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Ditching—Techniques, Hazards, and Survival: A Basis for Assessing Risk

General

Civil Aviation Authority Advisory Circulars contain information about standards, practices, and procedures that the Director has found to be an **Acceptable Means of Compliance (AMC)** with the associated rule.

An AMC is not intended to be the only means of compliance with a rule, and consideration will be given to other methods of compliance that may be presented to the Director. When new standards, practices, or procedures are found to be acceptable they will be added to the appropriate Advisory Circular.

An Advisory Circular may also include **guidance material (GM)** to facilitate compliance with the rule requirements. Guidance material must not be regarded as an acceptable means of compliance.

Purpose

This advisory circular provides advice to operators and pilots on ditching an aeroplane and provides a discussion on ditching techniques, and procedures that may enhance the chance of survival should a ditching become necessary.

The advisory circular also provides guidance on preparing a risk assessment before an extended over-water operation is carried out as required by rule 125.87(a)(3).

Related Rules

This advisory circular relates to Civil Aviation Rule Part 125 and specifically to rule 125.87.

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Ditching

Introduction

The aeroplane types operating under Part 125 are not required by the type design and certification process to have ditching certification. Therefore less attention would have been, or can be, paid to design factors that benefit ditching such as the height and location of exits, attitude of the aeroplane when floating, and so on.

The guidance material contained in this advisory circular is intended to provide operators conducting extended overwater operations under Part 125 with enough information to enable them to comply with the intent of rule 125.87(a)(2) and (3), and rule 125.363(3). These rules deal with ditching from a risk management perspective so that in the rare event that a ditching is required there will be an element of preparedness that will maximise the chances of survival.

Ditching is of interest to all operators who fly over water, regardless of the size of the aircraft, the size of the body of water, or the proximity to shore. This advisory circular has been drafted to include material that is general in nature which is applicable to medium fixed-wing aircraft and which may be applicable to other types of flight operations.

Definitions

Ditching means an emergency landing of an aircraft on water.

The hazards of ditching

Ditching an aeroplane is an extremely hazardous manoeuvre, and should only be considered when no other reasonable option is available.

During the ditching manoeuvre the ability of the airframe to remain intact depends to a large extent on the surface conditions at the time.

Compare two ditchings that occurred in 2009. The ditching of an IAI Westwind near Norfolk Island resulted in the main door being unusable and the fuselage quickly filled with water. The passengers and crew only just managed to get clear of the aeroplane before it sank.

In contrast, the 2009 ditching of an A320 in the Hudson river New York showed that a controlled ditching onto a body of relatively calm water may result in little damage to the airframe and it may remain intact, and float in a reasonably level attitude for a significant amount of time.

In a rough sea there is a strong possibility that the airframe may break up on impact with the water. The airframe of larger aeroplanes is likely to break into at least 2 pieces, breaking the fuselage at the front and/or rear of the wing root structure.

If the passengers and crew survive the ditching they then face a number of issues that will affect the likelihood of their continued survival until rescue occurs.

What are the issues?

Why ditch?

Some reasons for considering the ditching option are:

- (a) Fire: An uncontrollable fire may provide few options other than to put the aeroplane down as soon as possible.
- (b) Fuel exhaustion: Should the aeroplane be facing total fuel exhaustion it is best to use what fuel is left to make a controlled landing, be it on water or land.
- (c) Aeroplane performance or systems degradation: This can be due to total or partial loss of power (e.g. fuel exhaustion, volcanic ash encounter), or airframe, electrical or control issues that make continued controlled flight doubtful.

Whatever the reason to ditch, the decision to do so should be made early enough to allow a controlled landing.

Preparation

Plan

Having a plan is particularly important when faced with a ditching. A ditching is a manoeuvre that is flown according to a plan (**a water landing made under control**) as opposed to a crash into water (an uncontrolled water landing).

The plan needs to be made after making a number of considerations. Many of these considerations can be made ahead of time – a base plan for the operator's extended over-water operations. What is taken into consideration on the day will depend entirely on the circumstances the crew face at the time. However, this advisory circular has been written with the intention of providing sufficient information to assist in the formulation of a successful ditching plan.

It is ideal that a plan is flexible. The plan may need to be reviewed as the flight unfolds, but it is essential to **have a plan and act upon it**. Ditching is a high risk manoeuvre but following a well developed plan will increase the chance of survival.

Even a successful ditching may not mean survival for all. Unfortunately, even with the best preparation it must be accepted that such a high risk manoeuvre, even if perfectly executed, may result in fatalities.

Cabin

- (a) The amount of pre-ditching preparation that can be completed will depend on the amount of time available.
- (b) Loose items both in the cabin and flight deck area should be secured. A good place to put all the loose items is in a toilet cubicle if the aeroplane has one available.
- (c) Securing loose items is important because they not only become missiles which may cause injuries at impact, but they may also float should water enter the aeroplane. Floating debris inside the cabin may hinder evacuation.
- (d) Depending on the situation (nature of emergency, preparation time available, ditching environment) it may be prudent to don extra clothes prior to ditching to reduce the effects of hypothermia following water entry. Passengers should follow the directions of crew, and in any case, should avoid donning large loose clothing items such as overcoats which may become snagged when exiting the aeroplane.

- (e) All persons on board should don their life jacket but passengers need to be reminded by the crew **not** to inflate them until leaving the aeroplane.
- (f) The accessing, launching, and securing of life rafts needs to be called to mind.

Distress Call

- (a) The Mayday call should be made on the current radio frequency if in radio contact with air traffic services. The ELT should also be activated at this time.
- (b) If operating in oceanic airspace, distress calls should be made on 121.5 MHz, the appropriate enroute frequency, HF or via data link.
- (c) The transponder should be set to 7700.
- (d) Other aircraft may assist in relaying emergency details to ATS if direct contact is difficult.

The water landing

Power

Having power available allows control over the rate of descent and allows a greater choice of the actual touchdown point. Therefore the decision to ditch should be made while power is still available.

Aeroplane weight

As it is best to impact the water under control at the slowest possible speed, the best results would be achieved with a low stall speed i.e. low weight. Therefore, if practicable, excess weight should be jettisoned from the aeroplane prior to impact.

With modern aeroplanes the only action available to reduce weight may be to dump excess fuel but this is an avenue worth considering if a ditching is inevitable and the aeroplane is so equipped.

Aeroplane configuration

If required to ditch, the procedures found in the Aircraft Flight Manual (AFM) or Flight Crew Operating Manual (FCOM) should be followed unless another course of action is necessary in the interest of safety. Generally speaking, these procedures will call for the ditching configuration to be gear up, maximum flap and minimum approach speed. For fixed undercarriage aeroplanes a lesser flap setting could be an advantage to enable the aeroplane to rotate to a high nose attitude just prior to touchdown. However, a degree of judgement is required here as a high nose attitude limits forward vision which may have an adverse effect on the last and most important part of the approach.

Fixed gear aeroplanes may exhibit a violent nose down pitching moment which may cause the nose section to go well underwater after impact. The actual behaviour after impact will be different for each aeroplane type. Those with a significant portion of their structure in front of the main wheels may exhibit a less violent forward pitching moment.

Direction of ditching

Selection of the landing direction will to a large extent affect the outcome of the manoeuvre.

- (a) Rivers: There is limited choice available here; a landing along the axis of the river is usually the only manoeuvre possible. If time permits, choose the best wind option.
- (b) Lakes and small bodies of water: The size of the body of water, and its approaches will be the main considerations here. When considering a ditching in a smaller body of water, it is preferred to land into wind. This may have to be modified to accommodate terrain or obstacles near the shore. If possible land into wind, parallel and close to shore. Choose an

area which will allow easy access to the shore after evacuating the aeroplane. Landing adjacent to a cliff should be avoided! If circumstances allow, a low pass over the selected ditching area checking for objects just below the surface would be advantageous.

(c) Large bodies of water:

- (i) Smooth water or long swells: Land into wind. Follow the manufacturer's recommendations, if any, or those discussed above if there are none.
- (ii) Breaking waves or large swells: Once again follow the manufacturer's recommended procedure if any. If none is provided, then the best technique will be to land along the swell, accepting the crosswind and higher touchdown speed.

The best technique is to land on the top of the swell, or on the back of the swell. Try to avoid touchdown on the advancing face of the swell.

Endeavour to land in the water with the airframe aligned with the direction of travel. This may require considerable correction for drift in strong crosswinds. Landing in this manner will reduce the side loads on the fuselage structure and maximise the chance of maintaining structural integrity after contact with the water has been made.

(d) Night Ditching:

- (i) Unless there is 4 octas of cloud or less, and a full moon, judging surface conditions at night will be very difficult. Knowledge of the local weather forecast and in particular the swell state would be advantageous under these circumstances.
- (ii) Due to altimeter inaccuracies and local pressure variances a radio altimeter may be the instrument of choice when trying to gauge height above the surface during the approach.
- (iii) The GPS may be used to derive wind and drift data if flight can be sustained at low level long enough for the data to be displayed prior to ditching.
- (iv) Landing lights may be used to advantage but with caution due to their disorienting effect, particularly during periods of high wind, high sea and/or surface spray conditions.
- (v) Nearing the surface reduce the rate of descent to 200 fpm or less, or select the minimum approach speed.

Surface contact

It is best to land on the water under full control and as slowly as possible. Use remaining power to advantage and reduce the rate of descent to the minimum so that gentle contact is made with the surface.

Unless the landing attitude is specified by the manufacturer the optimum attitude for most types is about 10 degrees pitch up.

Try to ensure the wings are kept level so that they contact the water simultaneously. Should one wing tip contact the water first it can induce a large slewing motion which will result in loss of further control and a violent impact with the surface.

Evacuation

Some aeroplanes float nose high, so caution must be exercised before using the rear doors during the evacuation. The aeroplane is more likely therefore to sink tail first, so even the use of over-wing exits may not be advisable as this area could be immersed before the front exits are opened. Therefore, if the over-wing exits were opened the fuselage would fill with water quite rapidly and thus considerably reduce the “floating time” of the airframe. It should be noted that, for the type of aeroplane under discussion, the floating time may be very short in the best of circumstances.

Life rafts are often quite heavy and bulky, therefore crew members should enlist the help of able bodied persons when launching the life rafts (on aircraft not equipped with automatic slide rafts).

Post Ditching

Survival

General

Once the life rafts are in the water and inflated they should be tethered together to avoid drifting apart. It may be difficult for some persons to actually get themselves out of the water into a raft, so it is recommended that fit persons are the first in so they can assist others out of the water.

The environment may be hostile and not conducive to sustaining human life. Continued survival will depend on water and air temperature, wind and sea state, clothing, the availability of survival equipment and the physical condition of the survivors.

It is imperative that rescue be as quick as possible. To aid in the rescue effort, the emergency locator transmitters should be activated, and the flares should be ready to use if a ship or aircraft is heard or sighted.

Hypothermia

General

One of the prime causes of death is hypothermia.

If a person is immersed in cold water survival time will depend to a large extent on the onset of hypothermia. Just how that occurs and its effects on the body is the subject of a short discussion below.

Cold water

For the purposes of this advisory circular, cold water can be considered to be the temperature that triggers the mammalian diving reflex (refer page 9) – approximately 21 degrees Celsius¹ and less.

What happens in cold water?

The first hazards to contend with are panic and shock; and by shock we mean the physiological changes – e.g. heart rate and breathing. That initial shock can place severe strain on the body, producing instant cardiac arrest.

Survivors of cold water accidents typically comment that their breath is driven from their lungs on first impact with the water. If a person’s face is in the water during that first involuntary gasp for

¹ Definitions of “cold water” vary. A strict definition would be anything less than body temperature. However, Dr Alan Steinman, co-author of *Cold Water Immersion* notes that “significant risk of immersion hypothermia usually begins in water colder than 25°C”; while for the purposes of their regulations the United States Coast Guard define cold water as where the monthly mean temperature is less than 59°F (15°C).

breath, they are most likely to inhale water rather than air. Total disorientation may occur after cold water immersion. Persons have reported "thrashing helplessly in the water" for thirty seconds or more until they were able to get their bearings.

Immersion in cold water can quickly numb the extremities to the point of uselessness. Cold hands cannot fasten the straps of a lifejacket, grasp a thrown rescue line, or hold onto an over-turned raft. Within minutes, severe pain clouds rational thought. Finally, hypothermia sets in, and without rescue and proper first aid treatment, unconsciousness and death.

Normal body temperature is 37 degrees Celsius. Shivering and the sensation of cold can begin when the body temperature lowers to approximately 35.8 degrees. Loss of cognitive ability can begin to set in at approximately 34, unconsciousness at 30 and death at approximately 26 degrees.

What to do in the water

Cold water robs the body's heat 32 times faster than cold air. If a person should fall into the water, all efforts should be given to getting them out of the water by the fastest means possible.

All crew members should be thoroughly skilled in rescue and self-rescue techniques.

Physical exercise such as swimming causes the body to lose heat at a much faster rate than remaining still in the water. Blood is pumped to the extremities and quickly cooled. Few people can swim a mile in water which is only 10 degrees. Should you find yourself in cold water and are not able to get out, you will be faced with a critical choice: adopt a defensive posture in the water to conserve heat and wait for rescue, or attempt to swim to safety.

Swimming or treading water will greatly increase heat loss and can shorten survival time by more than 50%. Even a strong swimmer should not attempt to swim to shore if it is more than 2kms away.

The major body heat loss areas are the head, neck, armpits, chest and groin. Survivors should, even if out of the water in a raft, huddle together or in groups of about 4 persons facing each other with upper and lower bodies pressed close together to maintain body heat. Children should be placed in the middle of the huddle.

First aid considerations for cold water victims

Treatment for hypothermia depends on the condition of the person. Mild hypothermia victims who show only symptoms of shivering and are capable of rational conversation may only require removal of wet clothes and replacement with dry clothes or blankets.

In more severe cases where the victim is semi-conscious, immediate steps must be taken to begin the re-warming process.

The person should be removed from the

Further information

If advanced rescue equipment is available it can be administered by those trained in its use. Warm humidified oxygen should be administered by face mask.

Immediately attempt to rewarm the victim's body core. If possible, place the person in a bath of hot water at a temperature of 40 to 43 degrees. It is important that the victim's arms and legs be kept out of the water to prevent "after-drop". After-drop occurs when the cold blood from the limbs is forced back into the body resulting in further lowering of the core temperature. After-drop can be fatal.

If a tub is not available, apply hot, wet towels or blankets to the victim's head, neck, chest, groin, and abdomen. Do not warm the arms or legs.

Never give alcohol to a hypothermia victim.

water and placed in a warmer environment. Remove the clothing only if it can be done with a minimum of movement of the victim's body. Do not massage the extremities.

Lay the semi-conscious person face up, with the head slightly lowered, unless vomiting occurs. The head down position allows more blood to flow to the brain.

In a ditching situation there will be little or no equipment available; a rescuer may use his or her own body heat to warm a hypothermia victim.

Some important facts to remember

Most persons recovered in cold water “near drowning” cases show the typical symptoms of death:

- (a) Cyanotic (blue) skin coloration;
- (b) No detectable breathing;
- (c) No apparent pulse or heartbeat;
- (d) Pupils fully dilated.

These symptoms do not necessarily mean that the victim is dead but rather it is the body's way of increasing its chances of survival through what scientists call the mammalian diving reflex. This reflex is most evident in marine mammals such as whales, seals or porpoises. In the diving reflex, blood is diverted away from the arms and legs to circulate (at the rate of only 6-8 beats per minute, in some cases) between the heart, brain and lungs. Marine mammals have developed this ability to the point where they can remain under water for extended periods of time (over 30 minutes in some species) without brain or body damage.

Humans experience the diving reflex but it is not as pronounced as in other mammals. The factors which enhance the diving reflex in humans are:

- (a) Water temperature – at less than 21 degrees, the response is more profound and perhaps more protective to the brain;
- (b) Age – the younger the victim, the more active the reflex;
- (c) Facial immersion – the pathways necessary for stimulating this series of responses seem to emanate from facial cold water stimulation.

The diving reflex is a protective mechanism for humans in cold water immersions, but it may confuse the rescuer into thinking the victim is dead. Resuscitative efforts for these victims should be started immediately utilising CPR.

It has been recorded that numerous children have been recovered from freezing water after 30 minutes and been successfully resuscitated.

Expected Survival Time in Cold Water²

Water Temperature	Time to Exhaustion or Unconsciousness	Expected Survival Time
21–27°C (70–80°F)	3–12 hours	3 hours – indefinitely
16–21°C (60–70°F)	2–7 hours	2–40 hours
10–16°C (50–60°F)	1–2 hours	1–6 hours
4–10°C (40–50°F)	30–60 minutes	1–3 hours
0–4°C (32–40°F)	15–30 minutes	30–90 minutes
< 0°C (<32°F)	Under 15 minutes	Less than 45 minutes

Carriage of survival provisions

Carrying the required life rafts, life jackets, ELBs, flares and other flotation and attention getting devices is one thing, but how long will the average person survive without food and water while waiting for rescue?

(a) Requirements for food

Most doctors agree that a healthy human can go for up to 8 weeks without food. People have survived a longer period and been fine, while others have starved to death in less time.

Being in good physical condition can assist in living longer, but so does having extra body fat. The body stores energy it needs to survive in the form of carbohydrates, proteins and fat. Without food coming in the first to be used from the body stores are the carbohydrates, then the fat and last of all the protein. If the body is using protein it is basically feeding on itself and the situation is becoming critical.

Metabolism plays a part too. A person with slow metabolism will burn food at a slower rate and be able to survive longer. If no food is ingested the metabolic rate automatically slows down to adjust the rate of fuel burn in an effort to make energy stores last longer.

Extreme heat or cold will decrease survival time without food.

(b) Requirements for water

Living without water is very different from living without food. In hot conditions with no water dehydration can set in within an hour.

Humans lose water through sweat, urine, faeces, and breathing. This water needs to be replaced in order for the organs to work properly. In severe heat an adult can lose as much as 1.5 litres of water through sweat alone per day [source Scientific American].

In average weather conditions, and at a reasonable level of physical fitness, the average human can live for 3 to 5 days without water. An average human needs about 2 litres of water per day.

² These survival times are guidelines for the average adult wearing a life preserver. This table, or variations of it, are commonly found on the internet; in this case it was drawn from the United States Search and Rescue Task Force web site - http://www.ussartf.org/cold_water_survival.htm

(c) Points to Remember

Carry sea-sickness medicine and, where appropriate, administer it straight away. Most people will succumb to sea sickness quickly which leads to dehydration.

UV exposure also needs to be managed – stay under cover or apply sun screen (if available).

The USMC Marine Combat Water Survival Manual states the following rules:

- DO NOT drink saltwater.
- DO NOT drink urine.
- DO NOT drink alcohol.
- DO NOT smoke.
- DO NOT EAT unless water is available.

In regard to drinking sea water the U.S. Navy found the following after studying a batch of shipwrecked sailors from the Second World War:

	Total number	Number who died	Death rate
Those that drank sea water	997	387	38.3%
Those that did not drink seawater	3,994	133	3.3%

Therefore it can be seen that by far the most important consideration when flying over water is to carry sufficient supplies of potable water for each person on board. The emergency supplies need to be in containers that can be easily removed from the aeroplane if required for use. How much water will depend on the outcome of the pre-flight risk analysis which should consider all the factors surrounding rescue from the most inaccessible point along the proposed track.

Training

Training in most cases will be limited to scenario based discussion and practical ditching drills. These are best conducted in a controlled environment and some operators have employed quite sophisticated wet simulators for this purpose.

Smaller organisations can nevertheless make use of and obtain worthwhile training benefits from utilising the local council swimming pool complex. Best results are obtained from exercising in water more than 2 metres deep so that participants can extend to their full body length without touching the bottom.

Training of flight crew should include the practice launch of rafts, entry into them from the water, donning life jackets when in the water and fully clothed, assisting others into rafts and erection of the raft canopy, and anti-hypothermia techniques etc.

Note: Some rafts may not be suitable for use in the aeroplane again after being exposed to chlorinated or salt water. Use a raft that is dedicated to training and will not be required for in-service use.

Risk Assessment and Mitigation

General

The aviation industry faces a diversity of risks every day as a by-product of doing business. Not all risks can be eliminated, nor are all conceivable risk measures economically feasible – hence the term ALARP (As Low As Reasonably Practicable). The level of risk exposure for a given context is determined by the consequences and likelihood (or probability) of the hazardous event occurring. Having analysed the risk for a given activity, the operator must then decide whether—

- the level of risk is acceptable as is; or
- action needs to be taken to reduce the risk to an acceptable level; or
- the risk needs to be avoided.

In the context of ditching an aeroplane into the sea, a river or a lake, the variables surrounding the landing on water are almost infinite and should be considered in the same light as any flight over hostile terrain. However, there are practical measures that the operator can take to reduce both the consequences (through enhanced survival and recovery opportunities) and the likelihood of a forced ditching.

In the example below, consequence has been described in terms of possible injury to the occupants after ditching through a series of escalating ‘word pictures’:

Consequence	1 Insignificant	2 Minor	3 Moderate	4 Major	5 Critical
Injury to person after ditching and before rescue	No injury or damage to health	Superficial injury requiring first aid	Multiple injuries requiring medical treatment, minor health effects that are reversible	Multiple serious injuries, permanent partial disability, irreversible health damage with serious disability or death	Multiple deaths or permanent total disability

Note: Each operator will have differing risks, the above is only an example and not to be used operationally.

Likelihood (of forced ditching) expressed from rare to almost certain:

Likelihood	Definition
A – Rare	Could occur but only in exceptional circumstances – possible with this fleet / type of aeroplane
B – Unlikely	Could occur in some circumstances and is known to have happened with this fleet / type of aeroplane
C – Possible	Will occur in some circumstances and has happened in the company before
D – Likely	Happens (or is expected to occur) weekly or monthly in this location
E – Almost Certain	Happens (or is expected to occur) daily or weekly in this location

By combining the two we arrive at a determination of risk level:

Likelihood	Consequences				
	1 Insignificant	2 Minor	3 Moderate	4 Major	5 Critical
A – Rare					
B - Unlikely					
C – Possible					
D – Likely					
E – Almost Certain					

Minimal		Low		Medium		High		Intolerable	
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Examples of risk reduction measures (mitigation):

Phase	Risk Mitigation	Enhanced Mitigation
Ditching	Operator compliance with MEL, additional equipment fitted to improve redundancy	Satellite Phone
	Staggered maintenance activity for critical systems (e.g. engine time in service)	EDTO maintenance philosophy
	Crew training	
	Fuel reconciliation checks	
Survivability	Appropriate life jackets for all passengers and crew	Adequate clothing for environment
	Life raft(s) for all passengers and crew	Redundancy / over capacity
	Water supplies	Survival packs
	Survival training	Survival training using own type of equipment normally carried
Rescue	Fixed ELT	Portable ELT, flares
	Route planning - proximity to means of rescue	
	Communications equipment	Automated Flight Information System, Aircraft Communication Addressing & Reporting System etc.

Further Reading:

ICAO Safety Management Manual 2nd edition – 2009
(http://www.icao.int/anb/SafetyManagement/DOC_9859_FULL_EN_V2.pdf)

FAA Safety System Handbook
(http://www.faa.gov/library/manuals/aviation/risk_management/ss_handbook/)

FAA Report AR-95/54 Transport Water Impact and Ditching Performance
(<http://www.nts.gov/Dockets/Aviation/DCA09MA026/419887.pdf>)

SKYbrary
(<http://www.skybrary.aero/landingpage/>)

Transport Canada – Risk Management and Decision Making in Civil Aviation
(<http://www.tc.gc.ca/CivilAviation/SystemSafety/Pubs/tp13095/menu.htm>)

Civil Aviation Safety Authority Australia CAAP253-1(0) – Ditching
(<http://www.casa.gov.au/download/caaps/ops/253-1.pdf>)