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ICING OPERATIONS

(De-Icing Policy)

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Abstract **– The accumulation of ice, frost and snow on aircraft surfaces can drastically reduce the climb and maneuvering capabilities of an aircraft. The removal of such contamination prior to take off MUST be strictly adhered to in accordance with regulations and standards. The policy with respect to aircraft icing contamination should be "MAKE IT CLEAN AND KEEP IT CLEAN". All personnel associated with the dispatch and/or operation of aircraft share the responsibility for ensuring that no aircraft is dispatched unless it is clear of ice, snow or frost.**

Keywords - anti-iceing, de-icing, cold soaking, critical surface, non-newtonian fluid, stall, ice formation

I. INTRODUCTION

This article describes the requirements to meet regulations to ensure removal of all ice, snow, frost and slush from an aircraft prior to takeoff. There are many variables present in a de/anti-icing operation such as type and rate of precipitation, type and thickness of accumulation, ambient temperatures, aircraft temperature, wind etc. The information in this article are based on experience, but they may not meet every eventuality. So there must be judge the effectiveness of the procedure and adjust techniques to suit the conditions.

II. USEFUL TERMS

A. Anti-icing

Anti-icing is a precautionary procedure that provides protection against the formation of frost and/or ice and the accumulation of slush and/or snow on treated surface of an aircraft for a period of time during active frost, frozen precipitation, and freezing precipitation. The application of a freezing point depressant to a surface either following de-icing or in anticipation of subsequent winter precipitation is intended to protect the critical surfaces from ice adherence for a limited period of time. The fluid is capable of absorbing freezing or frozen precipitation until the fluid freezing point coincides with the ambient temperature. Once this fluid freezing point has been reached, the fluid is no longer capable of protecting the aircraft from ground icing conditions.

B. Cold Soaking

Ice can form even when the outside air temperature (OAT) is well above 0 C. An aircraft equipped with wing fuel tanks may have fuel that is at a sufficiently low temperature such that it lowers the wing skin temperature to below the freezing point of water. If an aircraft has been at a high altitude where cold temperature prevails, for a period of time, the aircrafts major structural components such as the wing, tail and fuselage will assume the lower temperature, which will often be below the freezing point. This phenomenon is known as cold soaking. While on the ground, the cold soaked aircraft will cause ice to form when liquid water, either as condensation from the atmosphere or as rain, comes in contact with cold soaked surfaces.

C. De-icing

De-icing is a procedure by which frost, ice, slush or snow is removed from an aircraft to render it free of contamination. De-icing is a general term for the removal of ice, snow, slush or frost from an aircraft's critical surfaces, by mechanical means, by the use of heat, or by the use of a heated fluid or a combination thereof. When frost, snow or ice is adhering to a surface, the surface must be heated and fluid pressure used to remove the contaminant.

D. Holdover Time (HOT)

Holdover time is the estimated time that an application of anti-icing fluid is effective in preventing frost, ice, slush or snow from adhering to treated surfaces.

III. FLUIDS

A. De-Icing Fluid, Type 1

This fluid is usually manufactured using either Ethylene or Propylene Glycol as its base. The fluid will begin to move immediately upon application of a stress. It has no yield stress to overcome before flow begins. These fluids give anti-icing protection for only a short time, and are heated for use as a de-icing agent. The temperature makes the viscosity change but shear stress does not.

As a result of extensive research and testing showing that holdover times of Type 1 fluid are shorter on composite surface than on aluminum surfaces.

B. Anti-Icing Fluids, Type 2.

This fluid is usually manufactured using either Ethylene or Propylene Glycol as its base. Type 2 fluid provides longer Holdover Time than Type 1 and was used in aviation industry for anti-icing. Type 2 fluids were replaced in recent years by Type 4 fluids as Type 4 provides better Holdover Time potential. They are usually very viscous at low levels of shear stress. When shear stress increases, their viscosity decreases very quickly. Temperature and the shear stress applied can change the viscosity of these fluids.

C. Anti-Icing Fluids, Type 4

This fluid is usually manufactured using either Ethylene or Propylene Glycol as its base. This is considered to be a Non-Newtonian fluid as its viscosity is both shear and time dependent. The shear rate of a Non-Newtonian fluid is not directly proportional to the shear stress. The fluid will not begin to move immediately upon application of a stress, it has yield stress to overcome before flow begins. However, the shear capability of Type 4 fluid decreases dramatically at temperatures below their Lowest Outside Use Temperature (LOUT). These fluids have good anti-icing capabilities providing better Holdover Time potential than earlier fluids.

Research has shown that propylene glycol (PG) and ethylene glycol (EG) fluids behave differently under certain temperature and ice pellet precipitation conditions. Specifically, higher aircraft rotation speeds are required to effectively remove PG fluid contaminated with light or moderate ice pellets at temperatures less than -10C. Therefore, there is no allowance time associated with the use of PG fluids on aircraft with rotation speeds of less than 115 knots in conditions of light or moderate ice pellets at temperatures below -10C.

Furthermore, recent research with newer generation type airfoils has shown that the allowance times are shorter when using PG fluids under certain conditions. Since it is challenging to determine exactly which aircraft may be affected, the allowance time when using PG fluids at temperatures of 5C and above is limited to 15 minutes in moderate ice pellets.

IV. ICING HAZARDS

Regulations required that takeoffs may not be attempted if frost, snow, ice, or other contaminants are adhering to the lifting surfaces or flight controls of the aircraft. These regulations provide that a light coating of frost is permissible from fuel cold soaking. All fuselage vents, leading edge devices, control surfaces, fuselage and the upper surfaces of the wings and horizontal stabilizers must be completely clean of all adhering contaminants. Regulations also require that no aircraft may be knowingly dispatched with an inoperative Auxiliary Power Unit (APU) to an airport where de-icing may be required unless engine ground start facilities are available.

A. Aerodynamic Effects

The normal variation of lift with angle of attack can be significantly altered by the accumulation of ice on the wing. “Wind tunnel and flight tests indicate that ice, frost or snow formation on the wing leading edges and upper surface having a roughness equivalent to medium or course sandpaper can reduce lift by as much as 30%, and increase drag by 40%”(7). The changes in lift and drag will significantly increase stall speed, possibly above stall warning actuation speed (stick shaker), reduce controllability and seriously alter flight characteristics. With the aircraft in motion, air flows over the wing smoothly, following the shape of the airfoil. The lift that the wing produces varies directly with the angle of attack of the wing. At a fairly high angle of attack, it becomes increasingly difficult for the air to follow the airfoil shape and it begins separating from the wing. When the airflow is essentially separated, the wing is considered stalled. Between the point where the airflow begins separating, and the actual stall, is an area sometimes referred to as “stall onset”. In this area flight characteristics become increasingly degraded as the angle of attack is increased. This is considered the normal variation of lift with angle of attack. However, this normal variation can be significantly altered by ice contamination. The effect of this contamination is such that it reduces the maximum lift capability of the wing and causes stall to occur at a lower angle of attack. These effects can become quite large consequently a pilot may encounter buffet, pitch and roll pre-stall flight characteristics during a normal takeoff.

B. Stall

When an aircraft is trimmed for takeoff, the stabilizer is set to balance the moments due to both aerodynamic forces and centre of gravity location, such that the stick force at climb-out speed will range from none to a slight pull. This balance is upset by wing ice contamination, particularly on a contemporary aircraft having a tapered swept wing. With contamination on the wing, the aircraft would behave as if it is mis-trimmed in the aircraft nose-up direction. This will result in the aircraft pitching up more rapidly than normal during takeoff rotation and will require an abnormal push force to maintain the desired airspeed during climb. This effect becomes greater as the amount of ice contamination increases. Ice contamination also affects the lateral or roll characteristics of an aircraft. Typically, as the angle of attack increases into the “stall onset” range, the increasingly unstable airflow over the wing and ailerons results in a corresponding degradation in lateral stability requiring larger and larger control deflections to keep the aircraft from rolling off. This degraded stability occurs at lower angles of attack as the amount of contamination increases. To compound an already hazardous situation uneven lift resulting from one wing carrying more contamination than the other can create an additional roll tendency. Significant increases in stall speed, also occur at a much lower than normal angle of attack. This can have at least two adverse effects.

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First: many contemporary stall-warning systems are actuated at a pre-scheduled angle of attack. If wing ice contamination causes stall to occur before reaching this pre-scheduled angle, the flight crew will receive no warning of impending stall.

Second: the reduced stall angle of attack is compounded by the tendency of an ice-contaminated aircraft to pitch up during takeoff rotation such that there is an increased risk of exceeding the stall angle shortly after lift-off.

Lift and stall speed are not the only flight characteristics affected by wing ice contamination. The increase in drag can be such that the difference between the thrust available and aircraft drag can adversely affect climb capability and may result in the inability to climb if an engine fails during takeoff.

Weight is another factor. Although it is difficult to determine the additional weight attributed to various types and amounts of contamination it is reasonable to assume that the increase in weight is significant.

Decreased performance resulting from an engine failure combined with a contaminated aircraft can only be increased when the additional weight is considered.

V. FLIGHT CREW PROCEDURES

A. External Inspection

When conditions warrant, a visual inspection of the aircraft critical surfaces must be conducted. In most instances where inspection is required the need is obvious, however, close attention should be given to those times when the need to deice/anti-ice is possible but less likely. The inspection should be conducted from a vantage point that provides a clear view of the area to be checked. Areas to be given particular attention are:

1 – Wing surfaces and leading edges

2 – Horizontal and vertical stabilizers

3 – Control surface cavities

4 – Fuselage

5 – Air data probes, static vents and angle of attack sensors

6 – Engine intakes

7 – Air conditioning intakes

8 – Landing gear and wheel wells

“Flight Crew must inspect the aircraft during turnarounds for ice, snow or frost not removed by aircraft anti-ice systems. Any contamination that has formed on critical surfaces from airborne accumulation must be removed prior to takeoff. Also, attention should be paid to landing gear, flaps, etc., for slush, which may have accumulated during taxi.”(6)

Generally the inspection prior to de-icing will be carried out by the flight crew. Usually this can be a visual check but if there is a suspicion that clear ice exists, touch is the only acceptable method of detection. Remember, underlying snow or slush can be a layer of clear ice.

Ice that has built up on aircraft surfaces during a descent will, if temperatures are low enough, remain on the aircraft. This ice can be hidden from view as is the case where it has formed on the flaps prior to retraction after landing. These deposits must be removed before any subsequent flight. It is important to note that the rate of ice formation is considerably increased by the presence of an initial depth of ice. Ground personnel must be advised when flight in icing conditions has been encountered. When slush is present on runways or taxiways there is a requirement to check the flap area for slush/ice accumulations and damage. All accumulations must be removed prior to flight.

Under freezing fog conditions it is necessary to check the rear side of the fan blades for ice buildup. Any ice accumulation can be removed by directing low flow hot air onto the affected area.

Figure 1. Aircraft deicing (5)

During inclement weather it is necessary to check the engine inlets to ensure that no ice or snow has accumulated in this area. It is not uncommon for a warm engine to melt snow that has blown into an engine intake. This subsequently freezes and if not removed prior to engine start can be ingested and severely damage the rotor. If experienced during takeoff it will likely reduce available power and cause severe engine vibration resulting in the necessity to shut down the engine.

Figure 2. Icing accumulation (4)

VI. CONCLUSION

There have been many accidents caused by improper technique or bet using of deicing procedure recently and an investigation showed that it is vital to be familiar with the hazard. Keeping this in mind it should be helpful to insert topic connected with icing operation into recurrent not only into annual training which is every year set up on spring but connect it with operation proficiency check, that is twice a year. It should be done as review lesson or as a questioner. There are normally only parts dealing with knowledge of aircraft systems and another part could be very helpful for refreshing and due to safety as well. If we take into account that icing is a phenomenon which is dealing mostly during winter time it is reasonable refine each knowledge before winter season. This article could serves as refreshing material for crew or operators can take an advantage of this information and set up their own guidance. Another practice could be set up check list which is dealing with icing condition and incorporate it into normal check list operation. It could be part of normal check list. There could be in front of the "preflight check list" optional condition: "If icing conditions are presented go to deicing check list" and the deicing check list could be on the other side of normal check list. This technique could be very helpful and it allows avoiding any possible mistakes. All operators should keep in mind that safe operation is the core of aviation business.

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