Mistral, G-MYST

AAIB Bulletin No: 6/2002	**Ref: EW/C2001/6/9**	**Category: 1.4**
Aircraft Type and Registration:	Mistral, G-MYST	
No & Type of Engines:	1 Rotax 532 piston engine	
Year of Manufacture:	1990	
Date & Time (UTC):	23 June 2001 at 1115 hrs	
Location:	Nash, Shropshire	
Type of Flight:	Private	
Persons on Board:	Crew - 1	Passengers - 1
Injuries:	Crew 1 fatal	Passengers 1 fatal
Nature of Damage:	Aircraft destroyed	
Commander's Licence:	Private Pilots Licence	
Commander's Age:	47 years	
Commander's Flying Experience:	67 hours	
	Last 90 days 1 hour	
	Last 28 days - nil	
Information Source:	AAIB Field Investigation	

Synopsis

The aircraft was being flown at low level in the general area of Tenbury Wells, Shropshire when it was seen to enter a spin or spiral dive from which it failed to recover. Both occupants were killed. Detailed examination of the engine revealed evidence of an abrupt engine failure caused by foreign object damage to the rotating disc valve. GPS data indicate that the aircraft was being flown very close to the stall just prior to the failure and it appears likely that the abrupt failure led to a stall and loss of control. The aircraft was being flown with the canopy removed and tests by the BMAA revealed that a limb accidentally extended into the airflow could lead to loss of control. Furthermore, part of the stall warning system was found to be insecure, and there was some doubt as to its effectiveness.

As a result of this accident, the BMAA intends to implement the following changes:

Mandatory fitting of a slip ball.
Mandatory requirement for canopy to be fitted for all flights
Mandatory fitting of ASI correction placard.

In addition, the BMAA will arrange the development of a more suitable stall warning device.

History of the flight

The pilot and owner of G-MYST had arranged to take two work colleagues for pleasure flights from Milson Airfield, near Tenbury Wells, Shropshire. The aircraft was normally kept at Otherton Airfield near Cannock, Staffordshire, and on the morning of 23 June 2001 the pilot flew his aircraft from Otherton to Milson landing at about 1020 hrs. The weather was fine and warm and the aircraft was flown with the detachable cockpit canopy removed.

After engine shutdown at Milson the pilot was met by his two colleagues who were already at the airfield and, following a short safety brief, the pilot and one of his colleagues got into the aircraft and prepared for flight. The take-off from Milson was uneventful and witnesses described the aircraft as apparently operating normally.

There was no pre-arranged plan for the pleasure flight but the two passengers lived in Tenbury Wells and it was expected that the flight would consist of flying around the local area viewing points of interest. A portable Global Positioning System (GPS) receiver fitted to the aircraft recorded the whole of the flight from Milson and showed the aircraft flying at an average ground speed of about 45 kt in the area around Tenbury Wells.

About 40 minutes into the flight the aircraft was seen by a number of witnesses flying at low level on a roughly north to north-westerly track about 3 miles north of Tenbury Wells. Most witnesses thought the aircraft was flying level, but slowly, and two witnesses, one of whom was an experienced glider pilot, thought the aircraft was flying out of balance. One witness who saw the aircraft from a car described the aircraft as being "tilted slightly to the left and slipping in the air like a car on ice". Without warning the aircraft was seen to yaw and roll rapidly into a very steep spin or spiral dive before disappearing from view just to the west of Harthall. Many of the witnesses were unable to hear the engine, either due to engine noise from their vehicles or because they were too far away. However, two witnesses thought they heard the engine fail just before the aircraft went out of control and one witness, located about 1.25 miles from the accident scene, thought that both the aircraft nose pitched up and the engine failed just before the aircraft entered the spin/spiral dive. (In consideration of the distance that these two witnesses were from the aircraft and the speed of sound in air, any engine failure was likely to have occurred some 6 seconds before any audible indication reached the witnesses). Several people proceeded in the direction that the aircraft was last seen and found it at the northern end of a field in an almost vertical nose down position with extensive damage to the cockpit area. Both occupants were trapped in the wreckage and were later certified dead at the scene.

Aircraft information

The Mistral is a three-axis, tricycle landing gear, microlight biplane, built by Aviasud Ltd in France. It is powered by a Rotax 532 two-stroke engine, located in the nose, and is fitted with a fixed pitch three bladed propeller of composite construction. The aircraft has side by side seating for the two occupants, with a single control column located in the centre between the two seats. Fuel is carried in plastic tank(s) located behind the seats. The BMAA stipulated never exceed speed for the Mistral is quoted as 80 mph (69 kt) and the stalling speed at maximum weight as 34 mph (30 kt).

The aircraft is highly unusual in two particular respects: firstly, in having swept forward wings and secondly, in having all-flying lower mainplanes in lieu of ailerons for roll control. Each of the lower mainplanes is pivoted on a pair of ball and socket joints positioned at approximately 30% chord, one at the wing root and the other at approximately mid span. The latter joint is supported by a vertical bracing strut connected at its top end to the upper mainplane spar, at the lift strut attachment point. The incidence of each lower wing is controlled directly by the pilot, via a system of rods and bellcranks linking the control column to the trailing edge of each wing, such that lateral movements of the control column move the trailing edges of the lower mainplanes in opposition to one another, in the manner of very large ailerons. The inboard end of each lower wing is fitted with a servo tab hinged to the trailing edge. With a ground-adjustable, fixed geometry, linkage to this tab a non-linear relationship between servo tab position and wing incidence is achieved. A specific aircraft's servo tab control characteristic will depend on the rigging of the wings and how the tab linkages have been adjusted. The overall characteristic of the system is such that the servo tabs will act primarily in opposition to pilot inputs (i.e. as an anti-balance tab) whenever the wing is at significant positive or negative angles of incidence. The servo controlmoments opposing pilot inputs are more pronounced in the positive wing incidence regime than for negative wing incidence and the wing incidence at which the servo tab control moment passes through zero will depend upon the individual linkage adjustment settings.

Pitch control is achieved via a conventional all flying tailplane, also equipped with an anti-balance tab, the linkage anchor point of which is adjustable in flight to trim the aircraft in pitch. The rudder is conventional and is operated by cables.

The aircraft User's Manual issued by the manufacturer makes the following comments on the aircraft's flight qualities:

> *At high angles of attack, the MISTRAL must be flown with rudder. If you move the stick roughly when approaching the stall, the MISTRAL will spin. You just need to release pressure on the stick to stop the spin. At all CG, the MISTRAL stops spinning spontaneously (1/4 to 3/4 turns according to the spin rate) if all controls are released. Your MISTRAL will recover itself, according to the trim adjustment, and will start to turn on the opposite side of the spin.*

Pilots experienced on type report that unbalanced flight will also increase the aircraft's tendency to drop a wing at the stall.

Aircraft background

A number of Mistral aircraft were imported to the UK from France in the late 1980s and the process by which the Mistral achieved its Permit to Fly in the UK was unusual. Normally a factory built microlight aircraft would be issued with a Type Approved Permit to Fly and this route is a UK only alternative to a C of A. However, the project to obtain Type Approval for these aircraft failed commercially leaving UK based owners with unapproved aircraft. Following lobbying of the CAA by these owners, the CAA tasked the BMAA to conduct an investigation into the aircraft with a view to the issue of a Homebuilt Permit to Fly. A Homebuilt Permit to Fly is considered a lower standard than a Type Approved Permit to Fly in that, although in both cases the aircraft is approved to the current certification standard (BCAR Section S, 'Small Light Aeroplanes', for this and most other microlight aircraft), only aircraft built by an approved manufacturer under CAA supervision qualify for Type Approval.

During the flight testing phase of the BMAA's investigation it was found that the aircraft could not meet the requirements of BCAR Section S207, which requires a clear warning of, and no more than 20° of initial roll at, the stall. In addition, the aircraft could not meet the lateral stability requirements of BCAR Section S177. As a result of these deficiencies the CAA Test Pilot made the following two recommendations:

The lack of lateral stability in a right sideslip could be acceptable for these aircraft as they will not be used for pilot training providing that deliberate sideslipping is not permitted.

The lack of lateral control at the stall when assessed against Section S requirements is likely to be due mainly to the unique design. The only solution that may be acceptable is to fit some form of artificial stall warning that would provide an adequate margin before the stall and meet S207.

On completion of its investigations in 1993, the BMAA issued Microlight Airworthiness Approval Note (MAAN), No. 1105. Addendum 2 to this MAAN required the installation of a stall warning system, various placards and the following amendments to the aircraft Users Manual:

Warning: This aeroplane is liable to:

a) Unstable roll at low airspeeds and b) low stability during side slip manoeuvres.

Use of Roll control input at low airspeed will seriously aggravate a wing drop. The following limitations must be observed:

- *Side slipping is prohibited*
- *Recovery from low airspeed must be carried out without roll control input, other than centring of the control stick away from roll input (and appropriate forward movement and use of rudder)*

The placards required to be fitted in the cockpit were to identify the stall warning light, to state that sideslipping was prohibited and that immediate speed recovery upon activation of the stall warning was necessary. G-MYST was fitted with a stall warning lamp but the required placard was not apparent, and no trace could be found of a placard requiring immediate speed recovery in the event of a stall warning. Also, the owner's copy of the User's Manual had not been amended in accordance with the BMAA MAAN.

Stall Warning System

G-MYST's warning system consisted of an angle of attack vane sensor, a warning buzzer and a lamp. The vane sensor was mounted on a bracket fixed to the left wing diagonal lift strut. The angle of the sensor housing could be set so that airflow changes would cause the vane sensor to trigger the system at an appropriate margin below the aircraft's stall. Operation of the vane activated a warning buzzer and the lamp in the cockpit, but the buzzer was not connected to the aircraft intercom system. Addendum 2 to the BMAA MAAN required the system to be set up to activate 5-6 kt before the aircraft's individually tested stalling IAS. The BMAA carried out tests on the stall warning system of the type fitted to G-MYST, on a similar microlight, to ensure that the buzzer was sufficiently loud to be heard when wearing a headset and with the engine at full power. However, tests with the canopy removed were not conducted. Pilots with considerable experience on type report that, notwithstanding these tests, the stall warning buzzer can be difficult to hear at high power settings.

Preliminary examination of the wreckage

The wreckage was examined in situ before recovery to the AAIB Technical Facility at Farnborough, where it was subject to detailed examination.

From the position and orientation of the wreckage in relation to witness marks at the impact point, it was evident that the aircraft had struck the ground whilst in a very steep spiralling dive, rotating to the left (viewed from above). At the instant of impact the nose was pitched down approximately 12° beyond the vertical and the aircraft was yawed approximately 20° right, causing the left wings to impact the ground slightly ahead of the right. The impact was non-survivable and resulted in major disruption of the cockpit.

The aircraft was complete and intact at the time of impact and no evidence was found at the scene to suggest that any pre-impact structural failure had occurred. No evidence of any disconnections was found in the remains of the flying controls which could not be directly attributed to the forces generated in the impact. The propeller blades had broken away from the hub on contact with the ground and the reduction gearbox casing had fractured, allowing the propeller shaft to detach from the engine. None of the propeller blades displayed any overt signs of engine power at impact.

The angle of attack sensor, which was installed on the left upper wing lift strut to provide artificial warning of the approach of the stall, was still in situ. However, it was noted that the sensor vane housing was not securely clamped to the back plate; consequently, the trigger point of the stall warning system would have been vulnerable to datum changes caused by accidental disturbance of the housing, for example, during ground handling before or after flight. Since the position for the housing is individually set according to flight test results, it could not be established whether the unit on G-MYST would have functioned reliably or if it would have operated at the required trigger point, nominally 5-6 kt before the aircraft's stall.

Detailed wreckage examination

Airframe fuel system

The fuel system fitted to G-MYST had evidently been subject to a number of modifications during the aircraft's history, which had included the installation of a second fuel tank alongside the main tank in the centre fuselage, just behind the seats. Elements of the dual tank system had subsequently been disabled, but it was not immediately apparent whether one or both tanks were being used at the time of the accident. Given that the Mistral's Homebuilt Aircraft Data Sheet (equivalent to a Type Certificate Data Sheet for an aircraft issued with a C of A) imposes limits on the amount of fuel which may be carried, together with the particular circumstances of this accident and the implications of CG position on aircraft handling qualities (the stall and spin characteristics in particular), the fuel system was reconstructed in order to establish its configuration at the time of the accident.

Detailed pattern matching of witness marks and fracture faces on the fuel system components showed that the secondary fuel tank re-fuelling gallery had been blanked off, suggesting that only the main tank had been in active use. However, most of the dual system fuel pipes were still installed on the outlet side of the tanks. Staining patterns on various fuel system filter screens and related components suggested that the secondary tank had not been in active use for some time. A motorcycle type shut-off valve on the secondary fuel tank outlet was found in the closed position, confirming that the secondary tank had been deactivated as a primary fuel source. However, a common water drain line formed an interconnection between the two tanks. Consequently, it would have been possible to fill both tanks, albeit at a very slow fill rate to the secondary tank, via the small bore water drain gallery as, over time, the tank fuel levels would have settled to a common level.

All of the fuel lines, including the vent lines, were checked and found to be clear of obstruction. The priming (bulb type) fuel pump in the cockpit was also clear of obstruction and appeared to function normally. The fuel shut off valve in the cockpit was in the OPEN position at the time of the accident.

Engine

The engine had suffered significant impact damage which included fracture of the reduction gear case and starter motor attachments. The carburettor and air cleaner had been torn away and were lying separately from the core of the engine.

Detailed strip examination of the carburettor revealed no evidence of any pre-impact abnormality. The inlet gallery was clear of obstruction, the float chamber was clean, the float was undamaged, moved freely and its valve seated correctly. The throttle cable was intact, the slide was free moving, the needle was undamaged and the main jet was clear. The fuel inlet pipe to the carburettor was ruptured internally but this had clearly been caused by the impact. The diaphragm type engine driven fuel pump was dismantled and no evidence of any defect found. The spark plug electrodes were of normal appearance.

Prior to bulk stripping the engine, preparatory movement of the crankshaft revealed a definite restriction when the crankshaft was turned. Progressive disassembly showed that the pistons, connecting rods, and crankshaft assembly were intact and there was no evidence of any bearing failure affecting the main, big end, or little end bearings. However, a small accumulation of bronze coloured metal shards was found inside the lower crankcase cover between the centre main bearings, together with a piece of broken gear. Further investigation revealed that the debris had resulted from a failure of the helical gear which drives a cross-shaft powering the water pump at one end and the induction rotary valve at the other. The failed gear, which meshed with a crankshaft gear set between the two centre main bearings, was found stripped and the resulting debris had evidently been projected with sufficient energy to carry it over the lip of a small web in the adjoining section of crankcase. This lip retained oil to form a small oil bath in which the gears meshed. The position of this debris on the far side of the web suggested that failure of the gear had occurred whist the engine was running at significant speed.

The rotary valve casing also forms the bifurcated inlet tract between the single carburettor and the two separate crankcase cavities. Upon removal it was apparent that the rotating valve disc, which is splined onto one end of the cross-shaft, had suffered foreign object damage at the leading edges of one of the valve cut-outs. Corresponding damage was noted at the edges of the valve port serving the rear cylinder. Secondary damage was evident within the disc valve cavity, caused by subsequent partial rotation of the damaged disc within the restricted confines of its housing. In light of this evidence, it was apparent that the cross-shaft drive gear had failed as a result of the disc valve having become jammed due to the ingestion of a foreign object. This would have resulted in an immediate engine stoppage.

Microscopic examination of the damaged valve assembly suggested that the foreign object had included a thin rectangular section with sharp corners, probably of the order of 0.6mm (0.025") in thickness, and that it was almost certainly of steel or some other hard material. The carburettor was re-examined in detail, in case any part had become detached and been ingested into the engine. It was confirmed that the nipple on the end of the throttle cable, which is a known potential source of a foreign object which may be ingested, was firmly in place on the cable and all screws, washers, and other items were in place. The air filter was found after the accident lying separately from the engine but, from the pattern of impact damage, it was possible to confirm that the filter had been securely fixed to the carburettor mouth at the time of impact. Consequently, it would not have been possible for the foreign object to have entered the inlet tract from outside of the intake filter. This was examined externally and then sectioned to provide access to the interior. The internal condition of the filter was good with no evidence of break-up or separation. With the exception of earth from the impact, the filter element was clean and no evidence was found to suggest that any foreign objects had been loose within, or lodged inside the folds of, the filter material.

In light of the gear failure, and the evidence of high rotational speed at the time when this failure occurred, it was not considered necessary to carry out further detailed strip examination and testing of the remaining engine components. However, a visual inspection did not reveal any abnormality and the ignition contact breaker points, in particular, were in good condition. It was noted that the water pump casing had been removed and the gasket replaced at some time in the engine's recent history, but there was nothing to suggest that these items had played any part in the engine failure.

Propeller and engine cowling

Of the three blades of the propeller, two were free of damage altogether; the third blade had evidently been trapped between the engine cowl and the ground in the impact. This blade was bent back and fractured in two places, one near the hub and the other close to the tip. Examination of the relevant parts of the engine cowl revealed red transfer (paint) marks indicating a linear contact region which extended backward along the top section of the cowl, just to the left of the centre line. These marks correlated closely with the damaged propeller blade and their overall character, together with a lack of smearing of the marks, was consistent with the propeller having been stationary at the time the aircraft impacted the ground.

Maintenance

The aircraft had a current Permit to Fly and the documentation included a CAA "Certificate of Validity - Permit to Fly" issued by the BMAA on 24 May 2001. The most recent inspection of the aircraft recorded in the aircraft log was for the Permit Renewal Inspection and Flight Test, which was dated 12 May 2001 at 492:40 total hours. The log book contained an unsigned entry, believed to have been made by the owner/pilot, and dated "2000" at 489.25 total hours which referred to replacement of the stall warning device. No specific entry was found in the log book, or anywhere else in the aircraft's documentation, which referred to removal or replacement of the carburettor air filter.

Meteorological information

An aftercast provided by the Meteorological Office indicated that the weather conditions over the UK on the day of the accident were generally fine with a high pressure system centred over the North Sea. This gave a slack south-easterly flow over the accident area. Visibility was 15 km with only a few scattered cumulus clouds at 4,000 feet amsl. Low level winds were light with a surface wind of 140° true at 5 kt increasing to 8 kt from the same direction at 500 feet, and 10 kt at 1,000 feet. With these reported conditions thermic activity would have been present producing, possibly, significant vertical motion of the air between the surface and the clouds.

GPS Data

The aircraft was fitted with a Garmin GPS Pilot III receiver mounted on a bracket attached to the instrument panel. Data recovered from the GPS memory after the accident provided time, track and ground speed information for both the positioning flight from Otherton and the accident flight. On the accident flight the data show that the aircraft departed from Milson to the south-west in the direction of Tenbury Wells. The aircraft orbited a point about 3 km north-west of Tenbury Wells and then flew a random route which eventually encompassed all sides of the town.

By applying an average wind of 140°/6 kt to the ground speed and track data, the airspeed during both flights was derived. As might be expected, the speed during the cruise from Otherton was quite stable at 50 kt, but during the accident flight the airspeed reduced significantly below 40 kt for several periods of up to one minute. Some of these periods of slow speed flight might be explained by local variations in the wind speed and direction, but equally it is possible that the airspeed was allowed to reduce, either intentionally or unintentionally, while the pilot surveyed points of local interest on the ground.

The last minute of data shows the aircraft in a very gentle left turn about 3 km north of Tenbury Wells. It was not possible to be precise about the point in the data where the aircraft departed controlled flight, and consequently the speed of the aircraft just prior to the engine failure could not be determined accurately. However, the derived airspeed at the start of the turn was approximately 49 kt and the speed decayed over a period of 47 seconds to about 34 kt.

Aircraft Safety Record

There are currently 12 Aviasud Mistrals on the UK register and the accident to G-MYST is the first one involving fatalities with this type in the UK. The exact number in service world-wide is unknown but just over two hundred were manufactured in France. The French Bureau Enquêtes-Accidents (BEA) report one similar accident in 1996 in which a loss of control occurred at low altitude. This also resulted a spin and the death of the two occupants. In addition there have been a further two non-fatal French occurrences of loss of control at the stall. Whilst investigating the accident to G-MYST, anecdotal evidence came to light of difficulties with control when the Mistral is flown with the canopy removed.

Tests and research

The process by which the Mistral achieved its Permit to Fly was unusual, and it remains a matter of judgement whether an aircraft with such sensitive handling characteristics at the stall should have been issued with a Permit. Nevertheless, the additional safety requirements introduced by the Mistral MAAN were sensible and, until this accident, the UK safety record for the type was good.

The BMAA's initial flight testing was conducted with the canopy fitted and anecdotal evidence of other control related incidents with the canopy removed suggested a need for further testing. It was therefore considered important for further flight tests to be conducted by the BMAA in order to establish the acceptability of the aircraft's handling characteristics with the canopy removed. In the meantime it was considered that the BMAA should advise Mistral owners that the aircraft should not be flown with the canopy removed until the results of these tests are available.

In the early stages of the investigation, the effectiveness of the stall warning system in alerting the pilot of an approaching stall came into question. In particular, the robustness of the design of the stall warning sensor and the audibility of the stall-warning buzzer gave cause for concern. The stall warning sensor vane housing was found insecurely attached to its backplate and it was possible that the warning trigger point had changed since the system's last annual inspection. Any change in this point would have altered the airspeed at which the stall warning activated. In addition, the stall warning buzzer is not designed to be wired into the intercom system and with both pilot and passenger wearing headsets, with the engine at cruise power and the canopy removed it was likely in any case that the stall warning buzzer would have been inaudible.

As a result of these concerns, the AAIB issued Safety Recommendations 2001-75 and 2001-76 which suggested that the BMAA should review the adequacy of the stall warning system and the aircraft handling characteristics with the canopy removed. In response to these Recommendations the BMAA designed a flight test schedule to address the issues. Subsequent to the publication of the Safety Recommendations, but before the tests were flown, evidence of engine failure came to light and it was therefore decided that the test flights would also investigate aircraft handling characteristics following a sudden engine failure at slow speed.

Two test flights were flown in February 2002. In summary the test flights found:

- *The stalling characteristics of the aircraft were poor, but acceptable when combined with a suitable artificial stall warning device. The existing device is adequately audible but erratic in operation and is considered unacceptable.*
- *The general handling of the aircraft with the canopy fitted and removed was satisfactory, but the aircraft tended to depart from controlled flight if an arm was put out of the side of the cockpit with the canopy removed. This feature was considered unacceptable.*
- *Sideslip forces were low and the pilot therefore had to rely upon the slip ball to maintain the aircraft in balance.*
- *The ASI fitted to the test aircraft exhibited gross errors, overreading by up to 28%.*

As a result of these findings the BMAA will require the following changes by 1 April 2002:

- *The mandatory fitment of a slip-ball.*
- *Mandatory fitting of a placard stating "Canopy is to be fitted for all flights".*
- *Mandatory fitment of an ASI correction placard.*

In addition the BMAA will institute action to arrange development of a suitable stall warning device, fitment of which will become mandatory.

During testing of a Mistral at maximum take-off weight, conducted previously by the BMAA, the rate of speed reduction from 44 kt IAS in level flight after simulating an engine failure by placing the throttle to idle was 1.7 kt per second.

Analysis

Evidence from eyewitnesses indicated that a loss of control and a spin or spiral dive occurred from a height at which recovery was not possible. Engineering evidence indicates that an abrupt engine failure occurred, however, this microlight is capable of gliding flight with a failed engine and stationary propeller and it is not immediately evident why such an engine failure should have led to a loss of control. In the absence of any other technical defects being discovered, the remainder of this analysis therefore examines the possible causes of the loss of control, based on the evidence available, and considers related aircraft airworthiness issues.

During the minute preceding the accident, GPS data indicate that the aircraft gradually lost speed at a rate of less than half a knot per second whilst in a gentle left turn. Eyewitness reports indicate that the aircraft was in level or slightly climbing flight before it entered its final manoeuvre. The GPS derived rate of speed loss is significantly less than the 1.7 kt per second recorded for simulated engine failures in level-flight, and tends to indicate that the engine was functioning for most of the last minute of flight. It is possible that a partial loss of engine power caused the recorded reduction in speed but, given the engineering evidence of an abrupt engine failure, it seems more likely that the engine functioned normally until immediately prior to the loss of control.

The speed in the last 45 seconds of controlled flight had gradually reduced to a few knots above the stall and the pilot would, therefore, have had very little time to react to an abrupt engine failure before the speed actually reduced to the stall. Flying slowly in conditions where updrafts generated by thermic activity are likely to be produced, could also precipitate a stall from a momentary increase in the angle of attack of the wings beyond the stall angle. If, as eyewitness evidence tends to indicate, the aircraft nose was raised, either by the pilot or due to thermic activity just before or just after the engine failure, the rate of speed reduction would have increased significantly and the time available to the pilot to prevent a stall would have been further reduced.

Several eyewitnesses indicated that the aircraft was not in balanced flight and if the aircraft stalled in this condition it is likely that it would have rapidly entered a spin. On the other hand the aircraft was operating with the canopy removed and, given the relatively confined space available in the cockpit, and the overall purpose of the flight, it would seem possible that one or other occupant's elbow or arm may have projected into the airstream at some stage. In light of the BMAA's findings it is therefore also possible that this latter eventuality led to the loss of control. Alternatively, a sudden or unexpected and uncoordinated movement of the aircraft, such as an incipient stall or spin, could also have resulted in an arm or elbow being thrust into the airstream involuntarily, thus exacerbating an already difficult situation, and making an otherwise potentially recoverable situation irrecoverable.

On the available evidence, the accident was most probably precipitated by a sudden engine stoppage caused by the ingestion of a foreign object, whilst the aircraft was flying close to the stall. The identity of this object remains unknown but is most likely to have been a small steel item such as a washer. Whilst there is no direct evidence as to its origin, it cannot have entered the system except from within the air filter housing. This suggested that it may have dropped into the filter whilst it was removed at some time in the aircraft's history, only to become free at some stage during the accident flight and become drawn into the engine. Witness evidence points to the engine failure having occurred at low speed close to the stall and it is possible that even a completely adequate stall warning system would not have prevented the loss of control. Nevertheless, given the aircraft's poor handling characteristics at the stall, the importance of an adequate and reliable stall warning system cannot be overemphasised, and it is appropriate that the BMAA should have decided to arrange for the redesign of the current system and to mandate the fitting of an improved system. Furthermore, given the BMAA's finding of sudden and adverse aircraft responses caused by projections of upper limbs into the airflow, it is also appropriate that the BMAA has decided to ban flight in the Mistral with the canopy removed.

Safety Recommendations

The following recommendations were made during this investigation. The response to these recommendations has been outlined in the text of this report.

Recommendation 2001-75

The BMAA should carry out flight tests to determine the acceptability of the Mistral's handling characteristics with the canopy removed. Further the BMAA should advise UK Mistral owners that the aircraft should not be flown with the canopy removed until these tests have been carried out.

Recommendation 2001-76

The BMAA should review the adequacy of the current stall warning system with particular emphasis on the standard of construction and adequacy of the aural warning. The review should consider whether the aural warning should be connected to the aircraft's intercom system.