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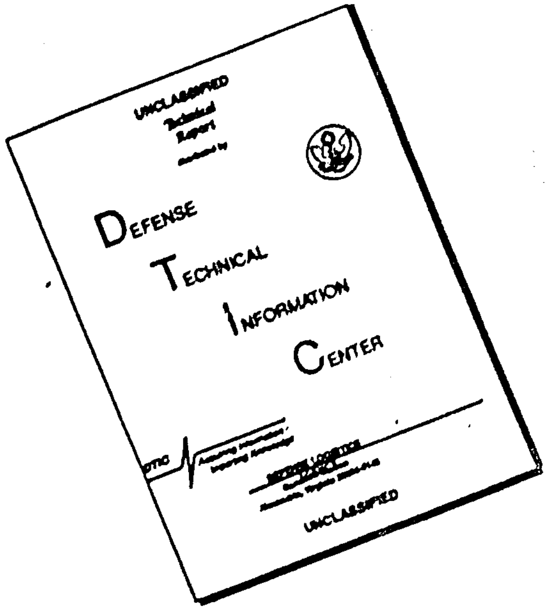


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TEST REPORT

# ENGINE SNOW INGESTION IN THE BELL 206A JET RANGER HELICOPTER

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SUMMARY

To investigate reported cases of engine flameout occurring during flight in snow, tests were made on a ground-running helicopter, using a device for generating artificial snow. The tests showed that operation in snow could result in engine flameout, largely as a result of accumulations of ice being formed in the engine inlet plenum chamber. It is concluded that flight in any condition of snow is unsafe with the existing engine inlet configuration of this helicopter.

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# ENGINE SNOW INGESTION IN THE BELL 206A JET RANGER HELICOPTER

## 1.0 INTRODUCTION

As the result of a number of flameouts occurring on Jet Rangers during flight in conditions of snow, the National Research Council of Canada was requested by the Canadian Department of Transport to perform tests for the purpose of determining the conditions conducive to flameout and the manner in which sufficient snow might be ingested to cause flameout.

In the absence of suitable natural snowfall conditions, it was decided to use a group of four small snow nozzles, designed for wind tunnel use, to produce simulated snow conditions. The use of these nozzles required that the tests be run under ground-running conditions; however, this provided the opportunity to observe the engine inlet areas more closely and continuously than could have been done under flight conditions.

A number of flameouts were produced under these simulated conditions, and the possibility that flameouts may result from the shedding of snow or ice from any one of several locations, outside or inside the engine plenum chamber, was demonstrated.

## 2.0 EQUIPMENT USED

### 2.1 Aircraft and Engine

Tests were conducted on two Bell Jet Ranger helicopters, registration CF-CGL and CF-CGK, both owned and operated by the Department of Transport.

The engine in these helicopters is the Allison T63-A-5A turboshaft engine, of 317 hp rating. The engine consists of a multi-stage axial-centrifugal-flow compressor, a single combustion chamber, a two-stage gas producer turbine, and a two-stage power turbine that supplies the output power of the engine. The weight of the engine is 136 lb.

In its installation in the Jet Ranger, the engine inlet bellmouth is situated in a plenum chamber behind the main rotor transmission housing. Air enters by a bifurcated intake with inlets on either side of the transmission housing. A woven wire debris screen is located where the short intake ducts enter the plenum chamber. The screen extends from the floor of the duct to about 80 percent of the height from the floor to the roof of the duct, the upper 20 percent being open to allow an alternate air path should the screen become blocked. The engine bay firewall forms the back wall of the plenum chamber, and the engine inlet bellmouth projects forward of the firewall about two inches.

### 2.2 Snow Generator

The snow generator consisted of four ice particle nozzles of convergent-divergent design, arranged in an 18-inch square array and mounted about three feet above the ground on a portable frame that was inclined at an angle of 45 deg above the horizontal.

Water was atomized in the nozzles by the shearing action of an annular jet of compressed air. By ensuring that the initial temperatures of the water and atomizing air were sufficiently cool, and by expanding the air to a sufficient degree so that adequate cooling of the resultant droplets was achieved, it was possible to achieve spontaneous freezing. The result was a cloud of small ice particles that in many respects resembled natural snow. However the geometry and the small size of the particles was not representative, and some degree of liquid water was present at temperatures close to 0°C.

About 90 cfm of air was supplied to each nozzle at a pressure of 100 psi. The water flow rate used was 2.5 lb/min/nozzle. Particle size was about 60 microns.

It was not possible to cool the water and air supplied to the nozzles as much as was desirable. Water temperature was between 10 and 15°C, and the air that left the air compressor at about 60°C was cooled some 25° in an air-to-air heat exchanger. Had the temperatures of both the water and air been no greater than 5°C, it would have been possible to use a higher water-to-air mass flow ratio to obtain a larger resultant particle size with no increase in wetness.

## 3.0 TESTS MADE

The probability of experiencing natural snow conditions at the right temperatures and of the right concentrations during the period (December 1967) when the test helicopters were available was small, so it was decided to use simulated conditions.

The tests made are grouped under the following headings:

1. Icing Tests
2. Natural Snow Tests
3. Simulated Snow Tests
4. Water Ingestion Test

### 3.1 Icing Tests

Initially, before it was decided to employ snow nozzles for simulation purposes, four icing runs were made. Because of the danger of flameout, these tests were made with the helicopter hovering about five feet above the ground. The first three runs were in a condition approximating a freezing drizzle (i.e. L.W.C. 0.5 g/m$^3$ and droplet size 60 microns), while the fourth run was at the appropriate continuous maximum icing condition for the temperature of the test (i.e. L.W.C. = 0.7 g/m$^3$, d = 30 microns, temp. = -6°C). Details of these and all other tests are given in Table I.

### 3.2 Natural Snow Tests

On three occasions natural snow conditions were used, although in all cases the snow was light, with visibilities of 3/4 mile or greater. The procedure was to fly slowly up and down the field at a height of a few feet, while trying to augment the falling snow with snow recirculated from the ground. The helicopter was landed periodically to inspect the engine inlet area.

### 3.3 Simulated Snow Tests

The bulk of the tests was made under simulated conditions, using the snow generator; this required the helicopter to remain stationary on the ground. Under these conditions it was possible for the engine to generate about 35 percent torque, resulting in a gas generator speed, N1, of 82 percent. Although not fully representative of actual flight, these conditions did permit conclusions to be drawn on areas of snow impingement and impaction within the plenum chamber, and on the effect of heat transmission through the firewall and the base of the bellmouth. In addition, by placing the snow generator to one side of the helicopter, it was possible to observe through the inlet on the other side the progressive accumulation of snow or ice within the plenum chamber, and in some instances to actually observe the ingestion of deposits that caused flameout.

At temperatures only slightly below the freezing point, a small proportion of the sprayed "snow" was still in liquid form (estimated at less than 5 percent), thus a wet snow condition was simulated at temperatures slightly below the freezing point instead of at or slightly above, as in natural conditions. The major effect was that the wet snow that blocked the screen froze fairly firmly in place, whereas it is reported that natural wet snow compacted on the screen does not attach firmly and may be lifted by the airflow and carried over the screen. With this exception, it was felt that the results obtained were fairly representative of natural conditions.

### 3.4 Water Ingestion Test

To assess the susceptibility of the engine to flameout in terms of the rate of ingestion of water, a test was performed in which water was injected into the engine intake. A measured quantity of water was sucked up into a 3/16-in ID tube by means of a rubber bulb, and then ejected into the engine by sharply squeezing the rubber bulb.

## 4.0 TEST RESULTS

Details of all tests made are given in Table I; however, the following comments amplify the more significant details.

### 4.1 Icing Tests

Four runs were made, the first three in conditions of simulated freezing drizzle at a temperature of about -6°C. Two minutes in these conditions (Run 1) had little effect except to increase the torque required to hover from 53 to 55½ percent because of a thin ice accretion on the main rotor blades to about 65 percent span. Five minutes exposure (Run 2) resulted in a 3/16-in thickness of ice on the wires over 50 percent of the area of the inlet screen; water was observed dripping off the engine bellmouth lip, and periodic vibration was experienced as ice self-shed from the main rotor. Run 3 exposed the helicopter to the conditions for 17 minutes; however, the ice that had formed on the screen on the port side during Run 2 was left intact, but the starboard screen was cleared of ice prior to commencing the run. The helicopter was on the ground for the first 15 minutes of this run to permit visual observation of the bellmouth through the cleared starboard screen. The last two minutes were made at the hover, and required a torque of 63 percent, but no increase in tail pipe temperature was noticeable. At completion, the port screen was completely blocked over 75 to 80 percent of its area, and a thin lip of ice (1/16 in to 1/8 in thick) had formed around the lower half of the engine bellmouth; this fell off shortly after the engine was stopped. Only a thin layer of ice was on the intake lip.

Run 4 was made in simulated continuous maximum icing conditions at a temperature of -6°C. Fifteen minutes of hovering in these conditions resulted in about 30 percent blockage of the screen, and, as in Run 3, a bead of ice behind the lower half of the lip of the engine bellmouth.

4.2 Natural Snow

On the three days that snow fell (i.e. 8, 26, and 28 December 1967) it was of quite light intensity and short duration.

During Run 5 the snow was in the form of small graupel pellets at a temperature of from -1.4°C to -0.9°C, and a total of 35 minutes exposure was possible before snowfall ceased. The run consisted of periods of flight (see para. 3.2), interrupted by periods of ground running during which inspection of the engine inlet areas was made. These alternations were approximately as follows:

10 minutes flight
5 minutes ground running
10 minutes flight
5 minutes ground running
5 minutes flight.

After the first 10 minutes of flight it was observed that ice had formed around the periphery of the engine bellmouth, being slightly heavier (about 1/8 in thick) at the 12 o'clock and 6 o'clock positions, and a rather ragged lump, 1/4 in high, had formed on the plenum floor beneath the bellmouth. Little change in this condition was noted during the remainder of the run.

On 26 December a very light snowfall occurred and permitted exposure for 15 minutes (Run 17). The temperature was -16.5°C, and at the end of the run there was slight moisture on the firewall and a small piece of ice on the floor beneath the bellmouth.

Three runs (Runs 20, 21, and 22) were made on 28 December in light snow, with visibility of one mile and temperature increasing slightly from -12°C to -11°C. The three runs were of 17, 20, and 19 minutes' duration. The first resulted in some light ice on the bellmouth lip, some on the bellmouth mounting flange, and a small lump of ice on the floor. After Run 21 there was slightly less ice on the bellmouth lip, but slightly more on the floor; Run 22 produced about the same result.

All the runs in light dry snow (visibility about one mile) resulted in light icing of the bellmouth lip and some ice on the floor of the plenum chamber below the bellmouth, but no adverse effects resulted.

4.3 Simulated Snow

Thirteen runs, using the snow generator, were made; these are designated as Run Type 3, in Table I.

Run 6 was the first run with the snow generator and was regarded more as a trial run for the generator than for the helicopter. However, the results were so revealing as far as the helicopter was concerned that there was little doubt as to the generator's usefulness, providing that the wetness fraction of the "snow" could be reduced. Accordingly, for subsequent tests an air-to-air heat exchanger was inserted in the compressed air line and resulted in cooling the air by some 25°C, reducing the wetness fraction appreciably. Run 6 indicated very clearly that a greater risk of flame-out, and even engine damage, could result from the ice that formed within the plenum than from compacted snow entering from without. Figure 2 shows the ice formed around the bellmouth lip and on the plenum floor ahead of the bellmouth.

Of the remaining 12 runs, seven terminated in engine flameout. Of these only one (Run 13) was thought to be caused by snow from external parts (i.e. transmission cowling or inlet lip). The causes of three flameouts were actually observed (Runs 12, 14, and 15), while those of the remaining three (Runs 8, 9, and 10) were inferred by noting that ice had obviously broken away from certain areas of the bell-mouth or plenum chamber roof.

It was thought that the heat conducted into the bellmouth from the engine front frame might be reduced if the engine anti-icing system were turned off, with resultant reduction in the amount of snow melted and refrozen on the bellmouth. This was attempted in Run 11, but owing to a certain wetness fraction at this high temperature (-0.6°C), ice began to form on the now unheated bullet nose and inlet guide vanes and resulted in excessive turbine outlet temperature, necessitating abandonment of the run before any conclusions regarding the bellmouth could be drawn.

Run 18 and its continuation, Run 19, which were at the lowest temperature attempted with the snow generator, were prematurely terminated because of problems encountered with the air compressor used to supply the snow generator. However, even at this low temperature, it was shown that there was enough heat in the firewall, bellmouth, and plenum floor to permit partial melting and refreezing of the impinging snow. Figure 3 shows the compacted snow/ice behind the bellmouth lip (thickest at the 9 o'clock position) and extending down to the plenum floor. That the artificial snow was completely dry was demonstrated by the absence of any formation on the wire screen.

A 32-minute run at -10.6°C (Run 23) resulted in a stable condition being reached after about 20 minutes. Snow packed behind the bellmouth in a similar fashion to that of Runs 18 and 19, the firewall was wet, and a mound of ice formed on the plenum floor. Figure 4 shows the snow on the cowlings, and the condition of the engine inlet.

4.4 Water Ingestion

The water ingestion test (Run 16) showed that 30 cc of water squirted into the engine were sufficient to cause flameout, while 20 cc were not. It was estimated that this water entered the engine in a period of one second, and assuming an air mass flow rate of 3 lb/sec, this would give a critical water/air mass flow ratio for flameout of approximately 0.02 (corresponding to a liquid water content of about 24 g/m$^3$).

## 5.0 DISCUSSION

It must be admitted that the method of testing under simulated snow conditions had certain shortcomings. As already mentioned in Section 2.2, the geometry and size of the particles were in poor approximation to natural snow; the particles produced were largely distorted and fractured spheres with little tendency towards hexagonal crystals, and their size was estimated to be 60 to 100 microns (i.e. about 1/100 that of natural snowflakes). The small amount of wetness present at temperatures close to 0°C was rather undesirable, but in some respects approximated wet snow conditions that normally occur at or slightly above 0°C.

No measurements of the snow concentration were made, but it was estimated that the simulated snow entering the engine inlet represented moderate to heavy conditions. Unfortunately no definitive measure of airborne snow concentration as related to probability of occurrence or temperature exists; the normally accepted definition of snow intensity is based on visibility as follows:

| Intensity | Visibility |
|---|---|
| Light | 5/8 mile or more |
| Moderate | 3/8 - 1/2 mile |
| Heavy | 1/4 mile or less |

Such a definition is of little application in the present context since visibility is a function of several parameters and cannot be related uniquely to concentration. However, this is perhaps the only indication a pilot has of snow intensity, although one wonders with what accuracy a pilot in flight can assess the true visibility.

One final shortcoming in the test procedure was the need to conduct the simulated snow tests under ground-running conditions. The helicopter was not tied down or loaded, so that it was not possible to operate in excess of 35 percent torque - rather less than any flight condition; mass flow rates and velocities in the engine inlet system were thus less than in normal operation. The absence of any appreciable air flow over the helicopter fuselage, in contrast to flight conditions, had three results.

1. Light fluffy snow accretions adhered to all external surfaces of the fuselage where impingement of snow from the snow generator occurred (see Fig. 4); under flight conditions, including hovering, the bulk of this would be blown off.

2. In flight. the impingement pattern on the fuselage would be different.

3. In forward flight, snow would tend to be packed fairly solidly in stagnation areas, such as the front of the transmission cowling.

These shortcomings and uncertainties notwithstanding, the tests shed considerable light on the mechanism of engine flameout under conditions of flight in snow.

It was shown that the ingestion of snow shed from external parts of the helicopter was not the only mechanism that could cause flameout, and, indeed, may not even be the most significant mechanism. The more common cause during the tests was the ingestion of accretions of ice or snow formed within the engine intake plenum chamber. That such a mechanism was not just a peculiarity of the method of simulation is attested to by the fact that, during the flights in light natural snow, ice was observed in some of the same critical areas as during the tests with simulated snow, but in lesser quantity. The main critical areas were the back side and lip of the bellmouth and the plenum floor; depending to a larger extent on the concentration and temperature, the roof of the plenum, the firewall, and re-entrant corners within the plenum were also potential danger areas.

It was clear that wet snow was not the only condition under which flameout could occur, although this seemed to have been a common belief before the tests were made. None of the flameouts that occurred were at temperatures below -3.1°C, but it should be noted that no ambient temperatures between this value and -10.6°C presented themselves during the tests. However, ice still formed in considerable amounts in the plenum chamber at lower temperatures, as Runs 18 and 19 indicate, but it adhered more strongly and larger amounts would have to build before breakaway occurred. Thus there exists a greater danger of engine damage at lower temperatures.

Although flights of fairly considerable durations may be made at temperatures below about -10°C (particularly since snow intensities are likely to be less extreme), a great danger exists should the helicopter subsequently move into air of a higher temperature, or when taking off again after landing and sitting on the ground for some time. It is therefore of extreme importance if an encounter with snow has occurred that, on landing, any evidence of snow or ice, both within the plenum chamber and on external surfaces, be entirely removed before attempting to continue flight. The existing cowling arrangement makes it extremely difficult to remove ice within the plenum, and perhaps the most satisfactory method is the use of a hot air blower to melt it all; however, a danger exists that, unless the engine is run immediately after this treatment, water may refreeze within the engine compressor with disastrous results when the engine is restarted. The use of alcohol is not recommended unless the accretion is very loose or fluffy, because the rate at which ice will dissolve in alcohol is very slow.

It seemed clear that considerable improvement within the plenum would result if:

1. the firewall were made cold by thermal insulation or other means, so that impinging snow would not be melted thereon and refreeze on other colder areas;

2. the bellmouth were made flush with the firewall, or at least faired in, to prevent ice formation on its back side;

3. all re-entrant corners within the plenum were eliminated and its geometry made simple and smooth in order to remove, as far as possible, all places where snow might pack.

The danger of snow being ingested from external areas might be avoided if full screens in the inlets were used and an alternate air supply provided by means of a blow-in door in the event that the screens become blocked.

The water ingestion test showed that this engine is not abnormally susceptible to water ingestion.

## 6.0 CONCLUSIONS

Tests under artificial snow conditions have demonstrated the susceptibility of the T63 engine in the Bell 206A Jet Ranger helicopter to flameout while operating in snow.

Under the test conditions, flameouts resulted primarily from the ingestion of pieces of the ice that formed within the engine inlet plenum chamber because of the large amount of stray heat in the plenum walls, particularly the engine firewall. Another cause of flameout was the ingestion of aggregates of snow that had shed from stagnation regions of the external cowling.

Although all flameouts resulting from the shedding of ice from within the plenum occurred at temperatures close to 0°C, it was evident that the danger of flameout from this cause exists at any temperature at which snow may be encountered. It is therefore essential, if snow is encountered in flight, that an immediate landing be made, and that all snow and ice be removed both from external parts of the helicopter and from the engine plenum, prior to resumption of flight in clear conditions. If snow or blowing snow has been encountered during ground running, the same precautions should be made before take-off.

It is considered that certain modifications to the plenum chamber design would substantially reduce the danger of ice accumulation that causes flameout.

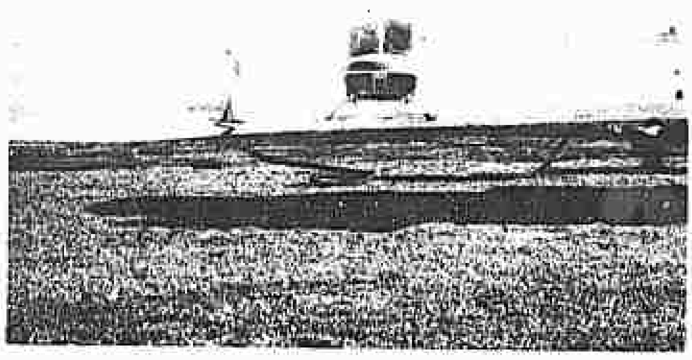
It does not appear that the engine itself is abnormally susceptible to flameout as a result of the ingestion of water; however, because of its small size, quite small quantities of water or ice may represent an appreciable water/air mass flow ratio entering the engine.

TABLE I

CONSOLIDATED TEST RESULTS

| Date 1967 | Run No. | Run Type* | Air Temp. °C | Duration min | Torque $\Delta$ Q % | Remarks |
|---|---|---|---|---|---|---|
| 6/12 | 1 | 1 | -6.4 | 2 | 53<br>55½ | L.W.C. 0.5 g/m³, d = 60μ. Light screen icing. Film of ice on inlet lip. Water dripping from bellmouth lip. Ice to 65%R on main rotor, light ice on tail rotor. No vibrations. ΔQ increased 2½%. |
| 6/12 | 2 | 1 | -6.2 | 5 | - | L.W.C. = 0.5 g/m³, d = 60μ. Inlet screen restricted ~ 50% by 3/16" ice. Water dripping from bellmouth - trace of ice on lower portion. Some vibration as blade ice shed. |
| 6/12 | 3 | 1 | -6.1 | Ground Run: 15<br>+<br>Hover: 2 | 63 | L.W.C. 0.5 g/m³, d = 60μ. Ice from previous run removed from starboard screen, but left on port screen. ΔQ = 63% at end of run. 75% of port screen blocked by ¼" thick ice. Lip of ice on lower 1/2 of bellmouth. |
| 6/12 | 4 | 1 | -6.0 | 15 | - | L.W.C. = 0.7 g/m³, d = 30μ. ¼" of knife-edge ice on wires of screen causing about 30% blockage. Bead of ice behind lip on lower half of bellmouth. Blade ice to 65%R. Some vibration. |
| 8/12 | 5 | 2 | -1.4 increasing to -0.9 | 35 | - | Light natural snow pellets. Run consisted of 10 min flight, 5 min ground run; 10 min flight, 5 min ground run; 5 min flight. Ice formed around bellmouth lip (1/8") and small mound of ice on floor underneath. |
| 15/12 | 6 | 3 | -5 | 20 | 35 | Trial run with snow generator. Nozzles directed towards starboard engine inlet. Spray estimated 30% wet. At end of run starboard screen fully blocked by ice with max. thickness 1". 1/8" ice on wires of port screen. Inside plenum: rime ice ½" thick on roof, water running down firewall, clear ice ~ ¼" thick around bellmouth - mostly behind lip - much heavier and ragged on lower half. Jagged mounds of ice on floor projecting to well above inlet lip. Fig. 2 shows interior of plenum after ice removed from screen. |
| 18/12 | 7 | 3 | -1.0 | 19 | 35 | Screen iced. Little ice formed on bellmouth. Some ice on plenum floor. Poor freeze-out of sprays at this temperature. |
| 20/12 | 8 | 3 | -1.6 | 15 | 35 | Sprays on starboard side of helicopter. Flameout at 15 min. Appears that ice ingested from rim of bellmouth at 2 to 5 o'clock. |
| 20/12 | 9 | 3 | -1.8 | 15 | 35 | Flameout at 15 min. Believed ice shed from lower part of bellmouth. |
| 20/12 | 10 | 3 | -1.6 | 21 | 35 | Flameout at 21 min. Believed ice shed from plenum roof. |
| 20/12 | 11 | 3 | -0.6 | 12 | 35 | Engine anti-icing system off. Test discontinued after 12 min because of excessive build-up of ice on I.G.V.s and bullet nose causing rise in T.O.T. |
| 20/12 | 12 | 3 | -0.6 | 19 | 35 | Engine anti-icing on. Flameout at 19 min caused by 3 pendent pieces of wet ice or slush falling from plenum roof. Those pieces about 3/4" long and 3/4" dia. at root. |
| 21/12 | 13 | 3 | -3.1 | 13 | 35 | Flameout at 13 min. Location of shed ice or snow causing flameout not observed, nor obvious. |
| 21/12 | 14 | 3 | -2.0 | 13 | 35 | Flameout at 13 min. Ice observed to shed from bellmouth lip in 6 to 9 o'clock position. |
| 21/12 | 15 | 3 | -0.5 | 11½ | 35 | Snow generator placed in front of helicopter nose. Flameout at 11½ min caused by snow shedding from plenum roof where it had formed a 1/8" layer. |
| 21/12 | 16 | 4 | - | - | 35 | Water ingestion test. 20 cc water squirted into engine - no flameout. 30 cc water squirted into engine - flameout. Slight puff from exhaust at flameout. |
| 26/12 | 17 | 2 | -16.5 | 15 | - | Light natural snow, augmented by recirculating snow on ground by hovering. After 15 min slight moisture on firewall, small piece of ice on floor beneath bellmouth. No problems. |
| 26/12 | 18 | 3 | -15.7 | 20 | 35 | Snow generator in front of helicopter, but moved to starboard side after 10 min because of low concentration entering engine. Run discontinued at 20 min - compressed air supply failed. Snow compacted at 3 and 9 o'clock on outer edges of bellmouth. Ice also on firewall and floor. Frosting on plenum roof. No blocking of screen (Fig. 3). |
| 26/12 | 19 | 3 | -15.9 | 5 | 35 | Attempted continuation of Run 18, but air compressor again failed. |
| 28/12 | 20 | 2 | -12.2 | 17 | - | Flight in light natural snow. Visibility 1 mile. Some slight ice formed on bellmouth lip and on bellmouth flange. Small lump on floor below bellmouth. |
| 28/12 | 21 | 2 | -11.8 | 20 | - | Continuation of Run 20. No ice now on bellmouth, but slightly more on plenum floor. |
| 28/12 | 22 | 2 | -11.2 | 19 | - | Visibility 3/4 mile. No significant change in ice formation from previous 2 runs. |
| 28/12 | 23 | 3 | -10.6 | 32 | 35 | Snow generator on starboard side. Snow compacting at 9 o'clock on back side of bellmouth and moderate ice build-up on floor at 15 min. Some snow compacted on plenum roof, and some light fluffy snow adhering to outside of inlet cowlings. The formations in the plenum seemed to reach a stable condition after about 20 min. (Fig. 4). |

* Type of Run:
1. Supercooled water droplet icing.
2. Natural snow.
3. Simulated snow.
4. Water ingestion.



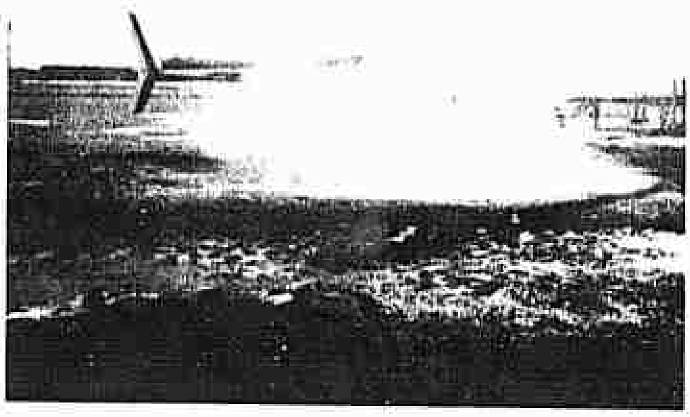


FIG.1: BELL 206A JET RANGER HELICOPTER

SNOW GENERATOR POSITIONED ON STARBOARD SIDE

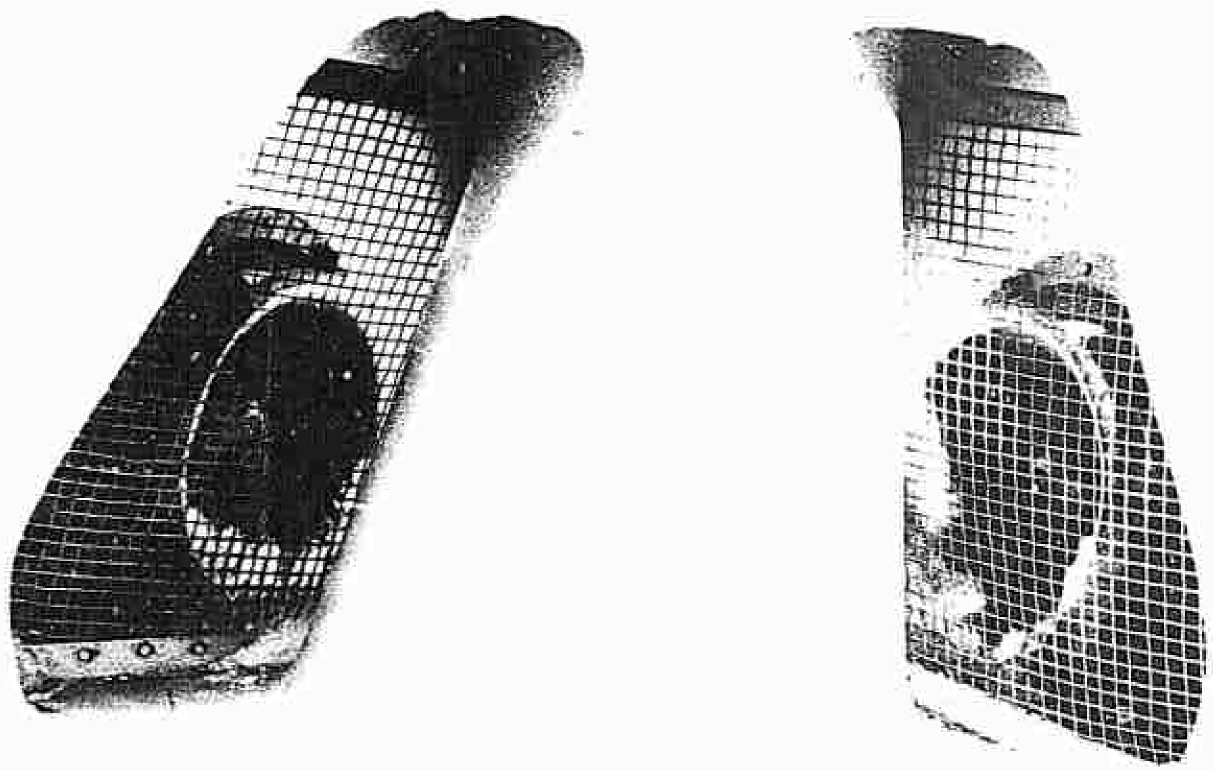


FIG. 2: ENGINE INLET AFTER TRIAL RUN WITH SIMULATED SNOW

RUN NO 6. 20 MINUTES AT -5° C. NOTE ICE RING IMMEDIATELY BEHIND BELLMOUTH LIP, RAGGED ICE FINGERS GROWING INTO BELLMOUTH AT BOTTOM, AND JAGGED MOUNDS OF ICE ON PLENUM FLOOR

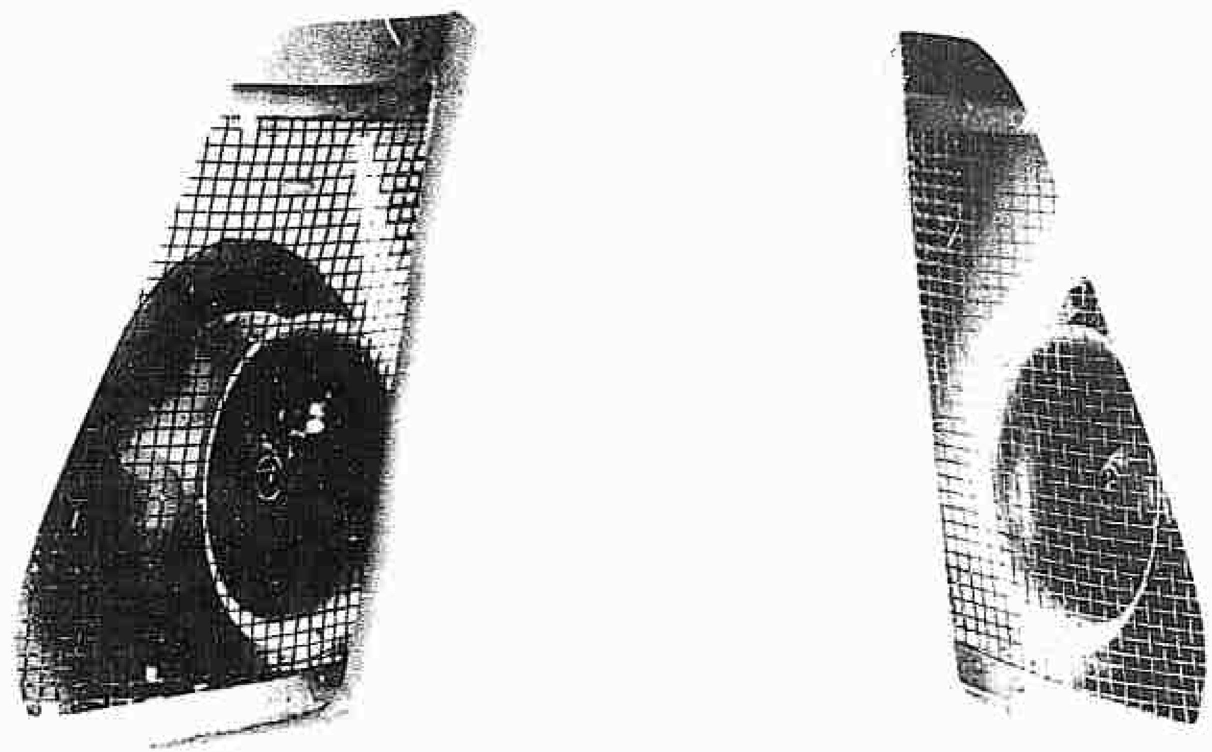


FIG. 3: ENGINE INLET AFTER 25 MINUTES OF SIMULATED SNOW AT -16°C

RUNS NO 18 AND 19. NOTE ABSENCE OF RING OF CLEAR ICE IMMEDIATELY BEHIND BELLMOUTH LIP AS AT -5° (RUN 6), BUT GREATER EXTENT OF PACKED SNOW EXTENDING OVER BELLMOUTH MOUNTING FLANGE. ICE BELOW LOWER PART OF BELLMOUTH AND ON PLENUM FLOOR

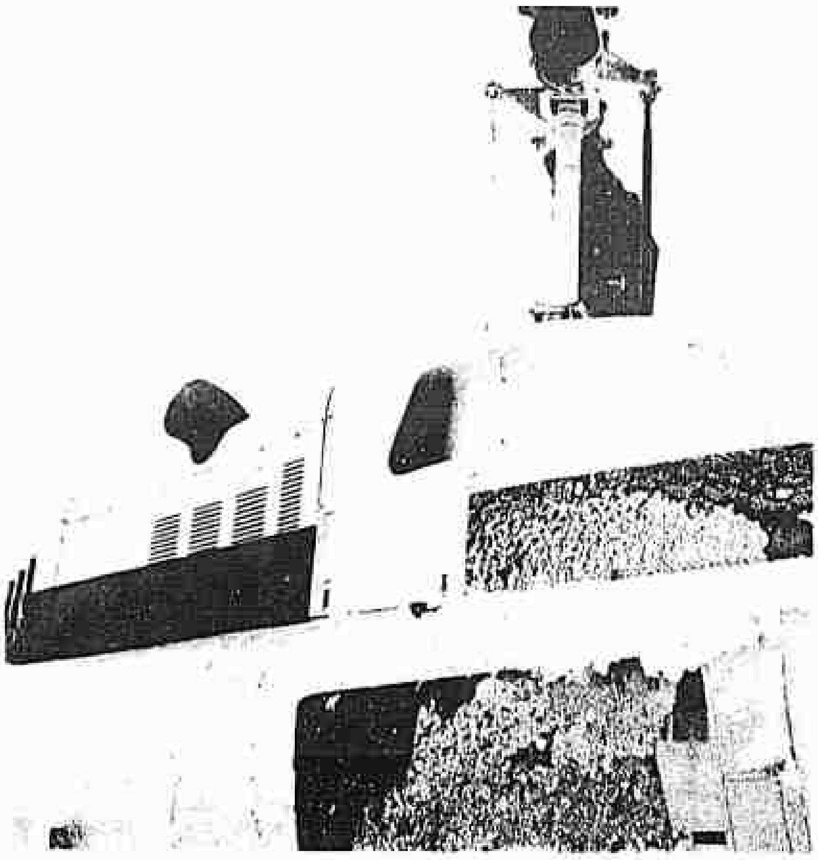


FIG. 4 : STARBOARD SIDE OF HELICOPTER AFTER 32 MINUTES OF SIMULATED SNOW AT -10·6°C

RUN NO 23. CONDITIONS WITHIN PLENUM SIMILAR TO FIGURE 3