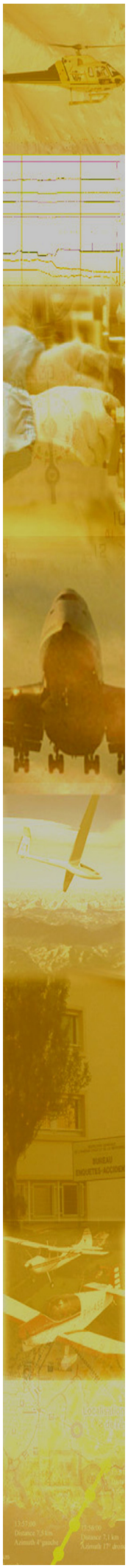
MINISTERE DE L'EQUIPEMENT, DES TRANSPORTS, DU LOGEMENT, DU TOURISME ET DE LA MER - BUREAU D'ENQUËTES ET D'ANALYSES POUR LA SECURITE DE L'AVIATION CIVILE



BEA

Fuel Starvation in General Aviation

STUDY

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Glossary

BKN	Broken cloud (5 to 7 octa), followed by the height of the cloud base
CAVOK	Visibility, clouds and current weather better than prescribed conditions
FEW	Sparse cloud (1 to 2 octa), followed by the height of the cloud base
FL	Flight level
Ft	Feet
IFR	Instrument Flight Rules
ITT	Private Aircraft pilot Instructor
JAR	Joint Aviation Regulations
Kt	Knot
Notam	Notice to airmen
NM	Nautical Mile
PP	Professional Pilot's License
SCT	Scattered cloud (5 to 7 octa), followed by the height of the cloud base
TT	Private aircraft pilot's license
ULM	Ultra-light motorized
VFR	Visual Flight Rules

CONTEXT OF THE STUDY

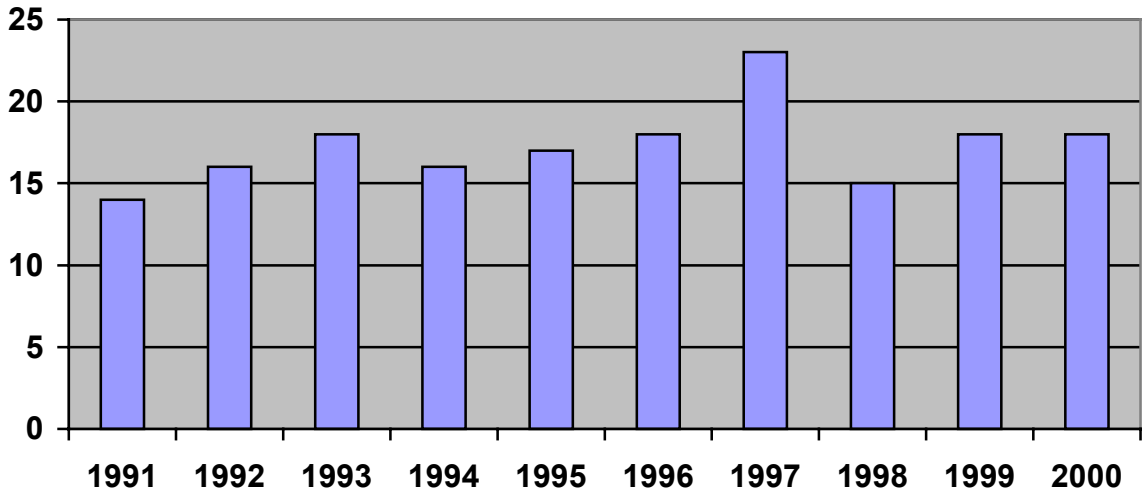
A study carried out by the BEA in 1995[1] showed that between 1991 and 1995, 79 accidents were due to fuel starvation and caused five fatalities and twenty-four injuries. Between 1996 and 2000, fifty-one accidents of the same type that caused four fatalities and twenty-two injuries and forty-one incidents were recorded: a total of nine fatalities and forty-six injuries between 1991 and 2000.

1 - NUMERICAL PRESENTATION OF FUEL STARVATION EVENTS

1.1 Annual distribution

The number of accidents directly linked to fuel starvation has not changed significantly in the last ten years. Every year the average has been seventeen accidents.

Fuel starvation events recorded by the BEA

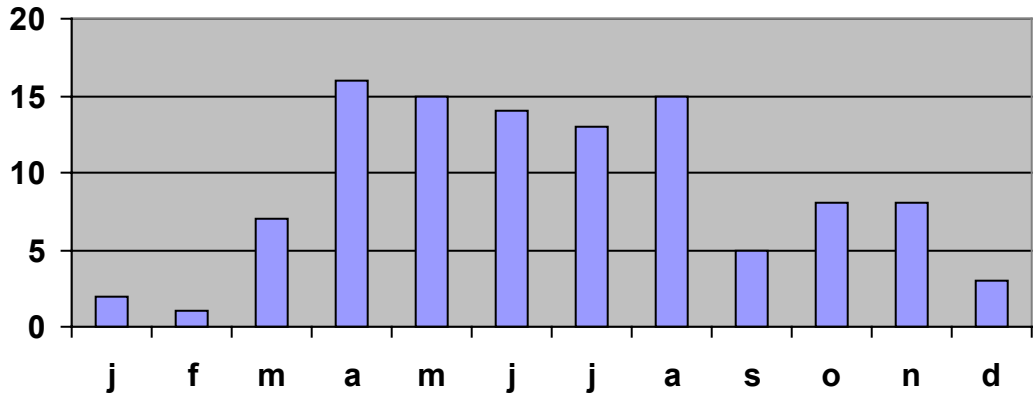


[1] The study was published by the BEA in the December 1995 bulletin.

1.2 Seasonal distribution

General aviation is a notably seasonal activity. The number of fuel starvation events is equally subject to seasonal variations. These variations are, however, modified by factors such as lack of training, in particular during the start-up of activity in the spring, or the strong desire to perform a flight at the beginning of the season, even if the meteorological conditions are unfavorable.[2]

Seasonal distribution of fuel starvation events during the period 1995 - 2000



1.3 Events studied

In this document, we will analyze in particular the fuel starvation events that occurred in the last three years.

In 1998, 1999 and 2000, thirty-one accidents and twenty incidents were brought to the attention of the BEA[3]. With the exception of five ULM's and a helicopter, they were events which occurred to light aircraft. There is a great degree of uncertainty as to the reporting of events involving ULM's and helicopters due to the fact that forced landings with these categories of aircraft usually only cause slight damage. The events that were notified to the BEA are accidents or incidents with very visible consequences. This study will thus concentrate on examining the forty-five events which occurred to light aircraft between 1998 and 2000.

[2] The study entitled "Objective : destination" published by the BEA in December 1998 shows that:
"One hundred persons were killed, in general aviation, during the period 1991-1996, in accidents which occurred when the objective of the pilot was to reach his/her destination. These pilots were faced with several obstacles:
- fuel starvation,
- unfavorable meteorological conditions,
- marginal lighting conditions."

[3] Since 1997 the BEA has collated its statistics on the basis of the international definition of an accident as defined by directive 94/56/CE. Certain events classified as accidents before 1997 have since been reclassified as incidents. This is particularly the case where material damage affected only the engine or the propeller.

2 - ANALYSIS OF ACCIDENTS/INCIDENTS

Between 1998 and 2000, only two examples of leaks were accepted as a descriptive factor in an accident and excessive fuel consumption was not a decisive during a fuel starvation event.

There are, on the other hand, numerous recurrent factors in this type of event, often having a cumulative effect. These causal factors occur during flight preparation and in the course of the flight itself.

2.1 Failings during flight preparation

Incomplete flight preparation was a factor in at least 75% of cases.

Insufficient attention to meteorological data, (wind, dangerous phenomena…) is cited to in seven events. Pilots, not having consulted the aeronautical meteorological forecast, met with strong headwinds and/or dangerous meteorological conditions that obliged them to change course en route. Delays due to a headwind, even a slight one, are particularly important for a slow aircraft.

Consulting Notams for the planned flight is also important. A pilot who had not informed himself of the availability of the destination aerodrome, where an air show was taking place, did not request priority for landing. He was obliged to make an emergency landing near the aerodrome.

Flight preparation can also be incomplete or erroneous, with a fuel estimate calculated cut to a very fine margin[4]. Thus a pilot, who ran out of fuel, had to make an emergency landing: the quantity of fuel required to undertake the flight was, according to his calculations, 92.59 liters while the possible quantity for the aircraft type was 93 liters[5].

The previous example also underlines the problems of **knowledge of the aircraft being used**. The quantity of useable fuel is always lower than the capacity of completely full tanks.

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[4] Article 5.6, relating to refueling and fuel reserves, in the order of 24 July 1991 specifies that :
"The captain must ensure, before any flight, that the quantities of fuel, lubricants and other consumable products will allow the planned flight to be performed, with an acceptable safety margin.
In no case may these quantities be less than those required to:

- reach the planned destination, taking into account the most recent meteorological forecast, engine speed, and planned altitude or, failing this, the quantities required without any wind increased by ten per cent;
- in addition, under I.F.R., if one or several alternate aerodromes are included in the flight plan, to reach the furthest aerodrome;
- and to continue the flight at economical cruising speed;
- in day V.F.R. for twenty minutes, except for ULM's and lighter-than-air craft;
- in night I.F.R. and V.F.R. flight, for forty- five minutes, whatever the type of aircraft.
- No one may undertake a local flight from his/her point of departure without adequate quantities of fuel to fly:
- in day V.F.R., for thirty minutes ;
- in night I.F.R. and V.F.R, for forty-five minutes.

No one may undertake a flight around an appropriate landing site if there remaining quantity of fuel on board is not sufficient to fly for fifteen minutes."

[5] Accident on 18 May 1999 to an F 152 (extract from May 1999 Bulletin).

In this example, the pilot had also failed to adjust the richness of the mix in relation to the altitude: the flight manual data no longer corresponded to the real consumption. Another pilot's engine cut out through lack of fuel; he was towing a streamer and the hourly rate of consumption used for his calculation was that of the aircraft alone.

In at least five accidents, the common element was an inadequate appreciation of the refueling possibilities at the destination aerodrome: flights to foreign destination without the correct currency, a refueling stop on a field without a fuel pump, fuel reserved for aircraft based at the aerodrome or impossibility of paying by credit card.

2.2 Failings during aircraft use

In several cases, investigations showed that the pilot had a false picture of the situation. Though intending to **perform a complete fill-up**, he did not completely fill the tanks. In fact, if the fuel nozzle is inserted fully into the tank, the automatic stop occurs before the maximum level is reached. This problem is accentuated when the pilot has to fill the tanks on an aircraft with high wings without a stepladder.

In addition, on certain aircraft, there is a fuel selector that allows fuel supply to reach the engine with both tanks connected (BOTH position). If, during fueling of one of the wing tanks, the selector is on BOTH, a part of the fuel from that wing is automatically transferred into the other wing. The pilot cannot perform a complete fill-up if the aircraft is parked on a sloping surface. These factors linked to fuelling were identified in several accidents.

In this area, a 1996 accident is particularly instructive. A pilot had to perform an emergency landing because the person who refueled the aircraft has added 88 Francs worth of fuel rather than the 88 liters requested. The pilot had not been able to perform a visual check as the refuel was partial.

In numerous cases, **information on refueling was not noted on the flight logbook or was erroneous**. The logbook is one of the main defenses against running out of fuel. The notations must be compared with the indications on the gauges[6] and with a visual examination of the level of fuel in the tanks when that is possible.

In seven cases, **faulty or inaccurate gauges** were identified. The quantity of fuel on board cannot be judged solely on the basis of the gauge indications.

[6] The JAR 23.1337 regulation mentions that fuel gauges are graduated to indicate as a zero value in level flight at a stabilized speed when the quantity of fuel remaining is equal to the usable quantity.

2.3 Failings during the flight

Seven events were due to problems of **tank selection**. In cases where the engine cuts out at a low height, a switch of tank after the first splutters does not always allow an in-flight restart. In three fuel starvation events, all of them on Jodels, the pilots were unable to say whether the fuel selector was in the forward or aft tank position, the position of the selector being difficult to interpret[7].

Some pilots use the totaliser integrated in the tachometer to count the flight time[8]. However, the indications on the totaliser are not a precise reflection of the real flying time (for example, flying a DR 400 with the engine running below 2 566 rpm, the totaliser reduces the flying time)

Several events also occurred during a tardy diversion, the remaining fuel autonomy making it impossible to reach either the destination aerodrome or the alternate.

Between 1998 and 2000, one fuel starvation event occurred with an instructor on board following an extension of the flight with no fuel estimate being carried out.

2.4 Decision to abort the flight

During at least eleven events, of which three with solo pilots in training, an element of **obstinacy** was noted. The pilots were conscious of the low quantity of fuel remaining but did not take the decision to abandon the flight.

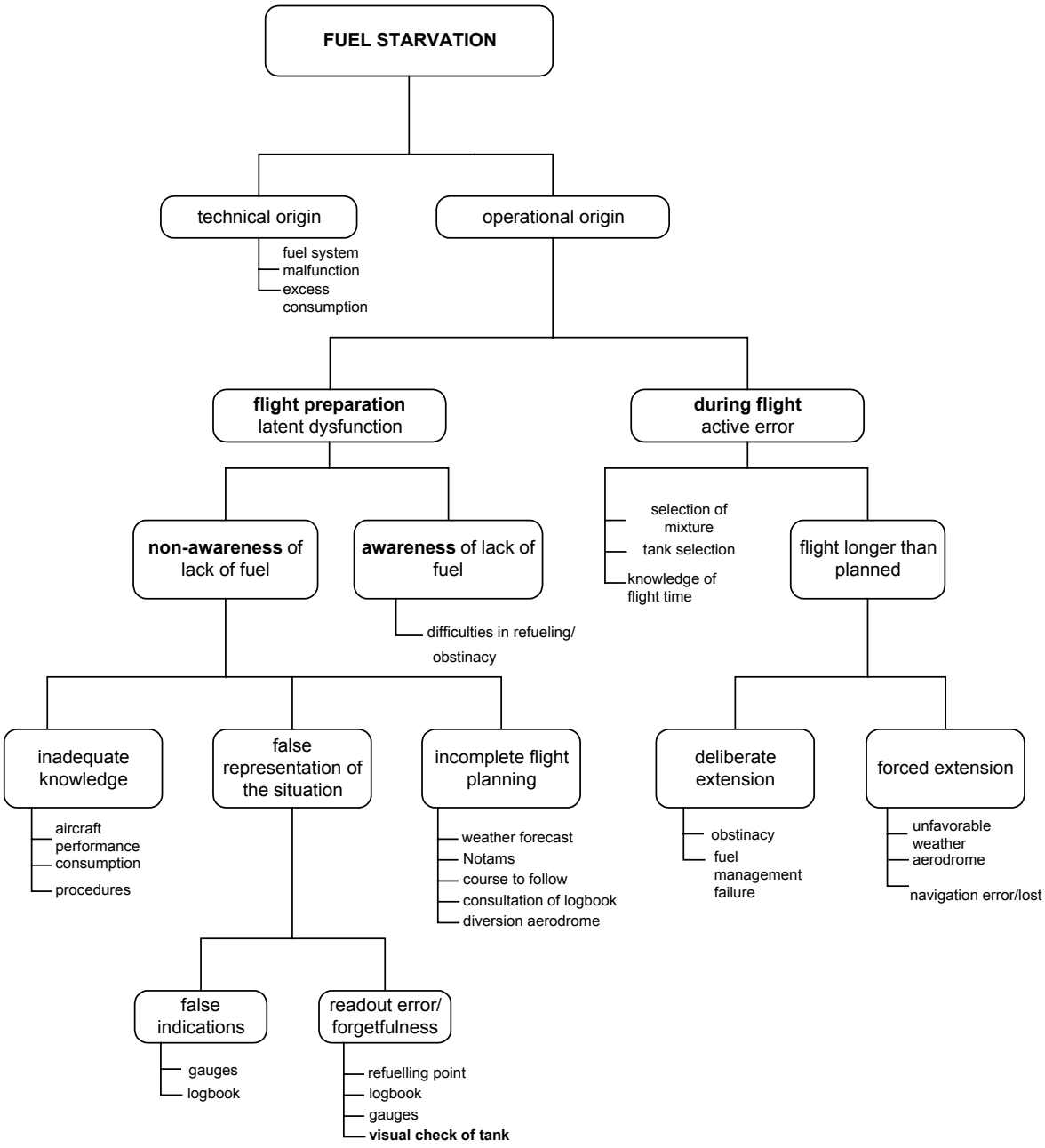
In contrast, for two other pilots who took that decision, the forced landing ended up causing no damage.

* *
*

The fault tree hereafter summarizes the situations that lead to fuel starvation.

[7] Incident on 17 January 1998 to a Jodel D 113 (extract from the January 1998 Bulletin in the appendix).
[8] Accident on 28 March 1999 to a DR 400-120 (extract from the March 1999 Bulletin in the appendix).

Tree diagram of factual sequences leading to accidents



This diagram is drawn from events studied. It is possible that other branches may be developed as a result of other events.

3 - CONCLUSION

Good knowledge of the performance and characteristics of the aircraft, as well as comparison between the information in the logbook, gauges and the level in the tanks are necessary to avoid fuel starvation. These elements are an essential part of flight preparation. Good fuel management during the flight will then allow the right decision at the right time: to divert or continue the flight.

4 - AVOIDING FUEL STARVATION

There follows, in the light of the events drawn from this study, a series of defenses that a pilot can use to avoid fuel starvation. The chronology of a flight has been chosen as a base for this list of defenses/checks.

- **<u>Flight Preparation</u>**

    - **Preparation of navigation/course**
        - route study, flight time, possibility of refueling at a stopover
        - study of meteorological dossier
        - study of Notams
        - fuel assessment
        - consideration of aerodromes for diversion

    - **Knowledge of aircraft**
        - performance, consumption
        - aircraft characteristics (characteristics linked to refueling, visual check, selectors ….)

    - **Update of information, pre-flight check**
        - weather update
        - quantity of fuel remaining
        - quantity of fuel added
        - total quantity loaded
        - comparison of data from the log-book, visual check, information from gauges

- **<u>Flight Management</u>**

    - **Fuel check**
        - precise knowledge of flight time elapsed
        - tank selection

    - **Re-planning of flight**
        - choice of diversion aerodrome
        - new fuel assessment

- **<u>In case of a critical situation</u>**

    - **Decision to abort the flight before running out of fuel completely**

    - **Precautionary landing**

List of Appendices

Extracts from the information Bulletin on accidents and incidents in general aviation

1) Incident on 17 January 1998 to a Jodel D 113

2) Accident on 28 March 1999 to a DR 400-120

3) Accident on18 May 1999 to an F 152

4) Accident on 28 April 2000 to a Cessna 336

Event *(incident)*:	engine cutout, forced landing.
Causes identified:	poor fuel management. poor management of engine cutout.

Damage and consequences: none.

Type of aircraft: Jodel D 113 (amateur construction).

Date and time: Saturday 17 January 1998 at 15 h 00.

Operator: club.

Place: La Roche-Blanche (63).

Type of flight : local.

Persons on board: pilot + 1.

Qualifications and experience: pilot 29 years old, TT February 1984, 282 flying hours of which 115 on type.

Meteorological conditions: wind 100°/04 kt, CAVOK.

Circumstances

The aircraft took off with 25 liters of fuel in the rear tank and 40 liters in the forward tank. After about 55 minutes flight the engine cut out. The aircraft was then flying at a height of 3,000 feet on a return bearing towards the departure aerodrome shortly before joining the aerodrome circuit. The pilot succeeded in restarting the engine but the engine cut out again a few seconds later. After vainly trying further restarts, the pilot landed the aircraft in a ploughed field free of obstacles.

On the ground, he noticed that the fuel selector was positioned on the rear tank that was empty.

The pilot explained that he was sure that the fuel selector was positioned on the forward tank since start-up before departure. He also explained that he had flown on Three Jodel's belonging to the club and that none of them had a fuel selector identical to the others.

Note: During the descent, he informed the ATC with which he was in contact and the fire service was alerted. Once on the ground, he asked an aircraft on a runway circuit to inform the ATC that the landing had taken place without problems.

Event *(incident)*:	fuel starvation, failed forced landing.
Causes identified:	poor fuel management.

Damage and consequences:	aircraft severely damaged.
Type of aircraft:	Robin DR 400-120.
Date and time:	Sunday 28 March 1999 at 16 h 34.
Operator:	club.
Place:	Carneville (50).
Type of flight :	trip.
Persons on board:	pilot + 2.
Qualifications and experience:	- pilot 60 years old, TT of 1990, 148 flying hours of which 35 minutes in the three previous months. - front passenger, TT of 1985, 734 flying hours. - rear passenger, TT of 1995.
Meteorological conditions:	wind 230°/09 kt, gusts to 17 kt, visibility over 10 km, FEW to 3,900 feet, SCT to 9,800 feet, temperature 13 °C, temperature of dew point 2 °C. wind at 500 m : 210°/15 kt ; at 1,000 m: 210°/20 kt.

Circumstances

The aircraft took off for a Cherbourg - Old Sarum (G-B) - Kemble (G-B) - Cherbourg flight. Each person on board was supposed to fly one route stage. Two other aircraft were participating in the trip. On the return to Cherbourg, the pilot contacted the control tower and requested priority for a semi-direct landing. On the base leg, the engine cut out and the pilot landed the aircraft in a field. The 110-liter tank was found to be empty.

The pilot stated that the estimated time of the flight was about three hours. The flight times noted on the logbook for the first two stages were, respectively, 1 h 10 and 55 minutes. The pilot stated that the flight time on the third stage was 1 h 42 (time deduced after readout of counter).

However, this counter, part of the tachometer, is directly linked to the engine rpm and is adjusted to be correct with an engine speed of 2,566 rpm. At a lower engine speed, this counter under-estimates the flight time. Thus it does not directly reflect the real flight time

During this flight the pilots flew in cruise at an engine speed of 2,400 rpm then 2,200 rpm, after the low level indicator light came on.

Hourly consumption at 2,400 rpm is about 24 liters per hour.

Refueling before the flight was not carried out by the pilot. Although 78 liters of fuel were added, it was not possible to state that the tank was full on departure.

The investigation showed that the aircraft had taken off from Cherbourg with an overweight of 18 kg.

Event:	fuel starvation, forced landing.
Causes identified:	incorrect flight preparation and failure to adjust the mixture during cruise.

Damage and consequences:	Aircraft damaged.
Type of aircraft:	Reims Aviation F 152.
Date and time:	Tuesday 18 May 1999 at 13 h 45.
Operator:	club.
Place:	Pissos (40).
Type of flight :	trip.
Persons on board:	pilot.
Qualifications and experience:	pilot, 43 years old, TT in 1993, 151 flying hours of which 31 on type and 9 in the three previous months.
Meteorological conditions:	evaluated at the site of the accident : wind south-south-east 6 to 12 kt, visibility over 10 km, BKN to 2,500 feet, locally stormy. The FL 50 wind chart possessed by the pilot showed an average wind of 15 kt from the south on the course.

Circumstances

The pilot took off at 10 h 20 from Toussus-le-Noble bound for Mimizan. At about 15 NM from his destination, he noticed a loss of power followed by engine misfiring. He decided to land in a field. The engine was still running on landing. The nose gear wheel stuck in the soft earth and the aircraft turned over onto its back.

The aircraft's left wing tank of was found to be empty, the right contained a few liters. The hourmeter indicated an operating time of 3 h 30 from startup.

The aircraft flight manual provides the following information:

- total fuel tank capacity 98 liters, usable fuel 93 liters,
- consumption of 23 liters per hour pour at a speed of 100 kt, at 4,000 ft at 2,450 rpm, with a standard temperature. To obtain this consumption a weak mixture is recommended.

The pilot explained that he had prepared his flight by taking into account consumption of 23 liters per hour. The trip fuel calculated for a distance of 318 NM is 73 l, for a flight time of 3 h 11. To this quantity he added 10%, 7 liters, as well as an extra reserve for 20 minutes of flight, 7.59 liters according to his flight plan. Taking into account an allowance of 5 liters for the taxiing, the pilot had decided on a regulation minimum fuel quantity of 92.59 liters.

Event:	fuel starvation, forced landing.
Cause identified:	inadequate knowledge of the aircraft leading to confusion in tank selection.

Damage and consequences:	Front propeller, left wing tip and tail damaged, nose gear collapsed.
Type of aircraft:	Cessna 336 "Skymaster".
Date and time:	Friday 28 April 2000 at 17 h 48.
Operator:	Company.
Place:	AD Montpellier Méditerranée (34).
Type of flight:	Check flight, following engine change.
Persons on board:	pilot + 1.
Qualifications and experience:	- pilot, 38 years old, PP of 1988, ITT of 1992, 5,840 flying hours of which 8 on type and 141 in the three previous months. Except for the stages performed on the day of the accident no flight on type for 13 months. - passenger, 29 years old, TT of 1997, PP October 1999, over 300 flying hours.
Meteorological conditions:	wind 030°/12 kt, visibility 5 km, BKN at 4,000 feet

Circumstances

The pilot landed at Montpellier Candillargues to refuel. Not having appropriate means of payment, refueling was impossible. The pilot then made a visual check of the level of fuel in the four tanks. The two outer tanks were empty but the two inner tanks contained enough fuel to perform the return flight planned to Béziers (65 km away). Nevertheless, the pilot decided to take off for Montpellier Méditerranée (9 km away) in order to refuel. At the end of the base leg to Montpellier Méditerranée, at a height of about 500 feet, the engines lost power. The pilot made a forced landing in a marshy area. During the roll, the nose gear collapsed, the aircraft turned over forwards then the left wing touched the ground and made a ground loop.

The pilot stated that he had positioned the selector on "main tanks", thinking that the latter were the inner tanks.