DATA SUMMARY

LOCATION

Date and time	**Monday, 18 July 2005; 17:47 h local time**
Site	**Near Salamanca Airport**

AIRCRAFT

Registration	**EC-FSP**
Type and model	**AEROSPATIALE SOCATE TB-10; s/n 1561**
Operator	**Adventia**

Engines

Type and model	**LYCOMING O-360-A1AD**
Number	**1**

Crew

Pilot in command

Age	**19 years**
Licence	**Student Pilot**
Total flight hours	**31:50 h**
Flight hours on the type	**31:50 h**

INJURIES

	Fatal	Serious	Minor/None
Crew			**1**
Passengers			
Third persons			

DAMAGES

Aircraft	**Major**
Third parties	**None**

FLIGHT DATA

Operation	**General aviation – Flight Training – Solo**
Phase of flight	**Takeoff – Initial climb**

REPORT

Date of approval	**March 29, 2006**

1. FACTUAL INFORMATION

1.1. History of the flight

After satisfactory completion of the ground engine check, the student pilot took off from runway 21 at Salamanca Airport to carry out his second solo flight. The take-off run was normal with all engine parameters normal. The aircraft rotated at around 70 kt and started a climb at 80 kt. When the aircraft was at 2,800 or 2,900 ft above mean sea level (AMSL; the airport is 2,595 ft AMSL), the pilot noticed the smell of smoke and initiated a turn to the right. He asked for authorization to enter the downwind leg of the circuit. When he was in the crosswind at 3,200 or 3,400 ft, he noted that the aircraft was "losing thrust". The loss of power was reported as gradual although a short time a total loss of power quickly followed. The pilot immediately declared an emergency and headed for a nearby field were he carried out an emergency landing in a recently harvested wheat field.

The aircraft travelled for approximately 120 m over the field befre coming to a stop after the nose landing gear collapsed and the propeller hit the ground. The pilot, who had breathed some fumes that entered the cockpit, was not injured. Nevertheless, he was taken to a medical center for an examination that did not reveal any problems. After the accident, an aerial photo of the accident site was taken by the operator (see Figure 1).

Personnel from the operator and the maintenance center quickly arrived at the scene of the accident. The aircraft had suffered major damage to the nose landing gear, pro-

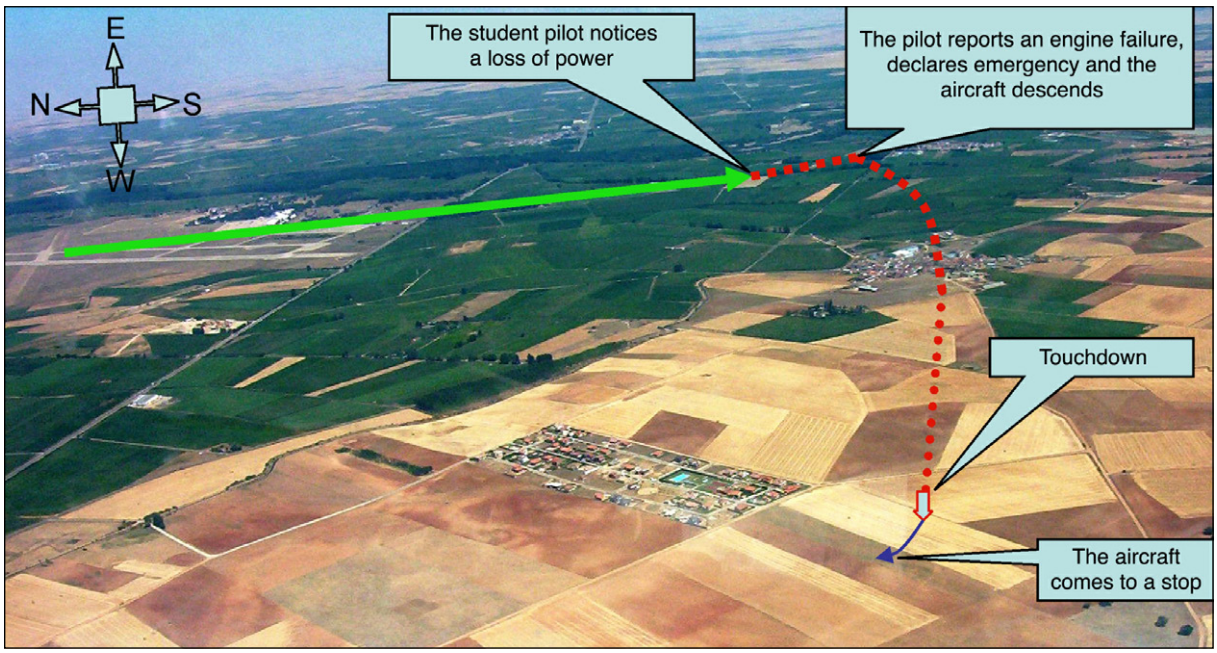

Figure 1. Photo taken by flight school personnel after the accident

peller and forward lower fuselage. It was noted that the left lower side of the engine cowling had been perforated due to fire or heat and a hole some 30 cm long had been produced. There were traces of smoke in the fuselage. A bundle of electrical wires had melted. The engine firewall was deformed.

The engine compartment was inspected in the field and it was evident that the clamp of the LH front exhaust pipe was loose and the pipe was detached from its normal position in the muffler. The end of the pipe had rotated and this had allowed the hot escape gases to be directed against the interior part of the engine cowling. The flow of other exhaust gases coming out from the entrance to the muffler also affected another forward zone of the cowling.

The lack of marks or damage to one of the propeller blades indicated that the engine was not rotating when the other blade, which was bent rearwards, hit the ground (see Figure 2).

After the accident, the power, prop, and mixture levers were found full forward in the cockpit. The cabin air cooling and demisting levers were found fully open (position "+"). The external air scoop on the pilot side was found open (see Figure 3).

Figure 2. Two holes produced by heat or fire in the engine cowling. One blade is undamaged. The smoke entered the cockpit via the external air intake scoop (marked with an arrow)

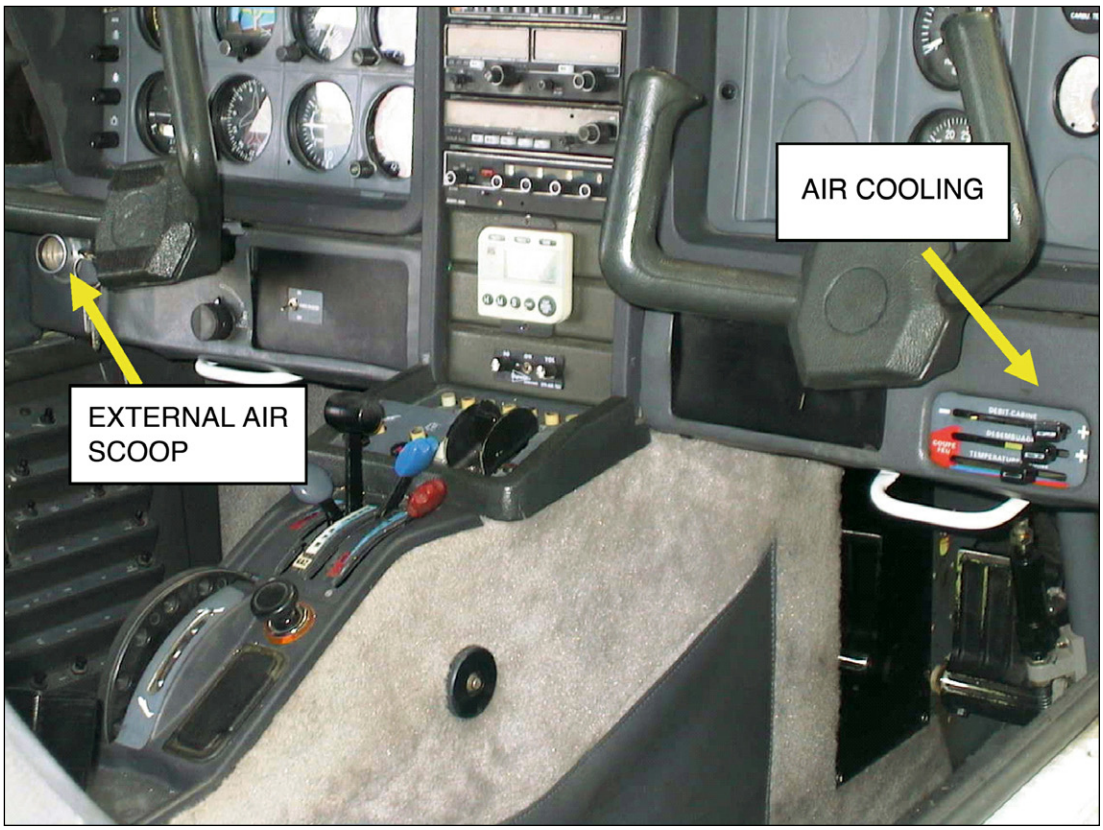

Figure 3. To close the external air duct, the small tube must be rotated clockwise several complete turns. The air cooling and demisting levers are located on the copilot side of the cockpit

1.2. Description of the exhaust system on the Tobago TB-10

The TB-10 complies with FAR-23 Amendments 1 to 16. Later, Amendment 23-17 and Amendment 23-23 of those requirements stated that the failure of any part of the exhaust system is considered to adversely affect the safety of the flight and, therefore, the suitability and durability of those parts must be established by experience or tests and take into account the effect of environmental factors such as temperature (FAR 23.603). In other words, the exhaust system of the TB-10 was not required to comply with those two specific requirements (suitability and environmental factors).

The exhaust gases from the four cylinders of the Lycoming O-360-A1AD are channeled through four inconel (nickel-chromium-iron based alloy) manifold pipes (items 050, 060, 070 and 080 of Figure 4, valid December 99 for a post-Service Bulletin 073 configuration) to the single exhaust pipe (item 020 of Figure 4), where they exit through a single tube which is closer to the RH side of the aircraft. The assembly is shrouded by the muffler (item 040). The forward LH cylinder exhaust manifold pipe (item 050) detached during the accident (at point C of Figure 4). The corresponding stainless steel clamp

(item 110) only has one screw (item 130 of detail C) to tighten the ears of the clamp. This is due to lack of space. The other lower clamps (item B) have two screws to hold the ears (item 130 of detail B). The clamp on the detached manifold was still tightened to it after the accident.

There had been a history of exhaust pipes detaching in TB-10 aircraft that had led to the issuance of an Airworthiness Directive by the DGAC in France that provided for the

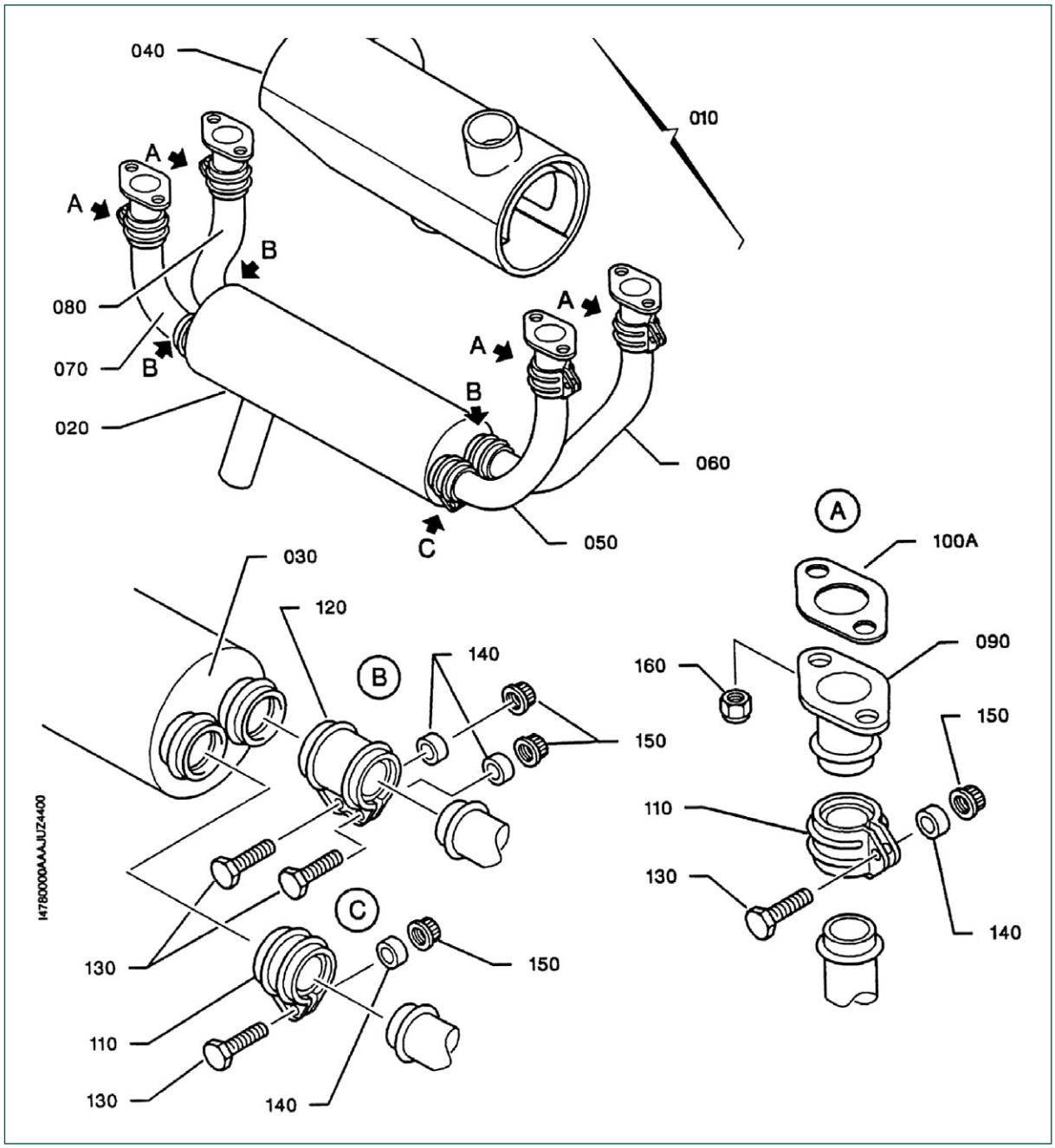

Figure 4. Exhaust system according to the IPC. The exhaust pipe or tube is perpendicular to the aircraft's longitudinal axis. The direction of flight is to the left of the drawing.

replacement of the exhaust pipe and the long manifold-to-exhaust-pipe clamps. The new revision AD 92-206(A)R3 required compliance with SOCATA Service Bulletin (SB) 10-073, Amendment 2, to replace the seals (item 100A, detail A in Figure 4) and to modify the tightening torques of the exhaust pipe attachments previously modified by an earlier issuance of the service bulletin. The service bulletin was originally issued in January 1994 and Amendment 2 was published in August 1996.

The new issuance of the bulletin required the replacement of the seals and the application of 18 to 20 N m of torque to the new locknuts (item 160, detail A) of the upper mounting flange (item 090). The bulletin stated: "Ensure a correct tightening in order to hinder the element relative rotation. An excessive tightening will cause clamp ears to distort. This distortion is unacceptable, when the ear ends are in contact".

To return the aircraft to service, after an engine run-up, there was a tightening check of the attaching locknuts of junction clamps and exhaust pipes. For this check, it is imperative that the engine be cold.

Apart from the service bulletin, the maintenance manual covered the assembly-disassembly of the exhaust system in Chapter 78-00-00 (September 2004). It provided no specific torque values for tightening the lower flange. There was the same caution as in the SB stating that contact between the ears' ends was unacceptable. Assembling the new clamps in accordance with the instructions was somewhat complex. The new clamps had a flexible flange inside that normally came from the factory with an overlap of some 2 mm between both lips, to avoid deformation during assembly (see Figure 5).

The maintenance manual also contained requirements to check the following items:

— "Check flange diameter of pipes, mounting flanges and exhaust pipe."
— "Check that diameter difference between both flanges of the same junction is less than 0.04 in (1 mm)."
— "Pay particular attention to the metallic strip position inside the clamp. This strip is spot welded inside the clamp and is used as a tightness strip for this clamp."

The manufacturer stated that they were not aware of any other exhaust manifold detachments after compliance with SB 10-073 Amendment 2. Only one other case appeared in their records in which the LH rear pipe of a French TB-9 detached in November 2000. The reason for the detachment remains unknown.

The thermal protection blanket was located in the inside of the cowling, in front of the pipe elbow in the exhaust area, and not in front of the end of the pipe end, as this was not required. This blanket and the cowling were perforated during the accident (see Figure 2). The manufacturer was not aware of any other case in which the cowling had been perforated by the engine exhaust following detachment of the manifold.

Figure 5. When torque is applied to the ears of this brand new clamp, the RH lip of the interior flexible flange goes above the LH lip due to the initial overlapping, and therefore the flange does not deform during the tightening process

Section FAR 23.1193 (Amendment 16, as complied with by the aircraft) stated:

> "(c) Cowling must be at least fire resistant."
>
> "(e) Each part of the cowling subjected to high temperatures due to its nearness to exhaust system ports or exhaust gas impingement, must be fireproof."

Fire resistant means the capacity to withstand the heat associated with fire at least as well as aluminum alloy in dimensions appropriate for the purpose. One means of compliance (FAA Advisory Circular 23-2) is to withstand a flame of 1,093 °C (+/– 28 °C) for 5 minutes. Fireproof means the capacity to withstand the heat associated with fire at least as well as steel in dimensions appropriate for the purpose.

The cowling had been tested to be fire resistant as required, and it was shown to withstand a flame of 1,090 °C +10 °C –30 °C for 5 minutes.

Additionally, the manufacturer informed that a test specimen representative of the TB-10 EC-FSP cowling (with protection blanket) was fire tested on 16-12-2005 (due to a design change). The test showed that the material withstood the application of a flame of 1,070 °C for 15 minutes, in compliance with FAR 23.1193 e).

1.3. Maintenance of the TB-10 exhaust system

The following information was retrieved from the aircraft maintenance records:

SB 10-073 was complied with in June 1994, with 448 total aircraft hours.

The clamp in question was disassembled and assembled again on 14-6-2005, with 7,477:35 total aircraft hours because the engine hade been changed during a 500 h inspection. The clamp and the manifold pipe were the same as the ones previously installed on the aircraft. It was not possible to determine how long they had been in service since their initial installation.

On 13-7-2005 (7,525 h) the aircraft underwent a 50 h inspection, during which the clamp was re-tightened (it was found it was somewhat loose). The accident happened on 18-7-2005 after a 16:50 further hours of flight and 7,541:50 total aircraft hours (364:35 engine hours). Therefore, the pipe detached after 64 h of service since the re-installation of the clamp.

Exhaust pipe (P/N TB-10 56012008) was installed on 20-11-2001. It was a repaired exhaust pipe that had come from another aircraft. This part is inspected every 50 h and replaced "on condition". The four manifold pipes are also replaced on condition.

The maintenance center, which had a lot of experience with the TB-10, stated that it was difficult in practice to keep the exhaust pipes correctly attached. It was normal to find the tubes somewhat loose during scheduled inspections. Re-tightening was the normal solution for this but, since no value of the correct torque to be applied existed in the AMM and the ears deformed under normal torque values, the mechanic responsible for tightening was placed in a difficult position because the more torque he applied to avoid relative rotation between the parts, the closer the ends of the ears would be. Nor was there a minimum clearance value between the ends of the ears. Additionally, they stated that sometimes brand new clamps came without the flange overlap (see Figure 5) to prevent incorrect assembly.

After the accident, the maintenance center adopted a preventive measure to inspect the clamps every 25 h and to change them when if there was any doubt over their condition. Those replacements were mainly due to the ears touching after tightening them several times.

The manufacturer and the DGAC in France stated that the applicable maintenance instructions provide adequate guidance to prevent incorrect assembly or deterioration of the exhaust system clamps, and therefore there was no need for any change in this regard.

1.4. General inspection of the aircraft

The aircraft was initially inspected in a hangar with the following findings:

— The ears of both clamps (upper and lower, which was the end that detached from the muffler during the accident) of the forward LH exhaust tube were not touching. The lower clamp was still tightened to the tube.
— The engine intake appeared to be in good condition. After gaining access to the air filter, traces and smell of burnt plastic material were noticed. The foam air filter appeared to have been affected by high temperatures, and it seemed to have compressed after the heating process.
— The electrical wires from the start key to the ground condenser of the magnetos had their isolation melted by the heat.
— A check showed that the LH magneto was operative. The RH magneto was grounded, probably because of the burnt wires. However, after some movement of the wires, the magneto became operative again. Therefore, no definitive conclusion could be reached regarding its status before the impact with the ground.

1.5. Detailed inspection of the aircraft exhaust system

The aircraft's exhaust system was later subjected to a more detailed inspection. Before that, the 1LH and 2LH spark plugs had been removed and they did not show any traces of an abnormal (i.e. too lean or too rich) mixture.

The aircraft's muffler had impacted the ground. This would probably have masked any previous torque condition, especially at the forward cylinder manifold attachments.

It was found that the ends of the ears of the clamps on the LH side of the engine were very close one to the other. The gap measurements were:

— LH forward cylinder exhaust manifold:

Lower clamp (the part that detached):	0.011 inch (item 050, C of Figure 4)
Upper clamp:	0.011 inch (item 050, A)

— LH rear cylinder exhaust manifold:

Lower clamp:	0.000 inch (the ends were touching) (item 060, B)
Upper clamp:	0.069 inch (item 060, A)

The ears of the four clamps of the two RH side cylinders were touching (items 070 B, A and 080 B, A).

A different aircraft parked inside the hangar was inspected and it was found that the end of the ears were already close one to the other, even though those clamps reportedly had around 60 h since new, due to the several tightenings that had already been

applied. Several discarded clamps were also inspected at the hangar to check for wear and distortion of the ears and interior flanges caused by hours of service.

The LH manifold tube (item 050), still attached by its upper end to the cylinder, could be moved by hand. This attachment (item 050 A) was disassembled and the status of the lower clamp inspected in detail. It was noticed that the internal flange was deformed because one lip had been pressed against the other (see Figure 6 and compare with a new clamp in Figure 5). It was determined to be incorrectly assembled and that this would have weakened the attachment, allowing gas leaks and preventing the torque of the clamp from being transmitted to the manifold pipe in the form of friction forces. The clamp itself was not disassembled so as to allow for further inspections if needed.

The diameter of the forward LH manifold pipe was then measured (taking two measurements at 90°). The results were:

— Diameter of the cylinder exhaust duct: 47.8/47.7 mm
— Diameter of the cylinder end of the manifold pipe: 48.4/48.1 mm
— Diameter of the muffler end of the manifold pipe: not taken because the clamp was not removed
— Diameter of the muffler/exhaust pipe duct: 46.8/46.6 mm

Figure 6. The lips of the internal flexible flange are touching and have deformed due to the torque applied to the ears

According to the manufacturer, the nominal values for those diameters are:

— Maximum: 48.8 mm ; minimum 47.3 mm.

Therefore, the exhaust pipe duct (item 030, LH duct of Figure 4) had a diameter below the minimum specified. This part had been in service on the aircraft since 2001, when it had been repaired.

The aircraft's air filter was also inspected in detail. This kind of filters is replaced every 200 h. It was deformed probably due to intense heating but was not burnt, and no obvious traces of smoke were noted. The filter was handed over to the manufacturer for further testing.

1.6. Emergency procedure for an engine fire in flight

The airplane flight manual (AFM), Revision 7 (30 September 1989) contained 5 emergency procedures related to fire situations: engine fire during start, engine fire in flight, electrical fire in flight (both for a fire in the engine compartment and in the cabin), cabin fire and wing fire.

In a real emergency, it would be difficult to distinguish between an engine fire in flight (visual detection by smoke or flames) and an electrical fire in the engine compartment. However, the approach to both emergencies in the AFM is very different. In the first case, the engine and fuel supply must be shut off immediately (fuel selector must be placed to off, the mixture to cut-off, etc.) and a power off landing must be carried out. In the case of electrical fire, the main switch must be placed in off and a landing carried out as soon as possible.

However, in both cases there is a common step: cabin air cooling and demisting selected to "fire cut-off" (-) (see levers in Figure 3). This would prevent smoke and fumes entering the cockpit from the engine compartment, although the manufacturer stated that there are other paths that would allow the smoke to enter the pilot compartment, like the pedal bellows or wire penetrations in the fire wall.

Nothing is stated in the AFM emergency procedures regarding the status of the external air scoop, which would be very difficult to close in a stressful emergency situation anyway (see Figure 3).

There is no evidence that the pilot applied any of those emergency procedures after he started noticing the smell of smoke. This was his second solo flight and he carried out the emergency procedure for engine failure after takeoff that was considered overriding in this case. The flight school informed that all the emergency procedures were reviewed and practiced before every student's first solo flight.

2. ANALYSIS AND CONCLUSIONS

The fact that the manifold detached after having been maintained by an organization with considerable experience with this aircraft model required an indepth analysis.

Additionally, the detachment of the forward LH exhaust manifold had the following serious implications:

— The fire hazard caused by the high temperature exhaust fumes that even perforated the heating insulation and the engine cowling.
— The fact that the engine stopped completely because of the detachment.
— The fact that smoke entered the cockpit and affected the pilot. This could have prevented him from landing the aircraft after the emergency.

The conclusions of the analysis of these factors are as follows.

2.1. Maintenance of the exhaust system

The most likely cause of the detachment of the exhaust manifold was probably the deformation of the clamp's flexible flange during assembly on 14-6-2005. New clamps were supposed to have some overlap between the lips of the flexible flange to avoid that kind deformation. However, the clamp of the pipe that detached in this case had been in service for an undetermined period before the accident. Additionally, the diameter of the exhaust pipe duct (to which the exhaust manifold was attached) was below the minimum value specified by the manufacturer. This could also have contributed to the detachment.

In summary, there were two conditions that were not in accordance with the specific instructions provided in the maintenance documentation.

Maintenance center personnel stated that they found it difficult to adequately adjust the exhaust system of the TB-10 in the field. According to reports from mechanics with experience on the system, it was normal to find the clamps somewhat loose during the 50 h scheduled inspections. The solution for that would be to retighten the screws and nuts on the clamp, but this would lead to the increasing deformation of the ears to the point of almost touching. There was no minimum clearance between the ears specified in the AMM, as long as they were not actually touching. There was also no nominal torque value for those clamps. Additionally, there is a possibility that the lips of the flexible flange come in contact at the start of the tightening process (as could have happened in this case) in which case the flange will deform causing a defective attachment of the exhaust manifold. The relative position of the clamp was not defined in the AMM. Therefore, sometimes the mechanic rotated the clamp around the manifold pipe to avoid having possible minor leaks of hot gases which could affect other parts of the

engine. In some of those situations, it would be possible for the flexible flange to remain outside the mechanic's field of vision and therefore for contact between the lips to remain undetected.

The aircraft manufacturer stated that the maintenance instructions were adequate for the system and they did not require continuous retightening. If all the parts comply with the SOCATA definition and maintenance instructions, this retightening should not be necessary. It systematic retightening were needed, it would mean that one of the parts was not in compliance (diameter of the pipes, position of the strip on the clamps, distortion of the ears, etc.) and that therefore they should all be checked.

To avoid further similar occurrences, it is considered convenient that mechanics are be made fully aware of this possibility of incorrect clamp assembly and that a safety recommendation be issued in this regard.

Additionally, the design of the clamp was analyzed to see if it could be further improved to reduce the possibility of incorrect assembly in the field. Although the internal strip or flange already provided some 2 mm of overlap and the manufacturer considered that this design and the proper application of the AMM ensured the correct assembly, an increase in the length of the overlap would further reduce the probability of incorrect assembly. However, the information received indicated that there was not enough basis to request this modification.

2.2. Causes of the engine stoppage

It is considered that the engine probably stopped primarily due to the ingestion of hot air coming from the exhaust system after the manifold detached. The exhaust pipe is located in the forward part of the engine compartment, and therefore the flow of the gases after the detachment goes directly to the engine intake. The loss of power was observed to be gradual but quick, leading to a complete stop. It is possible that the hot air started affecting the air filter until it was almost clogged.

The effect of the possible grounding of one of the magnetos due to the burning of the thermal isolation of the wires remains undetermined. It was found during the inspection that if the wires were moved, the grounding of the magneto would disappear, and therefore it cannot be assured that it was not functioning before the emergency landing.

2.3. Effects of the smoke

The detachment of the pipe probably caused high temperature fumes and gases to affect the cowling in an area not protected by the insulation blanket. This part of the

cowling was burnt and then the insulation blanket was also affected and a major part of it was missing after the accident (see Figure 2).

The manufacturer and the DGAC in France stated that the cowling complied with the applicable requirements, and that the thermal protection blanket was fireproof as demonstrated during a recent fire test. The certification requirements applicable to the aircraft did not require the cowling to be protected against the type of failure that took place in this accident.

The smoke probably entered the cockpit by a path not envisaged during the design: the external air scoop. This was caused by the burning and perforation of the insulation blanket and the cowling. This scoop is not required to be closed by the emergency procedures that, in any event, were not applied in this case. The effects of the smoke on the pilot are obviously very hazardous and this hazard was caused in the first place by the unusual fact that the cowling was perforated even though there probably was not an actual fire inside the engine compartment.

The pilot of the aircraft was successful in carrying out an emergency landing even though he had limited flight experience. He did not carry out any emergency procedures related to smoke. Instead, he carried out the emergency procedure related to engine failure after takeoff. As stated above, it is doubtful that the application of the "engine fire in flight" emergency procedure would have prevented the smoke in this case from entering the cockpit, although at least the closing of the air cooling levers could have been of some benefit. It seems that two emergency procedures would have been needed to be applied at the same time with the aircraft being very close to the ground and with no clear signs of smoke at the beginning of the event.

3. SAFETY RECOMMENDATIONS

REC 08/06. It is recommended to SENASA that the maintenance technicians be made aware of the importance of a carefully assembling the clamps of the TB-10 exhaust manifold pipes, so as to securely fasten the manifold and prevent its detachment in flight.