icing fluids to remove heavy ice formation from the induction system and carburetor of aircraft engines. Experiments were made at 25° and 40°F to evaluate effect of inlet-air temperature on de-icing fluid effectiveness. Results show that use of de-icing fluids is inadequate as the sole means of de-icing induction system when it is subjected to severe icing conditions.

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